GOVERNMENT OF WEST PAKISTAN

SCHEDULE OF RATES

VOLUME I, PART II

(SPECIFICATIONS FOR EXECUTION OF WORKS)
1967

WEST PAKISTAN STANDING RATES COMMITTEE, LAHORE

Publication No. 2

Dear Mr Fazlur-Rahman Khan,

We transmit herewith Volume I—Part II of the Schedule of Rates (Specifications for execution of works) as finalized by the Technical Sub-Committee. The Sub-Committee undertook this work during March 1964 and was able to finalize it in about 80 sittings. The process that was adopted in finalizing the specifications for materials of construction has been followed in this case too. The Technical Sub-Committee with its research staff conducted a vast survey of the literature available on the subject and in addition collected information from various projects that were being executed by different departments. The text has also been reviewed by Chief Engineers of the various participant departments before it was finalized.

This hand book is intended to introduce uniform engineering practices in the country and will thus replace all such compilations currently in use in various departments. Despite the fact that all efforts have been made to make this volume a comprehensive guide, the scope for improvement is always there.

We hope and recommend that like Schedule of Rates, Volume I—Part I, this publication should also be published and brought into use in all the departments of Government of West Pakistan as well as autonomous bodies in order to ensure uniform engineering practices in the country.

Your's sincerely,
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PREFACE

The Standing Rates Committee was constituted by the Government of West Pakistan to prepare a common Schedule of Rates and to keep it upto-date by revising it from time to time on the basis of market conditions. It consists of the following members at present:—

1. Additional Secretary to Government, West Pakistan, Finance Department: Chairman.
2. A Representative of Irrigation and Power Department of the Provincial Government.
3. A Representative of West Pakistan Water and Power Development Authority.
4. A representative of the Communications and Works (B & R) Department.
5. A representative of the Public Health Engineering Department.
6. A representative of the Pakistan Western Railways.
7. A representative of the W. Pakistan A.D.C.

The committee plans to bring out a complete Schedule in three volumes in parts. Part I of Volume I was published in 1964 and contained "Specifications for materials of construction". The Committee now presents Part II of Volume I containing "Specifications for execution of works". It contains the qualitative as well as contractual requirements of all types of engineering works normally carried out by various Departments.

These specifications shall come into force on 1st July 1967, and shall supersede all other books of specifications for execution of works in operation in the Government Departments and in the autonomous bodies to which these apply.

Fazlur-Rahman Khan, C.S.P.,
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Standing Rates Committee

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The Standing Rates Committee wishes to acknowledge the helpful advice and suggestions received from the following dignitaries in regard to the specifications for execution of works :—

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Introduction

Presently, there are no standard specifications for the execution of civil eng works which would have a uniform application to all the engineering works in departments in the province. Some of the departments have their own specifications conflicting to each other, while the others do not have any at all. Civil Engineers se in various departments in general and young engineers in particular do not (in the abs of a standard book containing specifications) get proper guidance in this respect. importance of a book of specifications that will uniformly and adequately cover all de ments is, therefore, very obvious.

This book—The Schedule of Rates, Volume I, Part II, Specifications for Execution of works—is one of a series of other similar books, like "Composite Schedule of Rates", "Specifications for Materials of Construction", "Analysis of Rates", etc. published by the Standing Rates Committee for use in various departments. On publication, this book, besides being a useful guide to Engineers, will have a legal binding value in the execution of various types of civil works, on the contractual basis. No originality can be claimed in the compilation of this book, in fact, a number of important books available on this subject have been consulted. A draft text of this book was sent to eminent engineers of the country for comments. Improvements suggested by them were taken due note of before the text was finalized and sent to press.

Since the science of Civil Engineering is undergoing revolutionary changes in the international field, the text of specifications of various items provided in this book is likely to be revised, or even completely replaced, periodically. This book will, therefore, require occasional revision.

Every item of work like masonry, concrete, earthwork, has been assigned a separate chapter in this book. These chapters have been sub-divided into two parts.

(1) Introduction. (2) Specifications. For the facility of reader not only glossary of terms has been added to the chapters of important items, but an index of the whole book has also been appended.

Malik Yaqub A

Standing Rates

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Specifications

Mode of Transport

1. Unless otherwise specified or directed in writing by the Engineer-in-charge, carriage of all materials between stations connected by rail shall be done only by the railway goods train and all rules and regulations in force in the Railway Department in this regard, shall hold good. Other means of transport shall be allowed only when:—

(i) The goods train is not available within the stipulated period. In this case a certificate shall have to be recorded by the Engineer-in-charge.

(ii) The railway track is not in order for a certain reason and is expected to take a considerable time before it is put in order.

(iii) The material to be transported is perishable, and the goods train takes a considerably longer time than the road transport, and thus does not ensure a safe transportation.

(iv) Any other unforeseen calamity which in the opinion of the Engineer-in-charge is so pressing as to make carriage by road essential.

Safe Delivery

2. Whatsoever may be the mode of transport (except goods train) the agency undertaking the carriage of material shall be responsible for its safe loading, unloading, delivery to the specified site within the specified time and stacking, unless it is damaged as a result of a calamity beyond the control of that agency.

Stacking

3. The material carted shall be properly stacked at the specified site to the satisfaction of the Engineer-in-charge or his authorized subordinate.

Carts, Animal Driven Transport

4. When carts or other animal driven transports are engaged for carriage on a daily wage basis, the quantity of material to be conveyed, the distance to be travelled and the number of trips to be made, shall be fixed by the Engineer-in-charge or his authorized subordinate.

Measurement

5. Carriage shall be contracted for by weight or by volume at a mileage or chainage rate or a fixed rate between specified places. In the former case the distance shall be measured by the nearest practicable route, and the miles measured shall be statute miles.

Rate

6. (i) The unit rate shall include loading of material within one chain, carriage to a specified site, unloading and stacking, as per above specifications, within a distance of one chain from the site of unloading.

(ii) If the lead for loading, unloading and stacking exceeds one chain the payment for additional chains shall be made at the rate of second and subsequent chains.

(iii) In case of works where item rates include the handling of material up to a certain distance any extra carriage involved beyond this distance shall be payable at the rate prescribed for the subsequent chains or miles, as the case may be. No additional payment shall be made to the contractor for charges like demurrage, wharfage and the toll tax.

NO. 17 EARTHWORK

Glossary Of Terms

Abkalani (Sindhi) The inundation or flood season which extends from 1st May to 15th October.

Accretion of Levels The rise in specific levels of the bed of river channel at any site. It is the converse of degradation or retrogression of levels.

Afflux The rise above the natural surface of water caused by an obstruction in the water-way.

Apron A floor or lining of stone, concrete, etc., to protect a surface from erosion and withstand hydrostatic pressure.

Avulsion The breaking through by a river across the narrow neck of a horse-shoe bend, or the entire change in the course of a river when it breaks through one of its banks in a deltaic region.

Back Water (Curve) A particular form of the surface curve of a river or stream which is concave upwards. It is caused by an obstruction in the channel, such as a weir or regulator or a low level of water heading up against higher land.

Bar A deposit of river-borne material at the mouth of a river or bye-river or at the offtake of an inundation canal.

Bed Load The detritus (silt, sand, etc.) rolled along the bed of a stream.

Berm An horizontal ledge on embankment given for the purpose of thickening and increasing "cover" in the rear lower part of a bund.

In the case of irrigation channels berm is formed by silting up where the channel is in filling and left at the time of construction (excavation) where it is in cutting (digging). It strengthens the bank, brings in saturation line and reduces possibilities of leaks and breaches. It has the maximum utility for canals having high embankments. The minimum width of a berm should be one half F.S.D. of the channel and it should be sloping towards the channel. The berm width usually prescribed is 2D to 3D or (1/2D+4 feet) for big canals and (1/2D+2 feet) for small canals. In the case of metalled roads berm is the horizontal earthen portion of the road embankment on both sides of the metalled track.

Blow-out (or Sandboil) An underground leak occurring through a sand stratum under the base or seat of a bund, breaking out through the ground surface on the rear of the bund in the form of a bubbling spring and carrying with it a volume of sand.

Borrow-pits Pits excavated for obtaining earth required for making embankments.

Breach A break or gap in the continuity of embankment line through which the river water floods the country on the rear of the bund line. In Sindhi, it is called gharo or khand. In the USA it is called a 'crevasse'.

Caving Erosion of a river bank or bund by the undermining action of water, which causes the super-incumbent earth to collapse.

Cove — The minimum thickness or height of earth required anywhere over a specified level or line measured vertically or horizontally, as the case may be. The cover over hydraulic gradient line or saturation line is measured vertically.

Clay — According to the definition of the International Society of Soil Sciences, all particles of soil less than 0.002 mm in diameter are classified as clay. These soils usually contain about 55 per cent clay, 40 per cent silt (0.002 to 0.02 mm) and 5 per cent sand (0.02 mm and above).

Creep — The movement of water under or around a structure built on permeable foundations. (Also see Piping.)

Crest — (1) The top of an embankment or weir or the highest floor level of a regulator or sluice at the point of control. It is also called 'crown'.

(2) The peak of a flood.

Crown — The top of an embankment or bund. (Also see Crest.)

Curtain-wall — A wall provided at the downstream and/or upstream extremity of a sluice or regulator to prevent the undermining of the sub-soil by scour, piping, or floatation.

Cusec — The unit of discharge used in irrigation practice and meaning a rate of flow of one cubic foot per second.

Cut-off — (1) The difference between the water levels upstream and downstream of a regulator or an obstruction.

(2) A channel excavated artificially or formed naturally by avulsion reducing the length of a course of stream or river.

(3) An anticreep wall in a sluice or regulator.

Debris or Detritus — Any material, such as floating trash, suspended sediment, or bed load, moved by flowing stream.

Delta — The alluvial tract formed by the deposit in the sea of the sediment carried by the river.

Diaphragm Wal or Core Wal — A wall of brick masonry in a section of the bund (especially in very bad and treacherous soils) to reduce percolation and avoid leaks or to gain sufficient time to close these leaks. (Also see Sandcore.)

Drop-down (Curve) — A form of the surface curve of a river or stream which is convex upward. It is caused by increase in velocity and slope, consequent upon a drop in the water level, or drawndown, such as near or at the entrance to a river "cut-off" or below a flume in a channel. (See Back water curve.)

Dowel — Short projection extending over a canal bank on its either edge constructed primarily to prevent cutting up of the bank slopes caused by rain. It provides additional safety so far as free board is concerned and also ensures greater safety for wheeled traffic in driving. The usual measurement of the dowel is: top width 1.25 feet, height about 1.25 feet and side slope $1\frac{1}{2}$:1 with bottom as 5 feet.

Erosion Line — A line ranged at right angles to the general alignment from the toe of the bund to the eroding edge of the pucca bank of the river.

Erosion Ordinate The measure of the erosion line, i.e., the distance from the toe of the bund to the edge of the eroding pucca bank of the river, generally ranged at right angles to the normal alignment of the bund.

Free Board The distance between the designed full supply level and the top of the embankment or masonry work left to allow for wave action, floating debris, or any other condition or emergency, without overtopping the banks of the channel or sides of the structure. In the case of dams it is the distance from the top of the dam to the water surface in the reservoir during maximum flood conditions.

Floatation The undermining caused by the residual force of water, flowing through the sub-soil, which acts in the direction of the flow and is proportional to the pressure gradient at that point.

Formation The top of embankments or the bottom of cuttings.

Formation (for Railway) The top of embankment or the bottom of cutting ready to receive the ballast as denoted by the ultimate grade line or level along the centre line on the longitudinal section.

Formation (Making up Formation for Railway) It includes:—

(1) All cuttings and embankments necessary to prepare the ground for receiving ballast and track.

(2) Side and catch water drains.

(3) Protection measures for cuttings and embankments and their slopes.

(4) Topping embankments with selected material.

(5) Diversion for roads and streams; and

(6) All similar works pertaining to the construction of railway line, its siding tracks and station yards.

Groyne An obstruction of stone, timber or brushwood constructed from the embankment of a river to divert or hold the flow. A stone groyne is called a spur. When constructed parallel to the river flow for protection against wavewash, it is called a "longitudinal groyne", or "muhari".

Guide Bank A protecting and training bank constructed to guide the river to and from the weir through the waterway provided. A river bund may, in effect, be a guide bank when it is at the edge of the river course, there being little or no foreshore between the river course and the toe of the bund.

Hydraulic Gradient Line In a bund, it is the same as the saturation line (q.v.).

Hydrograph A graph showing the gauge (or discharge) with respect to time.

Kalar Salt impregnated soil. The following types of kalar generally occur in the southern areas of West Pakistan.

White Kalar Main salts: sodium chloride, sodium sulphate and magnesium sulphate. This is the commonest type of kalar in the southern areas.

Dark Kalar In addition to the salts found in white kalar, it contains the chlorides of magnesium and calcium. It is found on land affected by waterlogging and seepage.

Black Kalar

It contains sodium carbonate, in addition to salts in white and dark kalar. The large amount of lime present in the soils in southern areas prevents excessive formation of black kalar. This kalar is present in badly drained localities.

Brown Kalar

It contains the nitrates of potassium and sodium in addition to the salts found in white kalar.

Key Trench

An excavation in the base of a bund or other structure filled with specially selected material, generally sand, in case of river bunds to bond the bund into the ground surface.

Lead Horizontal

The shortest possible horizontal route between the centre of gravity of the material excavated and the centre of gravity of the material finally placed in the embankment.

Lead—Total

The horizontal lead as defined above plus the lift converted into horizontal lead, if any.

Lift—Vertical

The vertical difference between the centre of gravity of the earth excavated and the centre of gravity of the earth placed in the embankment.

Lift into Lead—Conversion

Lift shall be converted into horizontal lead with the aid of table appended.

Leak

An increasingly swift passage of water through a hole or cavity in an embankment carrying with it the soil of which the embankment is built. The hole itself is also referred to as leak.

Loop Bund

When there are two lines of defence, the bund line constructed on the rear or on the side of the land is generally called Loop Bund. (The first line is called the front bund.) If the first line of defence is eroded or abandoned the loop bund may become the front bund, or vice versa. If another line of defence is constructed on the side of the river the front bund (so called prior to this new construction) becomes the loop bund.

Main Bund

The embankment which forms the principal line of defence, e.g., in a composite bund with wetting channel it is the bund on the rear or on the side of the land of the wetting channel.

Over-topping

River or canal water running over the top of the bank.

Piping

The flow of water under or around a structure built on permeable foundations which, if not prevented or stopped, will remove material from beneath the structure and cause it to fall. The erosion of sub-soil by high velocities of flow of water through it, when such velocities exceed a certain limit, is also referred to as piping.

Porosity

An index of void characteristic of a soil or stratum as it pertains to percolation and degree of perviousness.

Retrogression

The lowering of the specific levels, i.e. of the level of water surface of a channel for a given discharge.

Sand

According to the definition of the International Society of Soil Sciences, coarse river or canal sediment of size 0.02 mm and up to 2.00 mm in diameter is called sand. Sand soil contains up to about 5 per cent clay, 0.002 mm in diameter or less, 10 per cent silt, 0.002 to 0.02 mm in diamter, and 85 per cent sand of 0.02 to 2.00 mm in diameter.

Sand Core — A hearting or core of pure sand provided in the bund section, particularly in kalar, hard clay or bad soil and is intended to prevent or reduce leakage and rat holes through the bund section.

Seepage — The percolation of water through embankment or soil.

Saturation Gradient — The slope of the top-most seepage line, or the surface of the percolating water, through the cross-section of the embankment. (Also see hydraulic gradient line.)

Slip or Slide — Where the saturation gradient intersects the downstream slope or face, and water crops up making the lower part pasty, the dry-earth slips or sloughs over the saturated earth, squeezing it out. This leads to slides or slips, fast endangering the stability of the bund.

Silt — According to the definition of the International Society of Soil Sciences, all particles of soil from 0.002 mm to 0.02 mm in diameter are classified as silt. Silty soils contain up to about 20 per cent clay of 0.002 mm in diameter and less; 45 per cent silt of 0.002 to 0.02 mm in diameter; and 35 per cent sand of 0.02 mm in diameter and above.

Wave Wash — The damage done to the bunds when the flood waters strike and splash on their upstream face unless counteracted by jungle or pilchi pitching or other artificial devices.

Weep Holes — Openings left in diaphragm walls, pitching, etc., to permit drainage and wet the earth on their rear side or on the side of the land, so as to reduce unequal pressures owing to saturated earth on one side and dry earth on the other.

Wetting Channel — A device used for soaking (staunching) or preparing a bund in advance of the main rise of the river, for its task of holding back the river. It refers to both the gravity channel, from the river lip to the bund and to the channel between the trench bund and the main bund through which water is pumped to soak the main bund.

Introduction

Definition — Earthwork covers any or all works involved in cutting or digging in spoil or soil of various classifications; dressing the excavated pit to the specified grades and dimensions; sorting, transporting and rehandling of excavated material; stacking, filling or refilling, compacting and dressing the top and side slopes of the resultant embankment or spoil bank to the required grades and dimensions, along with all other related operations.

Types of Excavation — Broadly speaking all excavations (digging or cutting) can be grouped as (a) Precise excavations (b) Borrow-pit excavations.

Precise Excavation — Excavation for attaining certain definite levels, grades and dimensions shown in the drawings such as excavation for foundation of various types of buildings, irrigation structures; cuttings for rail and road formations; excavation for key trenches, irrigation channels, drains, sewers for other similar works; remodelling, regrading or desilting of existing channels and reconditioning of the choked drains and sewers etc. are known as precise excavation. These excavations are usually done in uniform lifts, reach by reach, and in such a fashion that they drain themselves automatically.

It is advisable to dig out a central trench first and then proceed to dress the sides to required slopes by cuttings. In all such cases the formation levels are observed before and after the actual excavation to adjudge the accuracy of the cutting. Any excess cutting has to be made good with selected material thoroughly compacted under instructions of the Engineer-in-charge.

The material obtained from these excavations may be disposed of in any of the following manners:—

(i) Finds like antique relics, coins, fossils, which normally cannot be used in the work are deposited with Government store under directions of the Engineer-in-charge.

(ii) Suitable excavated material may be used in raising dams, embankments, ramps, rail and road formations or refilling the voids of foundations after the erection of the structure.

(iii) Excavated material considered unsuitable for any of the above usages or rendered surplus, is usually dumped in spoil banks properly dressed under the directions of the Engineer-in-charge.

Borrow-Pit Excavation

Excavations which are necessitated for procuring suitable and adequate materials for raising dams, embankments, core walls, ramps, rail and road formations or refilling the voids of foundations after the erection of the structure or for other allied purposes are known as borrow-pit excavations.

The following factors govern the locations, spacing and dimensions of borrow-pits.

(i) Type and quantum of earth to be procured.

(ii) Type of embankments for which borrow-pits have to be dug.

(iii) Safety of the existing works or new works under construction.

(iv) Subsequent use of land under borrow-pits.

(v) Ease in recording and checking the measurements of the quantity of excavated materials.

(vi) Mode of excavation. (By machine or manual labour.)

Borrow-Pit Essential Requirements

(1) Borrow-pits should be located well away from the embankment so that they do not cut the hydraulic grade line of the resultant embankment but leaves some cover above it.

(2) The borrow-pit area should be clearly demarcated by a dagbel before commencing any digging. If old borrow-pits already exist in the demarcated area, they should be measured and their measurement recorded. Sizes, configuration and distinctive marks in the new borrow-pits should be so fixed that they do not get mixed up with the old ones.

(3) No borrow-pit should be excavated beyond the specified limits, or close to an existing road village track, embankments and other structure which are liable to be damaged.

(4) For storage dams, borrow-pits in the reservoir should not be dug nearer than twice the height of the dam from its front toe.

(5) Borrow-pits should not as far as possible be excavatd on the land side of a river embankment because that would increase the infiltration head acting on the embankment and may cause it to leak. On the river side it should not be nearer than 100 feet for repairs and 150 feet for new construction from the toe of the embankment. Borrow-pits, 150 to 200 feet, should not be more than 6 feet deep; 200 to 300 feet not more than 8 feet deep; and beyond 300 feet may be of any depth.

(6) Borrow-pits should not be nearer than 30 feet from the toe of a big canal bank, and 10 feet from the toe of a small channel bank if their depth does not exceed 2 feet. If the depth exceeds 2 feet, the minimum distance recommended from the toe of the bank of a small channel is 15 feet.

(7) Borrow-pits should be as shallow as possible so that the land can be subsequently ploughed over and brought under cultivation. In cultivated areas, where lands have been temporarily acquired, the depth should not be more than one foot; otherwise the maximum depth is 3 feet. No pit should be excavated more than 5 feet within a distance of 300 feet from tht toe of an embankment.

(8) Borrow-pits should not be continuous or otherwise they will form a channel. At least 10 feet wide strip should be left unexcavated in every chain or so.

(9) A space of about 5 feet should be left around all pits for labourers to pass.

(10) Borrow-pits should be in multiple of 10 feet length to facilitate recording and checking the quantity of the excavated material.

(11) No borrow-pit should be dug in the central portion of a channel berm nor in a canal bed below the bed level except as detailed below. Where the earth has to be borrowed from near a canal bank, the pits should not be more than 6 inches deep,

(12) In the case of large channels, borrow-pits can also be dug in the bed leaving 5 feet berm from the inner toe of the banks on either side and a width equal to half the length of the pit between each pit. The width of pits should not exceed half the bed width of the channel and depth 1 to 2 feet below the bed. Pits should not be dug near any masonry works or within 20 feet of the footpaths or cattle tracks crossing a channel since they tend to cause the inner slopes to the channel to slip down. These pits get silted up as the channel runs for a couple of months. No pit should be dug in beds of channels in which no silt is ordinarily deposited.

(13) Borrow-pits may be dug in berms where they are very wide and likely to silt up rapidly. The earth should ordinarily be obtained by cutting vertical pockets, whose long lengths should never be dug down to below bed level. The length of pockets should not exceed the bed width of the channel or 10 feet, whichever is less. Spaces left between the pockets should not be less than 5 feet wide.

(14) Before digging any materials for filling in the embankment, the entire surface of the borrow-pits should be cleared off all grass, roots, shrubs, jungle or any other organic matter liable to decay and form dangerous pockets.

Classifications of Soil

The formation of soil varies from place to place and usually the soil of the following classifications is found in various parts of West Pakistan.

(a) *Soft Soil*—It comprises sand, silt and those soils which offer no resistance to excavation and some time require shoring when foundations of exact dimensions are required to be excavated. Ordinary kassi (phawarah) shovel or spade can be used for excavation in such soils.

(b) *Ordinary Soil*—It comprises earth and sandy loam, spoil or rubbish of every description and any other formation into which a spade and kassi (phawarahs) pick or shovel can excavate.

(c) *Hard Soil*—It comprises stiff and heavy clayed soil having specific gravity of 1.5 and above and at times having small percentages of kankar or boulders mixed up. It can be excavated by repeated blows of kassi or with pick or shovel.

(d) *Very Hard Soil*—It comprises hard moorum with high percentage of kankar or boulders, mud concrete, shale lime or concrete, conglomorate formation, brick-work in lime, stone masonry in lime, metalled surface of road (tarred or untarred), hard core under floor and road bottoming, and any other formation into which a spade cannot enter and whose excavation requires the forcible application of a pick.

(e) *Gravel work and soft rock not requiring blasting*—It comprises gravel formation, cement concrete, brickwork in cement, soft varieties of lime stone, sand stone, fissured stone or any other formation which can be excavated by the use of pick, shovel, jumpers, wedges, hammers, etc., and do not require blasting.

(f) *Rock requiring blasting*—It comprises hard stratified rock like compact hard lime stone, hard sand stone or unfissured and unstratified masses like granite and basalt (trap) etc. or similar formation for the excavation of which blasting is required. Rocks falling under this class are sub-divided into following six grades depending upon the degree of toughness.

Grade 1—It comprises rock of any origin and description in which a group of two labourers can, in a maximum period of four hours, drill a trial bore 3 feet deep by means of a jumper bar of 1¼ inch diameter and a hammer miner weighing 7 lbs.

Grade 2 to 6—Every extra hour taken over four hours in making this trial bore corresponds with the next higher grade as shown below :—

Time taken	Grade
Between 4 and 5 hours	2
,, 5 and 6 ,,	3
,, 6 and 7 ,,	4
,, 7 and 8 ,,	5
,, 8 and 9 ,,	6 (Final)
Beyond 9 hours	do

If it is apprehended that blasting may prove harmful to nearby buildings or structures, other methods such as cutting out by means of chisel, wedge, pneumatic concrete breaker, sledge hammer or heavy points are normally adopted.

Slush—The above classifications of soil relate to dry excavations which extend up to a depth of 6 inches below the sub-soil water level. Beyond this depth the soil is said to be wet up to a depth which permits the labourers to work in the pit without getting themselves sunk into it. When the wet soil is so composed that it cannot support the weight of labourers working in the pit and the excavated material sticks to the implements used for digging, it is called slush and has an angle of repose less than 25°. Wet soil should start from half foot below the sub-soil water level and should go down till it can support man's weight.

Embankments

An embankment is constructed for any of the following purposes:—

(i) Storage of water as in case of dams etc.

(ii) Flood protections to check erosion and spill, etc.

(iii) River trainings on the headworks.

(iv) Keeping the water in the running channels in the fillings i.e. reaches where the water level in the channel is higher than the ground level.

(v) Maintaining uniform slope of rail track and road formation (metalled or unmetalled) in fillings i.e. reaches where the proposed formation level is higher than the natural surface level.

(vi) Bridging depressions or attaining uniform slopes of the link between two or more embankments.

(vii) Depositing the material obtained from precise or borrow-pit excavations considered unsuitable for any use or rendered surplus.

Embankments can be divided into three main categories depending upon their object. These are:—

a) Water retaining embankment.

b) Rail and road embankment.

c) Spoil bank.

Water Retaining Embankment

It is constructed with selected material on account of its following peculiarities: (i) It has to be watertight as much as possible to resist percolation. (ii) It should be strong enough to withstand the hydrostatic pressure. (iii) It should be impregnated to guard against erosion and wave-wash. (iv) It should have an adequate base friction to eliminate chances of sliding. (v) It should settle evenly on alternate wetting and drying without cracks or cavities.

RELATIVE MERITS OF VARIOUS SOILS AVAILABLE IN WEST PAKISTAN FOR CONSTRUCTION OF WATER RETAINING EMBANKMENTS

(a) *Sand*—It usually comprises 75 to 85 per cent of sand, about 10 to 15 per cent of silt and 5 to 10 per cent of clay. It has the following merits and demerits. The merits are:—

(i) It shrinks little and hence needs little settlement allowance.

(ii) An ideal material for hearting or core of an embankment since it does not permit leakage.

The demerits are:—

(i) It allows a considerable amount of seepage.

(ii) It is readily worn away by wave-wash because it has poor cohesion.

(iii) It has a very flat saturation gradient and thus requires a arge section and very flat slopes on water side.

(iv) It has a very flat angle of repose under water.

The sand embankments are, therefore, covered with at least one foot of pucca clay soil on top and 6 inches on the slopes to retain the section.

(b) *Clay*—It contains about 50 to 60 per cent of clay, 35 to 40 per cent of silt and 5 per cent of fine sand. This sort of soil is most unreliable and not very suitable for the main body of embankments, because it expands on wetting and shrinks unevenly on drying which give rise to cracks and cavities. These cracks and cavities make the embankment porous and cause numerous leaks. It should be employed only where it is unavoidable; but in this case the embankment should be trenched for wetting purposes and provided with sand core. Hard clay is, however, ideal for the outside facing or the cover and all embankments should, invariably, have a cover of the hardest clay available, particularly on their upstream slopes.

(c) *Sandy Clays*—This soil ranges between sand and clay and has approximately the following constituents: sand 50 to 70 per cent, clay 30 to 50 per cent and silt up to 20 per cent. Embankments constructed with this material, particularly, if they have the optimum admixture of clay and sand, and have been thoroughly compacted, are very satisfactory and can be relied upon. They are fairly resistant to wave-wash, and it is very rare that leaking occurs.

(d) *Loam*—It comprises 30 to 50 per cent of sand, 30 to 50 per cent of silt and less than 20 per cent of clay. Its particles are fine and packed well. It has, however, little stability when saturated. Embankments of loam require a facing of clay, and are resistant to leaks only when hearting is of sandy loam.

(e) *Kalar*—It is absolutely unsuitable for raising embankments since it decomposes under the action of water and gives rise to leaks. It is very treacherous and should be avoided as far as possible.

(f) *Numus and organic soils*—Thy are very bad for making embankments and should be carefully avoided.

(g) *Stabilized Soil*—If the existing soil does not possess the requisite qualities, stabilized soil for embankment can be obtained by blending the following proportions of material:

Sand (0.02 to 2.0 mm)	60 to 80 % by weight
Silt (0.002 to 0.02 mm)....	12 to 25% by weight
Clay (Below 0.002 mm)	8 to 15% by weight

Construction of Embankment

The following steps are involved in the actual construction of an embankment:

(i) The surface area of the ground to be occupied by the embankment is cleared of all rubbish, grass, roots, shrubs, brush, trees, fences, buildings, metalled roads, ruins and such other structures as may either cause hindrance in the execution of work or might decay and form dangerous pockets subsequently.

(ii) All loose surface or soft soil is removed to about 6 inches depth and the surface roughened by ploughing or digging all over. Small key-trenches are sometimes dug out in the bed to unite the body of the new embankment with the sub-soil. Another way of preparing the soil is by cutting V-shaped benchings, at intervals, running parallel to the central line. A key trench is very essential where the ground is porous, sandy or cracked. All soft soils are removed as far as possible, specially soils containing salt.

(iii) The central line of the embankment is distinctly marked with a dagbel, and pegs are fixed at every chain. The toes of the embankment are clearly lock-spitted and all curves in the alignment properly laid and half breadths carefully set out.

(iv) A complete profile of the embankment is set up at an interval of 500 feet and at every change of section as well as at every curve. This profile is 10 feet long of the actual completed embankment, with its correct heights, widths and all slopes dressed to true form. The correct height of this profile is 5 to 10 per cent greater than the final level of the embankment depending upon whether the embankment is to be compacted up to 95 per cent dry density or it has to guard against shrinkage and settlement. The ends of this profile bank are stepped so that proper locking takes place while constructing the banks adjoining them. Batter boards are employed for checking the slopes of the embankment.

(v) The embankment is completed according to the approved profiles by spreading earth in uniform horizontal layers of 6 inches to one foot thickness for the entire width. Each layer is thoroughly compacted before the next one above it is laid.

(vi) The top of the bank and slopes are carefully dressed and no hollows or humps are allowed to remain.

(vii) Proper ramps and turning platforms are provided for road crossings etc. In the case of ramps a gradient of 1 in 15 with an inner slope of 15 feet radius from the embankment on to the ramps usually works well.

Compaction of Embankment

The object of compacting soils is to improve their properties in respect of strength, liability to settlement and resistance to weathering. It involves the following processes:—

(i) The earth is placed in the embankment in uniform layers of 6 inches to one foot thickness depending on the hardness of the soil and the weight of rollers used for consolidation, stretching right across the whole section. An embankment is never, originally, made of less than full width so that it could be widened subsequently.

(ii) It is desirable to take earth first from the more distant pits, gradually lessening lead as the embankment rises, so that all earth is thrown into the slope and not tipped over.

(iii) All large clods are broken up in the borrow-pit, and no clod larger than man's fist is brought to the bank.

(iv) The width of each layer is usually a little more than the width required by the cross-section of the bank. The slopes are then dressed off to final section and not filled in afterwards.

(v) Each layer is compacted by rolling or ramming before laying the next one above it.

(vi) On important embankments each layer is brought to the optimum moisture contents and rolled to produce the maximum density.

(vii) Longitudinal bunds above 6 to 9 inches high and one foot wide on the top with side slopes of 2 to 1 may be made on the outer edges of the top of embankment. Also cross bunds of the same dimension at every 25 feet to 50 feet are provided so as to impound rain water to expedite consolidation before the monsoon sets in.

Rolling

The following are suitable rollers for rolling purposes.

(i) *Sheep foot rollers* are suitable for compacting dry, cohesive soils at low moisture contents.

(ii) *Pneumatic tyred rollers* are most suitable machines for compacting soils in embankments.

(iii) *Smooth-wheeled rollers* are satisfactory in most cases of sub-grade and base compaction.

(iv) *Vibrating machines* are suitably employed for compacting granular soils in confined areas like foundations and abutments.

(v) *Rammers* are employed for compacting clay soils in confined areas like foundations and abutments or where none of the types mentioned above could be available.

The organization of filling, spreading and rolling should be done in such a way that newly-deposited fill is spread and rolled smooth immediately in order to minimize the loss of moisture. To prevent the material from sticking to the rollers, dry earth is sprinkled, if necessary, on the surface before or during consolidation. Watering is not done till the layer has been completely rolled. Flooding with water to effect compaction of the fill is a bad practice. Water is, however, sprinkled over the rammed layer before the next one is spread to let the two layers adhere.

No matter how well an embankment has been consolidated it keeps on setting for some years owing to its own weight and weathering actions. The total vertical settlement of a well consolidated embankment is about 1/30 of its height.

Precautionary Measures

To safeguard against the failures of earthen embankments owing to percolation, piping, heaving, slipping, leakage, erosion, etc, the following precautions are observed:—

(i) *Increased width of slopes*—The width may be suitably increased in order to provide additional strength. In the case of embankments over 15 feet high and composed of materials containing high percentage of clay, the side slopes may be increased up to 4 to 1, depending upon the height of the embankments, next slope to which the material will stand without severe sloughing. Alternatively the berms may be provided 7½ feet wide for every 15 feet height of such embankments.

(ii) *Cut-off Trench*—In order to render the foundation of an earthen dam impervious to seepage water, a cut-off trench is made in the bed under the dam up to the depth that will prevent water from percolating underneath it. The trench is made in the centre of the dam, over which the core wall is built. Holes may be drilled all along the bed of the trench and thoroughly grouted with cement so as to provide a deep curtain below the bed, which is impervious to water. The trench is filled with puddled clay or concrete which is well bonded into the bottom of the trench by keys or grooves to ensure watertightness. Puddling in the trench is carried out by heeling by feet by workmen. The usual depth of a cut-off trench is 20 to 30 feet (it is not uncommon to have the trench 100 feet below the surface and still deeper walls have been built) and width 6 to 10 feet depending upon the depth.

(iii) *Key Trench*—A trench made under river banks which has the same functions as a cut-off trench and increases the path of percolation of the water. A key trench is very essential where the ground is porous, sandy or fissured. Usual section is: depth 3 to 5 feet, bottom width 4 to 6 feet, side slopes $\frac{1}{2}$ to 1 or 1 to 1. Where the cut-off trench is filled with concrete and puddle core wall built over it, suitable grooves should be made for the core wall to key into the concrete below. Strata which are not wholly watertight can be made impervious by injecting cement grout. The process consists of drilling small holes (2 to 5 inches diameter) into the strata and forcing in, under pressure, liquid cement either with or without sand or other fine aggregate. The cement enters and sets in the cracks and fissures in the soil, thus sealing them against the passage of water. If the trench is filled with concrete before grouting, it will provide an adequate weight to prevent undue waste of cement. Pipes are brought up through the concrete for grouting. It is interesting to note that sodium silicate has been used to seal strata into which it would have been difficult to inject cement grout. Under certain conditions of the soil it is obligatory to use cement concrete or grouting.

(iv) *Sand Core*—A sand core is sometimes provided where the embankment has to be built on an unreliable kalarish soil. It is keyed 3 feet into the ground and carried up to the high flood level line. Giving 4 to 6 feet width at the top with side slopes the sand will naturally stand. The core wall is usually provided in the centre of the bank, but if it is to be extended later on, it may be provided on the upstream slope with sufficient cover of earth over it. If any holes or cavities are formed by burrowing animals or ants, the sand will collapse and fill the holes, and thus breaches are avoided.

(v) *Core Walls*—The object of a core wall is to provide a barrier to the passage of seepage water from the water side to the rear of the dam and also to the passage o burrowing animals who cause dangerous breaches in embankments. A core wall may be of compact clay puddle, masonry (also called a diaphragm wall), concrete, or planks driven as sheet piling for small or temporary dams, taken down to impervious strata. The core wall may be located either in the centre of the embankment or on the water side of the slope.

Both the methods have their own merits and demerits depending upon the materials and other conditions. Although the outer core wall prevents percolation of water into the dam, it is liable to cracking owing to alternate wetting and drying as a result of fluctuations in the water level. It is also liable to injury owing to settlement of the slope. The puddle core wall is generally 4 to 8 feet wide at the top. Both sides batter outwards about 1 in 12 or 1 in 10 to the ground level below which the thickness is quickly reduced to about 2 feet wider than the top width and carried down in this way as far as necessary. The thickness is increased if the puddle clay is of poor quality. The top of the core wall is kept one foot above the high flood level and 2 to 3 feet below the top of the embankment. It is always preferable to make the whole embankment of one homogeneous watertight material and do away with the core wall which is liable to produce cracks and other defects in the body of the dam owing to unequal settlements of non-homogeneous materials. Earth for the dam near the puddle needs to be specially selected and well consolidated to minimize unequal settlement of the earth and the puddle core. The dry soil around the puddle core extracts moisture in the course of time. The construction of the puddle wall should be carried up simultaneously with the earthwork of the bank. At ground level a suitable groove or nose is constructed into which the puddle core is keyed. A covering of 3 to 4 feet of ordinary earth is placed over the top of the puddle core to prevent shrinkage and swelling caused by exposure to atmospheric changes. Where the height of dam exceeds 60 feet, a masonry core wall is preferred to a clay wall. It is the compact clay core which gives real strength and impermeability to dams.

(vi) *Clay Puddle*—Pure clay does not make a good puddle although it may be sufficiently impermeable to water, since it is liable to crack. An admixture of about ½ to 1 part of sand with 2 parts of clay (exact proportion depends upon the nature of clay) will reduce shrinkage considerably. Clay containing sodium carbonate is considered to be the best and most suitable for making roofing tiles. If sand is not easily available moorum should be tried, but the mixture must be free from stones. Where black cotton soil is found it should be mixed with moorum in the proportion of not less than 1 to 1, preferably 2 to 1. Puddle core of such materials should be thoroughly tested before attempting any important construction. The clay should be dug up and left exposed to air in layers not more than 12 inches thick for at least 2 to 3 days and watered a few times a day. The materials for making puddle should preferably be passed between a pair of rollers placed not more than half an inch apart so that stones and gravels, if any, are crushed before water is added. The scoured clay should be passed through a pug mill or thoroughly worked up by men's feet into a smooth homogeneous plastic mass, while just sufficient water is added. A puddle has a proper consistency when it can be squeezed in the hand and on release of pressure appreciable quantity does not adhere to the hand. A piece of clay puddle when dried should not shrink more than an inch and a half (preferably one inch) and not less than three-quarters of an inch per linear foot; otherwise it will probably not be sufficiently impermeable to water. The clay puddle should be consolidated compact and deposited in layers not exceeding 6 inches in thickness. Each layer should be thoroughly moistened before the new layer is laid and must be completely incorporated with the layer below by making cuts or keys. Special precautions should be taken to prevent the puddle from becoming dry; otherwise it will crack. The puddle that has become dry or has cracked must be replaced. There should not be any right angles in the cross-section of the puddle wall or trench, since they might produce fissures or cracks in the puddle. In building a clay core, the clay should be contained within boards which can be raised as the dam is built up. Ideally, each layer of puddle should be continued over the whole length of the core wall before another layer is placed, but in practice this is not always possible.

(vii) *Pitching*—Pitching is a covering of a hard material such as, stones, kankar blocks, concrete blocks or bricks, laid over slopes of an earthen embankment. If possible, one rainy season should be allowed to elapse and the bank given time to settle after it has been built, before pitching or any kind of stonework is undertaken. Slopes of embankments should not be steeper than 1:1, although 1½:1 should preferably be adopted. Rough stones are generally used for pitching with a thickness varying from 9 to 24 inches according to the velocity or wave action of the water. Stones should preferably be packed and firmly embedded over a bedding or backing of 3 to 9 inches thick layer of small broken stone, quarry rubbish, moorum, gravel, ballast or small kankar, thoroughly consolidated over the earthen slope to prevent the earth from being sucked out from between the stones by wave action.

Pitching should be constructed at right angles to the slope to be safe against sliding. The pitching stones should be the heaviest available that can be handled, and roughly cut to fit in properly. Stones should be tightly packed by hand and laid with their broadest face downwards, with as large a proportion of through stones as possible, giving due regard to bond. All interstices, hollows and inequalities between stones should be filled up with smaller pieces and wedged up tight with spawls driven in with slight hammering. The outer face of the pitching should be made as smooth as possible so as not to set up eddies that may cause scour lower down. The toe of the pitching should generally be carried 2 or 3 feet below the foot of the slope (into the ground) or a small retaining wall built. This should be done to give the toe a footing below saturated and soft top soil of the bed, for the stability of the pitching and security of the slope against slipping. Pitching should be widened out at the toe (near and below ground) so as to distribute the pressure over a wider area. If the bank is soft and erodible, the foot of the slope may be secured by piling (instead of a small retaining wall suggested above) and the thickness of the stone pitching downwards may also be increased at the rate of one inch per foot. The top most course should be horizontal and laid in one level line throughout the length of the embankment, preferably in mortar, and rounded off at the corners in side pitching. Pitching should be at least 3 feet higher than the high flood level and, if possible, should not be be carried up to a greater height than 10 feet, without giving a berm somewhere. In case concrete or kankar blocks are used they should not be less than one cubic foot in size. If brick pitching is used, only one brick should be placed for each course either as a header or strecther to prevent sliding. In reinforced brickwork pitching, care should be taken to leave expansion joints vertically at suitable intervals; the bricks are laid with frog downwards. In case stone pitching is to be pointed or grouted, the voids should be filled up with small chips or gravel and then pointed, or concrete grouting poured in.

(viii) *Revetment*—It is a facing of dry stone pitching or other material laid on a sloping face of earth to maintain the slope in position or to protect it from erosion, and is generally constructed with a slope of 1½ to 1 or 2 to 1 for ordinary soils and 3 to 1 for sandy soils. Its thickness generally varies from 1½ to 2½ feet according to the height. Other details given under "Pitching" should be followed. If stones are not procurable, mattress formed from brushwood may be used, which are bundles of branches and twigs from 8 to 12 inches in diameter and about 12 feet long and are bound with tarred ropes at intervals of 4 feet, laid side by side and tied together. These brushwood bundles should be secured by stakes or short piles to the bank on which they are deposited.

(ix) *Plantation and Turfing*—When banks dry up during the period of draught, the soil material of the banks becomes friable and cannot stand the action of water waves. If plantation is possible, pilchi, sarkanda, willow or other suitable trees should be planted for a width of about 100 feet in front of the toe of embankment. Such plantation breaks the force of the waves. Whenever practicable, grass (turf) should be grown on the sides of the slopes. Turfing should consist of sods not less than 4 inches thick and 9 inches square, well beaten into the bank. Before grass is grown, the slopes are properly dressed. It is kept in view that the earth placed on the slopes is suitable for the nourishment of turfing.

(x) *Failure of Earthen Embankments*—Failure of an earthen embankment is due to the following causes:—

(a) Erosion as a result of the velocity of water action of waves, rain and wind. Erosion causes slipping. To combat this menace stone revetment is made or pitching is done, as explained in the following pages.

(b) Overtopping because of insufficient height of freeboard. This cause is responsible for most of the failures.

(c) Percolation and leakage on account of insufficient ramming of the embankment and porosity of the material. The leakage water washes away the soil and caves are formed in the bund. Percolation may occur under the foundation or through the bund proper.

(d) Slipping owing to steeper slopes than the materials can stand. Slipping occurs on account of the over-saturation of the downstream side of the bund which has insufficient cover. The bund must stay within the "line of saturation" as explained earlier. Proper drainage should be provided by putting in granular material on the land side toe to drain out the surplus water. When a slip has occurred, all the slipped portion and the loose and slushy stuff must be removed and replaced by fresh dry material. The site of the slipped portion should be stepped back or benched and fresh soil added layer by layer, properly rammed and brought to the proper slope.

(e) Leakage on account of cavities or holes formed by the burrowing animals, insects and rats. Hollows are also formed by the roots of trees which have decayed, leaking outlet pipes or conduits. Efficient patrolling of the banks should detect these before they develop into breaches. Slopes and tops of embankments should be provided with a layer of hard material which the burrowing animals cannot penetrate. If a sand core is provided the sand collapses and fills the rat or ant holes and the leakage stops. Breaches also occur because of intentional cuts by cultivators.

(f) Excess supply raises the hydraulic grade line, wetting the portion of the bank which was never wet before. It settles down the dry earth of the bank above and causes a breach.

(g) General defective construction and maintenance can, of course, always be a cause for failure.

(xi) *Closing Leakages*—If the water flowing through a leak is sluggish and clear, it may be seepage water and there is no immediate danger. If, however, it is muddy and fast moving and carries the soil particles of the bank, the leak needs immediate attention. Correct location of the hole on both sides of the bank is essential which may not always be perpendicular to the bank. If the hole is of big size there is a whirling action in the water just above the hole. If it is small, heavy turf sods are thrown on the surface of water near its approximate location. They are soon attracted towards the leak and may come out at the rear. Leakage can be closed by throwing sawdust, bran, powdered dung, etc., just upstream of the leaks. The stuff is carried by water into the leaks where it swells and stops the leaks. Holes can also be plugged from the front side with balls of clay and turf which can be pushed into the holes. A method for closing big leaks is to cut an inverted T-shaped trench a little above the water line outside the bank, the entire leak is then opened out starting from the exit side, and all is filled with best material available (loam is ideal for the purpose), softened with water. The trench side should be made in steps for good bonding.

(*xii*) *Closing of Breaches*—Before starting to close a breach, labour and material (such as earth, sand, gunny bags, stakes, brushwood) should be collected at site in sufficient quantity. If earth is not available it can be obtained by cutting the outer slope of the existing bank. Enough earth should be collected on both sides of the breach on the existing bank. The ends of the banks should be protected first to prevent further widening. The process starts from both ends by slipping the earth from the heaps and protecting channel sides by grassy clods usually available from the berms. Earth baskets should never be thrown in the water. A semi-circular bund (ring bund) may be constructed on the water side with stakes, brushwood, mats, earth, etc., and water bailed out. The sides and bottom of the existing bund at the breach site should be cut into steps to remove all loose material and to form good bond with the new material. In case good soil is not available, a core wall should be provided.

Closing Breaches in Big Canals

This is usually done by driving a double line of stakes and filling jungle in between the stakes, pressing it down with bags filled with sand and by men walking over them. A temporary bank of gunny bags is thus raised in the position of stakes and bushing. Straight closure in large channels is not possible. No earthwork should progress before the flood through the breach has been arrested to some extent in this way. The closing of the breach is done by constructing a ring bund behind the line of stakes. Earth is slipped from both sides to form the ring bund.

NO. 17.1 (A) EXCAVATION & EMBANKMENT (EARTHWORK GENERAL)

Specifications

Scope

1. All excavations and earthwork shall be performed and executed in accordance with stipulations (specifications) and requirements set forth here which shall apply except when they are specifically modified in writing by the Engineer-in-charge for any particular item. The method of carrying out earthwork shall be subject to the approval of the Engineer-in-charge in writing.

Authorized Outlines

2. Unless otherwise specified or directed by the Engineer-in-charge in writing, all earthwork viz excavations, holes, trenches for foundations, filling, embankments, etc., shall be executed to the widths, lengths, depths, alignments, grades and levels shown on the approved drawings. If they are not indicated on the drawing, they shall be carried out to the profile agreed to by the Engineer-in-charge in writing before the commencement of work.

Site Clearance

3. The surface area of the ground to be occupied by all banks, spoils, borrow-pits and excavations shall be cleared off all roots, grass, shrubs, brush, trees, fences,

walls, buildings, roads, ruins and such other structures as may either cause hindrance in the execution of work or may decay and form dangerous pockets. Such works can be classified beforehand into following categories by the Engineer-in-charge for the purpose of making payment.

(a) Stripping of grass, uprooting bush stumps having girth and roots less than 3 feet and diameter less than six inches and their number not exceeding 200 per acre. The cost of this item is included in the unit rate of earthwork.

(b) Jungle clearance—Removal of roots, bush stumps, shrubs, trees and jungle. The Engineer-in-charge shall decide, on the basis of the actual sizes and concentration of such material, whether rate for ordinary jungle clearance or heavy jungle clearance is to be paid. His decision shall be final.

(c) Demolition of fences, walls, buildings, roads, ruins and other structures shall be paid according to the relevant item under the chapter "Dismantling". The rates for these works shall clearly state:—

i) The disposal of materials obtained during the operation of site clearance.

ii) Whether or not, it shall be a "set off" against the cost of site clearance. In the absence of such clarifications the materials shall be the property of government.

iii) That any damage to the works and public or private property caused by the contractor's operation in clearing shall be repaired or replaced at his expense.

Datum

4. Any bench mark, which is to be used for the work, shall be correctly related to the datum specified on the approved drawing or fixed by the Engineer-in-charge and the contractor shall make and maintain at his own cost all such permanent bench marks required for the proper execution of works in the vicinity thereof, in perfect order to the satisfaction of the Engineer-in-charge.

Setting Out

5. Before commencing actual execution the central line of the embankment or excavation shall be distinctly marked with a deep furrow (dagbel) at least 9 inches wide and 6 inches deep and pegs shall be fixed at every chain. Top and bottom edges of the excavation and toes of all embankments shall be clearly lock-spitted. All curves in the alignment shall also be properly laid and half-breadth carefully set out.

In the case of the excavation of foundation, the centre, longitudinal or face line and at least one main cross line, shall be marked by means of masonry pillars built clear of the point to which the slopes of the excavation shall extend. On each pillar, there shall be an accurate mark to enable a theodolite to be set up over it for setting out purposes.

All these operations involved in setting out are included in the unit rate for earthwork.

Profile

6. Having marked the alignment, a complete profile of the embankment or cutting, as the case may be, shall be set out at fifty feet interval or every change of section, and also at every curve. This profile shall have a linear dimension of 10 feet, its excavation shall be dug to the proper level, banks thrown up to the correct height,

widths and all slopes dressed to true form. The correct height of this profile shall be 10 per cent more than the desired final level of the embankment so that it may take care of shrinkage and settlement. The ends of all the profile banks shall be stepped so that proper locking takes place at the time of the construction of the bank adjoining them. All labour and implements like bamboos, stakes, strings, pegs, batter boards, etc., required for fixing profiles shall be supplied by the contractor and the cost is included in the initial rate.

Excavation

7. All excavations shall be done in accordance with the provisions of this chapter and to the lines and grades shown on the approved drawings or as directed in writing by the Engineer-in-charge. During the progress of work, if it is considered necessary or desirable by the Engineer-in-charge to vary the slopes or the dimensions of the excavations from those shown on the drawings or specified, he shall get the slopes or the dimensions revised by the competent authority and communicate the change in writing to the contractor. The contractor shall perform the work and make excavations according to the revised slopes and dimensions as communicated by the Engineer-in-charge.

Excavation in Foundation

8. (i) The bottom and side slopes of excavations, upon or against which structures or other required constructions are to be placed, shall be finished accurately to the required grades and dimensions, and if required by the Engineer-in-charge, shall be moistened with water and tamped or rolled with suitable tools or equipment for the purpose of forming a firm foundation. Whenever the natural foundation material is disturbed or loosened or excavated beyond the approved lines and grades, the loose material shall be removed and the extra excavation made good at contractor's expense with selected materials which shall be thoroughly compacted by tamping or rolling in layers not exceeding 6 inches. If at any point in the excavation, material unsuitable for foundation is encountered, as determined by the Engineer-in-charge, he shall direct in writing its removal and excavation shall be filled with selected materials thoroughly compacted by tamping or rolling in layers not exceeding 6 inches. The cost of this replacement with selected materials shall be paid under the rate for earthwork compacted.

(ii) When a safe and solid foundation cannot be obtained at the depth shown on the approved drawings, special measures (to be determined in all cases by the Engineer-in-charge) may be taken under a special agreement reached beforehand.

(iii) No excavated earth shall be heaped within 20 feet of the top edge of any foundation.

(iv) Foundation trenches shall be inspected and approved by the Engineer-in-charge before foundation is laid.

(v) All excavations shall be kept free from water from whatever source it may come, at all times to the entire satisfaction of the Engineer-in-charge except where otherwise specified or permitted in writing by him. No extra payment will be made for bailing, pumping or dewatering by any means. All swamps, drainage channels, etc., when no longer required, shall be filled in with concrete or other suitable material to the satisfaction of the Engineer-in-charge.

Slide Materials

9. Materials which do not stand on the slopes shown on the drawings or established by the Engineer-in-charge and the materials which are a part of slides extending beyond the established lines of excavation but are left into excavated areas, shall be removed by the contractor in an approved manner, and the slopes shall be re-finished to lines and grades established by the Engineer-in-charge. The contractor may be required to excavate potential slide areas beyond the limits of the originally staked excavation, if, in the judgment of the Engineer-in-charge, such excavation is necessary to prevent damage to the work.

Shoring for Foundation

10. (i) The contractor shall provide all timbering, steel sheet piles, or other approved supports, and shore the side of excavation, trenches, pits and walls, in such a manner as will be sufficient to secure them from falling and prevent any movement.

(ii) Shoring shall consist of frames of vertical and walling pieces supported by struts. These shall hold the laggings in position against the sides of the excavation. Laggings shall be further secured by wedges driven firmly down between the frame and the laggings. Scantling shall vary according to the foundation and their sizes shall be fixed by the Engineer-in-charge. Struts and frames shall be secured together by iron dogs and bolts, where necessary. In the case of deep foundation, additional vertical uprights shall be attached to the walling by iron dogs.

(iii) Excavation shall proceed as follows:—

When the sides of excavations show signs of caving in, the first frame and the first set of short-laggings shall be put in. The laggings shall be long enough to stand about 4 feet out of the ground. Wedges shall be driven in and excavation proceeded with. As excavation proceeds, two men on the top and two men below shall drive down each lagging separately, after drawing the wedges. When each lagging has been driven down as far as it can go, the wedge shall be replaced and the next lagging driven down in the same way......and so on. If the soil is dug away from under each lagging, the latter shall drop down in most cases without the aid of a mallet. Laggings shall be kept plumb and touching each other, otherwise it would be difficult to get the next frame in. When excavation has reached the full length of laggings, they shall be drawn out cautiously one by one, and the longer ones shall be put in or a fresh row driven inside the others. Excavation may then go down to the depth required, the frames being put in at least every 5 feet vertically. When concrete or masonry work is in progress, the process shall be reversed; the laggings shall be prized up one by one and the frames withdrawn as masonry is raised up.

(iv) Any cheap wood, cut in 6 inches or 7 inches planks, $1\frac{1}{2}$ inches to 2 inches thick, shall be used for lagging. The frame shall, however, be of sound wood that does not warp.

Excavated Material

11. (i) If cutting and filling are being done simultaneously all suitable materials obtained from excavation shall be used in filling. Wherever practicable, all meterials shall be placed in the designated final locations direct from excavation, except that the backfill material, when so directed by the Engineer-in-charge, shall be placed in tem-

porary stock piles and later placed in the designated locations. As far as practicable, as determined by the Engineer-in-charge, all materials designated for use in compacted embankments shall have the proper water content either by sprinkling or other suitable means before and during excavation or after placing.

(ii) All fill or refill around structures i.e. within the slopes and limits of the established lines for excavation for the structures and below the natural surface level, shall be placed as backfill or compacted backfill; and all fill or refill about structures i.e. above the natural surface level shall be placed as embankments or compacted embankments, except as otherwise specifically shown on the drawings or provided in these specifications.

(iii) If sufficient suitable materials are not available from the required excavations to construct the embankment, diversion, coffer dams, backfill and other earthwork construction shown on the approved drawings or directed in writing by the Engineer-in-charge, suitable materials shall be excavated from borrow-pits located in specified areas.

(iv) Excavated materials containing stumps, roots, vegetable matter and other objectionable material that are otherwise unsuitable or not required for backfill, compacted backfill, canals, channels, canal roads, rail track, road ways, level crossing or in any other permanent construction required under these specifications, shall be placed in designated spoil banks, adjacent to the canal or road. All spoil banks shall be levelled and sloped to drain and trimmed to reasonably regular lines as shown on the approved drawings or as directed in writing by the Engineer-in-charge.

(v) Materials of any kind such as shingle or hard good quality stone, obtained from excavation, as also any find made on the site such as antique, relics, coins, fossiles, etc., shall remain the property of the government. The rate includes the separation of the aforementioned materials and finds from each other and their depositing, as directed by the Engineer-in-charge. Any of these materials, if ordered by the Engineer-in-charge to be used by the contractor on the works, shall be charged to him at the "Material Supplied Only Rates" as in this schedule subject to the contractor's percentage, and if these rates are not available in this schedule, at the rates to be agreed upon between Engineer-in-charge and the contractor before the materials are used.

Filling around Foundations, Footings, Pipes, etc.

12. After the foundation structural works within excavations have been inspected and approved by the Engineer-in-charge excavations shall be refilled with selected material, taken from excavation, if so authorised by the Engineer-in-charge, well rammed and compacted by rammers in layers not exceeding 6 inches thick including watering, if directed. Material shall be placed with care around pipes to avoid damage. When the superstructure of a building is higher than the plinth level, the plinth area shall be filled in with excavated material if approved by the Engineer-in-charge in 9 inches layers well rammed, or with any other selected material as may be specified, for which extra payment shall be made.

The contractor shall be responsible for making good all settlement of filling and damage occurring thereby up to the end of the period of maintenance. No extra payment shall be made for this work.

13. (i) Embankments shall be constructed according to the approved profiles. Earth shall be taken from an approved source, borrow-pits or spoils, and shall be free from roots, grass, shrubs or other organic matter liable to decay.

Embankments

(ii) Embankments shall be built in horizontal layers, approximately 6 inches thick. These layers shall extend to the full width to the required side slopes and shall not be widened with loose material dumped from the top.

(iii) All clods and lumps of earth shall be broken up in the borrow-pits to a diameter of not more than 2 inches. Any clods or lumps thrown on to the bank shall be broken up and spread before compaction begins.

(iv) The top of the bank and the slopes shall be carefully dressed according to the approved profiles. No hollows or humps shall be allowed in the slope.

(v) Approaches to the roads and railway crossings will be made to a specified gradient, and crossings shall be so constructed that the roadway between the gates of level crossings is level for all classes of level crossings. The level portion will further extend outside the gates to such distances as are shown below:—

(i) *Special class level crossing*—Roadway shall be level upto 35 feet outside the gates followed by a gradient not steeper than 1 in 40.

(ii) "*A*" *class level crossing*—Roadway shall be level up to 24 feet outside the gates followed by a gradient not steeper than 1 in 30.

(iii) "*B*" *class level crossing*—Roadway shall be level up to 15 feet outside the gates followed by a gradient not steeper than 1 in 30.

(iv) "*C*" *class level crossing*—Roadway shall be level up to 10 feet outside the gates followed by a gradient not steeper than 1 in 20.

The angle of intersection between the central line of roads and railways shall not be less than 45°.

14. (i) Embankments and backfill designated on the drawings as compacted shall be compacted to the lines, grades and slopes shown on the drawings or as directed by the Engineer-in-charge in writing.

Compaction of Embankments

(ii) The contractor's operation in the excavation of material designated for use in compacted embankments or compacted backfills shall be carried in a way that results in an acceptable gradation of the materials, when placed. The compacted embankments shall be constructed of the finest and most suitable material for impermeability and stability.

(iii) The material in each layer before and during the time it is being placed shall have the optimum moisture content—2% throughout, required for the purpose of compaction as determined by the Engineer-in-charge. The material shall be brought to the proper moisture content at the site of excavation in so far as it is practicable, but such moisture shall be supplemented by sprinkling water at the site of compaction. If the moisture content is greater than the optimum, the compaction work shall be delayed till the material has dried to the optimum moisture content.

(iv) The material to be compacted shall be deposited in horizontal layers 6 inches thick as compacted. Its distribution shall be so as to ensure that the compacted material is homogeneous and free from pockets, lenses, streaks or other imperfections.

(v) When the material has been conditioned and placed as specified it shall be compacted by ramming or by suitable equipment of proper weight and size duly approved for use by the Engineer-in-charge.

(vi) For those portions of embankments or backfill which are adjacent to structures, including concrete pipes, where it is not possible to obtain adequate compaction with rolling equipment, the embankment or backfill shall be compacted with mechanical tampers or rammers of proper weight and size so as to obtain the same degree of compaction as the adjacent compacted embankment or backfill. The contractor shall be responsible for any damage to the structure caused by his operation in placing or compacting embankment or backfill material. Adjoining structure and all damages shall be repaired at his expense. In placing and compacting backfill or embankment adjoining concrete pipe, sufficient material shall be carefully placed on both sides of the pipe and tamped about the pipe so that the pipe is held firmly to the established line and grade. The material shall then be placed and compacted in layers as herein specified equally on both sides of the pipes to prevent displacement of the pipes during the placement and compaction of the adjoining material.

(vii) The material in compacted embankments and compacted backfill shall be compacted till the density of the compacted material is not less than 95 per cent of the maximum dry density as determined by suitable laboratory tests. The contractor shall afford all possible help to the Engineer-in-charge in obtaining representative samples for testing. Incidental cost of this operation shall be borne by the contractor as the rate for compaction is inclusive of it.

(viii) If any part of the work is being insufficiently consolidated earthwork shall be stopped till the consolidation is done to the satisfaction of the Engineer-in-charge. If the contractor fails to carry out specified compaction, the Engineer-in-charge may either add labour at the contractor's expense or take over the whole or part of consolidation and do it departmentally. In such cases the expenditure incurred departmentally shall be deducted from the contractor's bill.

(ix) Wherever the soil survey on the distribution of soils and groundwater conditions indicates the need for the stabilization of the bed of cuttings, the side slope and fills, by artificial means, i.e. injection under pressure of cement, sand, slurries or bitumen, it shall be carried out under the direction of the Engineer-in-charge. If the fill material requires stabilization, it shall also be carried out according to the direction of the Engineer-in-charge.

Key Trench and Sand Core

15. (i) The key trench shall be excavated true to alignment and section specified. Its bed shall be taken correct to the level shown on the approved drawings or as directed by the Engineer-in-charge and extra excavation shall be filled in with pure sand of the same quality as in the core. The extra filling shall be done by the contractor at his own expense, if he is responsible for this extra excavation.

(ii) Shoring and strutting necessary for the excavation of the trench to the specified dimensions shall be provided as per Specifications No. 17.1 (A) 10 by the contractor at his own expense.

(iii) In the event of slips during excavation, the trench or the front slope of the main embankment shall be remade to the correct slopes and bed levels and all loose and friable material removed from the bed by the contractor before filling is commenced. No claim for remaking the slopes, removing the loose and friable material or extra filling the side or slope or bed shall be entertained.

(iv) The excavated stuff shall be temporarily stacked in stock piles and finally deposited as directed by the Engineer-in-charge.

(v) No portion of the trench, however small, shall be filled in, unless approved by the Engineer-in-charge.

(vi) The key trench shall be measured and all deadmen or other distinctive marks removed. Such removal shall be inspected by the Engineer-in-charge or his authorized subordinate before filling is commenced.

(vii) The sand to be filled in the core shall be obtained from an approved source. The sand shall be also approved on the site of sand coring by the Engineer-in-charge or his authorized subordinate before filling is commenced. In the event of unauthorized filling prior to the approval of the bed of the trench, the contractor shall forthwith remove the filling to the correct bed level at his own expense when so directed by the Engineer-in-charge.

(viii) Sand shall be filled in 6-inch layers up to specified depth and properly compacted. Filling beyond sand core depth with earth shall not be commenced before the top levels have been checked and approved by the Engineer-in-charge or his authorized subordinate.

(ix) If the bank is to have a sand core, the sand filling, unless otherwise specified or directed by the Engineer-in-charge, shall be laid side by side with the layers of the embankments up to the height specified.

(x) Where sectional measurements of the embankments are proposed to be taken, no deduction shall ordinarily be made for bulkage of the sand in the sand core and the usual factors as contained in clause No. 20 of these specifications shall be applied.

(xi) The measurement and payment of sand utilized in the sand core shall be made according to the Specification No. 6.1.

Puddle Core

16. (i) The puddle shall be constructed when shown on the drawing or directed in writing by the Engineer-in-charge.

(ii) The clay for the puddle core shall be obtained from an approved source.

(iii) The clay suitable for brickmaking shall be generally acceptable. Preference will be given to one containing sodium corbonate.

(iv) Unless otherwise specified or directed in writing by the Engineer-in-charge, a mixture of about half to one part of sand with two parts of clay shall be used.

(v) Where sand is not easily available moorum (free from stone) and black cotton soil in equal proportion shall be used.

(vi) Before actual construction begins the mixture shall be thoroughly tested.

(vii) Clay shall be dug up and left exposed to the air in layers, not more than 12 inches thick, for at least two to three days and watered a few times every day.

(viii) Before mixing water, the materials for making puddle shall be passed through a pair of rollers placed not more than 1/8 inch apart or screened through a mesh of 1/8 inch so as to eliminate stone or gravel, if any. Thereafter it shall be passed through a pugmill or otherwise well worked up by men's feet into a smooth homogeneous plastic mass. Only sufficient water shall be added while this is being done. The correct consistency for good puddle shall be that at which it can be squeezed in hand without any appreciable quantity sticking to the hands when pressure is released.

(ix) The bottom layers in puddle trenches shall be made of puddle tempered upon the surface and thrown or dashed into the trench in balls to fill inequalities.

(x) Clay shall be deposited in layers not exceeding 6 inches in thickness and each layer shall be thoroughly moistened, compacted and incorporated with the layer below by making "cuts" or "keys".

(xi) If too much water has been used, the layer shall be excavated and removed from the trench before another one is laid upon it.

(xii) The construction of the puddle wall or clay puddle shall be carried up simultaneously with the earthwork of the bank.

(xiii) At ground level a suitable groove or nose shall be constructed to key down the puddle core.

(xiv) Special precautions shall be taken to prevent the puddle becoming dry; otherwise it shall crack. All puddles which have become dry or have cracks on account of contractor's ignorance, shall be replaced at his expense.

(xv) In building a clay core, the clay shall be contained within boards which can be raised as the embankment is built up.

(xvi) There shall not be any right angle in the cross-section of the puddle core.

(xvii) A covering of 3 to 4 feet of ordinary earth shall be placed over the top of the clay puddle to prevent shrinkage and swelling owing to exposure to atmospheric changes.

(xviii) Measurement of the clay puddle shall be made by volume. The unit of measurement shall be 100 cubic feet.

(xix) The unit rate shall include the supply of clay of an approved quality, working it up into puddle, laying, ramming, etc., as per above specifications. The earthwork involved in excavating the clay and the puddle trench shall be measured and paid as per clauses No. 19 & 21 of these specifications.

Borrow-Pits

17. (i) All earth for embankments and backfill shall only be obtained from borrow-pits set out (demarcated) by the Engineer-in-charge. The borrow-pits shall be located opposite to or as near as possible to the site of the fill.

(ii) When directed to do so, the contractor shall take earth from old bunds, mounds, key trenches, old borrow-pits, etc., only after they have been measured and measurement has been recorded by the competent authority. No such authorization shall be made unless the measurements mentioned above have been duly recorded.

(iii) The earth taken from any place, not duly authorized by the Engineer-in-charge, shall not be measured and paid for and the contractor shall be responsible for any damage arising from unauthorized pits.

(iv) No borrow-pit shall be excavated on or close to rail or road ways, village tracks, canals, level crossings or existing embankments and within 3 feet of the railway boundary. Borrow-pits shall not be located near residential and commercial areas but in case it is not avoidable their depth shall be limited and, where possible, arrangements shall be made to drain them. The sides of all such borrow-pits shall have a slope of 3:1. Any borrow-pit which does not conform to these specifications shall be properly filled in with earth obtained from approved pits and consolidated and dressed correct as specified at the contractor's expense.

(v) Borrow-pits, excavated to a depth not exceeding specified depth by 10 per cent, shall be paid for full excavated depths at the discretion of the Engineer-in-charge. However, where the actual excavated depths are more than 10 per cent of the specified depths, specified depths alone shall be paid for.

(vi) Borrow-pits shall preferably be multiples of 10 feet length, to facilitate recording of measurements.

(vii) As and when directed by the Engineer-in-charge borrow-pits shall be ploughed by the contractor after final measurement has been duly recorded and checked by the competent authority before the final bill of the contractor is paid.

(viii) All borrow-pits shall have deadman or such other distinctive marks, as directed by the Engineer-in-charge. The location of these marks shall depict the average height of the borrow-pit. Where the natural surface is regular they shall be left at equidistant intervals, and shall be allowed to remain intact till measurements have been recorded and checked. The contractor shall have to remove all such distinctive marks before he is paid finally. A certificate to this effect shall be given by the Engineer-in-charge in the final bill for payment.

Dealing with Bad Soil etc.

18. Any vegetation mound, kalar or other soil that the Engineer-in-charge may deem objectionable, shall be removed from the surface to be covered by the embankment or backfill and from the top of borrow-pits. This earth shall be disposed of as directed by the Engineer-in-charge and shall be measured up and paid for separately, and will not be included in the measurement of earthwork from borrow-pits. All holes and hollows on the site of embankment, or in existing banks under repair, shall be dug out and filled with good earth, duly approved by the Engineer-in-charge, properly laid and rammed. If the Engineer-in-charge directs the removal of any mounds their measurement shall be taken first and recorded in the measurement book. If the earth is considered good it shall be spread in the embankment in 6-inch layers.

Classification of Excavated Material

19. Excavation shall be classified under the following heads for recording measurement and making payment:—

(i) *Soft soil*—It includes all cutting in sand, silt and those soils which offer no resistance to excavation and sometimes require shoring when foundation (of buildings etc.) of exact dimensions is required to be excavated since they have small angle of repose.

(ii) *Ordinary soil*—It includes all cutting in earth which can be ploughed, irrespective of the fact whether picks or "phawarahs" have been used in the actual excavation. Usually it includes:—

a) Spoil or rubbish of every description.

b) Earth and sandy loam.

c) Any other formation into which a spade can be entered and can be easily excavated by the application of kassi, pick or shovel.

(iii) *Hard soil*—There are the following two types of hard soil : (a) It includes a stiff and heavy clay soil having specific gravity of 1.5 and above, which can be dug with repeated blows of kassi or pick axe.

(b) Soil having small percentage, say up to 15, of kankar or boulders which can be easily dug and removed alongwith the soil.

(iv) *Very hard soil*—The following types of soil fall under this definition:

(a) It includes hard moorum with high percentage of kankar (more than 15) or boulder (less than 20) which can be individually lifted by hand.

(b) Mud concrete.

(c) Conglomerate formation, shale lime concrete, brickwork in lime and stone masonry in lime.

(d) Metalled surface of the road (tarred or untarred).

(e) Hard core under floor and road bottoming.

(f) Any other formation into which a spade cannot enter and the excavation of which requires the forcible application of a pick.

(v) *Gravel work and rock not requiring blasting*—This includes:—

(a) Gravel formation, cement concrete, brickwork in cement mortar.

(b) Large boulders above 20 per cent which can be individually lifted by hand.

(c) Soft varieties of limestone, sandstone or fissured stone or any other formation which can be excavated by use of picks, jumpers, shovels, wedges, hammers, etc., and do not require blasting.

(vi) *Rock requiring blasting*—This includes hard stratified rock, like compact hard limestone, hard sandstone or unfissured and unstratified masses like granite and basalt (trap), etc. or similar formation for the excavation of which blasting is required since they cannot be excavated by jumpers, wedges, hammers, picks, etc.

Rocks falling under this class can be further sub-classified into 6 grades. These grades shall be determined as follows:—

Grade I A party of two men working with a jumper bar 1¼-inch diameter and hammer minor 7 lbs. shall be able to make a trial bore hole 3-inch deep in 4 hours or less.

Grade II to VI For every hour taken in making this trial bore over 4 hours a higher rate shall be payable up to 9 hours from which grade VI shall be paid irrespective of the type of explosive used.

Note I. The Engineer-in-charge shall make the above classification of soil and rock. In case of dispute between the Engineer-in-charge and the contractor, the classification shall be finally decided by the Superintending Engineer. The decision shall be binding on both the parties. The Engineer-in-charge shall also be responsible for deciding on the percentage of each classification to be applied in the case of mixed up soils or rocks. The Engineer-in-charge shall certify in writing that he has decided on the classification of rock on the basis of experimental bore holes made in his presence.

Note II. Blasting shall not be performed without the prior written permission of the Engineer-in-charge. The contractor shall check all necessary precautions for the safety of person and property, etc., as required by the Engineer-in-charge and shall obey all instructions as may be issued by the Engineer-in-charge.

(vii) *Rock requiring blasting but blasting prohibited*—

This includes all as No. (vi) above, where blasting is prohibited by the Engineer-in-charge. Blasting is prohibited when it is apprehended that it may cause harm to important buildings or other works located nearby. In that case other methods such as cutting out by means of chisel or wedges, pneumatic concrete breakers, sledge hammers and heavy points are normally adopted.

(viii) *Wet*—A soil shall be classified as wet when on being taken in a piece of cloth and pressed by hand, wets the cloth.

(ix) *Wet (slush)*—Wet soil when so composed that it cannot support the weight of labourer working into the pit and excavated material sticks to the implements used for digging, shall be classed as slush and paid accordingly.

Measurement

20. (a) *Quantity of Earthwork*—Earthwork (Excavation and Embankments) shall be measured in bulk. The unit of measurement shall be 1000 cubic feet. The exact quantum of earthwork shall be ascertained by taking measurements of borrow-pits from which the material has been taken out and not of the resultant spoil or embankment. When this is impracticable, measurement shall be taken of the resultant embankment and converted to solid measurement by multiplying it with factors mentioned below for soil and rocks.

DESCRIPTION OF EXCAVATION	CONVERSION FACTOR SOIL
1. Material excavated, spread, levelled and/or filled not rammed or equally consolidated or weathered for a period of 6 months.	90 per cent
2. Material excavated, spread, filled, levelled, watered and rammed or compacted at optimum moisture contents to attain a certain density or heaps and embankments consolidated by exposure to weather etc. for a period exceeding 6 months.	The factor to be applied shall depend upon the percentage of density obtained by compaction as determined by laboratory tests.

(b) *Lead and Lift*—Unless otherwise specified lead and lift shall have the following meanings:—

(i) *Lead (Horizontal)*—It shall mean the shortest possible horizontal route between the centre of gravity of the material excavated and the centre of gravity of the material finally placed in the embankment.

(ii) *Lift (Vertical)*—It shall mean the vertical difference between the centre of gravity of the earth excavated and the centre of gravity of the earth placed in the embankment.

(iii) *Conversion of Lift in Horizontal Lead*—The lift shall be converted into horizontal lead with the aid of table appended. (Table 5)

(iv) *Total Lead*—Total lead or lead shall mean the horizontal lead as defined above plus the lift converted into horizontal lead, if any.

Rates

21. The unit rate shall include the execution of earthwork according to above specifications. A special rate shall be settled and paid for the following items of works:

(a) For cutting down, removing and digging out roots of all trees (not shrubs, grass, etc) of 2 feet girth and over, standing on the site of embankment or cutting, measurement of girth shall be taken 5 feet above ground level. Rate shall be fixed for each tree. Trees shall be counted and marked before removal. This work may be done departmentally if thought necessary by the Engineer-in-charge.

(b) Special material such as sand, or selected earth, brought from a place other than regular borrow-pits.

NO. 17.1 (B) EARTHWORK FOR REPAIRS

Specifications

Repairs to Banks (holes and ravines)

(I) (i) All holes (gharas) and ravines shall be, wherever possible, first fully opened out to the bottom.

(ii) All lumps of fallen earth shall be dug away, and the sides dug down in steps not more than 1½ feet deep.

(iii) All jungle, grass, roots, or other rubbish shall be thoroughly cleared, and the work when ready for filling shall be inspected and passed by the Engineer-in-charge before filling begins.

(iv) Filling shall be done in accordance with the specifications No. 17.1 (a) indicated for foundation pits.

(v) At the end of day's work, top layer shall be flooded with water to attain consolidation.

(vi) During the work in progress rammers of approved type shall be employed for ramming, as directed by the Engineer-in-charge.

(vii) In all other respects it shall conform to specifications No. 17.1, unless otherwise specified or directed in writing by the Engineer-in-charge.

Repairing of Banks by Earth from Berms

(2) (i) Where a silt berm exists, earth for filling and repairs shall be obtained, as far as possible, by cutting away such berms.

(ii) Care shall be taken that a layer of at least 6 inches thick of silt adjacent to the bank is left intact except under special orders of the Engineer-in-charge and that cross dowels are left at close intervals in the silt berm so that borrow-pits may silt up quickly.

(iii) Any bank which is to be widened or raised shall be ploughed or cut into steps.

(iv) Raising of driving banks shall not be done with sandy earth or silt.

Repairing of Banks by Earth from Spoil Banks

(3) (i) In case there is no berm, earth shall be obtained from the spoil bank if there is one or from outside excavation.

(ii) In getting earth from the spoil bank, borrow-pits on top shall be strictly prohibited, since in wet weather they form tanks and lead to damage by breaching.

(iii) Earth shall preferably be obtained from the back of the spoil, or by widening the drainage gaps in the spoil banks.

Repairing of Banks by Earth from Borrow-Pits

(4) (i) Where there is no spoil, earth shall be obtained by levelling down any high lumps, and last of all from borrow-pits.

(ii) Where borrow-pits are unavoidable, they shall be dug as far from the toe of the bank as possible and shall not be more than one foot deep, unless otherwise specified.

(iii) Borrow-pits shall be neatly set out parallel to the banks, if there were no old borrow-pits.

(iv) The dimensions and distinctive marks in the new borrow-pits shall be fixed by the Engineer-in-charge to avoid any mixing with the old borrow-pits.

(v) All old borrow-pits shall be measured and measurement duly recorded and checked before new borrow-pits are put in.

(vi) A bar, at least 10 feet wide, shall be left after every chain to eliminate all chances of a regular rain water drain running along the bank.

Silt Clearance

(5) (i) The ultimate levels after silt clearance and the corresponding depth of excavation in different reaches of a channel shall be clearly shown on the working drawing.

(ii) All excavations for silt clearance shall be carried out according to the working drawing mentioned above or as directed in writing by the Engineer-in-charge.

(iii) The spoils from silt clearance of channel shall be spread out evenly in the neighbouring borrow-pits.

(iv) In the absence of borrow-pits, the spoil shall be spread evenly along the back of the bank, thus widening and strengthening it.

(v) Care shall be taken not to heap spoil on the top of the bank, or to throw it in lumps on the outside so that it may not be blown in by wind or rain.

NO. 17.2 EARTHWORK FOR RIVER EMBANKMENT

Specifications

General

1. Except as otherwise provided herein, river embankments shall be made to the alignments, grades and dimensions shown on the approved drawings or established by the Engineer-in-charge in writing and shall also be in complete conformity with the corresponding requirements set forth in the section, Excavation and Embankment (Earthwork General) Specifications No. 17.1 (A).

Preparation of Surface

2. After the site clearance work has been completed, the ground surface under all embankments to be compacted shall be ploughed thoroughly to a depth of not less than 9 inches, moistened, if so required, and compacted as specified herein.

Borrow-Pits

3. In addition to the Specifications No. 17.1 (A) 17 borrow-pits for river embankments shall conform to the following specifications:—

(i) Borrow-pits shall be on the river side of the embankment only and no excavation whatsoever shall be done on the land side without written orders of the Engineer-in-charge.

(ii) No borrow-pit shall be excavated within 150 feet of the toe of the bank on the river side for new embankments. Borrow-pits, 150 to 200 feet away, shall not be deeper than 6 feet, and 200 to 300 feet away, not deeper than 8 feet. Beyond 300 feet they can be of any depth. For repairs, raising and strengthening of the existing embankments and providing berms etc. earth may be taken from 100 to 150 feet. From 100 to 110 feet the pits shall not be deeper than 3 feet, from 110 to 130 feet not deeper than 4 feet, and from 130 to 150 feet, not deeper than 5 feet.

(iii) Borrow-pits shall be allowed on the land side of embankment only, if this is absolutely unavoidable. In such cases pits shall not be nearer than 80 feet of the land toe of embankment. The depth of the pits from 80 to 120 feet shall not exceed 2 feet and beyond that the maximum permissible depth is 5 feet.

Key Trench and Sand Core

4. (i) The key trench shall be excavated true to alignment and section specified. Its bed shall be taken correct to the level shown on the approved drawings

or as directed by the Engineer-in-charge and extra excavation shall be filled in with pure sand of the same quality as in the core. This extra filling shall be done by the contractor at his own expense, if he is responsible for this extra excavation.

(ii) Shoring and strutting necessary for the excavation of the trench to the specified dimensions shall be provided as per Specifications No. 17.1 (A) 10 at the expense of the contractor.

(iii) In the event of slips during excavation, the trench of the front slope of the main embankment shall be remade to the correct slopes and bed levels, and all loose and friable material removed from the bed by the contractor before filling is commenced. No claim for remaking the slopes, removing loose and friable material or extra filling the side or slope or bed shall be entertained.

(iv) The excavated stuff shall be temporarily stacked in stock piles and finally deposited as directed by the Engineer-in-charge.

(v) No portion of the trench, however small, shall be filled in unless approved by the Engineer-in-charge.

(vi) The key trench shall be measured and all deadman or other distinctive marks removed. Such removal shall be inspected by the Engineer-in-charge before filling is commenced.

(vii) The sand, to be filled in the core, shall be obtained from an approved souree. The sand shall be also approved on the site of sand coring by the Engineer-in-charge or his authorized subordinate before the filling is commenced. In the event of unauthorized filling prior to the approval of the trench, the contractor shall forthwith remove the filling to the correct bed level at his own expense, when so directed by the Engineer-in-charge.

(viii) Sand shall be filled in 6-inch layers up to specified depth and properly compacted. Filling beyond sand core depth with earth shall not be commenced before the top levels have been checked and approved by the Engineer-in-charge or his authorized subordinate.

(ix) If the bank is to have a sand core, the sand filling, unless otherwise specified or directed by the Engineer-in-charge, shall be laid side by side with the layers of embankments up to the height specified.

NO. 17.3 EARTHWORK ON CANALS

Specifications

1. Except as otherwise provided herein, earthwork on irrigation canals shall be finished to the alignments, grades and dimensions shown on the approved drawings or established by the Engineer-in-charge in writing and shall, in all respects other than those specified herein, be in complete conformity with the corresponding requirements set forth in the section, Excavation and Embankment (Earthwork General) Specifications No. 17.1 (A) **Scope**

Actual Excavation

2. Excavation shall be done strictly according to the instructions of the Engineer-in-charge. Normally, it shall be done in lifts of 2 feet to 5 feet. In each chain each lift will be completed as far as possible, before the one below is commenced. Care shall be taken that the final completed width of the channel is in no place exceeded. All gangways, rail or roadways and steppings shall be left within the channel and not cut into the slope. The final dressing of the slope shall then consist of digging only, and no filling or making up will be necessary. Excavation shall preferably be done by first cutting a centre trench with vertical sides and then trimming the slopes.

Construction of Banks

3. In addition to Specifications No. 17.1 (A) 13 the embankments for the canal shall conform to following specifications:—

(i) The banks shall be constructed according to the approved profile.

(ii) Earth shall be taken from an approved source, borrow-pits in the bed of channel or outside or spoils as actually specified, and shall be free from roots, grass, shrubs or other foreign matter liable to decay.

(iii) In case of a distributary, if the earth obtained from cutting is indequate for making the bank, extra earth required shall preferably be obtained by widening the bed of the channel itself. The bed may be widened to three times the normal width. Such widening shall be of the same amount through each length of low ground and not vary frequently.

Borrow-Pits

4. In addition to the Specifications No. 17.1 (A) 17 the borrow-pits for canal embankments shall conform to following specifications:—

(i) Borrow-pits shall be dug only where unavoidable. Spoil for the formation of the banks shall be laid along the channel, if possible, in preference to taking it from borrow-pits.

(ii) No borrow-pit shall be dug within 10 feet of the toe of the bank, and, if its depth exceeds 2 feet the distance from toe of the bank to top edge of pit shall not be less than 15 feet.

(iii) If directed by the Engineer-in-charge to have a borrow-pit in the bed of the channel a berm of 5 feet from the inner toe of the bank shall be left on either side. Each pit shall be separated from the other by a berm equal to half the length of the pit. The depth of these pits shall in no case exceed 1 to 2 feet below the bed of the channel. In case of a channel which is not expected to receive silt during its running, no pit shall be dug below the bed level. Pits shall also not be dug within 20 feet of the masonry works or the cattle track across the channel.

(iv) Borrow-pits shall be as shallow as possible and not more than one foot deep in the cultivated areas acquired temporarily. In lands permanently acquired the maximum depth shall normally be 3 feet. In no case a borrow-pit deeper than 5 feet shall be allowed within a distance of 300 feet from the front toe of the bank.

NO. 17.4 ROAD EMBANKMENT AND EXCAVATION

Specifications

Scope

1. Except as otherwise provided herein, all excavations and embankments for road work shall be made to the alignments, grades and dimensions shown on the approved drawings or established by the Engineer-in-charge in writing and shall also be in complete conformity with the corresponding requirements set forth in the section, Excavation and Embankment (Earthwork General) Specifications No. 17.1. (A)

Rock Cuttings and Earthwork on Hill Roads

2. (i) Before the work is started at any place, the proposed central line of the road or a line parallel to it shall be set out by theodolite.

(ii) Apex pegs shall be fixed in concrete. The position of apex pegs and tangent points shall be indicated by a white mark painted on the nearest parapet wall or rock. A bench mark shall be made on the nearest rock, away from the cutting in a prominent place and painted white so that it can be found at all times.

(iii) Level shall then be observed at every 25 feet along and at right angle to the central line and recorded. On each cross-section a permanent peg shall be fixed clear of the cutting and its position clearly indicated on the drawing. This peg shall be known as reference peg (R. P.) as the measurements of the work depend entirely on it.

(iv) The contractor's concurrence to the correctness of levels shall also be obtained in writing. All work executed by him prior to this concurrence shall not be measured for payment.

(v) On completion, the new profile shall be plotted on the sections which shall again be verified and signed by the contractor.

(vi) Pegs shall be supplied and fixed, and bench mark made by the contractor or at his expense by the department. The marking of the centre line shall also be done by the contractor. Work done in excess of that indicated on the approved drawing shall not be paid for.

NO. 17.5 MAKING FORMATION FOR RAILWAYS

Specifications

Scope

1. Except as otherwise provided herein, all excavations and embankments for railway track formation shall be made to the alignments, grades, levels and dimensions shown on the approved drawings or established by the Engineer-in-charge in writing and shall in all respects, other than those specified herein, be in complete conformity with the corresponding requirements set forth in the section, Excavation and Embankment (Earthwork General) Specifications No. 17.1. (A)

Site Clearance

2. Unless otherwise specified or directed, the site clearance shall be done as per Specifications No. 17.1(B). This work shall be kept at least 1000 feet in advance of making up formation, and grubbing work at least 300 feet ahead.

Formation

3. Unless otherwise specified or directed in writing by the Engineer-in-charge, the formation width and slope of the embankment cutting shall be as follows:—

(a) *Formation Width (Embankment)*

(i) Broad Gauge		
	a. Single line	20'—0"
	b. Double line	35'—6"
(ii) Meter Gauge		
	a. Single line	16'—0"
	b. Double line	28'—0"
(iii) Narrow Gauge		
	a. Single line	12'—0"
	b. Double line	23'—6"

(b) *Formation Width (cutting)* exclusive of side drains.

(i) Broad Gauge		
	a. Single line	18'—0"
	b. Double line	33'—6"
(ii) Meter Gauge		
	a. Single line	14'—0"
	b. Double line	26'—0"
(iii) Narrow Gauge		
	a. Single line	10'—0"
	b. Double line	21'—6"

(c) *Slopes*

(i) Embankments	2 to 1
(ii) Cutting	1½ to 1

Cuttings

4. In order that excavations may drain themselves automatically, the central block of earth or gullet shall be first excavated. This shall be done in a manner that the bottom of excavations shall, where possible, slope downwards from the centre of the cutting towards the ends. Excavation shall be made in such cuts or steps as may, from time to time, be directed by the Engineer-in-charge. In deep cuttings, the first cut or step shall approximately follow the surface of the ground where this will secure the necessary slope for drainage, and shall be excavated to such depth, not exceeding 10 feet, as may be directed, with perpendicular sides leaving pathways for the workman along the sides of the cuts, at about every 50 feet. In shallow cuttings not exceeding 6 feet in depth in the deepest part, the gullet shall be cut out straight away to formation level.

When so specified or directed, the central portion or gullet of the cutting shall be first taken out to full width of formation to enable the Engineer's representative to determine the slope suitable to the particular cutting or to the different lengths of it.

When the gullet is cut out to its full depth in shallow cuttings, or to the depth of the first cut in deep cuttings, the side portions of triangular section up to the slopes shall be excavated. In deep cuttings, the second cut shall not be started till the top portion is thus completed.

Slopes of all cuttings shall be cut true and straight, and all loose stones, boulders, roots, stumps and unstable ground in slopes shall be removed. Under-cutting of slopes shall not be permitted, except with the written approval of the Engineer-in-charge.

Side Drains

5. Side drains shall be made at the bottom of the slopes in cuttings, and shall normally be 4 feet wide at the formation level, with sides sloping 1 to 1, laid with a a minimum grade of 0.3 per cent, unless otherwise specified or directed by the Engineer-in-charge. For eroding velocities the drains shall be lined or the velocity reduced by check dams or drops.

Sub-Drains

6. Wherever required or directed by the Engineer-in-charge pipe sub-drains shall be constructed of the material, size and design, and in the location shown on the drawings and to depth and grade prescribed for them. The cross-section of the trench shall conform to the drawings. The trench shall be excavated and the pipe laid to true line and grade. Sufficient cribbing or shoring shall be used to prevent caving in of the trench excavations. All trenches shall be backfilled with an approved permeable material, to the sections indicated on the drawings or as directed by the Engineer-in-charge.

Excavation Below Formation

7. Unstable material in the bottom of a cut shall be removed to a depth shown on the drawings or as directed by the Engineer-in-charge and filled up to the formation level with approved material. The measurement of excavation shall be made to the bottom of the material removed. Payment for refilling shall be made under the relevant item of earthwork.

Excess Excavation

8. All cuttings shall be taken out carefully to the precise dimensions shown on approved drawings or directed in writing by the Engineer-in-charge. In case the bottom of the excavation of the cutting is taken out deeper than necessary by oversight or neglect of the contractor, the hollow shall be filled in to true depths with approved material and compacted to the satisfaction of the Engineer-in-charge or his authorized subordinate. No payment shall be made for excessive cutting and refilling to the true formation level. The removal of unpreventable slide to the extent to be decided by the Engineer-in-charge shall, however, be measured and paid for.

Berm in Rock Cutting

9. A berm of 5 feet shall be left between the top of slope of rock cuttings and the toe of the slope of the overlying earth.

Blasting

10. When explosives are used in rock excavations, the charges shall be so proportioned and placed that they do not loosen the rock outside the excavation lines as shown on the drawings or as provided in the specification. If the rock below the line of the side slopes should be loosened by blasting to an extent that renders it liable to slide or fall, such loosened rock shall be removed by the contractor at his own expense. Where blasting is likely to endanger person or property, the Engineer-

in-charge shall have the power to prescribe and enforce such rules and regulations as may be necessary. But the prescirbing or failure to prescribe such rules and regulations shall not absolve the contractor from any responsibility under the contract.

Source of Filling

11. Where the quantity of material from the cuttings of standard cross-section is not sufficient to form embankments, as specified, the deficiency shall be made up by widening the cuttings on one or both sides to the extent and with the slopes directed, unless the use of borrow-pits is indicated on the approved drawings authorized by the Engineer-in-charge.

Earth shall normally be obtained from the railway land, but if additional filling is required or if alternative borrow is desired, it shall be obtained from a source approved by the Engineer-in-charge. Before excavating material from such outside borrow-pits, the contractor shall at his own cost secure from the owner thereof and deliver to the Engineer-in-charge a written lease to railway from all damages arising from such use.

If the available fill material consists of sandy soils and clay, they shall not be mixed as far as possible. A part of the sandy soil shall be reserved for constructing the upper part of the embankment and the remainder either for the outer parts or for the lowest portion of the highest fill sections.

Borrow-Pits

12. Unless otherwise specified, borrow-pits for railway formation shall conform to specifications No. 17.1 (A) except for the following requirements:

(i) For railway embankment up to 8 feet in height, the earth shall be generally borrowed from borrow-pits on one side of the alignment. This shall be the side toward which flood water is expected to head up, or the upstream side in the case of sloping ground.

(ii) In setting out borrow-pits, 20 feet berms after every 180 feet shall be left out to allow convenient access to the line during construction and to prevent the borrow-pits from developing ultimately into water courses alongside embankment. The width of the pits shall vary according to the height of the embankment. The maximum depth shall not ordinarily exceed 8 feet. This is on the condition that the sub-soil water level is lower than the bottom of the pit.

(iii) Unless otherwise specified or directed by the Engineer-in-charge, the slopes of sides of borrow-pits, nearest to the line, shall generally be 2 to 1 and the slopes of the outer side and ends shall be 1 to 1.

(iv) In embankments over 10 feet high or where the ground is low and swampy only the outer halves of the borrow-pits are to be marked out. When work is completed on them to the full calculated depth, excavation may be commenced on the inner halves. These halves shall be marked when the outer halves have been excavated.

(v) In the case of embankments constructed for a single line of railway, berms on either side of the embankment shall be left as shown on the drawings or directed by the Engineer's representative. These berms shall be between the toe of the slope of the embankment and the top edge of the slope of the borrow-pits. Unless otherwise specified or directed these berms shall be 30 feet and 45½ feet, the latter being on the side on which doubling might eventually be done.

13. (i) Earthwork shall be done by ballast train when earth is not suitable for use as filling material. The source of borrowing earth shall be approved by the Engineer-in-charge. The conditions for running the ballast train shall be clearly indicated in the contract. **Earthwork by Ballast Train**

(ii) Unless otherwise specified, the earth shall be loaded into the wagons by baskets and unloaded by 'khudalies'. After unloading, the earth shall be pulled immediately to 10 feet clear of the rails and levelled down to sleeper level. Whenever directed by the Engineer-in-charge that earth may be unloaded by baskets, an extra rate shall be paid as contained in the agreement.

(iii) The measurement of earth shall be done in the loaded trucks unless otherwise specified. The unit rate shall include loading into the wagons, unloading and clearing track up to 10 feet in accordance with the above specifications.

14. Catch-water drains shall be made at the top of the slopes of all cuttings and along fills where the ground falls towards the centre line. A minimum berm of 3 feet inside the boundary of the railway land shall be left outside the catch-water drain. The spoil from the drain shall be thrown up on the side towards the cutting or the embankment. The size and grade of the catch-water drains shall be as shown on the drawing or as directed by the Engineer-in-charge and shall generally be 6 feet wide and 2-feet deep with 1 to 1 side slopes and a minumum grade of 0.3 per cent. For eroding velocities the drains shall be lined or the velocity reduced by check dams or drops. These drains shall be made before cutting or filling is started. **Catch-Water Drain**

15. Unless otherwise specified, embankments shall be constructed and compacted by mechanical means as per specifications No. 17.1 (A) 13. **Embankment**

16. Unless otherwise specified or directed in writing by the Engineer-in-charge, embankments shall be made without the help of mechanical compacting equipment. The fill shall be allowed to weather and to settle under its own weight and the weight of the traffic running over it for about 2 to 3 years. Hard ballast shall not be placed beneath the track during this period. **Consolidation of Embankment**

17. Embankments shall be carried to such heights above formation and to such increased widths as may be deemed necessary by the Engineer-in-charge to account for shrinkage, subsidence and erosion. Unless otherwise specified, the normal limit shall be 2 inches for every one foot of the height. As embankments become consolidated, their sides shall be carefully trimmed to proper slopes. Embankments shall be maintained at their proper heights, dimensions and shapes till the work is finally accepted by the Engineer-in-charge. **Shrinkage**

18. If an embankment is to be placed on sloping ground the surface shall be deeply ploughed or stepped. Whenever directed, boggy or unsuitable material shall be excavated so that the embankment is on a firm foundation. **Embankment on Slopes**

19. The top 3 feet to 4 feet of embankments shall always be constructed with non-swelling, selected material duly approved by the Engineer's representative before **Topping of Embankment with Selected Material**

it is used. The use of clay shall be avoided because, when damp, it is likely to squeeze under the influence of traffic into the voids of ballast causing settlement of the track and forming shallow trough in the crest of the fill which collects water and further softens embankments. A continuous process of deterioration of track is thus started, which results in increasing the maintenance costs. Where the use of clay as a topping material cannot be avoided the top 3 feet to 4 feet of the fill shall be mechanically compacted to 95 per cent of the maximum density at 1 or 2 per cent below the optimum moisture content and finished off by giving the clay surface a pronounced crown. (In this case, if so specified or directed by the Engineer-in-charge, cement grout shall be injected into the lower part of the ballast section to keep the clay out of the ballast.)

Embankment over Masonry

20. In filling over masonry or other structures, the material shall be deposited in layers not more than 6 inches thick with each layer carefully tamped. Only the best available material shall be used for this purpose. Wet or impervious materials shall not be used for filling over masonry. The filling over arches shall be deposited simultaneously from both sides. Large stone shall not be placed within 3 feet of the extrados of any arch. Waterproofing, if any, shall be kept intact and undamaged by filling operations.

Protection of Slope

21. Unless otherwise specified or directed, side slopes of formation shall be protected by either of the following methods:

(i) Check dams and drains.
(ii) Vegetation.
(iii) Surface blanketing.
(iv) Fencing.
(v) Picthing.

The method actually adopted shall be the one specified or directed by the Engineer-in-charge.

Retaining Structure

22. In sliding cuts where the slopes cannot be flattened to the angle of repose without the removal of an excessive amount of material or disturbing the ground surface beyond the right of way line and also where it is necessary to support all or a part of an embankment slope against the hydrostatic pressure or deep ravine, retaining structures such as timber, concrete or iron cribbing, timber and scrap rail piling or masonry retaining walls shall be provided, unless otherwise specified or directed by the Engineer-in-charge.

Cribs

23. (i) Cribs shall be open faced or close faced as actually specified and their cells shall be filled with locally available material such as earth or rock.

(ii) Unless otherwise specified, the width of the crib shall not be less than 4 feet on top or bottom. They shall be built vertical or with a batter (4 vertical to 1 horizontal), and the ratios of base width to height in cases where there is a firm foundation shall be as follows:

(a) With no surcharge: 45 to 50 per cent.
(b) With slight surcharge: 50 to 65 per cent
(c) With heavy surcharge: over 65 per cent.

The width of the crib shall be reduced by adopting multi-cell construction, but the bottom width shall be carried above the slippage plane or 1/3 height, whichever is higher.

(iii) Timber shall be used only for temporary cribbing and concrete or iron cribs shall be used for permanent cribbing.

(iv) Drainage arrangement from the back of cribs where considered necessary by the Engineer-in-charge shall be made by providing core pipes, perforated pipes and porous filling material of at least 2 feet thickness, unless otherwise specified.

24. Hard wood timber piles 12 to 14 inches in diameter or square in size with wooden planks 3 to 4 inches or scrap rail piles with wooden planks 3 to 4 inches thick or concrete piles with reinforced concrete planks or reinforced concrete grooved sheet piles or steel sheet piles as actually specified shall be used. Unless otherwise specified, the penetration of the pile into the soil shall not be less than the projection above the ground. The projection of the pile above ground level (H) and the spacing of piles without surcharge and with surcharge of earth sloping at 1½ horizontal to 1 vertical, shall be as per following tables unless otherwise specified. **Piles**

TABLE NO. 1

Timber Piles of 12 inches minimum diameter

H in feet	Spacing of piles	
	Without surcharge	With surcharge earth load at 1½: 1 slope
9	2′—6″	
8	3′—0″	
7	4′—0″	2′—6″
6	5′—6″	3′—6″
5	8′—0″	5′—6″
4	10′—0″	10′—0″
3	10′—0″	

TABLE NO. 2

Timber piles of 14 inches minimum diameter

H in feet	Spacing of Piles	
	Without surcharge	With surcharge earth load at 1½ : 1 slope
10	2′—6″	
9	3′—0″	
8	4′—0″	
7	6′—0″	2′—6″
6	8′—0″	3′—6″
5	10′—0″	5′—6″
4		9′—0″
3		10′—0″

TABLE NO. 3

75 B.S.S. Rail Piles

H in feet	Spacing of Piles	
	Without surcharge	With surcharge earth load at 1½:1 slope
9	2′—6″	
8	3′—0″	
7	4′—0″	
6	5′—6″	2′—6″
5	8′—0″	3′—6″
4	10′—0″	5′—6″
3 or less	10′—0″	10′—0″

TABLE NO. 4

90 B.S.S. Rail Piles

H in feet	Spacing of Piles	
	Without surcharge	With surcharge earth load at 1½:1 slope
10	2′—6″	
9	3′—0″	
8	4′—0″	
7	6′—0″	2′—6″
6	8′—0″	3′—6″
5	10′—0″	5′—6″
4		9′—0″
3		10′—0″

Walls

25. Retaining walls when specified shall be made strictly according to approved drawings or as directed by the Engineer-in-charge in writing. In respect of material and workmanship, relevant specifications of the masonry shall be strictly followed.

Measurement and Rate

26. In respect of measurement and rate, it shall conform to specification No. 17.1 (A) for Earthwork General, except for the retaining structures specified in clauses 20 to 24 of these specifications. The unit of measurement and rate for these shall be the same as contained in the relevant specifications for each work.

TABLE NO. 5

Conversion

In the case of earthwork measurement where extra lead is to be paid for lift the method will be as follows:

The lift will be measured from the centre of gravity of the excavated earth to that of placed earth. This will constitute the mean lift for the section.

When earth has to be carried over a spoil bank and dumped beyond it the mean lift would be the difference in level between the centre of gravity of the excavated earth and the top of the spoil bank omitting the dowel.

The equivalent leads for various mean lifts are given below:—

Lift in feet	Conversion factor	Equivalent Horizontal lead in feet
1	1' lift 8' lead	8
2	1' lift 8' lead	16
3	1' lift 8' lead	24
4	1' lift 8' lead	32
5	1' lift 10' lead	50
6	1' lift 10' lead	60
7	1' lift 10' lead	70
8	1' lift 10' lead	80
9	1' lift 11' lead	99
10	1' lift 12' lead	120
11	1' lift 13' lead	143
12	1' lift 14' lead	168
13	1' lift 15' lead	195
14	1' lift 16' lead	224
15	1' lift 17' lead	255
16	1' lift 18' lead	288
17	1' lift 19' lead	323

18	1′ lift 20′ lead	360
19	1′ lift 21′ lead	399
20	1′ lift 22′ lead	440
21	1′ lift 23′ lead	483
22	1′ lift 24′ lead	528
23	1′ lift 25′ lead	576
24	1′ lift 26′ lead	624
25	1′ lift 27′ lead	675
26	1′ lift 27′ lead	702
27	1′ lift 27′ lead	729
28	1′ lift 27′ lead	756
29	1′ lift 27′ lead	783
30	1′ lift 27′ lead	810

These conversion factors also incorporate allowance for extra lead due to cross lead with a view to ensuring a uniform system. The equivalent lead will be added to the horizontal lead to get the total lead to be paid for. The exact site or R.D.s between which extra lead is to be given must be recorded in the first column of detailed measurements in the measurement book.

DISMANTLING (DEMOLITION) AND PREPARATION OF SITE

CHAPTER 18

No. 18.1 Specifications

Screens

1. If specified or directed by the Engineer-in-charge, the contractor shall provide, erect and remove screens of canvas or other suitable material to minimize the nuisance from dust and shall provide for watering as the work of demolition proceeds.

Diversion of Service

2. The existing services such as electric supply, telephone connection, water supply, drainage, etc., shall be diverted according to the directions and to the satisfaction of the Engineer-in-charge.

Inventory of Serviceable Material

3. Before taking the work of demolition in hand, an inventory of all serviceable materials for which special care is to be exercised in demolition, handling or lowering down, shall be made and the list shall be checked and duly approved by the Engineer-in-charge or his authorized representative.

Damage

4. (i) The contractor shall be responsible for carrying out dismantling operations strictly in accordance with the specifications or directions of the Engineer-in-charge, with appropriate tools and in such a manner as to avoid unnecessary damage or injury to other adjoining work, and those parts of work which are to be retained, and to render unserviceable as little of the material as possible.

(ii) The contractor shall, if specified or directed by the Engineer-in-cahrge, make good any damage to work caused during demolition and shall protect as far as possible all trees, shrubs, etc., near the work.

Sewers and Drains

5. The contractor shall at once remove all foul matter, if sewers or drains are to be removed or disturbed. The rate for removing pipes does not include excavation or the demolition of any masonry or brickwork; all the works shall be paid for separately, according to their respective rates.

Shoring or Under-Pinning

6. Unless otherwise stipulated or specified, no allowance shall be made for shoring or under-pinning.

Lowering

7. Trusses, R. S. beams, battens, purlins, sheets, tiles, boards, wooden frames, water supply and electric fittings and all material liable to be damaged by dropping from a height, shall be lowered down to the ground by means of a rope or another approved appliance. If any serviceable article is damaged or broken on account of the negligence of the contractor he shall have to pay to the department the current market rates for the article.

Doors and Windows

8. Doors and windows shall be removed from the chowkats alongwith their hinges before dismantling the latter and shall be carefully carried and stacked where directed by the Engineer-in-charge.

Sorting, Stacking and Disposal

9. (i) Unless otherwise specified, all demolished materials shall be considered the property of Government and shall be disposed of as directed by the Engineer-in-charge. The rate of an item shall always include the sorting out of any demolished material, its stacking anywhere within 300 feet of the place of demolition and its safe custody till it is handed over to the department in accordance with the directions of the Engineer-in-charge.

(ii) When so specified or directed by the Engineer-in-charge, the contractor shall completely remove the whole or part of the dismantled material from the site of work and realize such profits as he can by disposing it of by a method approved in writing by the Engineer-in-charge. In such cases no payment shall be made to the contractor for dismantling this material.

Measurement

10. Dismantling (Demolition) shall be measured by bulk, surface area or linear dimensions depending upon the article to be dismantled. The units of measurement shal be 100 cubic feet, 100 square feet or 1 Rft.

Rate

11. (i) The unit rate for demolition shall include dismantling of material, its careful lowering to the ground, sorting out and stacking within 300 feet of the site of demolition, in accordance with the above specifications.

(ii) The rates for dismantling roofs or upper storey floors include the dismantling of all materials, except roof supports such as beams and trusses.

NO. 18.2 UNDER-PINNING

Specifications

Lengths

1. Unless otherwise specified or directed by the Engineer-in-charge, the under-pinning shall be executed in lengths not exceeding 5 feet at a time and all operations shall be carried out to the satisfaction of the Engineer-in-charge. No under-pinning shall be done simultaneously at a distance less than 6 feet apart.

Under-Pinning of Adjoining Foundations

2. Where the foundations of new walls are below the level of the foundations of existing walls of adjoining premises, necessary excavation shall be made and under-pinning done from the level of the bottom of new foundations up to the underside of foundations of old walls, to the full thickness of the wall. Unless otherwise specified or directed by the Engineer-in-charge, under-pinning shall be done in cement concrete 1:3:6 or brickwork first class in 1:3 cement sand mortar.

Planking and Strutting

3. Planking and strutting shall be provided to sides of excavation in under-pinning and across trenches if directed by the Engineer-in-charge without any additional charge.

Cutting of Projecting Foundations in Old Walls etc.

4. The projecting footings and concrete foundations on outside of the old walls to be under-pinned shall be cut away back to the face of wall.

Wedging

5. Unless otherwise specified or directed by the Engineer-in-charge, the top of new under-pinning shall be wedged and pinned up to the under side of old concrete

foundations, when required, with cement sand mortar 1:3, mixed fairly dry and well-rammed.

6. Temporary shuttering shall be provided to vertical face of concrete foundation to the depth of under-pinning and the same shall be removed when no longer required. **Temporary Shuttering to Concrete**

7. Timbering, needling, shoring, etc., shall be provided and fixed to ensure the safety of adjoining walls while under-pinning, where specified or directed by the Engineer-in-charge, and, on completion, all disturbed areas shall be cleared and made good. **Timbering, Shoring, etc.**

8. Measurement shall be made of each operation involved in under-pinning according to the relevant items of work. The unit of measurement shall be the same as of the relevant item. **Measurement**

9. The unit rate shall include under-pinning as per above specifications and carriage of materials to the site of work as in case of relevant items of work. **Rate**

NO. 18.3 SHORING

Specifications

1. Unless otherwise specified or directed by the Engineer-in-charge, all walls, floors, roofs, partitions of buildings on the site or adjoining the works shall be secured by means of shoring to the entire satisfaction of the Engineer-in-charge, and on completion of the work or when directed by the Engineer-in-charge or his authorized representative the shoring shall be removed and the area left in good order. **Use**

2. Unless otherwise specified, the shoring shall generally consist of dogs, hoop iron, hooks, shores or rakers, sole pieces, wall pieces or plates, braces, struts, needles, cleat, wedges and posts. The wooden components when used shall be of properly seasoned Shisham, except for rakers and struts which shall be of Sal, free from defects, unless otherwise specified. **Requirements**

3. The raking shores shall be provided at an angle of 40° to 75° to the building and each set of shores shall be 10 to 15 feet apart or as directed by the Engineer-in-charge or his authorized representative. Unless otherwise specified or directed by the Engineer-in-charge, the number of shores provided in each set and the size of rakers shall be as follows: **Raking Shores**

(a) *Number of raking shores in each set:*

For walls 15 feet to 30 feet high: 2.
For walls 30 feet to 40 feet high: 3.
For walls 40 feet and upwards: 4.

(b) *Sizes of the rakers:*

For walls 15 feet to 20 feet high: 4"x4" or 5"x5"
For walls 20 feet to 30 feet high: 9"x4½" or 6"x6"

For walls 30 feet to 35 feet high: 7"x7"
For walls 35 feet to 40 feet high: 6"x12" or 8"x8"
For walls 40 feet to 50 feet high: 9"x9"
For walls 50 feet and upwards: 12"x9" and upwards.

Sole Pieces, Needles, etc.

4. The sole pieces shall be inclined at an angle of about 85° to the top raker. The top needle shall be at least 2 feet below the top of the wall. In soft ground, the area of the sole piece shall be increased by forming a platform of timber under it. The needles shall be driven into a wall to a depth of 4½ inches, unless otherwise specified.

Wall Piece

5. The wall piece shall be 2 inches to 3 inches thick and of the same width as the shore. It shall extend about 3 feet above the top raker and 3 feet below the lowest raker.

Flying Shores

6. Flying shores shall be erected 10 feet to 15 feet apart with spans up to 35 and placed at three-quarters of the height of the wall or as directed by the Engineer-in-charge. Unless otherwise shown on the drawings or approved by the Engineer, the general arrangement and the sizes of the scantlings shall be as given below:

Span in feet		Horizontal Shore	Struts	Straining Pieces	Wall Plates
Up to 20 ft.	..	6"x4"	4"x4"	4"x2"	9"x2"
,, 25 ft.	..	6"x6"	4"x4"	4"x2"	9"x2"
,, 30 ft.	..	9"x6"	6"x4"	4"x2"	11"x3"
,, 35 ft.	..	9"x9"	6"x6"	6"x2"	11"x3"

Note.—Shores of large section may be built up of smaller sections bolted together.

Needle Shoring

7. When shown on the approved drawings or when directed by the Engineer-in-charge, the walls being under-pinned shall be supported by needles. The needles shall be 12 inches square of good hard timber such as Sal, with similar posts and the sole pieces spaced from 5 feet to 7 feet apart. R.S. beams shall be used as needles when the wall above is thick, heavy and high.

Measurement and Rates

8. In respect of measurement and rates the specifications for the relevant items of work shall be followed.

MORTARS

CHAPTER 19

Introduction

Mortar is defined as a material composed of fine aggregate and cementing material which forms a hardened mass when mixed with a suitable proportion of water. It is used for plaster work and for bonding bricks and masonry solidly together so that stresses from super-imposed loads are evenly distributed. The cementing material may be either clay or portland cement, or lime or a mixture of lime and cement. Sand is the aggregate commonly used for mortars; but in special cases surkhi and cinders are used in addition to or as substitute for sand in old burnt bricks ballast, or ground stones. The constituents of all mortars should be mixed thoroughly to ensure a uniformity of composition.

Mortars are usually defined by their composition rather than properties, and the proportions of ingredients are generally taken by volume. The following are the different types of mortars commonly used.

Mud Mortar

(i) Mud mortar is used in brickwork, masonry and plaster work, provided these works are not likely to remain under water. For brickwork and masonry, mud mortar is prepared from good brick earth, as defined in Chapter No. 3 Part I of this Vol. Brick earth is reduced into fine powder and freed from stones, grass, kankar, roots and other matter. Clay containing efflorescent salts or taken from a locality where there are white ants should not be used. This mortar is made by mixing clay with water on a plot of ground specially cleared and set apart for the purpose, and tempered for at least two days. During this period it is worked up at intervals with men's feet and phowrahs. If necessary or where soil is too clayey, sand or chopped straw is added. The consistency of the mortar is kept to the extent that it readily slides off the face of a trowel but is not so wet as to part into large drops in falling.

Mud mortar for plastering is prepared in the same way as described above, except that four pounds of chopped "bhoosa" is mixed thoroughly with each cubic feet of mortar which is kept in a plastic state for a week and is worked up by pugging with feet at intervals.

Cement Mortar

(ii) Cement mortar is used in brickwork, masonry, plaster work and concrete work. Its ingredients are cement and sand whose proportions may be 1:2, 1:3, 1:4, 1:5, 1:6, 1:7, 1:8 and so on by volume. The mortar is made by thoroughly mixing the ingredients in a dry state and then gauging the mix with water to make it workable. The quantity (weight) of water to be added with a fine rose should be 28% of the weight of cement plus 4% of the weight of the total aggregate. This assumes that the materials (aggregates) are dry.

Lime Mortar

(iii) This mortar is used in brickwork, masonry, plaster work and concrete work. Its ingredients are slaked stone lime and surkhi or kankar lime and sand. Nonhydraulic or semi-hydraulic lime mortars have low strength and are vulnerable to frost and, therefore, unsuitable for external work for which only hydraulic lime mortars may be used. The proportions of different mixes may be as below:—

Mortar	Ingredients		Remarks
1. Stone lime and Surkhi ..	Stone lime	1 part	
	Surkhi	1½ parts	
2. Kankar lime and sand ..	Lime	1 part	
	Sand	1 part	V. Storng Mortar
	Lime	1 part	
	Sand	2 parts	Strong Mortar
	Lime	1 part	
	Sand	3 parts	Ordinary Mortar

The mortar is prepared by mixing the ingredients twice in a dry state and then grinding the mix with sufficient water in a grinding mill.

Lime Cement Mortar

(iv) Lime cement mortar is used in brickwork, masonry, plaster work and concrete work. Its ingredients are slaked stone lime, cement and sand (fine aggregate). Usually their proportions taken by volume may be as follows:—

Lime		Cement		Sand
1	:	1	:	5
1	:	1	:	6
1	:	1	:	8
1	:	1	:	9
1	:	1	:	10
1	:	1	:	12
1	:	3	:	8
1	:	3	:	3

The presence of cement in the mortar ensures early strength and reduces the risk of frost attack both during setting and afterwards, while the presence of lime improves the working quality of mortar and reduces its tendency to shrink and crack on drying. The mortar is prepared by mixing, in a dry state, the thoroughly slaked and screened stone lime and sand, and then adding cement which is properly mixed with this material. Later the water is poured through a fine rose to give a mortar of the desired working consistency.

Mortar for Fire-Clay Brickwork

(v) Fire-clay or alternatively fire-cement is suitable for setting fire bricks. Generally the joints are the most vulnerable part of fire brickwork and when they crumble away, the arrises of these bricks become vulnerable to heat. Fire-clay can be used just as it comes out of hearth but it tends to contract on cooling and again on exposure to heat; so the best way is to use fire-cement that is especially prepared to resist construction under heat. Burnt clay, made by crushing ordinary fire bricks, does not expand or contract markedly and therefore constitutes a suitable aggregate for fire brick mortar mixed with high alumina or other bauxite cement.

The proportion of alumina cement to crushed fire brick is 1:2. The mortar is prepared in the same manner as described for cement mortars.

Mortar with Plasticiser

vi) It is often better to use a proprietary plasticiser with cement and sand than to use lime. It increases the "wetting" of cement particles, and the effectiveness of cement, permitting a weaker mix and improving its workability. It also tends to entrain air bubbles in the mix, making the mortar more elastic when set and reducing the chances of cracking. The recommended mixes vary, but the common one is one part of cement to six parts of sand plus the amount of plasticiser (usually added to the mixing water) recommended by the manufacturer.

NO. 19.1 MUD MORTAR

Specifications

Composition

1. Mud mortar for brickwork and masonry shall be prepared from good earth and water. Sand or chopped straw shall be added to the earth that is too clayey. Mud mortar for plastering shall be prepared from earth, water and chopped "bhoosa".

Earth

2. Earth shall be good brick earth or clay conforming to Specification No. (3.1) and shall be obtained from an approved source.

Water

3. Water shall conform to Specification No. (2.1).

Preparation

4. Clay shall be mixed with water on a plot of ground especially cleared for the purpose and tempered for at least two days. During this period it shall be worked up at intervals with men's feet and "phowrahs". Sand or chopped straw shall be added, as desired, to the earth that is too clayey. Mud mortar for plastering shall be prepared as specified above and four pounds of chopped "bhoosa" shall be thoroughly mixed with each cubic foot of mortar.

Consistency

5. The consistency of mud mortar shall be of a type that it shall readily slide off the face of trowel, but the mortar shall not be so wet that it parts into large drops in falling. No water shall be added to the mortar after it is delivered to job.

Pits

6. Unless otherwise specified or directed by the Engineer-in-charge, the contractor shall make his own arrangements for obtaining the necessary clay for the mortar. When permitted by the Engineer-in-charge to take earth from the site of work, the contractor shall fill all pits with good earth and dress them off properly on the completion of work.

Restriction of Use

7. Mud mortar shall not be used for any masonry or brickwork likely to remain under water at any time or likely to bear pressure other than directly vertical.

Measurement

8. The measurement of mortar, if required, shall be done by volume. The unit of measurement shall be 100 cubic feet.

Rate

9. The unit rate shall include the cost of clay, water and chopped straw or

chopped "bhoosa" as specified and the preparation of mortar as per above specifications at the site of work to be defined in the conditions of contract.

NO. 19.2 CEMENT MORTAR

Specifications

Composition 1. Cement mortar shall consist of portland cement, sand (fine aggregate) and water. Waterproofing agent shall be added when specially required or directed by the Engineer-in-charge.

Portland Cement 2. Portland cement shall conform to Specification No. (3.3).

Sand 3. Sand shall conform to Specification No. (6.1).

Water 4. Water shall conform to Specification No. (2.1).

Mix 5. Unless otherwise specified or directed by the Engineer-in-charge, the ingredients for cement mortar shall be proportioned by volume.

Preparations 6. Cement and sand shall be thoroughly mixed in a dry state on a pucca platform or in troughs as directed by the Engineer-in-charge. It shall be gauged with a quantity of water sufficient to make the mortar workable. Water shall be added with a fine rose. Only such quantity of mortar shall be prepared as can be used before the initial setting time.

Precuations 7. (i) Any mortar which has not been used within 30 minutes of the addition of water shall be discarded.

(ii) At the close of day's work the mixing troughs and pans shall be thoroughly washed and cleaned.

(iii) The mixing platform shall not be used for stacking materials.

Measurement 8. The measurement of mortar, if required, shall be done by volume. The unit of measurement shall be 100 cubic feet.

Rate 9. The unit rate shall include the cost of portland cement, sand and water and the preparation of mortar as per above specifications at the site of work to be defined in the conditions of contract.

NO. 19.13 LIME MORTAR

Specifications

Composition 1. Lime mortar shall consist of slaked stone lime, surkhi and water or kanker lime, sand and water.

Stone Lime 2. Stone lime shall conform to Specification No. (3.2).

Kanker Lime 3. Kanker lime shall conform to Specification No. (3.2).

4. Surkhi shall conform to Specification No. (6.2). **Surkhi**

5. Sand shall conform to Specification No. (6.1). **Sand**

6. Water shall conform to Specification No. (2.1). **Water**

7. Unless otherwise specified or directed by the Engineer-in-charge, the ingredients for lime mortar shall be proportioned by volume. **Mix**

8. (a) *Mortar for Masonry and Brickwork* **Preparation**

Thoroughly slaked and screened stone lime/kankar lime and surkhi/sand shall be measured in boxes and mixed on a pucca platform or in a mixing trough as specified. The troughs, if used, shall be capable of being washed and drained. These ingredients shall be mixed twice in a dry state and then ground in a grinding mill with a quantity of water sufficient to produce a mortar of specified consistency.

(b) *Mortar for Plastering or Pointing*

Unless otherwise specified one part of lime mixed with two parts of surkhi by volume shall be kept under water for at least 12 hours and then made to pass through a screen of 12x12 meshes to a square inch. Requisite colouring material shall be added to it and the mortar applied as fresh as possible.

10. The measurement of mortar, if required, shall be done by volume. The unit of measurement shall be 100 cubic feet. **Measurement**

11. The unit rate shall include the cost of stone lime/kanker lime, sand/surkhi, and water and the preparation of mortar as per above specifications at the site of work to be defined in the conditions of contract. **Rate**

NO. 19.4 LIME CEMENT MORTAR

Specifications

1. Lime cement mortar shall consist of portland cement, slaked stone lime, sand and water. **Composition**

2. Portland cement shall conform to Specification No. (3.3). **Portland Cement**

3. Slaked stone lime shall conform to Specification No. (3.2.). **Slaked Stone Lime**

4. Sand shall conform to Specification No. (6.1). **Sand**

5. Water shall conform to Specification No. (2.1). **Water**

6. Unless otherwise specified the ingredients of lime cement mortar shall be proportioned by volume. **Mix**

7. Thoroughly slaked and screened stone lime and sand in requisite quantities shall be thoroughly mixed and then a necessary quantity of cement shall be added. When this has been uniformly mixed a quantity of water sufficient to give a mortar of desired consistency shall be added through a fine rose. **Preparation**

Precautions

8. Any mortar which has not been used within 30 minutes of the addition of water shall be discarded. At the close of day's work, the mixing troughs and pans shall be thoroughly washed and cleaned.

Measurement

9. The measurement of mortar, if required, shall be done by volume. The unit of measurment shall be 100 cubic feet.

Rate

10. The unit rate shall include the cost of portland cement, slaked stone lime, sand and water and the preparation of mortar as per above specifications at the site of work to be defined in the conditions of contract.

19.5 MORTAR FOR FIRE-CLAY BRICKWORK

Specifications

Composition

1. Unless otherwise specified the mortar shall consist of alumina cement, crushed fire bricks graded as sand and water.

Alumina Cement

2. Alumina cement shall conform to Specification No. (3.3).

Crushed Fire-brick

3. Crushed fire brick graded as sand shall conform to Specification No. 6.1 for fine aggregate.

Water

4. Water shall conform to Specification No. 2.1.

Other Respects

5. In all other respects the mortar shall conform to Specification No. 19.2 of cement mortar.

CONCRETE

CHAPTER 20

Introduction

General

A proper proportion of cement, water and fine and coarse aggregate, when thoroughly mixed, produces a plastic material called concrete. It has the following properties:—

(i) While fresh, it can be placed in an economical and uniform manner and moulded into a desired shape.

(ii) When hardened, it is quite strong and durable. The hardening process (hydration) continues indefinitely under favourable moisture and temperature conditions, with a general improvement in the quality of the concrete.

Selection of Constituents

Concrete is used in works ranging from small repairs or replacement jobs to massive structures such as dams. Apart from the consideration of size the jobs differ widely in respect of the types of construction and thus require concrete of different qualities. It is, therefore, necessary to carefully select the constituent materials and mix them in such a manner as to get the special qualities required as economically as possible. For instance the qualities required in an engineering structure are generally weather resistance and strength on which the designer has based his calculations. In roads, concrete must be strong enough to sustain the pounding action of heavy and fast-moving traffic. In water towers and reservoirs, it must be impermeable. In foundations, it may be required to resist the disintegrating action of sulphates in the soil. Similarly sea structures must be resistant to the chemical attack of salts and to abrasive action. Concrete floors, in addition to abrasion by foot traffic and all types of vehicles, are often subjected to chemical attack by various sources. Other qualities, required in certain circumstances, include light-weight, thermal insulation, and impedance to X-rays or the products of nuclear fission.

Some special types of construction like piling, dock work, mass concrete dams, tunnel work call for a special technique. Similarly, the laying of concrete floors such as granolithic, the moulding of cast stone, precast concrete staircase units, concrete railway sleepers, fence posts, paving flags, kerbs, garden ornaments, and other items require individual modifications in procedure. Light-weight concrete and open-textured concrete form other classes of concrete product.

The selection of materials and method of construction is not easy, since many variables affect the quality of the concrete, and both quality and economy must be considered. Concrete of the same strength may be produced by a lean mix which is difficult to place, as by a somewhat richer and more plastic mix which is easy to place. In such a case it is probable that the increased cost of cement in the richer mix would be offset by the saving in the cost of its placing. In addition, the finish of the richer mix would in all probability be better. Other properties of the concrete are, of course, affected by an increased cement content, and must be considered according to their relative importance. It would be poor economy to aim at perfection in every property of concrete whereas, by a judicious choice of the constituents and correct proportioning, a balance can be achieved to satisfy all reasonable requirements of the structure for seviceable life, safety and appearance.

Limitations of Concrete

Concrete has certain limitations and disadvantages which should be kept in view by both the designer and the builder in order to eliminate difficulties in construction, and cracking and other structural weaknesses that detract from the appearance, serviceability and life of the structure.

The principal limitations and disadvantages are:—

- *LOW TENSILE STRENGTH*—In view of the low tensile strength of concrete, members which are subjected to tensile stress must be reinforced with steel bars or mesh.

- *DRYING, SHRINKAGE AND MOISTURE MOVEMENT*—Concrete shrinks as it dries, and even when hardened, expands and contracts with wetting and drying. This characteristic necessitates the provision of contraction joints at intervals to avoid unseemly cracks.

- *THERMAL MOVEMENT*—Concrete expands and contracts with changes in temperature at roughly the same rate as steel. Expansion joints must be provided in many types of structure to prevent failures.

- *PERMEABILITY*—Even the best concrete is not entirely impervious to moisture, and contains soluble compounds which may be leached out to a varying extent by water. Joints, unless special attention is given to their construction, are apt to form channels for the ingress of water.

Impermeability is particularly important in reinforced concrete where reliance is placed on the concrete cover to prevent the rusting of the steel.

Variability in Quality of Concrete

A list of variables likely to occur during the manufacture of concrete is given in the following table. While the list is not exhaustive, it does give some indication of the possible sources of variation in strength and other properties.

LIST OF VARIABLES

(A) *MATERIALS*:

(1) Cement	
(2) Fine aggregate	(a) Grading
	(b) Moisture content
	(c) Silt
	(d) Cleanliness
	(e) Bulking.
(3) Coarse aggregate	(a) Grading.
	(b) Moisture content
	(c) Cleanliness.
(4) Water.	

(B) *METHODS OF BATCHING AND MIXING*

(1) By volume.	(a) Moisture content of aggregate

(b) Bulking of sand.
(c) Accuracy of measurement.

(2) By weight. (a) Moisture content of aggregate
(b) Accuracy of measurement.

(3) Loss of materials entering mixer.

(4) Efficiency of mixer.

(C) *METHODS OF CONSTRUCTION*

(1) Compaction.

(2) Curing.

(3) Weather conditions during placing and curing of concrete.

Properties of Concrete

The properties of concrete should be considered in relation to the quality required for any given construction purpose. The closest practicable approach to perfection in every property would result in poor economy under many conditions, and the most desirable structure is the one in which concrete has been designed with the correct emphasis on each of its properties and not solely for obtaining, say, the maximum possible strength.

Although the attainment of the maximum strength should not be the sole criterion in design, the measurement of the crushing strength of concrete cubes provides a means of maintaining a uniform standard of quality and, in fact, is the usual way of doing so. Since other properties of any particular mix are related to the crushing strength in some manner, it is probable that, as a single control test, it is the most convenient and informative.

Crushing Strength

Concrete can be made having a strength in compression of anything up to about 10,000 lbs. per square inch, depending mainly on the water-cement ratio and the degree of compaction. Crushing strengths of between 3,000 and 7,000 lbs. per square inch at 28 days are normally obtained on the site for mixes roughly equivalent to 1:2:4 of cement: sand: gravel. In some types of precast concrete such as railway sleepers, strengths ranging from 6,000 to 10,000 lbs. per square inch at 28 days are obtained with rich mixes having a low water-cement ratio.

The crushing strength of concrete is influenced by a number of factors, in addition to the water-cement ratio and the degree of compaction. The more important factors are:—

- *TYPE OF CEMENT AND ITS QUALITY*

- *TYPE AND SURFACE TEXTURE OF AGGREGATE*—There is considerable evidence to suggest that some aggregates produce concrete of greater compressive and tensile strengths than smooth river gravels.

- *EFFICIENCY IN CURING*—A loss in strength of up to about 40 per cent may result from premature drying out. Curing is therefore of considerable importance both in the field and in the making of tests.

- *TEMPERATURE*—In general, the rate of concrete hardening quickens by increase in temperature. At freezing temperatures the crushing strength may remain low for some time.

• *AGE*—Under normal conditions concrete increases in strength with age. The rate of increase depends on the type of cement. For instance, high alumina cement produces concrete with a crushing strength at 24 hours equal to that of normal Portland cement concrete at 28 days. Hardening continues for a number of years but at a much slower rate.

Tensile and Flexural Strength

The tensile strength of concrete varies from one-eighth of the compressive strength at early ages to about one-twentieth later. It is not usually taken into account for the purpose of designing the reinforced concrete structures. The tensile strength is, however, of considerable importance in resisting cracking which is caused as a result of changes in moisture content or temperature.

Shear Strength

In practice the shearing of concrete is always accompanied by compression and tension caused by bending, and even in testing it is impossible to eliminate an element of bending. Failure of concrete in shearing is therefore, due to failure of the material in tension. Such tests as have been made show that the shearing strength is about half of the compressive strength.

Deformation Under Load

Deformation of the concrete occurs when it is loaded and increases with the increase in load, like steel and other materials. However, whereas steel deforms elastically at loads below the elastic limit so that the specimen returns to its original size when the load is removed, concrete deforms partly as a result of elastic strain, and partly as a result of plastic strain or creep.

Modulus of Elasticity

The common measure of the elastic properties of a material is the modulus of elasticity, which is the ratio of the applied stress to the deformation per unit length resulting from the application of that stress.

$$\text{Then, } E = \frac{f}{e} = \frac{WL}{AX}$$

Where E is the modulus of elasticity.

$f = \frac{W}{A}$ is the applied stress, W being the load, and A the cross sectional area.

$e = \frac{X}{L}$ is the deformation per unit length or strain, X being the deformation under load W, and L is the length of member.

Where A, X & L are measured in the same unit.

The modulus of elasticity may be expressed in terms of compression, tension or shear. For concrete, it may be taken as the same in tension and compression. Although it is not directly related to the other properties of concrete, higher strengths are usually accompanied by higher values of E. As concrete ages, its modulus of elasticity increases—a fact of some importance since a restrained concrete member which is already in a stage of strain due, for instance, to cooling after the initial hardening, becomes subjected to an increasing tensile stress. If completely restrained, the stress at any time would be given by the usual formula $f = Ee$.

Poission's Ratio

When compressed, concrete contracts longitudinally and expands laterally. The ratio of the lateral strain to the longitudinal strain is known as Poission's ratio, and within the normal working range of loading has a value of about 0.08 to 0.18. Within this range it increases with increase in cement content, an average value of 1:2:4 concrete being 0.11. The ratio also varies with the factors which affect other properties of the material.

Creep

Some mention of plastic flow or creep has already been made in connection with the modulus of elasticity. Creep is a non-elastic deformation under load, believed to occur as a result of the closure of internal voids, viscous flow of the cement-water paste, crystalline flow in aggregates, and the squeezing of water from the cement gel under load. In practice, creep and drying shrinkage usually occur simultaneously and are often confused; exceptions are dams, tunnels and other underground works, and massive structures where little or no drying out occurs. Creep is useful in that it enables a readjustment of stre s, when local stresses of high intensity might otherwise result in failure of the structure. This is particularly true when concrete is reinforced with steel. In this case creep generally leads to a transfer of load from the concrete to the steel.

In prestressed concrete, creep has an adverse effect and reduces tension in the reinforcement; it is therefore necessary to increase the initial pretensioning. Creep reduces the tendency to crack in restrained concrete members by relieving stresses resulting from shrinkage.

The creep of non-reinforced concrete is approximately proportional to the stress within the normal range used in design, but as failure is approached the rate of creep increases rapidly. The rate of creep is dependent on the following factors apart from the stresses imposed.

- *STRENGTH*—An increase in strength usually leads to a reduction in creep.
- *CEMENT*—Composition and fineness creep characteristics. At the same age concrete made with normal Portland cement has a greater creep than that made with rapid-hardening or aluminous cement.
- *PROPORTION OF MIX*—Creep decreases as the water-cement ratio and the volume of cement paste decrease. The movement in a very wet mix may be as much as twice than in a dry mix.
- *AGGREGATE*—Creep increases as the aggregate becomes finer; and it is generally greater when porous aggregates are used.
- *CURING*—Creep decreases as cement hydration proceeds so that concrete kept continuously wet creeps less than that cured in air.
- *AGE*—The rate of creep decreases as the concrete ages.

Drying-Shrinkage and Moisture Movement

There are two stages in the shrinkage of concrete. (i) An initial stage in which shrinkage occurs while the concrete is still in a fluid or plastic state. This happens because of various reasons like the loss of water by seepage through the forms; absorption by the forms; or in the case of roadwork by formation; and by evaporation. This shrinkage may be masked by the thermal expansion accompanying rise in temperature which results from the chemical reaction in the setting of the cement. (ii) A later drying stage in which shrinkage occurs is as the concrete hardens and is allowed to dry. This may be accompanied by a thermal shrinkage as the concrete cools.

The extent of "initial" shrinkage depends on the type of the curing arrangements and the extent to which water can be absorbed by shuttering or formation. It can therefore be minimized by taking proper precautions. The "later" shrinkage which occurs on account of the shrinkage of the cement gel is partly irreversible. It is only partly irreversible because on subsequent wetting it expands, although not sufficiently to recover its original volume. Further drying and wetting produce a practically reversible shrinkage and expansion. Continued immersion in water from the time of casting produces a slight expansion, but on drying the concrete shrinks as before.

The extent of the drying ("later") shrinkage varies with different cements, the richness of the mix, and the water content. It should be noted that the use of excessive mixing water leads to a high shrinkage. The mineral character of the aggregate also affects this shrinkage. In general, it is found that limestone and the igneous rock aggregates give the least shrinkage, while flint gravel aggregates give the highest. These differences are, however, small compared with those resulting from changes in water-cement ratio and cement content.

The rate at which drying shrinkage occurs decreases as the size of specimen increases. For instance, in the case of a small specimen (2 or 3 inches square) the drying shrinkage under constant temperature and humidity conditions is virtually complete in less than a month, whereas a bigger concrete section (say 2 feet square) continues to shrink for several years under the same conditions. The rate of shrinkage is high during the first few days, and afterwards decreases gradually with time. Cracking is not usually noticed till 6 months to 2 years after concreting. The slow drying of concrete as compared with quick drying tends to reduce cracking because of the compensating effect, and because of increased strength derived from the longer presence of moisture.

In normal reinforced concrete, creep results in a compressive stress in the bars which themselves resist and reduce the overall drying shrinkage in the reinforced concrete member. It is generally assumed that the drying shrinkage of a reinforced concrete member is half than that of a non-reinforced member, although the actual extent obviously depends on the amount of reinforcement used.

In prestressed concrete, it is necessary to make an allowance for the relief of stress in the steel resulting from creep in the concrete and the steel, and drying shrinkage in the concrete. A good average value for the loss of prestress in the steel is 20,000 lbs. per square inch, although in poor concrete it may be as high as 50,000 lbs. per square inch. Some authorities assess the loss of prestress at between 12 and 18 per cent of the initial steel stress.

Shrinkage and moisture movements are important because they result in the cracking of concrete unless the stresses developed can be relieved by creep, or in the case of large areas by suitably placed joints. Thus floors, roads, roofs and long walls are subdivided into panels or sections in order to control cracking.

Thermal Movements

The thermal coefficient of expansion and contraction is the change in a unit length per degree change of temperature. Its value varies a little with the richness of the mix and the water content, but for all practical purposes it may be taken as 5.5×10^{-6} per degree Fahrenheit for unrestrained movement. For estimating the movement likely to occur in large masses of concrete it is usually safe to assume a value of one-half than that given above, the other half being absorbed by creep without a serious danger of cracking.

Thermal expansion and contraction are often not uniform throughout a mass of concrete. In the first place the chemical combination of cement and water is accompanied by the generation of an appreciable quantity of heat which can only escape to the surface by conduction. It follows that the larger the mass, the higher the internal temperature at an early age compared with that at the surface, with a consequent difference in thermal shrinkage as the mass cools. This leads to the development of tensile stresses conducive to cracking.

In most structures and in roads, a temperature gradient is produced in the concrete either by artificial heating or by the sun rays. Differential thermal movements are induced which may in certain cases cause warping and cracking.

Thermal movements must be taken into account in design by the provision of suitable expansion joints.

Durability

The useful life of concrete is ordinarily limited by the distintegrating effects of:—

- Weathering by rain and frost, and expansion and contraction resulting from alternate wetting and drying.

- Chemical attack by such agencies as sea water; moorland, marsh and other waters; industrial chemicals and waste; sewage; animal and vegetable oils, fats, grease; milk and sugars.

- Wear by abrasion from foot and vehicular traffic, wave action, and by waterborne and wind-borne particles.

Weathering by rain and frost action is relative to watertightness or impermeability, since leaching and attack by the carbonic and other acids present in rain water, and disruption by frost action, depend on the penetration of water into the surface.

The quantity of cement in concrete does not affect its resistance to weathering to a very large extent unless the cement content is not sufficient to fill the interstices between the aggregate.

Permeability

Concrete has a tendency to be porous because of the presence of voids which are formed during or after placing. In order to obtain workable mixes it is usually necessary to use a greater quantity of water than is necessary for chemical combination with the cement. This water occupies space, and when it dries out, leaves behind air voids, Also there is a continual decrease in absolute volume of the reacting cement paste which occupies less volume than the fresh paste, whatever the water-cement ratio. In addition to these initially water-occupied voids, there is always a small percentage of entrained air voids.

If proper care is taken, Portland cement concrete can be made sufficiently impermeable for most purposes without the addition of any special materials.

From the above analysis of the cause of voids, it is clear that to make the densest and least permeable concrete, the water-cement ratio should be reduced to a minimum consistent with an adequate workability for thorough compaction without segregation. A compromise is, therefore, required between a low water-cement ratio and an adequate workability, and the best conditions will depend on the type of structure and the method of compaction.

Other factors influencing permeability are:—

- The soundness and porosity of the aggregate.

- Permeability decreases with age. The decrease is greater for wet mixes than dry ones.

- The grading of the aggregate should be chosen to give the most workable concrete with the least amount of water. Harsh gradings, especially in the case of sand, should be avoided.

- Curing has an important influence, and it is particularly necessary to keep the concrete moist during the first few days.

Joints are the weakest point in a concrete structure. If impermeability is important, it is advisable to provide some form of mechanical seal, since it is difficult to avoid local seepage owing to segregation, poor compaction or some other occurrence. Whether such measures are considered necessary or not, it is essential that every effort should be made to obtain a good bond. It is very difficult to measure permeability accurately, for tests are not generally made outside the research laboratory.

Resistance to Abrasion

Resistance to abrasion is directly related to crushing strength. It is generally safe to assume that concrete having the highest crushing strength has the greatest resistance to abrasion. Occasionally tests are made on the wear of paving flags, by exposing them to abrasion by steel balls for 48 hours, and finding the loss in weight. A tough igneous rock aggregate is often preferred to harder and more brittle flint aggregate in paving concrete.

Autogenous Healing

Many tests have shown that finer cracks in fractured concrete will completely heal under moist conditions. Apparently when fracture occurs, unhydrated cement is exposed and in the presence of moisture hydrates and sets.

Arbitrary Proportion of Constituents

When specifying concrete mixes, fixed proportions of cement, fine aggregate and coarse aggregate which have been found by experience to be suitable for the type of job in hand are usually stated. This arbitrary method of specifying the proportions is the most commonly used for big as well as small jobs. The mix consists of fixed proportions of cement, fine aggregate and coarse aggregate, such as 1:2:4, 1:1½:3, depending upon the type of construction for which it is being used. The fine-corase aggregate ratio is generally 1:2 keeping in view the fact that most coarse aggregates have approximately 50 per cent voids, but other ratios may also be used.

Workability is fixed by the requirements of placing. A suitable quantity of water is added to secure concrete of the desired workability. The quantity of water that goes into a batch therefore depends upon the mixerman's judgment to secure uniform consistency, and permits the quality of the concrete to vary with the variations in water content. To what extent the quality of the concrete may vary is indicated in Table 1 where a 1:2:4 concrete mixed with 5½ gallons of water per bag of cement gives a strength of 4,850 p.s.i. As more water is added either through neglect or to meet the requirements of complicated placing, the strength decreases till with 6¾ gallons of water, it is only 2,540 p.s i. Incidentally the table shows that the specimen with 5 gallons of water produced a mixture too stiff to compact properly and give a lower strength than the 5½-gallon mix. A whole bag (1 cwt) of cement is a convenient unit for measurement and the proportions of fine and coarse aggregate are very often expressed as so many cubic feet to a bag of cement. As a bag of cement is considered to measure 1.2 cubic feet (90 lbs. to a cubic foot), a volumetric mix such as 1:2:4 could be expressed as 1 cwt of cement to $1.2 \times 2 = 2.4$ cubic feet of sand to $1.2 \times 4 = 4.8$ cubic feet of coarse aggregate.

Table 2 gives a list of concrete mixes usually specified and the type of work for which they are used. The mixes are expressed in nominal volumetric proportions and also in terms of the volumes of fine and coarse aggregates required per 1 cwt bag of cement. The quantities of materials required to produce 100 cubic feet of concrete are also indicated. The main objections to the method of arbitrary proportions may be summed up as follows:—

- The lack of proper control over the quantity of water that goes into a batch of concrete produces a concrete of varying strength and density.

- The fixed proportions of cement, fine aggregate and coarse aggregate do not allow the use of favourable types and gradings of aggregates to secure a workable mix at the least possible cost of materials, and without harm to the strength of the concrete.

Other Methods of Proportioning

Other methods of proportioning the ingredients of concrete aimed at obtaining the maximum density, minimum void space, the most economical cement content, minimum surface area, or other objectives which would, theoretically, ensure the most desirable qualities in the resulting concrete, have been put forward from time to time but none have been found to be thoroughly satisfactory in practice. The vast amount of research done in this regard has led to the establishment of certain fundamental laws and empirical relationship which govern the properties of plastic and hardened concrete. With a thorough understanding of the available knowledge, it is possible to design concrete mixes for any given set of materials and job conditions. These concrete mixes will approximate predetermined characteristics.

Proportioning for Strength

The design problem essentially is to combine the ingredients of concrete-cement, water, fine aggregate and coarse aggregate in such practicable proportions that the concrete will have the required degree of workability, and on hardening will possess the stipulated strength and resistance against external agencies. It will be noted that a new method of specifying concrete is implied in the above statement. What is specified is not the proportions but the strength of concrete, and the contractor is left free to operate the mix in the most economical way possible depending upon the physical properties of available materials.

Absolute Volumes

Before proceeding to describe the fundamental laws and relationships of concrete mixes and their application to a procedure for design which has been adopted as a standard of the American Concrete Institute, it may well be pointed out that the systematization of mix design procedure owes itself entirely to the fact that the volume of mixed concrete is equal to the sum of the absolute volumes of its components (including admixtures, if any) with a plus correction for entrapped air and a minus correction for the volume of cement going into solution with water. In well-compacted fresh concrete, the volume of entrapped air is usually less than one per cent and can be disregarded. If w=absolute volume of water, c=absolute volume of cement, a and b = absolute volumes of fine and coarse aggregates respectively, then, for all practical purposes.

$$w+a+b+c=1$$

Even though the relation of the particles to each other in a concrete mix is essentially one of absolute volumes and the analysis of a mix revolves about this relationship, it is impracticable to proportion materials in the field in terms of absolute volume. Proportioning by bulk volume is often employed but, as will be seen later, it is not susceptible to uniform control. Weight proportioning of concrete materials satisfies all the basic absolute volume relationships and yet eliminates most of the practical difficulties in accurate field control because the absolute volume of a material is related to its weight and specific gravity as follows:—

$$\text{Absolute Volume} = \frac{\text{Weight of material}}{\text{Apparent specific gravity} \times \text{unit weight of water}}$$

Substituting weight and specific gravities for absolute volumes in the previous formula.

$$\frac{Ww}{1 \times 62.4} + \frac{Wc}{Sc \times 62.4} + \frac{Wa}{Sa \times 62.4} + \frac{Wb}{Sb \times 62.4} = \text{volume in cubic feet.}$$

where Ww, Wc, Wa and Wb are the weights and 1, Sc, Sa, and Sb are the specific gravities of water, cement, fine aggregate and coarse aggregate respectively.

Water-Cement Ratio Law

The first and most important law upon which the design of concrete mixtures is based describes the relationship between the properties of the hardened concrete and the quantity of mixing water used, and was enunciated in 1918 by Duff Abrams. This law may be stated as follows:

For plastic mixtures, using sound and clean aggregates, the strength and other desirable properties of concrete under given job conditions are governed by the net quantity of mixing water used per bag of cement.

The law, known as the water-cement ratio law, was first established with respect to compressive strength. Subsequent studies, however, have shown that it applies equally well to flexural and tensile strength, to the resistance of concrete to wear, and to the bond between concrete and steel. Still more recent investigations have established that the properties of watertightness and resistance to weathering are in the same way controlled by the proportion of water to cement. It should be noted that in the statement of the water-cement ratio law, its application is limited to plastic mixtures and to given job conditions. In the laboratory studies leading to the discovery of this principle it was found that, unless the mixtures were of such consistency that they could be readily moulded into a dense, compact mass, the strength result did not conform to the general relationship. Likewise in the studies of watertightness, it was found that, unless the mixtures were easily placeable and were at the same time not so fluid as to segregate in placing, no regular relationship existed between watertightness and quantity of mixing water. The need for this plastic consistency during construction is just as important as in laboratory studies if the concrete in the structure is to have the properties for which it is being designed. The reference to given job conditions applies to the various conditions peculiar to a job, such as the characteristics of the materials in use, the methods of mixing and handling and the temperature and moisture conditions under which the concrete cures.

It will be seen that the quantity of mixing water governs the quality of the cement paste, upon which in turn depends the properties of the hardened concrete. The quantity of fine and coarse aggregate does not affect the strength of the concrete, provided of course the concrete is truly plastic and workable. As aggregate is cheaper than cement paste, it is economical to use as much aggregate as possible. However, the greater the quantity of aggregate the greater the stiffness of the concrete, which makes it more difficult and costly to place properly in the forms. This fact must be kept in mind when estimating the economic advantage of adding aggregate in order to save cement.

Designing a concrete mix, therefore, consists of two operations:

(a) To select the water-cement ratio which will produce concrete of the desired durability and strength, and

(b) to find the most suitable combination of aggregates which will give the necessary workability when mixed with cement and water in this ratio.

Selection of Water-Cement Ratio

The selection of the water-cement ratio as a basis for designing a concrete mixture involves consideration of both the degree of exposure to which the concrete is to be subjected and the strength requirements of the structure. Because of the high strengths that are now obtained with Portland cement, it is possible to provide ample strength for most exposed structures, if the requirements of exposure are properly cared for. For this reason the first step in designing mixtures should be to select the water-cement ratio necessary to meet the degree of exposure. Table 3 gives the recommended water-cement ratios which experimental data and field examinations of structures in service have shown and will insure durable structures if used with good materials and careful mixing, placing and curing. If a strength higher than one that can be expected from this water-cement ratio, is needed then a ratio appropriate for this requirement can be chosen as described below.

WATER-CEMENT RATIO FOR STRENGTH. On any specific job the relationship between the water-cement ratio and strength should be determined by a series of tests and plotted as shown in Fig. 1. The curves in this figure represent a fair average of the strengths that may be expected with modern cements on a job where all the materials, including water, are controlled. If it is not possible to carry out tests and plot a job curve, the water-cement ratio required for a given strength may be determined from these curves or from Table 4. The engineer must, however, use his discretion as to what values he would use bearing in mind his particular job conditions. There is generally a very considerable variation in the strength of concrete obtained in the field, the amount of variation depending principally upon the accuracy of the batching and control operations and on the uniformity of the raw materials used. Table 5 is a rough guide to the ratio of average to minimum strengths that might occur in typical works. Strictly speaking, however, an absolute minimum strength cannot be given in this way, as there is always a chance of a very low result occurring sporadically. The value for minimum strength given in the table is that which would normally be expected to occur in, say, several hundred test results.

Consistency of Concrete

The next consideration in the design of a concrete mix is its handling and placing requirements. In describing the character of fresh concrete, three terms are most often used—consistency, plasticity and workability.

Consistency is a general term referring to the state of fluidity from the driest to the wettest possible mixtures. It requires a qualifying term for definiteness.

The term plasticity is used to describe a consistency of concrete which can be readily moulded but which permits the fresh concrete to change form slowly if the mould is removed. A plastic mass does not crumble but flows sluggishly without segregation as in the wetter mixtures. Thus, neither the very dry, crumbly mixes nor the very fluid, watery mixes have plastic consistency.

The term workability is used to describe the case or difficulty with which concrete is placed between the forms. In this respect the various conditions under which concrete is placed—size and shape of the member, space between inforcement bars or other details interfering with the ready filling of the forms—have to be taken into account. A stiff plastic mixture with large aggregate which is workable in an open form would not be workable, for example, in a thin wall with complicated reinforcement details.

Under conditions of uniform operation, however, changes in consistency as indicated by the slump are useful in showing changes in the character of the material, the proportions, or in the water-cement ratio. A range of slumps suitable for various types of construction is given in Table 6 and a value falling within the indicated limits should be used, if mixes which are too stiff or too wet are to be avoided.

Unit Water Content

For a given set of materials and water-cement ratio, the unit water content (water required per cubic yard of concrete) is another important, basic factor affecting the quality of concrete. In 1929 F.R. Mcmillan called attention to the fact that the consistency of a concrete mix, for a given type and grading of aggregates, is determined by the water-content, and remains very nearly constant regardless of the richness of cement content. Fig. 2 gives an analysis of different concrete mixes, rich and lean in cement content, but having a uniform consistency (slump 2 to 3 inches). With the same grading of aggregates and a fine-coarse ratio of 1:2, the net water-content per unit of concrete is shown to remain constant for all mixes. It follows that if the absolute volume of water per cubic yard is constant, the absolute volume of solids per cubic yard must also be constant. In order to change a lean mix into a rich mix (using the same materials and same slump) a certain absolute volume of cement has to be added and the same absolute volume of aggregate has to be reduced. In other words, it means that if water content is kept constant cement may be interchanged with aggregate by absolute volume without change in consistency.

As it will be seen later, the rule finds application in the adjustment of concrete mixes. When the trial mix has been brought to the required slump the water-cement ratio is usually different from the one stipulated. As cement content is inversely proportional to the water-cement ratio, an increase in water-cement ratio will mean that a part of the cement should be replaced by an equal solid volume of aggregate. The method is reversed if the water-cement ratio is to be decreased.

Influence of Aggregate Characteristics on Mix Design

The characteristics of aggregates such as maximum particle size, particle shape and texture, grading, the proportion of fine to coarse aggregate, etc., have an important bearing on the properties of concrete mixes. Generally speaking, cost and availability affect the selection of aggregates, but for the purpose of this discussion, it will be assumed that such considerations are on an equal basis.

Maximum Size of Aggregate

The use of the largest practicable size of coarse aggregate reduces both cement and water content required for a given slump and water-cement ratio. Fig.3 based on laboratory and field data, illustrates the influence of size of aggregate on the cement content of concrete of a given slump and the quality of paste. It will be noted that there is a marked economy in use of cement as the maximum size is increased up to about 3 inches. From a practical point of view, the maximum size of aggregate is controlled by the handling, mixing and placing equipment, the thickness of section and the space between reinforcement bars. Satisfactory results have been obtained with concrete containing a maximum size of 9 inches for mass work, but experience shows that 6 inches is the largest size of aggregate that can be handled efficiently for mixing, transporting and placing with the desired degree of uniformity. The maximum size for thin, reinforced work seems fairly well established at not more than one-fifth of the narrowest dimension of the forms or two-thirds of the clear distance between the bars. Table 7 gives recommended values of the maximum size of aggregate for various types of construction.

Particle Shape and Texture

It is well-known that aggregates made up largely of particles which are angular, flat, elongated, flaky, or splintery and have rough surface, decrease the workability of concrete, and necessitate more highly sanded mixes and a consequent use of more cement and water. It is, therefore, necessary to limit the quantity of such particles. Stone screenings or "stone sand", produced as a by-product in crushing rock, is sometimes used as fine aggregate. Owing to the roughness of particles and thin splintery shape, stone sand requires more cement paste than natural sand to produce a given consistency. While using stone sand, its relative economy, vis-a-vis the use of natural sand, to produce concrete of the required qualities should be the determining factor.

Proportion of Fine to Coarse Aggregate

For any given degree of workability, the proportion of fine to coarse aggregate varies with the water content of the paste. The optimum percentage of fine aggregate for a concrete mix is that quantity which requires the lowest unit water content, and provides the required degree of workability with an adequate margin to prevent difficulties from variations in working conditions and materials. Obviously, for a given water-cement ratio, the mix requiring the lowest water content will also require the least quantity of cement. Fig.4 indicates the relationship of paste content to sand. It shows that smaller or greater percentages than the optimum will require more paste. Points on the curve to the left of the optimum represent mixes that would be too harsh unless additional cement paste was used. Points to the right of the optimum represent mixes that would be too stiff owing to the increased sand, and again additional paste is required to maintain the workability. This curve is for concrete of medium consistency, but similar curves could be drawn for other consistencies and other aggregate gradings.

The optimum percentage of sand can be determined to best advantage, on the job, under working conditions. However, laboratory mix tests with the materials to be used in the work will provide information permitting a close approximation to the proper proportion. When laboratory tests cannot be made, the values for sand and water content may be taken from Table 8 which has been prepared from a composite of data, information, and experience from many sources.

It is sometimes stated that the best proportion of fine and coarse aggregate is the one that gives the maximum density of mixed aggregate. This is not necessarily true, as shown in Fig. 5 which gives relationships between the percentage of sand and water-cement ratio of the paste and the workability of the mixtures. The gradings of sand and coarse aggregate were the same in all of these tests, the maximum size of coarse aggregate being 1½ inches. The curves, each representing a different degree of workability, indicate the proportions of sand which required the least quantity of cement paste. The cross-hatched area represents the proportion of sand which gave the maximum density of mixed aggregate. It will be noted that the optimum percentage of sand differs considerably from this percentage for mixtures of low water-cement ratio and for stiffer consistencies.

Grading of Aggregates

The proper proportions of fine and coarse aggregates are also affected by the grading of each aggregate. Table 9 gives results of tests in which the same grading of sand was used throughout but the grading of coarse aggregate varied, the maximum size being 1½ inches in each case. A constant water-cement ratio and degree of workability were used.

It will be noted that the cement requirement did not vary when the optimum amount of sand was used, but the requirement changed considerably with an arbitrary percentage of sand. In all later cases, the requirement of cement was higher. If a constant cement factor is used, the optimum amount of sand as described above will produce a mixture requiring the least quantity of water for a given consistency and therefore will produce the best concrete.

The grading of the fine aggregate also influences the desirable proportions. Fig. 6 shows the effect of this grading on cement requirements of concretes of similar strength and workability. Three different types of sands were combined with coarse aggregate of the same gradation, and as will be seen in Fig. 6, there was a considerable difference in cement content for a given percentage of sand. For example, at 45 per cent sand the cement content varied from 3.9 to 4.5 bags per cubic yard of concrete. On the other hand, when the optimum amount of sand was used, as represented by the lowest point of each curve, there was little difference in cement content. There are many theories on the best grading for aggregates to produce maximum workability and economy, and "ideal" gradings have been much discussed. An ideal grading would vary somewhat with the type of aggregate, with the degree of workability desired, and with the amount of cement in the mixture. It may be possible to produce one or more ideal gradings for the specific conditions of a given job, but this would be practicable only on large jobs and even there might not be economical. Practical considerations in the production of aggregates usually limit selection to a few materials which have been produced to meet the requirements of most concrete work. There are, however, certain fundamentals which should be understood.

As seen from Fig. 6 there is little difference in cement requirement in concrete whether fine sand or coarse sand is used, provided the quantity of sand is optimum. In general, the percentage of sand should be less when it is fine than when it is coarse. There are certain objections, however, to using very fine sand such as plaster sand or beach sand because it is difficult to avoid segregation when fine sand is mixed with coarse aggregate. There is also a tendency for too much mortar to come to the surface. The finer the sand, the more likely it is made up predominantly of one or two sizes. It is, therefore, generally accepted that coarsely-graded sands are most desirable. On the other hand, all sands must contain a sufficient quantity of fine particles in order to produce a mortar of good workability. Specifications usually permit a rather wide range in the quantity of material passing the 52-mesh sieve being 5 to 30 per cent. This lower limit may be sufficient in relatively rich mixes under easy placing conditions and with mechanical finishing as for pavements. But it is not sufficient in the usual mixes used in wall construction, where the minimum should be 10 per cent and where 15 to 30 per cent gives better results. A grading of sand in which one or two particle sizes predominate, should be avoided. Such a sand has a large void content and therefore requires a large amount of cement-water paste to produce a workable mixture. Fig. 7 gives the grading limits of both fine and coarse aggregate as specified in British Standard Specification No. 882:1944, and curves representing sieve analysis should lie between these lines.

Concrete Mix Design Procedure

To recapitulate briefly the principles involved in the design of concrete mixes are that strength and durability depend upon the water-cement ratio, consistency depends upon the unit water content, and workability depends upon consistency, the proportion of fine-coarse aggregate, and other aggregate characteristics. A simple design procedure based on these relationships is given below. The five steps involved in the determination of a trial mix for initial field use are:—

1. Select the water-cement ratio necessary to produce concrete of the required durability and specified strength. Table 3 gives recommended values for various types of construction and exposure conditions. The water-cement ratio for specified strength should be determined by test. When this is not practicable, values may be selected from Table 4. The lower of the two values obtained should be used.

2. Select the lowest slump that will permit proper handling and consolidation of the concrete under the job conditions involved. Table 5 gives recommended values.

3. Determine the largest size of available aggregate which will be suitable for placing under job conditions. Table 6 gives recommended values.

4. Estimate from test data or from Table 7 the minimum proportion of fine to coarse aggregate and the lowest unit water content that will give the required degree of workability.

5. Compute the trial mix proportions. Make adjustments in succeeding batches. If the amount of water used in item 4 is more than for the water-cement ratio, decrease the amount of aggregate added to the batch, and if it is less, increase the amount of aggregate. It may be desirable also to increase or decrease the percentage of sand slightly to secure the most suitable mix for conditions prevailing on the job. An under-sanded mix is indicated by hardness, difficulty in placing, and by stone pockets and honeycomb in the hardened concrete. An over-sanded mix is indicated by an excess of mortar.

Example

Assume a project which involves an ordinary heavily reinforced retaining wall having a minimum thickness of 8 inches. The wall has been designed on the basis of a cube crushing strength of 3500 psi at 28 days. Ordinary Portland cement will be used and concrete will be controlled as accurately as possible with weight batching and good supervision. Consolidation will be by vibration. A trial concrete mix is required to start construction. The following information regarding the materials to be used on the job is available:

Cement	Ordinary Portland. Specific gravity—3.15 (assumed).
Sand	River sand, damp. Medium fineness and grading. Specific gravity—2.65 (saturated, surface-dry). Free moisture content—5 per cent by weight.
Coarse Aggregate	Crushed stone (saturated, surface-dry). Reasonably well-graded, angular. Specific gravity—2.80 (saturated, surface-dry). Absorption of water—negligible.

From Table 3 it is found that a water-cement ratio of 0.54 (6 gallons per bag of cement) is the maximum which should be used for the type of structure and service conditions involved. Table 5 shows that under conditions of accurate control of concrete with weight batching, the minimum strength may be expected to be about 75 per cent of the average strength. The average strength to be aimed at in the mix design procedure would, therefore, be $\frac{100}{75} \times 3500 = 4700$ psi at 28 days, which (as shown in Table 4) requires a water-cement ratio of 6 gallons per bag. From Tables 6 and 7 it is concluded that a 3-inch slump and $1\frac{1}{2}$-inch maximum size of aggregate will be satisfactory.

On the basis of information given in Table 8, it is estimated that the percentage of sand for the trial mix should be 36 by absolute volume of the total aggregate, and that 305 lbs. ($30\frac{1}{2}$ gallons) of water will be required per cubic yard of concrete. (Actually the water content may be more or less than the estimated amount as determined by the amount of water required for a 3-inch slump when a trial batch is mixed in the laboratory or on the job.)

CEMENT CONTENT

$$\left\{\frac{\textit{Net water content}}{\textit{Water-cement ratio}}\right\}$$

$$= \frac{305}{0.54} = 565 \text{ lbs. per cubic yard.}$$

$$= \frac{565}{112} = 5.05 \text{ bags per cubic yard.}$$

$$\left\{\begin{matrix}\textit{Absolute volume}\\ \textit{Water} + \textit{cement}\end{matrix}\right\}$$

$$= \frac{\text{Water content}}{62.4} + \frac{\text{Cement content}}{\text{Specific gravity} \times 62.4}$$

$$= \frac{305}{62.4} + \frac{565}{3.15 \times 62.4}$$

7.77 cubic feet per cubic yard of concrete

$$\left\{\begin{matrix}\textit{Absolute volume}\\ \textit{total aggregate}\end{matrix}\right\}$$

$$= 27 - \begin{Bmatrix} \text{Absolute volume} \\ \text{Water+cement} \end{Bmatrix}$$

$$= 27 - 7.77$$

$$= 19.23 \text{ cubic feet per cubic yard of concrete}$$

$$\begin{Bmatrix} \textit{Absolute volume} \\ \textit{sand} \end{Bmatrix}$$

$$= \text{Percent sand} \times \begin{Bmatrix} \text{Absolute volume} \\ \text{total aggregate} \end{Bmatrix}$$

$$= 0.36 \times 19.23$$

$$= 6.93 \text{ cubic feet per cubic yard of concrete}$$

$$\begin{Bmatrix} \textit{Absolute volume} \\ \textit{coarse aggregate} \end{Bmatrix}$$

$$= \begin{Bmatrix} \text{Absolute volume)} \\ \text{total aggregate)} \end{Bmatrix} - \begin{Bmatrix} \text{Absolute volume} \\ \text{sand} \end{Bmatrix}$$

$$= 19.23 - 6.93$$

$$= 12.30 \text{ cubic feet per cubic yard of concrete (sand content)}$$

$$= \text{Absolute volume x specific gravity x } 62.4$$

$$= 6.93 \times 2.65 \times 62.4$$

$$= 1149 \text{ lbs. per cubic yard of concrete (coarse aggregate content).}$$

$$= 12.30 \times 2.80 \times 62.4.$$

$$= 2150 \text{ lbs. per cubic yard of concrete}$$

$$= \textit{Trail mix proportions}$$

$$= \frac{565}{565} : \frac{1149}{565} : \frac{2150}{565}$$

$$= 1 : 2.03 : 3.8$$

$$= 1 : 2 : 3.8, \text{ say.}$$

This mix provides a starting point for field operations. The equipment available on the job includes a one-bag batch mixer equipped with a water tank which is calibrated in gallons, and batching scaled for weighing the separated sizes of sand and coarse aggregate.

Cement is to be batched on the basis of whole bags. Each batch will, therefore, contain 112 lbs. of cement. The batch weights of sand and coarse aggregate will be:

$\text{Sand} = 1149 \times \frac{112}{565} = 228$ lbs. (net) to which must be added the weight of the free moisture in the sand:

$228 + (0.05 \times 228)$.

$= 239$ lbs. damp sand

$\text{Coarse aggregate} = 2150 \times \frac{112}{565} = 426$ lbs.

Essential Factors in Control

Once a satisfactorily proportioned concrete has been produced the only problem would be to ensure its continuous supply to the place of deposit. Each batch of concrete should be as nearly like the other batches as possible. Uniformity in this sense refers not only to the water-cement ratio (and therefore strength) but also to consistency since nothing so disorganizes the work of placing as varying consistencies of concrete.

Essential factors in the proper control of the quality of concrete in the field may be summarized as follows:

CONTROL TESTS—These tests are required for making proper adjustments in the mix for variations in the materials, so that uniform batches are turned out all the time.

MEASUREMENTS OF MATERIALS—Materials should be accurately measured so that quantities are uniform from batch to batch.

MIXING OF CONCRETE—Mixing should be thorough enough to distribute the materials uniformly and spread the cement-water paste evenly on the surfaces of the aggregate.

TRANSPORTING, PLACING, COMPACTING AND FINISHING—Concrete should be conveyed, placed, and compacted without segregation. Compaction should be so thorough as to fill all parts of the forms, eliminate air and rock pockets, and form a bond with adjacent steel or concrete. Finishing should produce a dense surface free from excessive shrinkage.

CURING—Concrete should be adequately cured so as to realize its full potential strength.

FOLLOW-TESTS—These tests are required to confirm the quality of concrete.

Slump Test

As mentioned earlier a test that will indicate changes in consistency is the slump test. The apparatus consists of a metal cone, 4-inch diameter at the top, 8-inch diameter at the bottom and 12-inch high, and a metal tamping rod 2 feet long and $\frac{5}{8}$-inch diameter, bullet pointed at the tamping end. The cone should be first inspected to make sure that the internal surface is clean, dry and free from set cement. It is then placed on a smooth, flat, impervious surface such as a steel plate, the operator holding it firmly in place by standing on the foot pieces. The cone is then filled with freshly mixed concrete to about one-fourth of its height and tamped with 25 strokes of the rod. The filling is completed in successive layers similar to the first and the top struck off level with a trowel. Immediately afterwards, the cone is removed by lifting vertically, the moulded concrete allowed to subside, and the height of the specimen measured after coming to rest. The consistency is then recorded in terms of inches of subsidence of the specimen during the test, which is known as the slump. The idea in controlling the slump is to control directly the consistency and workability necessary for concrete placement, and indirectly the water-cement ratio; the principle being that repeated batches of the same mix having the same consistency will have the same water content and consequently the same water-cement ratio provided factors like batch weights or volumes, aggregate grading, and temperature of materials are practically uniform. Fortunately variations in water content have a much more pronounced effect on slump than variations in the factors mentioned above. Hence on jobs where grading and batching are properly controlled, slump variations will reflect variations in water content and water-cement ratio.

Volume Batching

Wooden batch boxes locally known as 'farmas' are made for the purpose of batching by volume. The boxes should be able to measure the correct quantity of aggregates to be used with a 1-cwt bag of cement for the required mix. They should not be made so large as to be unwieldy; it is preferable to have a box that will contain, say, half the required quantity of material and could be filled twice. The joints of the boxes are usually nailed, sometimes screwed, and occasionally bolted. The board thickness should not be less than 1½ inches, and the handles should be shaped to provide an easy grip.

Weigh Batching

The system of expressing mix proportions and batching materials by volume leads to inaccuracies in as much as a cubic foot or a cubic yard of concrete aggregate is an indefinite quantity. A cwt or a ton of aggregate, on the other hand, is a definite quantity. Furthermore, the weight of any concrete material is directly related, through specific gravity, to the solid space which the material occupies in the concrete. The weight system of measurement is, therefore, logical and makes for accuracy, flexibility and simplicity in batching. Weigh batching arrangements and equipments vary with the size of job. These include folding weigh batchers and portable attachments to be fixed on concrete mixers to batching plants of every description and should be selected according to the requirements of the job.

Mixing Concrete

In order to mix concrete in a satisfactory manner the various materials should be uniformly distributed through the concrete mass and the cement water paste should completely cover the surface area of the aggregate. Concrete can be mixed either by hand or by machine, but the machine process is more efficient and produces concrete of a better quality at a faster rate and generally at a lesser cost. Mixing by hand should be allowed on very small and unimportant works. In all cases where the mixing of concrete is done by hand an additional 10 per cent of cement must be used and the engineer should insist on a thorough and long-continued mixing.

The use of mixers is, however, more usual, even for small jobs. A mixer should have sufficient capacity to cater for the demand without speeding the machine or reducing the mixing time below the specified period, and without overloading it above its rated capacity. In case of greater demand, a larger mixer or additional mixers should be used. A mixing time of not less than two minutes after all materials have been put in the mixer drum is generally recognized as a satisfactory period for mixers having capacity up to one cubic yard. For mixers of a larger capacity the time should be increased at the rate of 15 seconds or more for each cubic yard or fraction thereof. While small changes in the speed with which the mixer drum revolves have little effect on the strength of concrete, mixing time has an important bearing on this quality. Tests show that the strength of concrete is increased by longer periods of mixing. Typical values from these tests have been plotted in Fig. 8. The rapid increase in strength for different periods of mixing up to about two minutes can be seen on these curves. For instance the concrete mixed for two minutes is stronger by 20 to 35 per cent than the concrete mixed only for 15 seconds.

Thorough mixing also makes for a more uniform concrete. Specimens of concrete mixed for only 15 seconds show a variation in strength of 30 per cent from the average while specimens mixed for two minutes show a variation of less than 10 per cent. Furthermore, thorough mixing gives increased workability which, in turn requires less labour in placing. In waterproof construction and where the structure is to be exposed to severe weather conditions a somewhat longer period of mixing than is customary proves of great advantage.

Batch Mixer

An ordinary batch mixer has a revolving drum fitted with blades to stir the materials. The mixers are of two types: rotary or non-tilting type and tilting type. In mixers of the rotary type the drum is cylindrical and revolves about a horizontal axis. The drum is charged by means of a cable-operated loading skip or a charging hopper, and a hand-operated swinging discharge chute collects and leads out the mixed concrete. The tilting type is equipped with a conical or bowl-shaped drum revolving about an inclined axis and is also charged by means of a loading skip, though the smaller sizes may be fed directly into the drum. In general, the tilting mixer is considered more efficient than the other type, since it enables the concrete to be discharged in a short time with the minimum of segregation. Besides it can be cleaned more easily. For normal construction, standard mixers of British make have capacities of $3\frac{1}{2}$, 7, 10, 14, and 28 cubic feet, while those of American make have capacities of $3\frac{1}{2}$, 6, 11, 16, and 28 cubic feet. On larger work and central mixing plants, mixers of 56 and 84 cubic feet capacities may be used. The power for rotating and tilting the drum and for hoisting the material skip is provided by petrol or other type of oil engine or by an electric motor. For small contracts, the most popular mixer used today is of 10/7 or $\frac{1}{4}$ cubic yard capacity. It is economical because it permits a whole bag of cement to be used in each batch of a nominal mix of 1:2:4, a batch requiring approximately 9 cubic feet of cement and aggregate. For bigger works, the mixer should be selected keeping in view the extent of the work, the requirements for proportioning and the method of distribution, compaction, and finishing the concrete. Under normal running conditions, about 10 per cent of the quantity of water required should be put in the drum before the dry materials are added. Water should then be added uniformly with the dry materials, leaving about 10 per cent to be added after all other materials have been put in the drum. It is better to feed cement, sand and coarse aggregate into the mixer simultaneously than introducing them one after the other. The concrete produced in this way would be more uniform. Concrete should not be allowed to harden around the blades or on the inner surface of the drum because this would affect the efficiency of the mixing action. Regular cleaning at the end of each spell of mixing is, therefore, necessary, especially when still mixes are in use.

Transporting Concrete

The plant required for transporting concrete from the mixer to the point where it is to be placed will vary according to the size of the job and the height above the ground-level at which the concrete is to be poured. Obviously, very expensive plant, however quick in operation, cannot be economically used to pour small quantities of concrete, since the cost of erection and dismantling and the hire charges would be excessive. Whatever the means of conveyance, the following main requirements should be fulfilled:

(i) Concrete delivered at the point of placing should be uniform and of proper consistency.

(ii) There should be no separation of materials in the concrete.

(iii) Concrete should not dry or stiffen during conveyance.

Segregation

The most important consideration in handling and transporting concrete is to avoid the segregation of coarse aggregate from the concrete. It is a common fallacy to say that separation occurring in handling will be eliminated during other operations. Separation must be prevented and not corrected afterwards. The reason why separation occurs is that concrete is not a homogeneous product but a collection of materials widely different in particle, size and gravity. As a result, from the time the concrete leaves the mixer there are internal and external forces which act to separate the dissimilar constituents. Separation can be prevented by ensuring that concrete is dumped or dropped vertically. When dropped at an angle the larger aggregate is thrown to the far side of the container and the mortar is thrown to the near side thus resulting in segregation that may not be corrected upon further handling of the concrete.

The prevention of separation must first be ensured at the mixer itself. The segregation of material owing to uncontrolled chuting of the concrete as it is discharged from the mixer is particularly noticeable with non-tilting mixers where the concrete passes out in relatively small streams over the discharge chute. This can be prevented by providing a down-pipe at the end of the chute so that the concrete drops vertically into the centre of the receiving container. With tilting mixers, the batch usually slides out in a bulkier mass and is thus less prone to segregate.

Methods of Conveyance

Concrete may have to be deposited below or at about the same level as the mixer; or as in the case of buildings and dams, concrete must be hoisted and distributed above mixer level. There are many devices for conveying concrete, and they are used either singly or in combination to suit different conditions.

Hand Pans, Wheelbarrows, and Carts

The most common contrivance used in this country for transporting concrete from the mixer to the forms is the hand pan, or ghamela, which is passed from hand to hand. This method is tedious, slow, wasteful, and with the rising cost of labour is likely to be expensive. Where concrete is to be deposited at or below the mixer level, it is better to use a steel wheelbarrow. For placing concrete much below the general ground level, as in basement slabs, foundations and footings, a wood or steel chute may be used. Such chutes are made with a flared upper end for convenience in dumping the barrow or cart direct into them. For lifting concrete above the mixer level special provisions have to be made. In a single-storey structure where the concrete has to be lifted not more than 10 or 15 feet above the ground level, inclined runways for wheeling the concrete are easy to build. These runways may be built with one or two landings to break the slope.

Hoists

For most of the building jobs, however, a hoist of some sort is required. A wooden hoist tower can be made by carpenters, but steel towers have a longer life and can be erected and dismantled with ease. Very often, no special tower is required, a cage being formed from the external scaffolding members to accommodate the hoisting arrangement. Barrows, carts, skips or other containers may be used to convey the concrete.

Buckets

Steel buckets transported by railway wagons, motor lorries, derricks, or cableways, and frequently by a combination of these, are the most satisfactory methods of conveying concrete over long distances and extensive sites like dams and barrages. They are of varying shape and design and have capacities ranging from 1 to 8 cubic yards.

The larger buckets usually have a rectangular cross-section, but most buckets are circular. The usual method of releasing concrete is by tripping a gate or gates fitted at the bottom of the bucket. The bucket is lowered as close to the forms as possible or to the surface of the concrete already placed before releasing the concrete to avoid the impact of concrete falling from a height which may not only impair the quality of the concrete, disturbing that already placed, but may seriously damage formwork itself. For use on huge structures, the buckets usually have straight sides and gates opening to the full area of the bottom of the bucket. For smaller formed sections the bucket is provided with a regulating gate of smaller size than the section of the bucket which may be closed at will during unloading so that the remainder of the contents may be deposited elsewhere. Gates may be operated by hand or by mechanical or pneumatic means. Where the buckets are handled by a cableway, mechanically or pneumatically operated gates are the safest, because they can control the discharge of the concrete in a much better way and thus prevent sudden jerks on the cableway.

Chutes

Concrete may be distributed by means of long chutes or chute systems for covering fairly large areas, whether at ground level as in reservoir floors, or at various elevations as in large multi-storied buildings. This method may, however, be considered most objectionable because of the tendency of the concrete to segregate and dry. The chutes should be of metal or metal lined, round-bottomed and of ample size to guard against overflow. The slope of the line of chutes has to be so adjusted that the concrete flows regularly, though not so fast as to allow the materials to segregate. The slope depends upon the consistency of the concrete, the nature of materials, and the design of the chutes, but it is generally not flatter than 1 to 3 nor steeper than 1 to 2. The addition of extra water to the concrete to enable it to flow down the chutes is, of course, not to be allowed. When long chutes are used the concrete is delivered into a hopper, preferably of the bottom gate type before it is deposited into the forms. In this way some remixing action takes place to correct any segregation which may have taken place. If concrete is placed direct in the forms, it should not fall freely more than a few feet and nor shoot out at an angle.

Placing Concrete

Placing and compacting concrete are the last stages in concrete construction before initial setting takes place, and are very important in this operation. It is not enough that a concrete mix is correctly designed and properly manufactured. Proper methods of placing and compacting are also necessary to prevent segregation and porous or honeycombed areas; avoid displacement of forms and reinforcement: secure a firm bond between layers; minimize shrinkage cracking; and to produce a structure of neat appearance. Before placement commences, however, the formwork or the surface which is to receive the concrete must be carefully prepared. Concrete may be required to be placed in a rocky foundation, or on a compacted soil surface, or bonded to a concrete construction joint. All these must be treated so as to be fit to receive the concrete.

Preparation of Forms

Forms should be properly set to line and grade. They should be tight and strong enough to hold the concrete, and adequately braced to stay in alignment. If the forms are not tight, there is a likelihood of loss of mortar resulting in honeycombing, or loss of water resulting in sand streaking. Before placing concrete, saw-dust, shavings, chips, nails and all loose debris should be brushed off, and the forms wetted or oiled to facilitate their removal when the concrete is set. Plywood forms are often lacquered instead of wetted or oiled. Reinforcing steel should be clean and free of loose rust or mill scale at the time the concrete is placed. Any coatings of hardened mortar should be removed from the steel.

Depositing Concrete

There are many details incidental to placing concrete which, if not closely attended to may result in serious defects in the finished structure. Concrete should be dropped vertically and from not too great a height to avoid segregation, entrainment of air, and damage to forms, embedded material, and concrete already in place. For concreting walls and other thin sections, concrete should be dropped through flexible drop chutes or through rectangular metal ducts. This will prevent concrete repeatedly hitting the reinforcement and sides of the forms and coating them with mortar that is likely to dry out long before it can be covered with concrete and thus causing segregation. Metal ducts may be provided in sections which can be hooked together so that the length can be adjusted as concreting progresses. In deep, narrow, reinforced walls where even narrow ducts cannot be inserted, the drop chutes can be arranged to discharge through port holes cut in the formwork.

Concrete should be deposited as near its final location as possible. It should not be placed in such large quantities that it flows or has to be worked laterally for more than a short distance, say 2 or 3 feet. Otherwise it causes segregation, because the mortar tends to flow out ahead of the coarser material. It may also cause work planes to slope between successive layers of concrete. While shallow sections such as slabs and beams can be concreted in a single thickness, deeper sections require to be placed in successive layers. Each layer should be placed in one continuous operation as far as possible and worked well into the preceding layer while it is still soft. The top of a layer should be kept level or nearly so. It is common practice in mass concrete work where concrete is usually deposited by means of buckets to spread it in layers from 15 to 18 inches thick. In reinforced concrete work, however, the layers should not be more than 6 to 12 inches thick. The thickness actually depends upon the width between forms, the amount of reinforcement and the fact that the layer should not stiffen before another one is placed on it. It is also important to adopt a proper order of placing. In walls, beams and girders, the first batches should be placed at either end and concreting should then continue towards the centre. This should be done for each layer. In large open areas, the first batches should be placed around the perimeter. In all cases, it must be ensured that water does not collect at the ends and corners of forms and along form faces. In slab construction the placing of concrete should begin at the far end of the work so that each batch will be dumped against previously placed concrete, and not away from it. To avoid cracking caused by settlement, concrete in columns and walls should be allowed to stand for at least two hours before concrete is placed in the slabs, beams, or girders which they are to support. Haunches and column caps are considered part of the floor or roof and should be placed integrally with them.

Placing Concrete under Water

The methods of placing concrete under water differ from those ordinarily employed in placing it in air.

TREMIE—By far the largest volume of concrete placed under water has been done by means of tremies. The tremie is a watertight pipe, often 10 inches in diameter and long enough to reach from a working platform above the water-level to the lowest point of deposit. A receiving hopper is provided at the top of the pipe and the lower end is sometimes equipped with a valve. The concrete to be placed with a tremie should have a fairly high slump, say 6 or 7 inches, and a richer mix than ordinarily used for placing in air. The cement content should not be less than 6 bags per cubic yard of concrete. To start operation with an open-end tremie, the lower end is usually plugged with bags, straw, or concrete in bags. When the pipe is lowered into position and filled with concrete the plug is forced out. After concreting has started the lower end of the tremie should be kept as deeply submerged in the previously placed concrete as conditions permit. This depth will depend largely on the head of concrete that can be maintained in the tremie. The tremie should be lifted slowly to permit the concrete to flow out and care should be taken not to loosen the seal at the bottom. If the seal is lost it is necessary to raise the tremie, plug the lower end, and then lower the tremie into position again.

Every precaution must be taken both in handling and placing the concrete to reduce to a minimum the tendency to segregate. No attempt should be made to puddle the concrete, as experience has shown that the less it is disturbed after it is deposited the better. Once concreting has started the tremie should not be moved laterally through the deposited concrete as this will again disturb it. If it is necessary to shift the tremie, it should be lifted out and moved to the new position.

BUCKET—Concrete can also be satisfactorily placed under water by means of open top rectangular or cylindrical buckets with full drop-bottom or roller-gate openings in the bottom. The method has been especially successful in placing concrete in very deep water—as much as 240 feet—for bridge pier construction. Concrete for placing by bucket should be much the same as that for tremie placing although a slightly stiffer mix can be used. The bucket should be completely filled and the top covered with a canvas flap to protect the surface of the concrete from being washed away by swiding water above while the bucket is descending through water. It should be gently lowered so that the canvas is not displaced. It should not be dumped until it rests on the surface upon which the concrete is to be deposited and when discharged shall be withdrawn slowly until well above the concrete. Soundings at frequent intervals should be taken to see that the top surface of the concrete is level.

Compaction

As concrete is being placed it should be compacted thoroughly and uniformly by means of hand tools, vibrators, or finishing machines to secure a dense structure, a close bond with reinforcement, and smooth surfaces. Concrete should be worked well around the reinforcement and embedded fixtures and into the corners of the forms, but should not be worked more than necessary, since any disturbance of the concrete in place makes for segregation of materials, and the water and fine particles move towards the surface. This water may collect under the bars and the larger pieces of aggregate, thereby weakening the bond and opening channels for possible leakage through the concrete. Also, excessive working of concrete at formed surfaces brings undesirable fines and water to the surface. Sufficient equipment and operators should be provided in order that the entire mixer output can be handled without delay, otherwise the concrete may stiffen too much before it is thoroughly compacted and the surface is finished.

Hand Compaction

Ordinary hand methods of consolidating concrete consist of ramming, tamping, spading, and slicing with suitable tools. Tramping of the workmen while handling these tools also plays an important part in the compaction. Spading is done at or near vertical form faces in order to secure a smooth surface, but too much of spading will draw out an excess of cement paste which will later craze, crack or scale. For compacting dry concrete the surface is rammed with a heavy flat-bottomed rammer until a thin film of mortar or paste appears at the surface, showing that the voids of the aggregate have been filled.

Compaction by Vibration

Vibration as a means of consolidating concrete has many advantages over hand compaction methods. Modern high frequency vibrators make it possible to place, economically, mixtures which cannot be placed by hand. For example, a concrete of still consistance—1½ inches slump—can be placed in forms containing closely spaced reinforcement by vibrators whereas a much wetter consistency is necessary, probably 5 or 6 inches slump, for hand puddling. The action of vibration sets the particles of fresh concrete into motion, reducing friction between them, and affecting a temporary liquefaction of the concrete which enables it to settle easily into place.

While vibration in itself does not affect the strength of concrete which is controlled by the water-cement ratio just in the case of hand compaction, it permits the use of either less water or a leaner mix. Concrete of higher strength and better quality can, therefore, be made with a given cement factor because less mixing water can be used. Where only a given strength is required, it can be obtained with leaner mixes than possible with hand placing, thus making for economy. This shows that vibration makes for improvement in the quality of concrete as well as economy.

In the case of vibration process, stiffer mixtures and also mixtures containing less fine material can be used than are required to give the cohesive qualities necessary to prevent segregation in hand-placed mixtures. A larger proportion of coarse and a smaller proportion of fine aggregates can, therefore, be used. Since coarser gradings prevent less surface area to be coated with paste, less water or less paste can be used for a given consistency. Thus improvement in quality and economy is effected by harsher as well as stiffer mixtures.

The vibration method can be conveniently used for placing concrete under conditions where it is difficult to get good results by hand placing. Vibration makes it possible for the concrete to flow through small openings, and in and around closely spaced reinforcement.

Shrinkage of a vibrated concrete owing to less moisture is somewhat less than concrete placed by hand because of the higher aggregate factor or lower water content. If the potential advantages of vibration are fully realized, volume changes due to changes in moisture content may be reduced by as much as one-half.

When using vibrators for compacting, care must be taken in the construction of formwork. It must be stronger than that for hand-rammed work in order to withstand the hydrostatic pressure which develops when the concrete liquefies under vibration. For the same reason, the forms must be watertight.

Vibratory Equipment

Most of the high-frequency vibrators now available give at least 3,600 impulses per minute. Some of them produce twice this number or even more. They may be electrically driven, or operated from a petrol engine or air compressor. The vibrations are caused by eccentric weights attached to the shaft or the motor or to the rotor of a vibrating element. Electric magnet pulsating equipment is also available.

Vibrators are of the following four general types:—

- Internal, "spud" or "needle" vibrators consist of a metal spud or rod, which is inserted into newly-placed concrete and which vibrates while being withdrawn.
- Surface vibrators which are mounted on screeds or platforms and are chiefly used for consolidating road slabs, floors, etc.
- External or "form" vibrators which are attached to formwork and external shuttering of walls, columns, etc. The forms transmit the vibrating action of the concrete.
- Vibrating tables which are used for making precast products.

Any of these types should be applied systematically at short distances on the surface so that vibrated areas of concrete may overlap without omission of any part. Vibration should be continued till concrete has been thoroughly compacted and the voids have been filled, as indicated by the appearance of mortar or paste at the exposed surface or at faces of contact with the forms. Then vibration should be stopped; otherwise it would cause coarse aggregate to settle to the bottom and water or paste to rise to the top. Usually vibration should secure the desired results within 5 to 15 seconds at points 16 to 30 inches apart. It should not be done for longer periods at wider distances. Internal vibrators should be inserted to the full depth of the layer. They should be inserted and withdrawn slowly and operated continuously while being withdrawn so that no hole is left in the concrete. The entire depth of a new layer of concrete should be vibrated, and ordinarily the vibrator should penetrate the layer below for several inches to ensure thorough union of the layers. Concern has sometimes been expressed of the effects of revibration of a lower layer which may be partially hardened and in which the cement may be setting. Tests, however, indicate that revibration of partially set concrete actually improves its strength. Apparently the kneeding action on the concrete further consolidates it.

Form vibrators are particularly effective on columns and in the casting of precast units such as pipes, slabs, piles. The machine is fastened to a wale or gut and transmission of the vibration around the perimeter of the member is further assisted by means of an encircling chain where this is practicable. Form vibrators are also used on thin wall sections where reinforcement, ties and spreaders interfere too much with internal vibrators. The portable electric or air hammers are especially useful in such work as architectural concrete where the appearance of the finished work is particularly important, and also on sections that are too thin for internal vibrators. Vibrating tables are used for precast units which are made in gang moulds fastened to the table. Tables are available in various sizes and are usually equipped with adjustable eccentries so that both the speed and amplitude can be adjusted.

Personal preference and job conditions will affect the selection of the motive power for operating vibrators. On large jobs both electricity and compressed air are generally available. For smaller work compact, portable electric generating equipment is available which will not only furnish power for the vibrators but also for other small tools and for lighting. Petrol engines are also used to drive vibrators directly and can be very cheaply operated. On most jobs, power costs of operating vibrators are not important and personal preference and convenience will therefore generally govern the selection. High frequencies can be secured with all three kinds of power with properly designed equipment.

Curing Concrete

Concrete hardens because of chemical reactions between Portland cement and water. This process, known as hydration of cement, is not fully known but, it is believed that the principal reaction products are silicate gels which form at the surfaces of the cement grains and in the spaces between them. So long as the temperatures are favourable and the water necessary for the chemical reactions is present, the formation of gels proceeds from the surface of the grains inwards, gradually transforming them completely. The gel structure between the grains increases in density at the same time. The quality of the concrete, therefore, depends on the uninterrupted development of the hydration process.

The water used in mixing concrete is actually more than necessary to fill the intergrain spaces. However, the loss from evaporation from the time of the initial set of the concrete is normally so rapid that the hydration process may be seriously affected. The primary aid of curing is to prevent or replenish this loss of moisture during the early relatively rapid stage of hydration. The commonest method is to keep the exposed surface of the concrete continually moist by spraying, ponding, or covering it with earth, sand, straw or hessian maintained in a moist condition. Precast concrete is often cured in chambers in which steam is released, keeping the concrete moist. All these methods are collectively known as moist curing. Fig No. 9 shows how moist curing during the early hardening period greatly increases the strength of the concrete. In these tests all specimens were tested at 4 months but they were damp cured for various periods and allowed to cure in dry air thereafter till tested. It will be seen that an increase of 72 per cent in strength was obtained by keeping the concrete damp the first ten days instead of letting it dry out. Keeping the concrete damp three weeks increased the strength 124 per cent and for four months 207 per cent over the strength of concrete cured during the entire period in dry air.

EFFECT OF TEMPERATURE—The effect of temperature during curing on the rate at which concrete hardens is shown in Fig No. 10. The best result is obtained when concrete hardens in a warm, damp atmosphere. If the weather is cold and the concrete is exposed to a temperature below 40 degrees Fahrenheit, the rate of hardening will be extremely slow and the concrete will have, for equal periods, considerably lower strength than concrete cured in a temperature of 70 degrees Fahrenheit. If, on the other hand, the concrete is exposed to a hot atmosphere and drying winds, there is a danger that the water required for hydration might evaporate and prevent the hardening of the concrete. Quick drying out of the concrete will also lead to contraction cracks, since the concrete is not hard enough at an early age to resist, without cracking, the stresses set up by contraction. Special precautions are, therefore, necessary during hot weather. Concreting should be done at night, using cold mixing water, sprinkling or covering aggregate, and avoiding the use of hot cement. To reduce absorption of mixing water the aggregates, wooden forms, sub-grade, foundation or other moisture absorbing surfaces should be well wetted before concreting. To lessen evaporation, the fresh concrete should be protected from the direct rays of the sun and from the drying wind. Mat canopies supported on light framework may be used for shading concrete.

Period of Curing

Specifications generally require that concrete must be kept moist for a period of at least 7 days and preferably 14 days, when ordinary Portland cement is used. Rapidly hardening cements require less time (about half), and slowly hardening cements require more time, than ordinary Portland cement. When low-heat cement is used, the curing period must extend to 21 or 28 days.

Moist Curing

Moist curing is by far the easiest and most efficient method and is extensively used. It consists in the application of water direct to the concrete or by means of continuously saturated coverings of earth, sand, straw, hessian, etc. Even when other methods are to be used, moist curing by means of spraying is usually specified for the first one or two days. Water should be applied on unformed surfaces as soon as it can be done without marring the surface, and on formed surfaces immediately after the forms are stripped. Wooden forms, kept wet, and metal forms provide satisfactory protection against loss of moisture. Hence they should be left on as long as practicable. The exposed top surfaces should, however, be kept wet.

Spraying

If properly applied, spraying is a satisfactory method of curing formed or unformed surfaces and is also extensively employed in the curing yards of precast concrete factories, where mechanical sprinklers are usually installed. Spraying within the first few hours after concreting may wash some of the cement; hence hessian should be used on unformed surfaces for several hours at least. Hand spraying may not in certain cases be quite satisfactory, because the surface is likely to get dry.

Ponding

This is a good method to use for flat horizontal surfaces such as floor slabs and pavements. Little earth dams are built over the surface to form squares which are flooded with water to a depth of 2 inches or so.

Wet Coverings

These consist of clean sand, straw, matting hessian, gunny bags, canvas, etc., which must be kept saturated with water. Wet hessian is particularly invaluable in that it can, unlike other wet-curing agents, be applied immediately after the finishing of the concrete without causing any damage to the surface. It is also very useful for curing vertical surface. In case wet earth or sand is used, it should be free from large lumps or stones, because they get dry more quickly.

Repair of Surface Imperfections

Surface defects which require repair when forms are removed usually are bulges caused by the movement of forms, ridges at form joints, honeycombed areas, damage resulting from the stripping of forms, and bolt holes. Bulges and ridges are removed by careful chipping or tooling and the surface is then rubbed with a grinding stone. Honeycombed and other defective areas must be chipped out to solid concrete, the edges being cut as straight as possible and perpendicularly to the surface, or preferably slightly undercut to provide a key at the edge of the patch. Shallow patches are filled with mortar similar to that used in the concrete. The surface of the patch is first given a coat of thin grout composed of an equal quantity of cement and sand. The mortar is placed in layers not more than half an inch thick, and each layer is given a scratch finish to secure bond with the succeeding layer. The last layer is finished to match the surrounding concrete by fleeting, rubbing or tooling or, on formed surfaces, by pressing the form material against the patch while the mortar is still plastic. Large and deep patches require filling up with concrete held in place by forms. Such patches are carefully levelled to the hardened concrete. Holes left by bolts are filled with mortar carefully packed into place in small quantities. The mortar is mixed as dry as possible, with just enough water so that it can be tightly compacted when forced into place. Tiered holes extending right through the concrete may be filled with mortar with a pressure gun similar to the gun used for pressing motor cars. Normally patches appear darker than the surrounding concrete, possibly owing to the presence on their surface of less cement laitance. Where uniform colour of the surface is important, this effect may be remedied by adding 10 to 20 per cent of white Portland cement to the patching mortar. The exact quantity may be determined by trial.

Patches must be cured with the same care as the whole structure. To prevent early drying curing must be started as soon as possible after the patch is finished. Damp hessian may be used, but in some locations it may be difficult to hold it in place. In such a case a membrane curing compound is most convenient.

Concreting in Saline Soils or Water

In saline areas the usual nominal mixes do not hold good. Their richness should be increased with the increase in salinity. Different proportions of the material have been prescribed for severe and moderate conditions. An area is considered severely saline if an existing concrete structure has deteriorated rapidly during a period of say 5 years or if the concentration of soluble sulphate in the soil is 0.3%. It would be termed as moderately saline if the concentration of soluble sulphate is less than this percentage and an existing structure has not been deteriorated during 5 years. For severe saline conditions the mix should not be leaner than 1:1:2, and for moderate conditions it should not be leaner than 1:1½:3.

Concrete under Water

Under normal circumstances the space to be filled with concrete must be dewatered and concrete placed against formwork. If, however, owing to some unavoidable circumstances the concrete has to be placed in water the following precautions must be observed:—

1. A nominal mix of 1:1½:3 should be used.

2. Concrete should have a slump of 6"—8" when being placed by tremies and 3"—6" when being dumped by bottom dump buckets or in sacks.

3. Cassions, cofferdams or forms used should be sufficiently watertight to prevent loss of mortar or flow of water through the space in which concrete is being deposited.

4. Pumping should not be done during placing of concrete and 24 hours afterwards.

5. Before actual dumping starts the surface under water should be carefully examined in order to know that the bottom surface is perfectly level.

6. Concrete should be deposited continuously till it has attained the desired level. During placing, the top surface should be kept as nearly level as practicable.

7. The formation of laitance planes should be avoided and if these planes are formed they should be immediately removed.

8. Concrete shall be placed by tremies, bottom dump buckets or in sacks depending upon the nature of work.

Concreting in Cold Frosty Weather

All concrete work should normally be discontinued when the temperature goes below 40° F. If, however, it is absolutely impossible to suspend the work, the following precautions must be observed:—

1. Water and aggregate should be heated before mixing, but the temperature of aggregate and water should not exceed 90° F.

2. The tem peratureof concrete should not be allowed to go below 40° F during its placing or till the time it has thoroughly cured and hardened.

Construction Joints

Whenever possible these joints should be avoided. When they have to be provided the following precautions must be observed:—

1. These joints are not made abruptly, but against a formwork previously prepared for the purpose. Before resuming concrete the joint surface is thoroughly cleaned and loose material removed. The surface is then treated with a thin layer of cement grout worked well into the surface, or of cement sand mortar mixed in the same proportion as the original concrete.

2. Care should be taken to obtain a thorough compaction and avoid segregation along the plane. In horizontal joints instead of treating surface with grout or mortar the workability of first batch of concrete placed in contact with the joint should be slightly increased.

3. Where the construction joints are required to be watertight a continuous key way should be constructed in the face of the first section of the concrete placed and continuous sheet of non-corrosion metal not less than 9" wide placed so as to extend the full length of the joint and be embedded equally in the concrete on each side of the joint. In columns these joints shall be located anywhere at the under side of the floor members and at the top of floor. Haunches and column cables should be considered part of and continuous with floor or roof. In beams and slabs these joints should not be located at the centre or within the middle third of the span. Horizontal joints at the top of the plinth or top or bottom of window openings should be avoided.

NO. 20.1 CEMENT CONCRETE (GENERAL)

Specifications

Scope

1. Unless otherwise specified, concrete shall be prepared, transported, placed, finished, cured and protected as specified hereunder.

Composition

2. Unless otherwise specified, cement concrete shall be composed of Portland cement, sand, coarse aggregate and water as specified herein, well mixed and having proper consistency.

Portland Cement

3. Portland cement shall conform to Specifications No. 3.3 and shall be handled, stored and used by the contractor as specified therein. Cement stored for more than three months or through a monsoon, shall be used only after it has been approved by the Engineer-in-charge.

Special Cements

4. Wherever the use of special cements has been specified, it shall be used strictly in accordance with the specifications of the manufacturer or as directed by the Engineer-in-charge. The high aluminia cement and super-sulphated cement shall not be mixed together or with any other cement, and all mixers, plant and tools shall be

thoroughly cleaned before and after using the cement to avoid interaction with other types.

Water

5. Water shall conform to Specifications No. 2.1.

Additive

6. No additive shall be added to cement concrete unless authorized by the Engineer-in-charge. When so authorized instructions of the manufacturer and the Engineer-in-charge must be strictly complied with.

Air Entraining Agent

7. When specified a duly approved air entraining agent shall be added to the mixing water in a specified quantity to yield the desired quality of concrete.

Aggregate

8. All aggregates (coarse and fine) shall conform to Specifications No. 6.1 A and 6.1 B respectively.

Size of Aggregate and its Grading

9. (i) The maximum size of aggregate in concrete for any part of the work shall be the largest of the specified sizes, the use of which is practicable for placing concrete.

(ii) Unless otherwise specified or directed by the Engineer-in-charge, the nominal maximum size of aggregate for reinforced concrete shall be ¾" for mass concrete work and 1½" for foundations.

(iii) If approved by the Engineer-in-charge "All in aggregate" shall also be used for mass concrete work.

(iv) The grading of coarse and fine aggregate shall be such that when cement and water are added thereto and mixed in the manner hereafter specified, a perfectly solid compact concrete free from voids is produced without at the same time forming an undue proportion of "mortar" in the mass, of which the Engineer-in-charge shall be the judge.

Modification of Aggregate Grading

10. The Engineer-in-charge shall have the power to modify the specified grading to improve the quality of concrete, and the contractor shall comply with his instructions in this behalf without additional charge.

Proportions of Ingredient

11. The proportions in which the various ingredients are to be used for different parts of the work shall be as determined from time to time during the progress of the work and as tests are made of the aggregates and the resulting concrete. Mix proportions and water-cement ratio shall be so determined as to produce concrete having suitable workability, density, impermeability, durability, and required strength, without the use of an excessive amount of cement. The net water-cement ratio of the concrete (exclusive of water within or absorbed by the aggregates) shall not exceed 0.60 by weight. Tests of the concrete shall be made by the Engineer-in-charge and the mix proportions shall be changed, whenever necessary, for the purpose of securing the required workability, density, impermeability, durability or strength. The contractor shall not be entitled to any compensation because of these changes.

The amount of water used in the concrete shall be so regulated as to secure concrete of a proper consistency and to adjust for any variation in the moisture content, or grading of the aggregates as they enter the mixer. Water shall not be allowed to be added to undo the stiffening of the concrete resulting from excessive over-mixing or objectionable drying before placing. Uniformity in concrete consistency from batch to batch shall be required. Unless otherwise specified or directed by the Engineer-in-charge the slump of concrete after it has been deposited, but before it has consolidated, shall have the following values under different situations:—

Purpose	Slump (inches)
1. Very high strength concrete for prestressed concrete sections compacted by heavy vibration.	0
2. High strength reinforced and prestressed concrete sections, pavings and mass concrete compacted by vibration.	0—1
3. Normally reinforced concrete sections compacted by vibration, hand compacted mass concrete.	1—2
4. Heavily reinforced concrete sections compacted by vibration, hand compacted concrete in normally reinforced slabs, beams, columns and walls.	2—4
5. Heavily reinforced concrete sections compacted without vibration and work where compaction is particularly difficult.	4—6

Minimum Cube Strength Requirement

12. Unless otherwise specified concrete mixes shall conform to the strength requirements given in the following table:—

Nominal Mix	Minimum cube strength required (in lbs/sq. in.)				General use
	Laboratory tests		Work tests		
	at 7 days	at 28 days	at 7 days	at 28 days	
1:1:2	4000	6000	3000	4500	In paving.
1:1½:3	3350	5000	2500	3750	For reinforced concrete other than in paving.
1:2:4	2700	4000	2000	3000	
1:3:6	—	2500	—	2000	For mass concrete.

Mixing

13. The mode of mixing (i.e. hand mixing or machine mixing) shall be determined by the Engineer-in-charge keeping in view the size of work.

Hand Mixing

13.1 Unless otherwise specified or directed, hand mixing shall be done on the following lines:

(a) Wooden batch boxes of one to three cubic feet capacity shall be used. Convenient sizes of these boxes are given below:—

Capacity (in cubic feet)	INSIDE MEASURE		
	Length (in inches)	Breadth (in inches)	Height (in inches.)
1	12	12	12
1¼	15	15	9⅗
1½	15	15	11½
1¾	15	15	13½
2	18	18	10⅔
2¼	18	18	12
2½	18	18	13⅓
2¾	18	18	14⅔
3	18	18	16

(b) Hand mixing shall only be done on a smooth watertight platform large enough to allow efficient turning over of the various ingredients both before and after the addition of water. The platform shall be wooden and rectangular in shape having close fitting joints between the boards or long sheet iron troughs. The platform shall in no case be utilized for storing material other than that required for immediate mixing.

(c) Size of each batch shall be regulated by the proportions of the ingredients. A batch mixed at a time shall not contain more than one bag of cement. The approximate yield of concrete per bag of cement and volume of loose materials for various nominal mixes is given in the following table:—

Nominal mix by volume	Volume of fine and coarse aggregate per bag of cement (in cft)	Yield per bag of cement (in cft)	Volume of loose materials for 1-bag batch (in cft)	Minimum size of mixer for 1-bag batch (in cft)
1:1:2	1¼:2½	3½	5	3½
1:1½:3	1⅞:3¾	4½	6⅞	5
1:2:4	2½:5	5¾	8¼	7

In case concreting has to be done at a faster speed different gangs of labourers shall prepare different batches at the same time.

(d) The measured quantity of cement shall be placed on top of the measured quantity of fine aggregate and then both of these shall be mixed dry three times or more till they attain a uniform colour. The measured quantity of coarse aggregate shall then be added and mixed with it. The required quantity of water, which shall be measured or weighed for each batch, shall then be added with a rose. The mixture shall be turned over and the process continued at least three times or till the entire mass has become wet and a homogeneous mixture of the required consistency has been obtained.

(e) The re-tempering of concrete or mortar which has partially set (that is remixing with or without additional cement, aggregate or water) is absolutely prohibited. Under no circumstances shall concrete which has partially hardened be deposited in the work.

Machine Mixing

13.2. Unless otherwise specified or directed by the Engineer-in-charge, the contractor shall provide such means and equipment as are required to accurately determine and control the amount of each separate ingredient forming the concrete. The selection and operation of such means and equipment shall at all times be subject to the approval of the Engineer-in-charge. The amounts of bulk cement, sand and each size of aggregate going into each batch of concrete shall be determined by weighing or by volumetric measurement. Where sacked cement is used, the concrete shall be proportioned on the basis of integral sacks.

All the ingredients of concrete, except the full quantity of water, shall be mixed in a batch mixer for not less than 1½ minutes. The mixing time will be increased where the batch mixer has a capacity of more than two cubic yards. The

Engineer-in-charge reserves the right to increase this time when the charging and mixing operations fail to produce a concrete batch of evenly distributed ingredients and the consistency is not uniform. The concrete shall be uniform in composition and consistency from batch to batch except when changes in composition or consistency are required. Water shall be added prior to, during, and following the mixer-charger operations. Excessive over-mixing requiring the addition of water to preserve the required concrete consistency will not be permitted.

Truck mixers will be permitted only when they produce concrete of uniform consistency and grading throughout the mixed batch and from batch to batch. Any concrete retained in truck mixers for so long a time that it cannot be satisfactorily placed without additional water shall be wasted at the expense of the contractor. Any mixer that at any time produces unsatisfactory results shall be repaired promptly and effectively or shall be replaced. Mixer in centralized batching and mixing plants shall be so arranged that mixing action can be observed from the station of the mixing plant operator. Mixers shall not be loaded in excess of their rated capacity, unless specifically authorized. Each mixer shall preferably be equipped with a mechanically operated timing and signalling device which will indicate the completion of the required mixing period and will count the batches.

Temperature

14. The temperature of concrete when it is being placed shall not be more than 90 degrees Fahrenheit and less than 40 degrees Fahrenheit. When the temperature is between 80 and 90 degrees Fahrenheit, the concrete shall be mixed at the job site and discharged into the work immediately after mixing. If it goes beyond 90 degrees Fahrenheit (which is to be determined by the Engineer-in-charge), the contractor shall employ effective means, such as pre-cooling of aggregates and mixing water and placing at night, to ensure that as concrete is being placed its temperature remains below 90 degrees Fahrenheit.

Form Design

15. Forms shall conform to the various shaped lines, grades and dimensions of the concrete as shown on the drawings or as established by the Engineer-in-charge. Their material and design shall be subject to the approval by the Engineer-in-charge before their construction is started. However, such approval shall not relieve the contractor of the responsibility for the adequacy of the forms nor from the necessity for remedying any defects which may develop or become apparent with use. The Engineer-in-charge may at any time condemn any sections of forms found deficient in any respect, and the contractor shall promptly remove the condemned forms from the work and replace them at his own expense.

Form Construction

16. (i) Forms to confine the concrete and shape it to the required lines shall be used wherever necessary. They shall be made of metal, of metal lined timber, or of smooth planed boards in good condition.

(ii) A smooth finished surface of the concrete shall be required. The forms shall be true in every respect to the required shape and size, and shall be of sufficient strength and rigidity to maintain their position and shape under loads and operations incident to placing and vibrating the concrete.

(iii) All forms when erected shall be tight. Adequate and suitable means for removing the forms without injury to the surface of the finished concrete shall be provided.

(iv) Chamfer strips shall be placed in the form so as to produce levelled edges on permanently exposed concrete surfaces if indicated on the drawings or instructed by the Engineer-in-charge.

(v) All forms shall be properly secured in position so as to prevent floating, or other movements, during the placing of concrete. Form supports shall be carried to firm foundation so that no settlement of the forms is possible during construction.

(vi) Unless otherwise specified sliding forms shall be used for enclosing vertical structures which maintain a constant section to give a lift of concrete from 2 to 4 feet. In very tall structures they shall be made to move continuously during concreting operations.

Treatment of Formwork Surface

17. Unless otherwise specified the faces of the formwork which come into contact with the concrete shall be treated with parting agents, such as, mineral oils, vegetable oils and soaps, before reinforcement is placed, in order to prevent concrete from adhering to formwork and to reduce the risk of damage when the formwork is struck.

Preparation for Concrete Placing

18. No concrete shall be placed till all formwork, reinforcement, installation of parts to be embedded, bracing of forms, and preparation of surfaces involved in the placing have been approved by the Engineer-in-charge. No concrete shall be placed in water, except with the written permission of the Engineer-in-charge, and the method of depositing concrete shall be subject to his approval. Concrete shall not be placed in running water and shall not be subjected to the action of running water until after the concrete has been cured for 28 days. All surfaces of forms and embedded materials that have become encrusted with dried mortar or grout from concrete previously placed shall be cleaned of all such mortar or grout before the surrounding or adjacent concrete is placed.

Immediately before placing concrete, all surfaces upon or against which it is to be placed shall be free from standing water, mud, debris or loose material. The surfaces of absorptive materials against or upon which concrete is to be placed shall be moistened thoroughly so that moisture is not drawn from the freshly placed concrete.

Where surfaces to be covered by fresh concrete are absorptive and where it will facilitate the placing and vibrating of conrete in paving and base slabs (which is to be determined by the Engineer-in-charge), the conctractor shall place a "blinding course" consisting of a 2-inch layer of concrete. The "blinding course" shall be spread uniformly over the foundation to be protected and allowed to set for 24 hours before fresh concrete is placed.

Concrete surfaces upon or against which concrete is to be placed and to which new concrete is to adhere, and have become so rigid that the new concrete cannot be incorporated integrally with them are defined below as "construction joints". The surfaces of construction joints shall be clean and damp when covered with fresh concrete or mortar. These surfaces shall be cleaned by wet sand-blasting or other approved methods and then washed thoroughly with high pressure air water jets or other approved means immediately before fresh concrete is placed. Cleaning shall consist of the removal of all laitance, loose or defective concrete, coatings or foreign material. All pools of water shall be removed from the surfaces of construction joints before new concrete is placed.

The surfaces of all contraction joints or expansion joints as shown on the drawings shall be thoroughly cleaned of accretions of concrete or other foreign material by scraping, chipping or by other means satisfactory to the Engineer-in-charge.

Placing of Concrete

19. (i) The methods and equipment used for transporting concrete must ensure that concrete having the required composition and consistency are delivered to the work without objectionable segregation or loss of slump.

(ii) Concrete shall be placed only in presence of the Engineer-in-charge.

(iii) Any concrete which has become so stiff that proper placing cannot be assured shall be wasted and no payment shall be made to the contractor for such wasted concrete, including contained cement. Concrete shall be deposited direct in all cases as near as practicable to its final position and shall not flow in a manner to permit or cause segregation.

(iv) Concrete shall not be placed during rains unless proper protection is afforded.

(v) Concrete buckets, where used, shall be capable of promptly discharging the low-slump concrete mixes specified and the dumping mechanism shall be designed to permit the discharge of as little as four cubic feet portion of the load in one place.

(vi) Each layer of concrete shall be consolidated to the maximum practicable density so that it is free from pockets of aggregates, and closes snugly against all surfaces of forms and embedded materials.

(vii) In consolidating each layer of concrete the vibrating head of the vibrator shall be secured to form or allowed to penetrate and revibrate the concrete in the upper portion of the underlying layer. All concrete shall be consolidated with electric or pneumatic power-driven vibrators having a frequency of not less than 5000 cycles per minute. Additional layers of concrete shall be placed after the layers previously placed have been worked thoroughly so that no air bubble comes to the surface. The operation shall be carried out by a person trained in the job.

(viii) Special care shall be taken in placing concrete when it has to be dropped from a height, especially when reinforcement is in the way, and every effort shall be made to reduce this drop to the minimum. In any case the drop shall not be more than 5 feet.

(ix) *SLOPING BEDS NOT ALLOWED*—Unless otherwise specified, no peripheral slopes shall be allowed in the bed when it becomes necessary for any reason to terminate placing operations. Such termination shall be against forms stepped as directed by the Engineer-in-charge.

(x) Ducts, recesses, rebates and holes shall be moulded in the concrete during placing at their proper position as shown on the drawing or as directed by the Engineer-in-in-charge.

Placing of Concrete under Water

20. When the space to be filled with concrete contains water which cannot be removed in some practical way or when so specified or directed by the Engineer-in-charge the concrete shall be deposited under water according to the following stipulations.

(i) Unless otherwise specified a nominal mix of 1:1$\frac{1}{2}$:3 shall be used for all concreting under water. Cement and aggregate shall be mixed for a period of 2 minutes with sufficient water to produce concrete having a slump not less than 6 inches and not more than 8 inches for concrete placed by tremies, and not less than 3 inches and not more than 6 inches for concrete placed by bottom dump buckets or concrete placed in sacks.

(ii) Caissons, coffer dams or forms shall be sufficiently tight to prevent loss of mortar or flow of water through the space in which the concrete is to be deposited.

(iii) Pumping shall not be done during the course of placing concrete and 24 hours afterwards.

(iv) The surface shall be examined by a competent diver and the results reported to the Engineer-in-charge who shall grant permission to start placing concrete only after he is satisfied that the bottom surface is level. The services of the diver shall be arranged by the contractor at his own expense.

(v) Concrete shall be deposited continuously till it has attained the desired level. During placing the top surface shall be kept as nearly level as possible by taking sounding and avoiding the formation of laitance planes or removing it, if formed.

(vi) Unless otherwise specified or directed by the Engineer-in-charge anyone of the following methods of placing shall be employed after getting approval from the Engineer-in-charge.

(a) *TREMIE*—The top section of the tremie shall be a hopper large enough to hold one complete batch of the mix or the entire contents of the transporting bucket when it is used. The tremie pipe shall not be less than 8 inches in diameter and shall be large enough to allow a free flow of concrete and strong enough to withstand the external pressure of water in which it is suspended, even if a partial vacuum develops inside the pipe. Unless otherwise specified, flanged steel pipe of adequate strength to sustain the greatest length and weight shall be used. A separate lifting device shall be provided for each tremie pipe with its hopper at the upper end. Unless the lower end of the pipe is equipped with an approved automatic check valve, the upper end shall be plugged with a wadding of gunny sacking or other approved material, before delivering the concrete to the tremie pipe through the hopper. The hopper shall be forced to and out of the bottom end of the pipe by filling the pipe with concrete. The tremie shall be raised slowly to cause a uniform flow of the concrete, but it shall not be emptied so that water enters above the concrete in the pipe. From the time the placing of concrete starts till it finishes, the lower end of the tremie pipe shall be below the top surface of the plastic concrete. This shall cause the concrete to build up from below instead of flowing out over the surface, to avoid formation of laitance layers. If the charge in the tremie is lost while depositing, the tremie shall be raised above the concrete surface, and if not sealed by a check valve it shall be replugged at the top end, as at the beginning, before refilling for depositing concrete.

(b) *BOTTOM DUMP BUCKET*—The bottom dump bucket shall be of the type that cannot be opened till it has rested, with its load, on the surface upon which concrete is to be deposited. The bottom doors shall be so equipped as to be automatically unlatched by the release of tension on the supporting line or cable of the bucket and shall open downward and outward as the bucket is raised. The top of the bucket shall be fitted with double, overlapping canvas flaps, or other approved covers, to cover the contained concrete and to protect it from being washed as the bucket enters the water and descends to the bottom. The bucket shall preferably be so designed that the hinged bottom doors shall operate inside a steel skirt, which shall surround the bucket while the bottom doors are shut and shall extend below the bucket as the bottom doors open, and thus minimize turbulence and motion while the concrete is being deposited. The bucket shall be submerged slowly till it is completely under water. The normal dive speed after that shall not exceed 200 feet per minute. After the bucket has reached the surface on which concrete is to be deposited, it shall be raised slowly for the first six to eight feet to allow concrete to be deposited properly.

(c) *SACKS OF CONCRETE*—When only a little quantity of concrete is to be deposited under water, it shall be placed in sacks, unless otherwise specified. The space to be concreted shall be filled with sacks of concrete carefully placed in header and stretcher formation, so that they become interlocked. Sacks used for this purpose shall be made of jute or other coarse material, free from deleterious materials and duly approved by the Engineer-in-charge. They shall be filled about two-thirds with concrete and their openings securely tied.

(vii) In cases where it is possible to place under water concrete of a limited thickness in the bottom of caisson or cofferdam and completely seal the structure, water shall be pumped out and concrete deposited in air after cleaning the exposed surface.

Placing Concrete under Sea Water

21. Unless otherwise specified, concreting under sea water shall be governed by the following stipulations:—

(i) The nominal mix employed shall under no condition be leaner than 1:1:2.

(ii) An air-entrant agent or admixture duly approved by the Engineer-in-charge shall be added to give three to six per cent entrained air in the concrete.

(iii) Sea water shall not be allowed to come in contact with the concrete till it has hardened for at least 4 days.

(iv) Reinforcement or other corrodible metal shall be placed not less than 3" from any plane or curved surface, and 4" adjacent surfaces at corners.

(v) If specially required the face of concrete shall be protected from severe climatic conditions or severe abrasion by stone of suitable quality, dense verified shale bricks or creosoted timber as shown on the drawing or as directed by the Engineer-in-charge.

Placing Concrete in Saline Soils

22. Unless otherwise specified, concreting in saline soils shall be done keeping in view the following:

(i) The nominal mix used shall be 1:1:2 or richer as actually specified by the Engineer-in-charge depending upon the degree of salinity.

(ii) Reinforcement or other corrodible metal shall not be placed closer than two inches from the surface of the concrete.

Placing Concrete in Cold Frosty Weather

23. Unless otherwise specified, concreting at temperature below 38° F shall be avoided. If it cannot be avoided the following conditions shall be observed:

(i) Water and frozen aggregates shall be heated before mixing.

(ii) Mixing water shall not be heated above 180° F to prevent the occurrence of flash set, and cement shall only be added after the heated aggregate and water have been well mixed. The resulting temperature of aggregate and water shall not exceed 90° F.

(iii) The temperature of the concrete shall not be allowed to go below 40° F during or after its placing till it has been thoroughly cured and hardened. The temperature of the concrete surface shall be determined by thermometers placed against the surface. Provision shall be made in form construction to permit the removal of small sections of form to accommodate thermometers at locations designated by the Engineer-in-charge or his authorized subordinates.

In determining temperatures at angles and corners of a structure, thermometers shall be placed not more than eight inches away from the angles and corners. In the case of horizontal surfaces, thermometers shall rest on the surface under the protection covering normal to the section.

(iv) If allowed by the Engineer-in-charge rapid hardening cement or rapid hardening cement and 12 per cent calcium chloride shall be used for preparing concrete.

(v) Floor slabs and all exposed surfaces shall be covered immediately after their placing with the protective materials like straw blankets as directed by the Engineer-in-charge.

Construction Joints

24. (i) The location of all construction joints shall be subject to the approval of the Engineer-in-charge. The joints shall be constructed in accordance with the provisions of these specifications.

(ii) Construction and expansion joints shall be built as shown on the drawing. These joints shall be made by forming concrete on one side and allowing it to set. Before resuming concreting, the joint surface shall be thoroughly cleaned and loose material removed. Then without rewetting the surface, a thin layer of cement grout shall be worked well into it or cement sand mortar mixed in the same proportions as the original concrete shall be placed. Special care shall be taken to obtain thorough compaction and avoid segregation along the joint plane. In horizontal joints, instead of treating surface with grout or mortar, the workability of first batch of the concrete placed in contact with the joint shall be slightly increased.

(iii) Unless otherwise specified joints in columns shall be made at the underside of the floor members and at floor level. Haunches and column caps shall be considered as part of and continuous with floor or roof. Concrete shall be deposited in floor system at least two hours after it has been deposited in columns or walls. Joint in beams and slab at the centre or within the middle third of the span and horizontal joints in walls at the top of plinth or top or bottom of window openings shall be avoided.

(iv) Where a construction joint is required in a section of a building more than 100 feet long or where the space between two expansion joints is more than 100 feet, special reinforcement shall be placed at right angle to the joint. Reinforcement shall extend in both directions of the joint and shall have 40 diameters in the case of deformed bars and 50 diameters in the case of plain bars. It shall be placed near the face of of the member opposite to the main tensile reinforcement and shall not be less than 0.5 per cent of the section of the members cut by the joint. Any additional reinforcement required as a result of such additional construction joints shall be provided by the contractor at his own expense.

(v) Where the construction joints are required to be watertight, a continuous key-way shall be constructed in the face of the first section of concrete placed, and continuous sheet of non-corrosive metal or any other approved material not less than 9 inches wide shall be placed so as to extend the full length of the joint and embedded equally in the concrete on each side thereof.

Expansion Joints

25. Expansion joints shall be located as shown on the drawing or as specified.

Elastic Joint Filler

26. Elastic joint filler of an approved type shall be placed in joints of concrete structure where shown on the drawings. Unless otherwise specified, the elastic filler shall be performed, non-extruding, resilient, self-expanding type, formed from clean, granulated particles securely bound together by a synthetic resin of an insoluble nature. It shall be furnished, wrapped in moisture proof covering.

The elastic joint filler and the concrete against which it is to be placed shall not be coated or painted. The filler shall be placed against the previously placed concrete before more concrete is placed. The edges of the filler shall be placed at a prescribed distance back from the finished surface of the concrete. In no case shall the elastic joint filler be unwrapped and placed in the joint more than four hours before placing the final section of concrete. Care shall be taken in storing and handling the filler so that the wrapping is not disturbed or broken, which may permit hydration.

Water Stops

27. If specified, non-corrosive metal, rubber or polyvinyl chloride water stops shall be placed in joints of structures as shown on the drawings. The contractor shall fabricate all special intersections, splices and joints, and make bends at corners as shown on the drawings. All joints, splices, bends and intersections shall be made in strict accordance with the printed instructions of the manufacturer. These water stops shall be stored strictly in accordance with these instructions.

Removal of Forms

28. (i) The time and method of removal of forms shall be as directed by the Engineer-in-charge. Removal shall be done with care to avoid injury to the concrete. No loading on green concrete shall be permitted. As soon as the forms are removed, the surface of the concrete shall be carefully examined, and any irregularities immediately repaired to the satisfaction of the Engineer-in-charge.

(ii) Unless otherwise specified, during a moderate weather (about 60° F) the form work for various types of work shall be removed after the period shown in the following table:—

Type of Formwork	Ordinary Portland cement	Rapid hardening Portland cement
(a) Formwork to vertical surfaces such as beam, side wall and column.	12 hours	—
(b) Slab (Props left under).	3 days	2 days
(c) Beams soffits (Props left under).	7 days	4 days
(d) Props to slabs.	7 days	4 days
(e) Props to beams.	16 days	8 days

If the temperature falls down to 45° F, the above timings shall be multiplied by $1\frac{1}{2}$ and if it falls down still further i.e. up to 40° F, the time shall be doubled.

Curing

29. (i) Unless otherwise specified or directed by the Engineer-in-charge, all concrete shall be cured by water curing as hereinafter specified.

(ii) Horizontal concrete surfaces cured with water shall be kept wet for at least 14 consecutive days immediately following placement. They shall be covered with water-saturated material like gunny bags, canvas, clean sand, matting, etc., or by any other improved method duly approved by the Engineer-in-charge which will keep these surfaces continuously (not periodically) wet. Water used for curing shall be according to Specification. No. 2.1 for water.

(iii) Unless otherwise specified, the curing of vertical surfaces shall be done initially by leaving the forms in place, hanging canvas or hessian cloth over the completed work and keeping it wet or by covering plastic sheet or membrane.

(iv) Membrane curing shall be adopted as a substitute for wet curing only when so specified or permitted by the Engineer-in-charge. The compound of approved quality shall be sprayed on finished surface as soon as the surface water has disappeared. Unless otherwise specified, spraying equipment shall be of the pressure tank type with a provision for continual agitation of the contents during application. If forms are removed during the curing period concrete shall be sprayed lightly with water and the moistening continued till the surface does not absorb water. The compound shall then be sprayed or brushed over. Care shall be taken that the film of this coating is not punctured during the curing period.

Finish and Finishing

30. Finishing of concrete surfaces shall be performed only by skilled workmen and in the presence of the Engineer-in-charge. Concrete surfaces shall be tested, where necessary, by the Engineer-in-charge to determine whether surface irregularities are within the limits hereinafter specified. Surface irregularities shall be classified as "abrupt" or "gradual". Offsets caused by displaced or misplaced form seating or lining, or form sections, or by loose knots in forms, or otherwise defective form lumber, shall be considered "abrupt" irregularities and shall be tested by direct measurement. All other irregularities shall be considered "gradual", and shall be tested by using a template, consisting of a straight-edge or its equivalent for curved surfaces. The length of the template shall be 5 feet for testing formed surfaces and 10 feet for testing unformed surfaces.

Unless otherwise specified, the contractor shall clean all exposed surfaces of unsightly encrustations and stains before the work is accepted.

Unless otherwise specified, the classes of finish for formed surfaces shall be as follows:—

(a) Formed surfaces upon or against which backfill or concrete is to be placed shall not be treated after the forms are removed, except in case of the removal and repair of defective concrete and the specified curing. Correction of surface irregularities shall be required only for depressions exceeding one inch. The depressions shall be measured as described in the preceding sub-clause.

(b) Submerged and below ground formed surfaces which are not exposed to the action of flowing water and are not prominently exposed to public view shall need no sack rubbing and no grinding other than that needed for repair of surface imperfections. Surface irregularities, measured as described in the preceding sub-clause, shall be classed as "abrupt", if they do not exceed 1/4 inch, and "gradual", if they do not exceed 1/2 inch.

(c) In the case of above ground formed surfaces of structures which are prominently exposed to public view, such as buildings, bridge decks, piers, abutments, caps, walls, headwalls, curbs and other structures there shall be no visible offsets, bulges or misalignment of concrete. Surface irregularities measured for abrupt irregularities shall not exceed 1/8 inch and for gradual irregularities 1/4 inch.

(d) The surfaces of all waterway passages, including the interior surfaces of culverts, conduits, aqueducts, drainage inlets, silt ejectors, regulators, and all other formed surfaces subject to the action of flowing water, shall not have surface irregularities exceeding 1/8 inch for abrupt irregularities and 1/4 inch for gradual irregularities.

Interior unformed surfaces shall have a slope for drainage where shown on the drawings or as directed by the Engineer-in-charge. Surfaces which will be exposed to the weather and which should normally be level, shall have a slope for drainage. Unless the use of other slopes on level surfaces is indicated on the drawings or directed by the Engineer-in-charge, narrow surfaces, such as tops of walls and curbs shall have a slope of approximately 1/4 inch per foot of width. Broader surfaces, such as platforms and decks, shall have a slope of approximately 1/8 inch per foot. Unless otherwise specified, classes of finish for unformed surfaces shall be as follows:—

(a) Unformed surfaces that will be covered by backfill or concrete shall be finished by sufficient levelling and screeding to produce an even uniform surface. Surface irregularities, measured as described in the preceding sub-clause, shall not exceed 3/8 inch.

(b) A hard steel trowel finish shall be applied to unformed surfaces that shall be exposed to view or that shall be subject to the action of flowing water. Floating and trowelling may be performed by using hand or power-driven equipment. Floating and trowelling shall be started as soon as the screeded surface has stiffened sufficiently, and shall be the minimum necessary to produce a surface free from screed marks and uniform in texture. Surface irregularities, measured as described in the preceding sub-clause, shall not exceed 1/4 inch for gradual irregularities and no trowel marks or abrupt irregularities shall be permitted. Joints and edges shall be tooled.

Screeds

31. Slabs or other members not required to be shuttered shall be screeded with a steelshod screed to give a smooth, dense finish. Care shall be taken to ensure that the concrete is properly "closed".

Repairing Concrete Surface

32. If on the stripping of forms, concrete is found to be not formed as shown on the drawings, or is out of alignment or level, or shows a defective surface, it shall be considered not conforming to the intent of these specifications and shall be removed and replaced by the contractor at his expense unless the Engineer-in-charge grants permission to repair the defective area, in which case patching shall be performed as described in the following sub-clauses.

Defects that require replacement or repair are honeycomb surfaces resulting from the stripping of forms, loose pieces of concrete, bolt holes, tie rod holes, ridges at form joints and bulges caused by the movement of the forms. Ridges and bulges shall be removed by chipping or tooling followed by rubbing with a grinding stone. Honeycomb and other defective concrete shall be chipped out, and the chipped openings shall be sharp-edged and shaped so that the filling shall be keyed in place. All holes shall be thoroughly moistened for 24 hours before the filling is placed. The surface of the filling shall be finished flush with the surrounding wall, and shall have the same texture. All patches shall be cured.

When in the opinion of the Engineer-in-charge the extent of imperfections in structures exposed to view are such that patching alone would not produce satisfactory results, the contractor shall have to give a sack rubbed mortar finish in accordance with the instructions of the Engineer-in-charge.

Imperfections, bolt and tie-rod holes, shall be filled with dry patching mortar composed of one part of Portland cement, two parts of regular concrete sand and just enough water so that ingredients are thoroughly mixed and mortar sticks together on being moulded into a ball by slight pressure of the hands which does not extrude free water. Mortar repairs shall be placed in thin layers and thoroughly compacted by suitable tools. Care shall be taken in filling rod, bolt and pipe hole so that the entire depth of the holes is completely filled with compacted mortar. Where concrete is exposed to view, mortar shall be made to match the colour of the concrete by substituting white cement in the required amount for a portion of the regular cement.

Measurement

33. Concrete shall be measured to the neat lines of the structures as shown on the drawings or as modified by the Engineer-in-charge for the appropriate parts of the structures in which such concrete is incorporated. In measuring concrete, the volume of openings, recess ducts, embedded piping and metal work (each of which larger than 36 square inches in cross-section) shall be deducted. Concrete shall be measured by volume. The unit of measurement shall be 100 cubic feet.

Rate

34. The unit rate per 100 cubic feet shall include the cost of cement, sand, aggregate, water, mixing, placing, vibrating, curing, preparing, assembling and removing form, and all other operations, procedures and requirements necessary to finish the concrete in accordance with these specifications.

NO. 20.2 PRECAST CEMENT CONCRETE

Specifications

General

1. Unless otherwise specified, precast units shall be prepared as shown on the approved drawings according to the following specifications:—

Precasting Floor

2. In laying out the workyards the contractor shall provide a precasting floor of 3 to 1 concrete-in-mass at least 6 inches thick to be laid over the entire floor area where precasting is to be done. The surface of the floor shall be finished perfectly true and level with a steel trowelled finish so as to produce even and fair beds for the concrete to be made thereon. Precautions shall be taken to prevent settlement of the floor. Should settlement take place the floor shall be relaid or other means adopted to reinstate the level surface before it is used again. During the time the floor is in use it shall be kept true, level, clean and dry. Drains shall be provided to drain away the

surplus water quickly, and sufficient space shall be provided between the various moulds to allow working room for handling them and clearing debris.

Moulds

3. Unless otherwise specified, the moulds in which the concrete is precast shall consist of mild steel and shall not be less than 3/16 inch thick for small items and 1/4 inch thick for large items, and suitable arrangements shall be made to prevent them from bulging. In all cases suitable precautions shall be taken to maintain the moulds vertical, rectangular and with true faces during the time concrete is being filled in and packed. Core pieces of the required shapes to form chamfers, radii, joggle recesses, cavities, tongues, grooves, and other recesses or chassis shall be provided and firmly attached to the inside faces of the moulds. Wooden moulds may be used for small non-repetitive items.

Design of Moulds and Lifting Apparatus to be Approved

4. The general arrangement of the floor with its mixing machines, methods of supplying materials to the machines and transporting concrete from them and the detail designs of the moulds shall be duly approved by the Engineer-in-charge. Methods of lifting precast concrete shall also be approved by the Engineer-in-charge.

Setting up Moulds

5. The floor shall be thoroughly cleaned and dried and cleared of all cement, scum and debris before setting up the moulds. The inside faces of the moulds shall be thoroughly cleaned and, if necessary, scraped. The moulds shall be set absolutely square and vertical. Their inside faces and the floor shall be coated with a vegetable oil or other parting agent duly approved so that concrete does not stick to them. The moulds shall be maintained in a serviceable condition, all damaged fittings and core pieces shall be replaced when required, and the various parts shall be checked from time to time to see that no distortion or alteration in size has occurred.

Depositing Concrete in Moulds

6. Concrete shall be transported from the mixing machine to the moulds as quickly as possible and shall be deposited and spread in them in layers. Each batch of concrete shall be well worked in and thoroughly packed against the faces of the moulds. On the completion of each block, its top surface shall be well beaten down and struck off true and level by means of a long straight edge and finally floated off with a hand float. When the manufacture of an item has begun the supply of concrete shall be continuous and the item shall be finished off complete in one operation.

All precast concrete shall be kept continuously watered for a period of at least 28 days after casting.

Removal of Moulds

7. When the concrete has set sufficiently the sides and ends of a mould shall be slackened off and eased away from the face of the green concrete to allow the circulation of air but this shall not be done till twenty-four hours have elapsed since concreting was completed, except when items have hollow faces.

Precast Concrete not Square or Honeycombed

8. If the sides or ends of any precast concrete are not true as a result of the bulging of the mould or faulty setting, all such roundings or inequalities shall be dressed off neatly and accurately by masons so as to produce true and even faces when it is set in position. If honeycomb exists in a slight degree only it shall be stopped neatly and carefully with 2 to 1 cement mortar rubbed in with dry sand by means of a hand float fair with the general face of the block. Precast concrete that is irreparably out of square or badly honeycombed shall not be accepted for use in the permanent work.

Broken or Damaged Precast Concrete

9. Broken or damaged precast concrete shall not be allowed to be set anywhere in the permanent work unless approved in writing by the Engineer-in-charge and provided that the concrete shall be good and sound.

Lifting and Dating Precast Concrete

10. No precast concrete shall be lifted off the floor till at least seven days have elapsed after precasting it. Its date of manufacture shall be legibly written on the top directly after it has been floated off and finished.

Stacking Precast Concrete

11. The precast concrete after being cured shall be placed in stacks to mature and air space shall be left around each one of them.

Date of Using

12. No precast concrete shall be set in the permanent work unless four weeks have elapsed since its date of manufacture.,

Other Respects

13. In all other respects precast concrete shall conform to Specifications No. 20.1 for Cement Concrete (General).

NO. 20.3 MOULDED CEMENT CONCRETE

Specifications

General

1. All copings, landing, steps, slabs, ashlar and other similar things specified or shown on the drawings to be moulded concrete shall consist of well-graded aggregate. The proportions of Portland cement shall be as specified. Concrete shall be cast in strongly proportioned moulds fitted with all requisites for the formation of chamfers, radii, V-grooves, recesses, lewis holes, etc., to produce blocks perfect in shape, true to dimensions, having smooth and true faces and clearly defined chamfers, radii and sharp arrises on all exposed edges.

Moulding

2. Concrete shall be deposited slowly in layers, and shall be thoroughly worked in and packed so as to dispel all air and fill the moulds perfectly. The moulds shall not be slackened off or removed till a period of 36 hours has elapsed since the blocks were made. Immediately after the removal of moulds, the back and side joints of the blocks against which concrete-in-mass or mortar will abut shall be thoroughly roughened whilst the concrete is still green. No plastering of any exposed face or surface shall be allowed. All moulded concrete shall be kept continuously watered for a period of at least 28 days after the moulding.

Carborandum Non-Skid Surface

3. If so specified, the top surface of copings of all descriptions and the treads of steps shall be impregnated with carborandum grains dusted through a No. 12 mesh hand-screen upon the concrete in such a manner as to ensure an even distribution. Each superficial square yard of surface so treated shall receive 2¾ lbs of carborandum grains which shall be well worked into the surface of the concrete by a wooden hand float.

Nipper Holes and V-Grooves

4. Nipper holes shall not be allowed in any exposed face whatsoever and if lewis holes are to be provided they shall be filled solid with 1 to 2 grout at the same time as the joints are filled. Lewis holes shall not be allowed in copings, but V-grooves shall be provided which can be used for setting with chain clips.

Other Respects

5. In all other respects moulded concrete shall conform to Specifications No. 20.2 for Precast Concrete.

NO. 20.4 REINFORCED AND PRESTRESSED CEMENT CONCRETE

Specifications

Strength Required

1. Materials for reinforced concrete and prestressed concrete shall be so proportioned as to form a concrete of the strengths not less than specified below:—

Detail	CUBE STRENGTH lb/sq. inch	
	Within 7 days after mixing	Within 28 days after mixing
Prestressed concrete ..	3,750	5,625
Reinforced concrete ..	2,500	3,750
Concrete-in-mass aggregate to cement		
4 to 1 ..	2,100	3,400
5 to 1 ..	2,000	3,300
6 to 1 ..	1,900	3,200
7 to 1 ..	1,800	3,100
Grout (for 4 inches cube) ..	2,500	

Size of Aggregate

2. Unless otherwise specified, the nominal size of graded aggregate shall be:—

(a) Floors, piers, abutments, and such like: 1½ inches to 3/16 inch.

(b) Prestressed beams for bridges: ¾ inch to 3/16 inch.

Reinforcement

3. Unless otherwise specified, reinforcement shall conform to Specifications No. 10.1 to 10.3. Reinforcement shall not be stacked on the ground to save it from mud, rust or other dangerous coatings. Different sizes shall be stacked separately to facilitate identification. The bent bars ready for fixing shall be correctly marked in order that there is no difficulty in selecting the correct bars. The bars to be fixed shall be free from dust, oil, paint, rust or loose scale. All bending of bars shall be done cold by the application of slow, steady pressure or with a suitable machine. No heating of bars shall be allowed except for fishtailing. Welding shall be permitted under suitable conditions and safeguards in accordance with Pakistan Standard Specification for Welding. Where the reinforcement is congested or complicated, spot welding shall be done for the assembling of reinforcement.

Placing Reinforcement

4. The number, size, length, form and position of all bars, links, stirrups, distance pieces and other members of the steel reinforcement shall be in exact accordance with the working drawings. The contractor shall take particular care that the reinforcement is laid out correctly in every respect and temporarily suspended by annealed wire or supported on small tapered concrete blocks in the forms to prevent displacement before or during the placing of concrete. Pieces of steel or wood shall not be used on the bottom boards or against the sides of moulds for this purpose. Stirrups and distance pieces shall be kept tight to the bars they embrace or support. Stirrups shall be kept away from the face of the concrete at the distance shown on the working drawings.

Laps in Bars

5. Laps in bars in any member shall be staggered. The length of lap in bars in tension shall not be less than:

$$\text{the bar diameter} \times \frac{\text{the tensile stress in the bar}}{\text{4 times the permissible average bond stress}}$$

or 30 bar diameters, whichever is greater.

The length of lap in bars in compression shall not be less than:

$$\text{the bar diameter} \times \frac{\text{the compressive stress in the bar}}{\text{5 times the permissible average bond stress}}$$

or 24 bar diameters, whichever is greater.

In case of deformed bars 25 per cent increased bond stress shall be allowed.

Shear Reinforcement

6. All bent up bars acting as shear reinforcements shall be fully anchored in both flanges of the beam. The anchorage length shall be measured from the end of the sloping portion of the bar.

Hooks

7. Hooks shall be of such form, dimensions and arrangement as to ensure their adequacy without over stressing the concrete or other anchorage material. They shall normally be of U-type, unless otherwise specified, and shall be of following dimensions:

(i) the internal radius of the bend should be at least twice the diameter of the bar except where the hook fits over a main reinforcing or other adequate anchor bar, when the radius of the bend may be reduced to that of such bar; and

(ii) the length of straight bar beyond the end of the curve shall be at least four times the diameter of the bar.

Bars in Compression

8. A bar in compression shall extend from any section for a distance that the average bond stress does not exceed the permissible limit by more than 25 per cent. This condition shall be satisfied if the length measured from such section is not less than:

$$\text{the bar diameter} \times \frac{\text{the compressive stress in the bar}}{\text{5 times permissible average bond stress}}$$

The bar shall extend at least 12 bar diameters beyond the point at which it is no longer required to resist stress.

Distance between Two Bars

9. The horizontal distance between two parallel steel bars shall not be less than the three following distances, unless otherwise specified:—

(i) The diameter of either bar, if their diameters are equal.

(ii) The diameter of the larger bar, if the diameters are unequal.

(iii) $\frac{1}{4}$ inch more than the nominal maximum size of the coarse aggregate used in the concrete.

A greater distance shall be provided when convenient.

A vertical distance between the two horizontal main steel reinforcement or corresponding distance at right angle to two inclined main steel reinforcement shall not be less than $\frac{1}{2}$ inch or the nominal maximum size of the aggregate, whichever is greater, except where one of these reinforcements is transversed to the other.

Binding Wire for Reinforcement

10. Binding wire for steel reinforcement shall be soft annealed wire of No. 16 gauge and lashings. It shall be considered enough to secure the bars in position.

Inspection of Reinforcement

11. After reinforcement has been placed and fixed in the correct position, no concreting shall be done unless the Engineer-in-charge has inspected and approved it.

Cover over Reinforcement

12. Unless otherwise specified the following minimum thickness of concrete cover, exclusive of plaster or other decorating finish, shall be provided in all cases:—

a) for each end of reinforcing bar, not less than 1 inch or twice the diameter of such bar.

b) for a longitudinal reinforcing bar in a column, not less than 1½ inches or the diameter of such bar. In the case of columns with a minimum dimension of 7½ inches or less where bars do not exceed ½ inch diameter, one inch cover shall be used.

c) for longitudinal reinforcing bar in a beam not less than one inch or the diameter of such bar.

d) for tensile, compressive, shear or other reinforcement in a slab not less than ½-inch or the diameter of such reinforcement.

e) for any other reinforcement not less than ½-inch or the diameter of such reinforcement.

f) in case of works in saline or corrosive conditions a minimum of 1½ inches cover over bars, stirrups or links.

Depositing Concrete in Forms

13. Concrete shall be deposited in the forms in layers or as best suited to the work in hand. Concrete shall be well packed and rammed between and around reinforcement. Flat wooden tools, rammers and spatulas and subsequently vibrators shall be employed to ensure compact concrete and smooth surfaces to the face work. Great care shall be exercised to prevent the displacement or bending of any portion of reinforcement.

Removal of Forms

14. In all cases the contractor shall satisfy himself that reinforced and prestressed concrete has thoroughly set before removing formwork and shuttering or supports and shall obtain the permission of the Engineer-in-charge before removing formwork, shuttering and supports. The following minimum times shall elapse after depositing reinforced concrete in forms before the later may be removed.

	Cold Weather	Hot Weather
Sides to piers, abutments, beams, etc. ..	3 days	2 days
Props to slabs and beams ..	10 days	7 days
Props to beams and slabs in composite action ..	14 days	10 days

Shuttering of the hollow sides of the prestressed concrete bridge beams shall, however, be removed before concrete starts shrinking.

Curing Reinforced and Prestressed Concrete

15. Reinforced and prestressed concrete shall be watered and kept wet for 28 days. If reinforced precast articles are stacked previous to use in the work, they shall

be stacked on battens or otherwise kept apart to allow free circulation of air around each member. No load of any kind shall be imposed on any reinforced concrete members after the removal of the supports until concrete is well cured.

16. In all other respects it shall conform to Specifications No. 20.1 for Cement Concrete (General.) **Other Respects**

NO. 20.5 LIME CONCRETE (ORDINARY)

Specifications

1. Aggregate shall consist of either brick ballast, broken stone or shingle. It shall comply with the Specifications No. 6.1 (B) for Coarse Aggregate. **Aggregate**

2. Unless otherwise specified or directed, the size of the aggregate shall not exceed 1½ inches gauge for ordinary lime concrete and ¾-inch gauge for fine lime concrete. All coarse aggregate shall be screened through ¼-inch mesh to remove dust and rubbish. **Size of Aggregate**

3. Unless otherwise specified, lime shall be stone lime and shall comply with Specifications No. 3.2 for Stone Lime. **Lime**

4. Surkhi shall comply with Specifications No. 6.2. **Surkhi**

5. Unless otherwise specified, concrete for ordinary works shall consist of 13 cubic feet of lime and 26 cubic feet of surkhi mixed with 100 cubic feet of aggregate. For important work the proportion shall be 17 cubic feet of lime, 34 cubic feet of surkhi and 100 cubic feet of aggregate, all mixed dry before the addition of water. **Proportion**

6. If aggregate is brick ballast, it shall be soaked by heavily sprinkling with water for at least 3 hours before the layer of surkhi and lime is added. **Soaking**

7. The materials shall be measured and mixed on a pucca platform and protected from any admixture of earth, dirt or other foreign matter. The measurement shall be done by stacking the ballast in a rectangular layer of one foot thickness and spreading on its top the mixed surkhi and lime in a uniform layer of thickness to give the specified proportion. **Platform for Stacking and Mixing**

8. The materials shall be turned over 3 times dry and 3 times wet. The quantity of water which shall be added by means of a can fitted with a rose shall be just enough to make a wet, but not sloppy, concrete. No further water shall be added either during laying or ramming. **Mixing**

9. The mixture shall at once be laid (not thrown from a height) in layers not exceeding 6 inches in thickness, and thoroughly consolidated with rammers. Square rammers shall be used for consolidating the edges. Consolidation is not considered complete till a skin of pure mortar covers the surface and completely hides the aggregate and till a stick dropped endways from a height rebounds with a ringing sound. **Laying and Ramming**

10. The mixing and ramming shall go on continuously when once started. No concrete shall be placed later than two hours before work is stopped for the day. **To be Continuous and Adequate**

Test

11. Unless otherwise specified, the following test shall be applied. Two days after ramming is completed, a hole shall be made, wherever directed by the Engineer-in-charge, and filled with water. If the water is retained in the hole, it means the concrete is good and well compacted; otherwise (if the water runs through), the concrete is either not properly rammed or the quantity of mortar used is insufficient. Any layer of concrete which fails to pass this test shall be removed and replaced by sound and well-rammed concrete at the expense of the contractor.

Joints

12. The lower layer shall in each case be swept or washed clean before the next is laid. Where joints in layers are unavoidable, the end of each layer shall be sloped at an angle of 30°. Where vertical joints occur in an upper and lower layer they shall be at least 2 feet apart horizontally.

Curing

13. When completed, concrete shall be kept wet for a period of not less than 14 days. No brickwork or masonry shall be laid on concrete for at least 7 days after laying.

Protection

14. In all concrete work suitable plans and gangways shall be provided to prevent traffic over the surface of the work.

Measurement and Rate

15. In respect of measurement and rate it shall conform to Specifications No. 20.1 for Concrete (General).

TABLE 1

VARIATION OF STRENGTH OF 1:2:4 CONCRETE WITH VARYING AMOUNT OF MIXING WATER

Specimen	1	2	3	4	5
Water, gallons per bag of cement ..	5	5½	6	6½	6¾
Slump, inches	½	2½	6½	7	8½
Cylinder strength, psi	4,000	4,850	4,030	3,320	2,540
Cement content, bags per cu. yds. of concrete	5	5	5	5	5

TABLE 2

CONCRETE MIXES USED FOR VARIOUS TYPES OF WORK

Nominal volumetric proportions	Quantities of Materials required per 100 cu. ft. of finished concrete			Type of work for which used
	Cement Cwt.	Sand cu ft.	Course aggregate cu. ft.	
1 : 4 : 8 1 : 3 : 6	9.6 13.0	48 46	96 92	Mass concrete foundations piers, walls, caisson, etc. Blinding layers.
1 : 2 : 4 1 : 3 : 3	17.6 17.6	44 66	88 66	General reinforced concrete building and similar work, beams, slabs, stairs, lowload columns, foundations, retaining walls, bunkers, siles.
1 : 1½ : 3 1 : 2 : 3	22.4 21.0	42 52	84 78	Impermeable construction, water reservoirs, concrete deposited under water, bridge constructions, piles, medium load columns.
1 : 1 : 2 1 : 1½ : 1½	31.5 31.5	39 58	78 58	Long span arches, high load columns, prestressed concrete work.

TABLE 3

NET WATER-CEMENT RATIOS FOR VARIOUS TYPES OF CONSTRUCTION AND EXPOSURE CONDITIONS*

Mild climate, rain or semi-arid, rarely snow or frost

Type or location of structure	Gallons per bag of cement				
	Thin Sections		Moderate Sections		Heavy and mass sections
	Reinfed	Plain	Reinfed	Plain	
A. At the water line in hydraulic or water-front structures or portions of such structures where complete saturation or intermittent saturation is possible, but not where the structure is continuously submerged					
In sea water	5	—	5½	—	6
In fresh water	5½	—	6	—	6½
B. Portion of hydraulic or water front structures some distance from the water line but subject to frequent wetting.					
By sea water	5½	—	6½	—	7
By fresh water	6	—	7	—	7½
C. Ordinary exposed structures, buildings and portions of bridges not coming under above groups	6	—	7	—	7½
D. Complete continuous submergence:					
In sea water	6	—	6½	—	7
In fresh water	6½	—	7	—	7½
E. Concrete deposited through water ..	**	**	5½	—	5½
F. Pavement slabs directly on ground:					
Wearing slabs	6	6	**	—	**
Base slabs	7	7	**	—	**

G. Special case: For concrete not exposed to the weather, such as interiors of building and portion of structures entirely below ground, no exposure hazard is involved and the water-cement ratio should be selected on the basis of the strength and workability requirements.

*Adapted from Table I of the 1940 Joint Committee Report on Recommended Practice and Standard specifications for concrete and reinforced concrete.

**These sections not practicable for the purpose indicated.

TABLE 4

COMPRESSIVE STRENGHTS FOR VARIOUS WATER-CEMENT RATIOS (ORDINARY AND RAPID-HARDENING CEMENTS)*

Net Water-cement ratio**		Probable cube crushing strength, psi			
		Ordinary Portland		Rapid hardening Portland	
By weight	Gallons per bag of cement	7 days	28 days	7 days	28 days
0.36	4	5,600	7,300	6,800	8,400
0.40	4½	5,000	6,700	6,000	7,700
0.45	5	4,300	6,000	5,400	6,900
0.49	5½	3,700	5,400	4,800	6,300
0.54	6	3,200	4,700	4,100	5,600
0.58	6½	2,800	4,200	3,700	5,100
0.63	7	2,400	3,700	3,200	4,500
0.67	7½	2,100	3,300	2,900	4,100
0.72	8	1,800	3,000	2,600	3,600
0.76	8½	1,600	2,700	2,400	3,300

*Adapted from Design of Concrete Mixes, Road Note No. 4, Department of Scientific and Industrial Research, Great Britain.

**Surface water carried by the aggregate must be included as part of the mixing water.

TABLE 5

ESTIMATED RELATION BETWEEN THE MINIMUM AND AVERAGE CRUSHING STRENGTHS OF WORKS CUBES FOR DIFFERENT WORKS CONDITIONS*

Works Conditions	Minimum strength as percentage of average strength
Very good control with weight batching, moisture determinations on aggregates, etc., constant supervision ..	75
Fair control with weight batching	60
Poor control, volume batching of aggregates	40

*Adapted from Design of Concrete Mixes, Road Note No. 4, Department of Scientific and Industrial Research, Great Britain.

TABLE 6

RECOMMENDED SLUMPS FOR VARIOUS TYPES OF CONSTRUCTIONS*

Type of Construction	Slump in Inches**	
	Maximum	Minimum
Reinforced foundation walls and footings	5	2
Plain footings caissons, and sub-structure walls	4	1
Slabs, beams, and reinforced walls	6	3
Building columns	6	3
Pavements	3	1
Heavy mass construction	3	1

*Adapted from Table 4 of the 1940 Joint Committee Report on Recommended Practice and Standard Specifications for Concrete and Reinforced Concrete.

**When high frequency vibrators are used, the values given should be reduced about one-third.

TABLE 7

MAXIMUM SIZE OF AGGREGATE RECOMMENDED FOR VARIOUS TYPES OF CONSTRUCTIONS*

Minimum dimension of section (inches)	Maximum size of aggregate in inches**			
	Reinforced walls, beams and columns	Unreinforced walls	Heavily reinforced slabs	Lightly reinforced or unreinforced slabs
2½—5	½—¾	¾	¾—1	¾—1½
6—11	¾—1½	1½	1½	1½—3
12—29	1½—3	3	1½—3	3
30 or more	1½—3	6	1½—3	3—6

*Adapted from Recommended Practice for the Design of Concrete Mixes (ACI 613-44), American Concrete Institute.

**Based on square openings.

TABLE 8

APPROXIMATE SAND AND WATER CONTENTS PER CUBIC YARD OF CONCRETE*

Based on aggregates of average grading and physical characteristics in mixes having a water-cement ratio of about 0.57 by weight; 3-in. slump, and natural sand having a F.M., of about 2.75.

Maximum size of coarse aggregate inches	Rounded coarse aggregate		Angular coarse aggregate	
	Sand per cent of total aggregate by absolute volume	Net water content per cubic yard, lb.	Sand per cent of total aggregate by absolute volume	Net water content per cubic yard, lb.
½	51	335	56	360
¾	46	310	51	335
1	41	300	46	325
1½	37	280	42	305
2	34	265	39	290
3	31	250	36	275
6	26	220	31	245

Adjustment of Values in Table 8 for other Conditions

Changes in conditions stipulated in table 8.	Effect on values in table 8	
	Per cent sand**	Unit water content**
Each 0.05 increase or decrease in water-cement ratio ..	±1	0
Each 0.1 increase or decrease in F.M. of sand ..	±½	0
Each 1 in. increase or decrease in slump ..	—	±3%
Manufactured sand (sharp and angular)	+3	+15 lbs.
For less workable concrete as in pavements	—3	—8 lbs.

*Adapted from Recommended Practice for the Design of Concrete Mixes (ACI 613—44) American Concrete Institute.

**(+) Indicates an increase and (—) a decrease corresponding to the conditions stated in the first column.

TABLE 9

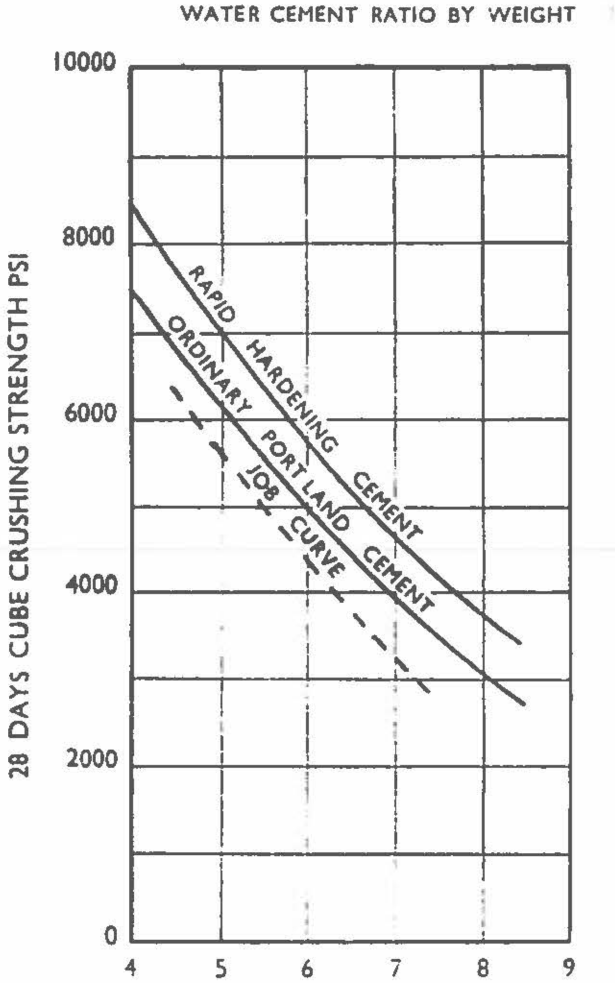
EFFECT OF GRADATION OF COARSE AGGREGATE ON CEMENT REQUIREMENT

Water content 6½ gal. per bag of cement content degree of workability

Composition of coarse aggregate per cwt by weight			Optimum* amount of sand	Cement required at per cent sand indicated, bags per cu. yd.	
3/16 to 3/8 in.	3/8 to 3/4 in.	3/4 to 1½ in.	Per cent	Optimum	35%
35.0	00.0	65.0	40	4.5	4.8
30.0	17.5	52.5	41	4.5	4.9
25.0	30.0	45.0	41	4.5	5.2
20.0	48.0	32.0	41	4.5	5.0
00.0	40.0	60.0	46	4.5	5.9

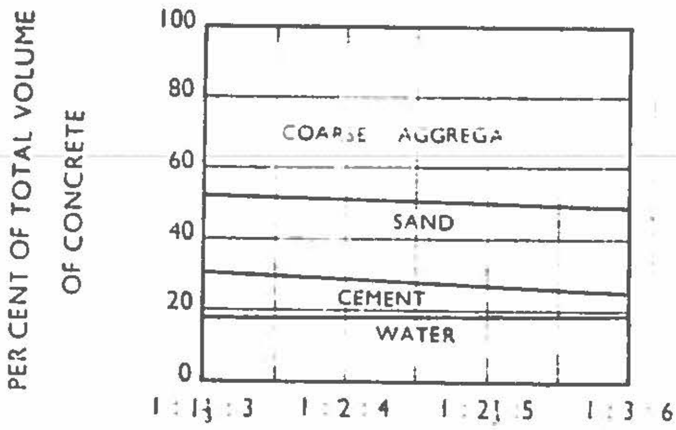
*Amount giving best workability with the aggregate.

FIGURE 1



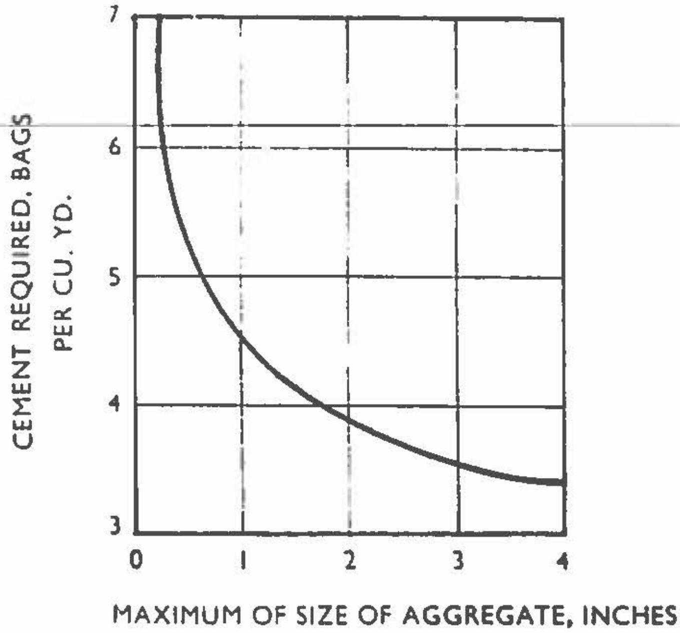
WATER CEMENT RATIO, GALLONS PER BAG
RELATION BETWEEN WATER CEMENT RATIO AND 28 DAYS CRUSHING STRENGTH OF CONCRETE

FIGURE 2



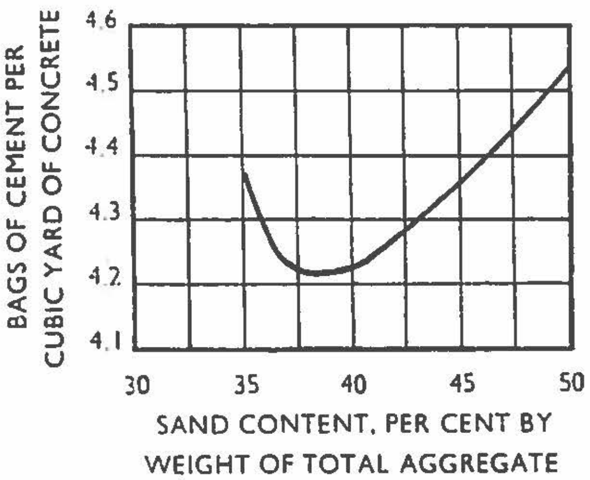
CONCRETE MIX
ANALYSIS OF CONCRETE MIXTURES OF UNIFORM CONSISTENCY (SLUMP 2 To 3 INCHES)

FIGURE 3



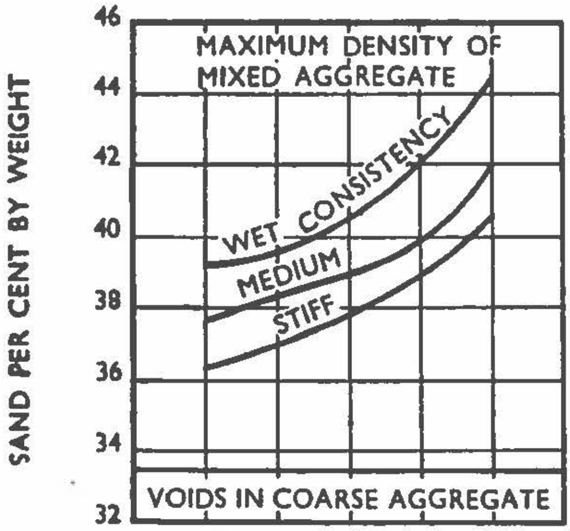
EFFECT OF MAXIMUM SIZE OF AGGREGATE ON CEMENT REQUIREMENT OF CONCRETE OF 3 TO 5 IN. SLUMP AND 6½ GALLONS MIXING WATER PER BAG OF CEMENT

FIGURE 4



EFFECT OF SAND CONTENT ON CEMENT REQUIREMENT. 6½ GALLONS OF WATER PER BAG OF CEMENT. MEDIUM CONSISTENCY SAND GRADED O—3/16 INCH GRAVEL 3/16—1½ INCH.

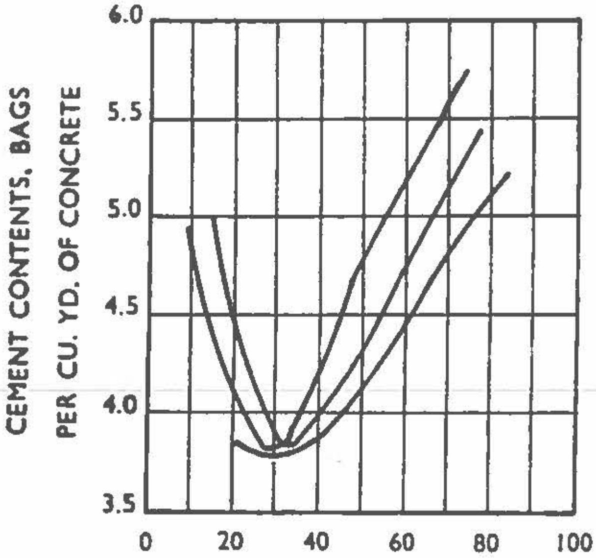
FIGURE 5



WATER CONTENT GALLONS PER BAG

RELATION OF SAND REQUIREMENT TO WATER CONTENT OF PASTE FOR CONCRETE MIXTURES HAVING DIFFERENT DEGREES OF WORKABILITY

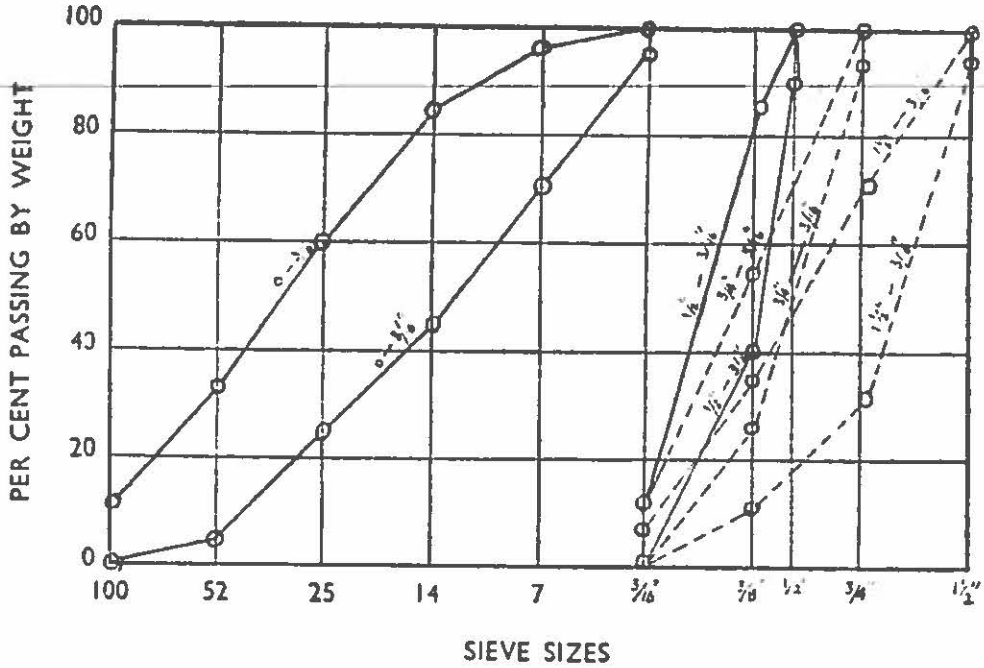
FIGURE 6



SAND PER CENT TOTAL AGGREGATE

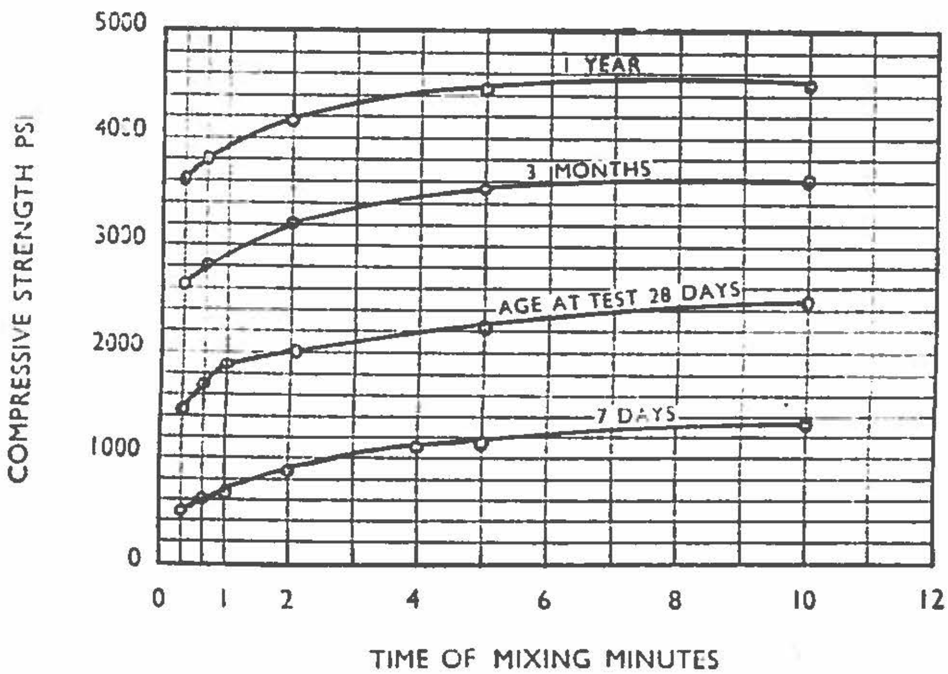
RELATION BETWEEN SAND CONTENTS AND CEMENT REQUIRED TO PRODUCE CONTENTS OF SIMILAR WORKABILITY TESTING 2500 PSI AT 28 DAYS

FIGURE 7



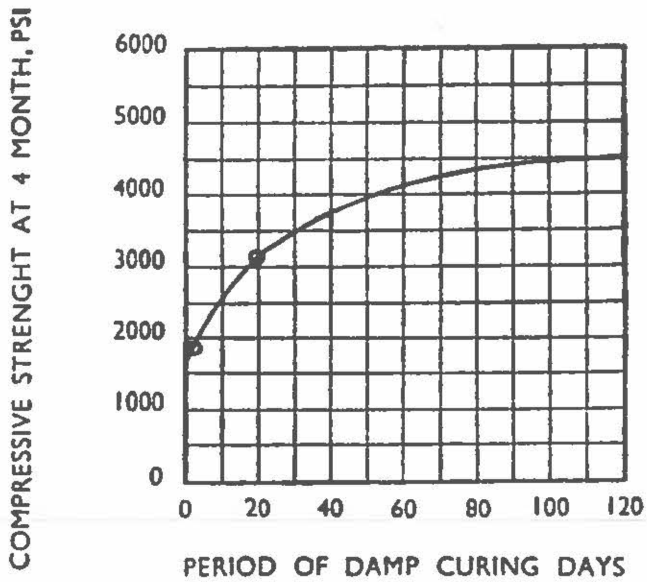
GRADING LIMITS OF COARSE AND FINE AGGREGATES AS SPECIFIED BY B.S. 882. 1944

FIGURE 8



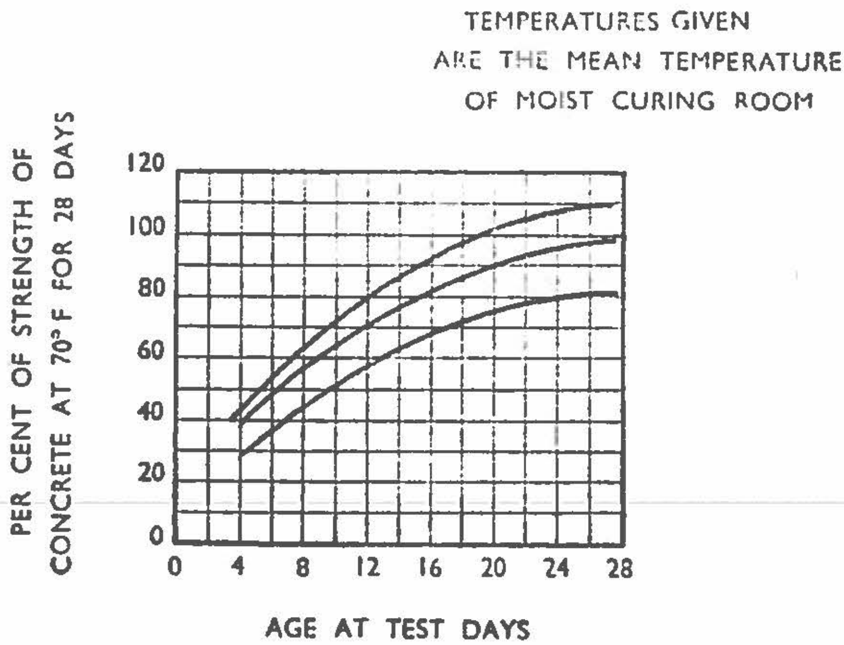
RELATION BETWEEN TIME OF MIXING AND COMPRESSIVE STRENGTH OF CONCRETE

FIGURE 9



TYPICAL RELATION BETWEEN CURING CONDITION AND COMPRESSIVE STRENGTH OF CONCRETE

FIGURE 10



CURVE SHOWING EFFECT OF TEMPERATURE DURING CURING PERIOD ON COMPRESSIVE STRENGTH OF CONCRETE

BRICKWORK

Introduction

The art of bricklaying consists in arranging and bedding bricks in mortar so as to form a homogeneous mass and bond them in a manner that the point or other loads and stresses are dispersed and distributed through the mass without tending to disintegrate the structure. Brickwork has a wide variety of uses e.g. to carry heavy loads as in engineering structures, to resist chemical attack as in sewers, to provide a wall facing of good appearance and weather-resistance, to form a stable backing to such a facing or some other finish. Its ability to meet these requirements depends on the properties of its constituents (bricks, mortar, damp-proof courses and possibly wall ties), on workmanship, and the design of the structural element itself.

Glossary Of Terms

Different terms used in brickwork are described below with their respective application.

Frogs

In hand-made and machine-pressed bricks indentations known as frogs are formed in their bedding surface. The object of the frog is two-fold: first, to form a key for the mortar, and secondly to provide space for the manufacturer's trade mark. The frog face is kept upward in brickwork. Frogs are not formed in wire-cut bricks because the method of manufacture renders this impossible.

Course

Course is the name given to the row of bricks between two consecutive bed joints. Its thickness is taken as one brick plus one mortar joint.

Bed Joints

Bed joints should always be normal to the pressure.

Quoins

Quoins are the external corners of walls. The term is sometimes used for bricks or stones which form the quoins e.g. quoin brick, quoin stone.

Perpends

Perpends are vertical joints of the face of the wall. In plain walling it is necessary for good bond that these joints should, in alternate courses, be vertically one above the other.

Stretchers

Stretchers are bricks laid with their lengths on the face of wall or parallel to the face of wall.

Headers

Headers are bricks laid with their widths on the face of wall or parallel to the face of wall.

Bats — Bats are pieces of bricks and are usually known as 1/2 or 3/4 bat according to the fraction of a whole brick.

Lap — Lap is the horizontal distance between the vertical joints in two consecutive courses.

Queen Closer — Queen closers are bricks made with the same length and thickness but with half the width of a brick. They are usually placed next to the quoin header to obtain the lap. They are usually made economically by cutting the broken bricks.

King Closer — King closers are bricks which are cut in such a way that one end is half the width of the brick. They are used in the construction of reveals to avoid having any face brick less than four inches on the bed.

Squint quoins — They are bricks cut or moulded to form angles other than right angles in plan. They are cut to show a 3/4 brick on one face and a 1/4 brick on the return. No closers are then used on the front of the brickwork.

Keyed brick — It is used to provide effective key for plaster.

Cellular brick — It is used to lighten the weight of wall and to increase thermal insulation.

Plinth bricks — They are moulded with a splay or moulding of a projection of 2¼" and are used to form the top member of a projecting plinth.

Bull-nose bricks — They are moulded with an angle employed to form quoins. The radius of the curve lies on the long centre line of the brick.

Cow-nose — It has a double bull-nose on end brick.

Junctions of Cross Walls — The bond is obtained in cross or party walls abutting against main walls by placing a closer of 4½ inches from the face in every alternate course in the main wall thus leaving a space 2¼ inches deep and having a length equal to the thickness of the cross wall for the reception of the 2¼ inches projection in every other course of the cross wall.

Projecting Courses — There are three cases in which it is necessary to enlarge the horizontal area of walls: first, to increase the area of the base to distribute the pressure over greater area of earth as in footing; secondly, to form a projection to afford a bearing area to support the ends of girders or joist; and thirdly, to obtain architectural effect, as in the construction of strings or cornices. The following two rules must be complied with in order to obtain the greatest efficiency. First, in any course the projection should not exceed one-fourth the length of the brick. This is to prevent the bricks from overturning, provided they are properly weighted at their back end. Secondly, all bricks as far as possible should be laid as headers; this renders the bricks more secure from being drawn from the wall.

Footings — They are the wide courses placed at the base of a wall to distribute the pressure over a greater area of foundation.

Corbelling — It is sometimes necessary to support loads. It consists of one or more courses projecting a distance sufficient to afford the required bearing area for the load.

Throating — It is a groove on the surface of copings or string course.

Coping

It is done at the highest, covering the course of brickwork. It forms the waterproof top to prevent the interior of the wall from wetting. Copings are commonly throated.

Drip Coures

Drip course throws off water clear of walls. It has a throated under surface and is usually done over arches, doors and window sills and parapets.

String Courses

These courses are horizontal projections of brickwork often constructed below windows.

Various types of mortar joints for face brickwork are mentioned below:

Flush joint

This joint is formed by slicing the surplus surface mortar on the face of brickwork.

Raked joint

This joint is formed by raking the mortar about 1/4 inch or 3/8 inch so that the joint is in shade. It is effective when the perpends are flush.

Weathered joint

This joint is the best joint for reducing the ingress of water and is formed by drawing the point of trowel at a slight angle along the course.

Mason's V Joint

Where it is desired to produce the even looking joints, mason's V joint is formed.

Brickwork (Building)

Walling

The usual procedure for erecting a wall in bricks is to build its corners or extremities to a height of 2 to 3 feet. The bricks must be carefully plumbed on both faces. The base of the corner is extended along the wall and is raked back as the work is carried up. The intermediate portion of the wall is then built between the two corners. The bricks in the courses are kept level and straightened by building their upper edges to a line stretched between the corners. The entire wall should be carried up simultaneously, and no part of the wall should be built higher than 3 feet of another part so as to avoid the risk of unequal settlements before the mortar has sufficiently set.

WALL CLASSIFICATION—Walls are divided into two main types:

(a) Load bearing walls: These include all solid building walls supporting a continuous load from the roofs and floors, and retaining walls for retaining earth and water.

(b) Non-load bearing walls: These include all panel filling walls which carry no superimposed load.

Durability of Brickwork

There are four main causes which impair the durability of brickwork: frost action, crystalization of soluble salts, chemical action and moisture movement. Since it is the presence of water in brickwork which is responsible for bringing these causes into action the first safeguard is to protect the work by avoiding unnecessary exposure and providing damp-proof courses, where practicable.

Frost can affect both the bricks and the mortar, and its effects are fairly straightforward. The affected part spalls or crumbles with the action of ice-forming in its saturated pores. Crystallisation of salts and chemical action depend on the presence of soluble salts which may originate in the bricks or the mortar or both. The movement of salts to the surface of the wall is influenced by pore structure of its elements, so that some of the salts from the brick may come out at joints and vice versa. It is possible to control to some extent the incidence of efflorescence and crystalization by ensuring that the parts at which these actions would be least harmful are most porous. In the case of chemical action, an important type of failure occurs when clay bricks containing a dangerous proportion of calcium sulphate are bonded in mortar containing cement or covered with a rendering containing cement. In certain damp conditions the sulphate can combine with cement and cause general expansion and failure of work.

Thickness of Brick Walls

The thickness of brick walls is regulated by the following rules which only apply to walls not more than 45 feet long between supports or cross walls and buildings three storeys high. Local authority by-laws may be referred for detailed information. Walls built of various types of brickwork detailed in the table below, should not go beyond the maximum permissible height shown for various thicknesses, subject to the following further limitations.

(i) The bricks are not less than 9 inches long.

(ii) The thickness of external and party walls (i.e. walls separating adjoining buildings) is not less than one-sixteenth of the height of the storey in the case of ordinary buildings and one-fourteenth in the case of warehouses. The thickness of walls below is increased to a like extent, though any such additional thickness be confined to piers, properly distributed, of which collective widths amount to one-fourth of the length of the wall.

(iii) Thirteen inches and a half is the minimum thickness for the external party walls of any storey more than 10 feet high.

(iv) Walls do not support super-incumbent external walls and are not built of burnt brick in mud mortar. The thickness of cross walls is two-thirds the thickness of the external party walls but never less than 9 inches (except in case of bricks in cement suitably reinforced with steel). No wall should be considered a cross wall unless it is carried up to the floor of the top most storey and unless in each storey the combined area of openings and recesses is less than 50 per cent of the wall area. Properly bonded cross walls may be considered return walls for determining the length of external or party walls.

Materials of which the wall is built	f=safe pressure in tons per square foot	Maximum permissible height for a thickness of				
		9" or 1 brick	13½" or 1½ bricks	18" or 2 bricks	22½" or 2½ bricks.	27" or 3 bricks
Burnt brickwork in 1:3 cement mortar.	8	25	38	51	..	..
Burnt brickwork in lime mortar or lime: cement: sand, mortar 1:1:6:	4	16	24	32	40	..
Burnt brickwork in mud	2½	11	17	23	28	34
Sun-dried brick in mud	1	6	9	12	15	18

These heights are calculated by the following formula:—

$$\text{Height in feet} = (6F)^{0.7N}$$

F=Safe allowable pressure in tons/square feet.

N=thickness of wall in bricks.

In no case the pressure on any portion of the wall should exceed the safe pressure given in column 2 of the table. Wherever it is necessary to exceed the pressure, the thickness of the wall shall be increased to satisfy this condition.

Resistance to Damp Penetration

Dampness is eliminated from buildings to provide healthy living conditions and to protect the structure itself from decay or unsightly effects such as efflorescence. Measures are, therefore, adopted to exclude rain or ground moisture. Rain falling on a brick wall can penetrate the body of the work through pores of the bricks and mortar or cracks in the joints. Resistance to water penetration through brick walls can be achieved by either of the two methods:

(a) the provision of a degree of absorption sufficient to hold, without full penetration, the greatest amount of water likely to accumulate in the wall;

(b) the use of dense, impervious units and mortar and the avoidance, by good workmanship, of cracking through which penetration could occur.

From the point of view of excluding dampness, however, the mortar should not be richer in cement than is necessary. In addition to being exposed to the falling rain, brickwork may be in contact with more constant sources of dampness such as the ground or may have specially vulnerable points such as the base of a roof parapet. In such a situation it is customary to insert a damp-proof course of impervious material. Wall construction with two separate thicknesses of materials connected only with horizontal metal ties is the most positive method of excluding rain. The ties should be of correct design and be protected from mortar drippings during building to ensure that no water runs across them.

Thermal Insulation

The insulation provided by brickwork depends mainly on the thickness, design (i.e. whether solid or cavity), finish and dryness of structure. Variation in the type of bricks, unless cavity is used, does not make a very great difference. A light porous brick when dry would, however, give slightly better insulation than a heavy dense one; sand lime bricks as a class give slightly less insulation than average clay bricks.

Wetting of Bricks

The presence of water in mortar is necessary for the setting action to take place. Precautions should, therefore, be taken to prevent the work from drying too quickly. Bricks should be saturated before bedding, except during frost, to remove all loose dust from the surface that is to be in contact with the mortar.

Bedding of Bricks

While bedding bricks, both the bed and side joints must be thoroughly flushed or filled up with mortar.

Levelling

While bedding bricks, great care should be taken to keep all courses perfectly level. To do this, the footing and the starting course should be carefully levelled, using a spirit level with a stack at least 10 feet long.

Toothing

The usual method while leaving a brick wall which is to be continued at some future time is to tooth the wall. This consists in leaving alternate stretchers projecting $2\frac{1}{4}$ inches beyond the stretching courses above and below.

Usually, new cross walls are joined to old main walls by cutting out a number of rectangular recesses in the main wall equal in width to the width of the cross wall, three courses in height, and half a brick in depth. A space of three courses is left between the sinkings, and the new cross wall is then bonded into the recesses with cement mortar to avoid any settlement. The sinkings should not be less than 9 inches apart, since in the cutting, the portion between is likely to become shaken and cracked. This is known as block-bonding.

Thickening

Where old walls have to be thickened, recesses 9" x 9" x $4\frac{1}{2}$" deep are usually cut, one in every yard square of the surface of the old wall. The new work is then built against the old and block-bonded at every recess. The surface of the old work is well cleaned, brushed and wetted before the new work is added. This is also known as block-bonding.

Racking

Racking is the term applied to the method of arranging the edge of a brick wall, part of which is unavoidably delayed while the remainder is carried up. The unfinished edge must not be built vertically or simply toothed, but should be set back $2\frac{1}{4}$ inches at each course, with a maximum of twelve courses, to reduce the possibility and the unsightliness of defects caused by any settlement that may take place in the most recently built portion of the wall.

Stability of Brickwork

The stability of brickwork is affected in three general ways:

(1) By loading a given area of ground beyond its ultimate resistance, by an irregular concentration of great pressures on a soft sub-soil, by the tendency of the sub-stratum to slide or by eccentric loadings, the walls are thrown out of the upright, crack or disintegrate.

(2) By bad bonding, resulting in disintegration.

(3) By side thrusts which may be distributed or concentrated, and their tendency is to overturn the walls; they are provided for by designing the walls of a sufficient thickness, or by placing buttresses at regular intervals.

Bond

Bond is the name given to any arrangement of bricks in which no vertical joint of a course is exactly over a verticle joint in another course immediately above or below it, and has the greatest possible amount of lap, which is usually one-fourth the length of a brick.

Bonds in Brickwork

To ensure good bond the following rules should be rigidly adhered to:—

(a) Bricks must be arranged in a uniform manner.

(b) Fewest possible bats are employed.

(c) Vertical joints in every other course must be perpendicularly in line on the internal as well as the external face.

(d) Stretchers are to be used only on the faces of the wall, the interior should consist of headers only, as also the footings and corbels.

(e) When bedded the length of a brick should equal twice the wih, plus one mortar joint.

(f) ~~Lateral lap between perpends is 1/4 of brick length.~~

Common types of bonds used in brickwork are described as follows:—

(a) *ENGLISH BOND*—It consists of one course of headers and one course of stretchers alternately. In this bond, bricks are laid as stretchers only on the boundaries of courses, thus showing on the face of the wall. The joints in a course running through from back to front of a wall must not be broken. The course which consists of stretchers on the face is known as a stretching course. The courses above or below should consist of headers with the exception of the closer brick, which is always placed next to the quoin header tc complete the bond. These courses are called as headin, courses.

It may be noticed that in walls the thickness of which is a multiple of a whole brick the same course will show **either**

(a) Stretchers in front elevation and stretchers in back elevation.

or

(b) Headers in front elevation and headers in back elevation.

But in walls whose thickness is an odd number of half bricks, the same course will show **either**

(a) Stretchers in front elevation and headers in back elevation.

or

(b) Headers in front elevation and stretchers in back elevation.

In setting out the plan of a course to any width, the quoin or corner brick should be drawn; then next to the face (which in front elevation shows headers) closers should be to the required thickness of wall; after which all the front headers should be set out and, if the thickness is a multiple of a whole brick, headers in rear should be set out. The intervening space, if any, should always be filled in with headers.

(b) *DOUBLE FLEMISH BOND*—This bond has headers and stretchers alternately in the same course, both in front and back elevations. It is weaker than the English Bond because of the greater number of bats and stretchers, but is considered by some to look better on the face. It is also economical, since a greater number of bats may be used in it and thus bricks broken in transit may be utilized. By using the Double Flemish Bond for walls one brick in thickness, it is easier to obtain a better appearance on both sides than with the English Bond.

(c) *SINGLE FLEMISH BOND*—It consists in arranging the bricks as Flemish Bond on the face, and English Bond as backing. This is often done on the presumption that it attains the strength of the English Bond and the external appearance of the Double Flemish. It is generally used where expensive bricks are specified for facing. The thinnest wall where this method can be introduced is 1½-brick thick.

(d) *STRETCHING BOND*—Stretching Bond is used for walls half-brick thich such as partition walls, bricknogging in partitions. All bricks are laid as stretchers upon the face.

(e) *HEADING BOND*—All bricks in this bond show as headers on face. It is used chiefly for rounding curves, for footings, corbels and cornices.

(f) *RACKING BOND*—Walls as they increase in thickness increase in transverse strength but become proportionately weaker in a longitudinal direction, owing to the fact that stretchers are not placed in the interior of walls. This defect is remedied by using racking courses at regular intervals of four to eight courses in the height of a wall. The joints of bricks laid in this position cannot coincide with the joints of the ordinary courses directly above or below, the inclination to the face usually being determined by making the longitudinal distance between the opposite corners equal to the length of a brick. It is not advisable to use one racking course directly above another, since there is always a weakness at the junction of the racking with the face bricks.

Racking bonds are most effective when placed in the stretching courses in walls of an even number of half-bricks in thickness. In this way they are effective over a greater area than if they were placed in the heading courses.

The alternate courses of racking bonds should be laid in different directions in order to make the tie as perfect as possible. There are two varieties of racking bonds, *viz.* herring bond and diagonal.

Reinforced Brickwork

Brickwork may advantageously be reinforced by iron and steel. Hoop-iron bond has been used for a considerable time, but probably in many cases without any exact knowledge of its true value.

Reinforcement skilfully applied adds considerable tensional strength to the brickwork. The mortar should be good Portland cement, one to three of sand, and the reinforcement should be effectively bedded and surrounded with the mortar so that all air may be excluded, to prevent the rusting of the metal. All rods should be treated with two coats of bituminous paint.

Where structures are erected on soils of unequal bearing value, or on the side of a hill where sliding of the sub-stratum may take place, proper reinforcement is of great value to resist unequal settlement or the dislocation of parts of brickwork.

Scaffolds

There are several proprietary makes of brick-reinforcement, all of which are coated with bitumen to avoid rusting. They are made in several widths and lengths.

Temporary erections constructed to support a number of platforms at different heights so as to enable the workmen to get at their work and to raise the necessary material, are termed as scaffolds. A scaffold consists of a number of uprights, called standards, placed about 8 feet apart, which are fir poles about 5 inches in diameter and 30 feet in length. Standards may be increased to any length by lashing a number of poles together; this is done as occasions require during the erection of the building. Standards rest with their bottom ends on the ground, but to increase their stability and prevent lateral motion the ends are often embedded for about 2 feet in the ground. If any difficulty is experienced in doing so a barrel filled with earth is employed to receive the ends of the pole, a York stone flag immediately beneath the standard extends the bearing surface; they are placed approximately 8 feet apart. Similar poles, called ledgers, are placed horizontally and with a vertical distance apart of 5 feet, and are lashed to the building side of the standards (5 feet being the greatest height that an average man can work with ease).

Scaffolds form a frame which is erected about 4 feet 6 inches from the face of the intended building with which it is connected by means of horizontal members called putlogs. They take a bearing on the wall at one end, and on the ledgers to which some are lashed at the other end. Ledgers are wedged to the wall when it has been built sufficiently to permit this being done.

Putlogs are of square timber, usually 3" × 3" and 5 feet long. The pieces are not cut but split, to ensure the length fibres being uncut. These are placed about 4 feet apart, and on them the scaffold boards are laid to form the platform. These boards are 12 feet long, 9" x 1½" in size; the ends are bound in hoop iron to prevent their splitting.

The scaffold boards at their heading joints are butted. Two putlogs are placed at this part about 4 inches apart to support the ends. About the edges of the staging, guard-boards are placed, consisting of boards placed on edge and nailed to the standards.

The frames are braced to add stiffness and prevent the scaffold from rocking. The braces consist of poles lashed to the outside of the frames to triangulate the latter. For 9-inch walls a scaffold is only required on one side but for walls of a greater thickness it is required on both sides.

Piers

Piers in brickwork are constructed to support loads transmitted to them by beams and girders, or to receive the thrusts of two or more arches, the resultant of which falls in a vertical line. The height of any isolated brick or stone pier should not exceed eighteen times its least dimension. No pier should have a width less than 13 inches.

Attached Piers

Attached piers strengthen a wall at given intervals along its length. A usual spacing is 10 or 12 feet.

Chimneys

The function of the chimney flue is to remove smoke and other products of combustion from the fire to a position well above surrounding windows. Unfortunately large quantities of air, which the fire has just warmed up, are also removed by the draught up the chimney. Flues need careful designing so that fires do not smoke, and acids which are liable to form in flues to slow combustion appliances cannot cause damage to the mortar in the chimney stack.

Flues must be designed, as follows, to suit the type of fire.

Type of Fire	Size and Type of Flue
Open fires.	Minimum diameter 7 inches; traditional size 9" × 9" (Flues must be parged, i.e. rendered with mortar or lined with clay or other fired liners.)
Domestic boilers, slow-cumbustion stoves, etc, burning non-smokeless fuels.	6 inch diameter with salt galzed liners.
Domestic boilers, slow-combustion stoves, etc, burning exclusively smokeless fuels.	4 inch diameter flue with salt-glazed liners.

Draught

An open fire requires roughly four to six times the volume of air in a room per hour to keep it going satisfactorily. Only two air changes per hour are needed for purposes of health, so that two to four times as much air as is really required has to be heated up to produce comfortable conditions. This additional air comes from cracks, round window, under doors and between floor boards. That is why draughts are one of the characteristic discomforts of rooms warmed by open fires. If these cracks are draught-proofed, the fire may be starved of air and it may smoke.

Air supply to the fire should, therefore, be provided independently of the air in the room by means of pipes laid beneath the floor communicating with the outside air. These pipes should be 4 to 6 inches in diameter and should be arranged so that they can draw air from both sides of the house. (In a wind, the leeside of a house is in reduced pressure, and air is then sucked along any ventilation pipe opening to one side only.) Ventilation pipes should be arranged to supply air to the space immediately below the grate.

In order to reduce the waste of air up the chimney, the bottom of the flue should be formed, immediately above the head of the fire, into a throat 8 to 10 inches wide, 4 inches from front to back, and 6 inches deep. Precast throat units and cast-iron throat units with register doors to ensure that the throat is formed to the right dimensions can be purchased.

Smoke Shelf

Immediately above and to the back of the throat unit is the traditional site for the smoke shelf. It is not necessary to design the other features in the proper traditional manner. In fact some people consider that it is a trap for soot and may cause chimney fires.

There must be a smooth transition from the fireplace opening through the throat unit to the beginning of the flue with no cavities exposed at the back of the fire place. The throat unit, of course, is not necessary where the appliance has its own flue connection, as in the case of a stove or boiler.

Flues

They should generally be positioned within the house so that the heat coming from them can warm the building. Flues placed on outside walls waste heat. Not only that. The brickwork is also liable to get chilled below the dew point of the flue gases, and water vapours condense out on the flue lining, bringing with them sulphur compounds, tar, acid, or ammonia. These compounds can and do attack the lime or the cement in the mortar, and can cause severe damage to chimney stacks, and leakage of flue gases back into the building. This acid attack is severe with slow combustion appliances and that is why it is necessary to provide a flue lining of salt-glazed drain pipes (sockets upwards) to remove the possibility of this type of attack. When these liners are used, the stove-connection is brought in at right angles to the flue, with the bottom end of the flue emptying over a vessel to collect the condensate. This can be removed from time to time through a flue door.

If the walls of a flue are only half a brick thick the outside of the flue (within the building) must be plastered. If the flue passes through a roof of shingles or thatch, the flue must be thickened out to at least 9 inches—one brick thickness—to a distance of at least 4 inches above and below.

Insulation of Flues

Brickwork in flues for slow combustion stoves and boilers where they are exposed to the outside air should be at least 9 inches thick and preferably constructed of an insulating block with fireclay liners. This insulation will reduce the risk of condensation in the flue.

Inclination of Flues

The flue should not be inclined more than 45°, but if it is, the thickness of the top side of the slope should be at least one brick thick.

Fixings

Wooden plugs should not be within 9 inches of a flue or nearer than 6 inches to a fireplace opening. Similarly, metal fastenings should be kept at least 2 inches away from a fireplace opening.

Hearths

Hearths should be constructed so that there is no danger of any fire spreading to combustible structure. By-laws lay down that the hearth must project 16 inches from the front of the fireplace and must be 6 inches. The jambs to the fire should be at least 9 inches thick. The thickness at the back of the fireplace opening can be reduced to 4½ inches, except on party walls.

Chimneys Through Roofs

Where the slope of the roof is not less than 10° the chimney should project above the ridge at least 2 feet. Where the chimney stack comes through the roof other than at the ridge, it must project through the roof a distance of 3 feet measured from the highest point of its junction with the roof.

Chimney Pots and Flaunching

There is no need for the chimney pot to project more than 2 or 3 inches from the top of the brick or stonework. The pot is merely a convenient termination to the flue and should not be exposed. The top of the brick or stonework should be flaunched to throw water to the side in order to prevent undue penetration of rain into brickwork. It is better to cap the top of the stack with an impervious material such as a concrete cap.

Arches

One method of spanning an opening in brickwork is to form an arch. A curved template of wood is placed in position and the voussoirs (bricks forming the arch) are bedded together on it. Properly speaking, arches are curved. They transfer the weight of the walling above into the abutments. Lateral thrust is produced, the amount of which depends upon the span, the rise of the arch and the load of the brickwork above. This lateral thrust must be taken by either producing a sufficiently wide and heavy abutment or buttress, or by placing a similar arch alongside to balance the thrust. Confusion often arises because reinfored concrete or steel lintels face bricks which are called flat arches (vertical arches, or tiled arches). The sooner the word arch in this context falls out of use, the better.

If a square opening is cut in a plain brick wall, the brickwork within a 60° triangle above will tend to fall out, forming a triangular arch. This formation results from the diagonal support which each brick provides to the brick above. A lintel, therefore, only supports the weight of this triangle. If, however, floor joints come into the wall immediately above the opening the lintel will have to be strong enough to carry these additional loads.

ROUGH ARCHES—These arches are made of bricks which are not specially shaped to fit the curve of the arch. In order that the wedge-shaped mortar joints may not get unseemly thick near the top, stretchers are usually replaced by half bricks with perpends overlapping them. This form of construction is often used behind gauged arches so that the rather untidy half bricks are not seen.

GAUGED ARCHES—Here the bricks are formed to the tapered shape necessary to make neat jointing in the arch. A saw cut of $\frac{1}{8}$ inch is first made in the brick to give a precise line of finish, and then the unwanted part of the brick removed by axing (with a bricklayer's axe or scutch). Alternatively, softer bricks may be used and instead of being axed may be rubbed with a rubbing stone or file.

RELIEVING ARCHES—In the past relieving arches were often built over square openings to take most of the load. The flat head of the opening was then carried on timber joists.

NO. 21.1 BRICKWORK (GENERAL)

Specifications

Scope 1. Unless otherwise specified, all brickwork shall be finished in a workmanlike manner, true to dimensions and grades shown on the drawings according to the following specifications.

Classification 2. Unless otherwise specified, brickwork shall be of the following 4 classes.

(i) First class brickwork
(ii) Second class brickwork
(iii) Third class brickwork
(iv) Sun-dried brickwork

Bricks 3. Bricks shall conform to Specifications No. 4.1 for Clay Bricks, unless otherwise specified.

Mortar 4. Mortar shall be either as shown on the drawing or, if not shown, as specified or directed by the Engineer-in-charge. It shall be prepared in accordance with the relevant provisions set forth in Specifications No. 19.1—19.5 for the specified mortar. When specified for face work, its colour shall be of an approved quality and brand. Waterproofing material shall be added to the mortar only when specially required or directed by the Engineer-in-charge.

Water 5. Water in brickwork shall conform to Specifications No. 2.1.

Brick-Bats 6. No bats shall be used, except where absolutely necessary for obtaining the dimensions of different courses or the specified bond.

Tools 7. All equipment used for mixing mortar, transporting it and for laying bricks shall be clean and free from set mortar, dirt, or other injurious foreign substances. It shall be thoroughly cleaned at the end of each day's work.

Wetting of Bricks 8. Before use all bricks, except sun-dried bricks, shall be soaked in clean water in a tank or pit for at least 2 hours. In the case of masonry in mud mortar, however, dry bricks shall be used.

Bond 9. Unless otherwise specified, all brickwork shall be laid in English Bond with frogs upward.

Laying of Bricks

10. Each brick shall be set with both bed and vertical joints filled with mortar and thoroughly bedded in by tapping with handle of trowel. At every fourth course bricks shall be flushed with mortar and grouted full.

Joints

11. Horizontal joints shall be parallel and truly level. Vertical joints in alternate courses shall come directly over one another. Thickness of joints, unless otherwise specified, shall not be less than 1/4 of an inch and shall not be more than 3/8 of an inch. The height of 4 courses and 3 joints as laid shall not exceed more than 1 inch the height of 4 bricks as piled dry one upon the other.

Corner

12. At all corners alternate courses of bricks shall be laid header-wise and stretcher-wise so as to bond the two walls well together.

Where particularly required, cut or moulded bricks shall be used in jambs, arches and projecting corners, so as to eliminate sharp angles from the inside of a building. This item shall be included in the unit rate if the radius of the finished (plastered) corner does not exceed 3/4 of an inch. In case it exceeds 3/4 of an inch extra payment shall be made by making linear measurement.

Round Pillars

13. Round pillars shall be built with quadrant shaped bricks; if the pillars are of considerable height flat circular discs of stone or cement concrete of the same diameter as the pillar about 3 inches thick shall be introduced at every 4 to 6 feet as bond stone. The cost of this operation will be included in the unit rate.

Plumb Bobs and Straight Edges

14. All brickwork shall be truly plumped and each set of 4 brick courses shall be checked with plumb bob and straight edge.

Face Work

15. All face work shall be finished with neat drawn joints and pointed out if it has not to be plastered. If it has to be plastered the joints shall be raked out before any plaster is laid on. For face work the bricks shall be of true edges, uniform colour and correct dimensions. If specially required, face work shall be laid up with pressed bricks. All brick courses shall be so proportioned that they will work out evenly with the height of windows and doors. Backing of the pressed brickwork shall be done as per specifications for brickwork Ist class.

Joining Works

16. When fresh masonry is to join masonry that has partially or fully set, the exposed joining surface of the set masonry shall be cleaned, roughened and wetted so as to effect the best possible bond with the new work. All loose bricks and mortar shall be removed.

In all cases, returns, buttresses, counterforts, etc., shall be built up well course by course and carefully bonded with the main wall and shall never be joggled on afterwards.

Striking of Joints

17. Where in the case of brickwork in lime or cement mortar, pointing or plastering to the face work is not provided as a separate item the joints in face work shall be struck. This operation shall be paid for separately.

Raking Joints

18. The joints of brickwork, which is to be pointed or plastered, shall be raked out with a hook to a depth of half an inch. The raking shall be done before the mortar sets each day.

Cut Brickwork

19. Bricks shall be cut, dressed or grooved, as required for shaping jambs, fitting chokhats and for architectural features of the building. Corners shall be made with cut bricks; five bricks shall be used for each corner.

Fixtures

20. Holdfasts and similar fixtures shall be built in with the surrounding brickwork in their correct position in specified mortar. They shall be built in as the work progresses and not inserted later on into space left for them.

Progress

21. Brickwork shall be carried up in a uniform manner. No portion shall be raised more than 3 feet above another at the same time. Temporary spaces left during construction shall be racked and not toothed. Straight edges supplied to brick-layers shall have courses marked on them with saw cut or measuring rod shall be provided and the height of course shall be checked all over the building from time to time so as to keep all courses level.

Bed Plate

22. Bed plates of concrete or stone shall be provided under each beam and joist. They shall conform to the dimension given in the drawing and shall be carefully laid in specified cement mortar to correct level. Backing up, if necessary, shall be done with tiles or split bricks.

Bricklaying in Freezing Weather

23. (a) *PROTECTION OF BRICKS*—All bricks delivered for use in freezing weather shall be fully protected immediately upon delivery by a weather-tight covering that will prevent the accumulation of water, snow or ice on the bricks; loose board covering shall not be permitted.

(b) *HEATING OF SAND*—All sand shall be heated in such a manner as will remove all frost, ice or excess moisture but will prevent the burning or scorching of the sand.

(c) *HEATING OF BRICKS*—All frosted bricks shall be defrosted by heating them to a temperature of approximately 180° F.

(d) *HEATING OF WATER*—All water used shall be heated to a temperature of approximately 180° F.

(e) *SLAKING OR SOAKING OF LIME*—All slaking of quick lime or soaking of hydrated lime shall be done at a temperature of at least 60° F, and this temperature shall be maintained until lime is incorporated into the mortar.

(f) *PROTECTION OF MORTAR AGAINST FREEZING*—After the mortar has been mixed it shall be maintained at such temperature as will prevent its freezing at all times and if necessary the contractor shall use metal mortar board equipped with oil torches. No anti-freez liquid, salt or other substance shall be used in mortar, except when specified or permitted by the Engineer-in-charge.

(g) *ENCLOSURES AND ARTIFICIAL HEAT*—All work under construction shall be protected from freezing for a period of 48 hours by means of enclosures, artificial heat or by other suitable methods duly approved by the Engineer-in-charge.

Openings

24. Door and window openings shall have flat or relieving arches or lintels spanning across them as shown on the drawing or as specified.

Centring

25. Centrings for all openings shall be strong enough to support the lintels or arches spanning the openings. They shall be subject to the approval of the Engineer-

in-charge and shall remain in position till the brickwork has set. No additional payment will be made to the contractor for this item of work.

Scaffolding

26. The contractor shall provide all scaffolding, staging, ladders, etc., necessary for the work. All walls or other brickwork shall be securely braced and protected against damages by wind and storms during the construction period. No extra rate shall be paid for this item.

Putlogs

27. Only headers shall be left out to allow a putlog to be inserted and not more than one brick shall be left out for each putlog. Under no circumstances shall putlogs be made immediately under or next to the impost or skew back of arches.

Protection Watering

28. All brickwork shall be protected during construction from the effects of rain and frost by suitable covering. The brickwork laid in cement or in cement and lime mortar shall be kept moist for a period of 10 days.

Measurement

29. Brickwork shall be measured by volume. The unit of measurement shall be 100 cubic feet. The measurement of cut bricks shall be in numbers. The unit of measurement shall be 1000 bricks. No deduction shall be made for openings having a superificial area of one square foot or less.

Labour Rate

30. The unit rate (on labour rate basis) for brickwork shall include cost of carrying out brickwork, cutting bricks whenever required, curing and protecting as per above specifications and/or any other specifications specially included in the contract. It shall further include the cost of providing, using and removing scaffolding, shuttering, centring, staging, ladders, supports and other tools and plants required for carrying out brickwork as per above specifications.

Composite Rate

31. The unit rate shall include the cost of bricks, mortar and any other material required, in addition to the labour rate detailed above.

NO. 21.2 BRICKWORK IST CLASS

Specifications

Bricks

1. Bricks shall conform to Specifications No. 4.1 (7) for First Class Bricks. Their size shall be as specified.

Other Respects

2. In all other respects it shall conform to Specifications No. 21.1 for Brickwork (General.)

NO. 21.3 BRICKWORK 2ND CLASS

Specifications

Bricks

1. Bricks shall conform to Specifications No: 4.1 (9) for Second Class Bricks. Their size shall be as specified.

Laying of Brickwork

2. Brickwork shall be laid in accordance with Specifications No. 21.1 for Brickwork (General), except clause No. 14 for face work. If facing is not to be plastered second class bricks shall not be used in the facing. No cut brickwork shall be executed with second class bricks.

Other Respects

3. In all other respects it shall conform to Specifications No. 21.1 for Brickwork (General).

NO. 21.4 BRICKWORK 3RD CLASS

Specifications

Bricks

1. Bricks shall conform to Specifications No. 4.1 (10) for Third Class Bricks.

Laying of Brickwork

2. Brickwork shall be laid in accordance with the Specifications No. 21.1 for Brickwork (General) with the following exceptions:—

- No cut brick shall be executed with third class bricks.
- Joints in third class bricks shall be ½ inch, but shall, in no case, exceed 5/8 inch.
- The height of 4 courses laid according to the above specifications with 4 horizontal joints shall not exceed 2 inches the height of 4 bricks piled dry one upon another.
- Third class brickwork shall not be bonded with any other class of brickwork.
- Third class bricks shall never be allowed for face work.

Other Respects

3. In all other respects it shall conform to Specifications No 21.1 for Brickwork (General).

NO. 21.5 BRICKWORK IN ARCHES

Specifications

Materials

1. All materials shall conform to Specifications No. 21.2 for Brickwork First Class, unless otherwise specified.

Centring

2. Centring shall be strong enough to bear the weight of an arch without any deflection. The surface of centring shall be correctly struck to the curvature of the soffit of the arch.

Wedges and Sand Boxes

3. Centres of arches over 5 feet in span shall be erected on wedges, those over 10 feet in span on double wedges and those over 20 feet span on sand boxes so as to allow the gradual lowering of centre (i.e. striking).

Building of Arches

4. The building of arches shall not commence till abutments have been built to their full width and up to the level of skew backs. Arch work shall be carried up evenly from both abutments and as soon as the arch is complete, masonry shall be built up evenly on both sides to the heights of the crown so as to load the haunches.

The brickwork in arches shall conform to Specifications No. 21.2 for First Class Brickwork, except with the following modifications:—

(i) In all arches, the voussoir joints shall be truly radial. Bricks shall be laid in full beds of mortar and shall be thoroughly rubbed and pressed into their beds so as to squeeze out surplus mortar and leave the joints as thin as possible.

(ii) Joints in arches shall not exceed 1/4 inch in thickness at any point Radial joints in gauged arches shall not exceed 1/8 inch in thickness.

(iii) Skew backs shall be formed of bricks correctly shaped to radiate from the centre of curvature and shall not be packed with mortar or chips. Before the building of an arch is commenced abutments shall be exactly at the same level and skew backs in place.

(iv) For gauged arch work, the arch shall be laid out full size on the ground on lime plaster and all joints carefully marked out. Templates shall then be made as a guide for the special shapes of bricks. Special bricks shall, where possible, be moulded and burnt but if the amount of work is small they shall conform in the requirements of the Engineer-in-charge and shall be carefully cut and rubbed to the required shape. All bricks for an arch shall be prepared in full and set up dry on the ground before the work begins.

(v) Segmental arches used over rectangular door or window openings shall have a flat rectangular soffit and segmental extrados.

(vi) Flat arches shall be built in the same manner as gauged arches but with all the voussoir joints converging on the apex of an equilateral triangle described on the soffit of the arch. Cross joints and extrados shall be parallel to the soffit. The arch shall be built with a camber of 1/8 per foot of span.

(vii) Arches shall be built in concentric rings and each ring shall be completed before work on the one above it is commenced. In all cases, whether, specially moulded bricks or ordinary bricks are used, the centre line of the brick face shall be radially placed. The arch rings shall, in all cases, be bonded together by a special bond stone (key stone) which shall be of stone concrete or brickwork, as actually specified or shown on the drawing.

Striking of Centres

6. Centre shall be struck as noted below:—

(i) For single segmental arch, centre shall be struck immediately after the arch is finished.

(ii) For series of segmental arches, centre of each arch shall be struck as soon as the arch succeeding it is completed.

(iii) For semi-circular, elliptical or pointed arches, centres shall be struck as soon as the brickwork has reached two-thrids the height of such arches.

Precautions for Relieving Arches

7. The space between the relieving and flat arches shall not be filled till the wall has been completed.

Other Respects

8. In all other respects it shall conform to Specifications No. 21.1 for Brickwork (General).

NO. 21.6 LINING TUNNELS WITH BRICKS

Specifications

Scope

1. This section covers the lining of new tunnels and the relining of old tunnels through ordinary formations.

Bricks

2. First class bricks or vitrified bricks shall have a crushing strength of not less than 6,000 lbs. per square inch and when broken in two parts and immersed in water for 24 hours, shall not absorb water in excess of 3 per cent of their weight.

Mortar

3. The mix of the mortar shall be as shown on the drawing and, if not shown on the drawing, as specified. It shall conform to Specifications No. 19.1 to 19.5 for Mortar.

Side Walls and Arches

4. In side walls, the bricks shall be laid with their 4 inches by 8½ inches face up, and every fifth course shall be headers; in arches, every alternate course shall be headers, and joints shall not be less than 1/4 of an inch and not more than 1/2 of an inch thick. All joints must be filled solidly with mortar.

The space between the natural face of the tunnel and bricklining shall be filled with concrete or hard durable stone, thoroughly rammed, or tamped into place. When it is necessary to temporarily support the face of the excavation with steel or timber supports, the space between the liner plates or lagging and the face of the excavation shall be firmly packed with hard durable stone rammed into place, or sand placed pneumatically. The space between the lagging or liner plates and the bricklining shall be filled with concrete or hard durable stone thoroughly rammed or tamped into place.

Drainage Openings

5. Weep holes shall be placed through the side walls at intervals of not less than 20 feet, unless drainage conditions require closer spacing. These holes shall be formed of cast-iron pipe not less than 4 inches in diameter and placed on a slope of 45 degree. The outer end of weep holes shall not be less than 12 inches above the bottom of the side drains.

Where the tunnel floor is paved with concrete and where moisture is present in the sub-grade below the concrete, invert, perforated drains to the gutter as required and shown on the drawings shall be provided. Four inches round drains shall be provided through the concrete ballast wall to provide drainage for the ballast section.

Side wall drainage shall be installed at not less than 20 feet centres and where moisture is present, at closer spacing. If groundwater is present, vertical and diagonal openings, trench drains, or iron pipe drains shall be provided in the rear of the lining. The drains shall be carefully installed and adequately anchored and shall terminate in openings through bricks of not less than 4 inches in diameter. Openings through the bricks shall be provided using cast-iron pipe with the outer ends of the outlets not less than 12 inches above the bottom of the side drains.

Refuge Niches

6. Refuge niches shall be at least 7 feet high and the dimensions as shown on the drawings. In single track tunnels the brickwork at back of niches should not be less than 1 course thick. Niches should be spaced approximately 100 feet apart and staggered with opposite side so that niches will occur every 50 feet in the tunnel. The bottom of niches shall be at the elevation of the base of rails.

Other Respects

7. In all other respects it shall conform to Specifications No. 21.5 for Brickwork in Arches.

NO. 21.7 CORBELLING

Specifications

Laying

1. Unless otherwise specified or directed by the Engineer-in-charge, corbelling shall be affected by 1/4th brick projection in ordinary work and 1/8th brick projection in a work where greater strength is required.

2. In all other respects it shall conform to Specifications No. 21.2 for Brickwork First Class. **Other Respects**

NO. 21.8 COPING

Specifications

1. Unless otherwise specified, the top courses of all plinths, parapets, steps, etc., shall be built in brick on edge. In case of parapet walls the outside half of the brick shall be weathered and throated. The corners shall be made by cutting fine bricks or by special bricks of 9" × 9" × 4$\frac{3}{8}$" size to give a radiated and keyed joint. **Laying**

2. In all other respects it shall conform to Specifications No. 21.2 for Brickwork First Class. **Other Respects**

NO. 21.9 WINDOW SILLS

Specifications

1. Unless otherwise specified, window sills shall be made by laying brick on edge over 1$\frac{1}{2}$ inch tile creasing to keep the joints in line. The bricks shall project 3 inches from the face of the wall and shall be weathered on the upper edge and throated underneath up to 3 inches from either end. **Laying**

2. The sills shall be measured by length. The unit of measurement shall be one running foot. **Measurement**

3. In all other respects it shall conform to Specifications No. 21.2 for Brickwork First Class. **Other Respects**

NO. 21.10 CORNICES

Specifications

1. Unless otherwise specified or directed by the Engineer-in-charge, all cornices shall be in line with the straight and parallel faces. All exposed cornices shall be weathered and rendered on top in specified mortar and throated underneath. The profile shall be checked constantly with the sheet iron templates. **Laying**

Cornices intended to be pointed shall be made with specially moulded bricks or bricks cut and rubbed so as to give mouldings true to drawings. In cornices to be plastered the bricks shall be roughly cut so as to allow the plaster to finish true to drawings and templates. Thickness of plaster shall not be less than half an inch and more than one inch.

2. The measurement of cornice shall be done by length. The unit of measurement shall be one running foot. **Measurement**

3. In all other respects it shall conform to Specifications No. 21.2 for Brickwork First Class. **Other Respects**

NO. 21.11 STRING COURSES

Specifications

Laying — 1. String courses shall comprise bricks laid on edge or flat in one or two courses as actually specified.

Other Respects — 2. In all other respects, it shall conform to Specifications No. 21.2 for Brickwork First Class.

NO. 21.12 EAVE BRICKWORK

Specifications

Laying — 1. Eave bricks shall be laid flat or on edge as specified with a projection of 3 inches and chamfered 1½ inches on the upper edge.

Measurement — 2. Eave brickwork shall be measured by length. The unit of measurement shall be one running foot.

Other Respects — 3. In all other respects it shall conform to Specifications No. 21.2 for Brickwork First Class.

NO. 21.13 DRIP COURSE

Specifications

General — 1. Brickwork in drip courses when made of flat bricks, shall conform to Specifications No. 21.12 for Eave Brickwork and measured and paid at the same rate. When built in brick on edge it shall conform to Specifications No. 21.9 for Window Sills and measured and paid at the same rate.

NO. 21.14 BRICKWORK IN REIMBURSEMENT TO DRAIN

Specifications

Laying — 1. Bricks shall be laid flat or on edge as shown on drawings or as specified. Each brick shall be set on a layer of at least 1/4-inch mortar with vertical joints filled with mortar and bedded in by tapping with the handle of the trowel. The width of reimbursement shall be 9 inches and shall be constructed on sides of the roads sloping towards the drain; the slope shall be 1/8 of an inch in 9 inches. Cut and dressed bricks shall be laid in imbursement for laying narrow strips in width along sides of drain, for all curves, bends, slopes, change of slopes and irregular areas. No extra amount shall be paid for any difficulty or complicated items required during execution.

Joints — 2. The thickness of the joint shall not be less than 1/4 of an inch and not more than 3/8 of an inch. All joints between bricks and along outer end and inner side of reimbursement shall be completely filled with mortar and struck.

3. The base concrete shall be of specified thickness. **Base**

4. All strips, sides and narrow width areas shall be filled with dry bricks on edge or flat. **Strike**

5. The brickwork in reimbursement shall be measured by length. The unit of measurement shall be one running foot. **Measurement**

6. In all other respects it shall conform to Specifications No. 21.2 for Brickwork First Class. The base concrete shall be paid separately. **Other Respects**

NO. 21.15 BRICKWORK IN TEGA TO DRAINS

Specifications

1. Bricks shall be laid on end, 3 inches or 4½ inches in thickness as specified on a bed not less than 1/4 of an inch and not more than 3/8 of an inch thick. All external surface joints shall be struck. **Laying**

2. The base concrete shall be of specified thickness. **Base**

3. In all other respects it shall conform to Specifications No. 21.2 for Brickwork First Class. **Other Respects**

NO. 21.16 SUN-DRIED BRICKWORK

Specifications

1. Bricks shall be in accordance with the provisions and requirements set forth in clay brick Specifications No. 4.1 for Sun-dried Bricks. **Bricks**

2. Mortar shall be in accordance with the provisions and requirements set forth in Mud Mortar Specifications No. 19.1 **Mortar**

3. The brickwork shall be laid in accordance with Specifications No. 21.1. Items No. 6, 7, 8, 10, 16, and 21 for Brickwork (General). **Laying of Brickwork**

4. Joints of sun dried brickwork shall conform to Specifications No. 21.4 for Third Class Brickwork. **Joints**

5. Bricks used for sun-dried brickwork shall be dry. The contractor shall protect the work from the effects of rain and water till it is roofed and plastered. **Precauations**

Unless otherwise specified two courses underneath the roof battens and jambs of doors and windows to a depth of 9 inches shall be built in second class brickwork in mud. All roof beams shall be carried on piers of second class brickwork in mud for the full height and thickness of walls and of such width as specified.

6. The measurement of brickwork shall be by volume. The unit of measurement shall be 100 cubic feet. **Measurement**

7. The unit rate (on labour rate basis) for sun-dried brickwork shall include cost of carrying out brickwork and protecting it as per above specifications and/or any **Labour Rate**

other specifications specially included in the contract. It shall further include the cost of providing, using and removing scaffolding, shuttering, centring, stagging, ladders, supports and other tools and plants required for carrying out sun-dried brick-work as per above specifications.

Composite Rate

8. The unit rate shall include the cost of sun-dried bricks, mud mortar and any other material required in addition to the labour rate detailed above.

NO. 21.17 KACHA WALL

Specifications

Scope of Work

1. Kacha walls shall consist of the materials specified before and shall be proportioned, formed and erected in accordance with the specifications stated below.

Clay

2. Clay shall be in accordance with the provisions and requirements set forth in Specifications No. 3.1.

Water

3. Water in brickwork shall be in accordance with the provisions and requirements set forth in Water Specifications No. 2.1.

Type

4. Kacha wall shall be either of mud walling or pise walling type as specified.

Building of Kacha Wall

5. Mud walling shall be constructed from the slop moulded clay bricks of a size convenient to be handled. Bricks shall be used while moist and shall be placed without any mud mortar in joints.

Pise walling shall be made by laying mud in 3 to 6 inches thick layers and tightly rammed between two parallel boards which form the front and back face of the wall. As soon as the space between boards is completely filled, the same shall be moved to the next length and so on till the whole wall is complete.

Measurement

6. The measurement of kacha walling shall be done by volume. The unit of measurement shall be 100 cubic feet.

Labour Rate

7. The unit rate (on labour rate basis) for kacha wall shall include cost of making kacha wall and protecting it as per above specifications and/or any other specifications specially included in the contract. It shall further include the cost of providing, using and removing scaffolding, shuttering, centring, stagging, ladders, supports and other tools and plants required for making kacha wall as per above specifications.

NO. 21.18 GHILAFI BRICKWORK

Specifications

Scope of Work

1. All ghilafi brickwork shall consist of materials specified below and shall be carried out in accordance with the following specifications.

Pucca Bricks

2. Pucca bricks shall be in accordance with the provisions and requirements set forth in Specifications No. 4.1 for First Class Bricks.

Sun-Dried Bricks

3. Sun-dried bricks shall be in accordance with the Specifications No. 4.1 for Sun-dried bricks.

4. Mortar shall be in accordance with the provisions and requirements set forth in Mud Mortar Specifications No. 19.1. **Mortor**

5. Water in brickwork shall be in accordance with the provisions and requirements set forth in Water Specifications No. 2.1 **Water**

6. The ghilafi brickwork shall consist of first class brickwork laid in mud mortar at the outer face; the balance work shall be executed in sun-dried bricks, laid in mud mortar on the inner side. The thickness of first class brickwork at the face shall be as shown on the drawing or as specified. The face work shall conform to Specifications No. 21.2 for First Class Brickwork. The sun-dried brickwork on the inner side shall conform to Specifications No. 21.16 for Sun-dried Brickwork. **Laying**

7. Ghilafi work shall be measured by volume. The unit of measurement shall be 100 cubic feet. **Measurement**

8. The unit rate (on labour rate basis) for brickwork shall include the cost of carrying out brickwork, cutting bricks, whenever required, curing and protecting as per above specifications and/or any other specifications specially included in the contract. It shall further include the cost of providing, using and removing scaffolding, shuttering, centring, stagging, ladders, supports and other tools and plants required for carrying out brickwork as per above specifications. **Labour Rate**

9. The unit rate shall include the cost of pucca bricks, sun-dried bricks, mud mortar and any other material required, in addition to the labour rates detailed above. **Composite Rate**

NO. 21.19 BRICKWORK WITH HOOP IRON

Specifications

1. In partition walls 3 inches or 4½ inches thick a reinforcement of 1 inch wide 18 guage hoop iron shall be placed in courses not more than 12 inches apart and continued for 9 inches into the main wall on which the partition wall abuts. If the partition wall exceeds 20 feet in length or 15 feet in height the hoop iron shall be introduced at courses not more than 6 inches apart. **When Used**

2. In respect of materials, workmanship, curing and protection, it shall conform to Specifications No. 21.2 for Brickwork First Class. **Material and Construction**

3. It shall be measured by the superficial area. The unit of measurement shall be 100 square feet. **Measurement**

4. The unit rate (on labour rate basis) for brickwork with hoop iron shall include cost of carrying out brickwork, cutting bricks, whenever required, curing and protecting as per above specifications and/or any other specifications specially included in the contract. It shall further include the cost of providing, using and removing scaffolding, shuttering, centring, stagging, ladders, supports and other tools and plants required for carrying out brickwork with hoop iron as per above specifications. **Labour Rate**

5. The unit rate shall include the cost of brick, hoop iron, mortar, tools and plants and any other material required, in addition to the labour rate detailed above. **Composite Rate**

CHAPTER 22

STONE MASONRY

Introduction

Definition

Stone masonry is the art of building in stone. In order to reduce expenses involved in the cutting and dressing of stone, only the face stones are dressed. The interior or hearting is made up with smaller stones roughly positioned with a hammer or backed up with concrete or brickwork. In most of the cases, stones of varying dimensions are used, which makes it a matter of great skill to obtain a proper bond in the work. Owing to the irregular shape of materials the walls have also to be built considerably thicker than walls of the same height in brick, except the walls made of fine dressed coursed stones. The large dimensions in which stone may be obtained, render it superior to brick for a building of architectural value and make it possible to have cornices of great projection and other bold features characteristic of classic styles. The comparatively large size of the blocks gives scale to the subject which is destroyed by the numerous joints inevitable with brickwork. It requires considerable experience to determine the appropriate size of blocks of stone to be used in a certain position and to ensure that they will conform to the general scale of the building. For instance very small stone used in the plinth of a huge building would look shabby and ridiculous.

General Principles

Usually stones have a granulated structure and a low tensional and shearing resistance. They should, therefore, always be laid keeping the following points in view:

(1) that they resist compressional stresses.

(2) that they have their laminae at right angles or thereabouts to the pressure.

(3) that with side thrusts, the mass of stone must be so disposed that its weight when compounded with the thrust will give a resultant that will fall within the middle third of the bed joint.

(4) that eccentric vertical loads such as from ends of beams should always have their centre of pressure within the middle third of the wall to avoid tensional stresses.

(5) that laminated stones should never be laid with their laminae planes parallel to the face of the wall, otherwise there is a danger of scaling.

Glossary of Terms

A list of terms covering the entire field of stone masonry grouped up in separate sections is as follews :—

Section I: Tools Employed

Archimedean Drill

A tool in which a to-and-fro axial movement causes a boring tool to rotate.

A mason's tool with a head of hard tempered steel which is tapered to an edge on both ends and fitted with a wooden handle.	**Axe**
A bench made of heavy timber or blocks of stone, on which a stone is set at a convenient height for the mason to dress.	**Banker**
A chisel usually having a width of 3 inches to $4\frac{1}{2}$ inches used for 'batting' or making a fine tooled finish.	**BattingTool, Broad Tool**
A tool used for obtaining and testing angles and for working chamfers.	**Bevel, Shiftstock**
A broad-faced chisel used for dressing a stone to a comparatively smooth surface.	**Boaster/Drove/ Bolster**
A pendant used to determine the position of a point vertically below a datum point.	**Bob, Centre Bob**
A tool used for scribing parallel or concentric lines on circular work or positioning working points and depths at right angles to a face or in sinkings.	**Box Trammel**
A tool used to rotate a boring tool, or a bit used for drilling holes in stone and marble.	**Brace**
A tool set on a shaft and used in the granite industry for dressing off unwanted material. After the cutting edge is positioned on the stone the head is struck with a sledge hammer.	**Bull Set**
A circular saw in which the steel disc is rimmed with Carborundum (see 'Circular saw').	**Carborundum Saw**
A power-driven saw consisting of a chain which has cutting tips attached to the links.	**Chain Saw**
A steel tool, having a plain shaft, with a cutting edge having a width varying from $\frac{1}{2}$ inch to $1\frac{1}{2}$ inches used for drafting or chiselling granite and hard sandstones.	**Chisel, Hammer Headed Chisel**
A heavy axe used for chopping off the rough surface of stone before dressing.	**Chop Axe**
A machine with a power-driven revolving steel disc to the rim of which abrasive elements are attached.	**Circular Saw**
A tool, usually having a width of $1\frac{1}{2}$ inches to 2 inches, used in conjunction with a mallet in making drafts over a stone surface, the teeth being formed to prevent the stone plucking or lifting in holes.	**Claw-Chisel**
A thin gauge steel plate with a serrated edge (resembling the shape of a cock's comb), used for scribing around a zinc templet on stone and also for combing a very fine surface to moulded stone work, see also 'Drags'.	**Cock's Comb**
A power-driven machine similar to a 'planer', but capable of being set at an angle.	**Coulter-Machine/ Canting-Arm Machine**
A tool used for sawing large blocks of stone into smaller sizes.	**Cross-Cut Saw**
Chisels of various sizes used in conjunction with an iron hammer, chiefly for letter cutting and carving.	**Cup-Headed Tools**
A circular saw in which the steel disc is rimmed with industrial diamonds. It is used for fast cutting of hard stone.	**Diamond Saw**

Punch/Hammer Headed Punch — A steel chisel drawn nearly to a point and used for shaping the rough stone before tooling.

Quarryman's Axe — A double bladed steel axe, approximately 14 lb in weight, used for scabbling rough block stone to square dimensions.

Quirking Tool — A tool similar to the lewising chisel. It has a width of 3/8 of an inch to ¾ of an inch, and is used for cutting grooves in sills, grooves for lead flashings, and the like.

Rubbing Table — A flat, circular table, having a cast iron top which rotates slowly on a vertical axis, on which stone, marble or granite can be rubbed to a fine finish.

Scabbling Hammer — A hammer that has one end pick pointed; it is used for roughly dressing granite or hard stone.

Spall Hammer — A hammer having a concave end, forming two cutting edges used for removing superfluous stone.

Splitter — A hammer headed tool, 3 to 4 inches wide, having a cutting edge approximately 1/16 of an inch thick.

Templet/Template — A pattern of wood or metal cut to a required profile and used to outline a shape for cutting and to gauge the profile as the work proceeds.

Tracer — A large chisel used for tracing a shallow groove along a series of plug holes to assist in the splitting of a mass of rock.

Trammel and Scriber — A tool used for scribing parallel lines.

Trammel Points — Metal points used in conjunction with a wooden beam to strike large circles.

Vertical Polisher — A mechanically-driven vertical shaft having a universal joint, terminating in a disc to which abrasive elements can be fed or fitted.

Whip Saw — A narrow saw of flexible steel, 2½ feet to 4 feet long and 1 inch to 2 inches wide, having 4 to 5 teeth to an inch and a wooden handle at each end in line with the blade. It is used for sawing around curves.

NOTE.—The whip saw is specially used for tracery work and one handle is sometimes made detachable to allow the blade to be threaded through small openings.

Wing Compasses — Compasses having a thumb screw which works against a quadrant bar so that the spacing of the points can be fixed.

Section II: Types of Surface Finishes

Angle Tooled/ Angle Droved — Stone dressed so that the tool marks run diagonally across the face.

Axed — A patent axe or a bush hammer having a surface obtained by using an axe. A surface is said to be 'fine axed' when it has been chopped with fine axe marks. 'Once-axed' is the term used for rough chopping of a surface with an axe.

Batted (Broad Tooled) — A surface having been obtained by using a batting tool in parallel strokes each traversing the full depth of the stone face. The strokes may be vertical, when it is often referred to as tooling or oblique at an angle of 45° to 60°. The result is a regular pattern of fluted cuts in the stone face. The number of strokes per inch may vary from 8 to 10.

Roughly shaping a slab or stone. **Blocking out**

A stone finished by dressing with a boaster. **Boasted/Droved**

Reduced by rough dressing, usually with a point tool, to approximately the form required by a sculptor. **Boasted for Carving**

Worked with a point to show diagonal or horizontal furrows. **Broached (Droved)**

Having a smooth sawn face, as produced by a carborundum saw. **Carborundum Sawn**

Hacked or hammer dressed. **Cloured**

The surface obtained by splitting or cleaving a rock. **Cloven**

Having all irregularities on the exposed surface of soft stones worked off by the use of a drag or a comb. The comb is drawn over the surface of the stone in all directions after it has been roughly reduced to a plane with a saw or chisel, making it approximately smooth. **Combed**

Fine and close sparrow pecked with a sharp point. **Dabbed**

A tooled margin, ¾ of an inch to 2 inches wide, worked on the face of a rough squared stone. **Drafted Margin**

See 'Combed'. **Dragged**

1. Having any kind of worked finish. **Dressed**

2. Of slate; having a bevelled edge as left by a dressing knife or guillotine as opposed to a sawn edge which is not bevelled.

Having a dull polish or a matt surface. **Eggshell/Honed Snaked**

A stone cut with the laminae running vertically and parallel to the face. **Face Bedded**

Having a surface worked into a regular series of concave grooves. **Fluted**

Having a surface consisting of small flutings. **Furrowed**

Having a rough face prepared with a hammer. **Hammer Dressed/ Bull Faced**

A stone cut with the laminae running vertically and parallel to the joints. **Joint Bedded**

The labour in forming the intersection of two mouldings, splays and the like; the seen faces making an angle less than 180°. **Mitring Internal**

The labour in forming the intersection of two mouldings, splays and the like; the seen faces making an angle greater than 180°. **Mitring External**

Cut to the profile of a moulding. **Moulded**

Having a fine dressing made with a chisel. It is generally applied to kerbs. **Nidged**

Having the arris rounded to a radius of approximately one-eighth of an inch. **Pencil Arrissed Pencil Edged**

Picked/Pecked/ Sparrow Pecked — A dressing obtained by means of a point tool or a pick.

Pitched — A surface produced by a pitching tool to resemble the natural rock face.

Polished — Having a high-gloss mirror-like finish. It is also synonymous with the term 'rubbed' used for stones.

Punched — A finish obtained by removing the larger irregularities by means of a point tool.

Reticulated — An irregular network of bands worked on a true-faced stone. The sinking between the bands is about 3/8 inch deep, worked true to a gauge and 'picked' with a fine mallet headed point.

Rock Faced — The natural face of the rock or a dressing resembling it.

Rubbed — A finish obtained by rubbing with abrasives to the degree of required smoothness.

Rusticated/Channel — A stone having a sunk dressed margin.

Sanded — Finished by rubbing with abrasives.

Scabbled — Finished by fine angled droving.

Scappled — Roughly faced with pick or hammer.

Scribbled — Hammer dressed beds or joints of masonry with marginal chisel drafts.

Shotted — The face resulting from grinding with steel shot by means of a heavy steel ring used in a polishing machine.

Stugged — Pecked stone faced with a pick or pointed tool.

Vermiculated — Having a dressing, taking the form of irregularly shaped sinkings resulting in winding worm like ridges.

Section III : Handling Equipment for Stone

Chain Tackle — Pulley blocks having an endless chain used for hoisting stone.

Dogs and Chains — A pair of steel hooks, having rings attached to it, into which a chain is slung so that a vertical pull on the chain draws the hooks together in a horizontal direction, thus gripping the stone.

Lewises/Chain Lewis — Two curved steel legs inserted back in a mortice cut in the top of a stone, and connected together at the top by three rings in such a way that a direct pull causes the legs to spread at the bottom and grip the sides of the mortice.

Lifting Pins/Pin Lewis — Steel pins approximately an inch in diameter and about 9 inches long having an eyelet at the end with a ring attached, used in pairs for lifting stone into position. The pins are inserted into inclined holes drilled in the stone, and are connected by a lifting chain.

Three-Legged — Two wedge-shaped steel legs separated by a removable rectangular section, the whole connected at the top by a shackle and pin. The wedge-shaped sections are inserted separately into a dove-tailed mortice cut in the top of the stone. The centre section is then inserted and the shackle and pin assembled so that the stone can be lifted by a pull on the shackle.

Rolls Lewis — A lighter type of three-legged lewis for lifts up to 25 cwt.

Nibs — Small projections left on the faces or sides of a worked stone in which dog holes can be cut for lifting the stone into place. The nibs are worked off after positioning the stone.

(*NOTE*—A prominent projection from the general face of marble dressings is sometimes called a Nib.)

Shears, Snips, Scissors — A device, similar in shape to tongues or scissors, used to grip the ends of a stone in the same way as chain dogs.

Silver — Thin strips of steel, approximately 5/8 inch wide, used to pack a badly fitting 2-leg or 3-leg lewis hole to ensure safe hoisting.

Sling Chain — Chain passed round a stone and attached to the lifting apparatus.

(*NOTE*—The arrisses of the stone should be protected by wooden slates.)

Section IV: Fixing Stone in Position

Anchor Bolt — A T-shaped bolt for attaching fascia and similar stones to a supporting R.S.J. The arms of the 'T' engage in mortices cut in the joint faces of the stone, and the threaded end of the bolt is inserted in a hole drilled in the R.S.J. and fitted with washer and nut.

Cement Joggle/Grout Nick — A V-shaped sinking in the side joint of each adjacent stone in the same course. After fixing, two sinkings together form a rectangular hole which is filled with cement grout in order to prevent lateral movement.

Centring — A temporary wooden structure on which arches are built.

Corbel Plate — A metal plate let into and projecting from the backing to provide support for facing slabs.

Cramp — A short length of metal or slate suitably bedded into sinkings cut in stones. It is used to tie stones to one another or to their backing.

Dowel/Slate Dowel — A short piece of metal or slate bedded in sinkings cut in the joint faces of adjacent stones to prevent independent movement of the two stones.

Fixer's Bedding — Lime putty used by fixers.

Grout — Liquid mortar consisting of cement and sand.

Hollow Bedded — Blocks set with mortar at the ends only. The centre portion is left hollow to guard against breakage in case of settlement.

Slate Cramp — A piece of slate, approximately 2 inches by 7 inches by 1 inch. It is generally used in flat coping stones and cut to a double dove-tail form. It is embedded in Portland cement in sinkings formed to receive it.

Slate Joggle — A small piece of slate left into a vertical joint and into the top bed of the stone below to prevent independent movement of stones.

Slurrying — Protection of the finished surface by coating with a weak mix of lime and stone dust to prevent staining. This slury is washed off on completion of the job.

Section V: Architectural and Engineering Terms

Abutment — The solid structure at the extremity of an arch or beam.

Apex Stone — The top stone of a gable, spire or pediment.

Arch — A method of spanning an opening with masonry consisting of a series of wedge-shaped stones, known as voussoirs or arch stones which are supported by lateral pressure induced across the radial joints.

Flat Arch — An arch in which the voussoirs or arch stones are arranged to provide a horizontal soffit.

Joggled Arch — An arch in which adjacent stones are interlocked by means of rebates or tongues and grooves.

Skew Arch — An arch whose face is not at right angles to its supports.

Squinch Arch — An arch built across an internal angle, such as across that of a square structure, to support one side of an octagonal spire rising from the structure.

Stilted Arch — An arch having its springing line higher than the line of the impost.

Arris — The line or edge made by the junction of two surfaces forming an external angle.

Band Course — A plain course continued horizontally along the face of a building or structure.

Band Stone — An intermediate coping stone or stones inserted in a gable between a springer and the apex and bonded into the gable wall.

Barge — A projecting stone drip at the base of a chimney stack to throw off water.

Base Course — The lowest course of a wall.

Batter — An inward inclination of the exterior face of wall.

Bed — The lower surface upon which a block of stone rests, and the upper surface which supports the stone above.

Bed Joint — A horizontal joint in a wall or a radiating joint between the voussoirs of an arch.

Bed Mould — The lowest moulding or course of a cornice.

Bedstone — A large flat stone upon which machines or structural members are mounted or bedded.

Belting — A course which protrudes from the face of a wall into which it is built, and which may have a convex surface.

Bridsmouth — A notch cut on the edge of one piece of stone to receive another.

Block Stone — A stone roughly squared at the quarry.

Blocking Course — A plain course of masonry over a cornice.

Bollard — A short strong post (originally intended for holding a hawser).

An arrangement of stones whereby the vertical joints in one course do not coincide with those in the courses above or below.	**Breaking Joint**
A stone whose longer dimension is in the thickness of the wall and which may run right through the thickness of the wall.	**Bonder/Bondstone**
The flat surface formed by planing off the sharp angle made by the meeting of two surfaces. This term is usually applied to stone or wood surfaces, while a 'bevel' refers generally to glass or metal surfaces.	**Chamfer**
A sinking either in the form of a rebate or a slot.	**Check**
Thin slabs of stone or other material used externally as a non-load-bearing covering for the structure of a building.	**Cladding**
The inside vertical surface of a stone which extends through the thickness of the wall and forms a face on the inside.	**Clean Back**
A stone placed in a course to close or fill a gap.	**Closer**
A free standing vertical member, usually circular on plan.	**Column**
The topmost course of masonry on a wall, which may overlap the surface to give protection from the weather to the courses beneath.	**Coping**
A coping weathered both ways from the centre of the section (i.e. twice splayed) and either projecting from the wall and throated on both sides or flushed with the wall on both sides.	**Saddle Back Coping**
A coping with a rounded top.	**Segmental Coping**
A wedge-shaped coping. It is higher on the front face to divert water towards the back and has a horizontal bottom bed and a weathered top bed. The coping usually projects beyond each face of the wall, and these projections are throated on both the undersides. Sometimes, the coping projects and is throated only at the back with the front face flush with the face of the wall.	**Wedge Coping**
A stone or series of stones which project from a wall and often used as a support.	**Corbel**
Crow step in a stepped gable.	**Corbel Step**
The stone from which steps are formed in a stepped gable of a wall.	**Crow Step**
A general term used for all masonry.	**Dressings**
See 'Hood Mould'.	**Dripstone**
One of the stones composing the shaft of a column.	**Drum**
A stone cut with the laminae running vertically rather than horizontally.	**Edge Bedded/Joint Bedded**
(*NOTE.*—Edge bedding is used in the cutting of voussoirs with a view to distributing strain around the arch and so helping to avoid breakage and exfoliation when the stone is submitted to the action of time and atmosphere.)	
Rebate in stonework into which a door closes when hung without a frame.	**Giblet Check**

Header	A stone laid so that its greatest dimension is in the thickness of the wall. c.f. Stretcher.
Hearting	The infilling which forms the core of a rubble wall.
Hood Mould/ Dripstone/Label	A projecting moulding or canopy over a door or window opening to throw off rain from the walls of the building.
Impost	The top member of a pier or pillar from which an arch springs.
Inban/Inband	A quoin or jamb stone short on main wall face and long (for bonding) in return or reveal, c.f. Outban or Outband.
Inband Rybat	Header stone in a jamb of an opening.
Inbond	Header on a reveal or return.
Indenting	The omission of stones to form recesses into which future work can be bonded.
Jamb Stone	One of the number of stones forming part of the vertical surface at the sides of a door or window opening.
Joggle	1. A projection on one stone to fit into a corresponding recess in another stone. 2. Adjacent recesses for filling with cement grout or mortar.
Jumper	A stone that in facework bonds two or more stones on each side. It is used in squared, uncoursed and snecked rubble work.
Kerb/Curb Stone	A stone used as an edging (See 'Curb Stone').
Keystone	The central stone of an arch.
Kilt	Slight weathering commonly given to stone steps in the setting.
Kneeler	A stone bonded into the wall and forming an intermediate length of the coping to a gable end.
Linings	Thin slabs of stone or other material used internally as a non-load-bearing covering.
Lintel (Head)	A stone which spans, in one piece, the top of an aperture.
Long Stone/Saving	A relieving arch over a lintel.
Mason's Mitre	A mitre worked out of a single piece of stone and not forming a joint at the mitred angle as in a joiner's mitre.
Mortice	A sinking in a stone to receive a corresponding projection, dowel, rail, etc.
Mullion	A vertical member sub-dividing a window.
Outban/Outband	Quoin or jamb stone long on main wall face for bonding and short in return or reveal c.f. Inban or Inband.
Outband Rybat	Stretcher stone in a jamb or opening.

A stone incorporated in the structure to distribute a concentrated load.	**Padstone/Template**
A through bond stone faced on both ends.	**Parpend**
A birdsmouth rebate.	**Pen/Pen-Check/ Pend**
A vertical joint in masonry.	**Perpend**
Any load bearing vertical mass of masonry, either isolated or attached to a wall.	**Pier**
A flat rectangular pillar which projects from a wall.	**Pilaster**
A free standing vertical member rectangular or polygonal on plan.	**Pillar**
A series of small shallow stones introduced at intervals to make up the height of certain courses, thus giving a chequered effect.	**Pinning**
The projecting base of a wall or column.	**Plinth**
An eaves course, wall head course, or plinth course.	**Plinth Course**
A raised platfrom forming the base of a building.	**Podium**
A stone at an external angle of a wall.	**Quoin**
A sinking to receive a flashing for the edge of steps.	**Raggle/Raglet**
The process of cutting a raggle.	**Ragletting/Ragling**
A continuous rectangular sinking, along the edge of a stone either to receive window or door frames or another member.	**Rebate**
The termination of stone worked to form an internal mitre on a moulding or splay or on weathering.	**Reprise**
A half pillar or pilaster corresponding to another or to a pillar opposite to it.	**Respond**
A change of direction in a wall, member or moulding.	**Return**
The termination of stone worked to match the face with an external mitre.	**Returned End**
That part of the jamb of a window or door opening which is not covered by a frame.	**Reveal**
Reveal stone, c.f. Inban, Outban.	**Ryhat**
1. Apex stone to a gable. 2. A coping splayed both ways.	**Saddle**
A stopped joint in a coping or projecting course used to prevent penetration of water.	**Saddle Joint/Half Checked Joint**
1. Interval reveal. 2. The facing to a reveal behind an outband rybat (q.v.) return of a pier or pilaster. 3. Open finished end of a wall.	**Scuntion/Scontion Scuncheon**
The lower horizontal member of window openings and certain external door openings.	**Sill/Cill**

Skew The sloping dressed stones or copings that finish the top of a gable.

Skewback An inclined or splayed surface of an abutment from which an arch springs.

Skew Putt/Club Skew, Skew Corbal The bottom stone at skew supporting a raking, coping or skew above.

Slip Narrow piece of stone inserted between large blocks.

Soffit The under surface of a lintel or an arch, or the lower surface of a vault.

Spandrel A triangular space enclosed by the curve of an arch with a horizontal line drawn through its apex and a vertical line drawn through its springing.

Splay Any surface included to a main surface, e.g. an inclined window reveal.

Springer The stone from which an arch springs.

Springing Line The level from which an arch begins.

Spur Stone/Powl Stone/Stone Codding A stone suitably shaped and fixed at the corner of a building or opening to prevent damage to the structure from traffic.

Stool A seating such as that on both ends of a sill to which a window jamb is fixed.

Stopped End The termination of a moulding worked in the solid.

Stretcher A stone laid in a way that its greatest dimension is in the length of the wall.

String/Stringer A series of inclined slabs at the free end of steps covering the concrete core and following the line of the staircase.

String Course/Belt Course/Band Course A narrow moulded or plain projecting course continued horizontally along the face of a building.

Throating/Throat/Drip A groove worked in the under surface of projecting stone work to prevent rain-water from flowing back to the wall.

Through Stones Stones which extend through the entire thickness of a wall as a tie or bond.

Toothing The end of a wall left with courses breaking joint for future extension.

Transom A horizontal bar sub-dividing a window or other opening.

Upstart/Start A reveal stone long in vertical dimension.

Voussoir A wedge-shaped stone forming a unit of an arch.

Section VI : Walling

Ashlar Masonry consisting of plain blocks of stone, finely dressed to given dimensions and laid in their courses.

Block in Course Roughly squared blocks of stone which may vary in length having worked beds and hammer dressed faces and joints, and set in courses which may vary in height not exceeding 12 inches.

(*NOTE*—Used in heavy engineering masonry.)

Walling, similar to uncoursed rubble, which is roughly levelled up to courses at intervals and varies in height according to the locality and the type of stone used. **Brought to Courses**

(*NOTE*—The course heights usually correspond with the heights of the quoin and jamb stones.)

A filling of undressed stone used in the interior of a wall. **Core**

A continuous layer of stones of uniform height. **Course**

Rough squared stone walling in courses to suit the heights of corner stones or rybats. **Coursed Rubble**

A layer of material impervious to moisture e.g. slate, interposed between other materials to prevent the passage of water by capillary action or otherwise. **Damp-Proof Course**

Walling without mortar. **Dry Walling**

A rubble boundary wall. **Dyke**

Having small stones inserted into the mortar face joints in unjointed walling, usually for decorative purposes but sometimes to wedge the larger stones in position. **Galleted/Garnetted**

Flint cobbles or nodules split across and used in walls with the split face showing. **Knapped Flint**

A course of bricks, dressed stone, tile or other material built into walls of random rubble or flint to give added stability and strength. **Lacing Course**

Ashlar faced on both sides, as for parapet walls. **Parpend Ashlar**

Walling built of stones of irregular shape which may be roughly pitched to fit the adjacent stones. **Polygonal/Rag Walling**

Walling built of irregular unsquared stone not in courses. When it is levelled up, about every 12 inches in height, it is called 'Random rubble brought to courses'. **Random Rubble**

Stone of irregular shape and size. **Rubble**

A small stone in squared rubble work to make up the bed for bonding. **Sneck**

Rubble walls in which the stones of irregular size squared with small stones or snecks are introduced to break the courses. **Snecked**

Walling, built of irregular squared stone, not in courses. When it is levelled up, about every 12 inches in height, it is called 'Squared rubble brought to courses'. **Squared Rubble**

A wall in which each flint is cut to a uniform, regular size generally 4 inches square and laid in courses. **Square Flint Facing**

Working the top face of a stone to a plane surface inclined to the horizontal for the purpose of throwing off rain water. **Weathering**

Section VII : Cast Stone

The application of an acid solution to the surface of cast stone for the purpose of removing the superficial cement film and producing slight exposure of the aggregate. **Acid Treatment**

Cast Stone/ Artificial Stone (Deprecated)/Re-constructed Stone — A building material manufactured from cement and natural aggregate for use in a manner similar to and for the same purpose as natural building stone.

Crazing — The cracking of the surface into small irregularly shaped contiguous areas.

Curing — The process of maturing cast stone under controlled conditions.

Dry Pressing/Dry Temping — The process of producing cast stone using a mix with a minimum water cement ratio. The process permits very early de-moulding.

Drying Shrinkage — The slight contraction occurring in a unit during the first drying after casting.

Etching — A term almost synonymous with 'Acid treatment', but it is generally assumed to be a rather more severe treatment, producing a greater aggregate exposure.

Exposed Aggregate — A finish produced by the removal of surface to expose the colour, texture and pattern of the aggregate.

Filling in/Bagging in/Ragging in — The treatment of the surface of a unit after casting. with a mixture of cement and fine crushed stone rubbed into the pores of the material to produce a closer texture.

Handling Reinforcement — A material, such as mild steel rod, incorporated in cast stone solely for the purpose of permitting the unit to be handled without damage till it is built into its position on the site.

Insitu Concrete — Concrete which is cast in the place where it is required to harden as part of the structure.

Laitance — The thin layer composed of cement and fine particles of aggregate that may form on the surface of concrete.

Masoned Cast Stone — Cast stone, after reaching a mature state, treated by hand or by machine to produce surfaces commonly used for natural stone, e.g. boasted, bush-hammered, sparrow pecked, tooled and rubbed.

Maturing — The process of the hardening of cast stone.

Mould — A container made of metal, timber or other material, shaped to the pattern it is desired to reproduce, into which concrete is placed.

Plain Cast Stone — Cast stone which is untreated after removal from a mould.

Precast Concrete — Concrete which is cast in separate units before being placed in position in a structure.

Retarder — Material added to concrete during mixing, or applied as a coating to the mould, which reduces the rate of hardening of the cement.

Rubbed Finish/Fine Ground Finish — The finish produced by stoning.

Stoning/Rubbed Finish/Fine Ground Finish — The grinding by hand of the surface of cast stone with an abrasive to produce an even and smooth texture, but only exposing slightly the surface of aggregate.

Structural Reinforcement — Material, usually mild steel, incorporated in cast stone to make it strong enough to withstand the tensile stresses induced in the permanent structure.

Terrazzo — A finish consisting of marble (or similar) chippings in a cement matrix, ground after casting to produce a polished surface.

Tooled Finish

A finish obtained by removing the original face with a hand or power-operated tool.

Water Repellent

1. *Integral*—A material incorporated in a cast stone mix for the purpose of improving the resistance of the finished product to the penetration of moisture.

2. *Surface*—A material, usually in liquid from, applied to the surface of cast stone after manufacture for the purpose of improving its resistance to the penetration of moisture.

Milling

The process of converting quarried blocks of stone into a finished product is called milling. It includes the sawing of blocks into slabs of the desired thickness with various types of saws; planing them to improve the surface finish or cut mouldings on their surfaces; turning columns, balusters etc., in lathes; milling recesses, pattern and lettering on the faces of stones by means of a milling machine; and carving and dressing the stones into various shapes and forms with hand tools or with pneumatic tools operated by hand and finishing the surface to the desired degree of evenness.

The cut or the dressed stone is the product of the stone mill. A stone of large size or special shape or any stone for which all dimensions are specified in advance, other than finished cut stones, is called dimension stone.

Surface Finish

There are various methods of finishing the exposed surface of building stone. The finish which is suitable for a given surface is governed by the kind of stone and the manner in which it is used and varies from the rough face formed in quarrying to the highly polished face often used on marbles and granites. The various types of surface finishes are described below:

(a) *QUARRY FACE OR ROCK FACE*—It is the original face of a stone when it comes from the quarry. It may be formed by quarrying operations, or may be a natural seam. In the later case it is known as a seam face. Quarries producing seam-face stone are traversed in all directions by natural seam forming relatively small blocks of stone of irregular shape and size. Seam faces are often highly coloured by deposits from mineral laden waters which have penetrated into the seams. It is employed in pitching, dumping, retaining walls, etc.

(b) *HAMMER DRESSED OR SCABBLED FACE*—Scabbling means taking off the irregular angles of stone with the scabbling hammer. That is usually done at the quarry, and the stone is then said to be quarry pitched, hammer faced or hammer blocked. If, after scabbling, the face of stone is roughly dressed also by Waller's hammer, the finish is called hammer dressed face. Hammer dressed faces are commonly used on granite and harder limestones and sandstones but are not suitable for softer varieties of limestone. This type of stone is used in rubble masonry or stone pitching.

(c) *ROUGH TOOLED FACE*—Rough tooled (also called one-line dressed face) is sparrow pitched or chisel dressed. No portion of the dressed face is more than 1/4 inch from a straight edge placed on it. It is analogous to rough or coarse pointed finish. This sort of finish is usually employed to give a bold appearance to quoin and plinth stones and where so used, it usually has a chisel drafted margin about the perimeter.

(d) *CHISEL DRESSED FACE*—Chisel dressed face (also called two-line dressed face) is again sparrow pitched or chisel dressed. No portion of the dressed face is more than 1/8 inch from a straight edge placed on it. It is analogous to medium pointed

Classification of Stone Masonry

In classifying stone masonry, it is necessary to take into account the degree of refinement used in shaping the stones, the way the face stones are arranged in the wall and the surface finish of the stones.

There are no accepted standards for classification, but in general the crudest type of masonry made of stones with little or no shaping is called rubble, and the best type made of stones accurately shaped so as to make thin joints possible, is called ashlar. Between these two extremes, there are various degrees of refinement in shaping the stones and many ways of arranging them in the wall. The most common classification divides masonry into rubble, squared stone masonry or ashlar block in course masonry and ashlar as far as the shaping of stones is concerned, and into range, broken range, and random as far as the arrangement of stones in the wall is concerned. The latter classification does not apply to rubble which is classed as coursed and uncoursed. Ashlar is also called cut stone. There is no definite line of demarcation between ashlar and squared stone masonry (or ashlar block in course masonry) or between squared stone masonry and rubble. When stratified stone is used, the horizontal joints of rubble may be as narrow and as uniform as those of squared stone masonry and the distinction between the two classes would lie in the vertical joints. If the work done on such stone consists only of knocking off loose rock or sharp corners, rubble would probably be the result; but, if the stone is shaped to give a uniform vertical joint, squared stone masonry would be produced. If the end joints are not vertical, but are uniform in thickness, the class of work would be the same as that on squared stone masonry. Such masonry could not locally be placed in that class because of the shape of the stone.

Various classes of stone masonry are briefly described below:

(a) *ASHLAR MASONRY*—It consists of sawed, dressed, tooled rubbed, or moulded stone with extremely fine bed and end joints. The thickness of these joints never exceeds 1/8 inch. Such accurate work is only possible when the stone blocks are cut perfectly true to the required shape, and therefore the beds and joints at least are sawn. Great care is exercised in determining the sizes and proportions of the blocks of stones to ensure that they conform to the general scale of the building. Badly proportioned stones, which are either too small or too large for the purpose, completely mar the appearance of the work. The minimum thickness of the stones or the course recommended for this sort of masonry is 12 inches. An adequate bond of blocks of uniform size is obtained if the length of each stone ranges from two to three times the height and if the courses break joints on the face by at least half the height of the course.

(b) *ASHLAR FACING*—Ashlar is the best and the most expensive grade of masonry. Usually the cost is greatly reduced by having a backing of brickwork, rubble, or concrete and a facing of ashlar blocks. It is necessary that the facing is effectively bonded with the backing and if the latter is of brickwork, unnecessary cutting of the bricks is avoided. Effective bonding is obtained and waste of bricks, labour and cutting is avoided when: (a) ashlar courses are alternately 9 inches and 4½ inches thick on the bed. (b) the thickness of the backing is a multiple of half bricks; and (c) the height of each course of ashlar is equal to the combined height of brick courses and thickness of the bed joint.

On account of thin mortar joints of ashlar and larger number of bed joints of the backing, it is necessary that the latter joints are as thin as possible so as to guard against unequal settlement. To ensure that ashlar vertical joints are completely filled with mortar, a "V" shaped notch is usually formed in each vertical joint surface forming a square hole between each pair of adjacent blocks. In constructing ashlar, mortar is spread on the front edge of the vertical surface (about 2 inches wide) of the last fixed stone; the adjacent stone is then placed in position; the back of the vertical joint is pointed with the mortar; and liquid mortar (grout) is poured down the hole to form joggle, filling completely the space between each pair of stones. The complete beds of the ashlar blocks are squared with the face. If a bed is "'worked hollow" (i.e. the surface is brought below the outer edge of the stone to form an equivalent to a frog of a brick), there is a danger of the pressure being concentrated on the outer edge, causing the stone to crack and splinter off. Minimum thickness or the height of a course in the ashlar facing is 8 inches. Almost 1/3rd of the entire length of each course consists of headers. Usually the stones used are not less than $1\frac{1}{2}$ feet long and 8 inches high. It is extremely necessary that both the facing and the backing are done simultaneously. To ensure effective bonding, bond stones spaced 5 to 6 feet apart in a course run right through the backing when the wall is less than $2\frac{1}{2}$ feet thick. In thicker walls two bond stones overlap each other by at least 6 inches.

(c) *ASHLAR BLOCK IN COURSE MASONRY*—This is the type of masonry used for harbour walls, embankments and similar heavy works. The stones are usually rock faced, square, brought to wide joints, and set in cement mortar 1:3 or hydraulic lime mortar (1 of lime and 2 of sand). The blocks are built in course, the height of which usually ranges from about 9 inches to 14 inches, and in no case is less than 6 inches. The maximum height of courses does not exceed 24 to 30 inches in the largest class of work. All the stones of any one course are of the same height, but the height of all the courses need not necessarily be the same; they may diminish regularly from the bottom to the top. No stone is less in width than $1\frac{1}{2}$ times its thickness. The length of the header and stretcher should be at least $2\frac{1}{2}$ times their thickness. In the smallest class of work no stone has a bed area less than 2 square feet and in the largest not more than 15 square feet. There is one header for every two stretchers. In walls less than 2 feet thick, through stones are inserted in every course at 5 feet intervals, breaking joints with smaller stones in courses above and below. In thicker walls more than one through stones have to be used which overlap each other by no less than the height of the course. The thickness of face joints does not exceed 1/4 inch. The interior stones called hearting or backing stones are of the same height and breadth as the face stones. They are arranged to give the best possible bond and to break joints as far as possible.

(d) *COURSE RUBBLE MASONRY*—It is frequently used for the smallest sizes of bridge abutments, small arch culverts, box and open culverts, wallings for unimportant buildings, foundations of buildings and backings of ashlar masonry. It is composed of roughly shaped stone fittings, approximate on level beds and wall bonded. When carefully executed with good mortar, the masonry possesses the strength and durability required in ordinary structures and is much less expensive than ashlar. The blocks are built in horizontal courses, the height of which ranges from 8 inches to 14 inches, but in no case is less than 6 inches. The height of all the stones in a course is the same, and all courses are preferably of the same height. All the headers of bonding stones are of the same height as the course in which they are used, and are so arranged that there is one header to three or four stretchers. The length of these headers is more than 2 feet so that only one is required for a wall of 2 feet thickness. In a thicker wall, however, more than one header are used overlapping each other by not less than the height of the course. All side joints are vertical and beds horizontal having a thickness of not more than 3/8 inch. The joints are broken on the face by at least half the height of the course. The quoins of the same height as the course in which they occur are formed of header stones at least 1½ feet long, laid lengthwise alternately along each face. They are laid square on their beds and are fairly dressed to a depth of at least 4 inches. The interior of the walls consists of flat bedded stones carefully laid on their proper beds and solidly bedded in mortar. Chips and spawls of stones are wedged, where necessary, to ensure that no dry work or hollow spaces are left anywhere in the masonry, so that thick beds or joints of mortar are avoided. The face work and backing are brough up evenly. The quality of work on the exterior face should not differ considerably from the interior one, excepting that the side joints in the latter need not be vertical.

(e) *RANDOM RUBBLE MASONRY*—This class of masonry is used for less important types of walls, like boundary walls. Stones are hammer dressed on the face, sides and beds to an extent that they come into close proximity. No stone shall project out or go into the wall less than 1½ times its height, and will not be of a greater height than either breadth of face or length of tail into wall. Beds and joints are not thicker than one inch. Stones are arranged to break joints as much as possible avoiding long vertical line of joining. It is usually laid uncoursed, but when laid in courses the height of the course is not less than 6 inches. At least one bond or through stone is provided in every 5 square feet of the face which runs right through the wall, if the wall is not more than 2 feet thick. In thicker walls continuous line is laid from face to back with an overlap of not less than 6 inches. The interior filling between the front and back faces consists of rubble stone not less than 6 inches in any direction. The stone is carefully laid, hammered down with a wooden mallet into place and solidly bedded with mortars, chips and spawls being wedged in to avoid thick beds of joints and mortar. Each stone is laid on its quarry bed.

(f) *DRY RUBBLE MASONRY*—This type of masonry is employed for constructing breast walls and retaining walls. Stones are very roughly dressed to secure the maximum bedding surface without unnecessarily reducing the size of the stone. Largest possible stones available are used in such construction, and larger stones form the lower courses. For the purpose of stability these dry walls are built with a face batter of 1:4 having a vertical back. The base as well as the courses run at right angle to the face of the wall. Proper bond is secured by providing at least one header at an interval of 5 feet in a course. As they are normally built to retain hill slides where springs are encountered, it is necessary to have weep holes for effective drainage. Stone spawls or chips are used immediately behind these walls for filling. Earth is not used unless it is absolutely impossible to get stone chipping.

(g) *MISCELLANEOUS*—In addition to the classes of masonry mentioned above, quite a few others are being employed depending upon the types of stones and other materials (like timber) available in a locality. A compound wall having wooden framing filled with random rubble masonry or brickwork is locally known as "dhajji walls". These walls are resorted to only at places where timber is cheaper, for instance in uphill areas like Swat, Dir, etc. In case of stone filling all stones are through stones with flat beds and laid to fit close against the frames and bracings. The joints in the filling are as fine as practicable and they are broken in every course. The framing and bracing are so arranged that door and window openings fit in properly without marring the shape of the facing or requiring additional 'chowkats'. Properly seasoned wood, usually deodar or oak, is used to avoid subsequent contraction, swelling or warping. The cross-sectional dimension of the post used in framing is designed properly to safeguard against future failures. The framings are erected on a plinth raised about one foot above the ground.

Joints

Mortar layers between stones are called joints. Horizontal joints may be called bed joints or simply beds, while vertical joints are known as joints. For the best arrangement of joints in masonry, each of the face stone is set out on the drawing, especially for building with a classic motif. The following general principles are observed:—

1. All bed joints should be arranged at right angle to the pressure coming upon them.
2. The joints should be arranged to prevent any members, such as sills, from being under a cross-stress.
3. The joints should be so arranged as to leave no acute angle on either of the pieces joined.

The first condition applies to all kinds of masonry. It is necessary to prevent any sliding tendency between the stones.

The second condition applies chiefly to sills and lintels. Sills, if bedded along their entire length, are liable to fracture becasue of the tendency to greater settlement under the piers than under the walls below the openings. To prevent cross-stress, only the extremities of the sills are bedded, the remaining portion is left under the surface having no bedding.

The third condition applies chiefly to the joints in tracery work, and any exposed joints in any other work. Stone being a granular material, anything approaching an acute angle is liable to weather badly; therefore in any tracery work having several bars intersecting, a stone is arranged to contain the intersections and a short length of each bar in such a fashion that the joints are:

(a) at right angle to the direction of the abutting bars, if straight, or

(b) in the direction of normal to any adjacent curved bar.

This not only prevents any acute angle occurring, as would be the case if the joints were made along the line of intersection of the moulding, but also ensures a better finish, because intersection line can be carved more neatly with the chisel. It is also more lasting than a mortar joint occurring along the above line.

Classification of Joints and Connections in Stone Masonry

Broadly speaking, it has the following three categories:

(a) *JOGGLE JOINTS*—This includes tabling joints, cement joggle, dowels and pebble joints which are described briefly below:—

Joggle—It is a form of joint in which a portion of the side joint of one stone is cut to form a projection, and a corresponding sinking is made in the side of the adjacent stones for the reception of the projection. It is chiefly used in landings to prevent any movement between the stones and to retain a level surface. It also assists in distributing weight over every stone in the landings.

Tabling Joint—It consists of a joggle formed in the bed joints to prevent lateral displacement in the stones of a wall subjected to lateral pressure, such as in sea-wall. The projection in this case is about 1½ inches in depth and 1/3rd of the stone in width. Slate joggles having a dimension of 12"×4"×2" are often substituted for tabling joints to reduce expenses.

Cement Joggles—It consists of a V-shaped sinking in the side joint of each adjacent stone in a course. These are generally employed in the side joints of the top courses of masonry to prevent lateral movement.

Dowel—It consists usually of pieces of hardstone, slate or copper about 1 inch square in section and varying from about 2 inches to 5 inches in length, being sunk and set in cement in corresponding mortices in the adjacent stones. They are used both in the side and bed joints. They are generally used in top courses of masonry where the weight on or of the individual stone is not great, and also in dressings, about openings and in the bed joints of the drums of columns, balusters, and in any position where lateral movement is likely to occur. The united mass thus formed from the connected stones renders any movement impossible under normal conditions.

Pebbles—Small pebbles bedded in cement in the joints of stone are used to prevent lateral motion; they are very economical and effective.

(b) *CRAMPS*—They are of different types like metal cramps, lead plugs, slate cramps, anchor bolts and rag bolts.

Metal Cramps—They are used like dowels to bind work together, but are more particularly useful for positions where stones have a tendency to come apart e.g. in copings, covering a gable, or in face stones of no great depth, or cornices and projecting string courses to tie the stones to the body of the wall or to the steel skeleton supports. Cramps are made of thin pieces of metal of varying length and sectional area according to the work, bent at right angle about 1½ inches at each end. A chase with a dove-tailed mortice at each end is made in the stones to receive the cramp, the ends of which are made rough. Metals, of which cramps are usually prepared, are wrought iron, copper and bronze. If wrought iron is used it is usually subjected to some preservative process, such as galvanising, tarring and sanding or coating with a wash of neat cement, to prevent oxidation. Care is taken to cover the cramp completely with the bedding material. The best bedding materials are cement, lead and asphalt. Lead is at times objected to for external work because it tends to form a galvanic couple with the cramp in the presence of moisture, in addition to oxidation.

Lead Plugs—Stones may be connected together by means of lead in the following manner. Dove-tail shaped mortices are made to correspond the side joints of two adjacent stones into which, when placed in position, molten lead is poured. When it becomes cool it is chaulked, thus completely filling the mortices and connecting the pieces.

Slate Cramps—Consisting of pieces of slate about 7"×2"×1" cut to a double dove-tail form they are bedded in cement in sinkings, formed to receive them, and are generally used in flat coping stones.

Anchor Bolts—Long iron bolts are frequently employed at the back of cornices that have great projection. In such cases the centre of gravity of the mass is dangerously near the edge of the wall. The bolts are passed through a hole drilled through the back of the cornice, or are inserted into a chase worked along the back face of the stone, and extended a sufficient distance down the back of the wall, being provided at their lower ends with large iron plates or washers. The effect gives homogeneity to the whole mass, thus bringing the centre of gravity of the combined mass back a sufficient distance from the front of the wall to ensure safety. In steel framed buildings, steel members of the roof, secured to the building, are designed to tail down most effectively the projecting stone cornices. In pinnacles at the tops of spires and buttresses, formed of small stones, it is usual to connect a sufficient number of them together with an iron bolt, which later usually contain their common axis and thus increase stability by rendering the mass homogeneous.

Rag Bolts—The ends of the bolts are often fixed by having the end that is let into the stone jagged, and run with lead, or cement. The mortices have dove-tail shape to secure it from any upward pressure. It is replaced by an anchor bolt and plate, where there is any probability of a great upward stress. The bolt is passed through a hole drilled through the stone.

(c) *WEATHER JOINTS*—The term includes all joints or precautions taken to prevent the deterioration of the joints of cornices or other exposed parts of masonry owing to the percolation of water into the joints.

Saddled or Water Joints—To protect the joints of cornices and other exposed horizontal surface of masonry, the sinking is sometimes topped before the joints and weathered off. Any water passing down the weathered surface is diverted from the joint.

Rebated Joints—These joints are used for stone roofs and copings to obtain weather-tight joints. They are of two kinds: (1) when both stones are rebated, (2) when the upper stone only is rebated. In the first case the stones are of the same thickness throughout, their upper surface being level when the joint is made. In the second case the stones are thicker at the bottom edges than at the top, the bottom edges having a rebate taken out equal to the thickness of the upper edge of the stone below it, over which it fits. The part that overlaps should not be less than 3/4 inch thick. The under surfaces or beds of the stones are made level. The upper exposed surface of all masonry built of soft or porous stones is protected by a lead covering.

Stone Lintels

Square openings in buildings are frequently bridged with stone lintels. Stone, owing to its low tensile resistance, is not well suited to act as a beam, and in wide openings every care must be taken to relieve these members as far as possible of the weight above. There are two kinds of lintels: (1) lintel made of one piece of stone where the opening is small, (2) lintel built with several stones where the opening is large. The first kind is divided into: (a) lintels bridging narrow openings, or those made of great depth, rendering any precautions for relieving the pressure unnecessary; (b) lintels with a relieving arch over, usually employed in rubble walls, and (c) lintels in rubble or ashlar work. Where it is inconvenient to use a relieving arch, a flat arch of three stones is constructed above the lintel. The centre stone or key in this type is termed as "The Save". In bedding the save stones, no mortar is placed on the lintel, but the stones are supported in their position by means of small wood wedges. After a sufficient mass of the wall has been built to tail down the side saves, the wedges are removed. In finishing the wall, the joint between the saves and the lintel is pointed only, thus no weight from the wall above is brought to bear on the lintel.

Where it is inexpedient to employ a relieving arch or a save stone, and where the opening is too great for a single stone to form a lintel, it is often formed by a number of blocks either joggled together or with an iron core. The method now frequently adopted is to build the lintel with a number of pieces, with vertical joints and in two thicknesses; and the front and back portions are made to envelop the flanges of a steel girder which bridges the whole span and takes its bearing on the columns. The back front pieces are connected on the soffit by small copper cramps. The latter are bedded in cement mixed with dust from the stones to be united. The upper surface is connected by cramps of iron or copper, extending from front to back either over the top of the steel girder or through its web. The whole soffit is finally rubbed over with a piece of stone similar to the lintels, to render the joint as invisible as possible. Care is taken to protect the steel girder from the danger of oxidation by applying one of the preservative processes described for iron and steel.

Where stone lintels are employed over shop fronts, and the span is too great for one stone, steel girders are used to take the weight of the superstructure. Stone fascia is built of a number of stones arranged either as voussoirs with radiating joints or longer stones with vertical joints. In both the cases, the stones are cut at the back to fit in the flanges of the girder and at each joint a bronze dowel is mortised into the adjacent stones securing them together. A bolt is passed through the web of the girder, being sunk half into each stone and hooked at the end over the dowel.

Arched Lintels

Lintels are often constructed as flat arches, and may be divided into the following kinds:

(a) lintels having radiating joint and joggle, (b) lintels having radiating joint stepped and (c) lintels having vertical joint, the stones bolted to steel girder.

In (a) the joints are radiated to a common centre and are joggled to prevent lateral movement. Portland cement joggle is used at each radiating joint.

In (b) the joints radiate to a common centre and are stepped—a method usually considered necessary where a moulded band traverses the lintel. The step renders any dropping of the central voussoirs impossible.

(c) This method is usually employed in the formation of large classic entablatures. The lintel has vertical face joints, a secret arch being sometimes formed in the central portion of the joint. However, this being a weak form of arch, the bulk of the weight is relieved by bolting or cramping the stones back to a reinforced concrete or steel beam.

Stone Arches

Stone arches are extensively used in building construction to span openings in walls and arcades. The stones forming the arch ring are accurately cut to shape, preferably with their bedding planes perpendicular to the arch axis. They are set in cement mortar. The backs of stone arches are commonly stepped to facilitate the joining of arch stones and stone courses of the wall. In arches up to 15 inches thick, through stones are used extending from the intrados to the extrados. In arches over 15 inches thick, it is, at times, convenient to build two rings, in which case the header and stretcher stones are laid alternately. The headers are through stones from intrados to extrados and the stretchers through stones for one ring. In the case of three rings the alternate headers break joint to the amount of the full depth of one ring. In the case of rubble arching, stones are not less than 3 inches thick on their least dimension and break joint for not less than 6 inches. All stones in one course are approximately of the same thickness. The thickness of the joint at the intrados does not exceed half an inch and the open extrado joints are solidly wedged with chips and spawls set in mortar.

For ashlar fine tooled work, no stone has a length of less than 12 inches while 50 per cent of them have a length of 18 inches or more. The thickness of the joints does not exceed 3/16 inch, and all joints radiate properly from the centre of the curve. In the case of block-in-course, the thickness of stones is not less than 6 inches on their least dimensions, but the thickness of joints does not exceed 1/4 inch.

Stone Pitching on Slopes

The slopes of rail or road embankments, spurs, excavations, canals, river banks, etc., are stone pitched to preserve and protect them from rain, wave-wash, weather, etc. This pitching is properly toed down by having a proper foundation, and it is usual to put an adequate length of horizontal bed pitching called the apron where deep scours are anticipated. The pitching is graded by having a layer of spawl or finer material under the stone which is known as backing or sub-grade and is compacted well. Backing as well as pitching are done simultaneously. The thickness of pitching depends upon the force of water current to which it is to be subjected. Groynes and flood embankments have usually 2 feet thick pitching made up of 0.7 foot spawl or sub-grade and 1.3 feet stone. Stones are as big as possible up to the size of the pitching and laid closely and firmly bedded with their length perpendicular to the face of pitching. They must be durable and tough stone. Surface of the pitching must be left rough and not dressed to smoothness, because rough surface is more effective for guarding against wave-wash. Normally pitching should be done by quarried stone. Boulders are only used where they are available locally or where it cannot be helped.

Pitching in Bed or Apron

As mentioned above it is necessary to provide a wide stone apron of suitable thickness at the toe of the pitched slope for protection against scour. Without an apron, the stone-pitched slope would obviously slip into any scour hole that is formed at the toe of the pitching. The stone apron would take up all the slipping into the scour hole that is necessary and thus keep the pitched face in tact. The design of a stone apron would depend upon the following factors:—

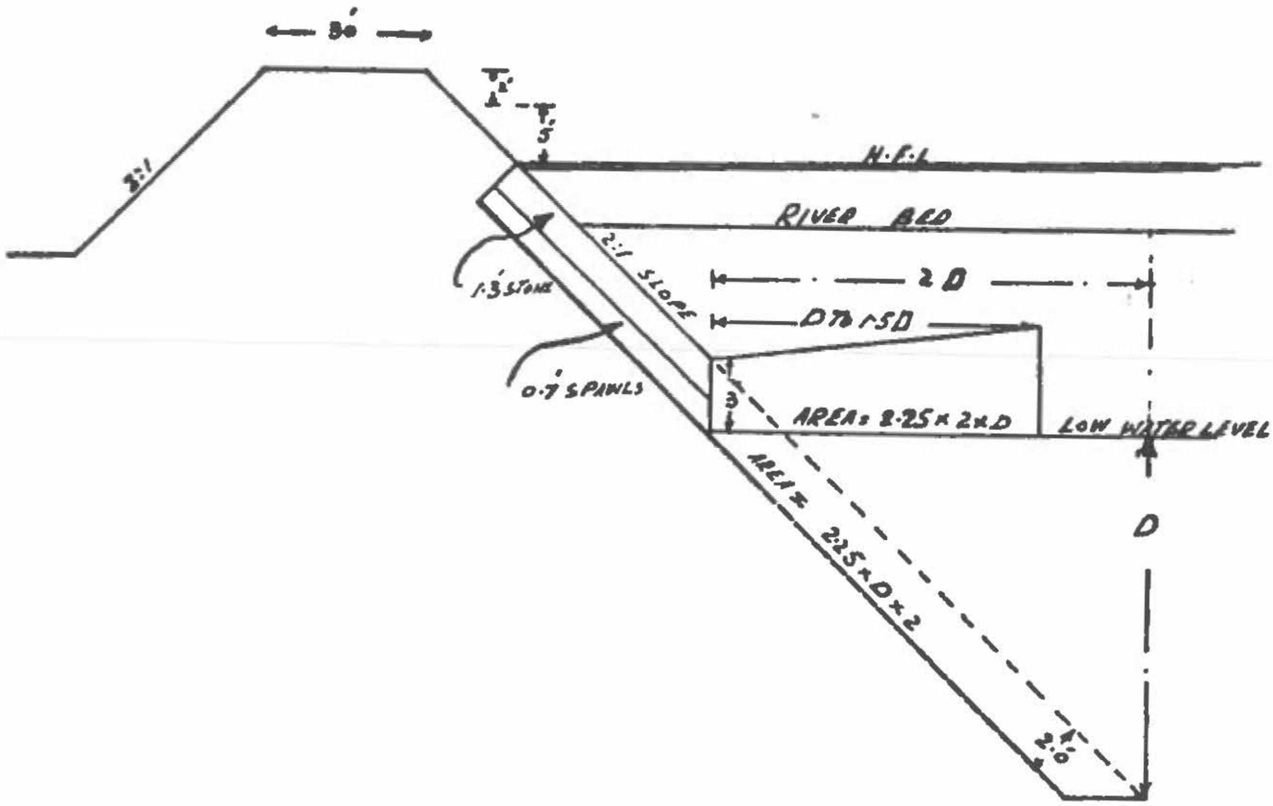
(a) The depth of the maximum scour that is likely to occur.

(b) The sub-surface slope which is likely to be taken up by the side of the scour hole. This is usually taken as 2:1 minimum.

(c) Thickness of the unerodible coating required on the slope of the scour hole. It is usual to take this thickness as 2 feet for the purpose of design. The volume of the stone per foot run of an apron would thus be:—

$\sqrt{5} \times D \times 2.0 = 4.5$ D cft. (approximate)

D is the difference between the low water level on which the apron is laid and the anticipated scoured bed measured in feet. The width of the apron is usually kept as 1½ time the depth of the maximum scour, since it is desirable to keep the scour hole at a distance from the slope so as to ensure a minimum sub-surface slope of 2:1. The apron is designed thicker at the outer edge than at the inner end adjoining the toe of the guide bank, as shown in figure given below:—



NO. 22.1 STONE MASONRY (GENERAL)

Specifications

Scope 1. Unless otherwise specified, all stone masonry shall be finished in a workman-like manner true to dimensions and grades shown on the drawings.

Stone 2. Stone shall be procured from an approved source and shall conform to Specifications No. 7.1 for Stone. Approved sample of the stone shall be retained as a standard of material to be furnished at the site of work. All stone used in the work shall be equal in all respects to the approved samples.

Stacking of Stone 3. Through bond stones shall be stacked separately, and shall be marked on the face with tar or paint. Marks shall be made on the inner face or the face to be plastered.

Mortar 4. Mortar shall be either as shown on the drawing or, if it is not shown, as specified or directed by the Engineer-in-charge. It shall be prepared in accordance with the relevant provisions set forth in Specifications No. 19.1—19.5 for the specified mortar. When specified for face work the colour of the mortar shall be of an approved quality and brand. No waterproofiing material shall be added to the mortar unless specially required or directed by the Engineer-in-charge.

Water

5. Water shall conform to Specifications No. 2.1

Tools and Equipment

6. All equipment used for mixing and transporting mortar and for laying stone shall be clean and free from set mortar, dirt, or other injurious foreign substances. The equipment shall be thoroughly cleaned at the end of each day's work.

Wetting of Stone

7. Before use, all stone shall be soaked in clean water in a tank or a pit for at least 2 hours, except in case of masonry in mud mortar where dry stone shall be used.

Laying Stone Masonry

8. (i) Every stone shall be laid in the work on its natural quarry bed or in such a manner that the stresses borne by it come normal to such bed.

(ii) Whenever possible, the entire masonry in any structure shall be carried up at uniform level. Where breaks are unavoidable, joints shall be made in gradual steps. Cross walls shall be carefully bonded into the main wall and all junctions of wall shall be formed at the time the walls are being built.

(iii) Each stone shall be set with both bed and vertical joints filled with mortar, except in case of dry stone pitching or masonry, and thoroughly bedded in.

(iv) All masonry shall be taken up truly plumb or at the specified slope in the case of batter.

(v) Quoins and jambs shall be laid at a true right angle to the bed, the corners being straight and vertical. In the case of masonry with hammer dressed stone, a chisel draft one-inch wide shall be given on each external face to allow accurate plumbing. Quoins shall be laid headers and stretchers alternately.

(vi) Jambs for door and window openings shall be formed with quoins of the full height of the course. The length and breadth of the quoins shall be at least 2½ times and 1½ times the depth of the course respectively. For door openings three, and for window openings two, of these quoins shall be stone of full thickness of wall. Door and window frames shall be let into ½-inch chassis in the quoins.

Fixture

9. Holdfasts and similar fixtures shall be built in with the surrounding stone masonry in their correct position in specified mortar. These shall be built in as the work progresses and not inserted later on into space left for them.

Lintel and Inside Stone

10. All lintels and inside stone, not to be plastred over, shall be of the full width of the wall in which they are laid, including the thickness of the plastered face or faces.

Openings

11. Door and window openings shall have flat or relieving arches or lintels spanning across them as shown on the drawing or as specified.

Scaffolding

12. The contractor shall provide all scaffolding, staging, ladders, etc., necessary for the work. All walls or other stone masonry of the building shall be securely braced and protected against damages by wind and storms during construction. No extra rate will be paid for this item of work.

Centring 13. The centrings for all openings shall be strong enough to support lintels or arches spanning the openings. They shall be subject to the approval of the Engineer-in-charge and shall remain in position till stone masonry has set. No additional payment will be made to the contractor for this item of work.

Putlogs 14. Only headers shall be left out to allow a putlog to be inserted, and not more than one stone shall be left out for each putlog. Under no circumstances shall putlogs be made immediately under or next to the impost or screw back of arches.

Rounded Corner 15. Corners shall be rounded where specified. (Such work shall be payable separately in the case of exposed masonry but not in the case of masonry to be plastered.)

Striking of Joints 16. The exposed surface shall be finished as specified. When not specified, joints shall be struck simultaneously with masonry work keeping the face of the work clean. (Payment for striking the joints shall be made separately on superficial area of the masonry.)

Bed Plates 17. Bed plates shall be provided under all beams and joists. They shall be chisel dressed on all faces and conform to the dimensions given in the drawing and shall be carefully laid having fine joints with the specified packing to give the correct level.

Cramps 18. Cramps, joggles and dowels shall be used whenever specified or directed by the Engineer-in-charge. Cramps shall be of copper or lead and shall be from 6 inches to 12 inches in length, 3/8 inch to 1 inch in thickness and 1 inch to 2 inches in width, as specified. They shall have each end turned at right angle. Copper cramps shall be forged, and set with neat cement. Lead cramps shall be formed by running moulten lead into the dove-tail channels. Joggles and dowels shall be of double wedge form and made of copper, slate or similar stone and set in neat cement. On no account iron cramps, joggles or dowels, whether galvanized or otherwise, shall be used.

Protection and Watering 19. All stone masonry shall be protected during construction from the effects of rain and frost by suitable covering. The masonry laid in cement and lime shall be kept moist for a period of 10 days.

Copings and Corners 20. Coping stone shall be full size throughout, of dimensions indicated on the drawing or as specified, if not shown on the drawing. Beds, joints and top shall be fine pointed. All copings shall be dowelled or cramped, as specified, and the corners of pillars, skew backs and similar work shall be joggled to the stone below, if so specified.

String Courses 21. The string courses shall tail at least 9 inches into the work with a full bearing for at least 4 inches and shall be paid for at a rate per running foot along the course. They shall also be throated on the underside, if so directed by the Engineer-in-charge.

Labour Rate 22. The unit rate (on labour rate basis) shall include the cost of building stone masonry, cutting and dressing stone to the specified degree of refinement, curing and protecting as per above specifications and/or any other specifications specially included in the contract. It shall further include the cost of providing, using and removing scaffolding, shuttering, centring, staging, ladders, supports, tools and plants required for building stone masonry as per above specifications.

Composite Rate 23. The unit rate shall include the cost of stone, mortar and any other material required, in addition to the labour rate detailed above.

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NO. 22.2 DRESSING AND CUTTING STONES

Specifications

1. Stone shall be dressed to the exact size shown in the approved drawing or as specified. All visible edges shall be free from chippings. **General**

2. It shall be executed accurately in accordance with the design and worked to approved templates. The exposed faces shall be finished as specified or as directed by the Engineer-in-charge. **Cut Stone Work Or Moulding**

3. Also called three-line dressed stone, it shall be fine chisel dressed having the best surface which can be given to a stone with chisel and without rubbing. A straight edge laid along the face of the stone so dressed shall be in contact with the surface at every point. **Fine Dressed Stone**

4. Also called two-line dressed, it shall be sparrow picked or chisel dressed so that no portion of the dressed face is more than 1/8 inch from a straight edge placed on it. **Chisel Dressed Stone**

5. Also called one-line dressed, it shall be sparrow picked, or chisel dressed so that no portion of the dressed face is more than 1/4 inch from a straight edge placed on it. **Rough Tooled Stone**

6. Scabbled or hammer dressed stone shall be dressed with a scabbling hammer without any picking, chiselling or rubbing. **Hammer Dressed Stone**

7. All cut stone, moulded or ornamental work shall be measured by superficial area, unless otherwise specified. The dressed surface area of each stone shall be measured separately. **Measurement**

8. The unit rate for dressing/cutting or moulding shall include dressing/cutting or moulding the stone as per above specifications and stacking at the site of dressing. **Rate**

NO. 22.3 ASHLAR MASONRY

Specifications

NO. 22.3 (A) ASHLAR FINE

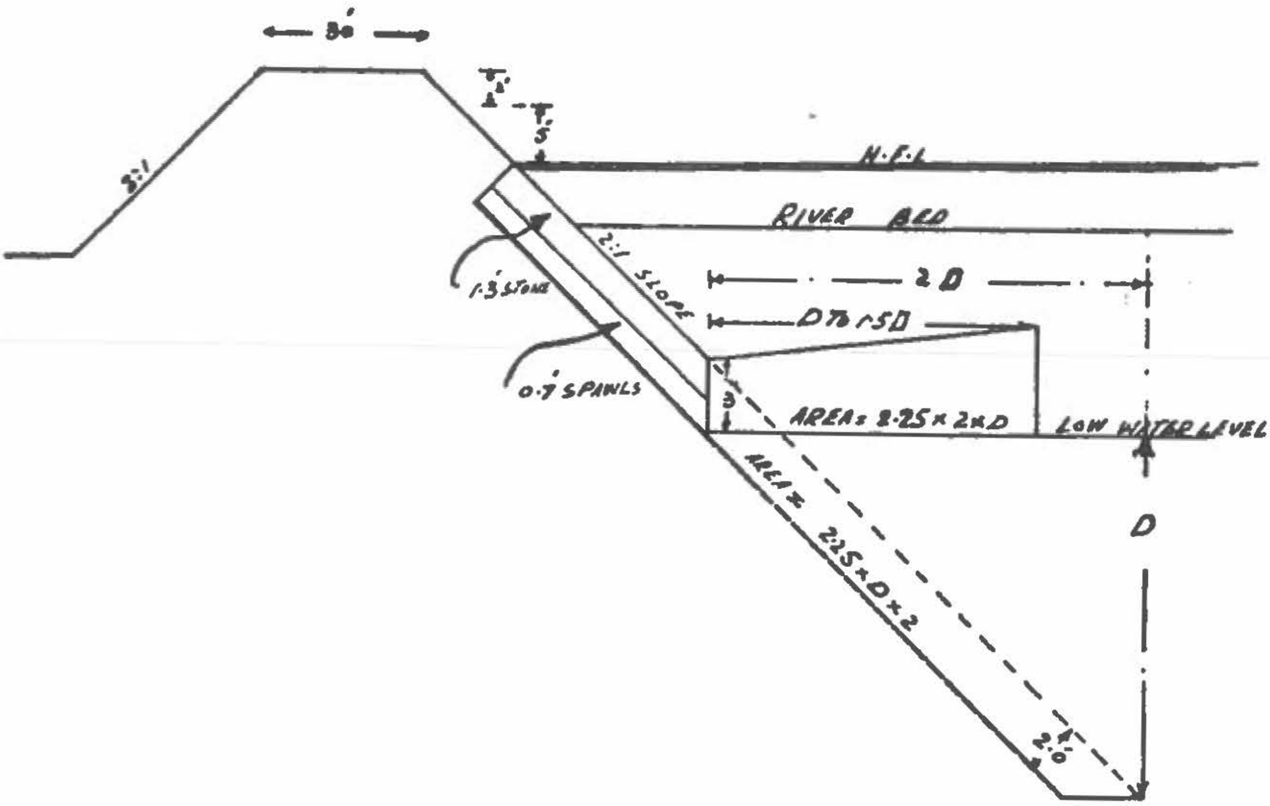
1. Ashlar masonry shall be finished in line with the specified architectural details, dimensions and grades in a workmanlike manner according to following specifications. **Scope**

2. Every stone in fine ashlar shall be dressed on all beds, joints and faces in accordance with the Specifications 22.2 for dressing of stone; full true and out of winding, if the surfaces are plain or to uniform curves and twists, if so specified. **Dressing**

3. Stone shall be set in specified fine mortar, the beds or joints being in no case more than 1/8 inch in thickness. Each stone shall be struck with a maul, when laid, to bring it to a solid bearing, both to the bed and the joint. **Thickness of Joints**

4. Stone shall be laid in regular courses not less than 12 inches in height. All courses shall be of the same height, unless otherwise specified. No stone shall be less in breadth than 1½ times its height or less in-length than 2½ times its height. **Size of Stone**

a distance from the slope so as to ensure a minimum sub-surface slope of 2:1. The apron is designed thicker at the outer edge than at the inner end adjoining the toe of the guide bank, as shown in figure given below:—



NO. 22.1 STONE MASONRY (GENERAL)

Specifications

Scope 1. Unless otherwise specified, all stone masonry shall be finished in a workman-like manner true to dimensions and grades shown on the drawings.

Stone 2. Stone shall be procured from an approved source and shall conform to Specifications No. 7.1 for Stone. Approved sample of the stone shall be retained as a standard of material to be furnished at the site of work. All stone used in the work shall be equal in all respects to the approved samples.

Stacking of Stone 3. Through bond stones shall be stacked separately, and shall be marked on the face with tar or paint. Marks shall be made on the inner face or the face to be plastered.

Mortar 4. Mortar shall be either as shown on the drawing or, if it is not shown, as specified or directed by the Engineer-in-charge. It shall be prepared in accordance with the relevant provisions set forth in Specifications No. 19.1—19.5 for the specified mortar. When specified for face work the colour of the mortar shall be of an approved quality and brand. No waterproofiing material shall be added to the mortar unless specially required or directed by the Engineer-in-charge.

Water

5. Water shall conform to Specifications No. 2.1

Tools and Equipment

6. All equipment used for mixing and transporting mortar and for laying stone shall be clean and free from set mortar, dirt, or other injurious foreign substances. The equipment shall be thoroughly cleaned at the end of each day's work.

Wetting of Stone

7. Before use, all stone shall be soaked in clean water in a tank or a pit for at least 2 hours, except in case of masonry in mud mortar where dry stone shall be used.

Laying Stone Masonry

8. (i) Every stone shall be laid in the work on its natural quarry bed or in such a manner that the stresses borne by it come normal to such bed.

(ii) Whenever possible, the entire masonry in any structure shall be carried up at uniform level. Where breaks are unavoidable, joints shall be made in gradual steps. Cross walls shall be carefully bonded into the main wall and all junctions of wall shall be formed at the time the walls are being built.

(iii) Each stone shall be set with both bed and vertical joints filled with mortar, except in case of dry stone pitching or masonry, and thoroughly bedded in.

(iv) All masonry shall be taken up truly plumb or at the specified slope in the case of batter.

(v) Quoins and jambs shall be laid at a true right angle to the bed, the corners being straight and vertical. In the case of masonry with hammer dressed stone, a chisel draft one-inch wide shall be given on each external face to allow accurate plumbing. Quoins shall be laid headers and stretchers alternately.

(vi) Jambs for door and window openings shall be formed with quoins of the full height of the course. The length and breadth of the quoins shall be at least 2½ times and 1½ times the depth of the course respectively. For door openings three, and for window openings two, of these quoins shall be stone of full thickness of wall. Door and window frames shall be let into ½-inch chassis in the quoins.

Fixture

9. Holdfasts and similar fixtures shall be built in with the surrounding stone masonry in their correct position in specified mortar. These shall be built in as the work progresses and not inserted later on into space left for them.

Lintel and Inside Stone

10. All lintels and inside stone, not to be plastred over, shall be of the full width of the wall in which they are laid, including the thickness of the plastered face or faces.

Openings

11. Door and window openings shall have flat or relieving arches or lintels spanning across them as shown on the drawing or as specified.

Scaffolding

12. The contractor shall provide all scaffolding, staging, ladders, etc., necessary for the work. All walls or other stone masonry of the building shall be securely braced and protected against damages by wind and storms during construction. No extra rate will be paid for this item of work.

Centring

13. The centrings for all openings shall be strong enough to support lintels or arches spanning the openings. They shall be subject to the approval of the Engineer-in-charge and shall remain in position till stone masonry has set. No additional payment will be made to the contractor for this item of work.

Putlogs

14. Only headers shall be left out to allow a putlog to be inserted, and not more than one stone shall be left out for each putlog. Under no circumstances shall putlogs be made immediately under or next to the impost or screw back of arches.

Rounded Corner

15. Corners shall be rounded where specified. (Such work shall be payable separately in the case of exposed masonry but not in the case of masonry to be plastered.)

Striking of Joints

16. The exposed surface shall be finished as specified. When not specified, joints shall be struck simultaneously with masonry work keeping the face of the work clean. (Payment for striking the joints shall be made separately on superficial area of the masonry.)

Bed Plates

17. Bed plates shall be provided under all beams and joists. They shall be chisel dressed on all faces and conform to the dimensions given in the drawing and shall be carefully laid having fine joints with the specified packing to give the correct level.

Cramps

18. Cramps, joggles and dowels shall be used whenever specified or directed by the Engineer-in-charge. Cramps shall be of copper or lead and shall be from 6 inches to 12 inches in length, 3/8 inch to 1 inch in thickness and 1 inch to 2 inches in width, as specified. They shall have each end turned at right angle. Copper cramps shall be forged, and set with neat cement. Lead cramps shall be formed by running moulten lead into the dove-tail channels. Joggles and dowels shall be of double wedge form and made of copper, slate or similar stone and set in neat cement. On no account iron cramps, joggles or dowels, whether galvanized or otherwise, shall be used.

Protection and Watering

19. All stone masonry shall be protected during construction from the effects of rain and frost by suitable covering. The masonry laid in cement and lime shall be kept moist for a period of 10 days.

Copings and Corners

20. Coping stone shall be full size throughout, of dimensions indicated on the drawing or as specified, if not shown on the drawing. Beds, joints and top shall be fine pointed. All copings shall be dowelled or cramped, as specified, and the corners of pillars, skew backs and similar work shall be joggled to the stone below, if so specified.

String Courses

21. The string courses shall tail at least 9 inches into the work with a full bearing for at least 4 inches and shall be paid for at a rate per running foot along the course. They shall also be throated on the underside, if so directed by the Engineer-in-charge.

Labour Rate

22. The unit rate (on labour rate basis) shall include the cost of building stone masonry, cutting and dressing stone to the specified degree of refinement, curing and protecting as per above specifications and/or any other specifications specially included in the contract. It shall further include the cost of providing, using and removing scaffolding, shuttering, centring, staging, ladders, supports, tools and plants required for building stone masonry as per above specifications.

Composite Rate

23. The unit rate shall include the cost of stone, mortar and any other material required, in addition to the labour rate detailed above.

NO. 22.2 DRESSING AND CUTTING STONES

Specifications

1. Stone shall be dressed to the exact size shown in the approved drawing or as specified. All visible edges shall be free from chippings. **General**

2. It shall be executed accurately in accordance with the design and worked to approved templates. The exposed faces shall be finished as specified or as directed by the Engineer-in-charge. **Cut Stone Work Or Moulding**

3. Also called three-line dressed stone, it shall be fine chisel dressed having the best surface which can be given to a stone with chisel and without rubbing. A straight edge laid along the face of the stone so dressed shall be in contact with the surface at every point. **Fine Dressed Stone**

4. Also called two-line dressed, it shall be sparrow picked or chisel dressed so that no portion of the dressed face is more than 1/8 inch from a straight edge placed on it. **Chisel Dressed Stone**

5. Also called one-line dressed, it shall be sparrow picked, or chisel dressed so that no portion of the dressed face is more than 1/4 inch from a straight edge placed on it. **Rough Tooled Stone**

6. Scabbled or hammer dressed stone shall be dressed with a scabbling hammer without any picking, chiselling or rubbing. **Hammer Dressed Stone**

7. All cut stone, moulded or ornamental work shall be measured by superficial area, unless otherwise specified. The dressed surface area of each stone shall be measured separately. **Measurement**

8. The unit rate for dressing/cutting or moulding shall include dressing/cutting or moulding the stone as per above specifications and stacking at the site of dressing. **Rate**

NO. 22.3 ASHLAR MASONRY

Specifications

NO. 22.3 (A) ASHLAR FINE

1. Ashlar masonry shall be finished in line with the specified architectural details, dimensions and grades in a workmanlike manner according to following specifications. **Scope**

2. Every stone in fine ashlar shall be dressed on all beds, joints and faces in accordance with the Specifications 22.2 for dressing of stone; full true and out of winding, if the surfaces are plain or to uniform curves and twists, if so specified. **Dressing**

3. Stone shall be set in specified fine mortar, the beds or joints being in no case more than 1/8 inch in thickness. Each stone shall be struck with a maul, when laid, to bring it to a solid bearing, both to the bed and the joint. **Thickness of Joints**

4. Stone shall be laid in regular courses not less than 12 inches in height. All courses shall be of the same height, unless otherwise specified. No stone shall be less in breadth than $1\frac{1}{2}$ times its height or less in-length than $2\frac{1}{2}$ times its height. **Size of Stone**

Bond 5. The face stone shall be laid header and stretcher alternately, unless otherwise specified. The headers are arranged to come as nearly as possible in the middle of the stretchers below and the stone in adjacent layers shall break joints on the face for at least half the height of the course, and the bond shall be carefully maintained throughout.

Through Stone 6. In walls 2½ feet thick and less the header shall run right through the wall.

Courses 7. The course line shall be horizontal and side joint vertical throughout.

Jambs 8. Jambs in door and window openings shall be formed with quoins of the full height of the course. Unless otherwise specified, the quoins shall not be less in breadth than 1½ times or in length less than twice the depth. At least three quoins in case of doors, and two quoins in case of windows, shall be stones of the full thickness of the wall.

Other Respects 9. In all other respects the work shall comply with the Specifications No. 22.1 for Stone Masonry (General).

NO. 22.3 (B) ROUGH TOOLED OR BASTARD ASHLAR

Specifications

1. The faces exposed to view shall have a fine dressed chisel draft, one inch wide, all round the edges and be rough tooled between the drafts, and on all beds and joints, which shall not exceed 3/8 inch in thickness.

2. The stone shall be set in specified mortar. In other respects such as size of stones, bond, jambs, courses, etc., specifications shall be the same as laid down for Fine Ashlar No. 22.3 (A).

NO. 22.3 (C) ROCK RUSTIC OR QUARRY FACED ASHLAR MASONRY

Specifications

1. It shall be similar to Specifications No. 22.3 (B), except that the exposed faces of the stone between the drafts shall be left rough as the stone comes from the quarry. But no rock face or "bushing" shall project more than 3 inches from plane of drafts. The drafts may be omitted altogether, except at quoins if required for architectural purposes, or as specified.

NO. 22.4 ASHLAR FACING

Specifications

General 1. The faces of stone shall be, as specified, rough-tooled, rustic (with or without chisel draft, except at quoins) or chamfered. For a particular work, facing shall have, as specified, a backing of brickwork, concrete or rubble masonry.

Dressing of Stones 2. In walls of rubbles or concrete faced ashlar, the dressing shall be as specified, except for the dressing of the backs of stone, which may be left rough in the state they are received from the quarry.

Size of Stone 3. No course shall be less than 8 inches in height. One-third of the entire length of each course shall be headers, used at regular intervals. Headers shall not be less than the breadth of the ashlar stone plus 18 inches. Unless otherwise specified, no stone shall be less than 1½ feet long.

Depth of Facing

4. Unless otherwise specified, the depth of the facing shall not be less than $4\frac{1}{2}$ inches and 9 inches in alternate courses.

Height of Courses

5. The height of the courses shall be equal to the exact number of courses of brick or rubble with intermediate mortar joints. The backing shall be carried up simultaneously with the face work.

Beds and Joints

6. Beds and joints shall be true and square for at least $4\frac{1}{2}$ inches and $1\frac{1}{2}$ inches respectively from the face. Beds and joints shall not be more than 1/8 inch thick and $\frac{1}{4}$ inch thick respectively.

Bond Stone

7. Bond stones shall run right through backing when wall is not more than $2\frac{1}{2}$ feet thick. In case it is thicker, stones shall overlap at least 6 inches and shall be inserted between 5 feet and 6 feet apart, clear in every course.

Measurements

8. In work of this sort, the face work alone shall be measured and paid for as ashlar, as is dressed back, according to the type of ashlar masonry 22.3 (A), (B), (C), true and square on the beds and joints, 1/3rd more is allowed for headers (e.g. in 12 inches courses a thickness of 16 inches from the face would be paid for as ashlar), and the remainder is paid for according to the character of the backing.

NO. 22.5 ASHLAR BLOCK IN COURSE MASONRY

Specifications

Dressing

1. Stone shall be rough tooled on all beds and joints so as to give rectangular shape. Faces shall be accurately square and all face joints dressed at right angle to the face for a distance of 4 inches.

Size of Stone

2. Each course shall consist of stones of even thickness and no course shall be less than 6 inches in height. Stones shall break joints on the face by at least half the height of the course. No course shall be greater in height than the one below it. No stones in face, except closer, shall have less breadth than height. No stone shall tail into the wall less than its height and at least 1/3rd of the face stones shall tail into the wall twice their height.

Laying

3. All courses shall be laid with beds truly horizontal and joints truly vertical. Each bed and joint shall be full of the mortar specified and each stone shall be struck with a wooden maul to bring it to a solid bearing. No face joint shall be thicker than 1/4 inch.

Bond Stone

4. In walls less than 2 feet thick, through stone shall be inserted at every course at 5 feet intervals breaking joints with similar stone in courses above and below. In walls more than 2 feet thick through stone shall overlap each other by at least 6 inches.

Other Respects

5. In other respects the work shall comply with Specifications No. 22.1 for Stone Masnory (General).

NO. 22.6 ASHLAR BLOCK IN COURSE FACING

Specifications

General

1. Walls built in brickwork, concrete or rubble masonry shall be faced with ashlar block in course masonry. The work shall comply with Specifications No. 22.5 for Ashlar Block in Course Masonry with the following exceptions.

Size of Stones 2. No stone shall be less than 6 inches, and 1/3rd of the entire length of the stone shall be header. No stone shall be less than 15 inches long. The depth of the facing shall not be less than 10½ inches. No header shall project less than 10½ inches into the backing.

Height of Course 3. The height of course shall equal an exact number of courses of brick or rubble with intermediate mortar joints. The backing shall be carried up simultaneously with the face work.

Beds and Joints 4. Beds and joints shall be rough-tooled, true and square for at least 3 inches and 1½ innches thick.

Bond Stone 5. Bond stone shall run right through the backing when the wall is less than 2 feet thick. In thicker walls they shall overlap at least 6 inches. Bond stone shall be inserted 5 feet apart in every course.

Face 6. The face of the stone shall be left rough (but no projection shall exceed 2 inches) without chisel draft, except at quoins, where 1/2 inch draft shall be given.

Mode of Measurement 7. Only so much of the face stone as is dressed back full, true and square from face shall be measured and paid for as block in course. One-third shall be added for headers. The remainder work shall be measured and paid for according to the character of the backing.

NO. 22.7 COPINGS, CORNICES AND COLUMNS

Specifications

Stone 1. Stone cornices, copings, pillars, string courses, corbels, brackets, chajjas and similar works shall be made from stone of uniform colour and texture and of the kind specified for each.

Dressing 2. The stone shall be dressed full or to the approved templates. Unless otherwise specified, the exposed faces shall be fine chisel dressed (three line). All visible angles and edges shall be free from chippings.

Size of Stone 3. No stone shall be less than 18 inches in length nor less in height than the height of the copings. In cornices and string courses which do not extend right through wall, every stone shall tail into the wall by at least as much as the projection behind the face of the wall and in no case less than 6 inches. Coping stone shall extend the entire depth of the coping, unless otherwise specified or directed by the Engineer-in-charge in writing.

Mortar 4. Cornices, string courses, corbels and pillars shall be set in lime mortar or cement mortar of specified mix, depending upon the rest of the masonry.

Chajjas 5. Chajjas, in the case of isolated windows, shall consist of a single stone; in continuous chajjas all joints shall come over the brackets.

Joints 6. No joint shall be more than 1/8 inch in thickness.

Weathering and Throating 7. All outside cornices, copings, corbels and similar projecting courses shall be weathered on the top and throated underneath.

Dowels 8. Coping stones and other similar works are to be cramped or dowelled and courses of pillars, skew backs and similar works shall be joggled, whenever specified.

Measurements

9. Cornices, string courses and chajjas shall be measured by length. The unit of measurement shall be one foot. Copings shall be measured by volume. The unit of measurement shall be 100 cubic feet.

Labour Rate

10. The unit rate (on labour rate basis) for cornices/string courses/copings/chajjas shall include the cost of carrying out cornices/string courses/copings/chajjas, cutting and dressing stone, whenever required, curing and protecting it as per above specifications and/or any other specifications specially included in the contract. It shall further include the cost of providing, using and removing scaffolding, shuttering, centring, staging, ladders, supports and other tools and plants required for carrying out cornices/string courses/copings/chajjas as per above specifications.

Composite Rate

11. The unit rate shall include the cost of stone, mortar and any other material required in addition to the labour rate detailed above.

NO. 22.8 COURSE RUBBLE MASONRY (IST CLASS)

Specifications

Height of Course

1. Stone shall be laid in horizontal courses not less than 6 inches in height. All stones in a course shall be of equal height and all courses of the same height, unless otherwise specified. But no course shall be thicker than the course below it. All stones shall be set full in specified mortar in beds and joints.

Dressing

2. The face stone shall be square on all joints in masonry. The beds shall be hammer or chisel-dressed, true and square, for at least 3 inches back from the face, and the joints for at least 1½ inches. The face of the stone shall be hammer dressed and "bushing" not to project more than 1½ inches.

Thickness of Joints

3. All side joints shall be vertical and beds horizontal, and no joint shall be more than 3/8 inch in thickness. No pinning shall be allowed on face.

Size of Stone

4. No face stone shall be less in breadth than its height, nor shall it tail into the work to a length less than its height; at least 1/3rd of the stone shall tail into the work at least twice its height or in walls thicker than 2 feet, three times its height.

Through Stone and Headers

5. Through stones shall be inserted 5 to 6 feet apart in every course, and shall run right through the wall, not more than 2 feet thick. When the wall is more than 2 feet thick, a line of two or more headers shall be laid from face to back, which shall overlap each other at least 6 inches. The headers shall have a length of at three times the height.

Breaking of Joints

6. Stone shall break joint by at least half the height of the course.

Quoins

7. Quoins shall be of the same height as the course in which they occur, shall be formed of stone at least 1½ feet long and shall be laid stretcher and header alternately. They shall be laid square on their beds which shall be fairly dressed to a depth of at least 4 inches.

Interior Face

8. The work on the interior face shall be precisely the same as on the exterior face, except that side joints need not be vertical.

Hearting

9. The interior of the wall, called hearting, shall consist of flat-bedded stones carefully laid on their proper beds and solidly bedded in mortar. Chips and spawls of

stone are wedged in, wherever necessary, so as to avoid thick beds or joints of mortar. No dry work or hollow spaces shall be left anywhere in the masonry. The face work and hearting shall be brought up evenly, but the hearting shall not be levelled up at each course by the use of chips.

Other Respects

10. In all other respects it shall conform to Specifications No. 22.1 for Stone Masonry (General).

NO. 22.9 COURSE RUBBLE MASONRY (2ND CLASS)

Specifications

Scope

1. Course rubble masonry (2nd class) shall conform to Specifications No. 22.8 for Course Rubble Masonry (1st class) with the following exceptions.

(a) All stones in a course need not be of the same height, but short lengths of course shall be made up by two courses, equal in height to the through course. No course shall be of a height greater than the course below it. The thickness of the joint shall not exceed half an inch.

(b) In each course, headers, hammer dressed and of the full height of the course, shall be placed 5 feet apart. Each header shall have a breadth not less than the height and shall tail into the work at least three times its height. Between the headers each course shall be built of smaller stones not less than 2 inches thick of which there may be two or three in the height of the course. These stones need not be dressed but shall be as flat-bedded as possible. Side joints need not be vertical, but no side joint shall form an angle with a bed joint sharper than 60°. No stone shall be less in breadth or length than its height, and care shall be taken to make the stone in different courses break joint. All stones shall be set full in mortar. The thickness of joint shall not exceed 5/8 inch.

Other Respects

20. In all other respects the work shall comply with the Specifications No. 22.1 for Stone Masonry (General).

NO. 22.10 RANDOM RUBBLE MASONRY

Specifications

General

1. Stone shall be hammer dressed on the face and on the sides and beds to such an extent that weak corners are chipped off and the stones come into close proximity, when laid. Each stone shall be laid on its quarry bed and shall be wedged or pinned strongly into position in the wall by spawls or chips which may show on the face.

Joints

2. No stone shall tail into the wall less than $1\frac{1}{2}$ times its height. The stone shall be arranged to break joints as much as possible. Care shall be taken to avoid long continuous vertical joints.

Through Stone or Headers

3. One header stone shall be inserted at least every 5 square feet of the surface (face) and shall run right through the wall if it is not more than 2 feet thick. If the wall is more than 2 feet thick, a line of headers shall be laid from face to back which shall overlap each other at least 6 inches.

Hearting — 4. Hearting or interior filling between the front and back face shall consist of rubble stone, not less than 6 inches in any direction, carefully laid, hammered down with a wooden mallet into place and solidly bedded in mortar. Chips and spawls of stone shall be used, wherever necessary, so as to avoid thick beds or joints of mortar. No dry work or hollow spaces shall be left anywhere in the body of the masonry. Hearting shall be laid nearly level with each course except that at about 3 feet interval vertical "plumbs" projecting 6 to 9 inches shall be firmly embodied to form a bond between successive courses. Hearting shall not be brought to the same level as the front and back stones by the use of chips. The use of chips shall be restricted to only wedges in the hearting.

Other Respects — 5. In all other respects, the work shall comply with the Specifications No. 22.1 for Stone Masonry (General).

NO. 22.11 DRY RUBBLE MASONRY

Specifications

Size of Stone — 1. Dry rubble masonry shall be constructed with the largest practicable size of the stone available—the larger stone being used in the lower courses.

Beds — 2. Stone shall be roughly dressed to secure the maximum bedding surface without unduly reducing the size of the stone. Each course shall be built through the entire thickness of the wall.

Bond Stone — 3. Bond stone shall be provided in each course at an interval of 5 feet. It shall be of the height of the course in which it is to be used, at least as broad and of the greatest length procurable. No bond stone shall be less than 2 feet long. When the length is less than the thickness of the wall 2 or more stones shall be used overlapping each other by at least 6 inches to provide through bond from front to back. All bond stones shall be separately stacked before use and marked so that they can be identified after having been built in the wall.

Filling — 4. Wherever required, filling behind dry stone walls shall be done immediately with stone refuse or chips. Earth shall not be used where stone refuse is available.

Measurements and Rate — 5. In respect of the measurements and rate it shall conform to Specifications No. 22.1 for Stone Masonry (General).

NO. 22.12 STONE MASONRY IN ARCHES

Specifications

General — 1. Unless otherwise specified, all stone masonry in arches shall be finished in a workmanlike manner, true to dimensions and grades shown on the drawings or according to the following specifications.

Cutting, Dressing of Stone — 2. Stone to be cut and dressed shall follow the Specifications No. 22.2.

Centring — 3. Centring shall be strong enough to bear the weight of an arch without any deflection. The surface of centring shall be correctly struck to the curvature of the soffit of the arch.

Wedges and Sand Boxes

4. *Centres of arches of over 5 feet span shall be erected on wedges. Centres of* over 10 feet span shall be on double wedges and of those over 20 feet span on sand boxes so as to allow the gradual lowering of centre (i.e. striking).

Building of Arches

5. The building of arches shall not begin until the abutments have been built to their full width and up to the level of skew backs. Arch work shall be done evenly from both abutments, and as soon as the arch is complete, masonry shall be built evenly on both sides to the heights of the crown so as to load the haunches.

Stone masonry in arches shall conform to Specifications No. 22.1 for Stone Masonry work, except with the following modifications:—

(i) In all arches, the voussoir joints shall be truly radial. Stone shall be laid in full beds of mortar and shall be well rubbed and pressed into their beds so as to squeeze out surplus mortar and leave the joints as thin as possible.

(ii) Joints in arches shall not exceed 1/4 inch in thickness at any point. Radial joints in gauged arches shall not exceed 1/8 inch thickness.

(iii) Skew backs shall be formed of stone correctly shaped to radiate from the centre of curvature and shall not be packed with mortar or chips. Before the building of an arch is started abutments shall be exactly at the same level and skew backs in place.

(iv) For gauged arch work, the arch shall be laid out full size on the ground on lime plaster and all joints carefully marked out. Templates shall then be made as a guide for the special shapes of stones. Stones shall be carefully cut and then rubbed to the required shape. All the stones for any arch shall be prepared in full and set up dry on the ground before commencing work.

(v) Segmental arches used over rectangular door or window openings shall have a flat rectangular soffit and segmental extrados.

(vi) Flat arches shall be built in the same manner as gauged arches but with all the voussoir joints converging on the apex of an equilateral triangle described on the soffit of the arch. Cross joints and extrados shall be parallel to the soffit. The arch shall be built with a camber of 1/8 per foot of span.

(vii) Arches shall be built in concentric rings and each ring shall be completed before work on the ring above is started. In all cases, care shall be taken that the centre line of the stone face is radially placed. The arch rings shall, in all cases, be bonded together by special bond stones.

Through Stone

6. In the case of arches in walls the two springers and the key stone and every third stone in between shall be through stones. Unless otherwise specified, all stones shall be through stones in the case of ashlar walls having a thickness of 2½ feet or less.

Size of Stone

7. Unless otherwise specified, the height of each stone shall be equal to the thickness of the arch up to 15 inches. Above this, two stones may be used, but no stone shall be less than 6 inches in height. The intrados of all stone shall be rectangular, no side being less than 4 inches (rhembold in skew arches).

Breaking Joints

8. All stones in arches shall have their ends inside the wall squarely dressed. All joints shall break with each other and no stone shall lie over a circumferential joint by less than half the width of the extrados.

Measurements and Rate

9. In respect of measurements and rate it shall confrom to Specifications No. 22.1 for Stone Masonry (General).

NO. 22.13 "DHAJJI" WALLS

Specifications

Timber

1. Timber for the framing shall comply with the general specifications for timber and wood work. If kail or similar wood are used in the framework, all exposed timbers subject to wear, such as the sills of doors and windows shall be made from deodar or oak, unless specified otherwise.

Framework Sills Bressumers Posts

2. The frame shall usually consist of a sill at the bottom and a bressumer on top each 5 inches by 5 inches in section, and of the longest lengths procurable. Vertical posts shall be tenoned into these at all corners and junctions of walls, and elsewhere about 4 feet apart, but so spaced as to form the door and window openings. All posts shall be single pieces, and 5 inches by 5 inches in section.

Horizontal Pieces

3. Into these posts shall be notched horizontal pieces, 5 inches by 3 inches in section, one line being at the level required to form the lintel of doors and windows, and the rest so spaced along the height of the wall that no panel shall be more than 4½ feet high.

Diagonal Bracing

4. The panels shall be strutted diagonally by board of 5 inches by 1½ inches fitting tightly into the corners halved into one another at the point of intersection. The diagonal bracing shall be omitted if brick nogging is provided in the panels. In that case first class burnt bricks shall be used.

Doors and Windows Separate Chowkats

5. The framing of door and window openings shall be so built that chowkats can be fixed to the timber forming the framework. When doors and windows are hung on chowkats, they shall be measured over the chowkat in the customary manner.

Without Chowkats

6. Where required, the framing shall be so constructed that no separate chowkats are needed, but the leaves hung on the frame timbers shall be made with necessary rebates to take the leaves. Doors and windows shall be paid in that case on the net area of the opening; the depth of the frame or chowkat shall be excluded from the measurement.

Protection from Damp Ground

7. The framing of dhajji walls shall be erected on a plinth of brick or stone not less than 12 inches high from the ground. The sill shall be laid on an adequate damp proof course, and at such a level that its top is not more than two inches above the floor.

Paint with Wood Preservatives

8. Before finally fitting the framing together all the timbers, including the shaped ends, scarfs and mortices, shall be given two coats of an approved and specified wood preservative like hot solignum, creosote.

Iron Fastenings

9. Having erected the framing, the vertical and horizontal members shall be firmly fastened together on both sides of all junctions with 3/8 inch diameter spikes, and the diagonal braces secured with 4 inches wire nails.

Filling 10. The framework shall then be filled with the specified class of brickwork or stone masonry. Brickwork or masonry shall comply with the relevant specifications for each type of work.

Filling to be Tight 11. All joints in the filling shall be as fine as practicable with the stones or bricks breaking joint in every course and firmly wedged against the framing to hold the panel against any lateral thrust. In the case of sone filling all stones shall be through stones with flat beds, and laid to fit close against the diagonal bracing.

Inner walls to be Plastered 12. Inner walls shall be plastered over the filling as well as the framework, which shall be covered with ½ inch mesh wire-netting kept ¼ inch away from the wood work or have nails driven into it to form a key for the plaster. The rate for dhajji walling shall include a suitable treating of the framework for plastering.

Finish of Outer Walls 13. Outer walls shall be finished with (a) plaster over the entire wall, or (b) plaster over the brick or masoory filling, (only the plaster being stopped against the frame) or (c) pointing. In the case of (a), the instructions in 12 above shall apply. If the filling only is to be plastred or if it is to be pointed the filling shall be so laid in the frame that the framework will project 1/8 inch beyond the finished plastered or pointed surface.

Measurements 14. Dhajji walling shall be measured by superficial area. The unit of measurement shall be one square foot.

Rate 15. The unit rate for dhajji walling shall include the provision and erection of the timber framing and filling with brickwork or masonry in accordance with the above specifications. This rate shall not include the plastering and/or pointing of the face of the wall.

NO. 22.14 STONE REVETMENT OR PITCHING

Specifications

Type of Stone 1. Stone for pitching shall conform to Specifications No. 7.1 for pitching stone.

Profile 2. The surface to be pitched shall be trimmed to the specified slope and well consolidated before the sub-grade is laid on it.

Sub-Grading 3. The backing or sub-grading shall consist of a well compacted layer of bajri, gravel, stone spawl or moorum in layers of 4 to 6 inches (whatever specified). This backing shall be carried up simultaneously with the face work unless otherwise specified.

Thickness 4. The thickness of pitching shall be as actually specified; the stone of size slightly larger than specified thickness need not be dressed off to get a uniform surface. (The rougher the pitching surface the better it is for wave-wash.)

Laying 5. The stone shall be laid closely in position and firmly bedded; the length shall be perpendicular to the face of pitching.

Boulder Pitching 6. When pitching with boulder stone is specified the minimum size of the boulders shall depend upon the thickness of pitching specified (generally 10-15 inches). All boulders less than the minimum size shall be rejected.

Size of Boulder in Grouted Pitching

7. Minimum size of boulder used in this type of pitching shall range between 1½ feet and 2 feet, unless otherwise specified,

Laying of Boulders

8. Boulders shall be laid so as to fit into one another as closely as possible and on no account shall be so laid as to have all the wide ends down and the taper ends up.

Grouting in Boulder Pitching

9. All pitching of this kind shall be bedded upon large shingle free from sand and to be thoroughly grouted with specified grouting mixture.

Measurements

10. The pitching of stone or boulders shall be measured by volume. The unit of measurement shall be 100 cubic feet.

Rate

11. The unit rate shall include the laying of sub-grade and the pitching of stone or boulders, as per above specifications.

CHAPTER 23

ROOFING

Introduction

The covering or the upper part of a building constructed to preserve it from exposure to weather is known as roof. Roofs are designed to suit the needs of different climates keeping in view the available materials. For instance, in plains where rainfall is meagre and heat intense, a thick, flat roof is more suitable to ensure greater protection from the sun. In coastal areas, however, where temperature is more or less even almost all the year round, but rainfall heavy, a pitched or sloping roof is desirable.

Type of Roofs

FLAT ROOFS—This type of roofs is extensively used on all kinds of buildings. They are sloped from $\frac{1}{4}$" to 1" in 20 feet to ensure proper drainage of rain water etc. Some designers make roofs without any slope whatever considering that watertight roofs can be secured without any slope. This simplifies the construction work.

PITCHED, PENT OR SLOPING ROOFS—These roofs are of various types as given below:

- *Shed Roof*—It slopes in one direction as shown in Figure I (a). This type is used generally on a temporary structure where appearance is not important and where it cannot be seen in connection with other types as shown in Figure I (b) to form a 'Lean to'.

- *Gable Roof*—It slopes in two directions as shown in Figure I (c). This type of roof is widely in use in big halls of cinemas, auditoriums, etc. The most common slopes are between 1:2 to 1:1.

- *Hip Roof*—It slopes in four directions as shown in Figure I (d). This type is widely in use. Its slope varies similarly as in case of gable roof.

- *Gambrel Roof*—It slopes in two directions but there is a break in the slope on each side as shown in Figure I (e). This roof is used for houses on account of efficient use which can be made of the space under the roof.

- *Mansard Roof*—It slopes in four directions, but there is a break in the slope as shown in Figure I (f).

- *Deck Roof*—It slopes in four directions, but has a deck at the top as shown in Figure I (g).

- *Sawtooth Roof*—As shown in figure I (h) and I (i), it is used quite extensively in industrial buildings on account of the advantage of sufficient light and good ventilation that it offers. The steep vertical faces as shown in figures are mostly glazed and are kept towards the north.

These days, flat roofs are generally in use especially for residential buildings. Some of the merits and demerits of this type of roof are :—

Flat Roofs

MERITS—

1. A building with a flat roof can be made fire-proof more easily.
2. The rooms with flat roofs are cooler than with sloping roofs. Flat roofs, if provided with sufficient thickness of mud and mud plaster, will have a fairly good heat resistance effects.
3. A flat roof can be very easily constructed.
4. A sloping roof to cover an excessive area of buildings, consistent with economy, to provide for light and ventilation and architectural appearance, is not an easy matter. Besides, a complicated designed sloping roof with members and valley, gutter, etc. is more likely to leak in rainy season and is expensive to keep in good condition.

DEMERITS—

1. On account of extreme variations in temperature in Pakistan hair cracks may occur on the surface which result in leakage.
2. A leak in a flat roof is very difficult to trace and set right, whereas in a sloping roof without ceiling it can be detected with lesser difficulty.
3. A flat roof exposes the entire building to the rain, sun, etc, whereas the projected eaves of a sloping roof tend to protect it.
4. A leaky flat roof may prove a source of danger to a building with walls in mud mortar; even in pacca buildings with walls in cement mortar the timber rots and steel rusts. Besides it makes the house damp which is dangerous to health.

However, all the above disadvantages except No. 3 are based on the assumption of unsound or faulty design or construction. With modern materials and progress in science, it is not difficult to make a perfectly watertight flat roofs.

The following is a desciption of various types of flat roofs.

Types of Flat Roofs

•*FIRST CLASS TILE ROOFING*—It is made up of different material viz, clay tiles, R.C.C. or wooden battens and mud. The following operation is involved in its construction.

(1) Laying of first layer of tiles on batten in 1:6 cement sand mortar or 1:2 lime surkhi mortar.

(2) Laying of second layer of tiles in 1:6 cement sand mortar or 1:2 lime surkhi mortar over a bed of half an inch thickness 1:6 cement sand mortar.

(3) Half an inch thick 1:6 cement sand plaster over second layer of tiles.

(4) Application of a coat of hot bitumen which is blinded with sand.

(5) Four-inch earth filling finished with one-inch mud plaster with gobri leaping.

The size of the tiles is 12" x 6" x 1½". The second layer of tiles is laid by breaking joints in both directions with the first layer of tiles laid underneath. Bitumen coating at the rate of 34 lbs per 100 square feet of surface area or 1/16 of an inch thick is given for making the roofs waterproof. In order to safeguard against attaching bitumen, sand is generally sprinkled over the bituminous coating at the rate of one cubic foot per 100 square feet of surface area. Battens are placed at 12 inches apart centre to centre.

•*SECOND CLASS TILE ROOFING*—It is exactly the same as first class tile roofing except that only one layer of tiles of size 12" x 6" x 2" is laid instead of two.

•3. *JACK ARCH ROOFING.* These are actually segmental arches commonly used for the construction of roofs. It is built of R.S. beams and brick arches. R.S. beams are usually placed at 4' to 6' apart centre to centre. The arch spanning the beams is generally 4½ inches thick. The thickness of an arch is determined by the following formula:—

1. For single segmental arch T is equal to the thickness of arch. $= \sqrt{\cdot 12 \times \text{radius in feet.}}$

2. For segmental arch in series T $= \sqrt{.17 \text{ radius in feet.}}$

For arch spanning 4 to 6 feet the thickness is equal to 4½ inches and for larger spans from 8 to 20 feet, the thickness is generally kept to 9 inches.

The rise of an arch is about 1/6 to 1/8 of smaller span and 1/4 of span in case of arches with bigger span, i.e. 12 feet to 20 feet. These arches are constructed in brick. with lime or cement mortar. The bricks are specially moulded for spring course and for voussoirs. In order to cater for the end reaction of the arches tie rods are provided at the ends of span. These tie rods are generally placed at 4 to 5 feet apart and are ½" to 5/8" diameter for spans up to 6 feet; ¾" diameter for spans up to 7 feet and one inch to 1½ inches diameter for span more than 7 feet. In series of arches having more than 10 spans intermediate tie rods are provided in every fifth span. It is, however, observed that the spacing of tie rods does not exceed 20 times the width of the flanges of the R.S. beams. Tie rods are put in the exact place and their ends are tightened up correctly with the R.S. beams on the one end and an angle iron placed on the wall on the other end.

These arches are constructed in the following two manners.

(i) Arches sprung from the bottom flanges of beams.
(ii) Arches sprung from the top flanges of beams.

Haunches of the arch are covered with cement concrete or lime concrete and are usually finished to a level so as to give a maximum thickness 1½ inches over the crown or the beams whichever is higher. R.C. beams, tie rods and wall plates before being erected are given two coats of red lead paints or other suitable paints.

Concrete of haunches is covered with earth filling etc. as in case of first class tile roofing. For making it waterproof similar treatment is given as in case of first class tile roofing.

• *R.C.C. ROOFING*. This roofing now-a-days is in extensive use in modern building construction. It is replacing Jack Arch Roofing or other types of flat roofs, and requires a covering of a heat resistant material because concrete itself has lesser resistance to heat than earth. It is, therefore, generally provided with 3 inches to 4 inches of earth and mud plaster as covering to safeguard against heat radiation. For making R.C.C. roofs waterproof, a treatment as explained under sub-head waterproofing flat roofs is generally given.

Waterproofing Flat Roofs. Flat roofs have a number of advantages over pent or sloping roofs, although an important question is how to make flat roofs waterproof so that there is no leakage of water from the ceiling and the joints of walls and slab or of the roofs.

There are a number of methods to waterproof them, but the most common in Pakistan is stated below:—

The surface to be rendered waterproof is thoroughly cleaned and made absolutely dry. After that bitumen heated to between 375° F and 400° F is poured on the surface and treated and pulled out so that the average thickness remains 1/16 of an inch. This can be obtained by evenly spreading 34 lbs of bitumen over 100 square feet of the surface area to be covered. The coat of bitumen is continued along parapet to drip course. The bitumen coating, when it cools down and is no longer tacky, is covered with 3 to 4 inches of earth and finished with one-inch mud plaster and gobri leeping.

The grade of bitumen used should be of a high melting point say of 20 to 30 penetration. In heavy rainfall regions two coats may be given. The coats should be blinded with sand before mud plaster is laid in order to ensure that mud is not attached to bitumen and both the materials remain segregated. Sand is generally applied at the rate of one cubic foot per 100 square feet of the surface area.

In case of first class or second class tile roofing or Jack arch roofing, bitumen coating is given when cement plaster laid over tiles or concrete is sufficiently cured and dry. In case of R.C.C. roof, bitumen is applied when the slab is cured and is thoroughly dry.

Now-a-days some engineers recommend that instead of applying bitumen, sheet of polythene of gauge 04/05 may be sandwiched between mud layers. In this case care should be taken to avoid rupture of polythene and to overlap the sheets in the direction of slope. The sheet must be inserted underneath the parapet to avoid penetration of rain water through them. Polythene is an organic plastic compound and has a life-long durability. It is neither attacked by alkali nor acid.

Some authorities also recommend that bitumen felt should be used as a roof covering for waterproofing purpose. Roofing felt selected should be built up to form continuous flexible weather proof covering and may be applied to any shape of roof or structure. The following table gives types and minimum weights of roof felt suitable for this purpose:

Type of felt	Minimum weight per 12 yards rolls 36" wide
Sanded-bitumen felt	45 lbs
Self-finished bitumen felt	30 lbs
Coated and sanded bitumen felt	45 lbs
Saturated bitumen asbestos felt	25 lbs
Self-finished bitumen asbestos felt	30 lbs
Bitumen glass fibre felt	30 lbs

Pitched, Sloping Or Pent Roof

Glossary of Terms

Abutment The sloping intersection of a roof surface with a part of the structure which rises above it.

Barge Board A member, usually of timber, fixed along the edges of a gable and covering the ends of the horizontal roof members.

Battens Horizontal timber members of small section on which tiles or slates may be laid. They are sometimes termed tile or slate battens, or tile or slate laths.

Bedding The laying of tiles or slates in mortar.

Counter Battens Timber members of small section fixed at right angle or obliquely to the direction of the battens between them and the surface below.

Dormer A vertical window formed in a sloping roof.

Eaves The lower edge of an inclined roof.

Flashing A strip of flexible impervious material, usually metal, used to exclude water from the junction between a roof covering and another part of the structure.

Apron Flashing A flashing whose lower edge is dressed over the roof covering.

Cover Flashing A flashing, used in conjunction with other components such as soakers, the vertical parts of which it overlaps.

Raking Flashing A flashing at an abutment, its upper edge being secured into the horizontal joints of brickwork or masonry and stopped up the slopes from course to course.

Gable The part of a wall above the general eaves level at the end of a ridged or partially hipped roof.

Gauge The distance from the line of fixings of a course of slates or tiles to the fixings of the course below.

Gutter
Any form of roof water channel.

Hip (Piend, Scottish)
The sloping intersection of two inclined roof surfaces which meet at a salient angle.

Hip Iron or Hip Hook (Piend Strap Scottish)
A metal strap bent to form a stop for the hip covering and screwed to the lower end of a hip rafter.

Lap
(a) *GENERAL*—The distance that one course of slates or tiles covers the course next but one below it.

(b) *SLATE HEAD-NAILED WITH A SINGLE NAIL*—The distance that one course of slate covers the course next but one below it, less the distance of the nail hole from the slate head.

(c) *SINGLE LAP TILING*—The distance that one course of tiles covers the course next below it.

Mansard
A roof with two pitches on each side of the ridge, the steeper commencing at the eaves and intersecting with a flatter pitch finishing at the ridge. The term is sometimes used for a roof with steeply pitched slopes surmounted by a flat.

Margin
The distance from the lower edge of a slate or tile to the lower edge of the course immediately above.

Pitch
The angle of inclination with the horizontal of the rafters or the surface on which slates or tiles are laid.

Ridge
The intersection of two inclined surfaces at the apex of a roof.

Slate Back
The upper surface of a slate as normally laid.

Slate Fillet
Slates fitted to form a fillet as an alternative to flashings.

Slate Head
The upper edge of a slate when laid.

Slate Tail
The lower edge of a slate when laid.

Soaker
Flexible members, usually of metal, lapped with slates or tiles and bent to form a watertight joint, as for example at abutments where it is used in conjunction with cover flashings, or at mitred hips, valleys and angles.

Tile Fillet
Tiles cut and fitted to form a fillet as an alternative to flashings.

Tilting Piece
A fillet, usually of wood, used at eaves or at open valley gutters to support the slates in the correct position relative to the roof surface.

Top Edge
The upper edge of a roof surface finishing at a ridge or against a part of the structure which rises above the roof surface.

Torching
The mortar pointing to the heads and/or the side joints on the underside of the tiles or slates.

Undercloak
A course or courses of tiles or slates laid under the bedding of slating or tiling at a verge.

Valley — The sloping intersection of two inclined roof surfaces at a re-entrant angle.

Valley, Laced — A valley in which the courses are not horizontal, each course being swept up to a tile and a half, or slate and a half, laid aslant on a wide board in the valley.

Valley, Mitred — A valley at which the tiles or slates of each course are mitred.

Valley, Swept — A valley in which tiles or slates, made or cut to a taper, sweep round in horizontal courses.

Verge (Skew Scottish) — The edge of a roof surface at a gable, or the edge of vertical tiling or slating at window reveals and ends of walls.

Description

A pitched or pent roof is composed of a framework and roof covering. Frameworks generally known as trusses are placed at suitable distances spanning the two supports. The top chord of a roof truss, known as main rafters or principal rafters, supports purlins which are laid at right angle to the plane of the truss. Purlins support common rafters which are laid at right angle to them. Sheathing is laid on common rafter, and on sheathing is fixed a suitable roof covering. In some cases i.e. in the case of corrugated sheets, common rafters and sheathing are not provided, and roof covering is directly laid on the purlins. Purlins may, therefore, be laid close together and common rafters omitted; or heavy planking may be used to span the main rafters, and both purlins and common rafters omitted.

Truss or Framework — A framework or a truss is an assemblage of bars, or members forming a structure to carry transverse load, and under vertical load as vertical reaction. The bars or members are so jointed together at their ends that they bear only direct tension or compression when the external load is applied at the joints.

Trusses are designed to support the roof and snow-loads and to withstand wind pressure and occasionally to support a false ceiling or lower floors which are hung from the truss by means of hanger rods. The general bay length i.e. distance from centre to centre of the two adjacent trusses, varies from 10 to 16 feets. In general, bay length is 10 feet in a span truss of up to 50 feet and beyond that 1/5 of the span. Purlins are placed at or near panels points which are the joints of top chords, so as not to cause flexure in the top chord members. Purlins are placed with their sides either vertical or at right angle to the main rafters.

Trusses are used to support roofs spanning openings up to 20 feet to 200 feet. For span exceeding 200 feet arches are generally used. These trusses are made of wood, steel or partly wood and partly steel. Wood is not used for trusses where the span exceeds 60 feet; instead they are made of steel. In fact, with the advanced process of manufacturing steel and its consequent cheapness and reliability steel trusses are now being preferred to the wooden trusses. They are more economical for span exceeding 40 feet.

Pitch

The pitch of a roof is the ratio of the rise to the spanned length. The minimum pitch for each of the most common roofing materials is as follows:—

1/4 for slates and tiles.

1/5 for corrugated sheets.

Roof Covering

The following are the most common roof covering materials used in the construction of a sloping roof:

- Thatch
- Allahabad tile.
- Manglore tile.
- Galvanized corrugated steel sheet.
- Corrugated asbestos cement sheet.
- Slates.

Thatched Roof

It is composed of bamboo framing which consists of vertical bamboos 1½ inches in diameter and 1 foot apart to which split bamboos are securely fastened at right angles 6" apart. Thatch is from 6 to 12 inches thick and laid in 3-inch layers. The first layer is generally attached to the bamboo framing before it is placed on the roof. The pitch of the roof is usually about 35 degrees. Thatch gives a watertight covering when skilfully applied. It has, however, several serious demerits, the most important of which are its combustibility and its tendency to become infested with vermins. The life of straw thatch is not more than fifteen years.

Allahabad Tile Roof

It is composed of special moulded brick tiles (called Allahabad tiles) laid in layers (either single or double) over battens placed 12 inches apart, centre to centre running along the length of roof and placed above common rafters of the roof trusses placed at suitable distance apart on the walls of a room. The lower flat tiles are laid on battens. The lowest eave battens are kept deeper than the battens above so that the line of the tile from ridge to the eaves is continuous. Battens are placed at 12 inches intervals and their size is 1 inch x 1½ inches. The three lowest tiles in each course of each layer as well as ridge and hip tiles are set in mortar. Unless special eave tiles with closed ends are used, the ends of the each row of semi-hexagonal and semi-circular tiles are stopped with mortar. In the case of double tiling, the spaces between the two rows of flat tiles are also filled. Tiles in contact with mortar are soaked in water mixed with cowdung for at least 6 hours before laying. A dry tile should not absorb water more than 1/6th of its weight when immersed in water for one hour. The general values of pitch in case of Allahabad tile roofing varies from 1:3 to 1:2. The barge boards are kept about 2 inches to 3½ inches higher than the eaves board for the single layer tiling system and about 5 inches to 6 inches higher for the double layer of tiling system so as to cover the end row of tiling.

Manglore Tile Roof

It is made up of special moulded tiles (Manglore tiles) laid over wooden battens placed at 12½ inches apart, centre to centre running along the length of roof and on common rafter of roof trusses placed at suitable distance over the walls of room. The roof generally pitches at a slope 1:3 to 1:2. The size of a Manglore tile is about 16 inches x $9\frac{1}{2}$ inches. The effective size after allowing for laps etc., however, is $12\frac{1}{2}$ inches x $8\frac{1}{2}$ inches. Usually 150 tiles are required for each 100 square feet of roofiing. The weight of 1000 tiles is about $2\frac{1}{2}$ tons. Each flat tile usually weighs about $5\frac{5}{8}$ lbs when dry, and each special ridge tile (about 16 inches long) weighs $7\frac{1}{2}$ lbs when dry.

The tiles are laid by breaking joint, i.e. the left channel of the upper tile lies in the rights of that below, and fits properly one to another, the "catches" resting fully against battens, with usual sizes as $1\frac{3}{4}$ inches x 1 inch or 2 inches and run parallel to the eaves. The lowest battens nearest to the eaves are fixed about 10 inches from the one immediately above, and have got double the ordinary thickness. Special tiles are used for ridges, hips and valleys, and all these tiles at gable ends are set in cement mortar. Tiles to be set in cement are immersed in water for four hours before they are laid. They must not absorb water more than one-sixth of their weight when immersed in water for one hour. In exposed situations and at all gable ends, eaves and places where the tiles are not readily accessible, they are secured to the battens by No. 18 gauge galvanized soft iron wire passing through the holes provided for the purpose in the underside of the tiles. A tile should have a breaking strength of not less than 2 cwts if a load is applied at centre of span when supported on battens at $12\frac{1}{2}$ inches apart centre to centre.

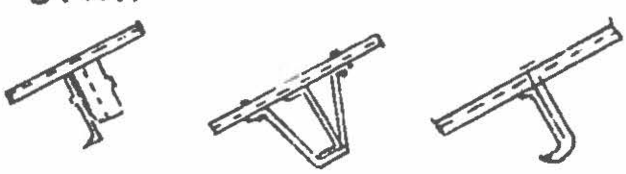
Galvanized Corrugated Steel Sheet Roof

This type is used primarily for roofs of factories, industrial plants, sheds, huts, etc. The material often combines the functions of both roof covering and ceiling and can be applied with a minimum of skill.

The sheets are manufactured in a number of gauges, widths and lengths. They are generally 26 inches and 32 inches wide and 8 feet and 10 feet long respectively. The thickness in common use varies from $\frac{1}{32}$ inch for 24 gauge, to $\frac{1}{16}$ inch for 16 gauge. The gauge of sheets depends upon the spacing of the supports, the load to be carried and the quality of the building. The type commonly used are bare corrugation $2\frac{1}{2}$ inches wide, 5/8 inch deep, and 3 inches wide 3/4 inch deep.

These sheets may be nailed to wood sheathing or supported directly by wood or steel purlins spaced usually at 3 feet to 5 feet apart. They are lapped $1\frac{1}{4}$ inches or 2 inches corrugations on the sides, and 6 inches or 8 inches on the ends depending upon the slope of the roof. For flat slope or building exposed to heavy rains, greater end laps and sealing them with mastic is required. Where steel purlins are used they may be provided with nailing strips to which the corrugated steel sheets are fastened as shown in Fig. (a) below or the sheet may be held in place by straps passing around the purlins and rivetted to the sheet on each side of the purlin as shown in Fig. (b) below. Long malleable nails called clinch nail may be driven through the sheet and clinched around the purlins as shown in Fig. (c) below:

(a) NAILING STRIF (b) STRAP (c) CLINCH NAIL



These sheets are fixed through the crowns of the corrugation also by hook bolts, screws and nails with curved G.I. washers and bituminous washer as shown in Fig. 3 (Details of corrugated steel sheeting). For fixing bolts the holes are punched in the crown of corrugation which are usually made 1/16 of an inch larger in diameter than of bolts. A washer made up of bituminous flat are also used for waterproofing purposes. Since steel is a very good conductor of heat, it may be necessary to provide some form of lining for building where wood sheathing is not used and which are to be heated in which the condensation of moisture on the under side of them is to be prevented. This anti-condensation lining usually consists of a layer of wire netting placed directly on the purlins and one or two layers of asbestos paper placed on the wire netting. The corrugated sheet is placed over the lining. The wire netting holds asbestos paper in place and protects it.

Corrugated Asbestos Cement Sheet Roof

Manufactured in various sizes they are now in extensive use as a roof covering material in the construction of buildings. A sheet having a depth of corrugation under 2 inches is known as small section sheet and more than 2 inches as large section sheet. The centres of corrugation in small sections is about 3 inches whereas in large sections it is 6 inches. "Bigsix" corrugated sheets and "Terafford Sheets" are usually used for roofing purposes. The following table gives particulars of the two types:—

Description		"Bigsix" Corrugated Sheet	"Terafford" Sheet
Standard lengths	..	5'6'7'8'9'10'	5'6'7'8'9'10'
Overall width	..	3'-5½"	3'-7/16"
Laid width	..	3'-3¾"	3'-4"
Cover efficiency	..	95.79%	92.89%
Purlin spacing	..	5'-6" (Max)	5'-6" (Max)
Spacing of rails for side cladding	..	6'-6" (Max)	6'-6" (Max)
Horizontal lap (for slopes not less than 21½°)		6"	6"
Actual cover of 10 feet sheet as laid	..	31.47 sq.ft.	31.76 sq.ft.
100 sq. ft. laid area required of sheeting (on basis of 5 percent less by end laps)		109.90 sq.ft.	113.31 sq.ft.
Weight of 100 sq. ft. as laid approximately	..	357 lbs	332 lbs.
Colours available	..	Natural Grey	Natural Grey

These sheets are laid in somewhat the same manner as corrugated steel sheets. The spacing of the purlin in the case of small section sheets is 3 feet and in the case of large sections it is generally 4½ feet to 5½ feet.

These sheets are laid with the smooth side upward and with a side lap of half corrugation and end lap of 6 inches. Holes for fixing sheets are always drilled and never punched. The diameter of a hole is drilled 1/16 of an inch larger than that of the bolt. These sheets are secured to the purlin through their crown by hook bolts with G.I. washer and bituminous washers. The diameter of a hook bolt varies from ¼ of an inch to 5/16 of an inch. Nuts and screws are screwed lightly at first and tightened when a dozen sheets have been laid. The laying of sheet always starts from the eaves end. If the sheets are laid from left to right the first sheet is laid uncut, and the remaining sheets in the bottom rows will have the top left hand cornor cut or mitred. The sheets in the second and other intermediate rows will have both the top left hand corner and bottom right hand corner cut. With the exception of the first sheet in each row which only have the bottom right hand corner cut and the last sheet in each row will have only the top left hand corner cut, the last or top row sheets will have the bottom right hand corner cut with the exception of the large sheet which is laid uncut. The mitre is cut from a point 6 inches up the vertical side of a sheet to a point 2 inches along the horizontal edge.

As these sheets are liable to be damaged or cracked, roof ladder or planks are always used when the workmen walk over them. Since they cannot take excessive stress care should be taken while fixing purlins that the limit of safe span is not exceeded. Additional joist are fixed where excessive loads are likely to be put on, such as for the repair of ventilators and chimneys.

Slate Roof

It is made from the natural rock which is split and shaped into rectangular pieces of the desired dimensions. Slate for roofing is hard and tough and has a bright metallic luster when freshly split. It rings clear when supported horizontally on three fingers and snapped with the thumb of the other hand.

Slate is available in a great variety of colours: grey, green, dark-blue, purple, red. It is furnished in about any size from 6 to 14 inches wide, 12 to 24 inches long and 1/8 inch to 2 inches thick. The common sizes are 12 x 16 inches and 14 x 20 inches; 3/16 and ¼ inch thick.

Roofs may be made of pieces of uniform sizes and thicknesses and colours, although generally random sizes, thicknesses and colours are used.

Slate may be laid by each course lapping 3 inches over the second course below or they may be laid at random. Care may, however, be taken to give sufficient lap. They are nailed to wood sheathing or nailing strips, or gypsum blocks, holes being punched in the slate at the factory. A layer of roofers felt is used between the slate and the sheathing. The nails are of copper, or yellow-metal slater's nails, although redipped galvanized nails and copper coated nails are commonly used.

Slates may be supported directly on steel sub-purlins to which they are wired. Slate roofs are used on slopes less than 6 inches vertical to 12 inches horizontal. These roofs are fire proof, durable and attractive, and may be classed as expensive.

Roof Drainage

Rain water may be allowed to run off and drip from the projecting eaves, but it is desirable to collect the water in gutters placed along the eaves of sloping roofs. The water is then carried off by the vertical pipes called downspouts, conductors or leaders. Flat roofs or other roofs which do not have projecting eaves are drained by means of downspouts or conductors placed to points where the water is carried by the slight slope provided in the roof. The size of the gutters and conductors is determined by the contributing area and by the intensity of rainfall.

Several types of gutters for sloping roofs are shown in Fig. 2 (a). The hanging gutter is the simplest form, but is not as attractive as the crown-mould gutter or the wood gutter which fits into the design of the cornice. The standing gutter or V-Gutter is inconspicuous and easily constructed, but the concealed gutter is quite expensive. Gutters are sometimes called eaves troughs. Cornices which are enclosed so that the rafters do not show are called open cornices.

Conductors or downspouts should be provided with strainers at their upper ends, as shown in Fig. 2 (c) so that leaves, sticks, and other debris cannot clog them. At very cold places it is desirable to run conductors down inside the building rather than to place them on the outside walls as the heat of the building keeps them from freezing. They may be placed in chases in the outside walls, along columns, or in partitions. If they are placed on the outside of outside walls, they should be kept away from north walls, if possible. Steam outlets are frequently provided in exposed conductors so that steam can be discharged into them to avoid freezing. Clean-outs should be provided so that clogged conductors and the connecting drains can be easily cleaned. Exposed conductors are commonly made of copper and galvanized steel, and copper, cast iron and steel pipes are used for concealed conductors or where appearance is not a factor.

Where a roof surface meets a vertical wall, it is necessary to provide flashing to make the joint watertight. Flashing usually consists of strips of some sheet metal such as copper or galvanized iron which is made L-shaped so as to fit over the joint as shown in Fig. 2 (d), one leg of the "L" running up the wall and the other along the roof. Rain water which is drived against the vertical face of the wall is kept from running down behind the vertical leg of the flashing by counter flashing or cap flashing, also made in the form of an "L". The "L" is inverted, the horizontal leg being built or fitted into a mortar joint and the vertical leg fitting over the flashing, as shown in Fig. 2 (d). Built up roofing is commonly flashed, as shown in Fig. 2 (d), without the use of sheet metal. To avoid the sharp corner between the wall and the roof, cant strips or boards or concrete cants are commonly used. Flashing blocks, as shown in the figure, are frequently used. The angle between the back side of a chimney or other projection, and a sloping roof is usually protected with a saddle or cricket which consists of two sloping surfaces meeting in a horizontal ridge perpendicular to the chimney. The valleys on sloping roofs are made watertight by sheet metal strips bent to fit the two intersecting roof surfaces. Roll roofing is often used for valleys on asphalt shingle roofs.

Comparison and Use of Roofing Materials

The factors which must be considered in the selection of a roof covering are:—

1. Slope of roof.
2. Durability.
3. Initial cost.
4. Maintenance cost.
5. Resistance to fire.

6. Weight.
7. Type of roof construction.
8. Appearance.

The relative importance of these factors will vary with different types of buildings.

• *SLOPE OF ROOF*—All forms of tiles and slates require a medium slope 1:2. Corrugated sheets should not be used on a slope less than 1:3 . Sheet metal roof may be used on practically any slope flat or steep.

• *DURABILITY*—The life of any roofing material depends upon so many variable factors that it is useless to give anything more than comparative figures. The following classifications will give an idea of relative durability.

1. Long lived: Clay Tile, slates, copper, zinc and lead.
2. Medium lived: Asbestos cement sheet and cement tiles.
3. Short lived: Corrugated iron sheet.

Various destructive agents must be considered in connection with durability. Tiles and slates may break if walked upon, for instance, during repairs; slate tiles may suffer severely in hailstorm. Corrugated iron sheet is vulnerable to corrosive gases and salt air. Winds have serious effect on tile roofing.

• *INITIAL COST*—The initial cost of roofing materials varies from time to time and with locality to locality. In determining the cost of a roof covering the indirect cost due to effect of weight on the cost of supporting structure must be considered.

The cost of preparing the supporting structure to receive the roofing has also to be taken into account.

• *MAINTENANCE COST*—Certain classes of roofing materials have to be maintained continually in the form of painting; others, only require repair when damaged by accident or wind storms; whereas on buildings there is practically no expenditure for maintenance. The following classification gives the relative cost of maintenance:—

A. Frequent painting or repairs:—Corrugated steel, tile, etc.

B. Occasional repairs:—Clay tile, Slate, cement asbestos sheets, etc.

• *RESISTANCE TO FIRE*—The actual resistance of the roof covering to fire is of more importance when the supporting structure is made of timber than when it is of fire proof construction. Cement asbestos roof covering will withstand quite severe fire exposure while tile roofing and slates are less resistant.

• *WEIGHT*—If a roofing material is to be replaced by another, the weight may often become determining factor in the choice of materials on account of the strength of the roof construction already in place. The weight of a given roofing material depends upon its design, its thickness and other factors. The following are weights in pounds per 100 square feet which give an idea of relative values:—

a. Clay tile 1000 to 2000 lbs.

b. Slate 500 to 1000 lbs.

c. Galvanized steel 125 to 200 lbs.

d. Asbestos cement 400 to 700 lbs.

• *TYPE OF ROOF CONSTRUCTION*—The methods used in fastening the various roofing materials to the supporting roof construction make it necessary to consider the nature of construction in selecting a roof covering.

Where roof coverings are to be laid directly on the members of the structural frame without sheeting or other material to form a continuous surface, it is necessary to use corrugated steel or zinc sheets. Where suitably spaced sub-purlins or rafters are provided, tile or slate coverings are the most suitable.

• *APPEARANCE*—If the roof is exposed to view, the material will be selected to harmonize with the remainder of the building giving due care to the factors in the above paragraphs. In high class buildings and residences, clay tile slates and asbestos roof coverings may be considered the most suitable. In cheapest class of building corrugated steel roofing may be used and in industrial buildings where appearance is of less importance than durability corrugated sheet roof covering is suitable.

NO. 23.1 FIRST CLASS TILE ROOFING

Specifications

1. Unless otherwise specified, first class tile roofing work shall be constructed according to following specifications. **Scope**

2. The first class tile roofing shall consist of:— **Operations**

   i) First layer of tiles laid in 1:6 cement sand mortar or 1:2 lime surkhi mortar resting on battens.

   ii) Second layer of tiles in 1:6 cement sand mortar or 1:2 lime surkhi mortar laid over a bed half an inch thick 1:6 cement sand mortar.

   iii) Half an inch thick 1:6 cement sand plaster over second layer of tiles.

   iv) A coat of hot bitumen blinded with sand.

   v) Four inches earthfilling finished with one inch mud plaster with gobri leeping.

3. *TILES*—Unless otherwise specified, tiles used in both the layers shall be of size 12"x 6"x1½" and shall comply with Specifications No. 4.1. **Materials**

CLAY—Clay used in mud mortar or earthfilling shall conform to Specifications No. 3.1.

BITUMEN—Bitumen shall be of approved quality.

4. The battens shall be of specified type and size and shall have proper finished **Laying of Battens**

surface on top so as to give a good bearing to the tile. They shall be spaced 12 inches apart centre to centre and shall be placed in straight and parallel lines.

Slope to Roof

5. The necessary main slope in the roof shall be formed by sloping the beam or battens.

Laying of First Layer of Tiles

6. Over the battens the first layer of tiles shall be laid in mortar with the joints coming over the centre of the battens. Tiles shall be laid straight and square. All vertical joints shall be as fine as possible.

Laying of Second Layer of Tiles

7. The second layer of tiles shall then be laid in specified mortar on half an inch thick bed of specified mortar spread over the first layer of tiles. The joints shall be broken in both directions with the first layer of tiles laid underneath. The vertical joints shall be as fine as in the case of first layer of tiles and shall be flushed with mortar at top.

Bonding of Tiles with Parapet Wall

8. Tiles resting on wall shall have bearing of preferably 4½ inches and in no case less than 3 inches. These tiles shall butt closely against the brickwork of the parapet wall leaving no voids; wherever possible, the ends of the tiles shall be bonded into the brickwork with specified mortar.

Cement Plaster to Parapet

9. The portion of the parapet wall between the tiles and drip course shall be plastered with half an inch thick cement sand plaster of 1:3 ratio, unless otherwise specified.

Bed for Bituminous Coating

10. Half an inch thick cement sand plaster of specified ratio shall then be laid over the surface of the second layer of tiles to serve as a bed for bitumen.

Curing of Bed

11. The bed shall be cured for seven days, and the surface shall then be allowed to dry thoroughly before bitumen is laid.

Application of Bitumen Thickness

12. Bitumen shall be heated to a temperature specified by the manufacturer and poured on the surface to be treated and pulled out so that the minimum thickness is 1/16 of an inch. The coat of bitumen shall be continued alongwith the parapet wall up to a drip course.

Blinding of Bituminous Coating

13. The bitumen coat shall be blinded with sand at the rate of one cubic foot per 100 square feet of the surface area.

Earthfilling and Mud Plaster

14. Four inches thick of good earth (clay) conforming to Specifications No. 3.1 shall then be put and shall be thoroughly rammed and watered. The roof shall be finished with one inch thick mud plaster with gobri leeping which shall be done in accordance with Specifications No. 25.7. This shall be done before laying the drip to ensure a close joint with the wall.

Khurras

15. Khurras shall be made before the earth is laid and shall be in accordance with the Specifications No. 23.10.

Pointing of Tiles Underneath

16. Unless otherwise specified, on the completion of the work the underside of the tiles shall be washed and neatly pointed with 1:2 cement sand mortar.

Filling Spaces Between Battens

17. In case of wooden battens, the spaces over the beam and between the battens shall be closed by one-inch planks nailed to distance pieces which in turn are nailed to the battens. Where concrete battens have been used the spaces shall be filled with 1:3:6 cement concrete block of exact size and laid in spaces with 1:3 cement sand mortar. The filling shall be equal to the battens in height and the outer faces shall be exactly in line with the edge of the beam.

Painting with Preservatives

18. The top surface of wooden battens in contact with the tiles and the end shall be painted with an approved preservative.

Measurements

19. First class tile roofing shall be measured by the superficial area of the roof. The unit of measurement shall be 100 square feet.

Labour Rate

20. The unit rate shall include:—

a) Laying of first layer of tiles in specified mortar on battens.

b) Laying of second layer of tiles in specified mortar over half an inch thick bed of specified mortar.

c) Laying of half an inch thick cement sand plaster over second layer of tiles.

d) Laying of coat of hot bitumen blinded with sand.

e) Laying of 4-inch earthfilling finished with 1-inch mud plaster with gobri leeping.

f) Cement plastering portion of parapet against which mud plaster and earthfilling butt.

g) Pointing the underside of the tiles with specified mortar.

h) Filling spaces between battens over the beam.

i) Providing, using and removing scaffolding, staging, ladders, supports and other tools and plants required for carrying out the work as per above specifications. It shall also include making good of any damaged portion of the walls or other structure on which the roof is being laid.

NOTE.—The rate does not include labour required for the construction of khurras or any other kind of rain water outlet. The rate also does not include hoisting and fixing in position, battens and beams. Painting of wooden battens with preservative is also not included.

Composite Rate

21. The unit rate shall include the cost of the material specified above for carrying out the work in accordance with above specifications, in addition to the labour rate detailed in para 20 above.

NO. 23.2 SECOND CLASS TILE ROOFING

Specifications

Second class tile roofing shall conform to Specifications No. 23.1 in all respects with the following exceptions:—

Only one layer of tiles shall be laid instead of two and their size shall be 12"x 6"x 2".

NO. 23.3 JACK ARCH ROOFING

Specifications

Scope

1. Unless otherwise specified, Jack Arch roofing shall be constructed according to the following specifications.

Operations

2. Jack Arch roofing shall involve the following operations:—

(i) Construction of brick segmental arches in specified mortar.

(ii) Filling of haunches and crown with specified cement concrete.

(iii) Laying of bitumen blinded with sand over half an inch thick bed of specified mortar.

(iv) Earthfilling finished with mud plaster and gobri leeping.

(v) Plastering soffits of arches.

Material

3. Unless otherwise specified, materials shall conform to the following specifications:—

- Bricks—Specifications No. 4.1
- Mortar—Specifications No. 19.1 to 19.4
- Steel—Specifications No. 10.1 to 10.3
- Paints—Specifications No. 9.1
- Concrete—Specifications No. 20.1

Rise of Arch and Type

4. Unless otherwise specified, the arches shall be true segment of a circle and shall have a rise equal to 1/8th of the span.

Painting of Steel

5. Before fixing in position, R. S. beams and all other iron work shall be given specified coats of paint as detailed in Specifications No. 27.9.

Laying of Tie Bars and Wall Plates

6. The end arch of series of Jack Arches springing from an unsupported outer wall shall be supported by an angle iron or a rail of specified section embodied in the wall immediately beyond the springing of the arch and shall be tied to the first joist by tie rods. Tie rods shall be perfectly straight and evenly spaced not more than 4 to 5

feet apart and shall be of ½ of an inch to 5/8 of an inch of diameter for span up to 6 feet, 3/4 of an inch diameter for span up to 7 feet and one inch to 1½ inches in diameter for spans more than 7 feet. In series of arches having more than 10 spans, intermediate tie rods shall be provided in every fifth span. Tie rods shall be put in at the specified place and nuts at the ends shall be tightened up correctly before centrings are fixed.

Supporting of Centring

7. Centring shall be of sufficient stiffness to retain its curved shape without deflection. Its surface shall be correctly struck to the curvature of the soffit of the arch. The centring shall be supported on pillars built up from the ground or shall be suspended from the bottom flanges of the beams only if approved by the Engineer-in-charge. In the later case, cross timber carrying the centring shall be suspended from the outer flanges of the beams by hook bolts of square section. No centring shall be attached nor shall the weight of centring come in any way on tie rods.

Precautions against Displacement

8. To prevent lateral displacement of the beams under the thrust of the arch at least 3 complete sets of centrings shall always be used so that each arch under construction shall have two preceding ones still supported till the whole roof is finished. Except in special circumstances in a wide roof where specified, all arches of one roof shall be started simultaneously from one side of the roof and the centring moved forward along the joists.

Building of Arch

9. Brickwork in arches shall conform to Specifications No. 21.1 for First Class Brickwork and for arch work Specifications No. 21.5 for Brickwork in Arches.

Spring Course

10. Bricks forming the spring courses shall be specially moulded so as to fit the joist and at the same time give a truly radiating skew back joints. In the absence of moulded bricks, the bricks shall be cut to the required shape, if approved by the Engineer-in-charge.

Key

11. Key shall be driven firmly into position with a wooden mallet and shall lie truly and centrally of a vertical line through the centre of the span.

Slope

12. Unless otherwise specified, the slope in the roof shall be given in R. S. beams while placing them in position.

Filling of Haunches and Crown

13. The haunches of the arch shall be filled and the arching covered with specified concrete thoroughly rammed and finished to a level so as to give a maximum thickness of 1½ inches over the crown, or the joists whichever is higher. The concrete shall be cured for ten days.

Bed For Bituminous Coating

14. After filling up haunches half an inch thick cement sand plaster of specified ratio shall be laid over the surface to serve as a bed for bitumen.

Curing of Bed

15. The bed shall be cured for seven days and the surface shall be allowed to dry thoroughly before bitumen is laid.

Application of Bitumen

16. Bitumen shall be heated to a temperature specified by the manufacturer and poured on the surface to be treated and pulled out so that the minimum thickness is 1/16 of an inch. The coat of bitumen shall be continued along with the parapet wall up to the drip course.

Blinding of Bituminous Coating

17. The bitumen coat shall be blinded with sand at the rate of one cubic foot per 100 square feet of the surface area.

Earthfilling and Mud Plastering

18. Three inches thick of good earth (clay) conforming to Specifications No. 3.1 shall then be put and thoroughly rammed and watered. The roof shall then be finished with one inch thick mud plaster with gobri leeping as per Specifications No. 25.7.

Plastering of Soffits

19. The soffits of the arches shall be plastered with specified mortar as per Specifications No. 25.2.

Plastering Bottom Flanges of Beams

20. In case where the lower (exposed) flange of the beam has to be covered with plaster, ½ inch mesh wire netting not lighter than 20 gauge shall be wound round it to let the plaster go under the flange. The netting shall be clipped on with hoop iron and shall be kept away from the flange by pieces of wood so as to afford a key to the plaster.

Measurements

21. Jack Arch roofing shall be measured by the superficial area of the roof. The unit of measurement shall be 100 square feet.

Labour Rate

22. The unit rate shall include:—

(i) Laying of bricks in segmental arches in specified mortar. Cutting of bricks, whenever required, curing and protecting as per above specifications and/or any other specifications specially included in the contract.

(ii) Filling of haunches and crown with specified concrete.

(iii) Laying of coat of hot bitumen blinded with sand over half an inch thick bed of specified mortar.

(iv) Laying of 3 inches thick earthfilling finished with mud plaster and gobri leeping.

(v) Plastering of soffits of arches in specified mortar.

(vi) Providing, using and removing scaffolding, shuttering, centring, ladders, supports and use of any other tools and plants required for carrying out the work as per above specifications.

NOTE.—The rate does not include hoisting, fixing in position and painting of R. S. beams, tie rods or other anchor. The rate also does not include the plastering of bottom flange of beams.

Composite Rate

The unit rate shall include the cost of all the materials supplied at site of work, except steel and paints, specified above in carrying out the work in accordance with the above specifications, in addition to the labour rates detailed above.

NO. 23.4 JACK ARCH ROOFING (SPRUNG FROM TOP OF BEAMS)

Specifications

Jack Arch roof (sprung from the top of beams) shall conform to Specifications

No. 23.3 of Jack Arch Roofing (sprung from the bottom of beams) in all respects, except the following:—

(i) *EXTRA TIE BARS ANCHORAGE.* A second length of 3"x 3"x 3/8" angle iron shall be provided whenever tie rods are to be provided, to serve as an anchorage for the other ends of the tie rods which in this case cannot be anchored to the beams.

NO. 23.5 JACK ARCH ROOFING (FOR CARRYING FLOORING OF THE ROOM)

Specifications

Jack Arch roofing intended to carry the flooring of a room shall conform to Specifications No. 23.3 or 23.4 for Jack Arch roofing (sprung from either bottom or top of beams) in all respects, except the following :—

Operations referred to in para. 2 (iii), (iv) and (v) of Specifications No. 23.3 shall not be performed.

Labour Rate

The unit rate shall include:—

(i) Laying of bricks in segmental arches in specified mortar. Cutting of bricks, whenever required, curing and protecting as per above specifications and/or any other specifications specially included in the contract.

(ii) Filling of haunches and crown with specified concrete.

(iii) Plastering of soffits of arches in specified mortar.

(iv) The cost of providing, using and removing scaffolding, shuttering, centring, ladders, supports and any other tools and plants required for carrying out the work as per above specifications.

NOTE.—The rate does not include hoisting, fixing in position and painting of R. S. beams, tie rods or other anchor. The rate also does not include the plastering of bottom flange of beams.

Composite Rate

The unit rate shall include the cost of all the materials supplied at site of work, except steel and paints, specified above in carrying out the work in accordance with the above specifications, in addition to the labour rates detailed above.

NO. 23·6 FLAT STEEL SHEET ROOFING

Specifications

Scope

1. Unless otherwise specified, plain flat steel sheet roofing shall be constructed in accordance with the following specifications.

Materials

2. Unless otherwise specified, material shall conform to the following specifications:—

FLAT STEEL SHEET shall conform to Specifications No. 15.6 for Flat Steel Sheets.

ROLLS shall be made up of 22 S.W.G. galvanised flat steel sheet conforming to Specifications No. 15.6 Flat Steel Sheets.

FIXING ACCESSORIES shall be screws and clips and shall be of approved quality and shall be invariably galvanized.

ROLL BATTENS/BOARDING shall be wooden conforming to Specifications No. 8.1 to 8.3 of Timber.

Roofing Boarding

3. The sheeting shall be laid on boarding of wood of thickness specified. The boarding shall be butt jointed unless specified otherwise with two screws (3-inch) holding each board to each rafter. Only that side of the boarding shall be wrought which is not covered by sheets.

Roll Battens

4. The roll battens shall be of specified wood, 2 inch by 1½ inch in section, with the top rounded to the curve of the ridge. They shall be fixed at the correct spacing, in parallel rows and secured to the boarding from underneath with 3-inch screws spaced not more than 2½ feet apart.

Preparing Sheets

5. The longitudinal edges of the sheets shall be curved to a radius of half an inch to that the rolled edge stands 3/4 of an inch above the sheet. The top end of the upper most sheet shall be bent up 1½ inches.

Laying Sheets

6. The sheets shall be laid between the battens from the lower edge of the roof upwards. The lower edge of the first sheet shall be held to the planking by galvanized iron clips 6"x3/4"x1/8" at the two edges and then middle. The upper edge shall be kept under the lower edge of the next sheet which shall be held by an equal number of similar clips but 10 inches long. The 10-inch clips shall be fixed to the boarding by two screws at one end leaving the other end free for at least 6 inches to allow the lower sheet to be tucked underneath. The top most sheet, the upper edge of which has already been turned up, will butt against a batten 1½"x1" running between the roll battens and parallel to the ridge plate, and the turned up portion shall be screwed to this batten.

The turned up longitudinal edges shall be kept down by 2"x1"x1/4" galvanized iron pieces recessed into and screwed to the battens with 2-inch screws. Two such clips shall be used at the ends and two spaced equally in between.

Preparing and Fixing Rolls

7. Rolls shall be made from 5-inch wide strips bent to a radius of 1 inch and leaving 1½-inch gap between the edges. They shall then be slipped down the roll battens so as to enclose the turned edges of the roofing sheets. Rolls shall be held at the lower end, in each case by a clip, 6"x 3/4"x1/8" countersunk into the batten and screwed to it.

Ridge Sheeting

8. Unless otherwise specified, the ridge shall be made from 2 feet strips, one longitudinal edge of which shall be turned up 1½ inches to a radius of ½ inch. The ridge sheet shall be laid on longitudinal planking which shall be of wood and thickness

specified, butt jointed and unwroughten both sides. The ridge boarding shall be fixed on top of roll battens after the rolls have been fixed in place and shall be secured with 2-inch screws per board to each roll batten.

The lower longitudinal edge of the ridge shall be secured by clips 6"x3/4"x1/8" screwed to the battens through the boarding, with 2-inch screws.

Ridge Roll

9. The ridge roll shall be made to a radius equal to the thickness of the ridge plate and with the edges separated by thickness of the beam, and slipped over the ridge sheets so as to enclose the turned-up edges.

Laps

10. Roof sheets and rolls shall not overlap to a length of less than 6 inches. Ridges, sheets and ridge roll shall not overlap to a length of less than 9 inches.

Wood Preservative

11. Unless otherwise specified, all boarding, battens and fillets shall be given two coats of hot creosote or other approved wood preservative.

Bending by Machine

12. A machine of approved type shall be used for turning the edges of sheets and making all rolls. No hammering shall be allowed.

Hips, Vallyes, Gutters and Flashings

13. Valleys, gutters and flashings shall be made in accordance with the Specifications No. 15.6 for these items. Hips shall conform to paras 8 and 9 of this specifications for ridges except that the end is stopped with a piece of galvanized iron sheet cut to fit. The junction between the ridges and hips shall be capped with milled lead sheeting weighing 5 lbs per square foot. The lead sheet cap shall be carefully moulded to fit and shall have less than 9-inch overlap.

Measurements

14. The measurement of flat steel sheet roofing shall be done by the superficial area of roofs. The unit of rate shall be 100 square feet.

Labour Rate

15. The unit rate shall include:—

(i) Painting of roll battens with wood preservatives and laying them in position.

(ii) Fixing of sheets and rolls in position with specified fixing accessories.

(iii) Labour for providing, using and removing all scaffodling, ladders and other tools and plants required for the satisfactory execution of work in accordance with the above specifications.

The boarding underneath the sheeting is not included in the rate. Also the labour for ridges, hips and the boarding to which they are fixed and gutters and flashing are not included in the rate.

Composite Rate

16. The unit rate includes the cost of (i) rolls batten (ii) flat steel sheets with all the specified overlapping and fixing accessories (iii) wood preservative paints required for carrying out the work as per above specifications, in additions to the labour rate as detailed above.

NO. 23.7 GALVANIZED CORRUGATED STEEL SHEET ROOFING

Specifications

Scope

1. Unless otherwise specified, galvanized steel sheet roofing (corrugated) shall be constructed in accordance with the following specifications.

Material

2. (*a*) Galvanized corrugated steel sheets shall conform to Specifications No. 15.7 for Corrugated Steel Sheet.

(*b*) Fixing accessories, hook bolts, screws, bolts, nuts, rivets, washers shall be galvanized or shall be of any other approved quality.

(*c*) Sealing material shall be bituminuous mastic or of any other approved quality.

(*d*) Flashing gutters shall conform to Specifications No. 23.11 for Flashing Gutters.

Lap

3. (*a*) End lap shall be minimum of 6 inches for slope and 4 inches for vertical falls which shall be sealed with specified sealing material.

(*b*) Side lap shall be formed on the sides of the sheet, away from the prevailing direction of wind. The side lap shall vary from one to two corrugations as specified.

Insulating Material

4. Wherever specified, insulating material of approved quality shall be laid either between the purlins and the sheet or under purlins incorporating air gap.

Purlin Spacings

5. Purlin spacings for roof covering with G.C.S. sheets shall be arranged with a view to using standard sheets of uniform length throughout, and the trusses shall be designed for purlin spacings to suit the standard length of these sheets to avoid unnecessary cuttings. Ridge purlins shall be as near to the ridge as possible having regard to the type of ridge capping to be used and the manner in which it is to be fixed.

Holes

6. The holes for fixing bolts shall be made through crown of the corrugations and shall be either punched or drilled and shall be 1/16 of an inch larger in diameter than the bolts or fixing screws to be used.

Holes shall be in the exact position to suit the purlins and no holes for fixing bolts shall be nearer than 1½ inches to the end of the sheet. These holes shall be made in a manner that the arrisses of the punched hole shall come on top when the sheets are laid. Where 4 sheets overlap, holes shall be drilled and not punched.

Laying of Sheet

7. Before the laying of sheet begins it shall be seen that all purlins are in true plane correctly spaced and securely fixed. The purlins spacing and the length of sheet shall first be checked to see that the arrangement will provide the specified overhanging at the eaves and the laps. The eave course shall be laid first and work shall start at

the leeward end of the building so that side laps have better protections from the rain driven by the prevailing wind. The top edges of eave sheet shall extend at least $1\frac{1}{2}$ inches beyond the back of steel purlins or 3 inches beyond the centre line of a timber purlin.

Fixing Sheets

8. Sheets shall be fixed to steel purlins by hook bolts and to timber purlins by mushroom-headed galvanized drive screws. Hook bolts and drive screws shall be from 1/4 of an inch to 3/8 of an inch in diameter as specified and shall be spaced at an interval of not more than 15 inches. Sheets shall be secured at every purlins by at least 2 bolts. Nuts or heads of drive screws shall have specially made washers to render the holes waterproof. Washers shall be "Limpet" patent doom and shall be bedded on bituminous felt. Screws or bolts shall be tightened sufficiently to seat washers over the corrugation.

Ridges and Hips

9. (a) General accessories. Ridge or hip capping, wherever possible, shall be secured to the purlins by the same bolts or screws which secured the sheeting.

(b) Ridge cap shall be made up of galvanized flat steel conforming to Specifications No. 15.6 or Flat Steel Sheet or otherwise specified. In case (a) above is not possible as the purlin is not sufficiently near the ridge, the capping shall be secured to the sheet by 1/4 of an inch to 3/8 of an inch diameter bolts: two roofing bolts to each wing capping at centre not further apart than the bolts used for sheets. The lap of the capping along the ridge shall not be less than 6 inches and shall be so arranged as to protect the joints from the prevailing wind.

(c) Hip cap shall be cut to the required mitre and shall be close butted. The slope joints shall be covered with plain ridge cap which shall be secured through the roof sheet or the slope runner by one bolt on each side at the same spacing as for the roof sheets. Hip caps shall have a minimum lap of 6 inches.

Special Fastening against Cables

10. For any situation exposed to strong winds, sheets shall be fastened down above the eaves by continuous length of $1\frac{1}{2}''\times\frac{1}{2}''$ flat iron bars bolted down every 5 feet by 1/2-inch bolt built a foot into the wall and secured at the lower end by a 3-inch square washer.

Painting of Sheets

11. Wherever desired, sheets shall be painted with specified paint.

Measurements

12. The measurement of corrugated iron sheet roofing shall be done by the superficial area of the roofing. The unit rate shall be 100 square feet.

Labour Rate

1. The unit rate shall include:—

(i) Hoisting and fixing of corrugated iron sheets in position with the specified fixing accessories.

(ii) Punching or drilling holes and cutting of sheets.

(iii) Providing, using, erecting and removing of scaffolding, benching ladders, templates and use of other tools and plants required for carrying out the work in accordance with the above specifications.

The labour for fixing purlins, gutters, flashing, ridges, specially fastening against cables etc., is not included. The labour for fixing insulating material is also not included.

Composite Rate

14. The unit rate shall include the cost of (i) galvanized corrugated steel sheets with all the specified overlaps, (ii) all bolts, nuts, hook bolts, screws and washers required for properly fixing sheets as per above specifications, in addition to the labour rate detailed in para 13 above.

NO. 23.8 CORRUGATED ASBESTOS CEMENT SHEET ROOFING

Specifications

Scope

1. Unless otherwise specified, corrugated asbestos cement sheet roofing shall be constructed in accordance with the following specifications.

Material

2. (a) Corrugated asbestos cement sheets shall conform to Specifications No. 15.2.

(b) Fixing accessories. Hook bolts, nuts, and screws shall be galvanized or of any other approved quality.
Washers shall be bituminous and galvanized iron or of any other approved type and quality

(c) Sealing Material. When specially required, sealing material shall consist of mastic of approved quality.

(d) Flashing gutters shall conform to Specifications No. 23.11.

Lap

3. (a) End lap shall be of a minimum size of 6 inches.

(b) Side lap shall be formed on the sides of the sheet away from the prevailing wind. It shall be half the corrugation of sheets.

Overhanging

4. The minimum end overhanging in case of eave verges and cable ends shall be 12 inches. Overhanging verges shall be supported by purlins over the full width of the sheet.

Purlin Spacings

5. Purlin spacings for roof covering with G.C.S. sheets shall be arranged with a view to using standard sheets of uniform length throughout, and the trusses shall be designed for purlin spacings to suit the standard length of these sheets to avoid unnecessary cuttings. Ridge purlins shall be as near to the ridge as possible having regard to the type of ridge capping to be used and the manner in which it is to be fixed.

Holes

6. Holes in sheets shall always be drilled and shall on no account be punched. They shall be 1/16 of an inch larger in diameter than that of bolt or fixing screw, and shall be drilled through the crown of the corrugations. Holes shall be drilled in exact position to suit the purlins. No hole shall be made in valleys of corrugations and closer than 1½ inches from the edge.

Laying of Sheets

7. Before sheeting begins the structure shall be inspected to see that all purlins are in true plane, correctly spaced and securely fixed.

Purlin spacings and the length of sheet shall be checked to see that the arrangement provides the specified laps and overhanging. The eave course shall be laid first, and work shall start at the leeward end of the building, so that the side laps shall have better protection from rain driven by the prevailing winds. The top edge of eave sheets shall extend 3 inches beyond the central line of purlins. Close fittings of sheets at the junction of side and end lap shall be ensured.

Fixing Sheets

8. G. I. bolts and screws required for fixing sheets shall be 1/4 to 5/16 of an inch in diameter. Nuts or heads of screws shall bear evenly on washers. Bolts or screws shall be fixed with G. I. washers over bituminous washers to fit tightly on the outer face of the sheet. Bolts or screws shall in the first operation be tightened lightly. They shall be tightened fully when about a dozen of sheets have been laid in position.

For metal angle purlins the sheet shall be secured by bolts of 'J' or 'L' shape. For wooden purlins the sheet shall be fixed with gimlet pointed roofing screws which shall not be hammer-driven.

Ridge Cap

9. Capping shall be secured to the ridge purlins by the same bolts or screws which secured the sheeting; if ridge purlin is not sufficiently near the ridge to permit this each wing of the ridge, capping shall be secured to the sheeting by 1½"×5/16" roofing bolts.

Other asbestos cement accessories such as flashing etc. shall be secured either to the structure or by the roofing bolt of the sheeting.

Painting

10. When specially required, the paint used for painting of sheets shall be of an approved quality.

Measurements

11. The A.C.C. sheet roofing shall be measured by the superficial area of the roof. The unit of measurement shall be 100 square feet.

Labour Rate

12. The unit rate shall include:—

(i) Hoisting and fixing of A.C.C. sheets in position with specified fittings, i.e. nuts, screws, washers, hook bolts, bituminous washers, etc.

(ii) Cutting of sheets and drilling of holes.

(iii) Providing, using and removing scaffolding, benching ladders and use of other tools and plants required for carrying out works in accordance with above specifications.

Labour for painting of sheets and fixing purlins, gutters, flashings, ridges, etc., is not included.

Composite Rate

13. The unit rate shall include the cost of (i) A.C.C. sheets with all the specified overlaps, (ii) all bolts, nuts, screws, washers, etc., required for the proper fixing of sheets, in addition to the labour rate as detailed in para 12 above.

NO. 23.9 HALF-SAWN SLEEPER ROOFING

Specifications

Scope

1. Unless otherwise specified, half-sawn sleeper roofings shall be governed by the specifications stated below, and shall consist of the specified materials in accordance with the requirements set forth as under:—

Materials

2. Unless otherwise specified, half-sawn sleeper roofings shall consist of wooden bed blocks of specified sizes obtained from unserviceable sleepers, flat-footed unserviceable rail girders, one layer of half-sawn sleepers obtained from unserviceable sleepers, and 5-inch thick layer of mud and mud plasters.

Composition

3. Unless otherwise specified, half-sawn sleeper roofings shall be constructed after the supporting walls have been raised to the specified height. Longitudinal wooden bed blocks shall be laid in the recess provided in the wall to the correct level and then specified rail girders from unserviceable rails shall be put across the supporting walls at specified spacings on these bed blocks. Half-sawn sleepers shall then be laid in the longitudinal direction of the walls butting against each other. Gaps between two such sleepers shall then be filled in with the specified mixture of sawdust and bitumen to make it watertight. Finally, a layer of 5 inches of mud and mud plaster shall be laid on the sawn sleepers and finished with a slope of 1 in 60 to drain out rain water efficiently. A water spout of approved type shall be also provided to the roof.

Ceiling

4. The exposed side of the sleeper shall be the sawn face, smoothed sufficiently to allow easy painting. The joint between the sleepers shall be fine and in no case more than 1/4 of an inch thick.

Painting

5. The exposed surface of the sawn sleepers and the rail girders shall be painted with specified paints. The rail girders shall be painted according to the Specifications No. 27.9 for Painting Iron Works, and the sawn face of the sleeper shall be painted according to the Specifications No. 27.2 for Painting Wood Works.

Measurements

6. The measurement shall be taken of the superficial area of the roof. The unit of measurement shall be 100 square feet of the roof surface.

Rate

7. The unit rate shall include sawing of sleepers, making bed blocks, hoisting rails in position, painting the sawn face of the sleeper and rails, making joints watertight, and providing a layer of 5-inch mud and mud plaster. Unserviceable sleepers shall be supplied by the Department. In case the sleepers are arranged by the contractor, the rate shall include the cost of the actual sawn sleepers laid in the roof, by cubical contents and paid for separately.

NO. 23.10 "KHURRAS" "PARNALAS" AND SPOUTS

Specifications

Top Khurras

1. Unless otherwise specified, top khurras shall be 2 feet x 2 feet and shall be made of 1:2:4 cement concrete 1½-inch thick, laid on 1:4:8 cement concrete. The oustide edge of the khurras shall be flush with the level of the mud plaster or leepai and the surface shall slope uniformly from that place to the outlet, which shall be 2 inches lower than the edges. Concrete shall have a slope 1:1 at the sides so as to be overlapped by earth and mud plaster. Cement concrete shall be continued into the outlet so as to ensure a watertight joint.

Bottom Khurras on Roof

2. Unless otherwise specified, bottom khurras on top of verandah or similar roofs shall be 2 feet × 2 feet and will consist of a 1½-inch layer of 1:2:4 cement concrete laid on 1:4:8 cement concrete. The surface shall be shaped like a saucer drain, the depth of the saucer being 2 inches, and joining up with the roof drain, described in paragraph 7.

Bottom Khurras on Ground

3. Unless otherwise specified, bottom khurras when used on the ground, in conjunction with spouts, shall be 4 feet × 2 feet and shall consist of bricks on edge laid in cement, laid on 3 inches of 1:4:8 cement concrete.

Revealed Parnalas

4. Unless otherwise specified, revealed parnalas shall be made by leaving a channel 7 inches wide and 2½ inches deep in the wall during construction, and afterwards plastering the channel with 1:3 cement plaster. The corner of the channels shall be rounded to a radius of one inch in plastering. If revealed parnalas are left in a wall made of brickwork in mud, the bricks shall be laid in cement mortar (1:3) for a depth of 4½ inches from the back and sides of the parnalas, this work being included in the rate.

Khassi Parnalas

5. Unless otherwise specified, khassi parnalas shall consist of two fillets of cement plaster (1:3) raised 1½ inches and spaced 9 inches apart, the space in between being plastered with 1:3 cement plaster. The fillets shall be prismatic in section (but with all corners and angles rounded), the inner sides being at right angle to the wall and the outer sides sloping.

Unless otherwise specified, khassi parnalas shall in no case be made on top of the cement or other plaster on the wall, but made in contact with the brickwork or masonry after raking out the joints.

Spouts

6. Unless otherwise specified, spouts shall be made of reinforced cement concrete and shall have an open channel 3½"x3½" with a semi-circular bottom. They shall project at least 15 inches from the face of the wall and shall be built into the wall for a depth of at least 13½ inches. The part built into the wall shall be sufficiently thickened to provide adequate support for the overhanging portion. Spouts shall be fixed

at a slope not flatter than 1 in 6 and shall have a lip at the lower edge to allow water to drip clear.

Roof Drains

7. Roof drains shall be provided on verandah and similar roofs to conduct water, discharged by the parnalas of a higher roof, to the outlet. They shall run in a straight line from the bottom khurra of one to the (top) khurra for the outlet concerned. Unless otherwise specified, the drain shall be saucer-shaped in section, the depth being 2 inches. Drains shall be made of 2 inches thick 1:2:4 cement concrete laid on cement concrete 1:4:8 of a section to give the necessary shape, with edges flush with the roof plaster.

Measurements

8. The parnalas and drains shall be measured along their length. The unit of measurement shall be per running foot.

The khurras and spouts shall be measured as a jobs item. The unit of measurement shall be for a complete unit.

Labour Rate

9. The unit of rate shall include (i) all the labour required for the above operation and (ii) use of all the tools and plants required for carrying out work in accordance with the above specifications.

Composite Rate

10. The unit rate shall include the cost of all materials at site of work required for carrying out the work as per above specifications, in addition to the labour rate detailed in para 9 above.

NO. 23.11 GUTTERS AND FLASHINGS

Specifications

Scope

1. Unless otherwise specified, gutters and flashings shall be constructed in accordance with the following specifications.

2. Unless otherwise specified, lead, copper, zinc or galvanized steel sheet shall be used for gutters and flashings:—

a) Lead sheets shall be made from melted lead and shall not be less than the following weight per foot:

Gutters	6 lbs.
Flashings	5 lbs.

b) Copper sheets used for gutters shall be cold rolled and shall not be thinner than 22 S.W.G. For flashing it shall be dead soft temper and shall not be thinner than 24 S. W.G.

c) Zinc sheets shall not be thinner than 20 S.W.G.

d) Galvanized steel sheets shall be:—

For gutters	No. 18 S.W.G. to No. 22 S.W.G.
For flashings	No. 20 S.W.G. to No. 24 S.W.G.

Gutters

3. Unless otherwise specified, gutters shall be semi-circular in shape, made of the material specified above and shall be properly finished and laid in specified shape. Gutters shall be supported with brackets fixed to wall or roofing at a specified distance apart.

Flashing

4. When the edge of a roof sheeting, or of a valley gutter is turned up against a wall, the edge shall be weather-proofed with a flashing. The flashing shall be inserted into the brickwork or masonry joints to a depth of 2 inches, the joints being filled up with 1:3 cement mortar unless otherwise specified. It shall be further secured in the joint by means of galvanized iron clip, in at least 4 inches into the masonry. The lower edge of the flashing shall overlap the sheeting below it by at least 4 inches, the edges of the sheeting and flashing being left free to expand and contract. Wherever flashing has to be laid at a slope, it shall be stepped at each course of the masonry, the steps being cut back at an angle of not less than 30 degrees to the vertical.

Measurements

5. The measurement of flashing shall be by the superficial area and its unit of measurement shall be per square foot.

The measurement of gutters shall be along its length and the unit of measurement shall be per running foot.

Rate

6. The rate for gutters and flashings is for completed work fixed in position, including all laps, supports and other fixing accessories.

NO. 23.12 SLEEPER ROOFING

Specifications

Scope

1. Unless otherwise specified sleeper roofings for temporary structures or unimportant buildings shall be constructed in accordance with the following specifications.

Composition

2. Unless otherwise specified sleeper roofings shall consist of a layer of full or half-sawn sleepers with their sides butting against each other and joints fully caulked with a mixture of hot bitumen and sand. The top surface shall also be coated with the same mixture and then covered with layers of earth and mud plaster on the top. Wooden strips firmly nailed underneath the joints of the sleeprs shall be provided.

Materials

3. (a) SLEEPERS—Sound unserviceable sleepers of a thickness of not less than 4" at the thinnest section in case of full sleepers, and 2" in case of half-sawn sleepers, shall be used.

(b) SAND—It shall conform to Specifications No. 6.1 (A).

(c) BITUMEN—It shall conform to Chapter No. 12 of book of Specifications for Materials of Construction Vol. I, Part I.

(d) CLAY—It shall conform to Specifications No. 3.1.

Laying

4. The ends of the sleepers shall be cut square, the sides planed properly and holes, if any, shall be filled with wooden plugs dipped in hot coaltar. The portions of the sleepers to be embedded in masonry work shall also be painted with hot coaltar. Each sleepers shall then be laid butting tightly against the adjacent one. These joints shall be provided with wooden strips measuring 2"x½" and firmly

nailed on the underneath side of the sleepers. The joints shall be then caulked with a mixture of hot bitumen and sand, and a coating of the same mixture shall be given all over the roof surface A layer of 4" of stiff clay of good earth as specified shall be laid over the coating. In preparing the stiff clay care shall be taken that the earth at site dries in the sun and is then powdered and stacked in heaps of about 100 cft. Water shall then be added and the earth thoroughly mixed by treading with feet and brought into a consistency of stiff clay. This layer of earth shall be allowed to dry till there is no free moisture on the surface. The roof shall then be finished off with 1" thick mud platser and leeped in accordance with Specifications No. 25.7.

In case of sloping roofs, wooden battens shall be provided along the free ends and the front edge to support the earth. Eave boards shall also be provided if directed by the Engineer-in-charge. The ceiling of only the half-sawn sleepers roofings shall be painted, if and as specified.

Spans

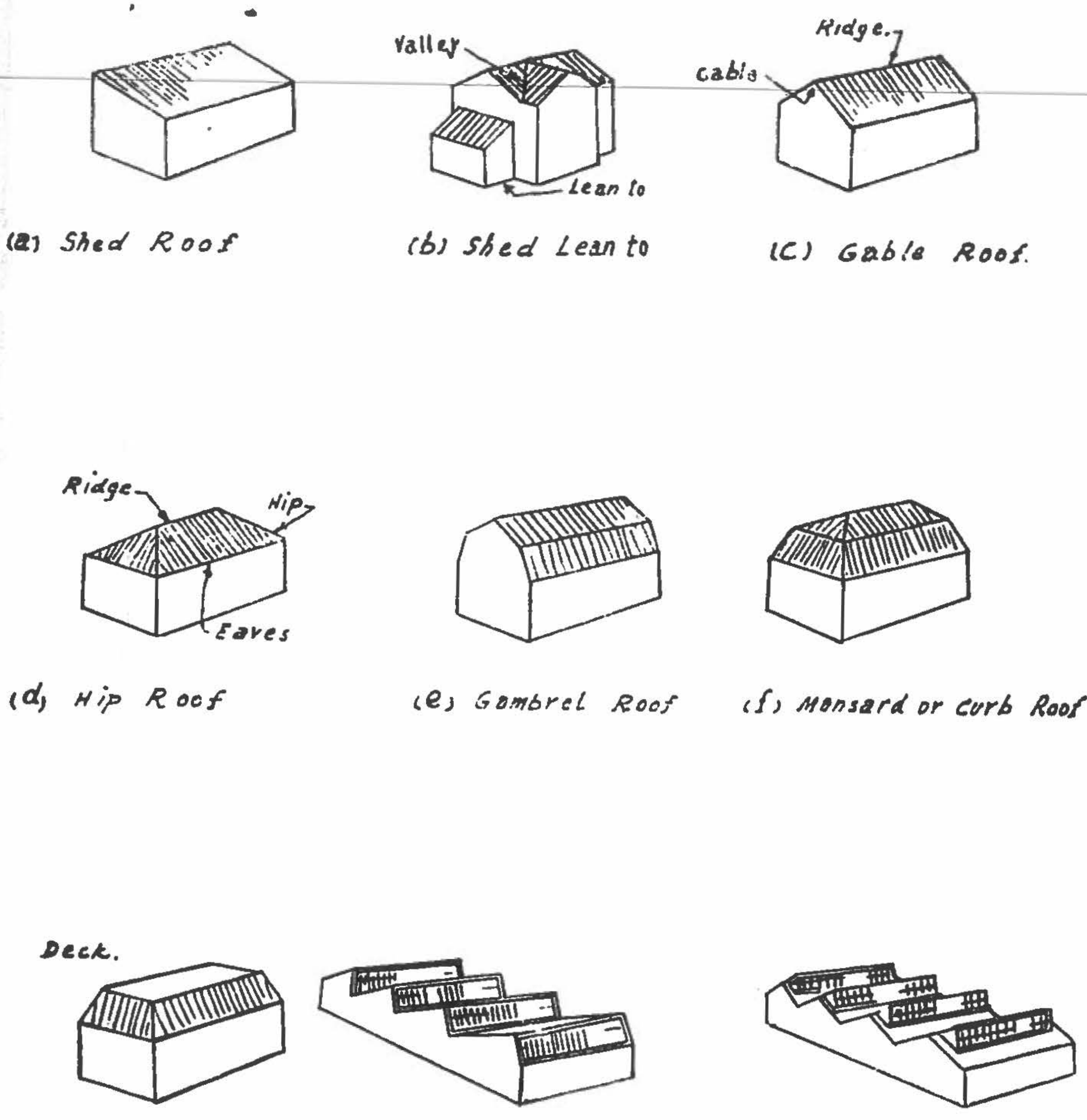
5. Both the half-sawn, and the full sleeper, roofings shall be used to cover spans from 4'-0" to 7'-6".

Measurements

6. The unit of measurement shall be 100 square feet of the roof area.

Rate

7. The labour rate shall cover the sawing of sleepers in case of half-sawn sleeper roofings, cutting ends, planing sides, plugging holes, laying on roof, caulking joints coating with bitumen and sand, providing 4" thick earth layer, and 1" mud plaster on top, and providing wooden strips underneath the joints. The battens and eave boards when provided shall be paid for separately as wood work.

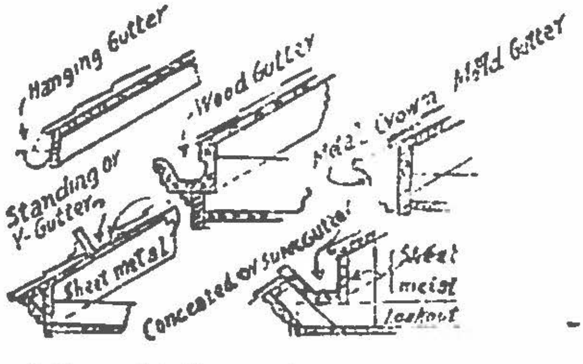


(a) Shed Roof (b) Shed Lean to (C) Gable Roof.

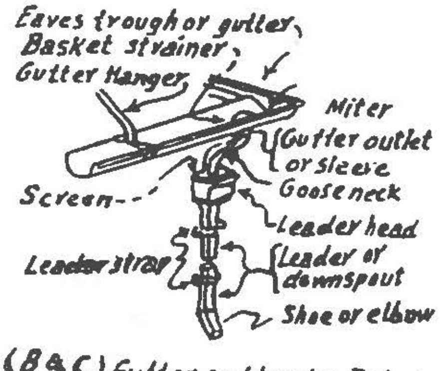
(d) Hip Roof (e) Gambrel Roof (f) Mansard or Curb Roof

(g) Deck Roof (h) Saw-tooth Roof. (i) Modified Saw-tooth Roof.

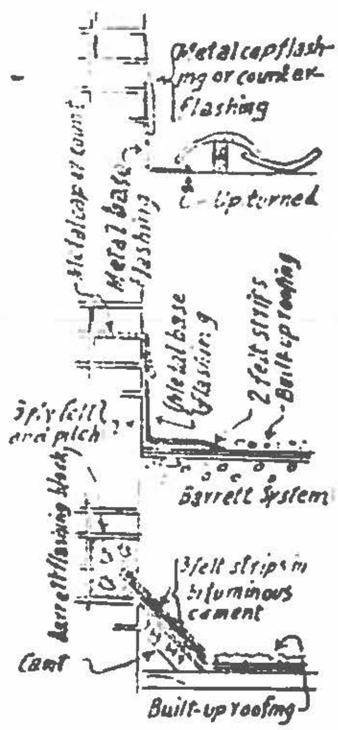
Fig: 1. Types of Sloping Roofs.



(A) Types of Gutters or Eaves Troughs



(B & C) Gutter and Leader Detail
(by Copper and Brass Research Ass'n)



(D) Roof Flashing Methods

Fig: 2 GUTTERS & FLASHING

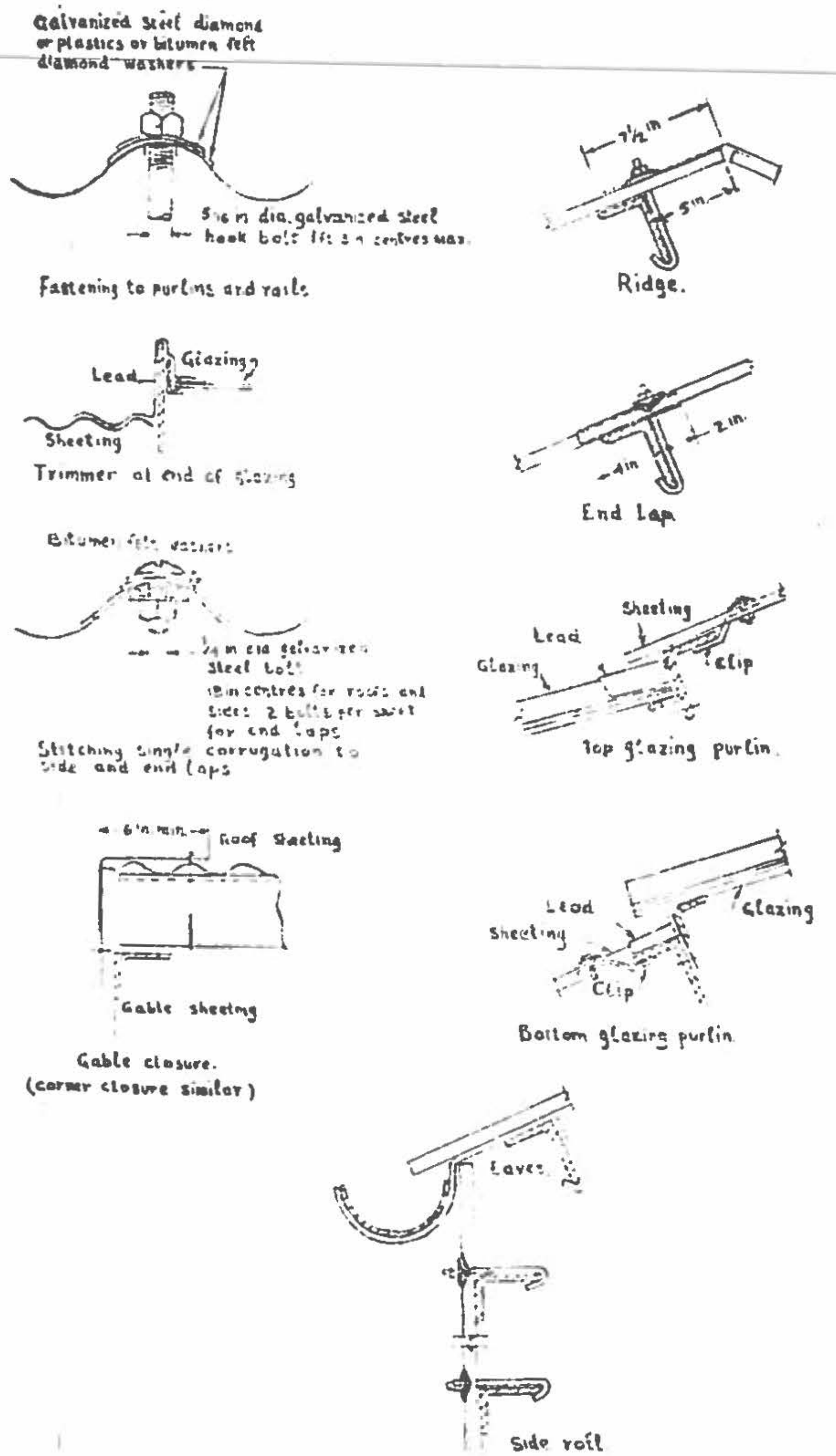


Fig: 3 Details of corrugated steel sheeting

CHAPTER 24

FLOORING

Introduction

The tier or levels which divide a building in two stages or storeys are called floors. These are made of materials quite different both in composition and construction. They range from relatively thin covering, contributing little or no structural strength to a building, to much thicker materials capable of withstanding reasonable stresses, and in some designs, essential to the strength of the building.

The selection of proper floor has an important bearing on the building. It affects its appearance, usefulness and the cost of upkeep. The relative characteristics of various floor surfaces are given as below:—

- *APPEARANCE*—Appearance is the attractiveness of the material, its colour range, texture and decorative value in an architectural sense. Floor surfaces, when suitably used, such as hard wood when properly finished, terrazzo, clay tile, marble, etc., are quite attractive; but concrete without special treatment, heavy asphalt mastic and industrial wood blocks do not give a good appearance. Concrete floors may be painted or waxed, and are attractive as long as the surface is maintained, but this is difficult to do where the traffic is heavy.

- *DURABILITY*—It may be defined as resistance to wear, temperature, humidity changes, decay and disintegration. The adhesion of a material to its base is another factor in durability. The most durable floor surfaces are clay tile, terrazzo, slate and concrete. With the exception of concrete, none of the materials mentioned so far are suitable or satisfactory for heavy traffic; and bricks, wood blocks and heavy asphalt mastic may be used under these conditions.

Characteristics Of Good Flooring

Comfort

Comfort under foot is determined by the shock-absorbing qualities, sure-footedness, evenness of surface and conductivity. A floor which is a good heat conductor will always give a cool feeling.

The most comfortable floors to work on are cork tiles and rubber. Wood and asphalt mastic are also quite satisfactory, but concrete, terrazzo, clay tile, marble and bricks are tiresome and cold.

Noiselessness

Cork tile and rubber floors are practically noiseless; wood and asphalt mastic floors, though less satisfactory, are not very noisy. Concrete, clay tile, marble, slate and bricks are the noisiest of the flooring materials.

Fire Resistance

Concrete, clay tile and bricks are the most fire resistant floor surfaces. Next in line are terrazzo, marble and slate. Rubber and wood are combustible, but if laid on a fire-proof base they are not considered a serious defect in a fire-proof building.

Sanitation

From the point of view of sanitation a floor surface must be non-absorbent and could be easily cleaned. Joints which are not watertight lead to unsanitation.

Terrazzo, clay tile and marble are the most sanitary floor surfaces. Concrete presents difficulty in cleaning, and wood is an unsatisfactory material on account of its porosity and the presence of open joints.

Acid and Alkali Resistance

This means immunity from damage by occasional spilling of strong acid solution and resistance to the continuous use of soap, cleaning and scouring compound and disinfectants. Clay tile is the most satisfactory floor surface in this respect; asphalt mastic is also quite resistant; terrazzo, marble and concrete are considered to be sufficiently resistant for ordinary purpose.

Grease, Oil Resistance

Grease and oil are not absorbed by polished clay tile and thus do not affect it. They are however absorbed by wood, brick, concrete, terrazzo and therefore spoil their appearance though do not seriously affect their durability.

Dampness

Clay tile, brick, concrete, terrazzo and asphalt tile are not affected by dampness and are suitable for use on floors located below grade such as in the basement. Wood, rubber, cork tile and other similar materials are not suitable for such location.

Indentation

The flooring materials such as clay tile, terrazzo, concrete and marble do not suffer indentation from chair legs, heels of shoes and other objects which rest on them or strike them. Material like rubber yields considerably under such loads but recovers quite well when the load is removed. Asphalt tiles and asphalt mastic, however, become permanently indented.

Maintenance

Polished tile, marble, terrazzo and rubber tile floors are easily cleaned and require little care in their maintenance; hardwood floors are fairly easy to clean when in a good condition, but require frequent surface treatment; asphalt tiles are easily cleaned, but should receive surface treatment occasionally; cork is not easy to clean and requires surface treatment. Concrete is not as easy to clean as terrazzo or marble, if it is not painted or waxed. Painting makes cleaning easy but requires frequent renewal.

The monolithical floors such as terrazzo and concrete are difficult to repair satisfactorily. Floors composed of separate unit of tile, slate, or marble are more easily repaired, but require skilled mechanics to do it.

The maintenance cost of wood block, brick or concrete floors is relatively low, except under extremely severe traffic. With the exception of concrete these materials are easily repaired as they require no surface treatment.

Initial Cost

One of the important factors governing the selection of a floor is its initial cost. It may be noted here that even the most expensive materials do not possess all the features which are considered desirable.

Types of Floors

Some of the most commonly used floors are (1) Earth Floors (2) Mud Floors (3) Brick Floors (4) Tile Floors (5) Marble Floors (6) Flagstone Floors (7) Cement Concrete Floors (8) Terrazzo Floors, and (9) Wooden Floors.

Earth Floors

These floors are made of good earth. Earth is filled to the required level in layers, with each layer not exceeding 6 inches in thickness. Each layer is well watered, rammed and consolidated before placing the next layer.

These floors are generally used for stables, cattle sheds, etc.

Mud Floors

Earth floors intended for human occupation are provided with one inch thick mud plaster surface which is finished with gobri leeping.

In rural areas of Pakistan mud floors are very common. They are constructed with scrupulous care and are usually maintained in excellent condition. These floors are cheap, easily made and repaired, and last sufficiently long. They keep an even temperature both in winter and summer and are thus very satisfactory, particularly in the home whose occupants move bare-footed.

Brick Floors

Brick floors are very common in areas where good, hard and well-burnt bricks are cheap and readily available. They are very durable, fire resistant and generally used for stores and godowns.

The bricks used are the best available and are selected for their smooth face, good colour and hardness. They are laid either flat or on the edge in parallel rows breaking joints or in herring-bone pattern or some other pattern.

The surface over which brick flooring is to be done is thoroughly washed, scrubbed with wire brushes and given a coat of thick bedding mortar three-quarters of an inch. The bricks are well soaked in water in case they are laid with mortar.

In case of dry pavement, the surface over which bricks are to be laid is thoroughly watered, rammed and dressed to the required slope. The bricks are then laid dry over mud plaster (generally half an inch thick) laid over the base surface.

Tile Floors

Tile floors are now being extensively used in modern buildings. They are quite durable, fire resistant and good in respect of sanitation. Their maintenance cost is relatively quite low.

Some of the most common types of tiles used are:

(a) *CLAY TILES*—They are manufactured in different shapes and designs. Most common sizes available in the market are (i) 12"x6"x2" (ii) 12"x6"x1½"; (iii) 9"x4½"x1½".

(b) *CEMENT CONCRETE/MOZAIC TILES*—They are precast tiles and are made generally in sizes (i) 6"x6"; (ii) 8"x8"; (iii) 9"x9"; and (iv) 12"x12". Tiles of sizes 9"x 9" and 12"x12" are usually used in large floor areas such as hostels, club lobbies and store rooms. Smaller sizes are used in bath rooms, kitchen floors and walls.

(c) *GLAZED TILES*—They are made of ball clay, China clay, China stone and flint. They are of two kinds: earthenware glazed and colour enamels and are available in different colours and sizes.

In order to achieve a proper bond in case of ground floors the surface of the base over which tiles are to be laid is washed and scrubbed with wire brushes. In case of suspended floors the base (R.C.C. slab) is roughened with wire brushes while it is still green. Tiles are laid to the required pattern and design over a bedding mortar which is generally three-fourths of an inch thick and is evenly spread on the base. In case of cement concrete, mozaic and glazed tiles the joints are very thin and are not more than 1/16 of an inch whereas in clay tile flooring the joints are 3/16 of an inch wide. In mozaic tiling the joints are rubbed with carborandum stone in order to level the slight projection or edges of mortar used for laying of tiles rising above the surface tiles.

Marble Floors

Marble slabs are laid over 3/4 of an inch thick bedding mortar of 1:2 lime surkhi or 1:2 cement sand evenly spread on a base. They are so laid that the joints are very fine i.e. not more than 1/16 of an inch thick which are well grouted in the lime putty. These slabs are available in different colours, shapes and are laid in various patterns. They are available in various thicknesses but in general a thickness less than 3/4 of an inch is not recommended. Polishing of joints is done with fine graded carborandum stone. The floor surface is generally polished with putty powder.

Flagstone Floors

They are composed of chisel dressed slabs or flags of stone laid to proper level on the base. The method of laying this floor is similar to that of tile floors. The joints are, however, not as fine as in tile flooring and are generally 1/8 of an inch. The flags are not less than $1\frac{1}{2}$ inches thick and the length and breadth of each stone are not more than 40 inches and not less than 13 inches. In superior quality work polish stone flags dressed and square all sides to the full depth are used and the flooring is laid to pattern to achieve the desired architectural effect.

Cement Concrete Floors

They comprise cement concrete (1:2:4) topping laid in panels over a base. Thickness of topping varies with requirement. In common practice the thickness varies from 1 inch to 3 inches. When the thickness is $1\frac{1}{2}$ inches or more, it can be laid either in single or double layers. In later case half an inch thick wearing surface composed of 1 part of cement and 2 parts of very fine aggregate is laid immediately on the lower layer of cement concrete in the ratio of 1:3:6 by volume. To avoid cracks the area of a panel is restricted to 16 square feet.

This type of flooring may be described as cold and non-resilient. It may be coloured with pigment, though it may lend a very good appearance. For factories, warehouses, lavatories, kitchens and houses it is a satisfactory flooring. It is also used as a base for other types of flooring e.g. mosaic or terrazzo flooring. These floors, if laid with care, are quite durable. Durability, however, depends upon:

(a) Choice of aggregate (a hard tough aggregate is essential to good durability).

(b) Water-cement ratio (a low water-cement ratio, compatible with workability is essential).

(c) Density of the flooring (durability increases with the increase in density of the topping).

Concrete flooring is slowly attacked by acids, vegetable oil, fat, sugar solution and various other agents, and a prolonged exposure to these agents will bring about a gradual deterioration.

All the factors that account for durability, tend also to reduce the rate of chemical attacks.

Cement-wearing surfaces or toppings must be carefully laid using a minimum amount of water, trowelling as little as possible and protecting against drying out for at least ten days. Excessive trowelling brings excess water and laitance to the surface, causing hair cracks to form and the floor to give off dust, called dusting, which is objectionable. Topping applied to a hardened base should be struck off and compacted by rolling or with tampers or vibrators and finished with a steel trowel. The use of dry cement or cement and fine aggregate sprinkled on the surface to stiffen the mix or absorb excess moisture is objectionable because it may cause hair-cracking, scaling or dusting. Dusting may be prevented or remedied, to a large extent, by using floor hardeners, other preparations or painting.

Painted surfaces are satisfactory when the amount of wear is small, otherwise frequent painting is required. Special paints are manufactured for use on cement floors. A cement coloured paint, of course, shows the less wear than paint of any colour. Paints should not be applied unless the floor has been in place for three or four months. Before painting, the surface should be thoroughly scrubbed with a 10 per cent solution of muriatic acid and washed to remove the acid completely. The floor should then be left to dry, after which a thin coat of paint is applied. Three coats are usually required. Cement wearing surfaces are some time coloured and marked off to imitate tile. Coloured cement floors finished with wax may be attractive in appearance. In case of artificial colouring matter, only those mineral colours which will not appreciably impair the strength of the cement should be employed.

Terrazzo Floors

Terrazzo-wearing surfaces are constructed in a manner similar to concrete-wearing surfaces, but a special aggregate of marble chips or other decorative material is always used and this aggregate is exposed by grinding the surface.

This type of floor is becoming more and more popular on account of its highly decorative and architectural effect. It is more expensive than concrete, but cheaper than marble floor. It is commonly laid in buildings where both attractiveness and durability are desired and can be laid into a large variety of patterns and colours. It is usually cast in situ over a hard concrete (1:2:4) as base with a sound, clean and rough surface.

Methods commonly adopted for laying the terrazzo surface are:—

1. 1½ inches to ¾ inch layer of concrete is laid where crushed marbles are used as aggregate.
2. The top course is made with a mixture of one cement and two marble chips laid not less than ⅜ inch thick over concrete base.
3. A layer of 1:3 cement mortar half an inch thick is laid over the concrete base, the next day after the base has been laid. A terrazzo topping ⅜ of an inch to ¾ of an inch thick consisting of one part of cement and two to 2½ parts of marble chips well mixed is laid and surface rammed to consolidate and finally trowelled light.
4. A stiff mortar of 1 cement 2 sand is laid over the base course to a depth of ¾ of an inch to one inch. Small cubes of various colours or pieces of terracotta are pressed into the mortar which may be arranged into various patterns. Alternatively small irregularly shaped chips of marble are sprinkled over the floating coat of cement pressed into the surface with a hand float and the whole consolidated by hand rolling.

These floors can be constructed in different colours by adding pigment to the cement. It is recommended that pigment not more than 12 per cent of the weight of cement should be used; for its excess reduces the strength of mortar. It is preferred to mix pigment in white cement than in ordinary grey cement.

Whichever method is adopted for terrazzo topping not more than 70 per cent of the surface should be covered with marble chippings. In order to achieve good results water added to the mix should be just sufficient to produce a workable plastic mix.

Terrazzo topping is always laid in panels over the base to the required thickness achieved by brass or aluminum dividing strips. The surface is then grinded with carborandum stone of different grades and then polished.

Wooden Floors

Wooden flooring is seldom recommended for ordinary dwelling houses on account of the high cost of timber of good quality. However, places like dancing halls, auditoria, usually have such floors. Wooden floors should not only be stiff and rigid for the maximum load that they have to carry but should also be perfectly smooth to add to the beauty of the surroundings. They are normally cambered from 1/40 of an inch to 1/30 of an inch for every foot of the span to allow for bending. The following types of wooden floors are commonly employed these days: single floor, double floor and framed floor. In all types of floors planking is carried by the bridging joists.

- *SINGLE FLOOR*—Wooden planking, in this case, rests in the single system of bridging joists which span the opening. These joists in turn rest on wall plate on either end and have to be as stiff as possible so that there is no difficulty in nailing planking to them. The basic requirement of a bridiging joist is its stiffness and rigidity for the maximum load the floor is to carry. For this purpose the timber is usually of greater strength than considered necessary by the usual design calculations. The bridging joists have a sufficient breadth (normally not less that 2 inches) and are placed one foot apart as shown in the Figure 9.

In general use, the single flooring does not have a span more than 12 feet since there is a danger of the joists bulking or bending sideways. To prevent bulking they are strutted apart.

- *DOUBLE FLOOR*—In this type of floors the bridging joists do not span the whole room but rest on other joists placed at right angle to them called the binding joists or binders. These binder joists are generally placed 6 to 8 feet apart and rest on walls as shown in Figure 10.

As far as possible they should not be placed immediately over window or door opening. If unavoidable, they should rest on strong wall plates or template, long enough to transmit the weight to the walls around the opening. Double floors are decidedly stiffer than single floors; they prevent the passage of sound better, but the weight of floors is concentrated on few points on the walls. The depth of the floor also increases with the height, which in turn increases the total height of the building and adds to the cost. For this purpose these are normally used in ceiling of the roof and not on the ground floors.

- *FRAMED FLOORS*—It is not possible to have either a single or a double system of joists where the span is greater. In such cases another timber in the shape of a girder is added and the binding joists are framed into the main girder as shown in Figure 11.

This generally weakens the girder considerably. To avoid it, the ends of the binding joists are separated by iron stirrups. The rest of the arrangement is the same as for double floor. However, girders and binders should be deep and as stiff as possible to eliminate danger of the ceiling cracking.

Where there are fire places or flues in the wall no joist should be placed in the masonry for the full width of the chimney breast. The ends of the joists should be carried by a trimming joists, placed 2 feet away from the chimney breast and supported by the two joists which are outside the chimney breast. These two joists should be provided by half an inch for each joist supported by the trimmer, which may be of the same dimension. The space between the trimmer and the chimney breast is covered with stone flags or reinforced slabs.

Wooden Flooring for Ground Floors

In ground floors, wooden floors are generally placed on two layers of concrete. The lower layer consists of lean mix of 1:6:12 and the upper of 1:2:4 mix concrete each 3 inches deep on which blocks of stone or brick masonry are placed at intervals both along the length and breadth of the room. The joists, normally 4 inches by 4 inches, which are termed as bridging joists rest on these blocks. The planking in turn is nailed to these bridging joists.

The timber joists and the planking is normally of deodar. Teak wood is also used for the bridging joists and the planking in some of the ground floors. Since teak wood is very costly, it is sometimes used only for planking and the joists are made of deodar wood. Seasoned shisham wood is used for planking in some cases.

Construction of Ground Floors

Wooden floors are liable to rot and decay, if adequate precautions are not taken to keep the timber dry and well ventilated. For this purpose, all vegetable soil should be excavated from the bottom of the floor and the surface covered with six inches of concrete laid in two layers, the lower one a lean concrete and the upper one of 1:2:4 mix. This saves the timber from wetting, as shown in Figure 12.

The joist should be kept well above the ground level to allow a free current of air to pass beneath the distance between the concrete and joist which is normally eight inches. The fresh air is admitted through the small openings nine inches square kept on either end of the walls.

Construction of Upper Floors

Upper floors differ from ground floors in many ways. First, in upper floors, the joists are placed across the shortest span of the space for the sake of strength and rigidity. Secondly, the support may be arranged on the walls having the smallest number of openings to avoid a heavy joist on the opening. Thirdly, the joists should, if possible, run continuously over partitions and/or intermediate walls since it would add considerably to the stiffness of the rafter.

Figure 13 shows a typical timber floor for an upper storey. The left hand plan indicates the general layout of the timber joists. The joists run across the partitions while they are stiffened by light struts to avoid buckling. It is important to note how the fire place opening has been separated by transverse joists from the rafters to avoid the danger of fire.

Construction of Wooden Block Floors

Sometimes the wooden floor is not laid on a system of bridging joists, but is directly placed over a layer of concrete. This type of floors, commonly used in public and residential buildings consists of various kinds of hardwood fixed on a concrete floor in order to form a decorative design or a geometrical pattern.

A wooden floor is built with small blocks of hard seasoned wood to a pattern on the concrete floor which has been covered with cement mortar and scratched to make a rough surface and form a key for the mastic solution with which the blocks are fixed.

The size of the blocks varies from 9 inches x 3 inches to 12 inches x 4 inches and are one inch to one inch and a half thick. There is a joint between each block which is provided by a tongued joint, a dowel or a dove-tail or by groove method.

The sketch for the wooden floor above shows a part of a floor laid in herring-bone pattern. These blocks have dove-tailed grooves along their edges and mastic solution is laid in which these have been preserved. Care should be exercised to see that the mastic solution is very hot when block is dipped into it. The blocks are cleaned, planed, scrapped and glass papering is done after the floor has been laid. Subsequently the floor is polished according to the general procedure.

Joints in Floor Planking

There are different methods of providing a joint between the planks which rest on the joist. These are classified as:

(a) Joints with visible fixing such as square grooved, rebated, etc.

(b) Joints with secret fixing where the screws or nails are only driven on the exposed edges of the boards.

In square joints nearly six battens are laid in position. One side is fixed, other one pushed together and the boundary is lined out by a pencil. The other loose outside batten is placed about half an inch near the board already fixed and the others are arranged alongwith this. A plank is placed across them and two persons jump over it. This puts all the boards in position and close fit joints are obtained. In this way, they are nailed to the joists.

In other cases an almost similar process is used. The advantage of the second type of joints listed above is that they do not have any visible fixings on the surface and thus give a good surface on the top.

Bearing of Joist

Normally all timber in partition walls should be at least 4 inches thick. The joists etc. should not be built in the walls where there is a danger of decay. In fact, it should be embedded in the wall plate which may consist of concrete and the ends of the joists should be tarred or dipped into solignum to prevent rot of the wood work.

Reducing Noise in Floors

In wooden floors, one of the most important considerations is to avoid sound transmission. The sound or noise can emanate both from rooms above or below the roof. Sound waves are partly reflected, absorbed and partly transmitted. Sound insulation may be done by the following three methods.

(a) By avoiding or reducing through timbers, the continuity of sound transmission is reduced. This is done by keeping every fourth joist deeper in section while still maintaining its top surface. The deeper sections are partly buried in the wall section as shown in Figures 14 to 23.

(b) By providing a double system of joists, each being entirely different from the other, so that they do not transmit any sound waves to each other.

(c) By providing felt, cork packing at the base of the rafters and by providing sound insulation boards in between.

Polishing

Wooden floors are generally polished by wax polish details of which are given in chapter on painting and varnishing.

NO. 24.1 EARTH FLOORING

Specifications

Scope

1. Unless otherwise specified, earth flooring shall be constructed in accordance with the following specifications.

Material

2. Earth (clay) shall conform to Specifications No. 3.1 of Clay.

Laying and Consolidation

3. Earth shall be placed in layers and shall be sprinkled with water and rammed to such an extent that a layer of 6-inch thick loose earth evenly spread is reduced to 4 inches in thickness. The consolidated surface shall be such that a very faint impression can be made on it with the heel of a boot or the blow of a rammer.

Measurements

4. Earth flooring shall be measured by the superficial area of the floor. The unit of measurement shall be 100 square feet.

Labour

5. The unit rate shall include the labour required for the laying and consolidation of earth as per above specifications.

Composite Rate

6. The unit rate shall include the cost of earth supplied at site in addition to the labour as detailed in the above specifications.

NO. 24.2 MUD FLOORING

Specifications

Scope

1. Unless otherwise specified, mud flooring shall be constructed in accordance with the following specifications.

Material

2. (a) Earth (clay) shall conform to Specifications No.3.1 of Clay.

(b) Mortar shall conform to Specifications No. 19.1 for Mud Moratr.

Laying

3. After laying earth floors as per Specifications No. 24.1 for Earth Flooring, the surface shall be finished with one inch thick mud plaster with gobri leeping conforming to Specifications No. 25.7 for Mud Plaster.

4. Mud flooring shall be measured by the superficial area of the floor. The unit of measurement shall be 100 square feet. **Measurements**

5. The unit rate shall include the cost of labour for mud plastering and gobri leeping in addition to the labour rate as contained in para 5 of Specifications No. 24.1 for Earth Flooring.. **Labour Rate**

6. The unit rate shall include the cost of earth, chopped bhoosa and cow-dung supplied at site in addition to the labour rate detailed in para 5 above. **Composite Rate**

NO. 24.3 BASE FOR FLOORING

Specifications

1. Unless otherwise specified, the base of all ground floors shall be constructed in accordance with the following specifications. **Scope**

2. (a) Sand shall conform in all respects to the Specifications No. 6.1 (A) for fine aggregate except for its grading, i.e. it shall pass through a sieve No. 16 and not more than 30 per cent shall pass through a sieve No. 100. **Material**

(b) Concrete shall be either cement concrete or lime concrete conforming to Specifications No. 20.1 and 20.5 respectively.

3. Earth (clay) conforming to Specifications No. 3.1 of Clay shall be used for the sub-base. Earth filling shall be done up to the specified level in a layer of six inches and shall be properly watered and consolidated as specified in para 3 of Specifications No. 24.1 for Earth Flooring. The sub-base shall be properly levelled before sand filling. **Preparation of Sub-base**

4. Sand filling shall be done in layers not more than 3 inches thick and shall be rammed after saturation to such an extent that a three-inch layer is reduced to about two inches after compaction. **Sand Filling**

5. Concrete shall be laid in one operation in a uniform layer of specified thickness, absolutely true and parallel to the required level of the finished surface and to the entire satisfaction of the Engineer-in-charge. **Concrete Laying**

6. Concrete shall be cured for at least 7 days before any topping is laid. The surface shall be kept wet and protected from earth, dirt or other foreign matter. Before laying the topping, the surface shall be washed and scrubbed with wire brushes so that the concrete and the topping are well bonded. **Surfacing to Bond with Concrete**

7. Unless otherwise specified, the base shall be perfectly level. A slope of 1:64 shall, however, be provided in verandah and bath rooms. **Levels and Slopes**

8. The base shall be measured by the superficial area. The unit of measurement shall be 100 square feet. **Measurements**

Rate — 9. The unit rate shall include (i) preparation of sub-base (ii) filling of sand, (iii) laying and protection of concrete, (iv) curing, (v) use of all tools and plants required for carrying out work in accordance with the above specifications.

Composite Rate — 10. The unit rate shall include cost of all the material required in the above operation and supplied at site in addition to the labour rate detailed in para (9) above.

NO. 24.4 BRICK OR TILE FLOORING

Specifications

Scope — 1. Unless otherwise specified, brick or tile flooring shall be constructed in accordance with the following specifications.

Material — 2. (a) Brick or tile shall conform to Specifications No. 4.1. for Clay Bricks.

(b) Mortar shall conform to Specifications No. 19.1 to 19.4 for mortars as actually specified.

Base — 3. For ground floor the base shall be laid as per Specifications No. 24.3 for first or subsequent floors, The top surface of roof slabs shall be roughened with wire brushes while it is still green.

Wetting of Bricks/Tiles — 4. Bricks or tiles shall be wetted in accordance with para 8 of Specifications No. 21.1 for Brickwork (General).

Pattern — 5. The laying of bricks or tiles shall be plain, diagonal, herring-bone or any other specified pattern.

Joints — 6. (a) Where pointing is not to be done the joints shall not exceed 3/16 inch in thickness. The mortar oozing out of the joints shall be struck off with trowel or wiped off with damp cloth.

(b) Where pointing is to be done, the joints shall not exceed 3/8 inch in thickness. The mortar in the joint shall be raked out one inch deep, while it is still green.

Pointing — 7. Unless otherwise specified, the joints shall be flush pointed with specified mortar.

Preparation of Base — 8. Before laying bricks/tiles the surface of the base shall be washed and scrubbed with wire brushes. Where bricks/tiles are to be laid directly on roof slabs the surface of the slabs shall be roughened with wire brushes while it is still green.

Thickness of Bedding Mortar — 9. The floor shall be laid on 3/4-inch thick bed of specified bedding mortar spread evenly on the base.

Laying of Bricks/Tiles — 10. Bricks/tiles shall be laid with specified mortar in position on the bedding mortar.

11. Flooring shall be allowed to mature undisturbed, and protected from the effects of weather. It shall be kept wet for at least 7 days after completion. If pointing is to be done, it shall be kept wet for at least 14 days after the completion of pointing. **Protection**

12. Surface shall be finished to specified levels. All joints shall be uniform, true and parallel and square bricks shall be rubbed to ensure this where it is very necessary, without extra cost. **Surface**

13. No damaged bricks or tiles shall be used. Bats shall not be used except to close any course of bricks or tiles. Unless otherwise specified, the overhanging edge of the paving shall be finished off by special bull-nosed bricks. **Edges with Bull-nosed Bricks**

14. The measurement of brick or tile flooring shall be by the superficial area. Its unit of rate shall be 100 square feet. **Measurements**

15. The unit rate shall include:— **Labour Rate**

(i) Washing, scrubbing and cleaning of base in case of ground floors and roughening and washing of the base slabs in case of upper floors.

(ii) Laying of bedding mortar over the base.

(iii) Laying of bricks/tiles in specified mortar over the bedding mortar.

(iv) Protection and curing of the work.

(v) Cost of providing tools and plants required for carrying out the work in accordance with the above specifications.

The labour for pointing is not included.

16. The unit rate shall include the cost of all the material supplied at site as specified above, in addition to the labour rate detailed in para 15 above. **Composite Rate**

NO. 24.5 FLAGGED FLOORING

Specifications

1. Unless otherwise specified, flagged flooring shall be constructed in accordance with the following specifications. **Scope**

2. Stone from which the flags are made shall conform to Specifications No. 7.1 for Stone. **Stone**

3. Mortar shall be as actually specified. **Mortar**

4. For ground floor the base shall be laid as per Specifications No. 24.3. For subsequent floors, the top surface of roof slabs shall be roughened with wire brushes while it is still green. **Base**

·ressing

5. Flags shall not be less than one inch and a half in thickness. The length and breadth shall not be less than 14 inches and more than 30 inches. The size of flags shall be such as to give uniform parallel courses.

Dressing

6. Flags shall be chisel dressed so as to have a flat surface, free from windings. All edges shall be accurately dressed, truly square to their full depth. Flags projecting over the edges of verandahs or steps shall have their outer edges bull-nosed.

Soaking

7. Flags thall be soaked in water for one hour before laying.

Joints

8. The thickness of joints shall not be more than 1/8 of an inch. Unless otherwise specified, the mortar in joints shall be made flush with a trowel.

Pointing

9. If pointing has been specified the flags shall be laid against wood or iron strips of uniform thickness, so as to form joints not less than 1/4 inch wide. When a row of flags is laid, the strips shall be removed and the open joints shall at once be filled with specified mortar, and shall then be flush pointed with specified mortar.

Preparation of Base Surface

10. Before laying flags, the surface of the base shall be washed and scrubbed with wire brushes. Where flags are to be laid directly on roof slabs the surface of the slabs shall be roughened with wire brushes while it is still green.

Thickness of Bedding Mortar

11. Flags shall be laid over specified bedding mortar not more than 3/4-inch thick.

Laying of Flags

12. Flags shall be placed in position and brought down to the required finished level and the joints shall then be filled with specified mortar.

Pattern

13. Flags shall be laid in the specified pattern. The courses thall be of uniform width and, unless otherwise specified, parallel to the wall having the main entrance. Flags shall break joint in adjacent courses by not less than 8 inches.

Protection and Curing

14. The floor shall be protected from the effects of weather. During the progress of work and for 10 days after laying, the floor shall be kept watered. Three clear days shall be given for setting before anyone is allowed to walk over, but no weight shall be brought on the surface till 7 clear days have elapsed after the completion of laying.

Measurements

15. The flagged flooring shall be measured by superficial area. The unit of measurement shall be 100 square feet.

Labour Rate

16. It shall include:—

(i) Washing, scrubbing and cleaning of bases (in the case of ground floor) and roughening, washing and cleaning of base slabs (in the case of subsequent floors).

(ii) Laying of 3/4-inch thick bedding mortar.

(iii) Laying of flags and filling of joints with specified mortar.

(iv) Curing and protection of work.

(v) Use of all tools and plants required for carrying out work as per above specifications.

The labour for pointing is not included in the rate.

17. The unit rate shall include the cost of all the material supplied at site of work as per above specifications, in addition to the labour rate detailed in para 16 above. **Composite Rates**

NO. 24.6 MARBLE FLOORING

Specifications

1. Unless otherwise specified marble flooring shall be constructed in accordance with the following specifications. **Scope**

2. Marble slabs of an approved quality shall be used. **Marble**

3. Mortar and putty shall be as actually specified. **Mortars and Putty**

4. For ground floor the base shall be laid as per Specifications No. 24.3. For subsequent floors, the top surface of roof slabs shall be roughened with wire brushes while it is still green. **Base**

5. Marble shall be of the size, colour and pattern, as specified. **Size, Colour and Pattern**

6. All slabs shall have a true plain surface and shall be accurately sawn; truly square at edges to the full thickness. All marble slabs shall have a minimum thickness of 3/4 of an inch. No joints shall be more than 1/16 of an inch in thickness. Slabs projecting over the edges of verandah or steps shall have their edges finished with a bull-nosed ending. **Thickness, Dressing of Edges and Joints**

7. Before laying marble slabs, the surface of the base shall be washed and scrubbed with wire brushes. Where they are to be laid directly over roof slab, the later shall be roughened while it is still green. **Preparation of Base**

8. Marble slabs shall be laid over specified bedding mortar not more than 3/4 of an inch thick. **Thickness of Bedding Mortar**

9. Slabs shall be laid in position on bedding mortar in specified pattern. The joints shall be filled with specified putty. **Laying**

10. The surface of marble slabs when laid shall be perfectly true, level, projected or sloped. **Levels**

11. The floor shall be protected from the effects of weather. During the progress of work and for 10 days after laying, the floor shall be kept watered. Three clear days shall be given for setting before anyone is allowed to walk over, but no weight **Protection and Curing**

shall be brought on the surface till 7 clear days have elapsed after the completion of laying.

Polishing

12. When properly set the floor shall be rubbed with carborandum stone or with some other hard stone of approved quality and sand. When roughness is removed, sand shall be washed off and the process continued either with very fine carborandum stone or with brick and emery powder. The surface shall then be finally smoothed down with a pumice stone. When the smoothing process has been completed, the surface shall be polished with putty powder rubbed by felt pads.

Measurements

13. The measurement of marble flooring shall be done by the superficial area. The unit of measurement shall be 100 square feet.

Labour Rate

14. The unit rate shall include:—

(i) Washing, scrubbing and cleaning of base (in the case of ground floor).

(ii) Roughening, washing and cleaning of base slab (in the case of upper floor).

(iii) Laying of bedding mortar.

(iv) Laying of marble slabs over bedding mortar.

(v) Filling of joints with putty.

(vi) Levelling, curing, polishing of marble slabs as per above specifications.

(vii) Use of all the tools and plants required for carrying out work in accordance with above specifications.

Composite Rate

15. It includes the cost of all the material supplied at site of work as per above specifications, in addition to the labour rate detailed in para 14 above.

NO. 24.7 GLAZED TILE OR CEMENT TILE FLOORING

Specifications

Scope

Unless otherwise specified, the work of glazed tile or cement tile flooring shall be done in accordance with the Specifications No. 24.4 for Brick or Tile Flooring in all respects, except with the following modifications:—

(i) Glazed tile shall conform to Specifications No. 5.3 for Glazed Tile.

(ii) Cement tile shall be of an approved quality.

(iii) All tiles shall be laid in water for 36 hours before they are laid.

(iv) The joints shall not be more than 1/16 of an inch which shall be grouted with cement, matching the colour of the tiles.

(v) When necessary the tiles shall be cut with wire saw to the exact size having a clean sharp edge so as to have fine joints.

(vi) Saw dust shall be used as the work proceeds for removing stains etc.

NO. 24.8 CEMENT CONCRETE TILES, MOSAIC TILES FLOORING

Specifications

Unless otherwise specified, cement concrete tile or mosaic tile flooring shall be done in accordance with the Specifications No. 24.4 for Brick or Tile Flooring in all respects, except with the following modifications:—

(i) Cement concrete tiles or mosaic tiles shall conform to Specifications No. 5.1 for Cement Concrete Tiles.

(ii) All tiles shall be laid in water for 36 hours before they are laid.

(iii) The joints shall not be more than 1/16 of an inch which shall be grouted with specified mortar.

(iv) In case of mosaic tiles, the joints shall be rubbed with very fine carborandum stone so that slight projections or edges of mortar etc. rising above the surface of tiles are levelled.

NO. 24.9 CONGLOMERATE FLOORING (CEMENT CONCRETE)

Specifications

Scope

1. Unless otherwise specified, the conglomerate flooring shall be constructed in accordance with the following specifications.

Material

2. Cement shall conform to Specifications No. 3.3. Fine aggregate shall conform to Specifications No. 6.1 (A). Course aggregate shall conform to Specifications No. 6.1 (B). Water shall conform to Specifications No. 2.1.

Base

3. For ground floor the base shall be laid as per Specifications No. 24.3. For subsequent floors, the top surface of roof slabs shall be roughened with wire brushes while it is still green.

Operation

4. Unless otherwise specified conglomerate flooring shall consist of laying a topping of cement concrete of specified thickness over the base.

Ratio of Concrete

5. Unless otherwise specified, cement concrete used for topping shall be of the ratio 1:2:4 by volume and shall conform to Specifications No. 20.1 for Cement Concrete.

Dividing into Panels

6. Before laying the topping, the surface of the base shall be divided into symmetrical panels by wooden or iron screeds. Unless otherwise specified the area of panels

shall not exceed 16 square feet. The top of the screed shall be adjusted to the specified level of the finished floor surface.

Preparation of Base 7. Before the laying of topping the surface of base concrete shall be washed and scrubbed with wire brushes so that topping and the base concrete are well bonded. Where topping is to be laid directly on roof slab, it shall be roughened while it is still green.

Mixing and Placing 8. Mixing and placing of concrete shall be in accordance with Specifications No. 20.1 for Cement Concrete.

Consolidation 9. Placing operation shall be specifically timed. No sooner the concrete has been evenly spread in a panel, than it shall be beaten for about 5 to 10 minutes with "wooden thapies" (about 5 lbs weight).

Finishing 10. Immediately after consolidation, the surface shall be levelled with a wooden trowel. Excessive trowelling in the early stage shall be avoided. The surface shall be tested with a straight edge to detect undulations, which, if found, shall be eliminated. The finer stuff in the concrete which has come to the surface with the stroking shall be quickly but carefully smoothed with the steel trowel. When the concrete has hardened sufficiently, trowelling shall be done with steel trowel. No dry cement or a mixture of dry cement with sand shall be sprinkled on the surface for hardening the surface.

Curing 11. The concrete for topping shall be cured in accordance with para 29 of Specifications No. 20.1 for Cement Concrete (General).

Preserving Panels already Laid 12. After 24 hours of laying, the screeds shall be removed and strips of non-absorbent paper placed against the exposed side and folded over the finished surface so as to prevent concrete of adjoining panels from adhering to the edge or spreading over the finished surface. Panels shall be laid alternately, where possible; the adjoining panels shall be laid at an interval of 24 hours.

Measurements 13. The conglomerate floor shall be measured by superficial area. The unit o measurement shall be 100 square feet.

Labour Rate 14. It shall include:—

(i) Washing, scrubbing and cleaning of base (in the case of ground floors).

(ii) Roughening, washing and cleaning of the base slab (in the case of upper floors).

(iii) Dividing into panels, mixing, placing, consolidation, finishing and curing of topping concrete.

(iv) Providing, using and removing of screeds, and use of other tools and plants for carrying out work in accordance with above specifications.

Composite Rate 15. It shall include the cost of all material supplied at site as specified above, in addition to the labour as detailed in para 14 above.

NO. 24.10 CONGLOMERATE FLOORING (TWO COAT WORK)

Specifications

Scope

Unless otherwise specified, the conglomerate flooring (two coat work) shall be constructed in accordance with Specifications No. 24.9 for Conglomerate Floor (Single coat) except with the following modifications:—

(i) It shall be laid in two layers with a top layer half an inch thick, wearing surface composed of fine aggregate and cement conforming to Specifications No. 6.1 (A) and No. 3.3 respectively and a bottom layer of cement concrete conforming to Specifications No. 20.1 of specified thickness.

(ii) Unless otherwise specified, the cement concrete for the bottom layer shall be composed of one cubic foot of cement, 3 cubic feet of fine aggregate and 6 cubic feet of coarse aggregate by volume and shall conform to Specifications No. 20.1 of Cement Concrete.

(iii) Unless otherwise specified, the surface layer shall compose of one part of cement and two parts of fine aggregate by volume.

(iv) The bottom layer shall be brought to a level so that top layer shall have a minimum thickness of half an inch. The bottom layer shall be thoroughly compacted by tamping but shall not be finished smooth. While the bottom layer is still plastic, the top layer shall be placed over it and levelled with a steel float after light tapping for five minutes.

NO. 24.11 TERRAZZO FLOOR

Specifications

Scope

1. Unless otherwise specified, terrazzo floor shall be constructed in accordance with the following specifications.

Material

2. (a) Marble chips shall be of the approved grade, colour, size and quality.

(b) Cement shall conform to Specifications No. 3.3 Coloured Cement, whenever used, and shall be of an approved quality.

(c) Fine aggregate shall conform to Specifications No. 6.1 (A)

(d) Course aggregate shall conform to Specifications No. 6.1 (B)

(e) Water shall conform to Specifications No. 2.1

Base

3. For ground floor the base shall be laid as per Specifications No. 24.3. For subsequent floors, the top surface of roof slabs shall be roughened with wire brushes, while it is still green.

Proportion

4. Unless otherwise specified, the cement concrete used for bottom layer shall be of the ratio 1:2:4 volume, conforming to Specifications No. 20.1. for Cement Concrete.

The mozaic topping shall consist of 2 parts of marble chippings and one part of cement by volume.

Thickness

5. The topping shall not be less than 3/8 of an inch thick and shall be laid monolithic with the bottom layer of cement concrete (1:2:4) of specified thickness. The total thickness of the topping and cement concrete shall not be less than 1$\frac{5}{8}$ inches.

Panels, Mixing, Placing and Consolidation

6. In respect of size of panels, mixing, placing and consolidation, bottom layer of cement concrete shall conform to paras 6 and 8 of Specifications No. 24.9 for Conglomerate Floors.

Finishing of Bottom Layer of Concerte

7. The bottom layer of concrete shall not be smooth finished but shall have a rough surface so that it shall be well bonded with the mozaic topping.

Preparing Surface of Bottom Concrete

8. Before laying mozaic topping the surface of bottom layer of concrete shall be cleaned. It shall be free from dust, plaster or other foreign matters.

Dividing into Panels

9. For pannelling the floor, dividing strips of brass, copper, zinc or other specified material shall be used. The panels shall coincide exactly with the panels of bottom layer of concrete. Dividing strips shall be to the full depth of topping. The strips shall be added in a manner that their tops are in level with the required finished surface of the floor.

Laying

10. The topping shall be laid while the bottom concrete is still plastic preferably the next day after the bottom concrete has been laid. If the surface is not plastic, a slurry of neat cement shall be brushed on to it immediately before the topping is laid. The terrazzo mix shall be placed on the bottom concrete and compacted by tamping.

Drying

11. After laying the topping, the surface shall be covered either with damp hessian cloth or wet soft wood sawdust and every precaution shall be taken to prevent its being subjected to the effects of weather. The flooring shall be maintained in a damp condition till it is fit for grinding.

Face Grinding

12. The grinding of terrazzo shall commence 3 days after the laying is completed. The grinding of the flooring shall be done manually preferably with machine of approved type.

(a) The first grinding shall be done with an approved coarse abrasive (carborandum bricks or disk) by sprinkling fine sand over the surface and by using an ample quantity of water to assist the grinding. The flooring shall be washed clean with plenty of water till trace of ground mud is removed and marble chips are visible.

(b) All holes or open pores shall be made good with neat cement, the grout being well worked into the surface by rubbing with a stone and finishing of a little above the level of the finished surface of floor. The portion so treated shall be kept damp till the floor is ready for the second grinding.

(c) The second grinding shall be done after about 5 days using an approved medium graded coarse abrasive (carborandum bricks or disk), and pores, if any, shall be treated similarly as after the first grinding.

(d) The final grinding shall be done with an approved fine graded carborandum stone and the surface thoroughly washed down with water.

Finishing

13. After final grinding the floor shall be thoroughly washed. Tartaric or powder oxalic acid shall be sprinkled over the floor and rubbed with gunny bags wrapped round rods. The floor shall be allowed to dry and then more oxalic or tartaric acid shall be rubbed with cloth pads.

Final Gloss

14. When floor is completely dry, the final gloss shall be given by an approved wax polish.

Measurements

15. The terrazzo floor shall be measured by the superficial area. Its unit of measurement shall be 100 square feet.

Labour Rate

16. The unit rate shall include:—

(i) The labour rate as per para 13 of Specifications No. 24.9 for Conglomerate Flooring, except for finishing and curing operations.

(ii) Preparing surface of bottom concrete.

(iii) Dividing into panels, mixing, pouring, curing, surface grinding, final finishing and polishing.

(iv) Providing, using or removing of screeds for mozaic topping and use of all other tools and plants for carrying out work in accordance with the above specifications.

Composite Rate

17. The unit rate shall include the cost of all material supplied at the site of work as per above specifications, in addition to the labour rate as detailed in para 16 above.

NO. 24.12 DRY BRICK PAVING

Specifications

Scope

1. Unless otherwise specified dry brick paving shall be done in accordance with the following specifications.

Material

2. (a) Bricks shall conform to Specifications No. 4.1 for Clay Bricks.

(b) Sand shall conform to para 2 (a) of Specifications No. 24.3 for Base for Flooring.

(c) Mud mortar shall conform to Specifications No. 19.1 for Mud Mortar.

Preparing Surface

3. The ground surface shall be thoroughly watered, well rammed and shall be dressed to the specified slope, camber or cross grade.

Laying

4. Bricks shall be laid dry, on edge or flat in the specified pattern over half an inch thick mud plaster given on the surface. The joints shall not exceed one quarter of an inch in thickness. After laying the bricks the joints shall be sand grouted.

Measurements

5. The measurement of dry brick paving shall be by the superficial area. Its unit of measurement shall be 100 square feet.

Labour Rate

6. It shall include:—

(i) Preparation of surface.

(ii) Laying of mud plaster.

(iii) Laying of bricks on mud plaster and grouting with sand.

(iv) Use of all the tools and plants required to carry out work according to the above specifications.

(v) Sweeping away all surplus sand and cleaning away all debris or broken bricks.

Composite Rate

7. The unit rate shall include the cost of brick, mortar and sand supplied at site of work, in addition to the labour rate detailed in para 6 above.

NO. 24.13 WOODEN FLOORS

Specifications

Floor Bearers: Ground Floors

1. In the case of ground floors, floor joints (bridging joists) shall rest on pillars, dwarf walls, rails or beams as may be specified.

The plinth under the flooring shall be excavated to the depth specified by the Engineer-in-charge and dressed level and rammed. If directed, a layer of lime concrete shall be laid as specified under "concrete", otherwise dwarf walls or pillars shall be built on a lime concrete foundation. The dimensions and spacing shall be as indicated in the drawings or otherwise directed by the Engineer-in-charge.

Floor Bearers: Suspended Floors

2. In the case of upper floors, the bridging joists shall rest on wall plates, beams, rails or on other joists as shown on the drawings, or otherwise directed by the Engineer-in-charge.

Floor Bearers: Material and Fixing

3. The timber for the floor joists shall be of the kind specified and shall be in accordance with the general specifications for wood work. The full number of joists for each continuous floor shall be laid and dressed to one level and tested before flooring is commenced.

Preservatives

4. All joists, wall plates, bearers, and the underside of planking shall be given two coats of hot wood preservative such as solignum, creosote, or coal tar, as directed by

the Engineer-in-charge. The rate does not include this work, which shall be paid for separately according to the rates for painting with these materials.

Boarding Materials and Size

5. The boarding for the floor shall not be planed on the underside in the case of ground floors and suspended floors to be coiled. Unless otherwise specified or shown in the drawings, in the case of deodar, kail or chir wood, the boards or battens shall be 1½ inches thick, not more than 6 inches wide and not more than 20 feet long. In the case of teak they shall be 1 inch thick, 4 inches wide and as long as possible. No board shall be less than 6 feet long, the ends being truly squared up after any split portion has been sawn off. All boards shall be uniform and parallel in width and shall have the same thickness.

Joints

6. The planks shall be planed true on one side (on both sides for uncoiled upper floors) the edges to be planed, rebated or tongued and grooved as directed by the Engineer-in-charge. Unless otherwise specified, the edges shall be tongued and grooved, with concealed joints for teak wood floors, and rebated joints for other floors.

Planking Method of Laying

7. The outer lines of boarding shall be accurately fixed paralleled with and close to the wall. Each subsequent line shall have the side joints carefully joined up and shall then be cramped into position by floor cramps, and nailed or screwed as specified, so that the heads shall be sunk below the finished surface of floor, or otherwise fixed with "secret joints". The cramps shall not be removed until the nails or screws have been fixed. The ends of plank shall rest on the centre of joist, and the ends of no two adjacent planks shall be on the same joist. Paved floors shall be stopped under a brass strip screwed to wooden floors where the two meet.

Nails and Screws

8. The nails or screws shall be subject to the approval of the Engineer-in-charge and shall have a length at least twice the thickness of the plank, two being used at each end and one at every intermediate joist alternately on opposite sides of the plank. All screws shall be oiled before insertion.

Planing

9. After the floor has been laid, it shall be planed in both directions and made perfectly smooth. All depressions in the wood, nail holes and all small defects of every kind, where permitted by the Engineer-in-charge to remain in the work, shall, unless otherwise specified, be filled with "Beaumontage" or stopping out wax conforming to Specifications No. 27.1.

Measurements

10. The measurement of wood flooring shall be done by the superficial area. The unit of measurement shall be 100 square feet.

Rates

11. The unit rate shall include the floor boarding laid and fixed in position and planed in both directions, provision of brass screws in the case of teak wood floor where concealed fixing is not employed. Works like sand papering, oiling, waxing, staining or varnishing are not covered and shall be paid for separately. The unit rate does not include joists, wall plates, bearers, beams, rolled steel joists, rails, concrete or masonry pillars. Payment for these shall be made separately.

NO. 24.14 RUBBER FLOORING

Specifications

Scope

1. Rubber flooring shall include rubber floorings, either plain or marbled, in sheet or tile form and shall be composed of vulcanized rubber compounds. This flooring may be provided in important buildings, important offices, hospitals, cinemas, hotels, restaurants, etc.

Materials

2. Rubber tiles shall be satisfactorily vulcanized, free from sulphur bloom, porosity and grit. The wearing surface shall be smooth, plain and the colour of the flooring shall not be noticeably affected by washing with water or with suitable cleansing material such as good quality soap or by treatment with a suitable floor polish. The standard thickness of the rubber flooring shall range from 1/8 inch to 1/2 inch. Rubber tiles shall comply with standard hardness, accelerated ageing, compression set and water absorption tests contained in the relevant British Standard Specifications No. 1711: 1951.

Composition

3. The flooring shall be made from good quality new raw natural rubber in conjunction with other suitable compounding ingredients. The finished flooring shall contain not less than 35 per cent by volume of good quality new raw natural rubber.

Base

4. Cement concrete or any other solid and hard surface shall form the base for rubber flooring. The surface of the base shall be thoroughly clean, and free from contamination of dust, moisture oil or grease. Any irregularity on the base shall be filled in and levelled off before laying the tiles.

Laying

5. The base shall be prepared as specified under base. While laying the rubber tiles, areas not exceeding 25 square feet at a time shall be coated with the approved adhesive material. Sufficient number of tiles for this area shall be first roughened at their bottom surface and all sides, and then treated with the adhesive material. Ten to 15 minutes shall be spent waiting after this, for exposing the coated surface to the air before fixing the tile in true position on the base. After laying the tiles, pressure shall be applied from the upper surface of the tile, to remove any air that may have been trapped in between the bounded surfaces. This shall be done with the help of a small hand steel roller or by an approved method. The finished surface shall be washed with soap and water after three days.

Curing

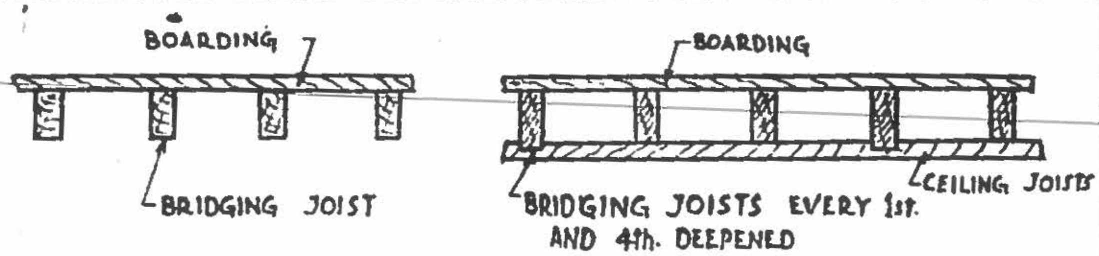
6. No load shall be applied on rubber tiles within three days of its laying.

Measurements

7. The unit of measurement shall be 100 square feet of the paved area.

Rate

8. Rate shall include the cost of rubber tiles, adhesive mixtures, and all labour required for preparing the base and laying the rubber tiles as specified above.



WITHOUT CEILING JOISTS. WITH CEILING JOISTS.

FIG. 9 SINGLE JOISTED FLOOR

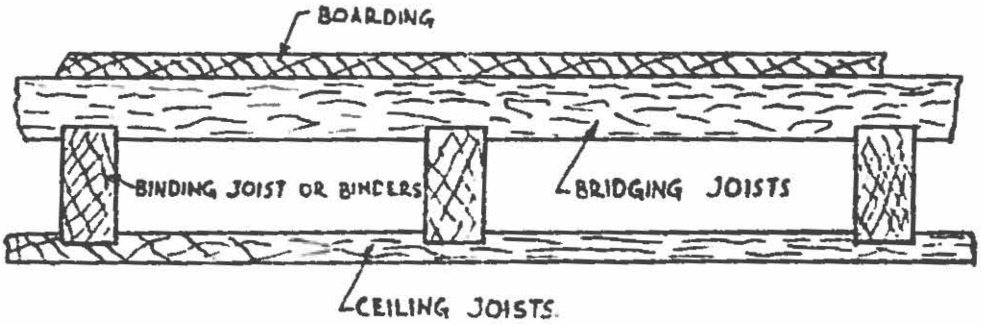


FIG. 10 DOUBLE FLOOR WITH CEILING JOISTS

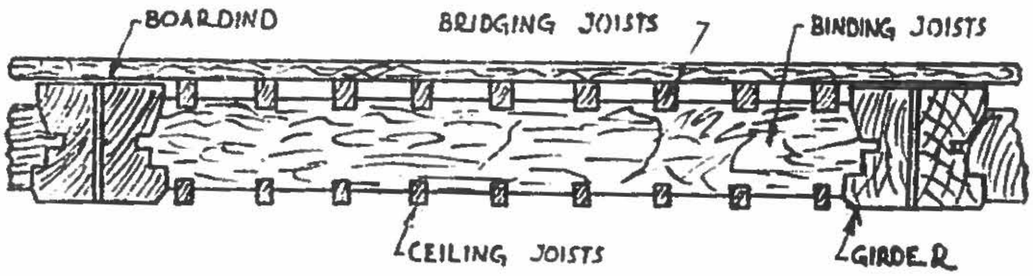


FIG. 11 - FRAMED FLOOR

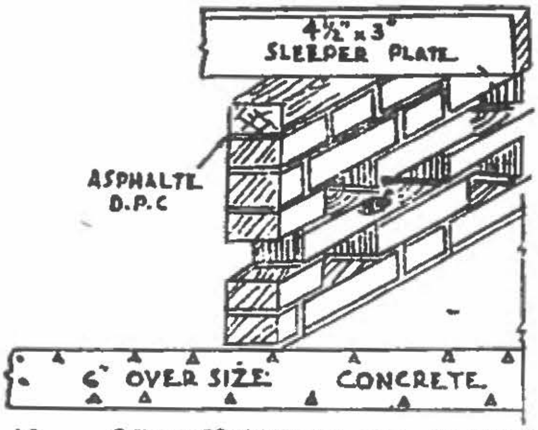


FIG. 12 CONSTRUCTION OF GROUND FLOORS

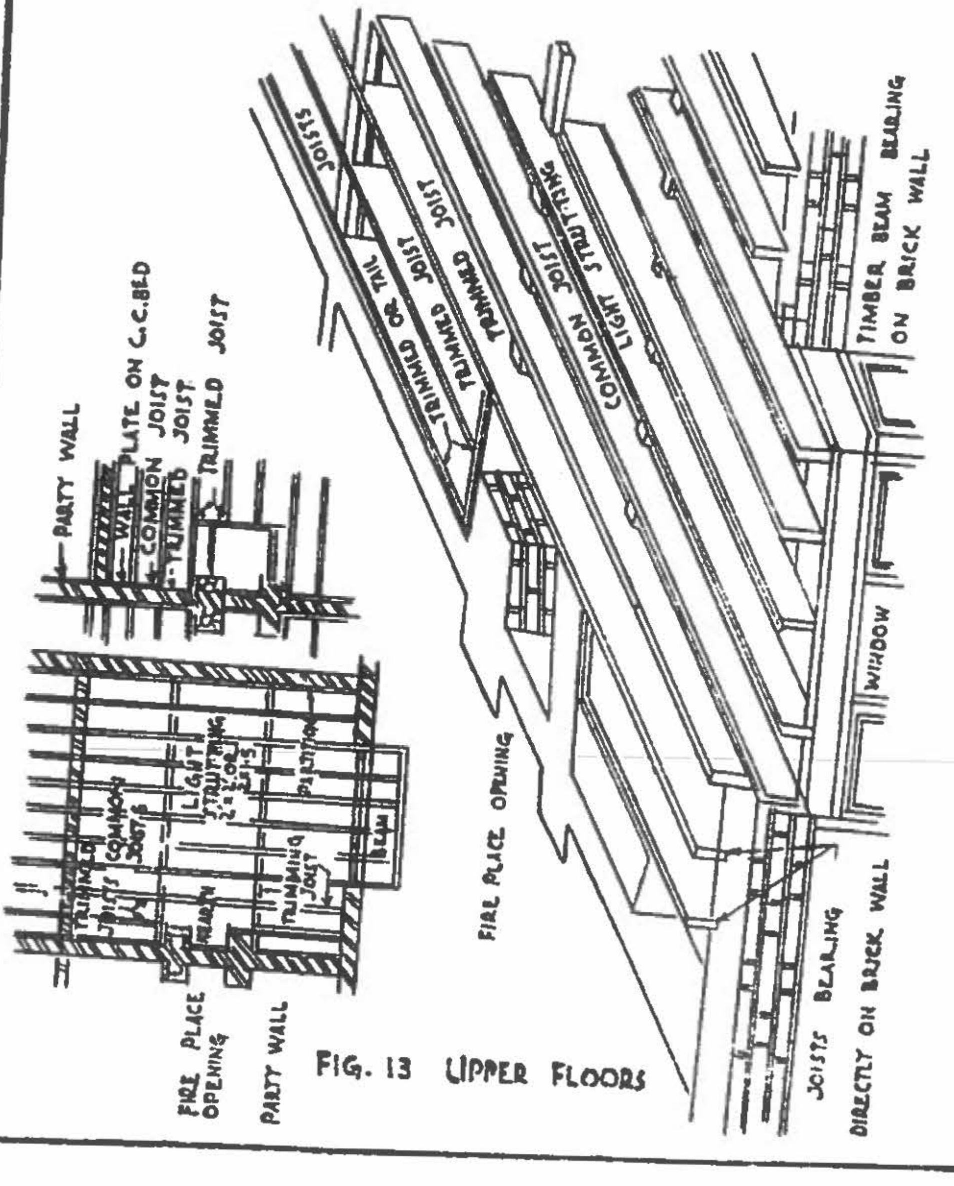


FIG. 13 UPPER FLOORS

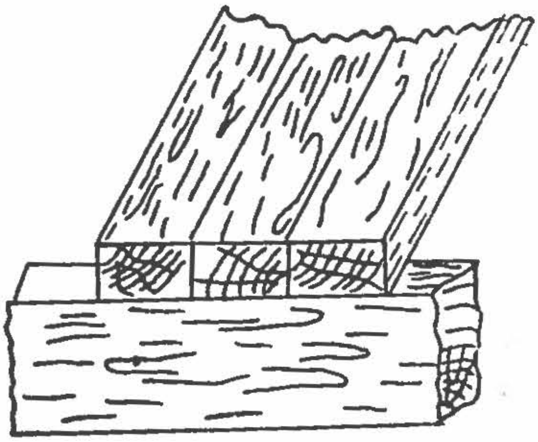


FIG. 14 SQUARED

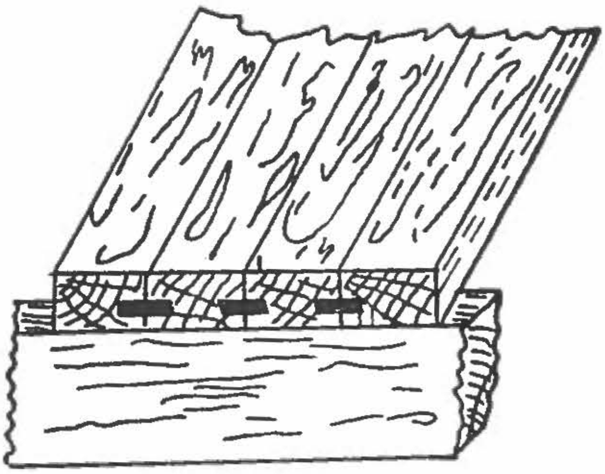


FIG. 15 CROSS TONGUED

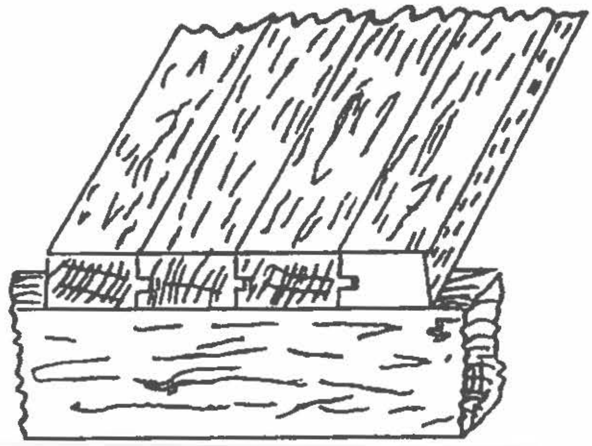


FIG. 16 GROOVED TONGUED

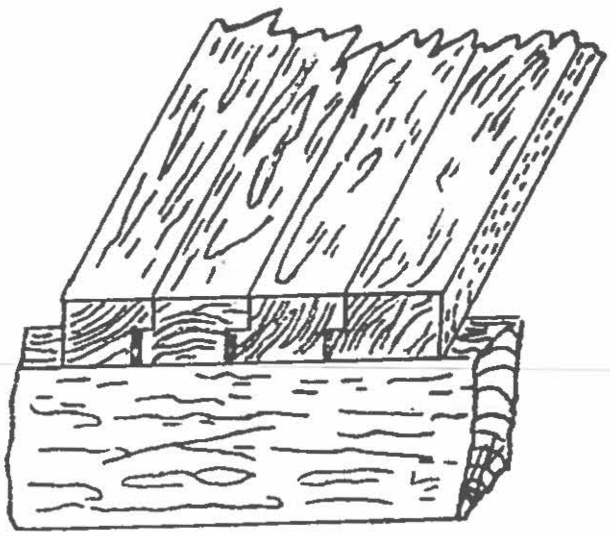


FIG. 17 REBATED

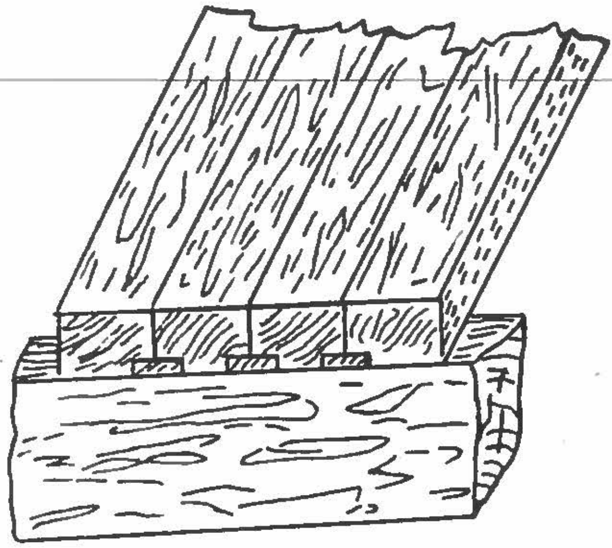


FIG. 18 FILLETED LONGITUDINAL JOINT

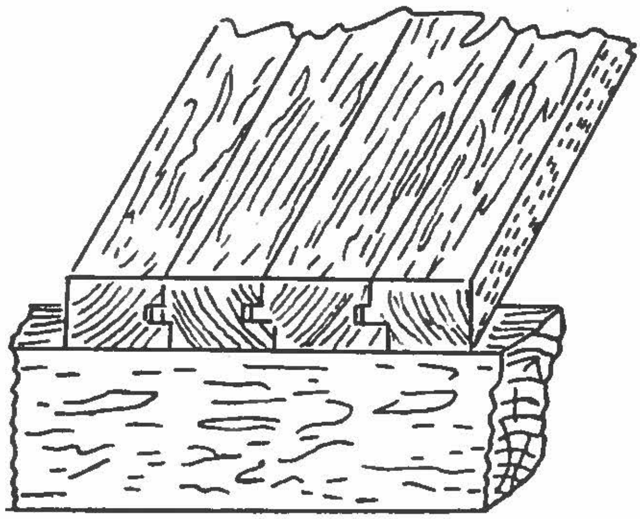


FIG. 19 REBATED GROOVED AND TONGUED

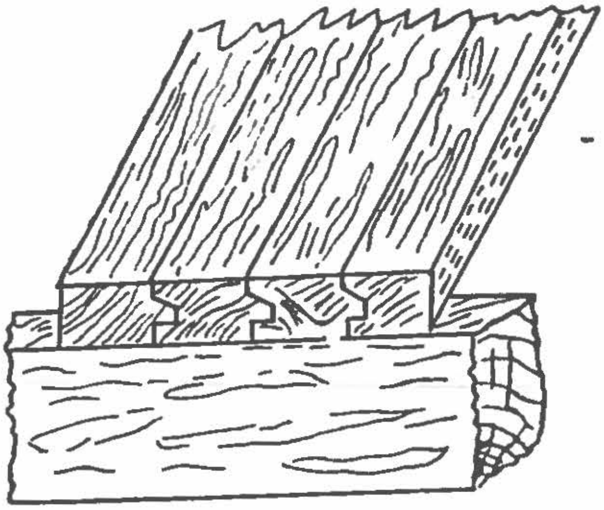


FIG. 20 SPLAYED REBATED G. AND T

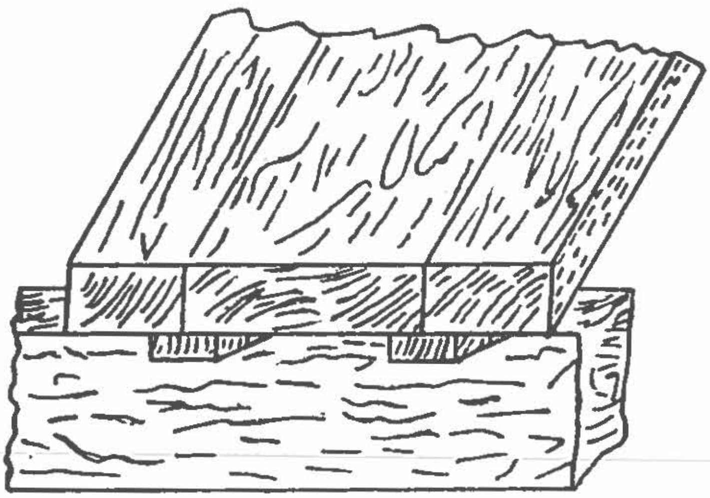


FIG. 21 SQUARE HEADING JOINT

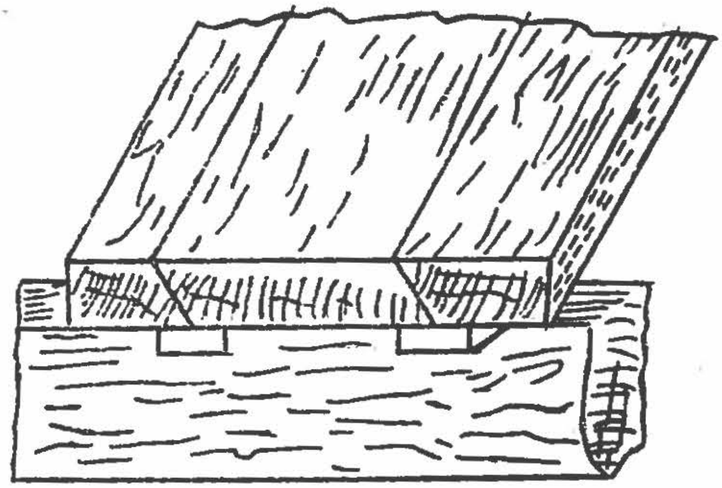


FIG. 22 SPLAYED

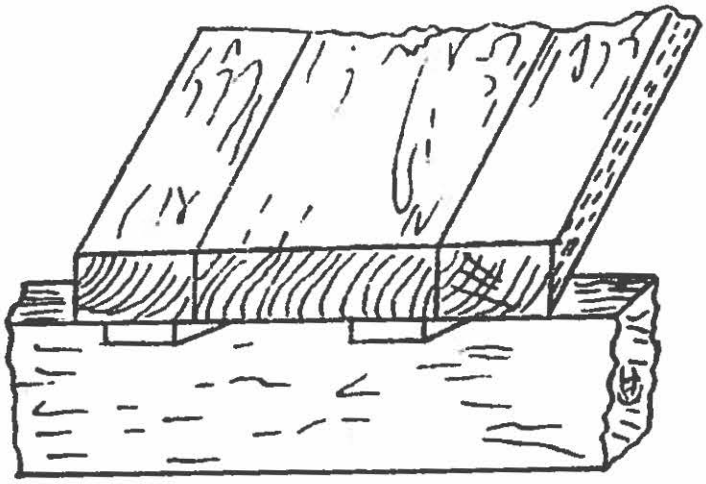


FIG. 23 – FORKED

SURFACE RENDERINGS

(A) PLASTERING

Introduction

Definition and Uses

Plaster is a material used in a plastic state, which can be trowelled to form a hard covering for interior or exterior surfaces, walls, ceilings, etc., in any building or structure.

Bases

Plasters are applied to bases of bricks, stones, hollow tiles, or concrete masonry, and to wood laths, metal laths and gypsum laths or similar materials finished in sheets.

Surface Preparation

A stiff wire brush is used to remove all loose dust from joints, and the surface is then thoroughly washed with water. Plastering should not be done on too much wet walls, because the results will not be satisfactory.

A good key is essential to a successful rendering and to avoid cracking and crazing. All joints in the masonry are raked to a depth of at least half an inch with a hooked tool specially made for the purpose and not with trowel or hammer. This is to be done while the mortar is still green and not later than 48 hours of the time of laying. After raking, the brickwork is brushed to remove all loose dust from the joints and thoroughly washed with water. (In case of old walls, it may sometimes be advisable to ensure a good key for the new rendering by destroying the smooth surface of the brickwork with some tool.) If the walls are washed with a solution of 1 part hydrochloric acid to 10 parts water, it will bring the grains in brickwork to the surface. This solution is left on for about quarter of an hour and then washed off with water.

Coats

Plaster may be applied in one, two or three coats; two are usually sufficient, but three should be applied only on wood or metal lathing or on a very rough, uneven background. The thickness of the first coat has to be just sufficient to fill up all unevennesses in the surface. The second and subsequent coats are thinner than the first, and no single coat has more than half an inch of thickness, because thick coats shrink more and crack. Under-coats of coarse stuff are allowed to dry and shrink properly before subsequent coats are applied; otherwise cracking and crazing is bound to occur. A good key for all stages of plastering is essential. The freshly plastered surface is scratched or roughened before it has fully hardened, to form a mechanical key for the second coat. The method of application of the mix influences the adhesion; the mix sticks better if thrown on than if applied by trowel.

Materials

Various materials employed for plastering have been described in detail in chapter No. 19 (Mortar). A rich mix tends to develop large cracks; a weaker one develops finer and distributed cracks. A strong coat is never applied over a weaker one since the latter would be unable to restrain its movement. (Also see Mortars for plastering at the end.)

Lime Plaster

The lime used for plastering ranges from fat lime to strong hydraulic lime. Fat lime is most commonly used on account of its yield of lime putty and ease in application. But hydrated lime is some time preferred because it can be used immediately on its preparation, while the ordinary lime has to be slaked by hand and kept in the form of a putty till slaking is quite complete. However, fresh slaked lime is superior in quality. Coarse, sharp sand is used with lime. Lime and sand plaster is weak and soft and takes a long time to harden. Fine stuff for finishing coat is made by mixing water with a thoroughly slaked lime to bring it to the consistency of cream; it is then left to settle. Superfluous water is either poured off or allowed to evaporate till the cream attains proper thickness. An equal volume of sand is then added. To improve their quality lime mortars are sometimes gauged with cement or surkhi. Lime plaster on walls which have to be whitewashed is not finished very smooth to allow the whitewash to stick to the surface. The plastered surface is kept wet for several days to prevent it from cracking.

Cement Plaster

Cement plaster is done exactly in the same manner as described above. The mortar is sometimes gauged with fat lime to improve its properties. Cement/lime/sand mortar hardens slowly and reduces the incidence of cracks; the addition of lime also makes for easier application. Sand used should not be very fine. The plastered surface is kept wet and allowed to dry slowly, avoiding draughts and exposure to excessive heat from sunlight for several days so as to prevent it from cracking. To ensure an even thickness and true surface, patches of plaster about four to six inches square or wooden screeds three inches wide and of the thickness of the plaster may be fixed vertically about six to 10 feet apart to act as gauges. Trowels for plastering have a face measuring about 10 inches x 4½ inches. Wooden trowels produce a sandy granular surface.

Architectural Plaster Finishes

There are usually the following three types of finishes falling under this head.

(a) *ROUGH CAST*—A wet plastic mix of 3 parts cement, 1 part lime, 6 parts sand and 4 parts of shingle graded between ¼" and ½" or crushed stone, which is thrown on the wall by means of a scoop or plasterer's trowel.

(b) *PEBBLE-DASH*—A 3/8" coat of 1 part cement, 1 part lime and 5 parts sand is laid. Shingle graded between ¼" and ½" is thrown while the coat is still soft.

(c) *ORNAMENTAL FINISHES*—A mix of approximately 1 part cement, 1½ parts lime and 6 parts sand which after application is finished by the use of combs, trowels, or a special tool.

Plastering on Lathing

Lathing constitutes a convenient base in some form of construction for plastering on walls and ceilings. Metal lathing, the most commonly used, is fixed to timber support by galvanized wire nails or staples at short distance. It is also often used to bridge the junction of two dissimilar backgrounds, or to provide a suitable key for plastering over a wooden beam. Metal lathing may be of expanded metal or woven wire, etc., which should weigh not less than 12 lbs per 100 square feet, except when used to provide the key. Lathing is stretched tight with the help of some tension device such as mild steel rods since plaster would crack on a loose lathing. After cleaning the rust, if any, the lathing is brushed with cement slurry. Most common defects in plaster on metal lathing are extensive cracking, particularly along the line of fixing of the lathing to its support or unevenness of the finished plastered surface.

Defects in Plaster

Various defects observed on plaster alongwith their causes are given below—

(a) *CRACKS*—Cracks briefly occur on account of (i) Structural defects in building and discontinuity of surface. (ii) Plastering on very wet background. (iii) Old surface not properly prepared. (iv) Over-rapid drying. (v) Excessive shrinkage of the plaster owing to thick coats and richer mixes.

(b) *PITTING AND BLOWING*—These defects are noticed in case of faulty slaking and hydration of the lime particles in the plaster.

(c) *FALLING OUT*—Plaster falls out mainly on account of (i) Lack of adhesion for not having formed a proper "key" in the background (ii) Excessive moisture in the background (iii) Excessive thermal changes either in the background or in plaster itself. (iv) Rapid drying. (v) Insufficient drying between each coat of plaster.

Repairing Cracks

Hair cracks generally disappear with whitewashing. Wider cracks can be filled in by forcing down a mortar consisting of plaster of paris, cement and sand in the proportion of 1:2:7 by weight. The mortar should be prepared in a quantity which must be consumed within half an hour.

Mortars for Plastering

The following proportions (by volume) of dry material are suggested.

	Cement	Sand	Lime Paste
General	1	2 to 6	
Watertight mortar	1	2 to 3	1/3 to 1/2
Under coat	1	4 to 6	1
Finishing coat	1	9	2
Watertight finishing	1	10 to 12	3
For chimney breasts	1	8 to 10	3

(B) POINTING

The surface of the work is prepared as explained under "Plastering". When commencing masonry each day, the first thing to be done, if the surface is to be subsequently pointed, is to rake out the face joints of all masonry finished the previous day. The joints are properly wetted in old work before pointing; for the mortar will not stick to a dry surface. The work pointed is kept wet for at least three days. There are about half a dozen types of pointing, but the most common are the flush, weathered and grooved or ruled. Weathered pointing is used for horizontal joints and grooved for vertical joints of walls; flush pointing is used for floors and all vertical and horizontal joints in walls which are to be whitewashed.

Mortar

Normally, pointing is done with mortar having the following mix ratios:—

	Cement	Sand	Lime Paste	Surkhi
Outside work	1	1 to 3	—	—
	1/3	—	1	1 to 2
	—	1	1	1/2 to 1

(C) WHITEWASH

Preparation

Whitewash, which is the cheapest water paint and has the desirable sanitary properties, is prepared from pure fat lime (white stone) or shell lime. Preferably, unslaked lime is brought to the site of work and slaked there. After slaking it is kept in a tank of water for at least two days and then stirred up with a pole till it attains the consistency of a thin cream. Where necessary, gum or rice water (2 Ozs. of gum for 1 cfc of lime) is added. Sometimes flour, skimmed milk, glue, molasses or other substances are mixed in the slaked lime to increase its adhesion. Preservatives such as salt or formaldehyde are added to keep these substances from spoiling. Whitewash may be tinted by using pigments and should be strained through a coarse cloth or a fine wire gauze before use.

Preparation of Surface

All loose material and dirt on the surface must be removed with a brush. Holes and irregularities of surface are repaired with lime putty, and the surface is allowed to dry before applying whitewash or colour-wash. Similarly dusting and repair are done to walls which have been whitewashed several times before. All greasy spots are given a coat of rice, water and sand. Surfaces discoloured by smoke are washed with a mixture of wood ashes and water or yellow earth before being whitewashed.

Application

Each coat of whitewash comprises four strokes applied vertically and horizontally. One stroke is given from the top downwards and the other from the bottom upwards over the first stroke before it dries up, and similarly one stroke from the right and another from the left over the first brush. Each coat is allowed to dry up before the next is applied. Normally three coats are applied on the new surface.

Methods for Slaking Lime

Keeping in view the various principles on which the hydration of quicklime depends, the following methods are employed for slaking different types of lime:

(a) *HAND SLAKING*

(i) *By drowning*—High calcium lime or fat lime is slaked by drowning the particles in a tub containing enough quantity of water. The tub is covered to preserve the heat.

(ii) *By Immersion*—Feeble hydraulic limes are slaked by immersion. They are put in a basket which is immersed in a tub filled with water. The basket is withdrawn when the sound of the reaction becomes apparent. The exact period of immersion is a matter of experience.

(iii) *By Sprinkling*—Hydraulic limes are usually slaked by this manner. They are spread on a specially prepared non-ferrous platform and water is sprinkled by means of a cane with a rose. Simultaneously the limes are turned over with spades. The slaking operation is accelerated, if the limes are initially pulverized in grinding mills.

(iv) *Air Slaking*—According to this method lime takes moisture from the air when kept in an exposed condition. This process of hydration is also accompanied by the formation of a certain proportion of calcium carbonate by taking carbon-dioxide from the air and in this way lime is spoiled. Besides, it is difficult to control this process.

(b) *MECHANICAL SLAKING OR HYDRATING*—Hydrated lime is produced on a large scale with the aid of various types of mechanical appliances. It may be produced in a specific quantity each time or the process kept continuous. By whatever method the hydration is done the following points must be observed:—

- Only the necessary quantity of water should be added to the lime at a uniform rate.
- Lime and water must be thoroughly mixed.
- The temperature of hydration should be properly controlled by a suitable cooling method.

A hydrating plant essentially consists of a crusher and a hydrator with a suitable storage tank and silos, and contains devices for conveying the material from one unit to the other. Hydrated lime is then passed through a sieve of 20 to 30 meshes to an inch to yield a powder of the required fineness.

Whitewashing Cement Concrete

Cement concrete surface requires treatment prior to whitewashing.

Treatment of Surface

Surface is scraped off with a wire brush to remove greasy patches, if any, and washed with soap-suds. A coat of sodium silicate and water in the ratio of 1:5 is given to avoid any future scaling or flaking off.

Preparation of Surface

Half to one part (by weight) of tallow in small lumps is added to 16 parts of quick lime, slaking it with only just sufficient water to form a thick paste, stirring occasionally to assist in dispersing the tallow, and allowing it to stand till it cools down. The resultant paste is thinned down to a required consistency, is strained and applied on the surface in the usual manner. In the absence of tallow, other oils or fats (for example, linseed oil or castor oil or some common vegetable oil) about 10% of the weight of dry lime are added to serve this purpose. If oil does not incorporate with the lime, the mixture is boiled a little till the oil disappears. In this way it becomes an insoluble soap which when once dry cannot be washed off even with heavy rains.

Cement Wash

Cement wash is simply a thin grout made of Portland cement and water and of such a consistency that it can be applied with a brush. Fine sand is sometimes added. This wash may be coloured, if desired, but with certain tints it is desirable to use white Portland cement. Paints consisting of two parts of Portland cement to one part of lime are usually used.

(D) COLOUR-WASHING

Colour-washing is nothing more than a lime-wash coloured with suitable pigments and treated to give a desired tint. It is applied exactly in the same fashion as the whitewash. The old paint is scraped off or a coat of whitewash is applied before the new colour is given. Gum or rice water is added as in whitewashing.

To give an idea as to how a colour is imparted to whitewash a brief description is given below for the preparation of:

Buff colour: 4 lbs of lime are slaked with 2 gallons of water to which 10 Ozs of brown earth dissolved in 1/4 gallon of water is added. To this mixture is added 2 Ozs of gum boiled in 1/8 gallon of water. It should then be strained through a cloth and applied.

Green colour: 4 lbs of lime are slaked with 2 gallons of water to which are added 7 lbs of fresh mango bark boiled for two minutes in half a gallon of water and 2 lbs of nilla tootya (blue stone or vitriol) boiled in half a gallon of water. The mixture is strained and applied.

(E) DISTEMPERING

Use

Distemper forms a cheap, durable and easily applicable decoration for internal use of plastered, cement concrete and various wall-board surfaces.

Composition of Distempers

There are different types of distempers like oil-bound washable paints, washable oil-free distempers, non-washable distempers and emulsion paints, which have been described in detail in Part I. The distemper mixture should be prepared only in a quantity that must be consumed in a day's work and is kept well stirred during application.

Preparation and Treatment of Surface

All loose and flaking materials are removed from the old walls by scraping or wire-brushing. The newly-plastered or whitewashed surface is either treated properly or distempered 12 months after plastering or whitewashing when it has become sufficiently dry. In case of cement plaster the surface is washed with a solution of I lb of zinc sulphate in one gallon of water and then allowed to dry; before distempering it is wiped with clean cloth to remove any efflorescence. Distempering yields poor results in wet locations and hence must be done in a dry weather.

Coats

To get good results a priming coat, if recommended by the makers, must be applied. It often happens that fresh coats of distemper pull off the old ones—as the old coats absorb water from the new adhesion weakens, and as the new coats contract while drying they tend to pull off the old ones. Two coats of distemper, in addition to a priming coat, are applied on newly-lime-plastered walls. But on old lime-plastered walls covered with one or two coats of hard, dry whitewash, one coat of distemper after a coat of warm glue without a priming coat will do. On previously distempered surface one coat of distemper would do if the new coat is of the same colour as the old one.

Application

Distemper is applied with a broad stiff brush (and not with the whitewash brush). It is first applied horizontally and then immediately crossed off perpendicularly. Brushing is not continued too long, as the distemper gets sticky and leaves brush-marks. After each day's work the brushes are washed with hot water.

NO. 25.1 GENERAL DEFECTS IN PLASTERING AND THEIR REMEDIES

Specifications

General

I. Unless otherwise specified or directed by the Engineer-in-charge the following measures shall be adopted to remedy defects and faults incidental to plaster work.

(*i*) Fine aggregate (sand) shall be clean and free from all impurities. It shall be washed before use.

(ii) Lime shall be properly slaked before use.

(iii) A proper key shall be provided.

(iv) The background shall be kept moist, but excessive moisture shall be avoided.

(v) Proper curing shall be done to eliminate excessive and rapid thermal changes.

(vi) Each coat shall be allowed to dry before the next is applied.

Scaffolding

2. The scaffolding for plaster shall always be double.

Inspection of Plastering

3. Plastering shall be inspected by the Engineer-in-charge or his authorized representative when the work is in progress and after its completion. The following points will be kept in view while making the inspection.

(i) If wood skirtings are specified, the plastering has been finished tight on to them.

(ii) The surface checked by means of straight edge and tips of the fingers is perfectly even.

(iii) All intricate places like soffits, cupboard and their recesses, specified to be plastered, have been properly plastered.

(iv) The work has been properly finished at the junction with other materials such as woodwork at window and door openings, fireplaces and similar other places.

(v) If wood angle-beads are specified, they are of proper section, under cut for key, securely fixed, and the plaster has been finished up to them in a proper manner.

(vi) Special care has been taken of cornices and moulding sections. The templates shall be thoroughly checked and compared with the approved drawing.

(vii) All ornamental work is true to design and securely fixed and bonded.

(viii) If Keene's or other hard plaster angles are specified, they have been duly executed.

(ix) In external stucco, rough cast, or pebble-dashing, the coats are of even thickness and are uniformly laid.

(x) The plastered surface struck with the knuckles does not give hollow sound. If it rings hollow, it is an indication of insufficient adhesion between various coats of plaster.

Remedies of Defects

4. Hair-cracks on fresh plaster normally disappear after whitewashing. But wide cracks shall be filled in by forcing down mortar consisting of plaster of paris, cement and sand in the proportion of 1:2:7, unless otherwise specified or directed by the Engineer-in-charge.

Surface areas showing pitting, blowing, popping and blister shall be remedied by cutting out patches in rectangular shape, under cutting the edges to form a dovetail key and making good on a portland cement ground.

All these remedial measures shall be carried out by the contractor at his own expense.

NO. 25.2 CEMENT LIME OR PUCCA PLASTER (SINGLE COAT)

Specifications

Preparation of Surface

1. (i) Before plastering, the joints of old brickwork or masonry shall be raked out with a hook (not hammer or tessi) to a depth of half an inch. In case of new masonry in cement or lime to be subsequently plastered, the joints shall be raked out at the end of day's work before the mortar has set.

(ii) The earth and mortar dust coming out of these joints as a result of raking shall be washed off, and the work watered for 24 hours before plaster is applied.

(iii) All putlog holes shall be filled up before plastering, as the scaffolding for masonry is being taken down.

Mortar

2. Unless otherwise specified or directed by Engineer-in-charge the arrises of all corners of door and window jambs shall be plastered with mortar compoesd of one cubic foot of portland cement to three cubic feet of sand.

The mortar shall be prepared in accordance with Specifications No. 19.4 of lime cement mortar.

Precautions

3. All precautions as contained in Specifications No. 25.1 shall be strictly observed.

Plastering

4. (i) Unless otherwise specified or directed by the Engineer-in-charge or his authorized subordinate in writing, wooden screeds three inches wide and having a thickness equal to the plaster shall be fixed vertically 8 feet to 10 feet apart to act as gauges and guides in applying the plaster.

(ii) The arrises shall then be plastered for a space of four inches on each side and up to the ceiling, except in case of openings where it shall run around them. This plaster shall also serve as a guide for thickness etc. Unless otherwise specified or directed by the Engineer-in-charge all corners and arrises shall be rounded off to a radius of 3/4 inch only and no more. This work is included in the unit rate of plastering.

(iii) The mortar shall be laid on the wall between the screeds, using a plasterer's float for the purpose and pressing mortar so that the raked joints are properly filled. The plaster shall then be finished off with a wooden straight-edge reaching across the screeds. The straight-edge shall be worked on the screeds with an upward and sideways motion, two inches or three inches at a time. Finally the surface shall be finished off with a plasterer's wooden float. Metal floats shall not be used.

(iv) The plaster shall be laid to a true and plumb surface and tested frequently with a straight-edge and plumb-bob. The straight-edge shall not be less than 10 feet in length. As the work proceeds, all horizontal lines and surfaces shall be tested with a level, and all jambs and corners with a plumb-bob.

(v) All mouldings and decorations shall be worked true to template and shall be neat, clean, level, and parallel, or truely plumb, as the casemay be.

(vi) Unless otherwise specified, plaster shall not exceed half an inch in thickness and shall not be less than quarter of an inch at the thinnest part.

Protection During Curing

5. After completion, plaster shall be kept wet for 10 days and shall be protected during that period from extreme fluctuations of temperature and weather.

Defects

6. All defects detected shall be treated at the contractor's expense according to Specifications No. 25.1.

Measurements

Para No. 7 amended AFC No. 2 of 17/8/69

7. Plastering shall be measured by the superficial area, no deduction being made for the openings of any size or additions for returns and soffits. The unit of measurement shall be 100 square feet. Ornamental work to be finished and plastered shall be measured and paid separately and their unit of measurement shall be one foot (linear).

Rate

8. The unit rate shall include:—

(a) When only labour rate is to be paid.

(i) Preparing, cleaning and watering the surface to be plastered.
(ii) Plastering surfaces and corners as per above specifications.
(iii) Curing and protecting the plaster after completion for 10 days.
(iv) Providing, erecting and removing scaffoldings.
(v) Providing tools such as special floats, straight-edges, levels and plumb-bobs.

(b) When rate for completed job is to be paid :—

(i) All items mentioned in (a) above.
(ii) All mortar usd at site of work.

NO. 25.3 CEMENT LIME OR PUCCA PLASTER (TWO COAT)

Specifications

Use

1. Where, owing to the irregularities of surface to be plastered (as in the case of 9-inch brick walls or certain other classes of masonry), it is not possible to obtain an even surface with a single floated coat half an inch thick, a preliminary coat shall be applied before the finishing or floated coat. The combined thickness of the two coats shall not exceed one inch at any point.

Application of Preliminary Coat

2. (a) After preparing the surface and fixing the screeds as detailed in the Specifications No. 25.2 for single coat, the first or preliminary coat shall be applied to an uneven surface by the wooden floats and kept half an inch behind the surface of the screeds. The surface shall be kept wet for at least four days or so till it sets.

b) Before it sets, the preliminary coat shall be scratched with a sharp tool to form a key for the floated or final coat which shall be finished in accordance with Specifications No. 25.2 for single coat, after the preliminary coat has been cement washed.

4. In all other respects the Specifications No. 25.1 for plaster in general and Specifications No. 25.2 for single coat shall apply. **Other Respects**

25.4 PUCCA PLASTER COLOURED AND POLISHED

Specifications

Use

1. When it is not required to subsequently paint, distemper or colour-wash the lime plaster, it shall be finished to the final colour and polished. Plasterer's putty shall be used for the finishing coat.

Plasterer's Putty

2. Unless otherwise specified plasterer's putty shall be made as follows:—
   (I) Pure fat lime shall be slaked and then immersed in water for at least 48 hours. The lime shall then be thoroughly stirred with water and strained through muslin cloth. On settling, the surplus water shall be removed and further water allowed to evaporate, till the paste becomes thick enough for use. Suitable pigments are added to it to obtain the desired colour as directed by the Engineer-in-charge.

Finishing Coat

3. (i) The finishing coat of plasterer's putty prepared as above shall be applied on the floated coat after it has set. The floated coat shall be finished according to specifications for single coat or double coat, as the case may be.

   (ii) The thickness of this coat shall be 1/8 of an inch unless otherwise specified. The surface shall be rubbed smooth with a steel plasterer's trowel to give it a polished surface.

Other Respects

4. In all other respects not specified here it shall conform to relevant parts of Specifications No. 25.1, 25.2 and 25.3, as the case may be.

NO. 25.5 PLASTER ON EXPANDED METAL OR LATHING

Specifications

Preparation of Surface

1. (I) Expanded metal or similar metal fabric or lathing shall be free from all rust, grease or other surface impurities, before plastering can be done.

   (II) When wooden lathing is used the wood shall be cleaned, slightly roughened and two coats of (creosote) or other wood preservative shall be given. Lathing shall be erected to break joint.

Mortar

2. Unless otherwise specified two coats of plaster shall be applied. The mortar for both the coats shall be 1:3 cement mortar prepared as per Specifications No. 19.2 except that for the first coat 3/4 lb of fine chopped jute or hemp shall be added and thoroughly mixed with each cubic foot of mortar.

First Coat

3. The first coat shall be applied in such a way as to enclose the fabric completely, or in the case of wooden lathing, to form a secure key between the lathes. The coat shall be worked to an even surface half an inch behind the screeds and kept wet for four days or till it sets.

Finishing Coat

4. Before the first coat has set the surface shall be scratched with a sharp tool both ways to give a key to the floated coat. All dust and loose plaster shall be washed off, the surface shall be cement-washed and floated coat shall then be applied and finished strictly according to the Specifications No. 25.2 for plaster single coat.

Other Respects

5. In all other respects, it shall conform to relevant portions of Specifications No 25.1 and 25.2

NO. 25.6 CEMENT RENDERING

Specifications

Preparation of Surface

1. (i) The surface to be rendered shall be thoroughly cleaned, and dust loose particles, grease and oil stains shall be removed by washing, using a wire brush, if necessary.

(ii) Brickwork, stone masonry or concrete shall be prepared to receive the rendering by harking, raking out joints to a small depth not more than ½", or in the case of hardened concrete by beating a thoroughly saturated surface by 1:6 solution of hydrochloric acid and water, washing down within six hours and wire brushing so as to expose the aggregate. If the Engineer-in-charge thinks that the surface so prepared provides a good key, a single coat of rendering 3/8" to ½" thick shall suffice.

(iii) If, however, a good key is not obtained, a base coat of coarse sand and cement in the proportion of 1½ parts sharp sand ½" down to 1 part cement, mixed in sufficient water, shall be applied. The mixture shall be dashed on to the wall in an uneven manner.

Preparation of Mortar for Rendering

2. (i) Aggregate, cement and water shall conform to respective specifications as contained in Part I, Volume I of Book of Specifications.

(ii) The grading of aggregate shall be ½" down for key coat and 1/8" down for finishing coat.

(iii) The proportions of cement and aggregate for key coat shall be 1:3 and for backing or finishing coat 1:1½. A mortar of required consistency shall be prepared by adding water from 12 to 16 per cent of the total volume of aggregate and cement for backing coat and 14 to 18 per cent for finishing coat, unless otherwise specified or directed by the Engineer-in-charge.

Application

3. (i) *BACKING COAT*—It shall be laid to a uniform thickness of 3/8" and just after the material has started to set, it shall be scored in wavy lines by a wire-nail comb to form a bond for the next coat, and the work then allowed to set for at least 30 hours. It shall be kept damp for that period.

(ii) *FINISHING COAT*—Unless otherwise specified or directed, the finishing coat shall be 1/8" thick. The backing coat (base coat) shall be washed clean and the finishing coat applied evenly with care.

Curing

4. The finishing coat shall be protected from the sun, hot winds or rain by wet screens till it has hardened sufficiently to remain unaffected by the external application of water. It shall then be watered and kept damp for a period of at least seven days and allowed to dry as slowly as possible.

Protection against Cracking and Crazing

5. The surface shall be divided by joints to prevent cracking, and these joints shall be placed horizontally at the sill and lintel levels of windows and vertically at opening in wall angles and corners.

Removal of Defects Measurements and Rates

6. In respect of removal of defects, measurement and rates, it shall conform to Specifications No. 25.1 and 25.2.

NO. 25.7 MUD PLASTER

Specifications

Preparation

1. Mud mortar for plastering shall be prepared as per Specifications No. 19.1.

Application of Plaster

2. The plaster shall be spread evenly over the wall so as to be not more than 3/4 inch thick. In case of roofs and floors, its thickness shall be 1 inch. After spreading, the plaster shall be floated with a straight-edge, till the surface is perfectly smooth, level and true. Any cracks that open out during drying shall be filled with liquid cow-dung.

Finish

3. (i) When the surface has dried, it shall be leeped over and finished off with a trowel or float in the case of walls and roofs. In the case of floors, it shall be applied and finished by hand.

(ii) The leeping shall be done with a preparation described below:—
Cow-dung is steeped in water to render it free from grass, straw, seeds and other impurities. If considered necessary, it shall be passed through a fine sieve. An equal part of finely-powdered clay shall then be mixed with it thoroughly in a tub.

Other Respects

4. In respect of measurement and rate, it shall conform to Specifications No. 25.2

NO. 25.8 POINTING

Specifications

Preparation of Surface

1. (i) Before pointing old brickwork or new brickwork in mud, the joints shall be raked out with a hook (not hammer) to a depth of half an inch. If, for any reason, the joints in new brickwork in lime or cement are not struck as the work proceeds, they shall be raked out before the mortar sets.

(ii) All earth and mortar dust coming out of the joints as a result of raking shall be washed off and the brickwork watered for 24 hours. The face shall once again be washed just before starting pointing.

(iii) The surface prepared in the manner described above shall be inspected by the Engineer-in-charge or his authorised subordinate, and shall be approved by one of them before actual pointing begins.

Pointing

2. Unless otherwise specified various types of pointing suitable for different situations shall be as follows:—

(a) *DEEP OR STRUCK LIME POINTING*

(i) This type of pointing shall be done to all unplastered faces of brickwork in mud. Its colour shall match with that of the bricks.

(ii) The mortar shall be prepared as per Specifications No. 19.3 for Lime Mortar.

(iii) The mortar shall be filled in the joints flush with masonry or brickwork with a pointing trowel and then pressed in with proper pointing tools. Lining with a spike on a mass of mortar shall not be allowed.

(b) *DEEP OR STRUCK CEMENT POINTING*

(i) This type of pointing shall be done to all unplastered faces of brickwork in mud where the brickwork is liable to be affected by dampness and saltpetre, such as in plinths of buildings.

(ii) The mortar shall be prepared as per Specifications No. 19.2 for Cement Mortar.

(iii) The mortar shall be filled in the joints flush with masonry or brickwork with a pointing trowel and then pressed in with proper pointing tools. Lining with a spike on a mass of mortar shall not be allowed.

(c) *FLUSH LIME POINTING*

(i) This type of pointing shall be done to all unplastered faces of brickwork in mud, where the finish of the faces is not important or where the face is to be ultimately whitewashed or colour-washed. Brick, tile or other paved floors shall also be pointed in this fashion.

(ii) The mortar shall be prepared as per Specifications No 19.3 for Lime Mortar.

(iii) The mortar shall be filled and pressed into the joints with a pointing trowel, and finished off level with the edges of the bricks to give the smoothest possible appearance to the work.

(d) *FLUSH CEMENT POINTING*

(i) This type of pointing shall be done to all brickwork with an exposed face, when the finish of the face is not important or when a flush floor surface is required or when the floor or brickwork is subject to wear or to the effects of dampness and saltpetre.

(ii) The mortar shall be prepared as per Specifications No. 19.2 for Cement Mortar.

(iii) The mortar shall be filled and pressed into the joints with a pointing trowel, and finished off level with the edges of the bricks to give the smoothest possible appearance to the work.

(e) *RULED POINTING*

(i) This type of pointing shall be done, when specified, to brickwork not liable to be flushed with water.

(ii) The cement or lime mortar as actually specified shall be used. These mortars shall be prepared as per Specifications No 19.2 and 19.3 respectively.

(iii) The mortar shall be filled and pressed into the joints with a pointing trowel, and finished off level with the edges of the bricks and shall then be ruled along the centre of all joints with a half round tool 1/2" wide.

(f) *STRIKING JOINT*

(i) All new unplastered faces of work in cement or lime mortar shall be finished by striking joints as the work proceeds according to the relevant part of Specifications No 21.1 contained under brickwork.

(ii) In case of walls, joints shall be struck by raking out the green mortar after the brickwork has been laid, and finished with a pointing tool.

Pointing Tools

3. The pointing tools for horizontal joint shall be such as to form weathered and struck joints; and for vertical joint, triangles, so as to make a (v) notch in the joint. Care shall be taken not to develop a cutting edge in the tools since the idea is to compress the green mortar into the joints and not to cut it away.

Edges of Bricks

4. The mortar shall not be spread irregularly over the edges and corners of the bricks, which shall be left clearly visible. The practice of smearing mortar over

defects in bricks, to hide them, shall not be allowed and shall render the whole brick-work liable to be rejected.

Washing after Pointing

5. After pointing, the face of the work shall be cleared off all surplus mortar sticking to the face. No washing shall be done till the pointing has set.

Curing

6. Lime pointed work shall be kept wet for five days and cement pointed work for 10 days after completion. The work shall be protected during that period from extreme fluctuations of weather.

Measurements

Para No. 7 amended vide : No. 2 d/- 17/8/69

7. Pointing shall be measured by the superficial area. The unit of measurement shall be 100 square feet.

Rate

8. The unit rate for pointing shall include:—

(a) When only labour rate is to be paid

(i) Raking out joints, cleaning and watering the surface to be pointed.

(ii) Pointing the surface as per above specifications.

(iii) Curing and protecting the pointing after completion for 10 days.

(iv) Provision, erection and removal of scaffoldings.

(v) Provision of all tools required for pointing.

(b) When rate for completed job is to be paid.

(i) All items mentioned in (a) above.

(ii) All mortar used at site of work.

NO. 25.9 WHITEWASHING

Specifications

Preparation of Surface

1. (i) The surface shall be clean, smooth and completely dry before whitewash is applied.

(ii) New plaster to be whitewashed shall not be trowelled to a glazed surface, because whitewash would not adhere to it.

(iii) The old loose whitewash shall be removed from walls previously white-washed, and the surface thoroughly cleaned.

(iv) If the old whitewash is not loose, but is discoloured by smoke, it shall be treated by a wash of wood-ashes and water before whitewashing.

(v) When the whitewash and plaster are in a deteriorated condition of repair, they shall be either pulled down completely or cut in squares and new patches put in as directed by the Engineer-in-charge or his authorized subordinate. As soon as these patches dry up two extra coats of white-wash shall be given prior to the regular coat. The work of scraping old whitewash and deteriorated plaster and of repairing the plaster in whole or in patches is not included in the unit rate and hence shall be payable separately.

Preparation for Whitewash

2. Whitewash shall be prepared from pure fat lime brought to the site of work in an unslaked condition and in order to slake the lime water shall be added to it in a tub till the mixture attains the consistency of cream, and is allowed to rest for 24 to 48 hours. It shall then be strained through coarse cloth and 4 ounces of gum or rice dissolved in hot water shall be added to each cubic foot of it.

Application

3. (i) Whitewash shall be applied with a brush. Each coat shall consist of four strokes, one in each direction.

(ii) Each coat of whitewash shall be allowed to dry and inspected by the Engineer-in-charge or his authorized subordinate. The next coat shall not be applied unless the previous one has been approved by either of them. A dry coat must not show any sign of cracking, nor must whitewash come off readily on fingers when rubbed.

(iii) Whitewash, when completed, shall form an opaque coat of uniform white colour, through which the old work does not show and shall present a smooth regular surface free from powdery matter.

Measurements

4. Whitewashing shall be measured by superficial area. The unit of measurement shall be 100 square feet.

sub Para no. 4 amended vide A+C No. 2 of 17/8/69.

Rate

5. The unit rate shall include:—

(a) When only labour rate is to be paid.

(i) The preparation of surface and whitewashing as per above specifications.

(ii) The provision, erection and removal of scaffolding and ladders (shot with gunny bags at both ends to prevent damage to the floor and walls).

(iii) The protection of floor, fixed furniture, doors and windows, as well as all such places and things as are not to be whitewashed. These places and things shall be protected from all droppings and slashes of whitewash, if any, and cleaned.

(iv) Provision of all tools and brushes required for whitewashing.

(b) When rate for completed job is to be paid.

(i) All items mentioned in (a) above.

(ii) All materials required for the preparation of limewash as per above specifications.

NO. 25.10 COLOUR-WASHING

Specifications

Preparation

1. The surface to be colour-washed shall be prepared according to the Specifications No. 25.9. (i) for Whitewashing.

Preparation of Colour-wash

2. The colour-wash shall be prepared by adding the necessary colouring pigment to the whitewash which has been strained. The mixture shall be stirred thoroughly and passed through a clean, fine cloth. Only such quantity of wash shall be prepared as can be consumed in a day's work.

Application

3. (i) New or scraped surface shall be given a coat of whitewash, prior to colour-wash.

(ii) Old surface, when the colour-wash is satisfactory, shall be given only one new coat of colour-wash.

(iii) When replacing one colour with another of a lighter shade, the old colour shall be thoroughly scraped and a coat of whitewash given before the new colour is applied.

(iv) Each coat of colour-wash shall be allowed to dry and shall be inspected by the Engineer-in-charge or his authorized subordinate. The next coat shall not be applied unless the previous one has been approved by either of them.

(v) The completed wall shall be of a uniform colour, free from blots, lines or cut shades, and shall present a smooth regular surface which shall neither crack nor come off readily on fingures when rubbed.

(vi) Each room shall be finished in one operation and work shall not start in a room so late that it cannot be finished the same day.

Other Respects

4. In all other respects not specified here, it shall strictly conform to Specifications No. 25.9 for Whitewashing.

NO. 25.11 DISTEMPERING

Specifications

General

1. (i) Unless otherwise specified or directed in writing, a newly-plastered wall shall not be distempered earlier than 12 months after the plastering. If distempered earlier, the plaster shall be treated with damp-proof compounds.

(ii) Distempering shall not be done in damp weather nor when the weather is excessively hot and dry.

2. (i) Newly-plastered surface, when absolutely dry, shall be sand-papered to remove all irregularities, making good inequalities and holes with gypsum, which shall be allowed to set hard. Unless the surface is perfectly clean and smooth, no pleasing effect shall result from distemper. **Preparation of Surface**

(ii) Old plastered surfaces shall be thoroughly cleaned. If it is whitewashed or colour-washed, it shall be rubbed off with sand-paper or cocoanut fibre in case it is loose and then stopped and sized.

(iii) After rubbing and cleaning, all plastered surface, old or new, shall be sized with a coat of equal parts of size and alum dissolved in hot water. Decomposed size shall not be used under any circumstances. Where the makers of the distemper recommend a special priming coat, only that coat shall be applied.

(iv) If the existing surface is cleanly distempered all the distemper shall not necessarily be removed. The surface shall be smoothed down with glass paper and any firm distemper that remains on the wall after such rubbing shall be left.

3. (i) Unless otherwise specified ready-made distempers shall be obtained from the market as they are easily available. **Preparation of Distemper**

(ii) Distempers shall be mixed strictly in accordance with the maker's instructions or as directed by the Engineer-in-charge, and the quantity shall be just sufficient for the day's work.

4. (i) Distemper shall be applied only with proper brushes as supplied or recommended by the maker. The brushes shall be washed in hot water after work each day and hung up to dry. Old brushes caked with dry distemper shall not be allowed to be used on the work. **Application**

(ii) Distemper shall be applied quickly and boldly leaving no dry edges. The brush shall be dipped in distemper and stroked cross-wise on the wall, then immediately stroked up and down and stopped.

(iii) Unless otherwise specified or directed two men shall work on a wall together, one working from the ceiling downwards as far as he can reach and the other following him applying the distemper from below. No patchy overlap shall be allowed under any circumstances.

(iv) Unless otherwise specified, the following number of coats of distempers shall be applied:—

(a) On newly-plastered walls two coats over one coat of priming.

(b) On old-plastered walls covered with one or two coats of hard dry whitewash free from efflorescence or kalar, one coat without priming coat.

Measurements 5. In respect of measurement and rates it shall conform to Specifications No. 25.9 for Whitewashing.

WOOD WORK

Introduction

Definition

Wood work is the process of converting timber into a desired shape and erecting it into its final position. It is mostly carpenter's and joiner's work.

Carpenter's Work

Carpenter's work includes all work on timber used in roofs, floors, verandas, staircases, doors and windows, frames, bridges, centrings, shores, struts, large gates, and generally all wood work of which the scantling exceeds three-quarters of an inch, except in case of battens used in roof trellis-works which is specially moulded or carved.

When the thickness of carpenter's work does not exceed two inches but its width exceeds twice the thickness, it is called "planking".

Joiner's Work

Joiner's work includes furniture, doors and windows, turned and carved, or moulded work of all kinds.

Glossary of Terms

A glossary of terms usually employed in wood work is given below:—

Apron Lining — A board used to form a finish at the edges of the floor around a stair well.

Architrave — The trim to a door, window or other opening.

(*Note.*—Not to be confused with facing.)

Arris — A sharp external angle.

Back Lining — A thin member closing a jamb or head of a cased frame. (See figure 6)

Baluster — A vertical individual member of a balustrade. (See figure 8)

Balustrade — The infilling between a handrail and a string, landing or floor. (See figure 8)

Battened and Ledged Shutter — The assembly of this type of shutter is composed of vertically V-jointed, tongued and grooved battens tied together by a cross.

Battened, Ledged and Braced Shutter — Same as battened and ledged, but braced against sag.

Bead — A rounded moulding which may have one or two quirks.

Bead Butt — A panel, flush with the framing, finished with a bead on two opposite edges only. (See figure 4)

Bead Flush — A panel, flush with the framing, finished with a bead on all edges. (See figure 4)

Bed Mould — A moulding under a window beared or shelf.

Blockings — Pieces of timber fixed as stiffeners in the angles of casings, as in the heads of sash windows, stairs, etc. (See figures 5 and 8)

Bolection — A moulding raised above a surface.

Borrowed Light — A window in an internal wall or partition.

Bottom Rail — The horizontal bottom member of a door, casement or lower sash. (See figures 5 and 7)

Brackets — Short pieces of board fixed to the carriage of a stair to give additional support to the treads. (See figure 8)

Carriage — An inclined timber placed against the underside of steps to add support between the strings. (See figure 8)

Cased Frame — The hollow built-up frame of a sash window housing the counter balancing weights. (See figure 6)

Casement — The hinged light of a casement window. (See figure 7)

Casement Door — A hinged door, or a pair of doors, almost wholly glazed. (French door, French window, glazed door)

Casement Window — A window in which one or more lights are hinged to open. (See figure 7)

Chamfer — The surface produced by bevelling an edge or corner.

Clear Span — The distance between the walls on which roof is to be constructed.

Combed Joint — An angle joint formed by a series of tenons engaging in corresponding slot. (Corner locked, finger-joined, laminated). (See figure 2)

Core — The solid or skeleton structure of a flush door.

Cover Strip — A plain or moulded strip employed to conceal the joints of wall boards and the like.

Door — A hinged barrier to close entrance to a room, consisting of a frame and one or more shutters.

Dead Light — A light in which the glass is fixed direct into the framing. (See figure 7)

Door Frame — The surround, usually rebated, to a doorway in which the door is hung.

Door Lining — The plain or rebated surround to an internal doorway in which the door is hung, usually the full depth of the opening.

Dowel — A cylindrical piece of wood or metal used for fixing one piece of material to another. Wood dowels are sometimes grooved (keyed) to facilitate glueing.

Effective Span — The horizontal distance between the centres of the bearings in roofs.

Fanlight — A glazed light in the upper part of a door window frame.

Fillet —

(a) A narrow strip of wood; and

(b) A small moulding of a square section.

A non-opening sash or casement.	**Fixed Light**
A tread with parallel edges in the straight portion of a stair, as opposed to a winder.—(See figure 8)	**Filler**
A series of steps without change of direction. (See figure 8)	**Flight**
A flush shutter is one in which the shutter has a framed core covered on both sides with plywood or hardboard with or without edge cover strips (lipping). The shutter may be solid cored or skeleton framed (hollow cored).	**Flush**
A bead run on a flat surface and level with it. (*Note*:—Not to be confused with Bead Flush).	**Flush Bead**
A door with a surface in one plane on each face.	**Flush Door**
A pair of casements, usually with rebated meeting stiles, hung in a frame having no mullion.	**Folding Casements**
A pair of doors, usually with rebated meeting stiles, hung in a frame having no mullion.	**Folding Doors**
A frame fixed to the soffits of an opening on which the shutter hangs.	**Frame**
A rebated member dividing light into panes (Sash bar, astragal). (See figure 5)	**Glazing Bar**
A small wood strip of moulding employed as an alternative to putty to retain glass in a rebate.	**Glazing Bead**
See Blocking.	**Glue Blocks**
A continuous narrow sinking.	**Groove**
The sawn or wraught member on which another finishing, e.g. a skirting is fixed.	**Ground**
A semi-circular moulding.	**Half Round**
A platform on width equal to two flights.	**Half Space Landing**
A rail parallel with a string or landing.	**Handrail**
The horizontal tap member of a window frame, door frame or lining. (See figure 7)	**Head**
A small additional member applied to the head of a window frame to protect the casement below. (See figure 7)	**Head Weather Moulding**
The projecting end of one of the members of a right-angled framing joint. (See figure 5)	**Horn**
The inner member of a cased frame. (See figures 5 and 6)	**Inside Lining**
A vertical outer member of a window frame, door frame or lining. (See figure 7)	**Jamb**
A platform at the termination of a flight. (See figure 8)	**Landing**
One of a pair of doors or casements.	**Leaf**
A single glazed unit of a window, fixed or opening.	**Light**
A solid wood strip applied to the edge or edges of a flush door.	**Lip**

Lock Block A piece of solid material in flush door providing for installation of lock, latch set, aldrop, etc.

Mitre An angle joint between two members in which each is cut to a corresponding angle at their intersection.

Mortise or Mortice A hole or slot to receive a tenon or dowel of corresponding size. (See figure 2)

Mullion (a) A vertical member dividing the lights of a window frame. (See figure 7)

(b) A vertical member between the door and sidelight of a door frame.

Muntin The vertical member between the panels of a door. (See figure 4)

Newel The post supporting the edges of a string and handrail. (See figure 8)

Nosing The projecting edge of a tread or board, usually rounded. (See figure 8)

Outside Lining The outer member of a cased frame. (See figures 5 and 6)

Ovolo A convex moulding, usually with quirk. (See figure 3)

Panel The infilling to framing.

Panelled Door A door composed of a framed surround, divided into rectangular or other shaped spaces filled with panels usually of thinner material. (See figure 4)

Panelled Shutter A panelled shutter is one in which the shutter frame is grooved or rebated to receive wood panel in openings between framing members. The frame may be constructed with mortice and tenon joints.

Parting Bead A narrow strip or moulding fixed to the pulley stiles of cased frames to separate one sash from another. (See figure 6)

Parting Slip A narrow strip suspended inside a cased frame to keep the weights apart. (See figure 6)

Picture Rail A trim fixed to the walls of a room, from which picture etc. may be hung.

Pitch It is the ratio of the rise of the truss to its span.

Planted Stop A moulding or strip applied to plain frame or lining against which a door or casement is stopped.

Plug Pieces of sound wood, suitably shaped, used to plug the wood from which defective portion has been removed. (See figure 6)

Principal The wooden roof truss when used in buildings is sometimes termed as principals. Principals are spaced 6 feet to 12 feet depending upon their type, distance between the walls and their pitch.

Pulley Head A horizontal member at the head of a cased frame corresponding to a pulley stile. (See figures 5 and 6)

Quadrant A convex (quarter-round) moulding.

Quarter Space/ Landing A platform of width equal to one flight. (See figure 8)

Quirk A narrow groove or sinking at the side of a head. (See figure 3)

The timber that supports the roofing materials.	**Rafter**
A horizontal member of a casement or sash, such as top or bottom rail, or of a door, including top middle, lock, intermediate and bottom rails. (See figures 4, 5 and 7)	**Rail**
A horizontal member at the top of a lower or the bottom or an upper sash. (See figure 5)	**Meeting Rail**
A step shaped reduction formed on the edge of a member. (See figure 2)	**Rebate**
The vertical side of a recess.	**Reveal**
The finishing of a reveal.	**Reveal Lining**
The highest point or line of a roof where the two opposite slopes meet.	**Ridge**
Horizontal piece of timber forming the ridge.	**Ridge Board**
The vertical part of a step. (See figure 8)	**Riser**
A window in which the opening lights slide up and down in a frame. (See figure 5)	**Sash Window**
A concave moulding (Cavetto). (See figure 3)	**Scotia**
To shape the abutting end of a member to the profile of another.	**Scribe**
A glazed light at the side of a door frame.	**Sidelight**
The horizontal bottom member of a window or door frame. (See figures 5 and 7).	**Sill**
A deep bead fixed to the sill of a sash window to permit ventilation at the meeting rails (Draught Bead). (See figure 5)	**Sill Bead**
A small additional member fixed to the sill of a window frame as an alternative to a sub-sill. (See figure 7)	**Sill Drip Moulding**
A recess on a surface.	**Sinking**
The trim fixed to the walls of a room at the floor level.	**Skirting**
The horizontal or sloping underside of any recess or stair.	**Soffit**
The finishing of any soffit.	**Soffit Lining**
A frame rebated out of the solid.	**Solid Frame**
A rebate in a frame or lining against which a door or casement is stopped.	**Solid Stop**
A triangular space formed by contiguous members. (See figure 8)	**Spandrel or Spandril**
A chamfer fully extended across a surface.	**Splay**
A series of steps, with or without landings, including necessary hand-rails and balustrades and giving access from floor to floor. (See figure 8)	**Stairs**
A portion of a stair consisting of a tread and a riser. (See figure 8)	**Step**
A vertical outer member of a panelled door, casement and sash. (See figures 4, 5 and 7).	**Stile**
The stile of a door or casement to which hinges are fixed.	**Hanging Stile**
The abutting stiles of folding doors or casement.	**Meeting Stile**

String — An inclined board supporting the ends of steps. (See figure 8)

Close String — An outer string having its top and bottom edges parallel. (See figure 8)

Out String — An outer string with its upper edge out to the profile of the treads and risers (Open string). (See figure 8)

Outer String — The string on the side of a stair away from a wall. (See figure 8)

Wall String — The string on the side of a stair next to a wall. (See figure 8)

Shutter — The moveable screen mounted on the frame with hinge.

Sublight — The lowest light of a window, usually below a casement. (See figure 7)

Sub-sill — A subsidiary sill member fitted to a window frame after manufacture. (See figure 7)

Tenon — The end of a member shaped to fit a mortise. (See figure 2)

Tenon and Mortise Joint — A joint in which a rectangular projection, machined on one piece, fits into a similarly shaped recessed opening, machined in a second piece, secured under pressure with an adhesive. In a through mortise joint, the mortise and tenon extend through the full width of the stile. In the blind mortise joint, the mortise and tenon do not extend through the full width of a stile.

Abutting Tenons — Two tenons entering from opposite sides and abutting in the centre of a single mortise.

Haunched Tenon — A tenon in which a portion of its width is reduced to form a tongue. (See figure 2)

Lapped Tenon — Two tenons entering from opposite sides and lapping in a single mortise.

Sub-Tenon — A short tenon not extending through the thickness of a mortised piece.

Through Teno — A tenon extending through the thickness of a mortised piece.

Threshold — The horizontal sill-piece fixed to the floor in a door opening.

Throat — A groove formed to prevent capillary attraction. (See figure 5)

Tongue — A reduction formed by rebate on one or both faces at an edge or end of a timber to fit into correspondingly shaped groove. (See figure 2)

Cross Ton — A strip of timber with the grain not running in the direction of its length, or a strip of plywood, fitted into corresponding grooves in abutting members (loose tongue).

Transom —
(a) A horizontal member dividing the lights of a window frame. (See figure 7)
(b) The horizontal member, between the door and fanlight, of a door frame.

Tread — The horizontal part of a step. (See figure 8)

Trench — A groove or channel extending across a member.

Trim — A collective term for products of uniform profile manufactured by liner machining only, such as architraves, skirting, and picture rails.

Ventlight — A small opening in the upper light of a casement window, usually hinged at the top. (Ven sash, night vent, ventilator) (See figure 5)

Weathered — The term denoting the sloping upper surface of a member. (See figure 5)

Weather Moulding — A wood moulding fixed to the bottom rail of an external door to divert water from the sill or threshold (Weather board).

Wedge — A tapered piece of wood.

Winder — A tapering step in the turn of a stair. (See figure 8)

Window Bead — A small moulding planted round a cased frame to retain the inner sash. (See figure 5)

Window Board — A horizontal board fixed internally at the foot of window opening. (See figure 5)

Window Frame — The surrounding portion of a window containing sashes, casements or deadlights and in which the casements are hung or the sashes slide.

Winglight — See sidelight.

Wrot (Wrought) Timber — A piece of timber planed on one or more surfaces.

Doors

Wooden Doors and Windows

In modern buildings, wooden doors and windows are extensively used.

Doors consist of a frame and either one or two shutters hung to the frame by means of hinges. Doors with two leaves are known as hung folding or double-leafed doors and those with one leaf are known as single-leafed doors. Generally single-leafed doors are used in partitions and double-leafed doors in walls.

Sizes of Doors

Sizes of doors vary to suit the requirements, and no general rules specifying them can be laid down.

The over-all dimensions of doors are usually determined by making the width equal to the height minus 4 feet. In ordinary buildings, the minimum height of a door is 6 feet without fanlight, and 7 feet 6 inches with fanlight. The maximum is usually not more than 7 feet 6 inches without fanlight and 9 feet with fanlight. The frame of a door is made of timber scantling usually 3 inches by 4 inches for doors of normal sizes; it is suitably increased for bigger sizes.

The modern trend is to omit the wooden sill of a door frame, since it causes obstruction to movement of the people and the floors cannot be easily washed and cleaned. Sill is, however, a must where air-conditioning is to be done. The sill portion of the door, equal in width to the timber of the door frame, should be raised by 3/4 inch to 1 inch and the jamb and reveal portion of the sill sloped down on either side from it to meet the floor level as shown in figure No. 4. The bottom of the door shutter will thus remain 3/4 inch to 1 inch above the floor level and will not interfere with a carpet and at the same time facilitate cleaning and washing. A half an inch rebate equal in width to thickness of the shutter is provided on the sides of the frame to receive the shutter.

Location of Doors

The location of doors should make for the maximum use of accommodation in the room and privacy, without sacrificing convenience. As a rule, particularly in residential quarters, doors should not be located in the centre of room, but on one side of the room.

Types of Doors

The doors are generally of following types:

- Framed and panelled doors (glazed, partially glazed and unglazed).
- Ledged doors.
- Ledged and braced doors.
- Sash doors.
- Wire gauze doors.

Framed and Panelled Doors

The panelled doors consist of stiles, rails, muntins and panels as indicated in a typical design shown in figure No. 4. The door has framing which is grooved to receive panels of timber material. The number of panels may differ with the size of door and the taste of the people.

A few standard designs of interior as well as exterior doors in common use are shown in the figure Nos. 9 to 17. Selection of any particular design is a matter of personal choice to match the general appearance of the building. The usual sizes of this class of doors is 7 feet by 4 feet, 7 feet by 3 feet, 6 feet by 4 feet and so on. The thickness varies from 1½ inches to 2½ inches depending upon the strength required.

Ledged Doors

Ledged doors are the simplest form of doors. They consist of a number of vertical battens, planks fixed by nails, driven in from the face of the battens and fixed to the horizontal nails. The battens or planks are generally one inch thick and six inches wide and tongued and grooved with 'V' joint. The ledges are generally 1½ inches thick and are fixed over the battens which are cramped together to form the desired width of the door as shown in the figure No. 18.

Ledged and Braced Doors

The ledged and braced doors are fundamentally similar to the ledged doors described above but have additional cross braces to make these stiff. Diagramatically this type of doors has been shown in figure No. 19.

Braces are nearly of the same size as ledges and make them strong enough not to drop down. Care should, however, be exercised to see that the battens of the brace lie on the hinged side, i.e. supported side; otherwise they would be of little use. The usual method of putting braces is to fix the door with ledges, and then fit them along with the nails to the battens.

Sash Doors

In these types of doors the lower portion is panelled while the upper portion is arranged for glass panels for providing greater light, the stiles are of smaller thickness and are sometimes called diminished stiles.

Flush Doors

These doors have flush outside surfaces and are very popular as interior doors in all types of buildings. In some cases the flush door may have a glazed panel at the top to let more light in the room as shown in figure No. 20.

Wire Gauze Doors

These doors are commonly used for refreshment rooms, kitchens, larder cupboards, meat safes, etc., to keep out flies. The shutters which are hung to the frame by hinges consist of stiles and rails which are rebated on the inside to receive the wire gauze. The gauze is fixed in position by a bead bradded to the frame of the shutter. Where wire gauze shutters are used in combination with some other type of shutters, the latter are intended for security. These shutters are usually provided with an automatic closing arrangement in the form of a spring.

Windows

The construction of windows is very similar to that of doors. Their size and shape depend upon the size of the apartment.

Windows may be fitted with any one of the previously described type of shutters. Windows on the ground are usually iron barred. The bars are of about 1/2 inch to 5/8 inch diameter spaced at about 4 inches centre to centre.

Sills of windows may be at floor level or at any height above it. However, its height above floor ranges from 2 feet 6 inches to 3 feet 6 inches, if the window is of normal size. The bathroom windows have a height of 4 feet 6 inches to 5 feet for the sake of privacy. For protection against the sun and rain, windows are occasionally fitted with weather sheds or R.C.C. canopies. Windows have acquired different names according to their shapes or position in the building.

Location of Windows

The position of windows depends on the orientation of the building. An attempt is made to get the most of the effective light from the windows in the north wall because those in the south wall are subsidiary and are mainly for ventilation. The restorative and recuperative value of light is almost equal to that of fresh air and this should specially be borne in mind in the case of factories, workshops and schools. Full advantage must be taken of the sunshine which is of real value in ventilation because it sets up convective currents in the air. It is also a powerful disinfectant.

The sills of windows are kept 2 feet 6 inches to 3 feet 6 inches above the floor and the window extends nearly to the ceiling.

The area of windows and ventilators is preferably between 1/10 and 1/5 of the floor area of the room. The latter value is adopted for *chawls*, dormitories, factories, schools and hospitals. The former value is adopted for residential buildings, in which the floor space per capita is more.

Types of Windows

Windows are generally of the following types:

- Fast sheet window
- Pantry window
- Sash and Frame window
- Casement window
- French window
- Skylight window

Fast Sheet Window

Fast sheet or fixed sash window consists of two stiles, top and bottom, with intermediate bars, if the size of the glass sheet is small, or if a special type of ornamentation is required. The stiles head and stile are usually 3 inches by 2 inches as shown is figure No. 21.

The joint is generally tenon and mortise: the stile A is mortised to receive tenons on the top and bottom rails.

Pantry Window

The pantry window is a modification of the fast sheet window in as much as a pivoted sash is added to give ventilation. The joint on the stile is the same as described for the fast sheet windows. The moulding is removed above the transom to receive the pivoted sash, which is rebated on the top and bottom rails only, as shown in figure No. 22.

Sash and Frame Window

The sash and frame window has two sashes sliding vertically in a cased frame. The sashes are hung by means of cords, and are balanced by weights. These cords support the sashes and pass over pulleys. Figure No. 23 shows three views of the sash and frame. In this case the frame consists of 6 inches by 3 inches sill, 5½ inches by one inch pulley stile.

Casement Window

The sashes of casement window are hung. The casement window consists of a frame having two stiles, head, sill transom and mullion all of 5 inches by 3 inches timber. The casements are similar to the ordinary sash, all members are of 2 inches by 2 inches timber, except the bottom rail which are 2½ inches or 3 inches wide. The casements open outside, hence the top lights are hung on the top, as shown in figure No. 24.

When the casements open inwards, as shown in the vertical section of the figure, it is difficult to make the window watertight. This is avoided by providing weep holes in the sill.

French Window

This form of window has a combined door and window in it and is extensively used in wooden houses. If the doors open outwards, there is no difficulty in making it watertight. If the doors open inward, drainage water is always a source of trouble, For this reason a projecting metal bar is put in as a rebate, through which the water is made to seep out as shown in figure No. 25.

Skylight Window

A skylight is an opening in the roof itself for the provision of light. This is done when there is no other window or door for the lighting arrangement. The light runs parallel to the roof surface and is lifted above the slates by a cube of 9 inches by 1½ inches. This has been diagramatically shown in figure No. 26.

Three sides of the cubes are at right angles to the inclined roof, but generally the front is perpendicular. A gutter is formed at the back and on the side to drain off the rain water. The sash consists of two stiles and slopes, 5 inches by 2 inches, with one or more bars of the same thickness. The most of the area in the skylight is fitted with glass to provide for light.

Hold Fasts

Hold fasts consisting of an iron patti quarter of an inch thick, 1½ inch wide and 13½ inches long folded on both ends (as shown in figure 19) are quite necessary for the stability of doors and windows. They are fixed to the frame by means of wooden screws and the remaining portion is embedded or mortared in the masonry to keep the door or window in position. Generally four of them are required for doors having a sill and six for doors without a sill.

Wooden Stairs

Wooden stairs are lighter than those of any other material, and are very commonly used in dwelling houses. The main objection to their use is that if fire breaks out they are liable to catch fire quickly and thus may prevent escape from the upper floors. Teakwood of at least 2 inches finished thickness in all parts is, however, sufficiently fire-resisting to enable the occupants to escape within a reasonable time.

The steps of a wooden staircase are supported at each end, and frequently, at intermediate points, by sloping wooden members called string or pitching pieces. Strings are of four kinds: cut strings, housed strings rough, strings, and wreathed strings.

Cut Strings

In the case of cut strings their upper surface is notched to conform to the tread and riser of each step; their lower edge is parallel to the slope of the stair.

In all but the commonest work, the vertical portion of the notch is mitred. The end of the riser is also mitred and fits against it, thus concealing the end grain of the wood. This is only done to the outer string which, when treated like this, is called a cut and mitred string. Cut strings in newel stairs are mortised and tenoned into the newel posts at top and bottom. The thickness of an ordinary cut string is $1\frac{1}{2}$ inches to $2\frac{1}{2}$ inches.

Housed Strings

Also known as closed strings, housed strings have both their upper and lower edges parallel to the slope of the stairs. Grooves or housings are cut in their inner sides to receive the ends of the treads and risers.

The housings are sloped at the lower side of the tread and the inner side of the riser to receive wedges. The grooves are tapered to receive wedges for fixing the treads and risers firmly.

The head room on the top of steps is of hard wood. These hold the tread and riser firmly in position. Against walls, housed strings are mostly used. In this position they are called wall strings. Closed outer strings are often moulded and panelled to produce an architectural effect.

Rough Strings (or Carriage)

When the stair is so wide that the steps require an intermediate support, this is given by what are called rough strings. Rough strings also serve the purpose of supporting the laths (strips of wood on which plaster is applied) where the soffit of the stair is to be plastered. A rough string supporting a step is shown in the figure No. 27.

Wreathed Strings

Wreathed strings are required in the construction of wooden geometrical stairs. Steps of wooden stairs are formed of boards. The treads are usually $1\frac{1}{2}$ inch thick and risers 1 inch thick. The tread is made to project slightly (about $\frac{1}{4}$ to $\frac{1}{2}$ inch) beyond the face of the riser so as to increase the available width of the tread. This projection is known as nosing which is usually rounded off or otherwise finished with a moulding.

The methods of jointing together treads and risers are shown in figure 27 on the left hand side of the lower most step in the figure, the riser is jointed to the tread on its top by a tongue. Other methods of jointing risers to treads are given below: on the top of the riser fitting into a corresponding groove on the underside of the tread. (1) by an angle block in the corner between tread and riser. (2) by a 5/8 inchx1/8 inch scotia glued into a groove in the bottom of the nose of the tread. The riser of the step above it is tongued both at top and bottom into treads, besides there are angle block and scotia. Th riser of the top most step has its bottom housed into a groove on the top of the tread and is further strengthened by screws.

Winders

Winders are formed by cantilevering out the risers of substantial thickness from the staircase wall, and these are used to support the treads. The outer end of the cantilevered riser is housed into the newel post. The front end of the tread rests directly on the riser, while the rear end is fitted in a groove cut into the riser of the upper step.

Alternatively, winders may be supported by means of bearers built into the wall at one end and framed into the newel at the other. The back of the bearer is flush with that of the riser immediately over it. Cross bearers to support the treads are framed between the risers and the bearers behind them.

In a geometrical stair, the winders and bearers are framed into the wreathed string, and have cross bearers in the same way as for newel stairs.

Landing

In forming half-space landings, a trimmer is fixed across the width of the staircase. It supports the bridging joints which are tenoned into the trimmer at one end and are supported on the wall at the other. The trimmer also takes the ends of the carriages or string of the up-and-down flights, and the newel is notched over it.

In forming a quarter-space landing, the pitching piece is built at one end into the wall. At the other end it is housed into the newel which may either be hanging or supported on the floor. In the former case, the picthing piece is required to be designed as a cantilever, and may have to be strengthened by means of a bracket on the under side. The pitching piece supports the bridging joints for the landing.

In a variety of wooden stairs illustrated in figure No. 27 lime concrete is poured into the stair box erected in position, consisting of two cut strings on either side, boarding supported by a rough carriage at bottom, and risers fixed in their respective positions. When the concrete has set, the top is levelled, and boards are screwed to form treads.

All the details mentioned under wooden stairs can be seen in figure No. 27.

Wooden Roof

In modern buildings wooden roofs are built to lend a decorative architectural touch or in less important buildings like country houses, domestic dwellings and temporary structures. But in hilly areas where timber is locally available, the wooden roof is cheaper as well as beneficial for quick disposal of rain water and snow. It is thus generally used.

There are two types of wooden roofs in common use:—

Types of Wooden Roofs

- Simple roof
- Trussed or triple roof

Simple roofs consist of common rafters over a wall plate on either end, with or without purlins. These are generally boarded at the top. The double roofs consist of double system of timbering such as roofs with rafters and purlins, supported on walls. The trussed or triple roofs consist of common rafters, purlins, and trusses such as arched rib truss, king post roof truss, queen post truss, etc. The composite roofs are built of wood and steel combined; the members taking tension are made in steel while the others are of wood. Some of the important types of roofs are discussed below.

Simple Roofs

Among the simple types of roofs, some of the important ones are lean-to roof, couple roof, couple close roof and the collar roof. They have been shown in the figure No. 28.

LEAN-TO ROOF : This is the simplest form of roof. It is generally used in buildings attached to the main buildings, sheds or verandahs. Figure No. 29 shows size of the members and their method of joining up for a span of 8 feet. If the span is bigger purlins must be used. The overhang of the rafters is sometimes chiselled out, and a soffit is attached to it which can serve as a drain. The roof is attached to the wall by means of an iron corbel at regular intervals or by wooden wall plates 3 inches by 4 inches carried all along the wall in which the rafters come and fit as shown in figure No. 29.

COUPLE ROOF : This roof derives its name from the number of rafters used and are built for smaller spans. The two rafters are fixed at their ends to the wall by resting them on wall plates. The arrangement of the roof is very simple. Since the two rafters have a tendency to spread out and thrust out of the wall, this type of roof is not used for spans wider than 10 feet. The supporting walls should, therefore, be sufficiently strong. See figure No. 30.

The roof has a suitable covering and to keep the birds out and prevent the wind from coming in, the brickwork is carried up to the under side of the boards.

COUPLE CLOSE ROOF : This roof is similar to the couple roof, except for a tie member, which is fixed at the base of the two rafters to prevent them from spreading out. The tie serves a double purpose. It reduces the wall size and acts as ceiling joist. This type of roof can be used for span up to 16 feet. Sizes of members are given in the table below:

Clear span	Rafter size	Ridge board size	Ceiling joists size
8 feet	$3\frac{1}{2}'' \times 1\frac{1}{2}''$	$7'' \times 1\frac{1}{2}''$	$4'' \times 2''$
10 feet	$4'' \times 2\frac{1}{2}''$	$7'' \times 2''$	$5'' \times 2''$
12 feet	$4'' \times 2\frac{1}{2}''$	$7'' \times 2''$	$6'' \times 2''$
14 feet	$5'' \times 2\frac{1}{2}''$	$8'' \times 2''$	$8'' \times 2''$

COLLAR TIE ROOF: To economise in space and to increase height, rooms are sometimes partly formed in the roof. For such conditions, a collar tie roof is made. This is done by providing a collar joining the two rafters, fixed about half way up the slope of the rafters. It acts similar to the tie in couple close roof, i.e. checks the spreading of rafters. Sizes of various members are given in the following table:

Clear span	Rafter size	Ridge	Collar
8 feet	$4'' \times 2''$	$7'' \times 2''$	$3'' \times 2''$
10 feet	$4'' \times 2''$	$7'' \times 2''$	$4'' \times 2''$
12 feet	$4'' \times 2''$	$7'' \times 2''$	$4'' \times 2''$
14 feet	$5'' \times 2''$	$7'' \times 2''$	$5'' \times 2''$
16 feet	$5'' \times 2''$	$7'' \times 2''$	$5'' \times 2''$
18 feet	$6'' \times 2''$	$7'' \times 2''$	$6'' \times 2''$

Trussed Roofs

If spans exceed the limit prescribed for collar tie or other types mentioned above, it is desirable to have a trussed roof both in the interest of economy and strength. In this type stresses are taken up by the members and only vertical load is transmitted to the wall. This keeps the wall section within economical limits.

Trussed roofs, therefore, consist of members arranged in such a manner that the shape of the truss does not alter and no member takes up bending moment. These are arranged 10-12 feet centre to centre on the walls or else on a convenient distance which is determined by the distance of columns. The important type of truss which is generally used is the king post roof truss.

KING POST ROOF TRUSS: This type of roof truss derives its name from its vertical member, called king post. It can be used for spans up to 25-30 feet. Figure No. 31 shows the section of members for this type of truss with 20 feet span.

All the details and names of members have been given in the diagram. It would be seen that the principal rafter carries purlins which in turn carry the common rafter.

The covering of a suitable material is arranged over the common rafter. In this diagram one of the sides is projecting out i.e. has overhanging canes on one side and on the other a gutter has been provided on the side of the wall as shown in figure No. 32.

Some details of the joint at the head of the king post, and joint at the foot of the king post have been given in figure No. 33.

QUEEN POST ROOF TRUSS : Queen post roof truss may be used up to 45 feet span. A typical roof of this type has been shown in figure No. 34 for a span of 35 feet.

This roof has been prepared for slate tiles while for other covering the pitch can be suitably changed as shown in figure No. 35 below.

There are two vertical members called queen posts from which this truss derives its name. The members are joined at their ends by proper joints and steel stirrups. A straining sill is attached to spikes to the top of the tie beam to assist the queen post in resisting the thrust of the struts. A straining beam is used at the head of the queen posts to resist the thrust from the rafters as shown in figure No. 36.

NO. 26.1 WOOD WORK (GENERAL)

Specifications

Quality

1. Unless otherwise specified timber shall conform to Specifications No. 8.1 Schedule of Rates Vol. I, Part I (Specifications for Materials of Construction 1964) for timber. The Engineer-in-charge shall at his option inspect all logs or sleepers before they are used and may reject any he considers defective. Timber so rejected shall be removed at once from the site of work at the cost of contractor.

Finish

2. All wood work shall be neatly and truly finished to the exact dimensions specified.

Joints

3. Unless otherwise specified, all joints shall be simple tenon and mortise joints with the end of the tenon exposed to view. All mortise and tenon joints or scarfs shall fit truly and fully, without filling. Where specified, in the case of special high class joinery, the end of the tenon shall not show. Joints shall be painted with specified lead paint before the frames are put together. Glue shall not be used in joints which are exposed to weather, and in such exposed work any hard stopping shall be done with tight driven plugs.

Screws and Nails

4. All nails and screws shall be of an approved type. Holes of correct size shall be drilled before inserting screws. Hammer shall not be used at all for driving in or starting in the screws. All screws shall be dipped in oil before they are inserted in the wood. The heads of nails or screws shall be sunk and puttied or dealt with as directed by the Engineer-in-charge.

Wood to be covered in ground or in wall

5. The contractor shall give at least 7 days notice to the Engineer-in-charge in writing, when any timber is to be covered in the ground, or in the walls of a building, or otherwise. Failing this the Engineer-in-charge may order it to be uncovered at the contractor's expense, or measure and pay for only so much as is uncovered.

Fixing

6. All wood work shall be fixed in accordance with the drawings or the instructions of the Engineer-in-charge.

Workmanship

7. All workmanship shall be of the best type and all joints shall fit accurately without wedging or filling. After the wood work has been erected, the contractor shall, if any undue shrinkage or bad workmanship is discovered, forthwith correct the defect without any extra charge.

Bearing

8. All beams and girders shall be bedded on plates with not less than 9 inches bearing. All joists shall bear not less than 4½ inches on wall plates, and every purlin or batten supported on a wall shall have a bearing in the direction of its length equal to its own depth subject to a minimum of 4 inches.

Air Space

9. An air space of quarter of an inch shall be left along sides of battens and other wood work buried in masonry or brickwork.

Preservatives

10. All portions of timber built into or against or close to masonry or concrete, and all junctions or rafters, purlins, beams and wall plates shall be given two coats of hot solignum, creosote or other wood preservative approved by the Engineer-in-charge.

Planks

11. All scantling planks etc. shall be sawn straight and shall have uniform thickness. They shall be sawn in the direction of the grain and shall have full measurement from end to end. All planks and scantlings shall be sawn 1/16 inch in excess of actual measurement to allow planing. They shall be supplied with straight square edge, or rebated, ploughed, tongued or dwelled, as may be directed.

Chimney Flue

12. As a precaution against fire no wood work shall be fixed within 2 feet of the interior face of a chimney flue.

Deodar Wood

13. Unless otherwise specified the wood used in construction or joinery work shall be deodar, kail, chir or teak.

Responsibility of Contractor after Fixing

14. The contractor shall be responsible for the easing or otherwise of all doors etc. and the closing down of all open joints which may occur within six months of the completion of the work and which in the opinion of Engineer-in-charge required attention.

Measurements

15. The measurement of wood work or planking shall be the net measurement after fixing in position. No allowance is to be made for waste overlaps, rebates or the dimensions supplied beyond those specified. The length of each piece, however, shall be taken over all so as to include projection for tenons or scarfs. The unit of measurement shall be 100 square feet or 100 cubic feet as specified.

16. The unit rate for wood work shall include the cost of labour involved to carry out wood work according to above specifications, fixed in position and with the exposed arrises finished with a bead or bead and quirk as specified. The rate shall further include the cost of labour employed for following operations: **Labour Rate**

(1) Fixing all spikes, nails, screws, glue.
(2) Bevelled heading joints to boarding.
(3) Boring for bolts as required.
(4) Cleaning of wrought face.
(5) Cramping and wedging.
(6) Fixing with hardwood or male bamboo pins, nails, spikes, hoop iron and wire in any position.
(7) Halving, tabling, lapping, notching, framing, straight, splay, circular or birds-mouth cutting, splayed and bevelled ends, and mitres, fair or returned ends, as required.
(8) Punching and clenching nails.
(9) Treating plugs with wood preservative.
(10) All notchings, firrings, or squarings to ballies, necessary to obtain level bedding, boarding or fixings.
(11) Rebates and chambers to door and window frames where required.

The rebate shall further include the use of all tools, plant and scaffolding, staging and ladders, etc., where necessary.

Note.—Sometimes timber in the form of log or wrought (wholly or partially) is supplied to the contractor from the Government stores or from a dismantled building. In such cases the cost of timber so supplied shall be deducted from the cost of the finished work. Where the contractor's schedule contains no rate for similar materials the cost to be deducted shall be determined by a special agreement. A separate rate shall be required when the material thus supplied has to be reframed or refitted.

17. The unit rate shall include the cost of all materials supplied to the site of work in addition to the labour rate detailed in para 16 above. **Composite Rate**

NO. 26.2 DOORS AND WINDOWS (GENERAL)

Specifications

1. Unless otherwise specified timber shall conform to Specifications No. 8.1 Schedule of Rates Vol. I Part I (Specifications of Materials of Construction), 1964 for timber. **Quality**

2. Unless otherwise specified the workmanship for doors and windows shall conform to Specifications No. 26.1 for Wood Work (General) in all respects, except those specified hereunder. **Workmanship**

Size of Doors and Windows

3. The size of doors and windows shall be as specified.

Sections and Fittings

4. Unless otherwise specified or directed, the particulars and dimensions of chowkats for doors and windows together with their fittings and furniture shall be as given in the table No. 1.

Chowkat, Framing and Corners

5. Chowkats shall be properly framed and mortised together. Door and window chowkats shall have 4½ inches wide horns left on the heads (also on sills where these are provided) or the corners of the chowkats bound with 2¼ inches by 1/10 inch iron straps bent into a right angle having legs of a length equal to the depth of the chowkats, and fixed with four 2-inch screws. The cost of horns or straps is included in the rate. Unless otherwise specified, the latter method shall be adopted.

Rebates

6. Chowkats shall have a rebate cut to receive the leaves. The rebate shall be ½-inch deep and its width shall be equal to the thickness of the leaf. The other side shall be finished with a bead and quirk, or other simple moulding, unless wire gauze is to be fitted. Where the plaster butts against the chowkat ½-inch deep rebate with a slight cut back shall be given to serve as key to the plaster.

Position of Chowkats in Jambs

7. Unless otherwise specified, doors and windows opening to another room, to a corridor or varandah, shall have the chowkats so fixed that they project 3/8 of an inch from the plastered face of the wall.

The plaster shall stop against the chowkat which shall have the rebate mentioned in the above paragraph as key for the plaster.

Other doors and windows shall be set back 4½ inches from the face of the wall.

In the case of doors and windows in dhujji walls, the depth of the chowkat shall be equal to the thickness of the wall and the faces flush with the plaster.

Chowkat to be ready before starting Superstructure

8. No chowkat shall be painted or fixed before the Engineer-in-charge has inspected and approved it. All chowkats shall be ready before the work reaches the sill level so that they can be built in as brickwork or masonry proceeds.

Chowkat painting with Preservative

9. Before fixing, chowkat shall have the side in contact with the brickwork or masonry painted with two coats of hot solignum, creosote, coal tar or other wood preservatives approved by the Engineer-in-charge. If doors and windows are to be subsequently painted, the priming coat shall be painted on the chowkats before they are fixed.

Hold Fasts

10. Chowkats shall be secured to the brickwork or masonry by hold fasts which shall be built into the wall with specified mortar. Hold fasts shall be made 1½"×¼" flat steel patti bent over at both ends leaving 13¾" clear length between bends; one bend shall have two screwed holes to which the chowkat is secured by bolt ½ inch in diameter. The head of the bolt shall be sunk into the chowkats and the hole plugged with wood. Where the chowkat is fixed at the extreme edges of the jambs, the hold fasts shall be worked or bent as directed by the Engineer-in-charge. The number of hold fasts to each chowkat shall be as indicated in the table No. 1, with the exception that, where no sill has been provided, one additional hold fast shall be given on each

side. The feet of the chowkat shall, in this case, rest on the damp-proof course or floor, as the case may be.

Seasoning

11. All door and window leaves shall be cut out and framed together, as soon as possible after the commencement of the work, and stacked in the shade to season. They shall not be wedged and glued for four months where possible and where the contract time permits. If it is not possible, they shall be wedged and glued just prior to being hung. Before final gluing, all portions in which defects appear shall be replaced.

Method of Framing Leaves

12. All stiles and rails shall be properly and accurately mortised and tenoned. The thickness of the tenon shall not exceed one-fourth the thickness of the plank and the width shall not exceed five times the thickness. All rails over 7 inches in depth shall have double tenons. All tenons shall pass completely rough stiles and shall be secured by 3/8 inch hard wood or bamboo pins. All rails shall be haunched to the depth of groove for panels.

Gluing

13. All tenons at the final assembly of the doors shall be glued and wedged at top and bottom of the tenon with glued wedges. Immediately after gluing, the frames shall be tightly clamped and so left till the glue has set.

Hinges

14. Unless otherwise specified, leaves shall be hung on hinges of the size and the number specified in the table No. 1. These hinges are to be of an approved type and quality. They shall be counter sunk into the chowkat as well as in the leaf; the recesses being cut to the exact size and depth of the hinge, no subsequent packing shall be allowed. Two inch screws shall be used with 5 inches to 6 inches hinges and 1½ inches for smaller sizes.

Fitting

15. The contractor shall deposit in the office of the Engineer-in-charge one sample of each fitting to be used in the work. Unless otherwise specified, fittings shall be of the number, size and type given in table No. 1.

Special Door Furniture

16. The cost of fittings as indicated in the table is included in the rate. Where special ironmongery or door furniture is required, it shall be supplied by the department, or provided by the contractor at an extra cost. The cost of fixing or mounting such special furniture shall, however, be included in the rate. The cost of fittings mentioned in the table No. 1, but superseded by the special ones, and thus not actually supplied, shall be deducted from the sum paid for wood work.

Screws

17. Screws of such diameter shall be used as fill completely the holes and cups in the fittings which they secure, and shall be oiled before being inserted. Unless the head can be counter-sunk flush with the fittings, round headed screws shall be used. Brass fittings of specified type shall be secured with brass screws.

Chocks

18. Hinged chocks shall invariably be fitted to all doors and windows to keep them open. Chocks shall be of hardwood and swung on 3 inches butt hinges and shall act on a sheet metal protector fixed to the door stile.

Stops

19. Wooden stops of a size suitable for the leaf concerned shall be fixed to the door or window chowkats to prevent the leaf from damaging the plaster of the jamb when fully opened.

Measurements

20. The measurement of doors and windows shall be done by the superficial area of the clear opening in brickwork or masonry. In case of circular or other similar joinery, measurement shall be taken of the net area. In the absence of any special rate being paid, measurement shall be taken of the least squares or rectangles to contain the opening in question. In case of double doors the superficial area of chowkat shall be included in one door only.

Labour Rate

21. The unit rate shall include the cost of labour involved in making and erecting doors and windows of the specified sizes complete in all respects, with fitting and furniture according to above specifications in specified places.

The rate shall also include the use of ladders, supports, staging and scaffolding for excuting wood work according to above specifications.

The rate shall further include the cost of labour involved in applying two coats of wood preservatives on the chowkats.

Composite Rate

22. The unit rate shall include the cost of all materials supplied at site in addition to the labour rate detailed in para 21 above.

NO. 26.3 PANELLED AND GLAZED DOORS AND WINDOWS

Specifications

Design

1. Unless otherwise specified the panelled and glazed doors shall conform to the design shown in figure 1 to 7.

Dimensions

2. Unless otherwise specified the dimensions of doors and windows shall be as shown on the approved drawing.

Quality of Timber

3. Unless otherwise specified or directed by the Engineer-in-charge the wood shall conform to Specifications No. 8.1 Schedule of Rates Volumn 1, Part 1 (Specification for Materials of Construction 1964), for timber.

Door Frame

4.(a) The members shall be joined with close fitting mortise and tenon joints which shall be further pinned with corrosion-resisting metal pins of not less than 8 mm (5/16 inch) diameter or with hard wood pins whose diameter shall not be less than 10 mm (3/8 inch). The framing shall be such as to ensure complete rigidity throughout.

(b) The entire surface of frame coming in contact with masonry shall be treated with a preservative of an approved type and quality.

(c) The frame shall be fixed to the masonry with at least four hold fasts. Two additional hold fasts shall be used if the chowkat is without a sill.

5. The stiles and rails of the frame shall be mortised and tenoned together. The thickness of each tenon shall be approximately 1/3rd the thickness of the rail, and the width of each tenon shall not exceed 5 times its own thickness. **Shutter Frame**

Panel

6. (a) Panels shall be made of solid wood or hard board or water-resistant plywood having both sides properly finished. They shall be truly cut and framed into rebates to a depth not less than 3/8 inch. Their thickness shall not be less than 12 mm (½ inch); in case of plywood and hard board it shall not be less than 7.5 mm (5/16 inch). Panels shall be in one piece up to 12 inches clear in case of deodar and 18 inches clear in case of teak. In larger sizes they shall be jointed, but the joints shall be glued and dowelled together to prevent all possibilities of its opening out afterwards.

(b) Panels shall be absolutely smooth so that no marks are visible. Unless otherwise specified, panels shall be splayed and fielded on both sides and the arrises of the frame receiving the panels finished with a simple mould.

Sash Bars

7. Sash bars shall be of the same thickness on the leaf and shall be 1 inch to 1½ inch wide, according to the size of the doors, and shall be twice moulded and twice rebated and mitred on the outside. The size of the rebate shall be 3/8 inch x ½ inch to receive the glass and its fixing.

Glazing

8. All glazing shall be done in accordance with the Specifications No. 26.12 for glazing. If specified, the doors and windows of bedroom and bathroom shall be glazed with blind glass up to full eye level. The glass panels of appropriate sizes shall be fitted into (3/8 inch) rebates and shall be retained in position with a thin layer of putty which shall be covered with wood beading.

Measurements and Rate

9. In respect of measurement and rate, they shall conform to Specifications No. 26.2 for Wooden Doors and Windows (General).

NO. 26.4 FRAMED AND BRACED DOORS AND WINDOWS

Specifications

Frame of Leaf

1. Framed and braced doors shall consist of two stiles, three rails and two braces forming the frame of each leaf to which the battens (planks) shall be fixed. In case of windows there shall be two rails and one brace. In the case of doors opening outside, where it is necessary to admit light, the Engineer-in-charge may direct the addition of a frieze rail. In this case the space between the frieze rail and the top rail shall be glazed by the contractor without any extra charge.

Framing and Bracing

2. The framing shall be made with mortise and tenon joints as per Specifications No. 26.2. The top rail (or frieze rail when the door has been glazed) and the bottom rail as well as stiles shall be rebated to receive the battens. The exposed edges of stiles and rails shall be chamfered or stop chamfered. Unless otherwise specified framing and batten shall be of the sizes contained in table No. 1.

Battens 3. Battens shall butt into rebates in the top (or frieze) rail and the bottom rail and shall pass over the braces and the lock rail. Battens shall not be more than 5 inches wide and shall all be parallel and uniform in width. The joints shall be ploughed and tongued and finished with a bead and quirk on the outside. Battens shall be secured with two screws at each end and with one screw over each brace and the lock-rail.

Other Respects 4. In all other respects, a framed and braced door/window shall conform to Specifications No. 26.2 for Doors and Windows (General).

NO. 26.5 LEDGED AND BRACED DOORS AND WINDOWS

Specifications

Frame of Leaf 1. Ledged and braced door leaf shall be formed with battens secured to three ledges, with two braces between the ledges. Windows shall have only two ledges and one brace.

The top edges and ends of ledges and braces shall be chamfered. Battens (planks) shall have rebated joints finished with a "V" on one side and shall be of a uniform width of not more than 5 inches. The battens shall be screwed, with two screws at each end and one over each brace and the middle ledge. Unless otherwise specified the size of ledges, braces and battens shall be as given in table No. 1.

Double Leaves 2. In the case of double doors a 3"x 1" cover bar shall be screwed on to the edge of one leaf so as to make it a master leaf.

Hanging 3. The chowkat shall be rebated to a depth equal to the full thickness of the door, i.e. the battens plus ledges. The doors shall be hung with the battens inside and the ledges outside. Hinges shall be fixed to the ledges.

Other Respects 4. In all other respects it shall conform to Specifications No. 26.2 for Doors and Windows (General).

NO. 26.6 LEDGED DOORS AND WINDOWS

Specifications

Frame of Leaf 1. Ledged type also called country doors and windows, shall be formed by fixing battens on to three ledges. The battens shall be of uniform width, not more than 9 inches, and shall have rebated joints. Unless otherwise specified, the thickness of batten and the size of ledges shall be as specified in the table No. 1.

Erection 2. Country doors shall be hung on pivot with the battens outside and ledges inside.

3. In all other respects the ledged doors and windows shall conform to Specifications No. 26.5 for Ledged, Braced and Battened Doors. **Other Respects**

NO. 26.7 CLERESTORY WINDOWS

Specifications

1. Unless otherwise specified the chowkats of clerestory windows shall be so fixed as to project 3/8 inch from the inner face of the wall. **Chowkats**

2. Unless otherwise specified brass cleats of the slanting single button type approved by the Engineer-in-charge shall be fixed by two brass screws to the polished wooden teak blocks with chamfered edges. The wooden blocks shall be 2" × 3½" × ¾" and shall be firmly fixed to the wall by means of plugs and screws of an approved type. **Cleat**

3. The leaves shall be hung 1 inch off centre so as to make them self-closing. In order to open them, a cord (stout, non-twisting picture cord) shall be provided with a hard wood weight at one end (to keep the cord in position over the cleat). **Leaves**

4. In all other respects it shall conform to Specifications No. 26.3 for Glazed and Panelled Windows. **Other Respects**

NO. 26.8 WIRE GAUZED DOORS

Specifications

1. Unless otherwise specified leaves of wire gauze doors shall be made from deodar, irrespective of the wood used in making the chowkats or the other leaves hung from the same chowkat. **Material**

✓(2.) Wire gauzed doors shall normally be hung on the same chowkat as other doors, and the rate shall include the provision of extra depth in the chowkat to take the rebate for the wire gauze leaf. Where wire gauze doors are hung on a separate chowkat a special rate shall be settled. **Chowkat**

3. Unless otherwise specified, wire gauze shall be of best quality and uniformly woven wire webbing 12x12 meshes to the square inch made from 22 gauge galvanized iron wire. All wire gauze panels shall be in one piece, no joints being allowed in the gauze. **Wire Gauze**

4. Wire gauze shall be fixed to the frame of the leaf after being stretched from out to out of rebate and nailed down taut by nails spaced at not more than 2 inches and then fixed that by a fillet of 3/4 inch x 3/4 inch screwed into a rebate of that size. The screws shall not be less than 1½ inches in length, nor spaced further than 9 inches. All exposed arrises of the fillet shall be finished with a small neat mould. **Fixing**

Spring Hinges

5. Unless otherwise specified all wire gauze doors shall be hung on self-closing spring hinges which shall be of an approved quality.

Double Doors to Project

6. All double leaf wire gauze doors shall close with the meeting stiles butting against each other, a felt or niwar strip being fixed to one leaf to close the joint. The leaves shall close to such an extent that the junction projects from the face of the chowkat, the projection being one inch for each foot width of leaf. The top of the chowkat (and sill when it has been provided) shall be enlarged to a corresponding wedge shape, the cost of this being included in the rate.

Matching Inner Leaves

7. Unless otherwise specified, the width and position of lock and bottom rails on wire gauze doors shall be the same type as those of the other leaves hung on the same chowkat.

NO. 26.9 WIRE GAUZED WINDOWS

Specifications

1. Where moveable wire gauze flaps or leaves are provided to windows, Specifications No. 26.8 for Wire Gauzed Doors shall be followed with the following modifications.

2. Wire gauze windows shall not be provided with springs or spring hinges.

3. Double hung wire gauze windows shall close flush with the chowkat without the meeting stiles projecting in any way.

4. Unless otherwise specified wire gauzed windows shall open outwards and shall be provided with hinged chocks to keep them in the open position, and with stops to prevent damage to plaster.

NO. 26.10 WIRE GAUZED CLERESTORY WINDOWS

Specifications

1. Unless otherwise specified, wire gauzed leaves for clerestory windows shall be hung on a separate chowkat set back one inch from the outer face of the wall (the glazed window being fixed in a separate chowkat, flush with inner face). The leaf shall be hung from the top, so as to close by its own weight and shall swing outwards. In all other respects, the Specifications No. 26.9 for Wire Gauze Windows shall be followed.

2. The cost of the chowkat shall be included in the rate, the measurement being out to out of chowkat.

NO. 26.11 FIXED WIRE GAUZE

Specifications

Wire Gauze

1. Unless otherwise specified, the wire gauze shall be of an approved quality, uniformly woven, wire webbing of 12x12 meshes to a square inch made from 22 gauge galvanized iron wire. All panels shall be in one piece and no joints shall be allowed in the gauze.

Method of Fixing

2. Wire gauze shall be fixed to the outside of the chowkat. This shall be drawn taut to the full width of the chowkat and nailed down by nails spaced not more than 2 inches and a cover strip, ¾ inch in thickness and of the same width as the chowkat so as to seem a part of the chowkat, fixed all round with 1½-inch screws fixed not more than 9 inches apart.

Alternative Method

3. If specially required by the Engineer-in-charge, the wire gauze shall be fixed to the chowkat by a fillet, ¾ inch x ¾ inch, screwed into a rebate of the same size. The wire gauze shall be stretched taut and nailed down by nails spaced not more than 2 inches to the chowkat, and then the fillet screwed down with one-inch screws spaced not more than 9 inches apart.

Finishing Rate

4. Exposed arrises shall be finished with a small but neat mould in each case. The rate shall be the same for either method of fixing.

NO. 26.12 GLAZING

Specifications

Glass: Thickness and Quality

1. Unless otherwise sepecified, all glass shall be flat sheet glass of fine quality known in the trade as "seconds". Glass shall be of the following weights per square foot for the various sizes mentioned below:—

Not exceeding 12"x14" — 16 oz (about 1/14" thick)
Exceeding 12"x14" but not exceeding 24"x24"—21 oz (1/10" thick)
Exceeding 24"x24" but not exceeding 30"x30"—26 oz (1/9" thick)
Exceeding 30"x30" but not exceeding 36"x36"—32 oz (1/7" thick)
Exceeding 36"x36" plate glass— (1/4" thick)

Glass shall be free from specks, bubbles, distortion and flaws of every kind, and shall be properly cut to fit the rebates, so as to leave a uniform space of 1/16 inch all round the panes between the edge of the glass and the rebate.

Putty (method of preparing)

2. Putty shall be prepared from pure raw linseed oil and best whiting, specially dry and ground fine to pass a sieve of 45x45 meshes to a square inch. The two shall be well mixed by hand and kneaded into a stiff paste. It shall then be left for 12 hours

and worked up in small pieces till it becomes quite smooth. If the putty becomes dry, it shall be restored by heating and working it up again while hot. Where the rebate is small a little white lead shall be added in making the putty. Putty required for glazing large panes or for bedding plate glass shall be made with a mixture of linseed oil and tallow with whiting so as to make it pliable and capable of standing expansion of the panes. Where required, putty shall be coloured to match the wood work.

Painting or Priming Rebates

3. If rebates have not been painted, they shall be well primed with boiled linseed oil to prevent the wood from drawing oil out of the putty. Putty shall be painted at the same time and the same number of coats as wood work.

Fixing Glass With Putty

4. Each pane of glass shall then be bedded on a thin layer of putty called "back putty" and secured into position with proper glazing springs or nails. "Front putty" shall then be applied chamfered and finished off neatly so as to ensure that the depth of the putty is exactly equal to the rebate.

Fixing Glass With Wood Fillets

5. In the case of all panes exceeding 12 inches in width, front putty shall not be used but the glass secured with fillets of wood, without extra charge. The fillets shall be plain or moulded and of a size depending on the type of door being glazed. The glass shall be protected from contact with the wood by putty made with tallow to act as a cushsion.

Blind Glass

6. Where blind glass is fixed the frosted face shall be away from the putty.

Putty (Coming Off)

7. All glass that has been fixed by the contractor shall if it becomes loose during the period specified in the contract, be refixed and puttied by him at his own expense.

Cleaning and Finishing

8. No glazing shall be considered complete until all paint and other stains have been removed from the surface of the glass. Glass shall be cleaned and polished with pads of damp newspaper, and then with a clean dry soft cloth (unsized). Cleaning shall be done by two men working on opposite sides of the same pane at the same time. The contractor shall make good all glass broken by his workers while cleaning the glass. On completion of the work all doors and windows shall be cleaned, damaged putty or glazing repaired and the whole work left perfect with a workmanlike finish.

Measurements

9. In measuring glazier's work all fractional parts under half an inch shall be omitted, and all above that, taken as one inch. Curved or irregularly shaped pieces shall be measured as the least rectangle from which they can be cut. Measurement shall be made net, from inside to inside of rebate. The unit of measurement shall be one sqare foot.

Labour Rate

10. The unit rate shall include the cost of labour involved in carrying out glazing in accordance with above specifications. It shall also include provision of all tools and plant required for glazing. It shall further include provision and removal of all ladders, scaffoldings, staging and supports required for glazing.

Composite Rate

11. The unit rate shall include cost of all materials required for glazing supplied at site of work in addition to the labour rate detailed in para 10 above.

NO. 26.13 WOODEN FLOORS

Specifications

Floor Bearers: Ground Floors

1. In the case of ground floors, floor joists (bridging joists) shall rest on pillars, dwarf walls, rails or beams as may be specified.

The plinth under the flooring shall be excavated to the depth specified by the Engineer-in-charge and dressed level and rammed. If directed, a layer of lime concrete shall be laid as specified under "concrete", otherwise dwarf walls or pillars shall be built on a lime concrete foundation. The dimensions and spacing shall be as indicated in the drawings or otherwise directed by the Engineer-in-charge.

Floor Bearers: Suspended Floors

2. In the case of upper floors, the bridging joists shall rest on wall plates, beams, rails or on other joists as shown on the drawings, or otherwise directed by the Engineer-in-charge.

Floor Bearers: Material and Fixing

3. The timber for the floor joists shall be of the kind specified in accordance with the general specification for wood work. The full number of joists for each continuous floor shall be laid and dressed to one level and tested before flooring begins.

Preservatives

4. All joists, wall plates, bearers, and the underside of planking shall be given two coats of hot wood preservative such as solignum, creosote, or coal tar, as directed by the Engineer-in-charge. The rate does not include this work, and shall be paid for separately according to the rates for painting with these materials.

Boarding, Materials and Size

5. The boarding for the floor shall not be planed on the underside in the case of ground floor and suspended floors to be coiled. Unless otherwise specified or shown on the drawings, in the case of deodar, kail or chir-wood, the boards or battens shall be $1\frac{1}{2}$-inch thick, not more than 6 inches wide and not more than 10 feet long. In the case of teak they shall be 1 inch thick, 4 inches wide and as long as possible. No board shall be less than 6 feet long, the ends being truly squared up after any split portion has been sawn off. All boards shall be uniform and parallel in width, and of the same thickness.

Joints

6. The planks shall be planed true on one side (on both sides for unceiled upper floors) the edges to be planed, rebated or tongued and grooved, as directed by the Engineer-in-charge. Unless otherwise specified the edges shall be tongued and grooved, with concealed joints for teak wood floors, and rebated joints for other floors.

Planking (Method of Laying)

7. The outer lines of boarding shall be accurately fixed parallel and close to the wall. Each subsequent line shall have the side joints carefully jointed up, and shall then be cramped into position by floor cramps, and nailed or screwed as specified, so that the heads shall be sunk below the finished surface of floor, or otherwise fixed with "secret joints". The cramps shall not be removed until the nails or screws have been fixed. The ends of planks shall rest on the centre of a joist and the ends of no two adjacent planks shall be on the same joist. Paved floors shall be stopped under a brass strip screwed to wooden floors where the two meet.

Nails and Screws 8. Nails and screws shall be subject to the approval of the Engineer-in-charge and shall be in length at least twice the thickness of the plank, two being used at each end and one at every intermediate joist alternately on opposite sides of the plank. All screws shall be oiled before they are inserted.

Planing 9. After the floor has been laid, it shall be planed in both directions and made perfectly smooth. All depressions in the wood, nail holes and small defects of every kind, where permitted by the Engineer-in-charge to remain in the work, shall, unless otherwise specified, be filled with "Beaumontage" or stopped out wax conforming to Specifications No. 27.2

Measurements 10. The measurement of wood flooring shall be done by superficial area. The unit of measurement shall be 100 square feet.

Rate 11. The unit rate shall include the floor boarding laid and fixed in position and planed in both directions, provision of brass screws in the case of teak wood floor where concealed fixing is not employed. The operation like sand papering, oiling, waxing, staining or varnishing are not covered and shall be paid for separately. The unit rate does not include joists, wall plates, bearers, beams, rolled steel joists, rails, concrete or masonry pillars, and payment for these shall be made separately.

TABLE SHOWING SIZES OF CHOWKATS, FRAMES AND OTHER PARTS OF DOORS AND WINDOWS AS WELL AS THE NUMBER, SIZE AND TYPE OF FITTINGS INCLUDED IN THE RATE

Line No.	Particulars or type of doors and windows (a)	Size of chowkat	No. of hold fast (e)	Thickness of leaves	Width of styles rails ledges or braces (h)	Hinges No. and size	Bolts—Size, Number and Position: Top of master style	Bolts—Size, Number and Position: Batten of master style or bottom rail	Bolts—Size, Number and Position: Top of under style	Bolts—Size, Number and Position: Lock or freize rail	Handles (u)	Hinged chocks	Door stops	Line No.	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	GLAZED OR PARTLY GLAZED FRAMED DOORS														
	(Partly panelled or battened)														
1	Double upto 4'x7'	3"x4½"	4	1¾"	3½"	6—4"	1—9"	1—9"	1—9"	6"—p.	3—6"	2—4"	2—6"	1	
2	Double exceeding 4'x7' upto 5'x8'	3½"x4½"	6	2"	4"	6—5"	1—(0)	1—9"	1—(0)	8"—p.	3—8"	2—6"	2—8"	2	
3	Double exceeding 5'x8' ..	3½"x5"	6	2"	4½"	6—5"	1—(0)	1—12"	1—(0)	10"—p.	3—10"	2—9"	2—12"	3	
4	Single upto 3'x6½'	3"x4½"	4	1¾"	4"	3—5"	1—9"	1—9"	..	8"—q.	2—6"	1—4"	1—6"	4	
5	Single exceeding 3'x6½' ..	3"x4½"	4	2"	4½"	3—5"	1—(0)	1—9"	..	10"—q.	2—6"	1—6"	1—8"	5	
	FRAMED DOORS PANELLED OR BATTENED														
6	Double upto 4'x7'	3"x4½"	4	1¾"	4"	6—4"	2—9"	2—9"	2—9"	..	3—5"	2—4"	2—6"	6	
7	Double exceeding 4'x7' upto 5'x8' ..	3½"x4½"	6	2"	4½"	6—5"	2—(0)	2—9"	2—(0)	..	3—8"	2—6"	2—8"	7	
8	Double exceeding 5'x8' ..	3½"x5"	6	2"	5"	6—6"	2—(0)	2—12"	2—(0)	..	3—10"	2—8"	2—12"	8	
9	Single upto 3'x6½'	3"x4½"	4	1¾"	4"	3—5"	1—9"	1—9"	..	1—9"	2—6"	1—4"	1—6"	9	
10	Single exceeding 3'x6½'	3"x4½"	4	2"	4½"	3—5"	1—(0)	1—9"	..	1—9"	2—6"	1—6"	1—8"	10	
11	Garrage doors ..	(b)	—	2½" f.	6"	6—18"	..	..	..	14"—p.	(t)	(t)	..	11	
	LEDGED AND BRACED DOORS														
12	Double upto 4'x7'	5"x4½"	4	2½"g.	4"	6—8"(k)	1—9"	1—9"	1—9"	6"—p.	3—9"	2—4"	2—6"	12	
13	Double exceeding 4'x7' ..	3½"x4½"	6	2½"g.	..	6—10"(k)	1—12"	1—9"	1—12"	8"—p.	3—5"	2—4"	2—6"	13	
14	Single upto 3'x6½'	3"x4½"	4	2½"g.	4"	3—8"(k)	1—9"	1—9"	..	8"—q.	2—6"	1—4"	1—6"	14	
15	Single exceeding 3'x6½' ..	3"x4½"	6	2½"g.	4½"	3—10"(k)	1—12"	1—9"	..	8"—q.	2—6"	1—4"	1—6"	15	
	LEDGED DOORS AND COUNTRY DOORS														
16	Double all sizes ..	3½"x4½"	4	2½" g.	4"	6—8"(k)	1—(r)	..	..	1—(r)	..	..	..	16	
17	Single all sizes ..	3½"x4½"	4	2½"g.	4"	3—10"(k)	..	..	..	2—(r)	..	..	..	17	
	WIRE GAUZED DOORS														
18	Double upto 4'x7'	3"x5"(c)	..	1¾"	4"	4—5"(l)	1—9"	1—9"	..	..	2—8"	2—4"	..	18	
19	Double exceeding 4'x7' ..	3½"x5½"(c)	..	1¾"	4½"	6—5"(l.)	1—(0)	1—(0)	..	..	2—8"	2—5"	..	19	
20	Single upto 3'x6½'	3"x5"(c.)	..	1¾"	4"	2—5"(l.)	..	..	..	1—4"	1—8"	1—4"	..	20	
21	Single exceeding 3'x6½' ..	3½"x5½"(c)	..	1¾"	4½"	3—5"(l.)	..	..	..	1—4"	1—8"	1—5"	..	21	
	SWING DOORS ALL VARIETIES														
22	Size of leaf upto 3'x6½' (a) ..	3"x4½"	4	1¾"	4"	2—4"(m.)	..	..	..	..	..	..	..	22	
23	Size of leaf exceeding 3'x6½' (a) ..	3"x5"	6	1¾"	4½"	2—5"(m.)	..	..	..	..	..	..	..	23	
	WINDOWS														
24	Glazed double upto 3'x5' ..	3"x3½"	4	1½"	2¾"	4—4"	1—(0)	1—4"	1—(0)	..	2—5"	2—4"	2—5"	24	
25	Glazed double exceeding 3'x5' upto 4'x5' ..	3"x4"	4	1¾"	2¾"	4—4"	1—(0)	1—5"	1—(3)	..	2—6"	2—4"	2—5"	25	
26	Glazed double exceeding 4'x5' ..	3"x4½"	4	2"	3"	4—5"	1—(0)	1—9"	1—(0)	..	2—3"	2—5"	2—5"	26	
27	Glazed single upto 2'x5' ..	3"x3½"	4	1½"	3"	2—4"	1—(0)	1—4"	..	..	1—8"	1—4"	1—5"	27	
28	Glazed single exceeding 2'x5' ..	3"x4"	4	1¾"	3"	2—5"	1—(0)	1—6"	..	..	1—8"	1—4"	1—5"	28	
29	Fanlights ..	(d)	2	1½"	2½"x3"	2—4"	..	2—4"	..	..	1—8"	..	..	29	
30	Clerestory windows	3"x3"	2	1½"	3"	pivots	(s)	..	..	..	..	..	..	30	
31	Battened double all sizes ..	3"x4"	4	2½"g.	3"	2—8"(k)	..	..	..	1—(r)	..	..	..	31	
32	Battened single all sizes ..	3"x4"	4	3½"g.	3"	2—8"(k)	..	..	..	1—(r)	..	..	..	32	
33	Wire gauzed upto 2'x5' (a) ..	3"x4½"(c)	..	1½"	3"	2—4"	1—(0)	1—4"	..	..	..	..	..	33	
34	Wire gauzed exceeding 2'x5' (a)	3"x5"	..	1½"	3½"	2—4"	1—(0)	1—4"	..	..	..	..	..	34	
35	Wire gauzed shutters to C. S. windows ..	2"x2½"	..	1½"	2½"	2—4"	..	2—3"	..	..	1—4"	..	..	35	

Remarks (column 16):

a. Dimensions given are out to out of the chowkat containing the leaves except where marked (a) where the dimensions of each leaf is given.

b. No chowkat doors will fit into rebate in the walls and lintel.

c. Dimension given is for a chowkat carrying two sets of leaves.

d. Chowkat to be the same as for main door or window.

e. Number to be increased by 2: if there is no sill.

f. 1½-inch deodar ledges and braces and, 1 inch battens.

g. 1½-inch ledges and braces, 1 inch battens.

h. (i) Meeting styles may be 3 quarter of the dimensions given.

(ii) For doors upto 7', 8' and above 8' in height, the lock-rails should be 6", 7" and 8" wide, respectively and the bottom rails 8", 9" and 10" wide respectively.

i. Strap hinges hung on 1 inch diameter pintles fixed to hold fasts which are embedded in cement concrete blocks let into the wall.

k. Cross garnet or "T" hinges—Dimension given is the length of the strap.

l. Single acting spring hinges.

m. Two double action spring hinges per leaf; no blanks.

o. Length to be such that the bolt is 6 feet 3 inches from the floor.

p. Black japanned wrought steel safety hasp (strap covering up fixing screws).

q. Galvanized iron safety door bolt with staple for padlock.

r. Good quality galvanized iron or japanned chain and staple.

s. Non-twist coloured cord with wooden weight: also brass cleat on wooden shield fixed to the wall.

t. Two 24" tower bolts fitted to the bottom of styles and working in eyes fixed to door stops, fixed in the floor.

u. Handles to be of best pressed steel, black japanned. Dimensions given are overall.

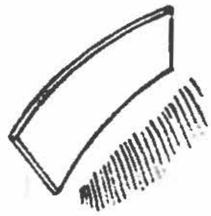
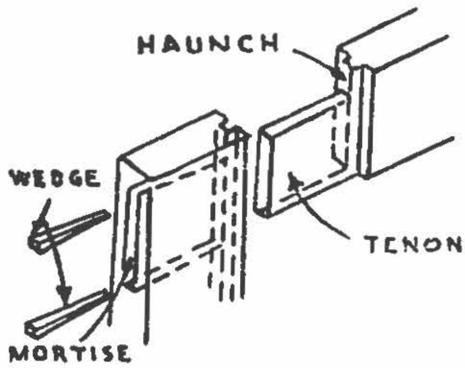
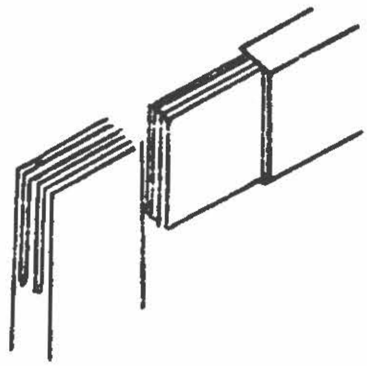


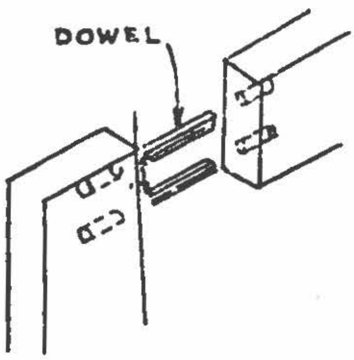
FIG NO 1 SPRING



MORTISE AND TENON JOINT



COMBED JOINT



DOWEL JOINT

FIG No 2

TON-GUED AND GROOVED JOINT.

FIG No 3 MOULDING

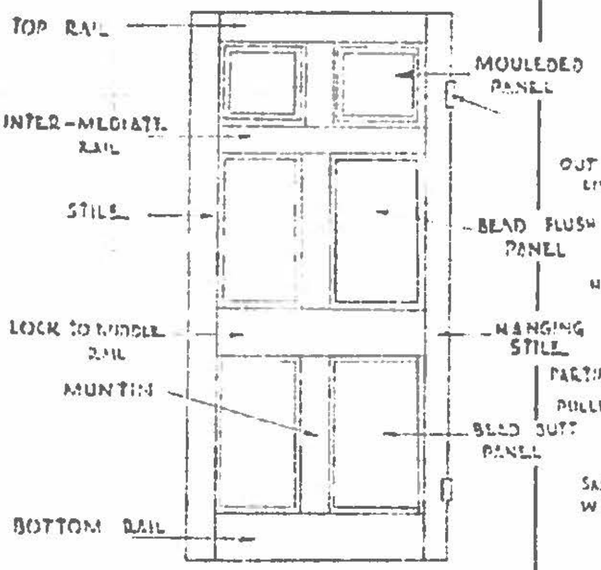


FIG NO 4 PANELLED DOOR

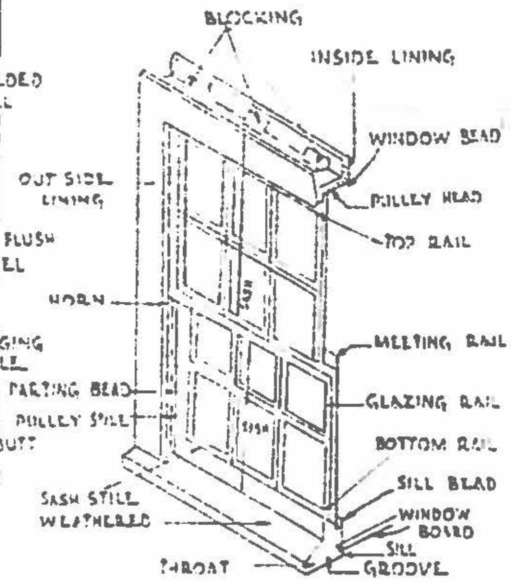


FIG No 5 SASH WINDOW

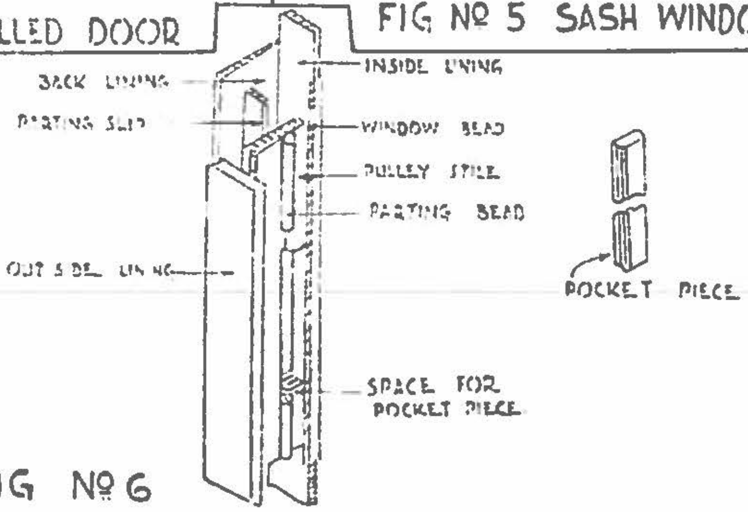


FIG No 6

DETAILS OF CASED FRAME OF A SASH WINDOW

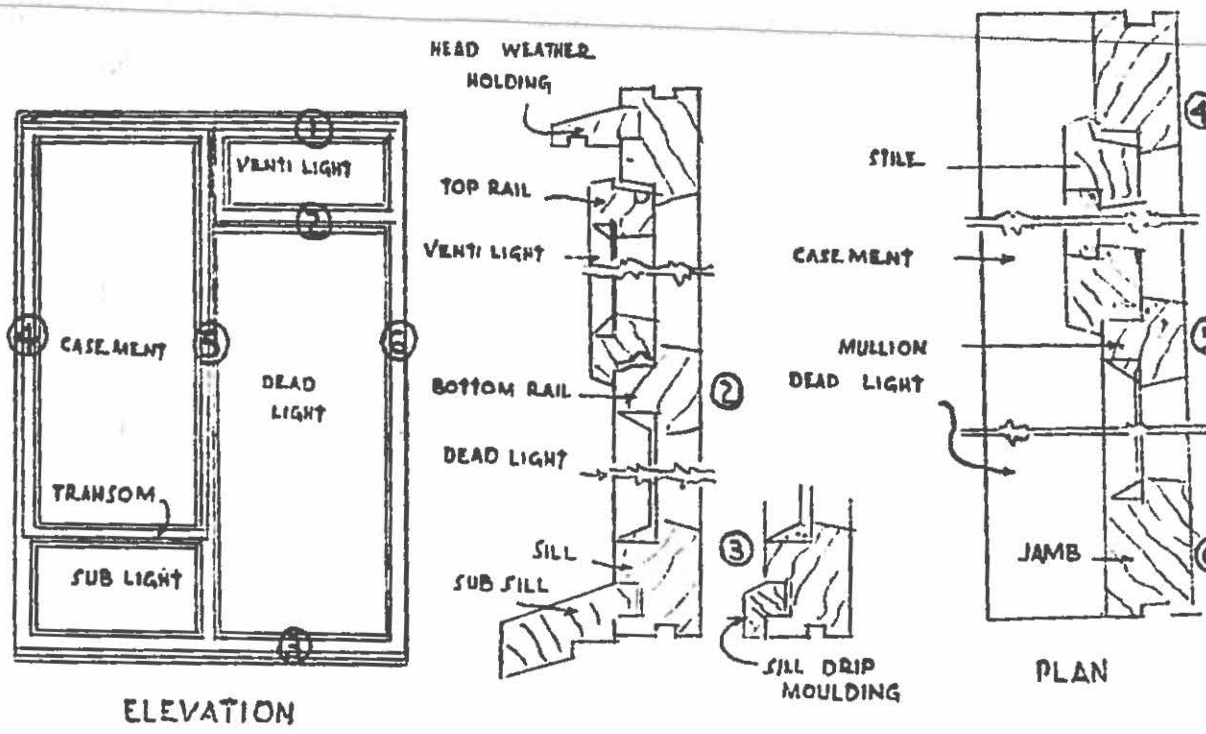


FIG No 7 CASEMENT WINDOW

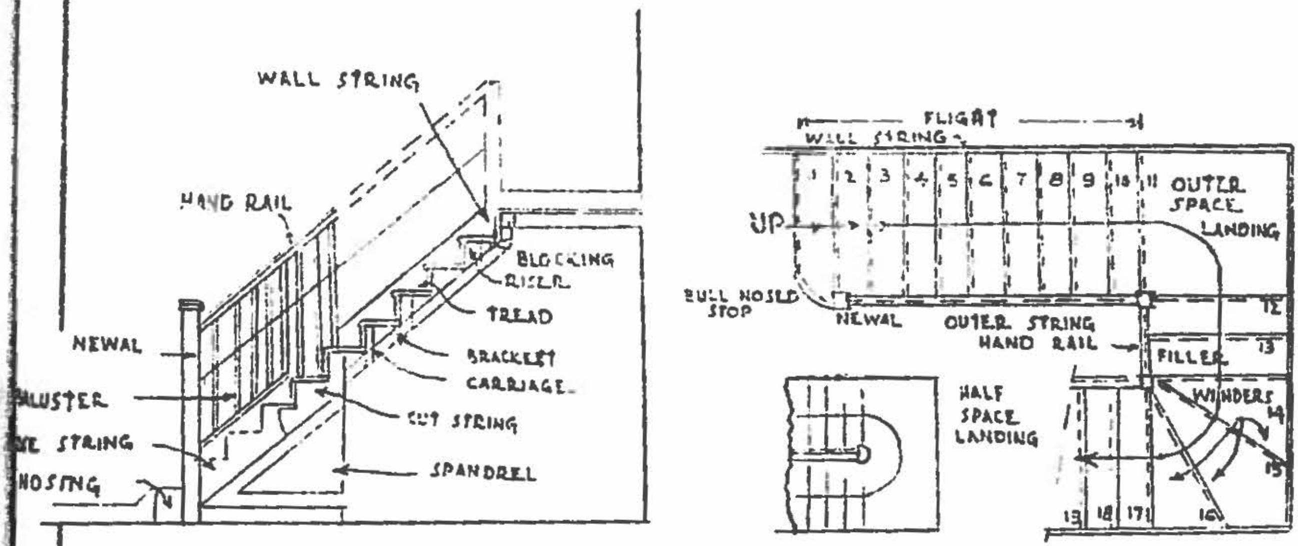


FIG No 8 STAIR

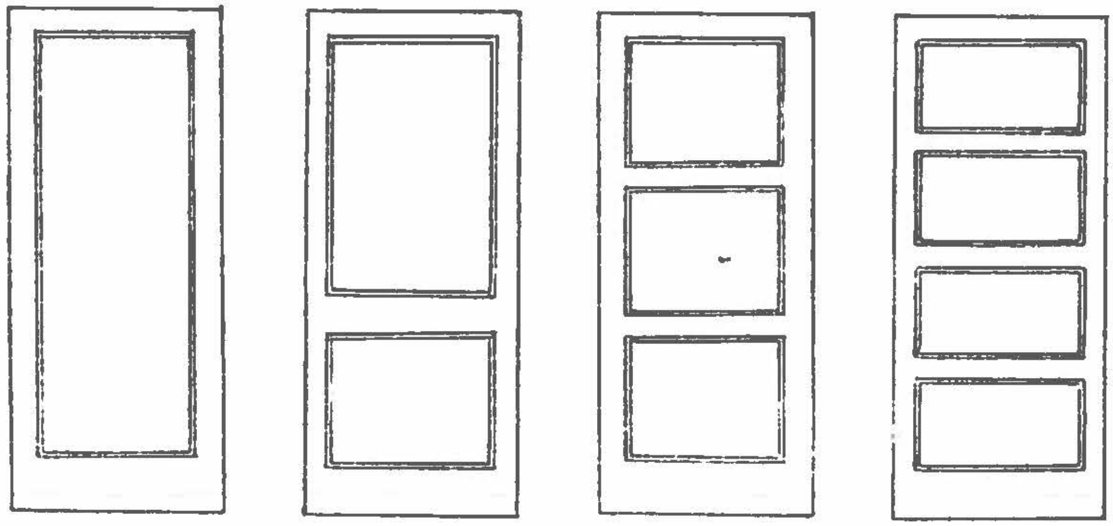


FIG. No 9. STANDARD WOOD PANELLED DOERS INTERIOR DOORS UNGLAZED

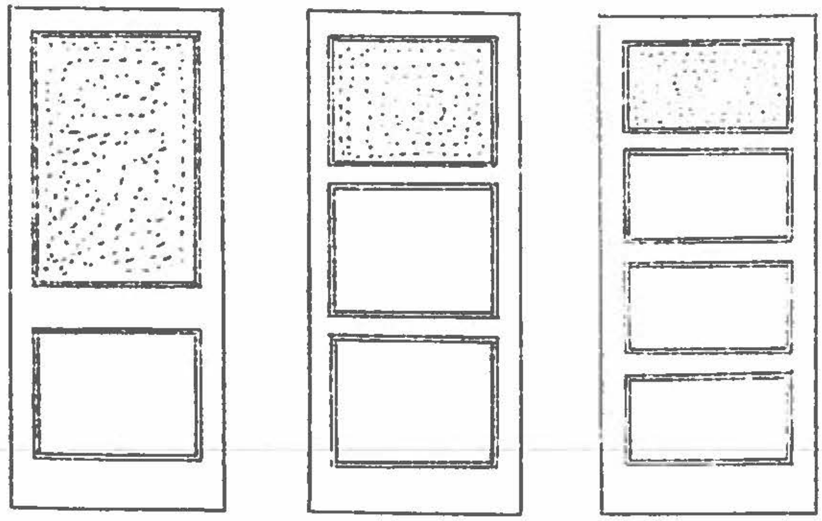


FIG. 10. STANDARD WOOD PANELLED DOORS
INTERIOR DOORS, GLAZED (GLAZING BEADS INCLUDED)

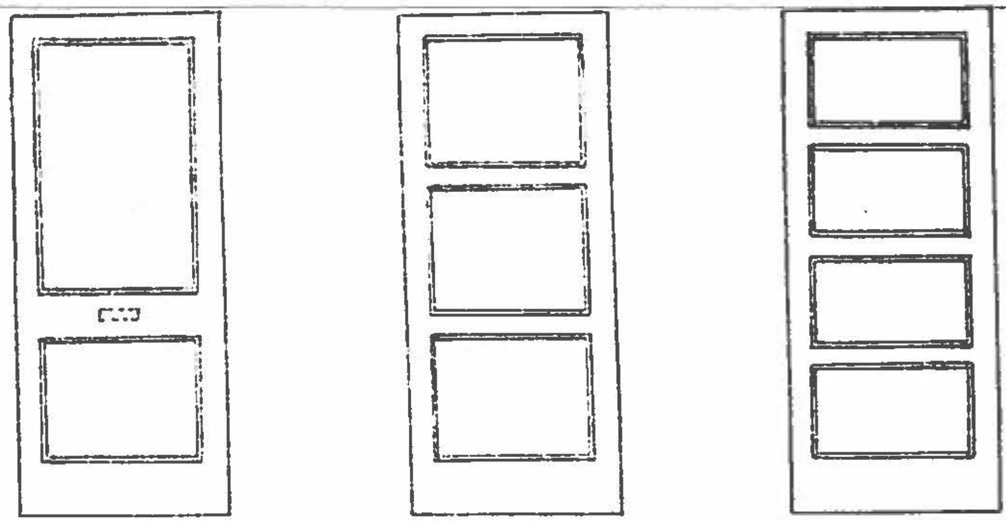


FIG 11 STANDARD WOOD PANELLED DOORS

EXTERIOR DOORS, UNGLAZED.

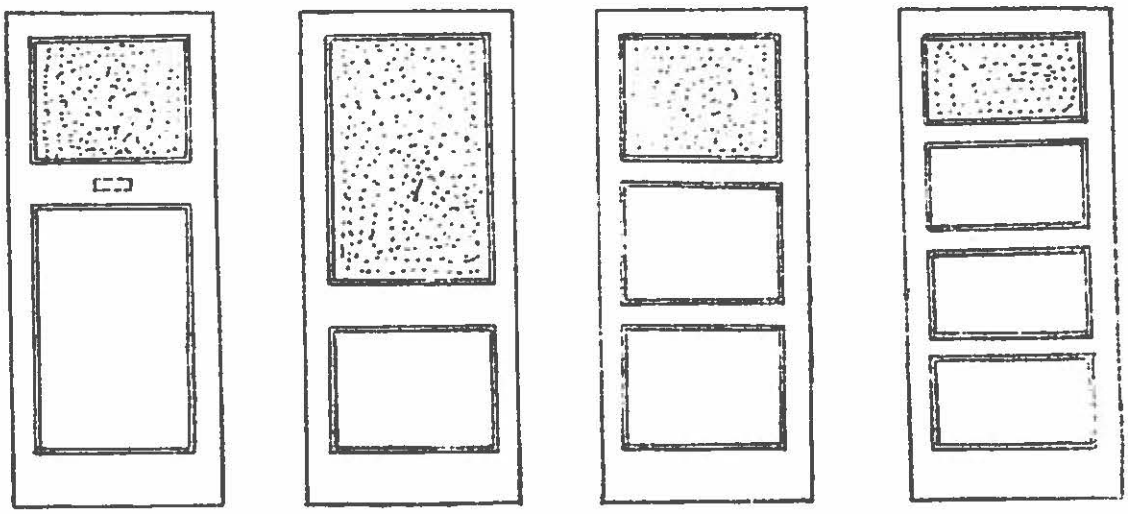


FIG 12 STANDARD WOOD PANELLED DOORS, EXTERIOR DOORS GLAZED.

(GLAZING BEADS INCLUDED)

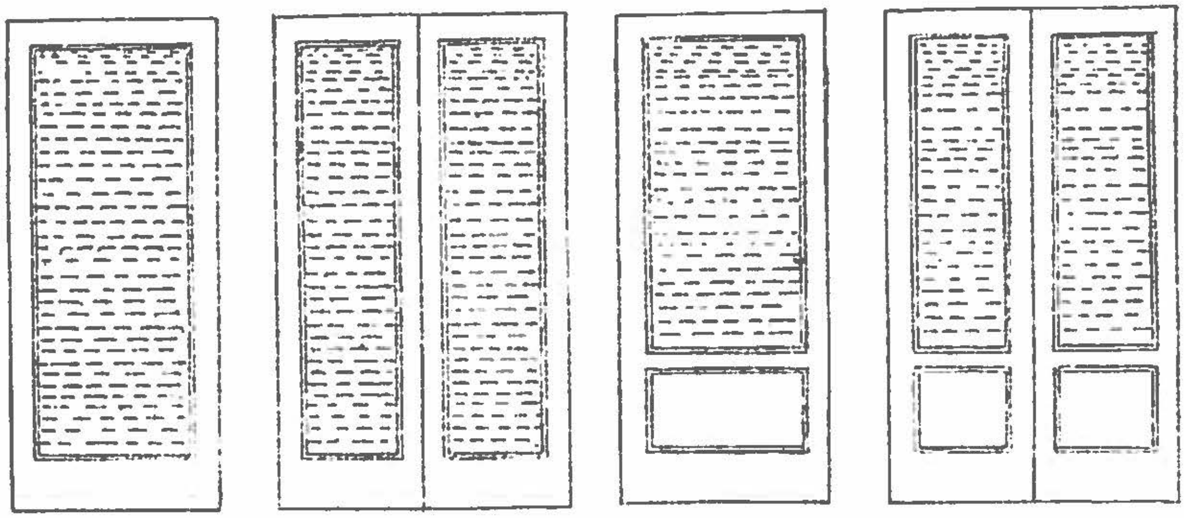


FIG 13 STANDARD GLAZED DOORS
EXTERIOR DOORS, No BARS.

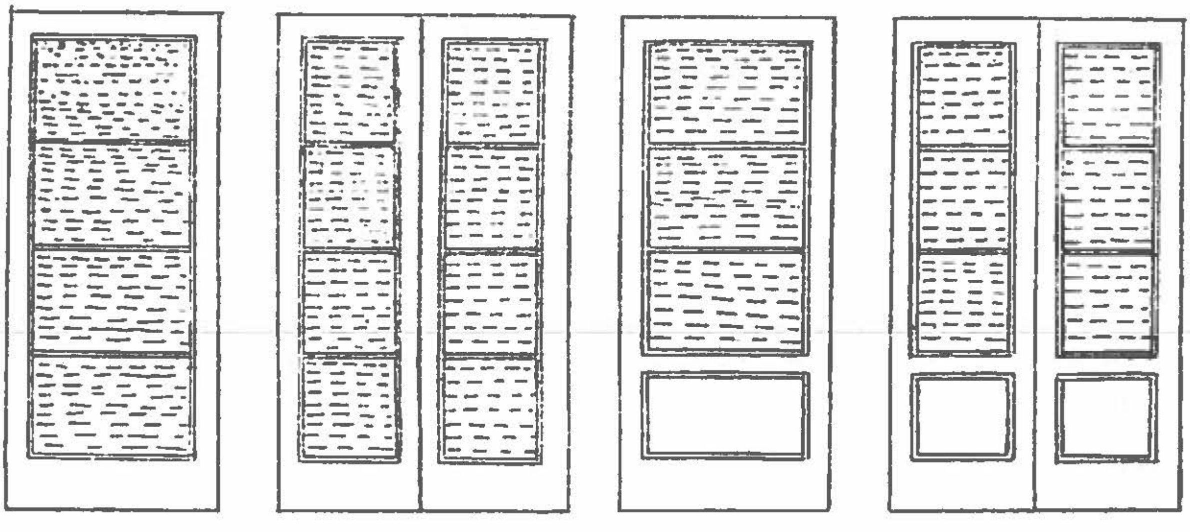


FIG 14. STANDARD GLAZED DOOR.
EXTERIOR DOORS. BARS

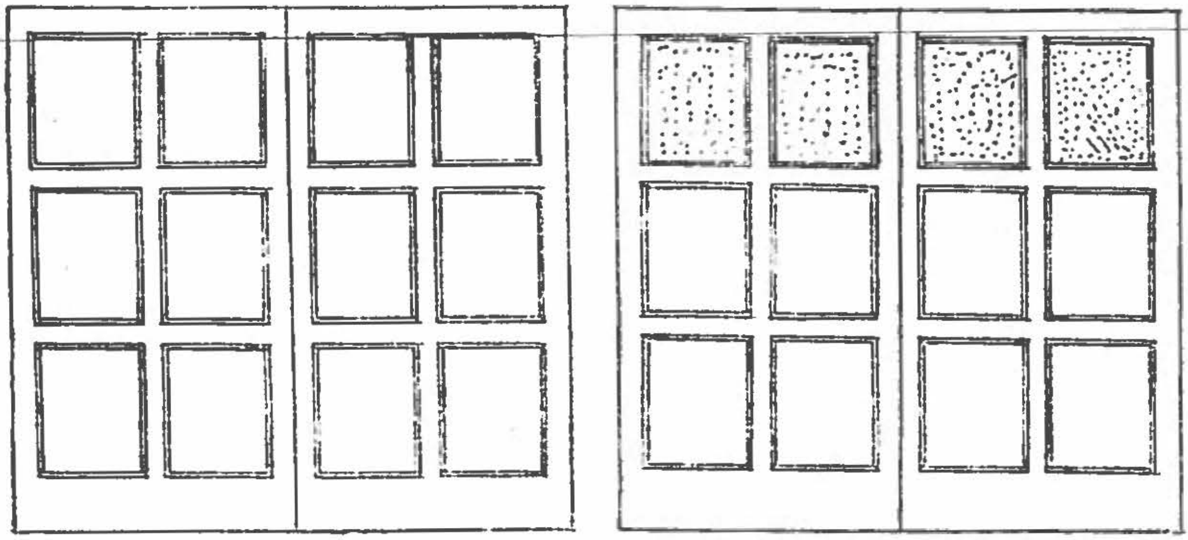


FIG. 15 STANDARD GARAGE EXTERIOR DOORS, UNGLAZED AND GLAZED.

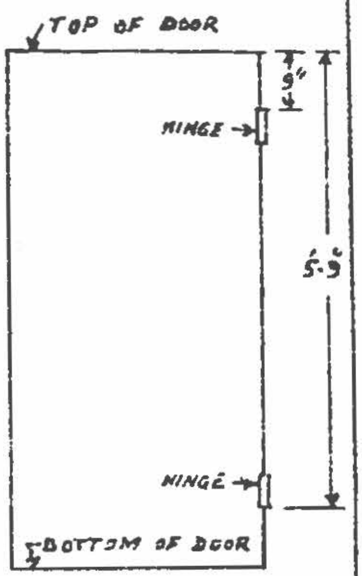


FIG. 16 STANDARD POSITION FOR HINGES

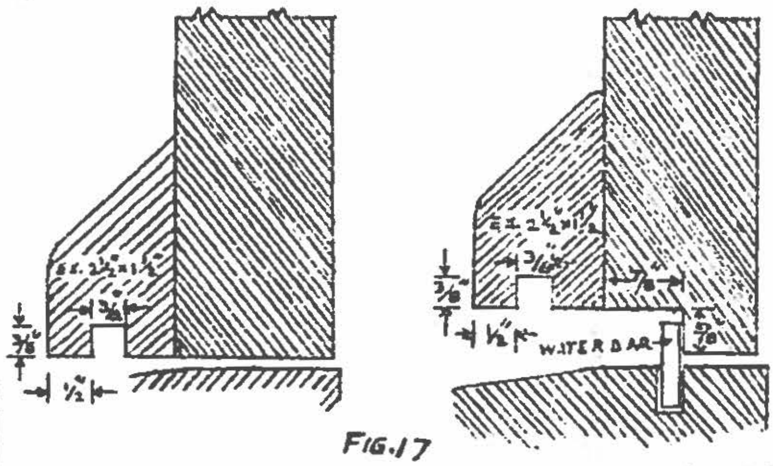


FIG. 17

TYPICAL POSITION WHERE DOOR NOT REBATED

TYPICAL POSITION WHERE DOOR REBATED

WEATHER MOULDING TO EXTERIOR DOORS.

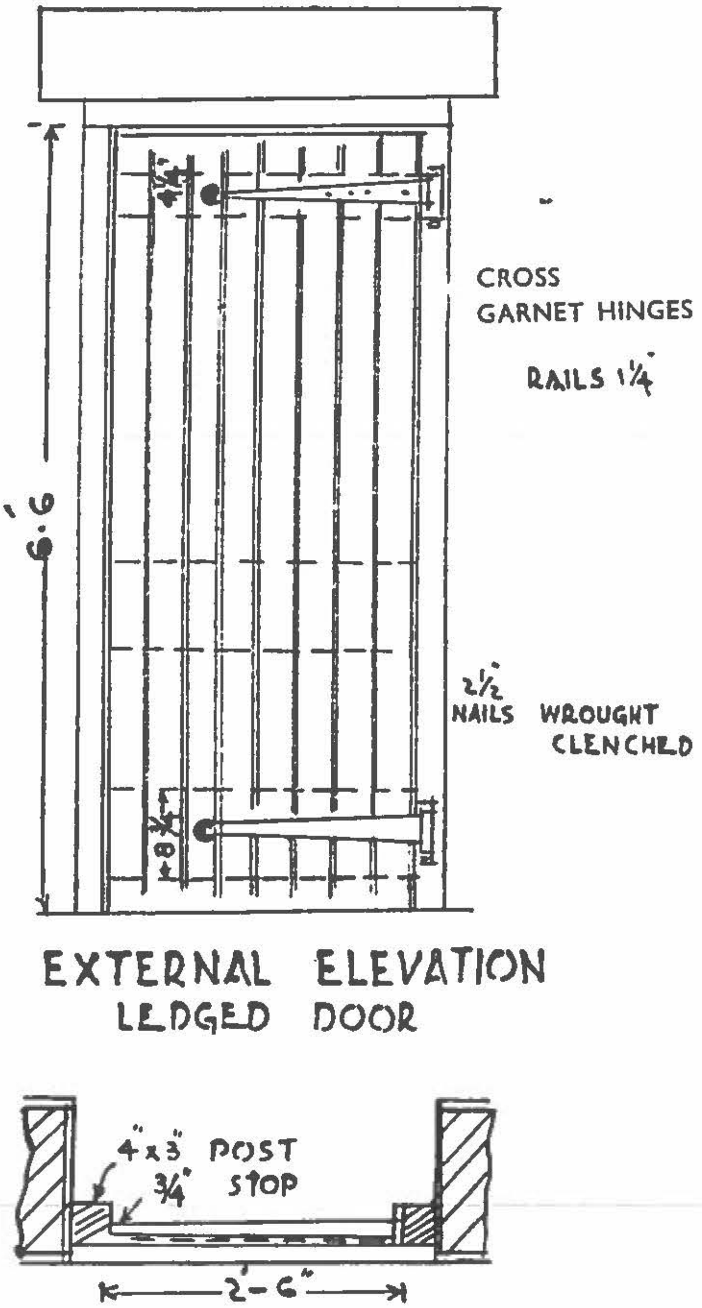

CROSS
GARNET HINGES
RAILS 1¼"
2½" NAILS WROUGHT CLENCHED
6.6'
8½"
EXTERNAL ELEVATION
LEDGED DOOR
4"x3" POST
¾" STOP
2'-6"

FIG No 18

EXTERNAL ELEVATION
LEDGED AND BRACED

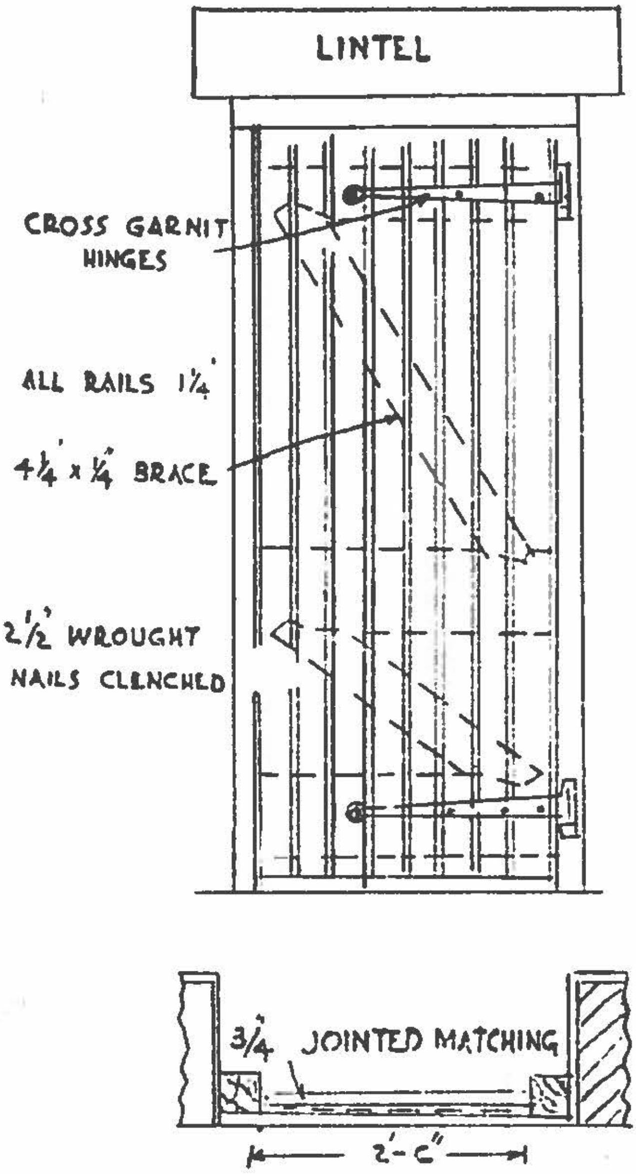


FIG Nº 19

HOLD FASTS

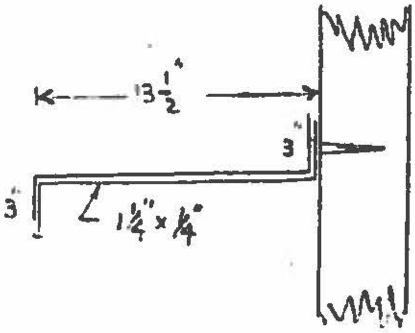


FIG Nº 19A

FLUSH DOOR

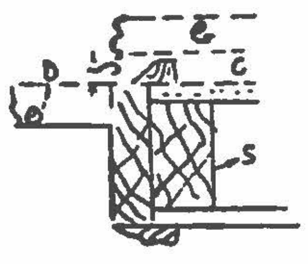


FIG No 20

FAST SHEETS WINDOW

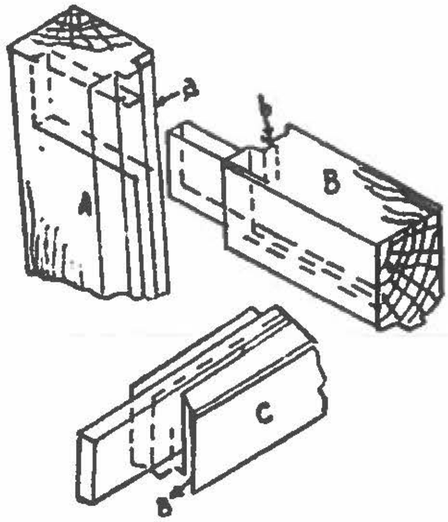


FIG No 21

PANTRY WINDOW

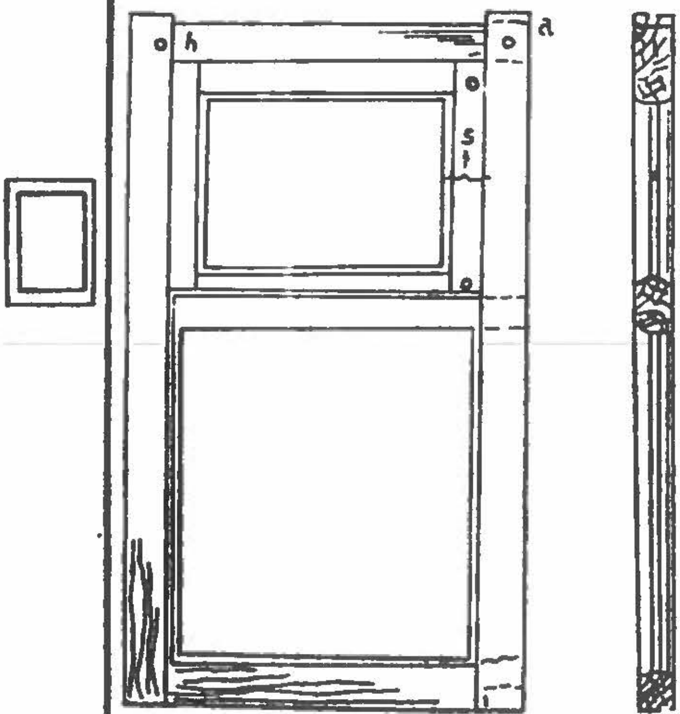


FIG No 22

SASH & FRAME WINDOW

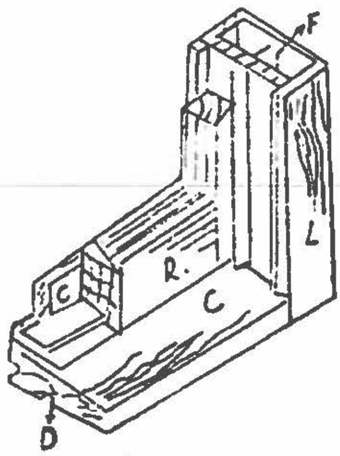
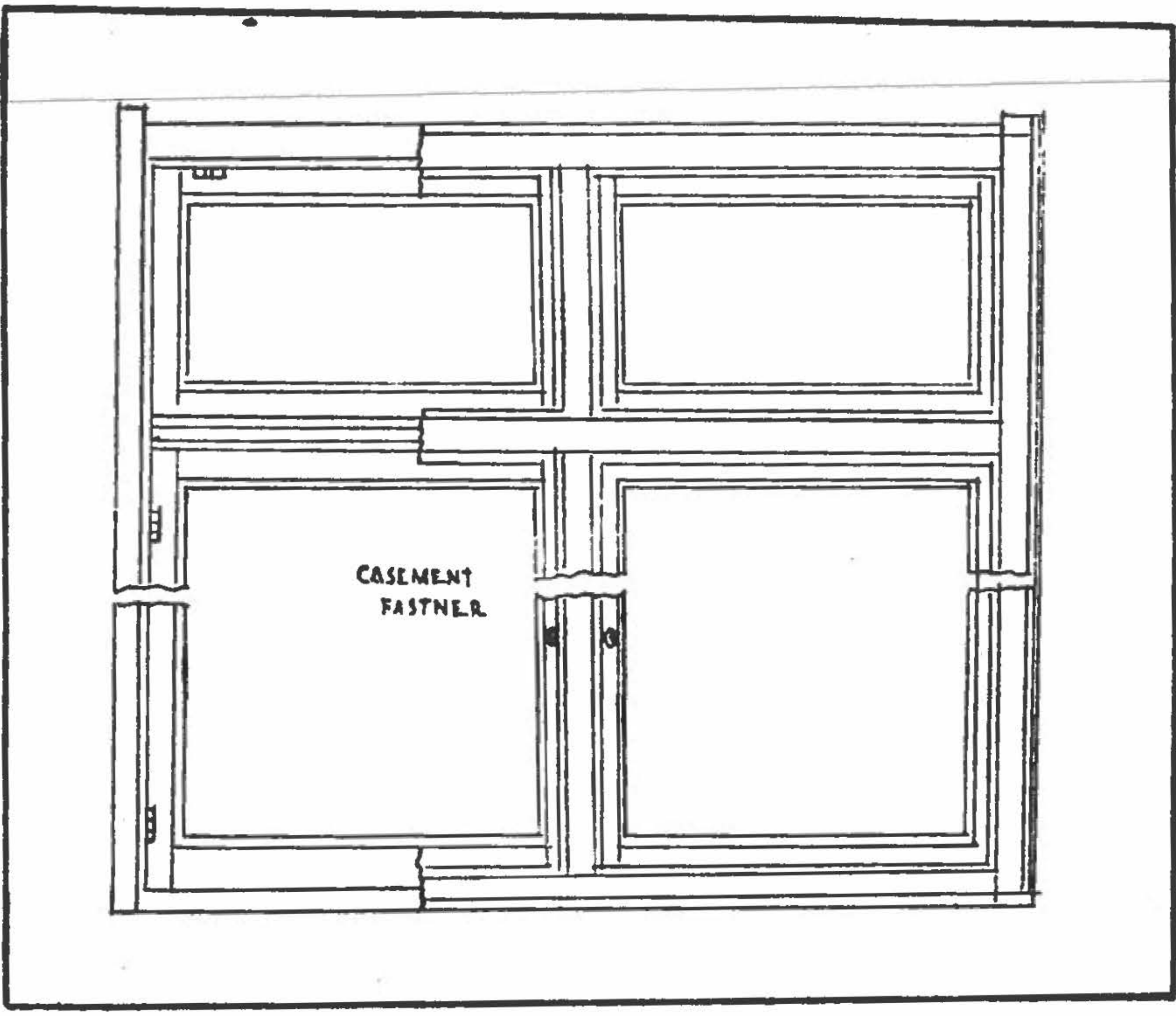


FIG No 23



CASEMENT WINDOW

FIG Nº 24

FRENCH WINDOW

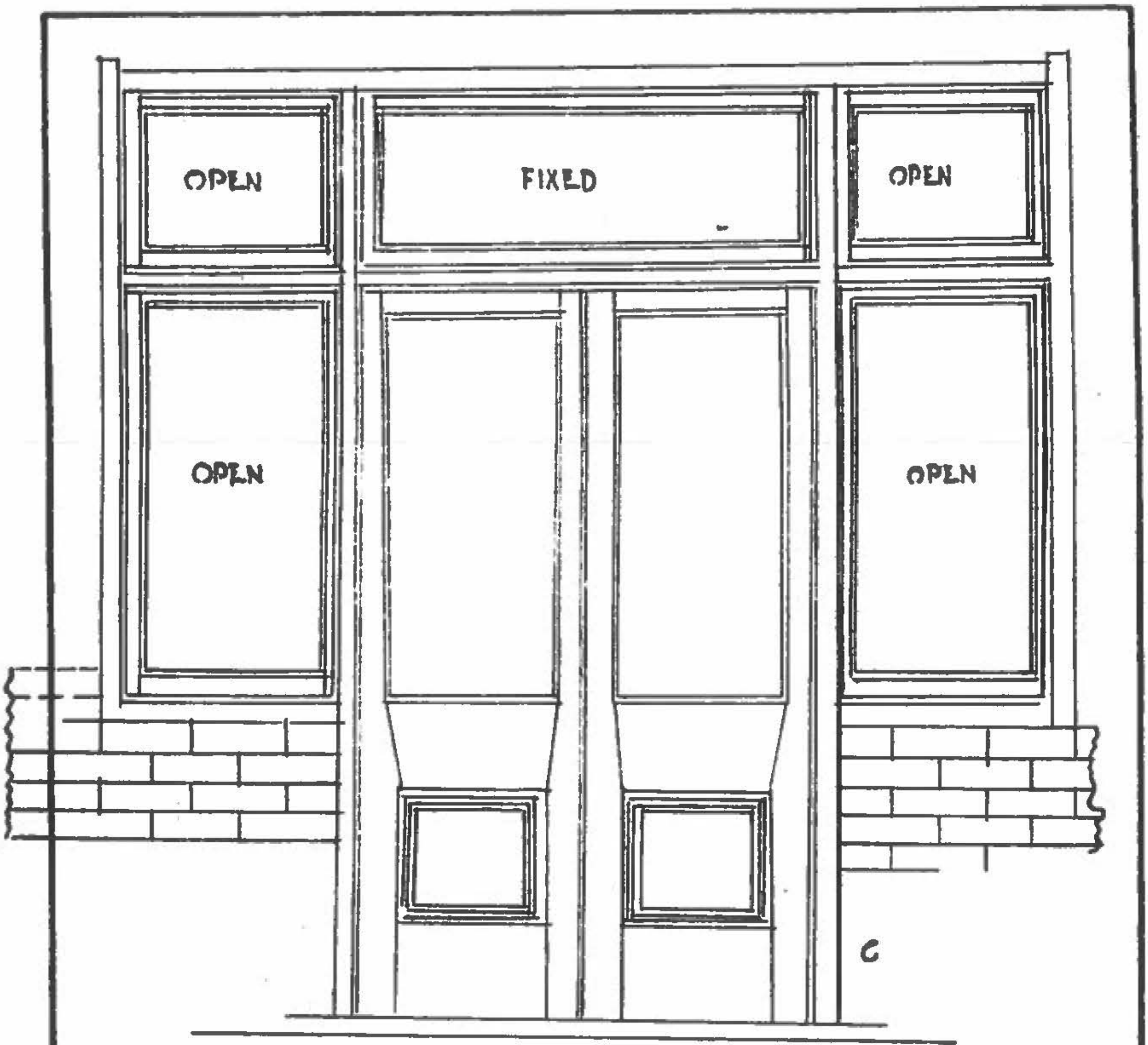


FIG No 25

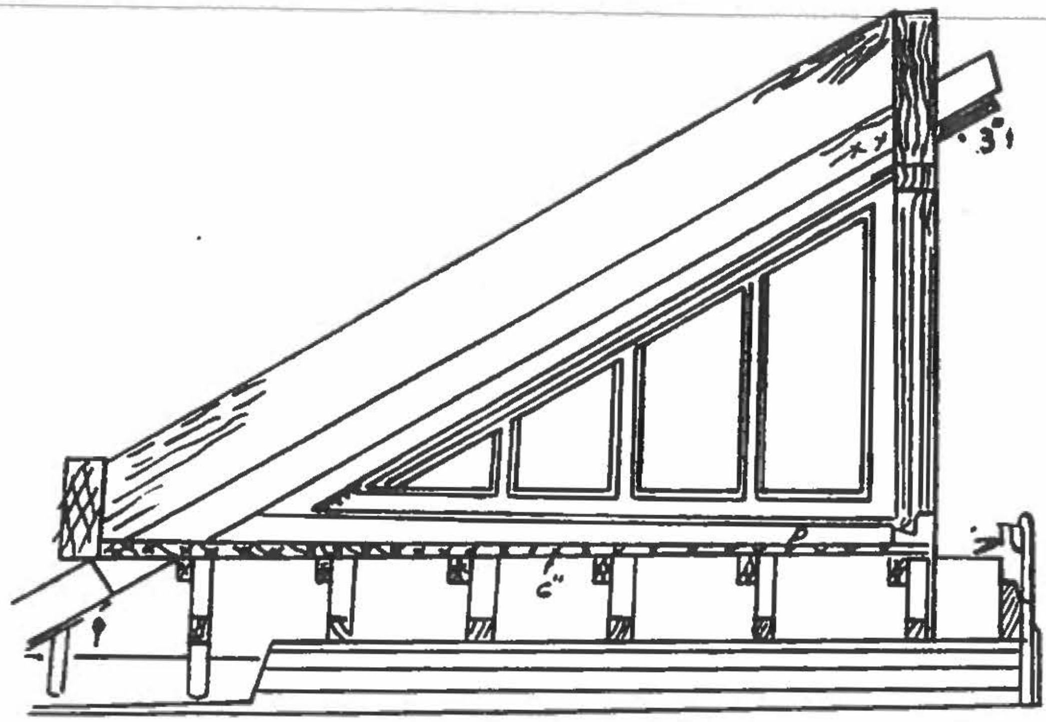


FIG. No 26 SKY LIGHT.

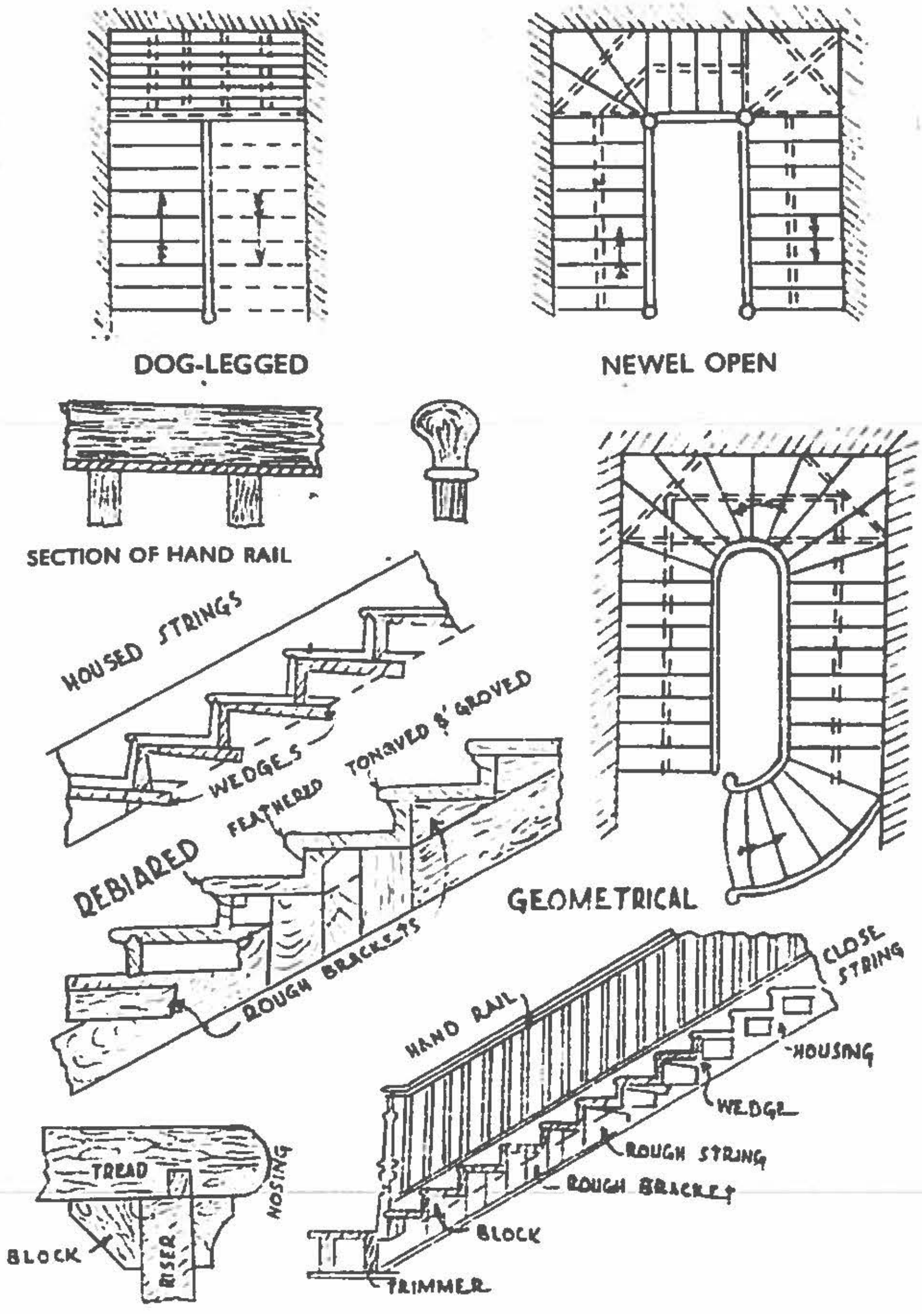


FIG Nº 27 WOODEN STAIRCASES

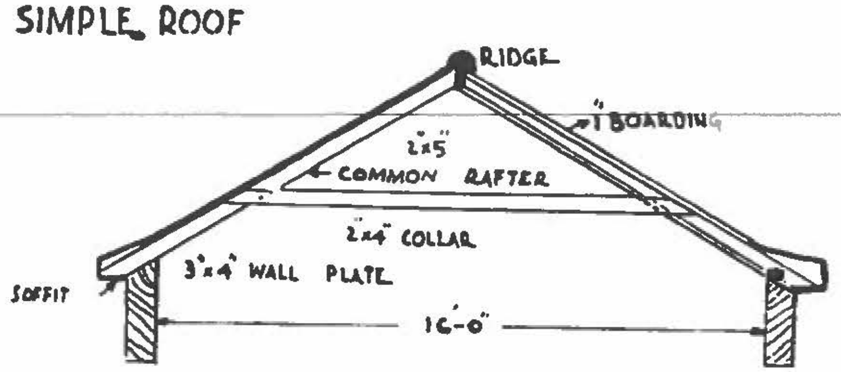


FIG No 28

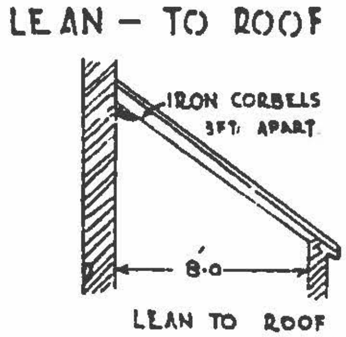


FIG No 29

COUPLE ROOF

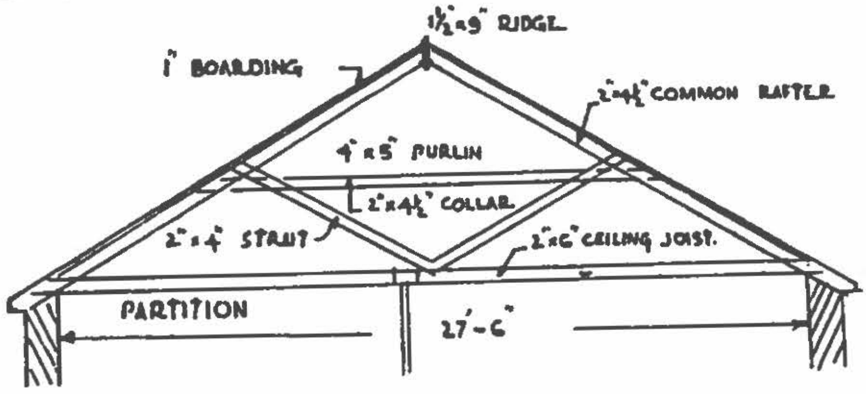


FIG NO. 30

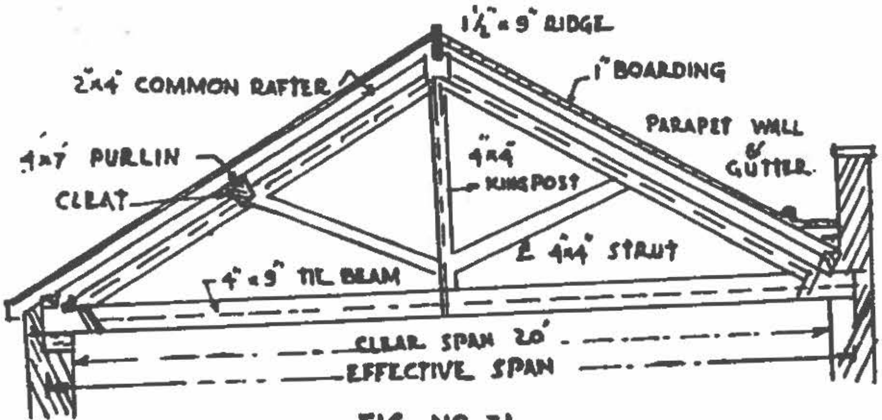


FIG NO 31

KING POST ROOF TRUSS

KING POST TRUSS

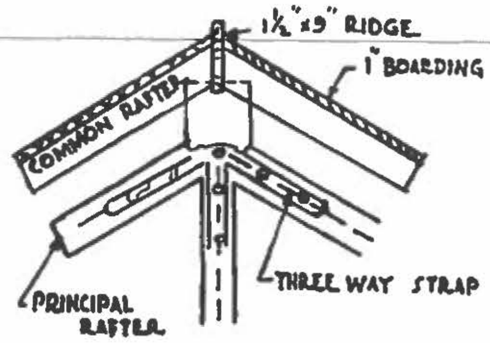


FIG Nº 32

KING POST TRUSS

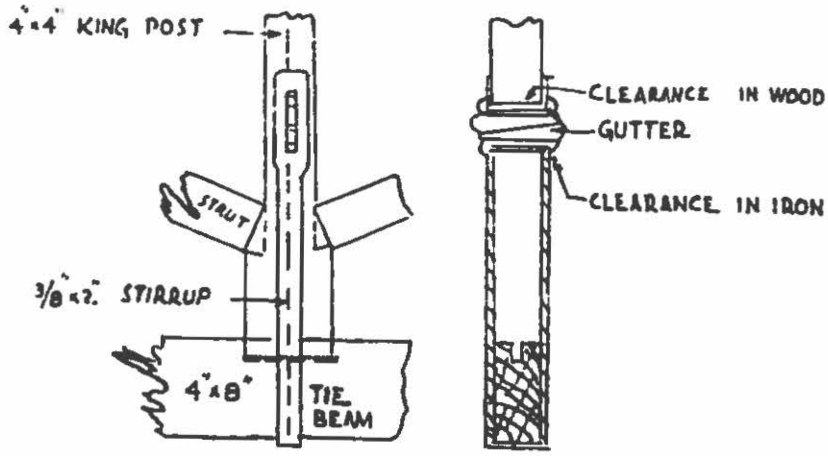


FIG Nº 33

QUEEN POST ROOF TRUSS

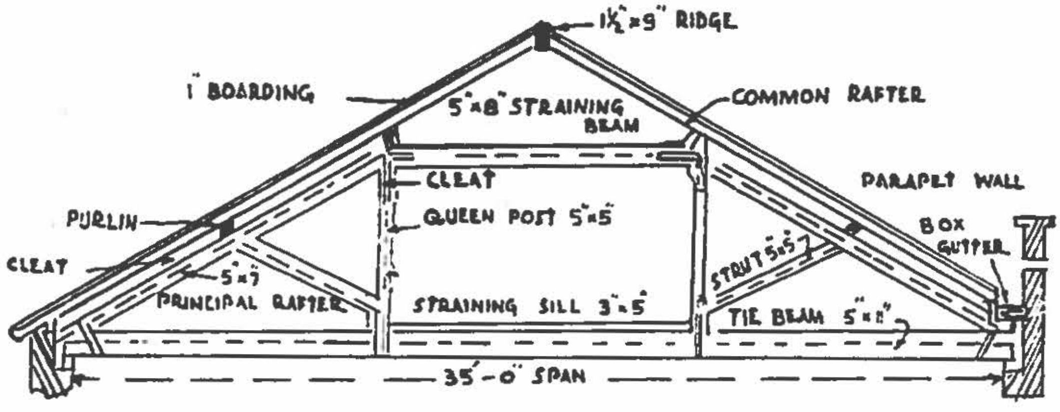


FIG Nº 34

QUEEN POST TRUSS

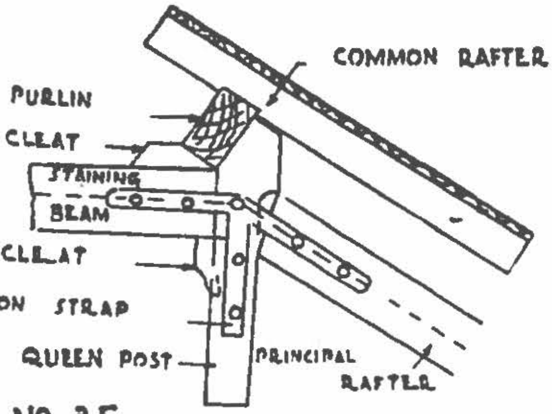


FIG No 35

QUEEN POST TRUSS

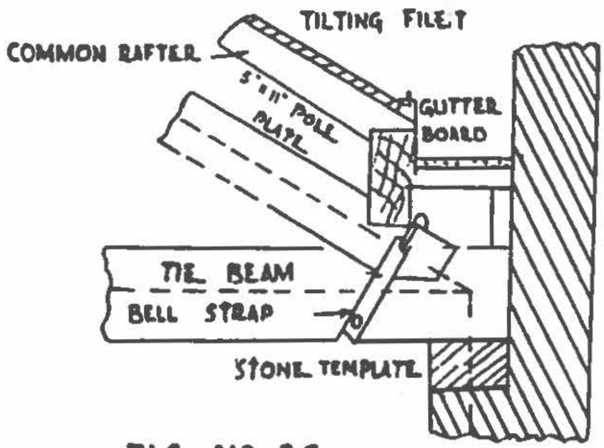


FIG No 36

PAINTING AND VARNISHING

Introduction

Definition

By painting is meant the application of paint, varnish, enamel and other protective coating in a liquid form to the surface of wood, metal, brick, or other materials to form a thin coating or film which solidifies and sticks to the surface. This coating is applied for one or more of the following reasons:

- to protect the surface from the elements and from wear;
- to improve its appearance and give it the desired colour and finish;
- to facilitate cleaning;
- to improve the lighting of interiors of buildings. Stains are applied to wood surface to produce the desired colour;
- to emphasize the grain, or to protect the wood. Metal surfaces may also be galvanized, sherardized, tin-plated, terne-plated, chrome-plated, or nickel-plated for their protection or improving their appearance.

Painting New Wooden Surface

The surface to be painted must be properly prepared because a large number of defects, appearing afterwards can be attributed either to faulty preparations or to the improper seasoning of wood.

Preparation of Surface

Assuming the wood to be properly seasoned, the surface is prepared by carrying out following operations in succession.

(a) *RUBBING WITH PUMICE OR MEDIUM AND FINE GRADE SAND PAPER*—This rubbing is continued till the surface becomes perfectly smooth.

(b) *KNOTTING*—This is done before the application of a priming coat to cover all knots in wood so as to prevent any exudation of resin or any mark from showing, through the three common methods of knotting: (i) Lime knotting (ii) Ordinary size knotting, and (iii) Patent knotting. Knots in deodar or other resinous woods are painted over with hot lime and scraped off after 24 hours. The knots are primed with red lead and glue is laid hot on them. A coat of knotting varnish is then applied and the surface is rubbed smooth with pumice stone or sand paper.

Ordinary size knotting is applied in two coats. The first is made by grinding red lead in water and mixing it with strong glue size used hot. The coat dries in about ten minutes. The second coat consists of red lead ground in oil and thinned with boiled linseed oil and turpentine.

Patent knotting consists of two coats of a varnish made by dissolving shellac in methylated spirit or naphtha. Knotting may be composed of 5 oz. of pure shellac dissolved in a pint of methylated spirit. After it has been thoroughly dissolved, 1/2 oz. of red lead is put into it and stirred. This is suitable for general purpose.

(c) *PRIMING*—Priming coat is the first coat applied to fill the pores of wood and prepare a smooth base for the subsequent coats of paints. It also quickens their drying. A priming coat may be of red lead, or red and white lead mixed in double boiled linseed oil (7 lbs of red lead or 7 lbs of red and white lead, mixed with 3/4 of a gallon of oil) and may be applied with a brush or spraying machine.

(d) *STOPPING*—This means the filling up of nail holes, cracks and other inequalities to level the surface. Stopping is done as soon as the priming coat dries up, with ordinary putty made of 2 parts of whiting, 1 part of white lead, mixed together in linseed oil and kneaded (3 oz. linseed oil to 1 lb. of whiting). High class interior work can be stopped with a mixture of 1/3 of white lead and 2/3 of ordinary putty. In the case of varnishing, the wood surface is usually stopped with hot weak glue size (one lb. of glue making about one gallon of size). When the surface dries up, it is thoroughly sand-papered. Stopping out wax is also a very useful preparation for concealing defects in wooden surfaces to be polished. It is applied hot and sets quite hard. As it does not take stains after setting, it should be coloured during its preparation to suit the finished work.

Painting

After having prepared the surface in the manner described above, a second coat of paint of the desired quality and colour is applied exactly in the same fashion as the priming coat. As soon as it dries up, the surface is rubbed with pumice stone or glass paper. This is followed by second and subsequent coats. Each coat is allowed to dry completely before the next is applied. Thin coats of paint are preferable; for thick coats not only take longer time to dry up but also scale off after some time in the form of blisters.

Turpentine instead of oil is used for the surface which is exposed to strong sunlight because oil paints show up all defects. The proportions used are 2 lbs of white zinc, 1 lb of turpentine and 1/2 lb of boiled linseed oil. For painting white, white lead is used for the surface exposed to weather and white zinc for interior works. If lead paint has been used, dry rubbing of surface should not be done on any account, since it causes lead poisoning among painters. Instead, waterproof sand papers or flint paper and cloth should be used.

Note: Woods having an excess of resin or oils are unsuitable for polished or painted work, e.g. the resin of deodar shows itself up in the discoloured patches even through a number of coats of paint.

Repainting Wood Work

Repainting of wooden surface is done in the same manner as the original painting; the difference lies only in the preparation of the surface.

Preparation of Surface for Repainting

If the old surface is firm and sound, it is rubbed with pumice or soap stone and washed with dhobi's earth and water. Afterwards all those processes like knotting, priming, stopping and rubbing are carried out to obtain a properly prepared surface for second and subsequent coats of repainting. If the old paint is in a blistered, cracked or perished condition it has to be completely removed and the surface prepared afresh for painting. Surface marked with smoke or otherwise dirty is cleaned by applying a coat of 3 lbs glue and 3 oz unslaked lime boiled in one gallon of water. Greasy places are brushed over with turpentine and then washed with soap and water.

Paint Removers

There are a number of ready-made paint removers. If none is available, any one of the following methods can be used for removing the old paint.

(a) A coat of caustic soda (2 lbs of caustic soda to a gallon of water) may be applied very carefully with a piece of cloth securely tied on one end of a long wooden stick. It is very dangerous and harmful to the eyes and skin, and, therefore, should never be touched by hand. A few hours after it has been applied the surface is thoroughly washed with clean water and neutralized with a weak acid solution or vinegar.

(b) Old paint may be softened by repeated application of naphtha. The surface can be then rubbed and cleaned.

(c) One lb of country soda (sajji) may be dissolved in hot water and mixed with stone lime to make a creamy paste. The surface, to be cleaned, is well coated with it and kept moist for at least 3 hours. The paint would become soft and can be easily rubbed off. To quicken the action unslaked lime may be used and the mixture applied hot.

(d) One part of soft soap may be mixed to two parts of potash and the mixture dissolved in boiling water. Then lime is added to it. This mixture may be applied, while it is still hot, with a brush on the suface of the old paint and left on for 12 to 18 hours. It would soften the paint which can be easily removed by washing with hot water.

(e) Sodium carbonate or washing soda diluted with water would clean greases and fats from the old painted surface. (One lb of washing soda is sufficient for one gallon of water.) Hot water would quicken the action of washing soda.

(f) Two parts of quicklime may be mixed with one part of washing soda and made to the consistency of a cream. A coat of this cream would soften the old paint very quickly.

Thick layers of old paints are generally burnt with a blow lamp and scraped. Flame of blow lamp cracks window glasses for which proper precautions must be taken.

Notes for Guidance

- Painting should be avoided during wet season.
- No painting should be done on a stormy or rainy day.
- Painted surface should not have any brush marks, runs or specks.
- If the wet painted surface is spoiled by any weathering action it should be rubbed and painted afresh.
- The paint should have a proper consistency. It should not be thinned down so much that it flows off the brush when it is being applied.

Fire-Proof Paints for Wood Work

A coating of paint of insulating and non-combustible type sodium silicate or ammonium phosphate acts as an efficient fire retardent. These chemicals decompose on painting and give out non-combustible gases and water-vapours which dilute the unflamable gasses and retard the combustion of wood. They also form readily a dense layer of charcoal and a fused viscous mass and protect the wood from radiant heat. The surface of wood is thus cut off from the supply of oxygen.

Varnishing

Varnishing and painting are similar operations; painting is generally prescribed for exterior works and varnishing for interior works. In both the cases, the surface is prepared in almost the same way. Wood work when prepared is sized with a coat of thin clean glue. If the wood is of oily nature a little brown earth and ochre is added. That is why varnish does not dry up readily. This is applied hot and rubbed smooth. A second coat of thin clean glue with necessary quantity of staining colour having equal parts of burnt umber and burnt sienna is then applied, and rubbed smooth with fine sand paper when it dries up. Two coats of boiled linseed oil can be given instead of glue size. Varnishes are applied in thin coats over the surface prepared in the above fashion as soon as it dries up. Of all the varnishers available English Copal varnish is considered the best. Normally for an old work a single coat would do, but for a new wood work a second coat is applied after the first has completely dried and rubbed with fine sand paper. Rubbing is done before and after each coat of varnish except the last. One pint of varnish covers about 150 square feet of surface in a single coat. Wood varnish dries up and is free from stickiness within two days.

French Polish

It is a spirit varnish applied to the prepared wood surface with a polishing pad of soft cloth and not with a brush, with quick and light strokes along the grain. The cloth contains absorbent cotton filling. Several coats will be necessary before the desired shine and finish is achieved. The pad may be dabbed with a drop of olive or mustard oil after each coat to allow a smooth working and finish. The wood to be polished is first painted with a filler composed of 5 lbs of whiting mixed with 1/2 gallon of methylated spirit and then sand papered, when dried. Fillers can also be made in any of the following ways:

(i) Whiting mixed with water.

(ii) Linseed oil and bee's wax (3:1) boiled.

(iii) Plaster of Paris either in water or raw linseed oil.

French polish is worked upon the surface of hard wood to obviate the effect of grain.

Wax Polish

The surface of wood work is smeared with wax polish prepared in the manner prescribed in the chapter of paints and rubbed with a soft flannel to a fine polish after 24 hours of its application. Wax polishing is mostly used for polishing the cement concrete floors.

Oiling Wood Work

One lb of bee's wax is mixed with 3 lbs of double boiled linseed oil and heated over a slow fire till it melts. It is allowed to cool and then 1 lb of turpentine is added to it. This will cover about 800 square feet of wooden surface. The wood work can also be oiled with country's sweet oil to which equal part of vinegar and turpentine have been added. This gives a darker effect. The mixture of oil and water should never be used.

Whitening

Whiting mixed with zinc and water is used for whitening ceilings and walls. Whiting is made by reducing pure white chalk to a fine powder.

Painting Iron Work (not Under Water)

In order to protect metallic products from corrosion, surface treatment is extremely essential, and painting is one of the many methods employed for this purpose. In addition, it improves the appearance of the article or structure.

PREPARING IRON WORK FOR PAINTING—It is essential to remove all rust, scale and dirt and have the surface absolutely cleaned before painting. Special attention is paid to the cleaning of corners and re-entrant angle. Usually any one of the following methods is employed depending upon the nature of surface to be cleaned:—

1) Loose dust is removed by bristle or wood fibre.

2) Rust scale and perished old paints are burnt off by the application of flat oxy-acetylene flame and then rubbed off with wire brushes and scrapers.

3) Oil and grease can be removed by gasoline (petrol) or benzine, excess of which shall be wiped off from the surface.

4) Old paint can be loosened by applying a solution of country soda and fresh slaked lime in equal parts.

PRIMING OR UNDER COAT—Priming coat can be a mixture of pure linseed oil and dry red lead in the proportions of 1 gallon of oil to 33 lbs of red lead. It is applied by brush or spraying machine immediately after cleaning the surface of the metal when it has dried up. If this coat is spoiled by rain within 24 hours of its application, it is removed and another coat is applied.

SECOND AND SUBSEQUENT COATS—The second coat is applied when the priming or first coat has thoroughly dried and set i.e. after about four days. It may be red oxide paint or paint with aluminium or graphite base (red oxide paint may consist of 6 lbs of red oxide paint, 1 lb of lamp black and 1 gallon of boiled linseed oil). The third coat is applied when the second coat has dried completely. It may consist of 7 lbs of red oxide paint, and 1 gallon of boiled linseed oil. For less important iron works, or for roof coverings red oxide paint can be made up of the following constituents.

(a) Red oxide powder dry	10 parts by weight
(b) Raw linseed oil	4 ,, ,, ,,
(c) Boiled linseed oil	1 ,, ,, ,,
(d) Turpentine	1 ,, ,, ,,

One gallon of this paint will cover about 400 square feet of surface in two coats.

Guarding Rusting of Steel Work

All structural steel work is primed and preferably given a coat of red oxide paint before erection, except the surfaces to be revetted in contact and the surfaces which have to remain in contact with concrete. Iron and steel work can be protected from rust as a temporary measure by means of a coat of whitewash or by covering it with slaked lime. Iron exposed to weather can be protected temporarily by a coat of paint made with pulverized oxide of iron, linseed oil, and a drier. A coat of cement wash is also beneficial.

Painting Galvanized Iron

Paint does not adhere to the new galvanized iron surface. It is exposed to weather for at least one year before painting. If it is necessary to paint it earlier the galvanized surface is treated with any one of chemical mixtures mentioned below.

The mixture will turn the surface black. The compositions of these chemical mixtures are:—

i) Copper acetate	6—8 ounces
ii) Water	1 gallon

or

i) Muriatic acid	2 ounces
ii) Copper chloride	2 ,,
iii) Copper Nitrate	2 ,,
iv) Sal-ammonia	2 ,,
v) Hydrochloric acid	Small quantity
vi) Soft water	1 gallon

Besides, the galvanized surface can be treated by washing it with vinegar or slaked lime and washing soda.

The surface treated by any of the above methods can be painted with a priming coat after about 12 hours. The paint may either be obtained ready-made from the market or prepared by mixing red lead with linseed oil and turpentine in equal proportions.

Painting Iron work (under Water)

Unprotected iron work suffers an average reduction in thickness of face by 0.003 inch per year if it is submerged in sea water and 0.002 inch per year if it is submerged in fresh water. From these figures it is obvious that painting of iron work under water is essential to safeguard against this recurring waste. Iron or lead oxide paint is sometimes satisfactory, but Khanki mixture is the most durable paint known so far for iron work under water. The mixture is applied hot, and two to three coats are sufficient. Subsequent coats are given only after the previous ones have dried up. Anti-corrosive black enamel paints and asphalt paint (asphaltum dissolved in naptha or benzine) are also used for this purpose.

Coal Tarring

Tar is applied as hot as possible. If practicable, the article is dipped into the tar. Preferably the iron article to be painted is heated red hot and then tar is brushed over. One lb of tar would cover 10 square feet. Tar paints are prepared in the following manner: For every gallon of tar 2 lbs of unslaked lime is added and the mixture heated till it begins to boil. It is removed from the fire and kerosene oil equivalent to 1/4th of its volume is added very slowly. Instead of kerosene oil, country spirit can be added in a proportion of 1/2 pint of country spirit to 1 gallon of tar. Solignum or creosote is also used sometimes. These too are also to be applied very hot.

Painting Walls and other Cement Surfaces

For painting walls, floors, etc., rubber paints or alkali resisting primers on plastic emulsions or cement paints are usually employed. They have been described in detail in part I. A brief description of their application is, however, given below:—

(i) The free alkali in new lime and cement plaster rapidly destroys the oil in paint and prevents it from drying. For this reason, it may not be possible to paint a plastered wall till after 12 months of its completion. In such cases the wall is whitewashed in the first instance.

(ii) All loose and flaking material is removed from old walls by scraping or wire brushing. All dust, dirt, oil, grease or efflorescence are carefully removed.

(iii) The walls are primed with boiled linseed oil or glue size (glue mixed with water); glue size is not used if the walls have been whitewashed.

(iv) First two coats normally consist of white lead and boiled linseed oil. The third coat can be of white lead tinted to approach the desired colour and mixed with raw linseed oil and a small proportion of turpentine.

(v) The finishing coat should contain a large proportion of turpentine with a little varnish to serve as a binder and applied when the previous coat is still sticky. This will give a flat finish as a glossy finish coat shows up the irregularities in the plaster.

(vi) If a wall is to be painted immediately after it is cement plastered, without waiting for a period of 12 months as mentioned in No. (i) above, a solution of 5 lbs of zinc sulphate in a gallon of water should be applied on it and when it dries up a coat of pure raw linseed oil should be given. Alternatively the surface can be treated with dilute sulphuric or hydrochloric acid (1 part acid to 50 parts water) and then washed with water. Two coats of paint thinned with turpentine and having a little varnish as a binder are then applied in succession. For the third coat, paint is thinned with a mixture of 3 parts of boiled linseed oil to 1 part of turpentine. The finishing coat can be the same as for lime plastered wall mentioned above.

A few varieties of ready-made paints are now available in the market which need no such formalities of surface treatment or waiting for 12 months and can be applied directly on newly-plastered walls.

Painting Damp Walls

Before painting damp walls they should be treated as described below, since otherwise the paints would not stick to them.

Take paraffin 2½ gallons, benzoline 2 gallons, pale resin 14 lbs in a vessel and shake them well. When completely dissolved add 24 lbs whiting and grind the whole mixture thoroughly. This mixture is kept airtight to prevent drying and 1 or 2 coats, depending upon the dampness of the wall, are applied as ordinary paint. It will dry up hard and then any suitable variety of paint can be applied, which will stick to it.

Painting Cement Surfaces with Cement Paints

Cement paints are available which are water paints and can be applied to all cement or concrete surfaces and brickwork. These paints resist the penetration of moisture and have particular advantage for use over exterior walls or floors. They are of two types, for general use and for use on water retaining structures. Neither of them may be mixed with sand (silica) when used on open textured walls. They are available in powder form and are stirred into water just before use and applied with distemper brushes.

The surface to be painted is first of all cleaned of all dust, dirt, oil, grease or efflorescence and wetted. Soap is not used for cleaning. The cement or concrete surfaces are cured, and a period of at least 3 to 4 weeks is allowed to lapse after curing before they are painted. Generally two coats are sufficient for most purposes and an interval of not less than 24 hours should lapse between the two coats. About 1 gallon of mixed paint is considered sufficient for 100 square feet of smooth surface and 40 square feet of very rough surface. After the paint has sufficiently dried, the surface should be kept wet for about 3 days by means of a light spray of water applied several times a day.

Lamp Blacking

It is applied on walls, floors, etc, of dark rooms and racquet courts. It has the following ingredients:—

(i) Lamp black	10 lbs
(ii) White lead	6 lbs
(iii) Boiled linseed oil	10 pints
(iv) Turpentine oil	1 pint

A paint prepared with above weights and volume of ingredients covers 800 square feet of surface area.

Painting Brushes

The brushes should be of bristle and not horse hair. Bristles can be distinguished by the fact that each bristle is split at end. A good brush has springiness in the bristles, and usually following sizes of brushes are employed:—

(i) 12 to 14 inches	For dusting large flat surface
(ii) 8 inches	For greater work
(iii) 6 inches	For wood work
(iv) 2 to 4 inches	For fine work

A round brush is considered the best for painting. New brushes should be placed in water for 2 to 3 hours and then allowed to dry for 1 hour before use. When a brush is used for another colour or is no longer required, it should be cleaned at once by dipping into kerosene oil. Old brushes should be kept in water or raw linseed oil (covering the bristle only) when not in use.

Painting with Brush

The paint should be applied by the end of the hair, and not by the sides. Application by the sides is not satisfactory, and the brush wears out more rapidly. Brush should be reversed at frequent intervals so that it wears down evenly. A free easy stroke should be cultivated. Short and jerky strokes result in uneven surface. Stretching the stroke too far also results in uneven surface.

Painting with Spraying Machine

When spraying machines are being used for painting the instructions given below should be followed.

(a) The gun should be held 6 to 10 inches from the object to be painted. Gun should be moved across the surface with steady and even strokes made with a free arm action. The gun should be kept perpendicular to and at an equal distance from the surface throughout the operation. Before actual work, gun should be tried on a cardboard surface, etc.

(b) The adjusting screw on the gun should be closed while starting and opened gradually till the spray runs right. A distorted spray indicates dirty air caps in which case it should be taken off and washed carefully in a clean solvent.

(c) Spray painting should not be employed for paints containing lead or for painting joinery work which should be done invariably by brush to obtain proper penetration into joints, cracks, etc.

NO. 27.1 PAINTING AND VARNISHING (GENERAL)

Specifications

Weather

1. Unless otherwise specified, no painting shall be done during wet, foggy or dusty weather or in the direct rays of the hot sun.

Number of Coats

2. Unless otherwise specified, all wood and iron work shall be given three coats, including the priming coat.

Cleaning and Preparation of Surface

3. Surface shall be thoroughly cleaned of all dust, rust, dirt, oil, grease, etc., and rendered smooth and dried before preparing it for painting or varnishing.

Priming, Knotting and Stopping

4. A priming coat without colouring matter shall first be applied, after which all holes, cracks, knots, etc., shall be stopped with the specified putty.

Paint

5. Paint shall be of an approved make and quality.

Painting

6. (i) Paint shall be applied with proper brushes of approved quality or spraying machine as specified.

(ii) Paint shall be constantly stirred, while it is being applied. It shall be stirred with a smooth stick and under no circumstances with a brush.

(iii) When more than one coat has to be given, every coat must be completely dry, rubbed and all dust removed before the next is applied.

(iv) Each coat shall differ slightly in tint from the preceding one, to distinguish quickly between each coat. The last coat shall be of the tint required for the finished work.

(v) Each coat shall be approved by the Engineer-in-charge before the next is applied.

(vi) All coats shall be applied evenly and properly, so that the work does not show any hair or brush marks, or drops of paints. The method of crossing and laying off shall be normally applied, the latter in the direction of grains in the case of wood work.

(vii) Paints, when not in use, shall be kept away from the air. The surface of the kegs of ground and mixed paints which have been partly used shall be covered with water.

Measurements

7. Painting and varnishing shall be measured by superficial area. The unit of measurement shall be 100 square feet. Moulded work of all kinds, unless otherwise specified, shall be measured by running the tape over and into all elevations and depressions. In the case of other classes of work painted on both sides the flat area of the surface on one side, including glazing and chowkat, shall be multiplied by the factors given below to arrive at the correct measurement of both sides for the purpose of making payment.

(i) Panelled or battened doors and windows	2 times
(ii) Glazed or partly glazed doors or windows	2 times
(iii) Plate glass windows (large glazed area)	I time

(iv)	Wire guaze doors or windows	1 time
(v)	Trellis work	2 times
(vi)	Grated doors and windows and other grating	1 time
(vii)	Palisade fencing	0.6 time

(Note):—In the case of chowkat having two rebates, one for wooden door and the other for wire gauze shutter, the surface area of the chowkat shall be included in the measurement of only one door.

Labour Rate

8. The unit rate shall include the cost of cleaning, preparing and painting the surface according to the above specifications or any other specifications specially included in the contract. It shall further include the cost of providing, using and removing scaffoldings, supports, ladders, shot with gunny bags at both ends, brushes or spraying machines of approved type and any other tool or plant required for doing painting as per above specifications and removal with turpentine or other approved methods of all defects from the painted surface to leave it perfect in every respect. It shall further include the cost of all allied operations like the removal of stains, smears, splashes and droppings on the walls, floors, glazing, furniture and other places.

Composite Rate

9. The unit rate shall include the cost of supplying paints of approved quality, paint remover in case of painting old work and all other material required for doing painting as per above specifications at site of work in addition to the labour rate detailed in para 8 above.

NO. 27.2 PAINTING NEW WOOD WORK

Specifications

Preparation of Surface

1. (i) *PLANING AND RUBBING*—Unless otherwise specified, wood work to be painted shall be finished smooth with the plane, but free from plane marks of every kind and rubbed smooth with sand paper, first with $2\frac{1}{2}$ grade and then with $1\frac{1}{2}$ grade or pumice stone.

(ii) *KNOTTING*—After rubbing all knots in the wood it shall be killed or covered with:—

a) Two coats of patent knotting (shellac dissolved in naptha).

or

b) Shellac varnish (5 oz shellac mixed with 1 pint of methylated spirit of vine, thoroughly dissolved and stirred with $\frac{1}{4}$ oz red lead).

or

c) A preparation of red lead and glue size in equal weight applied hot. Knots in deodar or other resinous wood shall be painted over with hot lime. This paint shall be scraped off after 24 hours, the knots primed with red lead and glue laid hot. Then one coat of knotting varnish shall be applied.

(iii) *RUBBING*—After knotting, the surface shall be rubbed again with pumice stone, or fine sand paper before the priming coat is applied.

(iv) *PRIMING OR FIRST COAT OF PAINT*—All new wood work shall be properly primed before being fixed in position. In the absence of an approved ready-made priming paint it shall be prepared by mixing the following ingredients :—

(a) For inside work (except in white and very pale shade):

(i) White lead	10 lbs
(ii) Red lead	$\frac{1}{4}$ lbs
(iii) Boiled linseed oil	4 pints
(iv) Raw linseed oil	2 pints
(v) Turpentine	1 pint

(b) For outside work:

(i) White lead	10 lbs
(ii) Red lead	$\frac{1}{4}$ lbs
(iii) Boiled linseed oil	2 pints
(iv) Raw linseed oil	4 pints
(v) Turpentine	1 pint

(c) For white or light shade:

(i) White lead	16 lbs
(ii) Lamp black	$\frac{1}{2}$ lbs
(iii) Raw linseed oil	5 pints
(iv) Turpentine	1 pint

(d) Genuine white lead:

Genuine white lead	7 lbs
Genuine red lead	7 lbs
Boiled linseed oil	1 gallon

or

White lead	15 lbs
Red lead	0.30 lbs
Litharge (drier)	0.30 lbs
Linseed oil	6.50 pints

The priming paints shall be applied either by brushes or by spraying machines as specified.

(v) *STOPPING*—After priming, all holes, cracks, gapping, joints and similar other defects shall be stopped with an approved putty made from pure whiting mixed to the proper consistency with raw linseed oil. A little white lead shall be worked in after mixing to help the hardening of the putty.

Second and Subsequent Coats

2. Unless otherwise specified, second and subsequent coats shall be applied as per Specifications No. 27.1 for Painting (General).

Measurements and Rate

3. In respect of measurement and rate it shall conform to Specifications No. 27.1 for Painting (General).

NO. 27.3 REPAINTING WOOD WORK

Specifications

Preparation of Surfaces

I. (i) If the old paint is firm and sound the surface shall be rubbed with pumice stone and washed thoroughly with soap, washing soda and water till all dirt, grease, projections and blisters, if any, are removed and the surface is rendered smooth.

(ii) Surfaces spoiled by smoke shall be cleaned by the application of a coat of 3 lbs glue and 3 oz. unslaked lime boiled in one gallon of water, unless otherwise specified.

(iii) Greasy surfaces shall be cleaned by applying a coat of turpentine over them and then washing them with soap and water.

(iv) When the old paint is in a blistered, cracked or perished condition, it shall be completely removed by burning off with a blow lamp or by means of a paint remover as specified or directed by the Engineer-in-charge. The blow lamp shall not be used on curved surfaces or surfaces adjoining glass, such as sashes, etc. Care shall be taken that the wood surfaces are not charred.

(v) When a ready-made paint remover of an approved quality is not available any one of the following recipes shall be used, unless otherwise specified.

(a) Naptha shall be applied repeatedly till the paint has softened. The surface shall then be rubbed and cleaned.

(b) A coat of caustic soda (2 lbs of caustic soda to a gallon of water) shall be applied very carefully by means of a piece of cloth securely tied on one end of a long wooden stick. After a few hours of its application the surface shall be thoroughly washed with clean water and neutralized with a weak acid solution or vinegar. This paint remover shall be applied only when particularly specified and permitted by the Engineer-in-charge and shall not be touched by hand or allowed to come in direct contact with the wood.

(c) One lb of country soda (sajji) shall be dissolved in hot water and mixed with lime stone reducing the whole to a creamy paste. The surface shall be coated with it and kept moist for at least 3 hours. If the lime used is unslaked and the mixture is applied hot, the action shall be quickened.

(d) One part of soft soap shall be mixed to two parts of potash and the mixture dissolved in boiling water. Four parts of lime shall then be added to it and applied (while it is hot) with a brush on the surface of the paint and left on for 12 to 18 hours.

(e) Sodium carbonate or washing soda, diluted with water, cleans grease and fat from the old painted surface. One lb of washing soda shall be sufficient for one gallon of water. Hot water quickens the action of washing soda.

(f) Two parts of quick lime shall be mixed with one part of washing soda and made to the consistency of a cream.

A coat of this cream shall soften the paintea surface.

(g) (i) Palmatic acid (vegetable)	25 parts by weight
(ii) Benzine	35 parts by weight
(iii) Amyle accetate	40 parts by weight

This solution shall be applied by brush.

(h) (i) Caustic soda	14 lbs
(ii) Whiting	9 lbs
(iii) Flour	2½ lbs
iv) Petroleum	2½ gallons
(v) Water	7 gallons

The solution shall be applied by any approved method on the surface.

(vi) After the paint has been removed the surface shall be rubbed smooth with sand paper, washed down and allowed to dry completely. It shall be wiped clean before paint is applied.

(vii) After rubbing all holes, cracks and other inequalities, the surface shall be properly stopped in the manner specified under "Painting New Wood Works".

Painting

2. (i) After preparing and treating the surface, it shall be painted according to Specifications No. 27.2 for Painting New Wood Work.

(ii) If old paint is completely removed the cost of removal is not to be included in the rate for first coat, but shall be payable separately.

(iii) If old paint is firm and is not removed completely but the surface is only rubbed and treated, the rate for the first coat of paint shall include the cost of treatment also.

Other Respects

3. In all other respects it shall conform to Specifications No. 27.2 for Painting New Wood Work.

NO. 27.4 VARNISHING

Specifications

Preparation of Surface

1. (i) New wood work to be varnished shall be finished smooth with the plane making sure that no marks are visible on the finished surface. It shall be rubbed perfectly smooth with sand paper or pumice stone.

(ii) Knotting shall be done as specified under painting.

(iii) *STOPPING*—The surface of the wood shall be then stopped, with hot weak glue size (1 lb of glue making about J gallon of size) so as to close up the holes. The surface when it dries up shall be again thoroughly sand papered. After rubbing the surfaces another coat of the same glue size shall be applied cold.

(iv) If the wood work is to be stained, the staining colour shall be mixed with second coat of size which shall be applied regularly, evenly and quickly keeping the colour on the flow.

(v) If the wood work is of an oily nature, a little 'Multani Mitti' and ochre shall be added to the first coat of size (otherwise varnish would not dry readily).

(vi) The sized wood shall then be rubbed with sand paper leaving the colour even and rubbing with the grain.

Varnish shall then be applied in very thin coats with a special fine-haired varnishing brush and not with an ordinary paint brush. Unless otherwise specified, the best Copal varnish, as described under paints and varnishes in part 1, shall be used. If more than one coat have been specified the first coat shall be rubbed with the fine sand paper. Other coats shall be applied as directed by the Engineer-in-charge.

Measurements

3. In respect of measurement, it shall conform to Specifications No. 27.1 for Painting and Varnishing (General).

Labour Rate

4. The unit rate shall include the cost of preparing, cleaning, rubbing, knotting, stopping the surface and applying varnish on it as per above specifications. It shall also include the cost of providing, using and removing scaffoldings, supports, ladders shot with gunny bags at both ends, fine-haired special brushes for varnishing and any other tool or plant required for doing varnishing as per above specifications and removal of all defects from the varnished surface to leave it perfect in every respect. It shall further include the cost of all allied operations like the removal of stains, smears, splashes and droppings on the walls, floors, glazing, furniture and other places.

Composite Rate

5. The unit rate shall include the cost of supplying varnish of an approved quality and all other materials required for doing varnishing as per above specifications at site of works in addition to the labour rate detailed in para 4 above.

NO. 27.5 WAX POLISHING

Specifications

Scope

1. Wax polishing shall be done where a dull polish, which shall not destroy the natural colour and graining of teak or shisham, is required.

Preparation of Surface

2. (i) New wood work to be polished shall be finished smooth with the plane making sure that no plane marks are left after finishing.

(ii) The surface shall be made perfectly smooth by rubbing it with sand paper or pumice stone.

(iii) It shall then be stopped and rubbed perfectly smooth first with medium grained sand paper and then with fine sand paper. The final rubbing shall be done with sand paper which has been slightly moistened with linseed oil and rubbed for a few seconds.

Preparation for Wax Polishing

3. The bee's wax polish shall be prepared by mixing two parts of bee's wax with two parts of boiled linseed oil over a slow fire. When it is dissolved, but is still warm,

one part of turpentine shall be added.

4. Bee's wax polish as prepared above shall be applied with a clean cloth pad and rubbed continuously for at least half an hour. **First Coat**

5. When the surface is quite dry, the second coat shall be applied in the same manner and rubbed continuously for one hour, or till the surface has dried. **Second Coat**

6. The final coat shall then be applied and rubbed for two hours (more if necessary), till the surface has assumed a uniform gloss and is quite dry, showing no signs of stickiness when touched. The final polish depends largely on the amount of rubbing which shall be done continuously with uniform pressure and with frequent change in direction. **Final Coat**

7. In all other respects it shall conform to Specifications No. 27.4 for Varnishing. **Other Respects**

27.6 FRENCH POLISHING

Specifications

1. Unless otherwise specified, the wooden surface to be polished shall be prepared according to the Specifications No. 27.4 for Varnishing. **Preparation of Surface**

2. (i) After the surface has been prepared it shall be first painted with a filler composed of 5 lbs of whiting mixed with 1/3 of a gallon of methylated spirit and then rubbed with sand paper. A thin coat of the polish shall then be applied. The surface shall then be rubbed with sand paper before the second and subsequent coats are applied. **Polishing**

(ii) Alternatively, plaster of paris, red ochre (sufficient to tint it), and linseed oil are mixed together to form a stiff paste which shall be applied sparingly and rubbed hard on the surface to fill up the pores of the wood. Prior to this, a piece of rag moistened with linseed oil shall be rubbed on the surface.

(iii) The surface shall be rubbed smooth with fine glass paper a few hours later and then polished.

(iv) Unless otherwise specified, two coats of french polish of an approved type shall be applied.

(v) To finish off, the surface shall be rubbed lightly and quickly with a circular motion by means of a piece of flannel rolled into the form of a rubber, covered with a piece of rag slightly damp with methylated spirit. If the rag sticks, the surface shall be touched with linseed oil.

3. In all other respects, it shall conform to Specifications No. 27.4 for Varnishing. **Other Respects**

27.7 OILING WOOD WORK

Specifications

Scope

1. Wood work not exposed to weather shall be oiled with linseed oil or sweet oil preparations as specified.

Linseed Oil Preparations

2. One lb of bee's wax shall be mixed with 3 lbs of boiled linseed oil and heated over a slow fire till the wax is melted. After the mixture has cooled, one lb of turpentine oil shall be added.

Sweet Oil Preparations

3. Country sweet oil shall be mixed with equal parts of vinegar and turpentine oil and shall be employed where a darker effect is required or when particularly specified.

Oiling

4. The specified oil preparation shall be up after cleaning and allowed to soak in.

Measurements and Rates

5. In respect of measurement and rates it shall conform to Specifications No. 27.1 for Painting (General).

27.8 PAINTING WOOD WORK WITH SOLIGNUM OR CREOSOTE OR COAL TAR

Specifications

Quality

1. Solignum, creosote or tar, whichever has been specified, shall be of an approved quality.

Heating and Preparing Paint

2. (i) Before applying, solignum/creosote/tar shall be heated to just short of boiling.

(ii) If tar is specified it shall be thinned with kerosene oil or common country spirit in the following proportions:—

4 parts tar to 1 part kerosene, or 1 gallon tar to ½ pint country spirit;

2 lbs unslaked lime shall be mixed with 1 gallon of tar to prevent its running

The mixture shall then be heated to a near boiling point.

(iii) It shall be then applied with a stiff flat brush or a spraying machine as specified.

(iv) The paint shall be stirred occasionally while it is being applied.

(v) The ends of the timber pieces shall be liberally coated and, where possible, dipped in the hot solignum or creosote.

(vi) Where more than one coat has to be applied, subsequent coats shall be applied when the previous one has dried.

3. In respect of measurement and rates it shall conform to the Specifications No. 27.1 for Painting (General). **Other Respects**

NO. 27.9 PAINTING IRON WORK ABOVE WATER

Specifications

Weather

1. (i) Painting of iron work shall not be done in damp, wet, stormy or extremely hot weather.

(ii) Too quick drying in the baking heat of a summer sun shall also be avoided.

Preparation of Surface and Application of Paint

2. (i) If the iron has not been painted previously it shall be thoroughly cleaned of all rust and scale by means of steel scrapers, chisels, or steel wire brushes till the bright shining surface of the iron appears.

(ii) The surface shall then be cleaned with dry cotton waste and the paint applied immediately.

(iii) Each small patch shall be painted as soon as cleaned if the painting is being done in damp weather since iron begins to rust within a few minutes after it has been cleaned.

(iv) In repainting iron work whose old paint is sound, the surface shall be rubbed with wire brushes and scrapers and all loose paint that comes away shall be taken off. If the paint is in a bad condition it shall be burnt off with a blow lamp or by other means as specified.

(v) If it is necessary to paint galvanized iron, a coat composed of eight ounces of copper acetate added to a gallon of water shall be applied first, this being paid for separately. Unless otherwise specified, the first coat of paint shall be composed of genuine red lead mixed with raw linseed oil and turpentine in equal proportion.

(vi) Second and subsequent coats shall be applied more uniformly with the paint brush in long strokes evenly drawn or with a spraying machine as specified.

(vii) Sufficient time shall be allowed between the coats to allow the paint to dry up. Unless otherwise specified, an interval of 24 hours shall be sufficient.

Number of Coats

3. (i) On new work, three coats shall be applied but on old work it is sufficient to have two coats only.

(ii) Each coat shall preferably vary slightly from the preceding one in shade, in order to ascertain that full number of coats have actually been applied.

Paints

4. The paint used shall be of an approved quality.

Other Respects

5. In respect of measurement and rates it shall conform to Specifications No. 27.3.

NO. 27.10 PAINTING IRON WORK WHICH REMAINS UNDER WATER

Specifications

Preparation of Surface and Application of Paint

1. (i) Unless otherwise specified, the surface shall be prepared according to Specifications No. 27.9 for Painting Iron Work Above Water.

(ii) The paint shall be applied hot as soon as the surface is cleaned.

(iii) Subsequent coats shall be applied only after the previous one has dried.

Painting Material

2. Unless otherwise specified, khanki mixture prepared in the manner described in Volume I Part I, page 70, or any other approved paint shall be used.

Number of Coats

3. Two to three coats as actually specified shall be given.

Protection

4. Work thus painted shall not be immersed in water until it has dried up; one week shall be generally sufficient for this purpose depending upon the weather.

Other Respects

5. In all other respects not specified here it shall conform to Specifications No. 27.9 for Painting Iron Work Above Water.

NO. 27.11 COAL TARRING IRON WORK

Specifications

Preparation of Surface

1. (i) The surface to be coal-tarred shall be cleaned off all dust, rust, scale and grease, etc.

(ii) It shall be dry and clean.

Heating and Preparing tar

2. To each gallon of tar 2 lbs of unslaked lime shall be added and the mixture heated till it begins to boil. Then it shall be taken off the fire and kerosene oil added to it slowly in the proportion of 1 part of kerosene to 4 parts of tar.

Application

3. (i) Tar shall be applied as hot as possible with a brush. On no account rags shall be used for applying tar.

(ii) Where possible, the article to be tarred shall be dipped in the hot tar.

Other Respects

4. In all other respects not specified here it shall conform to the relevant parts of the Specifications No. 27.9 and 27.10 for Painting Iron Work.

NO. 27.12 PAINTING PLASTER

Specifications

General

1. (i) Unless otherwise specified or directed in writing by the Engineer-in-charge, a plastered wall shall not be painted till 12 months have elapsed since plastering work was completed.

(ii) In the absence of special primers and wall paints, the plastered surfaces shall be prepared and painted as specified below:

Preparation of Surface

2. (i) All loose and flaking material shall be removed from old walls by scraping or wire brushing and the surface shall be carefully smoothed and cleared.

(ii) All dust, dirt, oil, grease or efflorescence shall be carefully removed.

(iii) To ensure a uniform appearance to the finished work and to make a lime plastered surface non-absorbent, the surface, if not previously whitewashed, shall be painted with glue size or otherwise, with boiled linseed oil and thin size, tinged with red lead.

Priming Coat

3. (i) Having prepared the surface, a priming coat composed of equal parts of white and red lead mixed in boiled linseed oil to the desired consistency, shall be applied.

(ii) When the priming coat dries up, all cracks, holes and such other defects shall be filled up with a mixture of 1 part white lead and 3 parts ordinary putty.

(iii) The surface shall then be rubbed with pumice stone or sand paper and dusted clean.

Second and Third Coats

4. (i) Second coat shall consist of white lead and boiled linseed oil.

(ii) Third coat shall consist of white lead tinted to approach the desired colour and mixed with raw linseed oil as a carrier and a small proportion of turpentine as drier.

Fourth or Finishing Coat

5. The finishing coat shall contain a large proportion of turpentine with a little varnish to serve as a binder and applied when the previous coat is still sticky and shall be evenly stippled over the surface with a stippling brush, so as to dry flat with a velvet-like surface.

Treatment of Newly Cement Plastered Surface

6. (i) In case it has been specified or directed in writing by the Engineer-in-charge to paint a newly cement plastered surface without waiting for 12 months, a solution of 5 lbs of zinc sulphate dissolved in a gallon of water, shall be applied to the surface and when it dries up, a coat of pure raw linseed oil shall be given.

(ii) Alternatively, the surface shall be treated with dilute sulphuric acid or hydrochloric (one part acid to 50 parts water) and then washed down with water.

Neither of these two treatments is included in the rate and shall be paid separately.

Priming and Second Coats

7. Unless otherwise specified or directed in writing by the Engineer-in-charge and in the absence of a special cement paint being specified, after treating the

surface, two coats of paint thinned with turpentine and having a little varnish as a binder, shall be applied.

Third Coat 8. The third coat of paint shall be thinned with a mixture of three parts of boiled linseed oil to one part of turpentine.

Fourth or Final Coat 9. The fourth and finishing coat shall be given as specified for lime plaster in paragraph (5) above.

Measurements 10. The plaster painting shall be measured by the surface area. The unit of measurement shall be 100 square feet.

Rate 11. The unit rate shall be as per Specifications No. 27.1 (8) for Painting (General).

...h Para No. 10 amended
...ide ATC No. 2 dt. 17/8/69

LINING OF CANALS

Introduction

Definition

Lining of canal means rendering its earthen cross-section impervious or semi-impervious and smooth by laying some suitable material.

Advantages

A lined channel has the following advantages over an earthen channel:—

(i) *REDUCTION IN WATER LOSSES:* It reduces considerably water losses through seepage. A really efficient lining can reduce seepage losses from about 10 cusecs per million square feet of wetted area to less than one-tenth of a cusec. The following table gives the seepage characteristics of lined and unlined channels (in cusecs per million square feet of wetted area).

Type of lining	*Initial rate of seepage*	*Stabilized rate of seepage*
1. Unlined channel	22.4	10.26
2. Cement sand (1:3) mortar sandwiched between two layers of 12"x6"x2" tiles	0.507	0.027
3. 4" thick cement concrete (1:3:6)	0.367	0.02

Lining is considered satisfactory if seepage losses are up to 0.5 cusec per million square feet of wetted area.

(ii) *ECONOMY IN CROSS-SECTION AREA:* The co-efficient of friction of a lined channel is much less than an earthen channel, and, therefore, higher velocities work out for the same slope which in turn require a lesser cross-sectional area for carrying a certain discharge. The danger of scouring the bed and sides is also eliminated.

(iii) *BETTER COMMAND:* On account of the reasons described in (ii) above, the lined channel conveys a certain discharge to a certain place with a comparatively much flatter slope than the earthen channel and thus commands the area under irrigation in a much better way.

(iv) *ECONOMY IN COST:* Since the section of the canal is considerably reduced there is a saving in the cost of excavation, construction of masonry works and land acquisition. However, this saving is not much on account of the fact that the cost of lining is substantial.

(v) *LOWER MAINTENANCE COST:* The rate of deterioration of the cross-section is much less. The cross-section hardly needs silt clearance since, usually, it is designed on non-silting velocities.

(vi) *STOPPAGE OF WATER PILFERAGE:* It stops the pilferage of water by cultivators.

(vii) *PREVENTION OF WEED GROWTH:* It prevents the growth of weeds.

(viii) *EROSION AND BREACHES:* It reduces bank erosion and breaches.

(ix) *WATER ABSORBING SALT:* It prevents water absorbing salts when passing through kalarish tracts.

(x) *WATERLOGGING:* It prevents waterlogging and efflorescence of adjacent lands which mainly occur owing to seepage of canal water.

Types of Lining

There are many types of lining having their own advantages and disadvantages. The selection of a type depends upon its cost, stability and effectiveness. The cost in turn depends upon the availability of various materials, required for lining, in the vicinity of the canal.

The following types of lining have been tried on different occasions.

Clay Puddle Lining

A layer of 3 inches to 6 inches of clay is spread on the bed and sides and covered with 9 inches to 12 inches of silt to form puddle lining. (Clay puddle has been described in details in chapter No. 17 on Earthwork.) This lining is quite satisfactory, but can only be used if good clay is available. If constructed and maintained properly it reduces seepage by about 80 per cent. Liable to develop cracks on drying, it is suitable for perennial canals only.

Brick Lining

It has three main advantages: first, no expansion or contraction cracks occur as in concrete lining; secondly, its repairs can be done easily; and thirdly, it costs less than concrete lining. If properly laid it can reduce seepage by about 75 per cent. But as the bricks are porous, the lining on the whole is not very efficient in preventing seepage, except when sandwiched by a layer of rich cement mortar. For a successful job it is very essential that the bricks and the brickwork used are of the best possible quality. The earth to be used in the manufacture of bricks should not have a salt content of more than 0.3 per cent, calcium carbonate not more than 2 per cent, and clay contents between 12 and 20 per cent.

The bricks may be laid in single layer flat, or on edge or flat in two layers (preferably tile). The bricks are usually laid in "herringbone" pattern and are bedded on half an inch layer of 1:5 cement mortar laid on well-compacted and damp sub-grade in 1:3 cement mortar. A layer of half an inch of 1:3 cement plaster is sandwiched by two layers of bricks (or tiles). In the floors of canals the top brick-on-edge is laid diagonally to the centre line of the channel, or in "herringbone" pattern. The lining may be plastered or pointed on the face, and may also be reinforced.

Concrete Lining

It is generally considered the most suitable for big canals, provided the cost is not prohibitive. Its usual thickness is 2½ inches to 6 inches depending upon the design. The Gunite and shotcrete linings are, however, superior to ordinary work. A thin coat of plaster is applied to give it a smooth surface. The longitudinal and transverse joints are provided according to the thickness of the concrete. The thinner linings have joints at closer intervals. Normally plain vertical butt joints at 8 to 12 feet intervals may be found suitable. To make the joints watertight, copper strips or steel plates may be placed and the joints filled with bitumen. In a joint less than 1/4 inch wide bitumen cannot be filled in properly. Kerosene oil 10 per cent by weight of cement makes concrete waterproof and also retards the evil effects of alkaline soils, for which otherwise high alumina cement is required.

Concrete may be reinforced, but the reinforcement is not generally favoured despite the fact that it helps in preventing the failure of lining caused on account of the settling of the sub-grade, and helps in increasing the spacing of the joints. Concrete blocks with joints filled with asphalt may be better in some cases.

Concrete lining is the most desirable for both service and operating conditions. Although the cost is higher than in most other types, its longer life and minimum maintenance requirements often make it more economical. The cost of concrete lining can be minimised by making it part of the original canal construction. At the design stage advantage can be taken of its superior hydraulic characteristics which permit the use of a much smaller section for a given capacity than is required for an unlined canal or other types of lining with higher co-efficients of roughness. Concrete is more resistent to erosion than most other lining materials and, because of its lean strength, usually bridges areas of poor sub-grade support. Therefore it is preferable for high water velocities or where safety is of primary importance. Concrete lining eliminates weed growth with benefits to flow characteristics and maintenance cost. Burrowing animals, which cause numerous breaches in unlined canals, also cannot penetrate. From a study of the many miles of concrete lining in existence, it is concluded that, if properly designed and constructed, its average serviceable life is about 40 years. There have been, however, numerous cases of early failures owing to adverse sub-grade conditions, excessive hydrostatic pressures beneath the lining, frost heaving, poor quality of concrete, faulty design or construction methods, etc. Where the sub-grade is not free, provision for adequate drainage is perhaps the most effective protection against frost heave.

Steel Reinforcement

A difference of opinion exists among engineers on the justifiability of reinforcement steel in concrete and brick canal lining. Some maintain that it is justified on the basis of longer serviceability and reduced maintenance cost. Others contend that the possible benefits are not commensurate with the added cost and increased construction difficulties.

The quantity of reinfrocement steel commonly used in canal lining (0.25 to 0.3 per cent of the area of concrete or brickwork), though not enough to add appreciable structural strength, reduces the width of cracks which occur as a result of drying and temperature changes, and thereby minimise seepage. It also guards against the possible faulting of the cracked slabs where unstable sub-grade soils are encountered. Additional structural strength can be obtained more economically by increasing the thickness of the lining.

According to the latest practice, reinforced lining is done only when safety is a primary consideration. A properly designed and constructed reinfroced concrete lining will withstand velocities of any magnitude considered feasible for canal. It is, however, susceptible to damage from alkaline water, alternate freezing-thawing action, and rupture by outside hydrostatic or other pressures. Whenever there are alkaline conditions or freezing and thawing, the drainage should, if possible, be away from the canal rather than into it.

Sub-Grade Preparation for Concrete Lining

A first prerequisite to the success of concrete canal lining is a firm foundation which eliminates, as far as possible, the danger of cracking or failure on account of settlement of the sub-grade. Usually undisturbed soils are satisfactory for a foundation without further treatment, but all filling material used to support the lining should be compacted prior to the trimning and placing operations. Natural inplace soils of low density should be thoroughly compacted or removed. Where this is impracticable, as in areas of deep loess, concrete or other rigid type linings are not suitable. All fillings in an embankment, to be ultimately lined, are placed in layers, not more than 6 inches thick, moistened and compacted at optimum moisture content to a dry density of not less than 90 per cent of the laboratory maximum density as determined by compaction tests. The material, when distributed and compacted, has to be homogeneous and free from nodules and pockets. The top width of the compacted embankments varies with the size and location of canals, the type of lining, and other factors. The density of the compaction of loose soil in cuttings or of soils replacing unsuitable sub-grade materials should be the same as for compacted embankments. In case where partial backfilling of an existing canal is necessary to reduce the cross-sectional area to that required for a lined canal, either the puddling or ponding method has been found satisfactory for compacting most soils. The compacted sections should extend not less than 2 feet inside the final section of the channel. After backfilling has beed done, the canal section is rough-trimmed to the approximate dimensions required for the lined canal, making due allowance for the settlement of the fill. The canal is slowly filled, using temporary earth dams to check water to a proper height water is allowed to stand for at least 24 hours before being drained. Lining is done when the sub-grade has become sufficiently dry, the section is fine-trimmed and the sub-grade is waterproofed by use of oil paper or crude oi.

Since canal linings are primarily done to prevent seepage, the sub-grade is usually relatively free draining. If not, it is very essential to provide artificial drainage in the form of tiles placed in gravel-filled trenches along one or both toes of the inside slopes. These longitudinal drains are either connected to tranverse cross drains which discharge water below the canal or to pump pits, or extend through the lining and connect with the outlet boxes on the floor of the canal. The outlet boxes are equipped with one-way flap-valves which automatically release pressure greater than the water pressure on the upper surface of the canal base. Pressure releases in the form of weep-holes have also been tried with success

A departure of 4 inches from established line and one inch from established grade of sub-grade are the usual tolerances permissible.

Expansion and Contraction Joints

The concrete slab of canal lining is subject to complex stresses resulting from temperature or moisture changes in the slab or from a combination of the both. The compressive stress resulting from temperature or moisture increase is of little concern; first because, a slab which is fully restrained at both ends and subjected to a 100°F increase in temperature will develop only about 1500 lbs per square inch of compressive stress which is considerably below the average compressive stress of good concrete. And secondly, the expansion of concrete owing to complete saturation is never as great as the contraction that results from the drying out of the concrete shortly after placing. Unless the contraction cracks resulting from drying shrinkage are filled with incompressible material, considerable expansion due to an increase in temperature can occur before complete closure of the cracks. If contraction cracks are filled early with an elastic material the entrance of incompressible particles is prevented and expansion joints are ordinarily not required, except where fixed structures intersect the canal. The filling material should be such as permits, without fracture or failure of its adhesion with concrete, the slow movement set up by expansion or contraction. The consistency of material is such that it does not flow on the vertical face and remain ductile throughout the expected variation in temperature without fracture or loss of adhesion.

Contraction cracking, which results from tensile stresses produced by a moisture or temperature decrease, is of primary concern in concrete lining. Canal lining cannot be economically designed to overcome cracking, but some control can be exercised by the use of reinforcement steel or the formation of contraction joints at proper intervals. Where lining operations are continuous, and reinforcement is not used, a weakened-plane type joint or "side-walk" groove is formed in the concrete to a depth of about 1/3rd of the thickness of lining. If the grooves are properly spaced, cracking will usually occur at these planes of weakness. In big canals both transverse and longitudinal grooves are provided at a spacing of 6 to 15 feet, depending on the size of canals and thickness of lining.

Pre-cast Concrete Lining

The use of pre-cast concrete blocks or slabs for lining small canals may have some limited adaptation and under certain conditions may be relatively economical, but their general use cannot be recommended. In special cases, where an adequate supply of cheap labour and material are available it may be feasible to use pre-cast slabs and blocks which require no particular skill and very little equipment. The small pre-cast blocks can be used even on curves. But the use of large slabs is limited to tangents. Joints in both the cases are sealed with either cement mortar or asphalt, if seepage control is important. On account of its high cost and little progress in laying it is not suitable for any extensive use.

Shotcrete Lining

Shotcrete is a term used for pneumatically applied cement mortar. Pneumatic application is done by using a special equipment which is available from several manufacturers. Shotcrete can be widely used for both lining and resurfacing of irrigation canals and ditches. This type of lining can be placed on an irregular surface obviating the need for fine trimming which is very expensive sometime, as in the case of rock cuts. Resurfacing by this method the badly cracked and leaky, but structurally sound, old concrete lining gives satisfactory results. On big projects it is costlier than concrete lining since it needs more cement as well as more time for placement.

MATERIALS AND MIXES—Sand for shotcrete should be of uniform grading with a maximum particle size of 3/16 of an inch. Particles should be hard because soft grains crumble as they pass through discharge hoes, and form powder reducing the bonding value of cement. Sand should contain 3 to 5 per cent moisture for an efficient operation of the equipment. Dry sand generates static electrical charges on the nozzles, increases the rebound and creates difficulty in maintaining uniform movements of the mix through hoes. Sand which is too wet causes frequent plugging of the equipment. No coarse aggregate is used in shotcrete. The optimum mix contains a little less water than that which will cause sloughing and just enough cement for the desired water-cement ratio. Proportions of cement to sand usually approximate 1:4 by weight. The rebound has a greater percentage of coarse sand particles and a much smaller cement content than the mortar leaving the nozzle. Therefore, the cement content of the materials as mixed should be less than that desired for the mortar in place.

SUB-GRADE PREPARATION OF SHOTCRETE—Sub-grade preparation for shotcrete lining varies with the characteristics of the sub-grade soil. Fine trimming of canal sections through stable rock-cuts is unnecessary, if the hydraulic characteristics of the rough surface lining are satisfactory. A stable sub-grade is an important prerequisite to the serviceability of shotcrete lining. With earth sub-grades, best results are generally obtained, if the sub-grade is trimmed to the same degree of accuracy as for concrete lining. If the sub-grade is not trimmed to a reasonably smooth alignment, control of the lining thickness becomes exceedingly difficult. It usually results in thin areas forming planes of weakness over high spots. If backfilling is necessary to bring the sub-grade to proper alignment, fill material is properly moistened and compacted with suitable tamping equipment. All absorptive surfaces against which shotcrete is to be placed are thoroughly moistened so that moisture may not be drawn from the freshly placed mortar. At the time of application, however, there should be no free water on the surface of the sub-grade.

THICKNESS OF SHOTCRETE LINING—Shotcrete is usually placed to a thinner section than concrete. The main reason for this practice is that this lining is "built up" to the desired thickness by successive passes of the spray from the hoe nozzles. Since the spray deposits mortar over a very small area at one time, the "building up" of the thickness is both time-consuming and expensive. Usually one inch to two inches thick shotcrete lining has been attempted in the past and found quite satisfactory.

EXPANSION AND CONTRACTION JOINTS—As in case of concrete lining, expansion joints are provided adjacent to the structure and also longitudinal and transverse grooves for contraction cracking at six feet and 10 feet intervals in non-reinforced and reinforced lining respectively. The depth of the groove is usually one-fourth to one-third of the thickness of the lining.

Asphaltic Linings

Since asphalt is comparatively inexpensive and is manufactured in many types, grades, and compositions, numerous variations are possible in its application to the lining and waterproofing of canals. Asphalt is a heavy bituminous material derived from the refining of crude petroleum. As the crude oil is heated in the refinery, the volatile materials such as gasoline distillate and light oils are drawn off and condensed. The residue is very heavy viscous oil containing a high percentage of asphalt. Semi-solid asphalt (asphalt-cement) is obtained by the removal of all but a small fraction of the remaining oil by means of high temperature steam and vacuum distillation. In canal lining applications this basic steam-refined asphalt-cement is used as the binder for asphaltic concrete or is further processed to form cut-backs emulsions, or air-blown asphalts for a variety of uses as described below. Certain catalytic agents during the air-blowing process give desirable characteristics to asphalt for use as a membrane seal. Such a produce is termed as "catalytically-blown asphalt".

Asphaltic Concrete (Hot Mix) Lining

It is a combination of asphalt-cement and aggregate, mixed, placed and compacted in a hot and plastic state. It is sometimes called as "hot mix". Asphaltic concrete lining is most satisfactorily placed by slip-forms. It is particularly well adapted to smaller canals. A suitable proportion of sand, gravel and asphalt-cement is mixed hot in a central plant (usually at about 325° F, in batches of 1,000 to 2,000 pounds). The mixture is carried in dump trucks to the site. Since no curing, sealing or other treatment is required, the "hot mix" is ready for use immediately after it has cooled.

The trimming of the sub-grade, which in this case is to relatively wide tolerance, may be done with an equipment of rather a simple design. The same machinery as used for trimming the sub-grade for concrete lining may be used in asphaltic concrete lining construction. Satisfactory sub-grade preparation has been done in small canals with blow-type ditchers pulled by one or two tractors.

WEE GROWTH—Owing to the plastic nature of asphaltic concrete, some types of weeds penetrate the lining. Weed growth is, in fact, promoted by the heat-absorbing property of the black surface. Therefore—especially when lining is placed in areas previously irrigated or in old canals where weeds are firmly rooted—it is advisable to treat the sub-grade with a soil sterilant, which will obviously increase the cost, but not more 10 per cent in any case. A water solution of polyborchlorate applied by spraying direct to the sub-grade before placing the lining is recommended. Adequate sterilization will ordinarily be secured by the use of an equivalent of 2 pounds of the powdered polyborchlorate for 100 square feet of sub-grade.

Buried Asphalt Membrane Lining

This lining is essentially a membrane (approximately 3/8 of an inch thick) of a special asphalt sprayed in place at high temperature (400° F) to form a waterproof barrier which is protected against injury and weathering (buried) by a layer of earth and gravel. If not already oversize, the canal section must be enlarged or over-excavated before placing the membrane. The side slope flattening and over-excavation are done by a dragline, sometimes assisted by a motor patrol, if equipment can be operated directly in the canal section. After rough excavation, the surface is prepared for the application of asphalt by light dragging and rolling to obtain a relatively smooth surface in order to facilitate the laying of a uniformly thick and impermeable membrane. The rougher the sub-grade, the greater the quantity of asphalt required for satisfactory coverage. The special asphalt used for the membrane is prepared by the catalytic blowing of asphaltic materials. It has a very low temperature susceptibility, a high degree of toughness, a resistance to tearing or breaking, and a long life. After the asphalt has been heated to approximately 400° F, it is applied to the sub-grade under about 50 pounds pressure through spray nozzles, using either hand sprays or multiple spray bars mounted on the distributor. Holes or rough areas in the sub-grade can be adequately covered by the hand spray, though, this method is somewhat slower. On the other hand, the distributor method is faster, and, therefore, more economical, but can be applied satisfactorily only to reasonably smooth sub-grades.

The hot-applied asphalt cools quickly and is soon ready for the application of the cover material. In fact, a few minutes after the application, the surface may be walked over by the construction personnel in covering operations. Since the purpose of the cover material is to hold the membrane in its place, and to protect it from the sunlight, water, wave wash, or livestock damage, the kind and depth of cover material depend on factors like wave-action, water turbulence and velocity. Where water velocities are below one foot and a half per second, the soil removed from the canal in over-excavation may be used provided it is of reasonable stability. If soil from canal excavation is not suitable, material with greater cohesiveness (clay contents) and stability may be burrowed. In canals with very high water velocities, gravel blankets (usually of pit-run material) may be placed over the soil cover to depths between 3 and 6 inches. Riprap is often used for areas below check structures or where turbulence is severe. Compaction of the cover material is not ordinarily required but may be advisable in some instances. Experience indicates that the life of an asphalt-membrane lining largely depends on the maintenance of the cover which is subject to beaching and weed growth in much the same manner as earth lining. (Beaching may be defined as the erosion of the canal bank at the water surface resulting primarily from wave-action.)

Since a buried asphalt membrane lining with cover operates essentially as an unlined canal, plans for the location and extent of such treatment can be altered on new construction without affecting the design of the canal or structures. Accordingly final decisions on these matters may be deferred till sub-grade conditions are exposed by excavation. Another distinct advantage of the membrane lining is that it can be satisfactorily done both in cold and wet weather.

Asphalt Macadam as Lining Or Cover

A two to three inch layer of coarse, screened gravel placed over a previously installed membrane, is sprayed with hot asphalt-cement which penetrates the gravel and thus stabilizes it. If placed direct on the canal sub-grade without the underlying membrane, it may be considered a lining by itself and has promise for resisting erosion. However, experiments have shown that it is not economically feasible to make the macadam lining watertight without using a membrane underneath it, because of the large quantity of asphalt required.

Prefabricated Asphalt Membrane Lining

This type of lining has been developed to permit the use of an asphalt membrane but to avoid the use of hot materials which require skilled personnel and special equipment. Prefabricated linings are designed to be handled and placed in the same manner as rolled roofing, with lapped and cemented joints. To protect and retain the prefabricated membrane, it must be covered with earth or gravel like the hot-placed membrane. A prefabricated lining without cover material has proved unsuccessful.

Two types of prefabricated asphalt membrane linings have been tried in a number of experimental installations. In one of these a heavy kraft paper is used upon which 3/16 inch coating of catalytically-blown asphalt is applied. The paper serves only as a temporary reinforcement during the period of manufacture, transportation and placement. After placement the paper disintegrates rapidly leaving an unreinforced membrane of a uniform thickness. The lining which is fabricated in strips, 3 feet wide and 36 feet long, is shipped in rolls and placed on the over-excavated sub-grade either transversely or longitudinally. Joints are lapped 2 inches and cemented with cut-back asphalt.

In the second type of lining a thin mat of glass fibers is used as reinforcment, instead of paper, to form the same size sheets, or strips 3 feet by 36 feet but only 1/8 inch thick. The material is lighter in weight than in the first type and is, therefore, cheaper to transport. The addition of the fiber-glass reinforcement increases strength which is beneficial for placing operations, but on the other hand it increases the cost. The lapped joints are sealed and cover is applied in the same manner as for the paper-backed material.

Soil-cement Lining

Soil-cement offers possibilities for use as a canal lining material in localities where sub-grade soils, or those adjacent to the canal, are of a sandy nature and other suitable materials are not readily available. As the name implies, the lining is made up of a mixture of cement and natural soil. These linings are divided into two general types: standard and plastic.

Standard soil-cement is compacted with the moisture content of the mix at about the optimum as determined by laboratory compaction tests. Material mixing is ordinarily done by disking and blading the two materials in place. This operation and the necessary compaction are difficult to perform on the canal side slopes.

Plastic soil-cement, having a higher water content and a consistency comparable to concrete, may be placed by the equipment similar to that utilized for concrete lining.

Both the types must be protected from weather action for a reasonable period after placement and should be water cured for at least seven days, covered with moist soil, or sprayed with curing compound as required for concrete.

Bentonite Lining

Bentonite is an earth material and contains a large percentage of montmorillonite clay. It is characterized by its high water absorption accompanied by swelling, imperviousness, and slipperiness (low stability). The fact that bentonite does swell and does become impervious on wetting makes it a very useful material in the control of seepage from canals provided it can be obtained from local deposits at low costs. The two types of bentonite canal linings that have proved satisfactory are:

(1) A bentonite membrane, one to two inches thick, spread over the canal sub-grade and covered with six to twelve inches of protective blanket of stable earth or gravel; and

(2) A sandy soil and bentonite combination mixed in place and compacted to form two to three inch finished lining which is preferable to the one to two inch membrane lining. The optimum amount of bentonite for the soil-mix type of lining usually ranges from 5 to 25 per cent, but the exact percentage should be predetermined by laboratory test. A protective cover of stable earth or gravel is also recommended over the mixed or combination lining.

Chemically pure bentonite is a natural hydrosilicate of alumina. However, most natural deposits are not chemically pure and, therefore, bentonite differs considerably in expansive characteristics. From the points of view of engineering and construction uses, bentonites have been divided into two groups based primarily on their swelling characteristics:

WYOMING TYPE BENTONITE—It exhibits a strong affinity for water and high swelling because of the presence of sodium; and

METABENTONITES—They have mineralogic properties similar to the Wyoming-type, but show less swelling on account of their contents of calcium, magnesium, aluminium and potassium. Although satisfactory results may be obtained by using metabentonite in canal lining, much more material will be required to secure a reduction in seepage comparable to that obtained with the Wyoming-type bentonite. Fine-ground or unground bentonites may also be satisfactorily used, but they would be required in a greater amount for comparable results.

Silt Lining

The deposition of silt over the wetted area of an unlined canal usually reduces seepage losses significantly. This is a natural process where water carries considerable silt; otherwise, silt is introduced by artificial means in this type of lining. Its effectiveness depends on the suitability of the material, the velocity of water, and the structural formation through which seepage occurs. This type of lining, although satisfactory in some cases, is not as good as other types of earth lining nor is it as permanent on account of the fact that the silt membrane is highly susceptible to attrition at the water surface, puncture, deterioration by weathering and destruction by cleaning operations. However, if the canal sub-grade contains sand and gravel of an open nature, or if seepage occurs through rock seams into which silt particles can penetrate, chances for lasting benefits are good. With less favourable sub-grade conditions, a layer of gravel over the sub-grade before silting operation is recommended to serve as a trap for the silt.

Stone Lining

Stone or rubble masonry linings were more widely used in the past than at present, as a measure to check seepage. They are less useful and more costly. Even in localities where suitable stone is found in abundance, the cost of preparing and placing in most cases makes these linings economically unattractive.

Free Board, Berm and Top Width of Bank

The height of lining above the water surface depends upon a number of factors, such as the size of the canal, the velocity of water, the curvature of alignment, the probability and the amount of storm or drain water entering into the canal, the fluctuation in the water level due to the operation of checks and turn-outs and the wind-action. Similarly the height of the bank above the water surface varies with the size and location of the canal, the type of soil, the amount of intercepted storm or drain water, etc. The usual practice is to provide a berm along each bank at the top of the lining in order to give space for the operation of the construction equipment, like the lining and trimming machines, to receive the material which may wash or slide down from the banks above, and to facilitate maintenance operations. The width varies from two to six feet, depending on the size of the canal. In some cases this berm is backfilled to a slope of about four to one after placing the lining. This serves to drain the intercepted water into the canal and prevent its entering into the sub-grade behind the lining which causes serious hydrostatic pressures.

The top width of banks varies from two to sixteen feet depending primarily on the size of the canal. If the top of the bank is to serve as a roadway, the width should not be less than 12 feet.

The table below gives the minimum recommended free boards and top widths for small canals where the bank is not to serve as a road.

Capacity (in cusecs)	*Free board (in feet)*	*Width of bank (in feet)*
1—9	0.5	2 to 3
10—24	0.5	3 to 4
25—49	0.5	4 to 5
50—99	0.6	5 to 6
100—200	0.75	6 to 7
200—400	1.00	7 to 8
400—800	1.00 to 1.50	8 to 9
800—1600	1.5 to 1.80	9 to 10
1600 and above	2.00	10 to 16

NO. 28.1 EARTHEN LININGS

Specifications

Material used

1. Unless otherwise specified the material for both compacted and uncompacted earthen lining shall be obtained from the concerned canal, structure or channel excavations or from the over-excavated material removed for placing the lining or burrow areas duly approved by the Engineer-in-charge.

Preparation of sub-grade

2. To accommodate earthen lining, the section shall be over-excavated to the lines shown on the approved drawings or as directed in writing by the Engineer-in-charge. The sub-grade shall be approved by the Engineer-in-charge or his authorized representative before the lining is placed.

Placing of earthen lining

3. The impervious material for constructing the compacted earthen lining shall be placed directly from excavation where practicable or shall be placed in stockpiles for later rehandling and placing in the lining. This lining shall be then compacted to the lines and grades as shown in the approved drawing or as directed by the Engineer-in-charge. Having laid the compacted lining, the uncompacted lining shall be placed over it and the section finally dressed up to the lines and grades as shown in the approved drawings for compacted section.

Compaction of lining

4. The earthen lining shall be compacted in conformity with the provisions of the Specifications No. 17.1 (A) for the compaction of earthen embankments.

Measurements

5. The earthen lining shall be measured by volume. The unit of measurement shall be 1000 cubic feet. Measurement shall be made on the same lines as for the over-excavation of the canal for earthen lining.

Rate

6. The unit rate shall include over-excavation of the canal section to accommodate both compacted and uncompacted linings and carry out earthen lining as per above specifications.

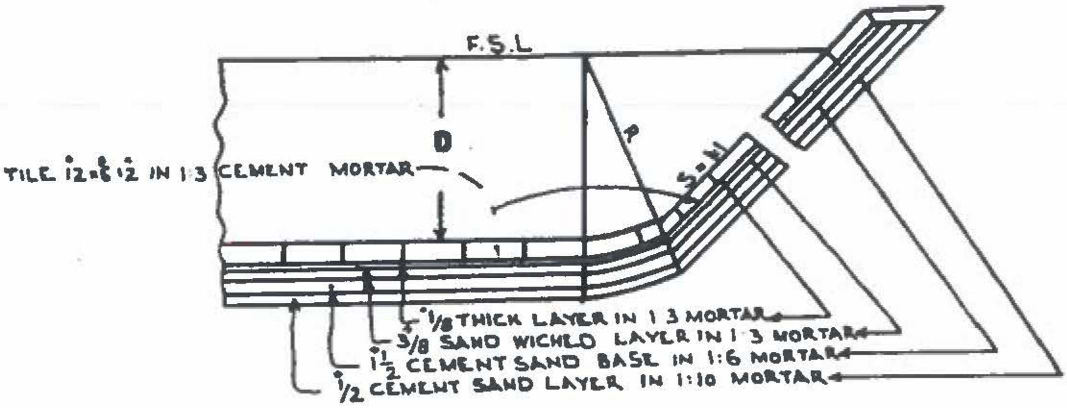
NO. 28.2 SINGLE BRICK OR TILE LINING

Specifications

Composition

1. The lining shall consist of one layer of bricks/tiles placed on a 1½" thick sand base (1 cement to 6 sand) with a 3/8" layer (1 cement to 3 sand) of cement sand mortar sandwiched. The whole shall rest on a ½" thickness of 1:10 cement sand mortar resulting in a section shown below:

SINGLE TILE LINING



Size of bricks/tiles

2. Unless otherwise specified or directed in writing by the Engineer-in-charge the size of the bricks/tiles used in brick-lining shall be 12"×6"×2".

Materials and workmanship

3. Unless otherwise specified or directed in writing by the Engineer-in-charge the brickwork for lining shall conform to Specifications No. 21.1 for bricks in cement mortar and the mortar shall conform to Specifications No. 19.2 for cement mortar.

Preparation of sub-grade

4. (i) Upon completion of the trimming and compacting operations the section of the excavated canal shall conform accurately to the finished dimensions as shown in the drawings or as directed by the Engineer-in-charge in writing.

(ii) The excavated section of the canal shall be trimmed and finished to provide a firm and smooth foundation for brick-lining.

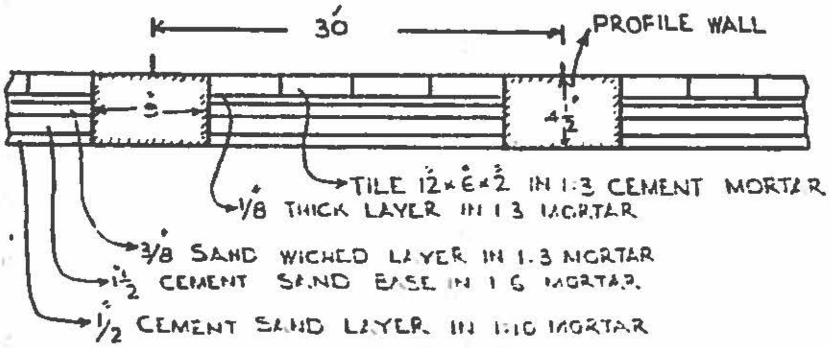
(iii) The entire surface on which brick-lining is to be placed shall be sprinkled with water till the optimum moisture contents for compaction are attained as determined by the Engineer-in-charge or his authorized representative. It shall be compacted by rolling. Rolling shall be performed by using a smooth cylindrical roller. Two passes of the roller over the sub-grade shall be required. Unless otherwise specified or directed by the Engineer-in-charge, the width of a roller drum shall not exceed 4 feet. The weight of the roller drum when fully loaded shall not be less than 50 pounds per linear inch of drum width. A roller may consist of two adjacent drum units, provided that a flexible coupling between drums is used, and that the space between drums shall not exceed 12 inches. Single drum rollers shall overlap each roll by one half the width of the roller, and two drum rollers shall overlap each roll by one half width of the roller plus one foot. No earth filling shall be permitted after the rolling of the sub-grade, and over-excavated or low portion shall be filled with mortar at the expense of the contractor.

(iv) After compaction the entire area to be brick-lined shall be thoroughly sprinkled with water till the finished sub-grade has been penetrated to a depth of 6 inches. The finished sub-grade shall be duly approved by the Engineer-in-charge or his authorized representative before any brick-lining is laid.

Profile wall

5. Unless otherwise specified or directed in writing by the Engineer-in-charge, profile walls shall be constructed 15 feet high centre to centre at right angle to the centre line of the channel on the side slopes and at 30 feet centres on the bed as per sketch given below. A profile wall shall also be constructed parallel to the centre line at each toe of the canal side slopes. The final excavation, trimming and compacting of the section may be performed before or after the completion of the walls. The profile wall shall be laid by means of a theodolite and constructed in accordance with the provisions of the Specifications No. 21.1 of Brickwork.

PROFILE WALL



Placing of lining

6. (i) A layer of 1:10 cement sand hand mixed mortar having an average thickness of ½ inch shall be plastered over the finally finished sub-grade for making up inequalities in the section.

(ii) Immediately over it a 1½-inch thick layer of 1:6 cement sand machine mixed mortar shall be laid. (The mortar used shall have a slump of ½ inch to ¾ inch.) To ensure that the correct thickness of 1½ inches is laid over the whole surface, precast cubes 1:6 cement sand mortar having each side of 1½ inches shall be placed on 1:10 plaster along the centre line of the slabs at right angles to the channel and at 4 feet intervals. The cubes shall be left embedded in the mortar with their tops flush with the surface.

The 1:6 mortar layer shall be lightly rammed with wooden rammer and then trowelled to level out irregularities in the surface. The surface shall be rammed again with wooden rammer having ½-inch long spikes with round ends to make indentations.

(iii) A 3/8-inch thick layer of 1:3 cement sand machine mixed mortar shall be placed over the 1:6 cement sand base. (The mortar used shall have a slump of

2 inches.) To ensure an even thickness, the 1:3 mortar shall be laid in strips 4 feet wide with the help of thin laths $1\frac{1}{2}'' \times \frac{3}{8}''$ and about 18 feet long laid on the 1:6 cement sand base. The 1:3 mortar shall be spread with a trowel and levelled with a straight edge flush with the top of the laths. A day after the mortar is laid, it shall be lightly scraped with wire brushes.

(iv) The next and the final layer shall consist of bricks/tiles. The courses shall be marked on the profile walls and a string shall be stretched to keep them straight. The laying of the bricks/tiles shall commence from the profile wall at the tangent point. The bricks/tiles shall be laid in 1:3 cement sand machine mixed mortar. The thickness of the mortar bedding under the bricks/tiles shall be 1/8 of an inch and the vertical joints between the bricks/tiles shall be 1/4 of an inch thick. All the joints shall be properly filled and to achieve this, the mason shall apply mortar to the sides of the bricks/tiles already laid, lay the next brick/tile 1 inch to 2 inches away and then press it towards the first brick/tile squeezing out the mortar which would indicate that the joint has been filled. Before the bricks/tiles are laid they shall be soaked in water for at least 24 hours in soaking tanks. The mason shall have with him a kerosene oil tin containing water, and the bricks/tiles from the soaking tanks shall be placed in these tins. The mason shall use bricks/tiles only from these tins for his immediate requirements. Strict supervision shall be exercised to see that no unburnt bricks/tiles are placed in the soaking tank and used.

The joints of the work done on the previous day shall be tested with a broad chisel pointed 5/8 inch diameter iron bar. The hollow joints shall be marked with coal tar raked out and filled with the 1:3 cement sand mortar immediately. The brickwork shall be finally brushed and cleaned.

7. Curing of each layer of the following work is necessary.

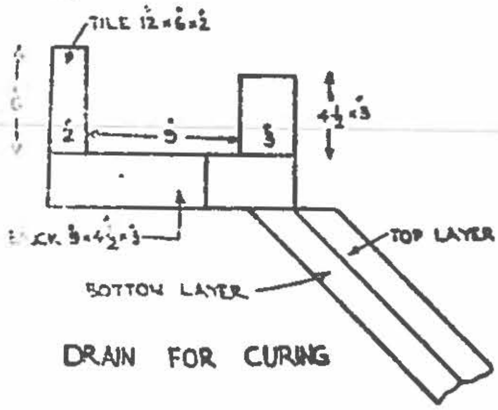
(i) Profile walls.

(ii) Sub-grade $\frac{1}{2}$ inch thick cement sand 1:10 mix.

(iii) Sub-grade $1\frac{1}{2}$ inch thick cement sand 1:6 mix.

(iv) Sub-grade 3/8 inch thick cement sand 1:3 mix.

During summer, curing shall start three hours after the completion of each layer, and during winter the very next day. Curing can be done by covering the layer with water saturated material or by a system of perforated pipes, mechanical sprinklers, porous hoses or pucca drains constructed along the top of the bank as shown in the sketch below:—



DRAIN FOR CURING

The overflow of water shall be effected by a man going along the drain and pushing water by a wooden rod, dipped in the drain. The watering of work shall be carried out on the following lines:—

(a) *Profile Walls.* A day after the walls are built, they shall be covered with jute cloth which is soaked by sprinkling water by hand, till curing can be started from the drain when ready.

(b) *Cement Sand Plaster* 1:10. A day after the mortar is laid, it shall be kept wet by sprinkling water by hand, till it is coverd by the 1:6 cement sand base.

(c) *Cement Sand Base* 1:6. A day after the 1:6 cement sand base is laid, the drain on its top shall be ready and the layer shall be kept thoroughly wet by overflow from this drain. Prior to the completion of the drain and putting it into operation the layer shall be kept wet by sprinkling water by hand.

(d) *Cement Sand Mortar* 1:3. A day after the 1:3 cement sand mortar is laid, it shall be kept soaking wet by water being made to overflow from the drain.

(e) *Brick Masonry:* A day after the masonry is laid it shall be kept wet for 28 days by water being made to overflow from the drain.

Measurements

8. Measurement of brick-lining shall be made of the surface area of the brick-lining and brick profile walls constructed in accordance with above specifications. The unit of measurement shall be 100 cubic feet.

Rate

9. The unit rate shall include the construction of brick-lining in accordance with above specifications or as directed by the Engineer-in-charge. No separate or additional payment shall be made for dressing and compaction of the canal section or for mortar required to fill over-excavation of the canal section.

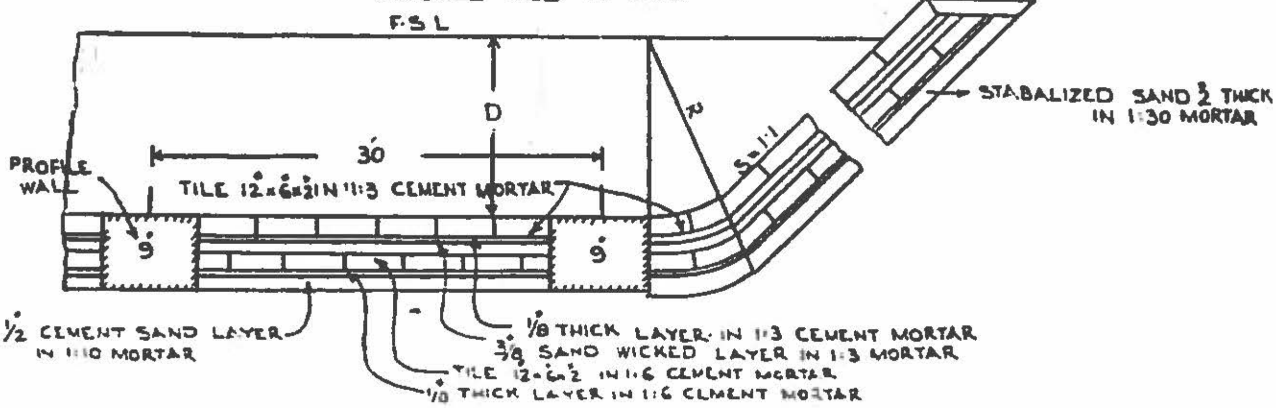
NO. 28.3 DOUBLE BRICK OR TILE LINING

Specifications

Composition

1. The lining shall consist of 2 layers of well burnt bricks/tiles with a 3/8 inch layer of 1:3 cement sand mortar sandwiched by two bricks/tiles. The whole shall rest on ½-inch thickness of 1:10 cement sand mortar resulting in a section shown below:—

DOUBLE TILE LINING



Size of Bricks/ Tiles

2. Unless otherwise specified or directed in writing by the Engineer-in-charge the size of bricks/tiles used in brick-lining shall be 12"x6"x2".

Materials and Workmanship

3. In respect of materials and worksmanship, double brick/tile lining, shall, unless otherwise specified or directed in writing by the Engineer-in-charge, conform to Specification No. 28.2 for single brick-lining.

Preparation of sub-grade

4. In respect of preparation of sub-grade (final trimming and compaction) double brick-lining shall conform to Specifications No. 28.2 for single brick-lining.

Profile

5. In respect of profile wall construction, double brick-lining shall conform to Specifications No. 28.2 given above for single brick-lining.

Placing of lining

6. (i) A layer of 1:10 cement sand hand-mixed mortar shall be applied on the dressed section of the channel. The thickness of mortar shall, on the average, be half an inch and shall make up inequalities in earth dressing. This layer shall be cured for at least 48 hours before the first layer of bricks/tiles is placed.

(ii) Then the first layer of bricks/tiles shall be placed in 1:6 cement sand machine-mixed mortar over 1:10 cement plaster. The thickness of the 1:6 mortar under the bricks/tiles shall be 1/8 of an inch on the average and the vertical joints between the bricks/tiles shall be 1/4 of an inch. To ensure that the bricks/tiles layer is placed level, the courses shall be marked on the profile wall and guided by a string fixed on section of the wall. To fill properly all the joints, mortar shall be applied to the side of the brick/tile already laid in position and then the new brick/tile shall be laid one inch to two inches away and pressed towards the first brick/tile squeezing out the mortar. This will indicate that the joint has been filled.

Before the bricks/tiles are laid they shall be soaked in water for at least 24 hours in the soaking tank. The mason shall have with him a kerosene oil tin containing water and the bricks/tiles from the soaking tank shall be placed in these tins. The mason shall use bricks/tiles only from these tins for his immediate requirement. Strict supervision shall be exercised to see that no unburnt brick/tile is placed in the soaking tank and used.

The joints of the masonry done on the previous day shall be tested with a broad chisel pointed 5/8 inch diameter iron bars. The hollow joint shall be marked with coal-tar, raked out and filled with 1:6 cement sand mortar. Planks, 1½-inch thick shall be provided for placing bricks/tiles and mortar in the bed as well as on the slope for the mason to sit on. The mason shall not sit on masonry or plaster.

Layer of sand-wiched plaster

7. Surface of the first layer of bricks/tiles shall be brushed with wire brushes on the third day. It shall be thoroughly cleaned and wetted. A ¾-inch tlick layer of 1:3 cement sand machine-mixed mortar shall then be applied. To ensure an even thickness, the 1:3 layer of mortar shall be applied in strips, 4 feet wide, by the help of thin laths 1½"x3/8" and about 10 feet long placed on the first layer of tiles. The 1:3 mortar shall be spread by a trowel and levelled by a straight edge flush with the top level of the wooden laths to ensure an evenness of the surafce and thickness of sand-wiched layer. A day after the mortar is laid, it shall be lightly hatched with wire brushes.

Second and final layer of bricks/ tiles

8. The final layer of bricks/tiles shall be placed on 1:3 sandwiched layer of mortar. The courses shall be marked on the profile wall and a string stretched across to keep

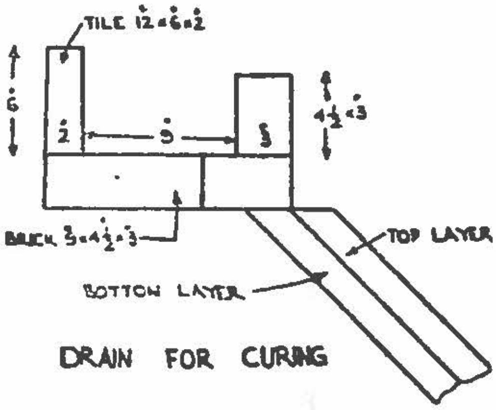
them straight and level. On the slopes brick/tile laying shall commence from bottom upwards. The thickness of 1:3 cement sand mortar for the bricks/tiles horizontal joints shall be 1/8 of an inch and of vertical joints 1/4 of an inch. The surface of the slopes and junction with the beds shall be checked respectively, by long straight-edge and curve checked by the level by an authorized representative of the Engineer-in-charge.

The procedures for the selection and soaking of the tiles, filling and checking the joints, mortar and its preparation, etc., shall conform to specifications for the first layer of bricks/tiles (para 6). The second and the final layer of bricks/tiles shall be finally brushed and cleaned on the third day.

9. Curing of each layer of the following work is necessary and should be carried out as soon as it is completed: **Curing**

(i) Profile wall. (ii) Sub-grade 1-inch thick mortar 1:10 mix. (iii) First layer of bricks/tiles. (iv) Sandwiched layer of cement sand plaster 1:3 mix. (v) Second layer of bricks/tiles.

In hot weather curing shall start three hours after the completion of each layer with a water saturated material or by a system of perforated pipes, mechanical sprinklers, porous hoses or a pucca drain constructed along the top of the bank as shown in the sketch below:—



DRAIN FOR CURING

The overflow of water shall be done by a man going along the drain and pushing water by a wooden rod dipped in the drain. The watering of the work shall be carried out on the follow ng lines.

(a) *Profile Walls.* A day after the walls are built they shall be covered by jute cloth, which is soaked by sprinkling water by hand, till curing can be started from the drain when it is ready.

(b) *Cement Plaster* 1:10. It shall be kept wet by sprinkling water by hand, till the first layer of bricks/tiles has been laid.

(c) *First Layer of Bricks/Tiles.* On the first day it shall be kept wet by sprinkling water by hand, and the next day the drain shall be ready and curing can be started.

(d) *Layer of Sandwiched Plaster* 1:3 *Mix.* On the first day it shall be kept wet by sprinkling water by hand. During the next two days the curing shall be done by drain, till it is covered by a second layer of bricks/tiles.

(e) *Second Layer of Bricks/Tiles.* -On the first day it shall be kept wet by sprinkling water by hand. Afterwards it shall be soaked for the next 28 days by the drain.

10. In respect of measurement and rate, it shall conform to Specifications No. 28.2 for single brick/tile lining. **Measurement and Rate**

Size of Bricks/ Tiles

2. Unless otherwise specified or directed in writing by the Engineer-in-charge the size of bricks/tiles used in brick-lining shall be 12"x6"x2".

Materials and Workmanship

3. In respect of materials and worksmanship, double brick/tile lining, shall, unless otherwise specified or directed in writing by the Engineer-in-charge, conform to Specification No. 28.2 for single brick-lining.

Preparation of sub-grade

4. In respect of preparation of sub-grade (final trimming and compaction) double brick-lining shall conform to Specifications No. 28.2 for single brick-lining.

Profile

5. In respect of profile wall construction, double brick-lining shall conform to Specifications No. 28.2 given above for single brick-lining.

Placing of lining

6. (i) A layer of 1:10 cement sand hand-mixed mortar shall be applied on the dressed section of the channel. The thickness of mortar shall, on the average, be half an inch and shall make up inequalities in earth dressing. This layer shall be cured for at least 48 hours before the first layer of bricks/tiles is placed.

(ii) Then the first layer of bricks/tiles shall be placed in 1:6 cement sand machine-mixed mortar over 1:10 cement plaster. The thickness of the 1:6 mortar under the bricks/tiles shall be 1/8 of an inch on the average and the vertical joints between the bricks/tiles shall be 1/4 of an inch. To ensure that the bricks/tiles layer is placed level, the courses shall be marked on the profile wall and guided by a string fixed on section of the wall. To fill properly all the joints, mortar shall be applied to the side of the brick/tile already laid in position and then the new brick/tile shall be laid one inch to two inches away and pressed towards the first brick/tile squeezing out the mortar. This will indicate that the joint has been filled.

Before the bricks/tiles are laid they shall be soaked in water for at least 24 hours in the soaking tank. The mason shall have with him a kerosene oil tin containing water and the bricks/tiles from the soaking tank shall be placed in these tins. The mason shall use bricks/tiles only from these tins for his immediate requirement. Strict supervision shall be exercised to see that no unburnt brick/tile is placed in the soaking tank and used.

The joints of the masonry done on the previous day shall be tested with a broad chisel pointed 5/8 inch diameter iron bars. The hollow joint shall be marked with coal-tar, raked out and filled with 1:6 cement sand mortar. Planks, 1½-inch thick shall be provided for placing bricks/tiles and mortar in the bed as well as on the slope for the mason to sit on. The mason shall not sit on masonry or plaster.

Layer of sand-wiched plaster

7. Surface of the first layer of bricks/tiles shall be brushed with wire brushes on the third day. It shall be thoroughly cleaned and wetted. A ¾-inch tlick layer of 1:3 cement sand machine-mixed mortar shall then be applied. To ensure an even thickness, the 1:3 layer of mortar shall be applied in strips, 4 feet wide, by the help of thin laths 1½"x3/8" and about 10 feet long placed on the first layer of tiles. The 1:3 mortar shall be spread by a trowel and levelled by a straight edge flush with the top level of the wooden laths to ensure an evenness of the surafce and thickness of sand-wiched layer. A day after the mortar is laid, it shall be lightly hatched with wire brushes.

Second and final layer of bricks/ tiles

8. The final layer of bricks/tiles shall be placed on 1:3 sandwiched layer of mortar. The courses shall be marked on the profile wall and a string stretched across to keep

them straight and level. On the slopes brick/tile laying shall commence from bottom upwards. The thickness of 1:3 cement sand mortar for the bricks/tiles horizontal joints shall be 1/8 of an inch and of vertical joints 1/4 of an inch. The surface of the slopes and junction with the beds shall be checked respectively, by long straight-edge and curve checked by the level by an authorized representative of the Engineer-in-charge.

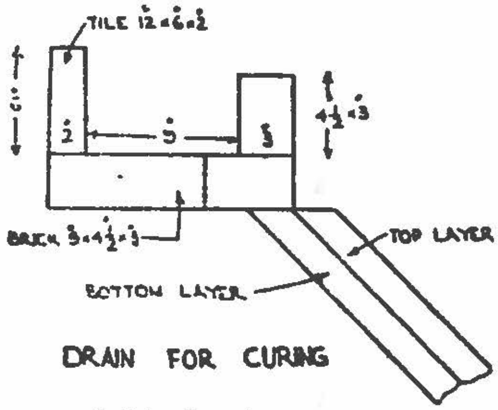
The procedures for the selection and soaking of the tiles, filling and checking the joints, mortar and its preparation, etc., shall conform to specifications for the first layer of bricks/tiles (para 6). The second and the final layer of bricks/tiles shall be finally brushed and cleaned on the third day.

Curing

9. Curing of each layer of the following work is necessary and should be carried out as soon as it is completed:

(i) Profile wall. (ii) Sub-grade 1-inch thick mortar 1:10 mix. (iii) First layer of bricks/tiles. (iv) Sandwiched layer of cement sand plaster 1:3 mix. (v) Second layer of bricks/tiles.

In hot weather curing shall start three hours after the completion of each layer with a water saturated material or by a system of perforated pipes, mechanical sprinklers, porous hoses or a pucca drain constructed along the top of the bank as shown in the sketch below:—



DRAIN FOR CURING

The overflow of water shall be done by a man going along the drain and pushing water by a wooden rod dipped in the drain. The watering of the work shall be carried out on the follow ng lines.

(a) *Profile Walls.* A day after the walls are built they shall be covered by jute cloth, which is soaked by sprinkling water by hand, till curing can be started from the drain when it is ready.

(b) *Cement Plaster* 1:10. It shall be kept wet by sprinkling water by hand, till the first layer of bricks/tiles has been laid.

(c) *First Layer of Bricks/Tiles.* On the first day it shall be kept wet by sprinkling water by hand, and the next day the drain shall be ready and curing can be started.

(d) *Layer of Sandwiched Plaster 1:3 Mix.* On the first day it shall be kept wet by sprinkling water by hand. During the next two days the curing shall be done by drain, till it is covered by a second layer of bricks/tiles.

(e) *Second Layer of Bricks/Tiles.* On the first day it shall be kept wet by sprinkling water by hand. Afterwards it shall be soaked for the next 28 days by the drain.

Measurement and Rate

10. In respect of measurement and rate, it shall conform to Specifications No. 28.2 for single brick/tile lining.

CHAPTER 29

PILES AND PILE DRIVING

GLOSSARY OF TERMS

Anvil — The part of a power-operated hammer which receives the blow of the ram and transmits it to the pile.

Composite Pile — A pile whose length is made up of more than one material, e.g., timber at bottom and concrete at top.

Dolly — A cushion of hardwood or other material placed on top of the helmet to recieve the blows of the hammer.

Driving Cap — A temporary cap placed on top of a pile to distribute the blow over the cross-section and to prevent the head from being damaged during driving.

Drop or Stroke — The distance through which the weight is allowed to fall to strike the head of the pile.

Drop Hammer — A hammer, ram or monkey (which are identical terms) is raised by a winch and allowed to fall by gravity. A single-acting hammer is raised by steam, compressed air, or internal combustion, and allowed to fall by gravity. A double-acting hammer is operated by steam, compressed air, or internal combustion, the energy of its blows being derived mainly from the source of motive power and not from gravity.

Helmet — A temporary steel cap placed on top of a reinforced concrete pile to retain the packing in position and to prevent the head from being damaged during driving.

Pile Bent — A number of piles projecting above the ground up to the bottom of bridge girders. The piles are connected by capping beams on which the bridge decking rests. (Also see under "Trestle bent".)

Ram — The rising and falling part of the hammer which delivers the blow.

Set — The penetraton of the pile per blow during the final stages of driving.

Introduction

Piles are used for the following purposes:

(i) Cut-offs or safety measure against scour under hydraulic structures.

(ii) For coffer dams, holding up the faces of excavations, for quay walls, retaining river or sea banks.

For uses in (i) and (ii) above, steel, wooden or concrete sheet piles are used. Steel piles are generally standardised or patented and are provided with longitudinal interlocking joints for watertightness and are driven with the help of supporting guide piles at intervals. Concrete piles have tongue and groove joints. Timber piles are generally 10 to 12 feet long, 9 to 12 inches wide and 3 inches thick. They are made of

3 planks of 1-inch thickness and bolted together to make a tongue and groove sheetings, or cut from a single plank, and are driven along guide piles which are driven first at intervals of 6 to 10 feet.

The advantages of steel sheet-piling over other forms of piling are that the section of the pile gives greater strength for the same weight and permits them to be driven and easily extracted. But steel sheet-piling is liable to deteriorate owing to the formation of rust. The average rate of corrosion per year is considered 0.003 inch in sea water and 0.002 inch in fresh water. A protective coating of tar or some similar anti-corrosive paint should be applied periodically.

(III) In pile foundation for transmission of load, where the soil under the base of the structure has insufficient bearing power and the soil near the surface is also incapable of supporting a mat foundation.

In foundation two types of piles are used: *bearing piles* and *friction piles*. The load taken by each pile varies with the soil characteristics and the arrangement of the soil layers.

Bearing Piles

These piles are driven through soft strata and go deep to rest on hard surface nd support the load by the resistance developed at their points by end-bearing, and act as long column the effective length of which is considered from 1/3 to 2/3 of the length in ground plus the length projecting above ground. The proportion (1/3 or 2/3) taken depends upon the firmness of the surrounding strata. In no case should the effective length be less than the projecting length plus 5 feet. In these piles the cross-section should be comparatively greater to resist the buckling effect.

Friction Piles

Also called as "floating piles" they are driven into hard strata. They take load on account of the friction of the soil against their surface. For stability they depend on the continued supporting power of the material that surrounds them, and any failure of the material will involve their settlement. In deep deposits of fairly uniform consistency and which are compressed by piles, the load carrying capacity of the single pile depends upon the surface area of the pile. For the same superficial area of the pile surface, a few long piles are more efficient than many short piles. Experiments on various types of the soil have shown that the following friction resistance is offered to the pile surface.

(a) Sand and gravel	1000 to 1800 lbs/square feet
(b) Stiff clay	800 to 1200 lbs/square feet
(c) Clay and sand mixed	400 to 800 lbs/square feet
(d) Dried and compact silt	200 to 300 lbs/square feet
(e) Silt and soft clay	50 to 100 lbs/square feet

The surface area of the pile multiplied by the frictional resistance gives the load which a friction pile would normally carry. Such piles should be long and have a high value for perimeter area ratios.

Timber Piles

These piles are extensively used because they have the advantage of being flexible and light, and in many places they are cheaper than other materials. Their disadvantage is the lack of durability in certain conditions. Durability depends on the type of wood, its moisture content, and its position. In general, timber piles are durable in permanently wet or permanently dry positions, but not where they are alternately wet and dry or where the moisture content is widely variable. Timber piles if used below the ground level last for a very long period; otherwise they do not last longer than 30 years or so and as such are usually preferred for temporary works or semi-permanent marine structures. Timber piles should be impregnated with solignum, creosote or some such preservative. Preservative treatment may not be necessary for piles which are to be completely and permanently submerged in a waterlogged ground in this case seasoning is not required and piles may be stored in water prior to use.

Pakistani timbers suitable for piles are: Teak, Sal, Deodar, Babool, Khair, Ippi, Jamba, Kumbia, Rayani.

These piles should be sound and free from sharp crooks and bends or decay, and sufficiently straight so that a line drawn from the centre of the head to the point at the bottom is wholly whithin the pile.

Timber piles are generally 6 to 16 inches (or even up to 18 inches) in diameter or square in section. Round piles are made of tree trunks whose bark has been stripped off, and square piles are cut from the heartwood of long logs. Their length is not greater than 20 times the diameter (or width) at the top. They either taper throughout the length or the upper half is kept straight and the lower half tapers off to about 6 inches square size. The bottom is shaped conically for a length of from 1½ to 2 times the diameter or about 1 foot 6 inches., and where the ground is hard it is protected with an iron shoe of V shape. Piles protected by shoes should have a blunt end 4 to 8 inches in diameter. The top is provided with an iron ring or band of size 3 inches by ¾ inch to 1 inch to protect it from splintering under the blows of a hammer. After driving, the heads of the piles should be cut off square to sound wood and treated with preservative before capping. For lengthening a timber pile, a piece can be added at the top by straps and bolts. And for increasing frictional resistance, small battens can be fixed on the side lengthwise.

Usual spacing of timber piles is 2½ to 2¾ feet. They must never be driven to "refusal". Piles are considered to be sufficiently driven when five blows fail to drive more than half an inch; or when the last blow does not sink the head more than quarter of an inch. Timber piles forming the foundation of a building should be cut off below the lowest groundwater level. If concrete cap is provided, the piles should be embedded for a depth sufficient to ensure transmission of load. The concrete should be at least 6 inches outside the piles and suitably reinforced to prevent splitting.

TESTING EXISTING TIMBER PILES (IN WATER) FOR DETERIORATION

A small bore made with a carpenter's auger (about ¾ inch in diameter) at the ground line where decay first sets in will disclose rot which is not apparent on the surface. A pointed rod of about the same diameter thrust into the pile will also indicate the position.

Precast Concrete Piles

Precast concrete piles may be divided into two kinds: tapered and parallel sided. They are usually of square, octagonal or hexagonal section since they are easier to cast than the round section. Square piles are most commonly used because they are easy to mould and convenient to drive. Having large superficial area per unit of length they are better than friction piles. Hexagonal piles are favoured for very hard driving, but their shape is inconvenient for moulding. The usual size is 6 to 24 inches, but piles have been made up to 36 inches size with cylindrical holes inside. Hollow piles are used to advantage where exceptional lengths are required; they proivde stiffness and large perimeter with lesser weight than solid piles. For piles larger than 16 inches x16 inches an octagonal section is preferable to a square section. Square piles should have chamfered corners.

The maximum lengths of piles are usually 40 feet for 12 inches square, 40 to 50 feet for 14 inches square, 50 to 60 feet for 16 inches square, and 60 to 70 feet for 18 inches square. It is preferable to keep the lengths less than 40 times the side for friction piles and less than 20 times the side for bearing piles. Where the piles are to act as columns, the maximum load allowed for concrete is 600 lbs and for steel 9,000 lbs. The stresses should be calculated as for ordinary columns. To prevent any damage to the head of a pile, the top edges should be chamfered liberally and additional lateral reinforcement provided and kept back from the head about 2 to 3 inches, according to the diameter.

Concrete piles should be cured for at least one month. Lifting holes should be made at one-fourth to one-fifth the length of the pile from each end and a toggle bolt hole 4 feet from the head at right angles to the lifting hole. One-inch diamater gas pipe ferrules may be fixed in the holes.

REINFORCEMENT FOR CONCRETE PILES

The area of the main longitudinal reinforcement may be 1½ per cent of the gross cross-sectional area of the pile for piles of lengths up to 30 times their least width and 2 per cent for lengths 30 to 40 times, which may be increased to 3 per cent for longer lengths.

One rod is provided at each corner in square piles, and one rod at each angle of octagonal or hexagonal piles. All main longitudinal bars should be of the same length and level at the top and should fit tightly into the pile shoe following the taper of the shoe. Joints in longitudinal bars, if unavoidable, should be made by butt welding or as explained under "Lengthening of R. C. Piles". Transverse reinforcement should be provided in the form of hooks or links of not less than 3/16-inch diamater, or one-quarter the diamater of the main bars, whichever is greater, and the quantity should not be less than 0.4 per cent of the gross concrete volume, spaced not more than half the least width of the pile. The links usually are of ¼-inch diameter up to 40 feet and 3/8-inch diameter above 40 feet and are spaced 2 to 3 inches for lengths up to three times the side at each end of the pile, lengthening to 6 to 8 inches at the centre. The cover over all reinforcment, including binding wire, should not be less than 1½ inches of concrete, but where the piles are exposed to sea water or other corrosive influences, the cover should not be less than two inches any place,

Reinforced concrete piles should be of 1:1½:3, or richer mix, with well-graded aggregate of maximum size limited to ½ inch and a slump of about 1½ inches.

Point of the Piles

For plastic soils a blunt point is suited ranging from no point at all to a diameter at the tip of ¼ of the pile diameter and a length equal to 1½ times the pile diameter. For sand and gravel or where hard strata are to be penetrated, a long tapered point is desirable; the tip may have a diameter of ¼ and a length of three times the pile diameter. Points should have cast steel shoes when penetration is in hard soils.

Lengthening R.C. Piles

Timber trial piles should be driven at various places over the site to ascertain the exact lengths required for the piles. Should the driven piles require to be lengthened, the concrete at the heads should be hacked off till the longitudinal rods are exposed for a length of at least 3 feet. Ferrules or sleeves of water-tubing or similar piping should be placed at the heads of the rods, new lengths butted on, and joints stiffened by fish bars at least 3 to 5 feet long, and this network is well laced by a steel wire. Longitudinal bars are also butt-welded. The old surface of concrete must be well-cleaned and brushed, the column shuttering erected and the additional length cast and allowed to cure; or at least one month before further driving is continued. If steel rods are required to be cut off, it can be done with an acetylene torch.

It is generally advisable to use a heavy monkey and a low fall for R.C. piles. With a final set of ½ inch or below, a 2-ton monkey with a 1½-foot fall or a 30-cwt. monkey with a 2-foot drop might be used where the load on the piles would not exceed 30 tons. For piles designed to carry a load of up to 40 tons with the foregoing final set, a 1½-ton monkey with two feet eight inches drop or a 2-ton monkey with one foot eight inches drop would be most suitable.

Cast-in-situ Piles

These piles are made by driving hollow tubes or heavy steel pipe casings and then withdrawing them or by boring and filling the holes formed with concrete. The tube is placed on top of a loose cast-iron point before it is driven into the ground and is slowly and steadily withdrawn as concrete is filled in. Piles are also formed by driving in steel shells, leaving them permanently there and filling them with concrete. The shells should be strong enough to avoid distortion by soil pressure or by the driving in of adjacent piles. Such piles can be used for lengths up to 70 to 80 feet. They can also be made with bulb toes, giving greater bearing value. There are many patented processes for these piles such as, Franki, Simplex, Vibro. No driving pile should be withdrawn till all piles within 10 feet radius have been driven.

Under normal conditions no reinforcement is necessary, but where required it is placed in the tube before concreting is done. The reinforcement used is made into cages properly wired; the bars are openly spaced; and the lateral ties are not kept closer than six inches centres. The reinforcement is exposed for a sufficient distance to permit it to be adequately bonded into the pile cap. Care is taken to prevent the influx of soil into the casings during boring. Before placing the concrete, the holes are inspected by lowering a light to find out if any undersirable material or water is present. The placing of concrete is not started till all the shells in a group have been driven and, in general, till all driving within a radius of 15 feet has been completed. Bored piles, unless sunk into hard and compact ground, should be test loaded.

Protection against Corrosion

Steel shells which are to be filled with concrete are coated externally with bituminous composition or tar, etc., before they are driven. In other cases all surfaces are coated. If tar is used, it is neutralized with slaked lime.

Screw Piles

A screw pile consists of a shaft with a steel screw blade attached to the lower end. The diameter of the shaft varies from 3 to 10 inches and the blade is 1½ to 5 feet in diameter. When the blade's diameter is 5 feet, it is called a disc pile.

Sometimes there are no blades, and only the shaft is screwed at the bottom. These piles can be screwed down to great depths in clay or similar soils. They also penetrate through small broken stones. The base area of the screw does most of the weight bearing. These piles are useful where shocks of driving other types of piles are injurious to the neighbouring structures. They are screwed down by long bars at the top by using manpower. They are, however, not much used these days.

Raking Piles

The vertical piles have some resistance to lateral loads if driven sufficiently deep into a compact soil. The raking piles are driven to take eccentric loads, and are, generally, in addition to the vertical piles. They can be driven to batter as great as 1 in 4, but on a larger batter, are difficult to drive and the batter tends to increase. As far as possible, the raking piles should be supported during driving right down to the level at which they enter reasonably solid ground. Bearing value of these piles is reduced by about 1 to 6 per cent.

Driving Piles

When the soil is soft to a great depth, the area should be enclosed with sheet piling to consolidate the ground before the main piles are driven. Piles should not be more than 2 per cent out of plumb and not more than 3 inches out of place.

The top of a pile must be cut square so that the impact of the hammer is distributed uniformly, and the pile is driven truly vertical. Where a pile has been driven out of alignment, its head should not be forced back into line unless the ground around the pile (in the direction of the pull) has been first excavated.

The pile driving should always progress away from an existing structure and not towards it. When close to old bents, walls or piers, pile driving should be started leaning slightly away, to prevent the lateral pressure crowding the points over. In the case of a river, it is done in the direction of the river bed.

Pile Hammers

Pile hammers fall into three main categories (i) drop hammers; (ii) single-acting hammers; and (iii) double-acting hammers.

Drop hammers are used for driving all kinds of piles, but are normally used for light and steel sheet piles. They are usually made of cast-iron, have a lifting eye and require a leader guide.

Single-acting hammers are normally steam operated. The ram is raised by the steam, and it drops by gravity when the steam is exhausted. These hammers are usually 2 to 4 tons in weight and have a stroke up to 5 feet.

In the double-acting type, the steam riases the ram and also drives it down to the pile. It delivers more rapid blows which for the small sizes may be as many as 300 per minute, if the hammer weighs less than one ton. The double-acting hammer can be used without a frame.

The weight of the hammer should be at least half the weight of the pile. With precast concrete piles, its weight should not be less than 30 times the weight of one foot of the pile. While using the single-acting or drop hammer for reinforced concrete piles, the stroke should be limited to 4½ feet or less. The weight of the hammer should also be enough to ensure a final penetration of not less than one-tenth of an inch per blow. It is always preferable to employ the heaviest practicable hammer and to limit the drop or stroke so as not to damage the pile.

The weight of the hammer for driving short concrete or wooden piles should be about 5 to 10 cwts. and for big and heavy piles about 2 to 3 tons, which gives about 80 blows per minute through a height of about 3 feet. In case of an uncertainty about the proper weight it is advisable to use a heavier, rather than a lighter, hammer.

A comparatively heavier ram with a short fall is better than a lighter ram with a high fall. The latter has a tendency to shiver the pile rather than forcing it down. A heavy ram with a short fall is the best for sand, and a light ram with a high fall for clay. A greater number of light blows are preferred to a lesser number of heavy blows, especially in sand.

Sinking Piles with the help of Water Jet

Pile driving is sometimes very much facilitated by using a water jet. It avoids very hard driving and vibrations in materials like sand. A jet pipe having a small diameter is taken down by the side of the pile, and the pipe is kept working up and down as required. Water pressure of about 5 to 7 lbs/square inch in sand and 30 to 40 lbs/square inch in clay is considered sufficient. A jet tube can also be cast into the pile and connected with the pile shoe which is provided with jet holes. At least two jet holes are necessary on the opposite sides of the shoe. The jetting pipes should have an internal diameter of not less than 2 inches terminating in a nozzle or fishtail of reduced area. The jetting should be stopped before driving is completed (which should always be finished by ordinary methods). The ground should not, however, be very much disturbed. In case the piles are to be sunk in sand the surface around should be flooded. This proves quite helpful.

Driving Piles without Engine

Where a pile driving engine is not available, the following method can be adopted. An iron rod 2 inches in diameter and 7 to 8 feet long is set about one foot into the centre of the head of each pile truly parallel to the length. A wooden monkey about 10 inches in diameter and 3 feet long is worked up and down this guide rod by labourers who stand on a platform fixed to the pile. The monkey is provided with four handles of three-fourths of an inch iron screwed by wood screws to the block under 2 inches iron rings shrunk on at either end. Down the centre of the monkey is a 2½-inch hole to allow it to slide freely up and down.

Another method is to erect a framework (similar to a tripodal lifting tackle) around the place where a pile is to be driven. A pulley is fixed over the top and the hammer is tied with a rope passing over the pulley and carried to a hand-operated winch. A timber framework is erected round the pile to guide the hammer and the pile and also to keep the pile vertical. This is quite a slow process, and hardly 15 to 20 blows can be given in an hour; thus only one pile may be driven in a day.

Cushions for Pile Heads

In order to avoid the impact of blows which may damage the top of the piles, cushions must be provided for the piles. In case of steam hammers a suitable driving head made of cast-iron is fitted to the top of the pile. A thick packing of felt, bags of the sawdust, gunny bags, old rags, ropes or such like material, are placed over the pile head, and above them on the top of the cast iron driving hood is placed a block of hardwood. The cushion should not normally be more than 3 inches thick. It should give enough protection to the pile head, but should not absorb too much of energy of blow. Two layers of soft wood boarding have also been found satisfactory. Where pile heads are made with the longitudinal bars protruding, the driving head should be designed accordingly; a steel helmet is fitted to the top of the pile and sand is filled in the helmet to form a cushion.

Extracting Piles

Piles can be extracted by the following methods: (a) by a direct pull from a winch in the case of short and easily removable piles; (b) by hydraulic jacks acting on a large grip surrounding the pile; (c) by an inverted double-acting hammer.

The piles to be pulled out should be kept lubricated with water in order to reduce friction of the soil. The pulling force is calculated from the frictional resistance of the soil. The safe uplift strength of friction piles in sand, clay or gravel, is generally taken at half the safe bearing load.

Making Foundations over Piles (Capping)

The pile tops should be extended into foundations of the structure for 6 to 9 inches and embedded in concrete, or a space 6 to 12 inches below the top of the piles and 1 foot outside the piles is excavated and concrete placed around and above the piles. Sometimes concrete is stripped off from the top of the piles for a length of about 2 feet and the rods are bent and incorporated with those of the caps or footings to form a monolithic whole. Steel rods are left protruding over the top of the pile to be embedded subsequently in the foundations. Isolated stanchions or piers supported by fully loaded piles should be preferred for the sake of stability, supported by groups of not less than three piles with pile-caps designed to transmit the load to each pile.

Test Piles

These piles should be of the same material and dimensions as the working piles and driven with the same type of plant. Whenever possible, test piles should be driven and installed near the borings so that the driving records can be studied in conjunction with the samples and the boring records.

These piles should ordinarily be not less than 20 feet long. Necessary observations to determine the supporting capacity of the piles should be made while they are being driven. And from these data the number and length of piles for a particular load can be determined. For a foundation covering a large area, it is good to drive test piles at frequent intervals.

In order to test that piles have been driven to a safe bearing, one of the following conditions is to be met:—

		Weight of monkey	Fall of monkey	Penetration with last blow (average)
Either	1	8 cwts	5 feet	1/5 inch in 30 blows
or	2	15 cwts	15 feet	1/4 inch in 10 blows
or	3	8 cwts	30 feet	1/5 inch in 10 blows

Load Carrying Capacity of Piles

It is very essential to explore the foundation strata before deciding for pile driving and the safe loads that the piles will carry. Resistance of a particular soil to pile driving is not always the correct indication of its load carrying capacity. At places where groundwater levels fluctuate, there may be a considerable variation in the soil resistance, especially in the case of permeable soils (sand, gravel) where water from the adjacent soils may lubricate the sides of the pile. The piles driven into loose fine sands or silts may sustain a much larger steady load than indicated by the final set per blow. Fine sands with some water show premature refusal to driving, sand and water both being incompressible; but after a little rest when the materials have adjusted the piles can be driven further. On the other hand, in the case of clays, a pile shows a higher loading capacity immediately after it has been driven than that which is lowered after few days when the clay particles have been adjusted and are set. In some cases, days are weakened by driving piles through them. Piles driven into clay, if left overnight, will set up and be difficult to start.

Special care and investigation are necessary for the piles driven through soft sensitive clays, since appreciable settlements may occur with piles embedded wholly in clays. In such cases bored piles may be better than driven piles. Occasionally, piles which give a large set under the hammer acquire much greater resistance after a few days rest. Therefore, full load tests should be carried out for all doubtful cases after the piles have been finally driven. The longest practicable time should be allowed to elapse between driving and testing to permit the recovery of soil conditions around the pile. A factor of safety of 2 to 3 is generally allowed. Driving to "refusal" or driving in a manner that obtains an exceedingly small set, should be avoided. In the case of concrete piles cast-in-situ, tests should be carried out by actual loading after 2 weeks of concreting, when it has set. The load at which a pile begins to show settlement should be taken as the ultimate strength of the pile.

Safe Loads

Safe Loads for Timber Piles and Struts
(In tons)

Length in feet	Size				
	4"	6"	9"	12"	15"
6	5.3	13.8	33.5	61.5	97.7
10	4.0	11.5	20.3	57.0	93.2
20	..	7.2	22.0	45.9	79.0
30	..	..	16.2	36.2	64.9
40	..	..	..	28.8	53.8
50	..	..	..	23.6	45.2

Safe Loads for Precast Reinforced Concrete Piles

Size of pile (in inches)	Maximum load (in tons)	Weight of piles shoe (in lbs)	Maximum length (in feet)	Diameter of main bars for length of					
				20'	30'	40'	50'	60'	70'
10x10	20-25	25	30	5/8	3/4	—	—	—	—
12x12	35-40	30	40	3/4	7/8	1	—	—	—
14x14	50-55	40	55	3/4	7/8	1	1 1/8	—	—
16x16	65-75	50	65	—	7/8	1	1 1/8	1 1/4	—
18x18	80-90	60	75	—	—	1	1 1/8	1 1/4	1 3/8

Reduction Factors for Piles Acting as Columns

Reduction Factors

Ratio of l/r	Timber	R.C.	Steel	Cast Iron
0	1.00	—	1.00	1.13
10	0.98	—	0.95	0.94
20	0.95	—	0.89	0.80
30	0.93	—	0.84	0.64
40	0.89	—	0.78	0.50
50	0.82	1.00	0.73	0.39
60	0.72	0.88	0.60	0.31
70	0.61	0.76	0.62	—
80	0.50	0.67	0.57	—
90	0.41	0.59	0.51	—
100	0.34	0.52	0.46	—
110	0.28	—	0.41	—
120	0.24	—	0.36	—
130	0.21	—	0.32	—

l is effective length and r is least radius of gyration.

The least width and cross-sectional area of a taper pile should be based on the dimensions at a point two-thirds of its exposed length from the top of the pile, the exposed length being increased as mentioned above if the top stratum consists of very soft clay or mud.

Piles should not generally be loaded above 15 to 20 tons, except in the case of bridges.

Pile Groups

The load carrying capacity of a group of piles is not always the multiple of the capacity of a single pile. For a group of piles, depending mainly on frictional resistance in cohesive soils, an appreciable reduction in the bearing capacity should be anticipated. In soils which are compressed by piles and have deep deposits of fairly uniform consistency, the computation of pressures should be made on the assumption that the load is spread uniformly at the bottom of the piles for a distance of 0.58 times the length of the pile. (In some soils, the individual bearing capacity is reduced only to one-third.) As this determines the spread of the load owing to the action of the piles, the number of piles required and their spacing under a specific load can be fixed. Piles must have a clear space equal to two diameters of the piles between them in all directions. Test loads should be applied to groups of at least four piles placed at the intended spacing rather than to single piles.

For piles depending mainly on end support in non-cohesive soils, no corresponding reduction in individual bearing capacity may be allowed, while in loose sands and in some silts, the bearing capacity of a group of driven piles may be higher owing to the effect of compaction. This capacity cannot be accurately forecast except by test loadings on the whole group.

Testing Piles for Loads

Ordinarily one-third of the total piles on an area should be tested, but their number should not be less than two piles for the entire site. A suitable platform should be built on top of the pile which has been in place for at least 24 hours after it has been finally driven. The total test load should be twice the proposed working load on the pile—some authorities, however, recommend only one and a half times—which should be put in about four to six increments starting with half the working load. If there is no settlement the next load should be put after about 12 hours. The final load should be allowed to remain for at least 48 hours after there is no settlement.

Determination of Ultimate Bearing Capacity

The bearing capacity is most accurately determined by test loading. The probable bearing capacity in non-cohesive soils (gravels, coarse sands and similar deposits) may be deduced from one of the dynamic pile formulae. However, many of these formulae are very unreliable and should be used with caution. The formulae are not applicable to systems which provide an enlarged base to the foot of the pile.

Formulae

Formulae for determining safe load on piles:—

"Engineering News" Formulae—Due to skin friction:—

For Timber piles: (Not driven to "refusal")

$$R=\frac{2\ W\ h}{S+1.0}$$ for piles driven with freely falling drop hammer.

$$R=\frac{2\ W\ h}{S+0.1}$$ for piles driven with single-acting steam hammer.

$$R=\frac{2h\ (W+Ap)}{S+0.1}$$ for piles driven with double-acting steam hammer.

R=Safe bearing power of the pile in lbs with a factor of a safety of 6; W=weight of hammer in lbs; h=Height of fall of hammer in feet; S=Average penetration in inches (per blow) in the last six blows; A=Area of piston in square inches; p=Mean effective steam pressure in lbs/square inches at the hammer.

For driving heavy piles with light hammers the above formulae were found unsatisfactory and further modifications have been suggested.

The modified formula is:

$$R=\frac{2W\ h}{S+o.1xp/W},$$ P is the weight of the pile.

Sander's Formula for timber piles: $R-\frac{Wh}{8s}$

Dutch Formula for precast concrete piles:

$$R=\frac{W^2h}{n\ (W+w)s}$$

$$R=\frac{4W^2\ wh}{n(W+w)^2}$$ (Modified formula).

R=Safe bearing resistance of piles in tons; W=Weight of hammer in tons; h=Height of drop in feet; s=Set or penetration of piles in feet (per blow); W=Weight of pile in tons; n=is a constant, 4 to 6 for concrete piles, 6 to 8 for timber piles.

Safe loads on isolated single piles or isolated pairs of piles should be reduced to allow for accidental misplacement during driving or inaccurate positioning.

Safe Loads on Piles in Tons

Penetration of piles (in inches)	3 cwt. monkey			6 cwt. monkey			1 ton monkey		
	Height of fall of monkey in feet								
	4	6	8	4	6	8	4	6	8
0.25	0.96	1.44	1.92	1.92	2.88	3.84	6.40	9.60	12.80
0.50	0.80	1.20	1.60	1.60	2.40	3.20	5.33	8.66	10.67
0.75	0.69	1.03	1.37	1.37	2.06	3.74	4.57	6.86	9.10
1.00	0.60	0.90	1.20	1.20	1.80	2.40	4.00	6.00	8.00

Choice of Piles

The choice of the type of pile is governed largely by site conditions. Under normal conditions, a driven pile is usually employed. But where vibrations and noise have to be avoided or where the headroom is limited the use of bored cast-in-place piles is preferable. The bored or driven cast-in-place piles are likely to derive additional carrying capacity when formed in soils such as coarse sand or gravel owing to the friction developed between the tamped concrete and the surrounding soil.

Spacing of Piles

The spacing depends upon the distribution and magnitude of the loads to be carried, the width of the piles, the soil structure and the manner in which the piles transfer their load to the ground. With end-bearing piles, the minimum spacing should not be less than 2 feet 6 inches centre to centre or twice the least width of the piles, whichever is greater. Friction piles should not have spacing less than 3 feet 6 inches or the perimeter of the piles, whichever is greater. For heavy piles, the maximum spacing varies from 5 feet to 7 feet 6 inches. In the case of screw piles, the spacing should not be less than twice the diameter of the screw in soft ground, but may be slightly less in ground of good bearing value. There should be no tendency of the side soil rising up owing to the driving of adjacent piles which is caused by driving closely-spaced piles into relatively incompressible strata, such as clay or dense sand and gravel. Spacings may be closer in loose sand or filling.

Short Board Piles and Beam Foundations

On shrinkable clays, it may be more economical to use short bored piles and beam foundations to support the external walls. This system is suitable on sites where firm to hard shrinkable clays occur. Where such clays do not overlie softer clays and peat, the system is not suitable for very stoney sites. The pile holes are bored to a depth of 8 to 12 feet by an auger. The most suitable hand auger is the bucket type post-hole auger. The average spacing of the piles is about 8 feet, depending upon the locations of doors and windows under which no piles should be bored. Piles should be cast immediately after the hole has been bored and concrete-tipped through a hopper so that no soil falls into the hole. Immediately before placing the concrete the bottom of the hole should be well-punned and also made dry so as to ensure a firm base. The lifts should be about one to two feet deep, and each lift should be thoroughly compacted before the next is poured. A lightly reinforced concrete beam about 12 inches wide and 6 inches deep spans in between and is anchored to the piles. The bottom of the beam trenches should preferably be blinded with ashes or clinker. Reinforcing rods about 4 feet long and ¾ inch in diameter should be set 2 feet in the head of each corner pile and bent over and cast in the beams.

The load carried by a pile depends on the diameter and length of the pile in addition to the type of clay. Sufficient bore-holes should be made to determine the nature of the clay, and in all cases the depth should be 2 feet greater than the anticipated length of the pile, with a minimum depth of 12 feet.

Load Bearing Capacity of Bored Piles

Strength Classifications	Dia. of pile (in inches)	Length of pile (in feet)			
		*6	8	10	12
Firm at 2 feet	10	2 tons	4 tons	5 tons	5 tons
and	12	3 tons		6 tons	7 tons
Stiff at 8 feet	14	4 tons	6 tons	7 tons	8 tons
Stiff at 2 feet	10	2 tons	6 tons	8 tons	—
and	12	3 tons	7 tons	9 tons	—
Hard at 8 feet	14	4 tons	9 tons	11 tons	—

*Six feet piles are advised only for internal situations given adequate shelter by a solid concrete floor.

NO. 29.1 CONCRETE LOAD BEARING PILES

Specifications

General

1.1 All concrete materials and their production, formation, placing, curing and repair under these specifications shall conform to Specifications No. 20.1 for Cement Concrete.

1.2 All fine and coarse aggregate used for concrete under these specifications shall conform to Specifications No. 6.1A & 6.1 B for fine and coarse aggregate respectively.

Manufacture

2. All concrete load bearing piles shall be manufactured in accordance with the details shown on the drawings or as directed by the Engineer-in-charge in writing. Piles shall be cast on level, and tight platforms shall be constructed to prevent settlement during the casting and curing operations. All concrete shall be thoroughly compacted by adequate vibration, spading and rodding during the placing operation, and shall be thoroughly worked around the reinforcement and into the corners of the forms. Vibrations shall be applied uniformly over the entire length of the pile and shall be of sufficient duration to ensure a thorough compaction. Pick-up points and date of casting shall be distinctly marked on each pile.

Dimensions of Piles

3. Unless otherwise specified or directed by the Engineer-in-charge in writing, the dimensions of the piles shall be as shown on the approved drawings.

Placing

4. Piles shall be driven as accurately as practicable in the correct location, true to line both laterally and longitudinally and to the vertical line as indicated on the drawing. A lateral deviation from the correct location at the cut-off elevation of not more than 3 inches shall be permitted. A variation in slope of not more than 2 inches per 10

feet of longitudinal axis shall only be permitted. The correct relative position of piles shall be maintained by the use of template or by other approved means. Any pile driven out of correct locations shall be pulled out and redriven by the contractor at no additional cost. No lateral force of any nature or magnitude shall be permitted to pull a pile into correct position or vertical alignment.

Driving

5. Piles shall be driven by means of a steam hammer or an air hammer or an air hammer of a size and type suitable for the work, as approved by the Engineer-in-charge. The weight of the moving parts of the hammer shall not be less than 8000 pounds, unless otherwise authorized by the Engineer-in-charge. The hammer shall be operated at all times at the steam or air pressure and at the speed recommended by the manufacturer. Boiler or compressor capacity shall be sufficient to operate the hammer continuously at full rated speed. During driving, piles shall be protected by a cushion and cap approved by the Engineer-in-charge. Pile drivers shall have firmly supported leads extending to the lowest point the hammer must reach to drive the piles to cut-off elevation without the use of a follower. Each pile shall be driven continuously and without voluntary interruption till the required depth of penetration has been attained. Deviation from this procedure shall be permitted by the Engineer-in-charge only in case the driving is stopped by causes which could not reasonably have been anticipated. Water jet shall be allowed to be used to assist driving only when specifically authorized by the Engineer-in-charge, who shall grant such permission only where satisfactory driving cannot be obtained otherwise. Where jetting is authorized, the jetting equipment shall be of a type and capacity approved by the Engineer-in-charge. The lowest 3 feet shall, however, be always driven without jetting. Unless otherwise authorized by the Engineer-in-charge, no pile shall be driven within 100 feet of concrete less than seven days old. Unless otherwise specified or directed by the Engineer-in-charge all pile tops shall be driven to cut-off elevation.

Damaged and Misplaced Piles

6. Any pile which is cracked or broken because of internal defects or by improper handling or driving, or which is otherwise injured so as to impair it for its intended use or any pile driven out of proper location, shall be removed and replaced by the contractor at his own expense. The Engineer-in-charge may require the contractor to pull out certain selected piles (up to a maximum of 2 per cent of the total number of the piles driven subject to a minimum of 2 piles) for test and inspection to determine their condition. Any pile so pulled out and found to be damaged to such an extent as, in the opinion of the Engineer-in-charge, would impair its usefulness in the completed structure, shall be removed from the site of the work, and the contractor shall furnish and drive a new pile to replace the damaged one. Piles pulled out and found to be in a sound and satisfactory condition shall be redriven and in such a case payment for both the initial driving, pulling out and redriving shall be made to the contractor.

Cut-off

7. A pile which cannot be driven to the required depth of penetration because of an underground obstruction shall be pulled out, the obstruction removed, and the pile redriven—all at the contractor's expense. If for any reasons it is not possible to drive a pile to the required depth of penetration, the Engineer-in-charge shall determine, whether an acceptable friction bearing capacity has been attained, and, if so, shall permit the contractor to cut the pile off perpendicular to the axis of the pile at the cut-off elevation as shown on the drawing. Otherwise, the contractor shall continue to

drive the pile or pull out and redrive the pile in order to obtain the required depth of penetration. The cut-off method shall be used in a way that does not damage the portion of the pile to be left in place nor the pile reinforcement.

Splicing

8. Piles should be lengthened, when so required, by splicing, after getting approval of the Engineer-in-charge. For this purpose, the longitudinal reinforcement of the pile shall be exposed for a length equal to at least 50 diameters of the bars. If necessary, the concrete shall be cut away to accomplish this. Bars of the same size and of a length sufficient for the required extension shall be fastened to the exposed bars and transverse reinforcement as shown on the drawing for the pile head; concrete cuts shall be made perpendicular to the axis of the pile; and all concrete shall be removed above the elevation of the 50 diameter length cut. Bars shall be lapped for the full length of the bars exposed. Alternatively the splicing can be done by welding the reinforc ment bars, if approved by the Engineer-in-charge. In such cases only enough concrete shall be removed to provide adequate working space for the welding operation.

When reinforcement has been properly placed, by lapping or welding, the top of the pile shall be roughened and the necessary formwork placed. Immediately before pouring concrete, the top of the concrete shall be thoroughly wetted and covered with a thin coat of neat cement mortar. Concrete of the same quality as that used to cast the pile shall then be placed, finished and cured as specified for all piles, except that forms shall remain in place for at least 72 hours after placing the concrete. Driving of a spliced pile shall not be resumed till it is approved by the Engineer-in-charge.

Storage and Handling

9. Storage and handling of the piles shall be executed in a way that does not subject them to over-stress, spalling or other injuries. Piles shall remain undisturbed after casting and shall not be subjected to handling till the specified curing period ends. They shall be lifted by means of a suitable bridle or slings attached to them at the marked pick-up points. Piles which are over-stressed or otherwise injured during curing or handling shall be removed away from the site of work by the contractor at his own expense.

Measurements

10. The length of the piles driven and installed below the cut-off elevation in accordance with the approved drawings and specifications or as directed by the Engineer-in-charge in writing shall be reckoned for the purpose of making payment. The unit of measurement shall be 1 linear foot measured along the axis of the pile.

Rate

11. The unit rate shall include the manufacture, storage, handling, transportation and driving of the concrete piles conforming to above specifications.

(i) At the site of work (to be defined in the conditions of contract).

(ii) Pulling out, removal and replacement of the damaged piles discovered during the process of testing as stated in these specifications.

(iii) Cutting off any pile which the contractor is unable to drive to the required depth of penetration or pulling it out and redriving it in order to obtain the required depth of penetration in accordance with the provisions of these specifications.

(iv) Splicing that may be required under the provisions of these specifications.

The following item shall be paid in addition to the unit rate per linear foot:,

(i) Piles driven to the cut-off elevations, which are pulled out at the direction of the Engineer-in-charge under the provisions of these specifications and found to be in good condition, shall be paid for at the unit rate per linear foot for pulling out and at 50 per cent of the unit per linear foot for re-driving.

NO. 29.2 CONCRETE SHEET PILES

Specifications

1. Unless otherwise specified or directed by the Engineer-in-charge in writing, concrete sheet piles shall be carefully located as shown on the approved drawings in a plumb position, each pile interlocked with adjoining piles for their full length so as to form a continuous diaphragm throughout the length of each run of sheet pile wall. All sheet piles shall be driven as true to the line as practicable by providing suitable temporary walls or guide structure to depths shown on the approved drawing and shall extend to the elevation indicated for the top of piles. In case of structure where watertightness is certified to be necessary by the Engineer-in-charge the following procedure shall be adopted. **Placing**

2. After driving sheet piles to the specified depth the joints between them shall be flushed out by a water jet from a pipe long enough to reach the bottom of the piling. The groove shall then be filled with cement grout composed of one part of cement to two parts of sand to ensure a watertight joint. **Watertight Joints**

3. Where new piling intersects existing pile line, a sufficient quantity of the existing piling shall be extracted to permit the new piling to be installed without a break in continuity or watertightness. Extraction of the existing piling shall be limited to that required for a workmanlike installation of new piling and shall be duly approved by the Engineer-in-charge. **Intersection of Existing Pile Lines by New Piling**

4. In all other respects concrete sheet piling shall conform to the relevant clauses of the Specifications No. 29.1 for Concrete Load Bearing Piles. **Other Respects**

NO. 29.3 MILD STEEL SHEET PILES

Specifications

1. Unless otherwise specified or directed, the type and pattern of mild steel sheet piles shall be as shown on the approved drawings. **Type**

2. The minus tolerance on the pile thickness shall not exceed 2½ per cent. **Tolerance**

Treatment Prior to Driving

3. When considered necessary by the Engineer-in-charge, each pile, before driving, shall receive two coats of non-setting cold applied bituminous material of a consistency that does not run or flow and yet can be easily applied into the interlock. Unless otherwise specified or directed in writing by the Engineer-in-charge, the material for these coatings shall be the same as specified in the approved drawings of the sheet piles.

Driving

4. Unless otherwise specified or directed in writing by the Engineer-in-charge the lay-out of the sheet piled cut-offs shall be as given on the approved drawings. The piles shall be normally driven in pairs with their clutches engaged for their full length and any indication that pile has become bent or a clutch has become disengaged shall require the immediate withdrawal of that pile.- The piles shall be driven vertically to the alignment shown on the approved drawings to true lines and even planes and to the levels indicated. Deviations shall not be greater than 3 inches from this alignment and one degree from the vertical plane, but the junction piles shall be located within one inch. The junction piles shall be provided at all points shown on the approved drawings or where rows of piles meet and shall be of the same length as the longer of the rows joined. If there is any defect in the horizontal or vertical alignment of the piling or a break has actually occurred in the continuity of the piling or is suspected to have occurred such a pile or piles, whether defective or not, shall be withdrawn and new piles driven to remedy the defect or suspected defect. If any distortion, creep or fanning occur in the line of piling, steps shall be taken to rectify the defects and where necessary suitably tapered piles shall be driven to the satisfaction of the Engineer-in-charge or his authorized representative. Driving by jetting shall be done only if approved by the Engineer-in-charge. Care shall be taken to ensure that the jetting does not loosen the soil below the feet of the piles, and for the last 3 feet the pile shall be driven without jetting.

Dimension of Sheet Piles

5. Unless otherwise specified or directed in writing by the Engineer-in-charge, the sheet piles shall be of the dimensions indicated on the approved drawings.

Measurements

6. The mild steel sheet pile shall be measured by weight. The unit of measurement shall be one ton.

Rate

7. The unit rate shall include furnishing sheet piles of an approved make and specified length, stacking and driving them as per above specifications at site of work to be defined in the conditions of contract. No payment shall be made for carrying out remedial measures necessary for driving the sheet piles to the correct depth and in the correct alignment as per above specifications.

Where the sheet piles are supplied by the Government, the unit rate shall include driving the sheet piles as per above specifications at site of work to be defined in the conditions of contract.

RIVER TRAINING AND DIVERSION WORKS

Introduction

River diversion works usually have earthern embankments provided with various precuationary measures to safeguard against percolation, slipping, leakage, erosion, etc. These measures have been described in chapter No. 17. Pilchi-pitching will, however, be explained here rather in detail.

Pilchi-pitching which means the laying of sarkanda, farash or pilchi-rolls as headers and stretchers (as shown in the figure on page) is usually done along slopes of river embankment and on the downstream of falls in the irrigation canals to protect the banks from side erosion and wave-wash.

Rolls used as headers are normally 5 feet long and 6 inches in diameter, while those used as stretchers are 30 feet long and 6 inches in diameter. Pilchi, farash, or sarkanda used for making these rolls must be green and of the best quality locally available. The rolls have to be well-compacted and tightly tied with coarse munjban or binding wire at one foot intervals. The complete process of pitching is described below:—

The lowest layer of rolls is laid as header. These rolls are laid as close to each other as possible in order to get one compact layer of pilchi. They are further secured by laying 30 foot long rolls across them as stretchers and tying them down to position by driving three feet long pegs at five-foot intervals. This is very essential; for otherwise the stretcher roll is liable to slip out on account of wave-wash and bouyancy. The exact location of this stretcher roll depends upon the inner slope of the embankment. It has to be so placed that it is just covered within the slope line as shown in the figure. After placing every layer of header roll a layer of good earth is placed and thoroughly compacted to make it level with the top of the stretcher roll placed over the headers. The process is repeated till the embankment has risen to the desired level. Normally this sort of pitching is done up to a height at least one foot above the full supply level in case of irrigation channels, and three feet in case of river embankments to serve as protection against wave action. The position of the ends of the headers vis-a-vis that of the stretcher rolls as well as the slope line is kept as shown in the figure.

In case of new construction the pitching is done alongwith the embankment, and horizontal layer in the main embankment corresponds with the earthen layers placed between the two consecutive layers of pilchi rolls and is compacted simultaneously. But where the pitching is subsequently done as a remedial measure either of the following course shall be followed:

(i) The inner scoured portion of the embankment is pulled down to accommodate pilchi-pitching. The scoured earth is re-used in building up between the rolls of pilchi.

(ii) Embankment is stepped and pitched. In this case the over-all dimensions of the embankment are increased to add to its stability. This may be comparatively costlier on account of borrowed earth utilized for the purpose.

PILCHI-PITCHING

Specifications

Quality

1. (i) The pilchi, farash or sarkanda used for pitching shall be of the best quality locally available and duly approved by the Engineer-in-charge.

   (ii) It shall be used when it is still green.

Dimensions

2. (i) Unless otherwise specified or directed, pilchi rolls as headers shall be five feet long and six inches in diameter and those used as stretchers 30 feet long and six inches in diameter.

   (ii) The rolls shall be well-compacted and tightly tied with coarse munjban or binding wire at one-foot interval.

Laying

3. (i) The inner side of the embankment shall be cut out to accommodate the pitching or pitching shall be done on the surface of the existing bank strictly as specified or directed in writing by the Engineer-in-charge.

   (ii) Unless otherwise specified or directed, the pitching shall be started from the ground level.

   (iii) The first or the lowest layer of rolls shall be laid as headers and as close to each other as possible in order to get one compact layer of pilchi.

   (iv) The second layer shall consist of stretcher rolls tied down by means of three-foot long pegs at five-foot interval. The stretcher roll shall be so located that it lies just within the inner slope of the embankment.

   (v) After laying header and stretcher rolls a layer of good earth shall be placed and thoroughly compacted to make it level with the top of stretcher roll.

   (vi) The second and subsequent layers of header and stretcher rolls shall then be laid as previously and then process repeated till the pitching has been carried to the specified level.

Measurements

4. The measurements of pilchi-pitching shall be done along the sloping pitched surface of the bank. The unit of measurement shall be 100 square feet.

Rates

5. The unit rate for pilchi, farash or sarkanda pitching shall include:—

   (i) Procurement of green pilchi, farash or sarkanda of approved quality.

(ii) Their cutting and transportation to the site of work by any means of transport approved by the Engineer-in-charge within one mile. Carriage beyond one mile shall be paid separately.

(iii) Making rolls of special dimensions to be used both as headers and stretchers including binding wire or coarse munjban whichever has been specified.

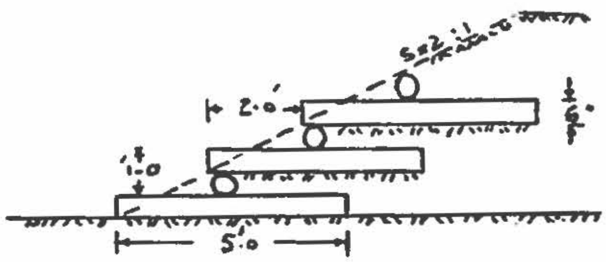
(iv) Laying header and stretcher rolls in position as per above specifications.

(v) Putting three feet long killas in position as specified above.

The unit rate does not include the supply of killas. The cost of placing earth between the rolls shall also be paid separately as earthwork.

(i) Use of farash shall be avoided, if pilchi is available.

(ii) Sarkanda shall be used as a last resort. In case of sarkanda mattress or pitching the distance of pegs shall be reduced as directed by the Engineer-in-charge or his authorized subordinate to check its tendency of floating.



PILCHI PITCHING

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