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6. PRESTRESSED CONCRETE

6.1 SCOPE

This work shall consist of pre-stressing pre-cast or cast-in-place concrete by furnishing, placing and tensioning of pre-stressing steel in accordance with details shown on the plans, and as specified in these specifications or as directed by the Engineer-in-Charge.

This work shall also include the furnishing and installation of any appurtenant item necessary for the particular pre-stressing system to be used, including but not limited to ducts, anchorage assemblies and grout used for pressure grouting ducts.

6.2 MATERIAL REQUIREMENTS

6.2.1 HIGH TENSILE WIRE

Pre-stressing steel (Cables) shall be high-tensile wire conforming to ASTM Specification A-421 or AASHTO Designation M-204, strand or rope conforming to ASTM Specification A-416 or AASHTO Designation M-203 or high tensile alloy bars as follows:-

High tensile strength alloy bars shall be stress relieved and cold stretched to a minimum of 9,100 Kg/Sq.cm. After cold stretching the physical properties shall be as follows:-

1.	Minimum Ultimate tensile strength	16,570 Kg/Sq.cm
2.	Minimum yield strength, measured by the 0.7 percent extension under load method shall be not less than	9,100 Kg/sq.cm
3.	Minimum modulus of elasticity	1.75x10 Kg/sq.cm
4.	Minimum elongation in 20 bar dia meter	4%
5.	Diameters after rupture	- 0.75 mm
6.	Diameters tolerance	- 0.25 mm

Table6.1 Areas, Strength and initial Tensioning load for Pre-stressing steels

Type	Minimum Tensile Strength (ksi)	Nominal Diameter (inch)	Nominal Area ($Inch^2$)	Ultimate Strength (Kips)
Grade 250 Seven-Wire Strand	250	0.250	0.03356	8.9
		0.313	0.0578	14.5
		0.375	0.0799	20.0
		0.437	0.1089	27.2
		0.500	0.1438	36.0
Grade 270 Seven-Wire Strand	270	0.250	0.03356	9.6
		0.313	0.0578	15.6
		0.375	0.0799	21.6
		0.437	0.1089	29.4
		0.500	0.1438	38.8
Stress Relieved Solid wire	250	0.192	0.0290	7.25
	235	0.276	0.0598	14.05

Type	Minimum Tensile Strength (ksi)	Nominal Diameter (inch)	Nominal Area ($Inch^2$)	Ultimate Strength (Kips)
Alloy steel bars (Regular)	145	0.750	0.442	64
		0.875	0.601	87
		1.000	0.785	114
		1.125	0.994	144
		1.250	1.227	178
		1.375	1.485	215
Alloy steel bars (Special)	160	0.750	0.442	71
		0.875	0.601	96
		1.000	0.785	126
		1.125	0.994	159
		1.250	1.227	196
		1.375	1.485	238

The steel shall be free from injurious defects and shall have a smooth surface. Material, which shows injuries defects during or prior to its installation in the work, shall be rejected.Wire and strand shall be supplied in coils of sufficient diameter to ensure that they lie out straight.

The Engineer-in-Charge may call for a relaxation test on pre-stressing steel in case, he is not satisfied with the source of manufacture. Relaxation for pre-stressingsteel shall be measured over a period of thousand (1000) hours stressed at seventy (70) percent of its ultimate tensile strength giving less than six (6) percent elongation.

6.2.2 TESTING

General

All wires, strands, or bars to be transported to the site shall be assigned a lot number and tagged for identification purposes. Anchorage assemblies to be transported shall be likewise identified.

All samples submitted shall be representative of the lot to be furnished.

All of the materials specified for testing shall be furnished free of cost and shall be delivered in time for tests to be made well in advance of anticipated time of use.

The contractor shall furnish for testing the following samples selected from each lot as ordered by the Engineer-in-Charge. The selection of samples shall be made at the manufacturer's plant by the Engineer-in-Charge or his representative.

a) **Pre-tensioning Method**

Samples at least 2.1 meter long shall be furnished of each wire, or strand size. A sample shall be take from each and every coil.

b) **Post-tensioning Method**

Samples of the following lengths shall be furnished.

For wires, sufficient length to make up one parallel lay cable one and half (1.5) M long consisting of the same number of wires as the cable to be furnished. For strands, one and half (1.5) M length shall be furnished.For bars to be furnished with threaded ends and nuts, one and half (1.5) M between threads at end.

c) **Anchorage Assemblies**

Two anchorage assemblies of each size of anchorage to be used shall be furnished, complete with distribution plates.The RCC precast end block where used shall be of reinforced concrete manufactured in accordance with the provisions of Section 5 – Plain & Reinforced Concrete.

6.3 CONCRETE

The materials for concrete shall conform to the requirement of relevant section and shall be of 5000 psi cylinder strength unless otherwise shown on the plans. The estimated volumetric batching for 5000 psi cylinder strength could be 1:0.75:1 subject to confirmation by trial mix.

6.4 REINFORCEMENT STEEL

Reinforcement steel shall be as specified on drawings shall conform to the provisions of Section 5.4 – Concrete Reinforcement.

6.5 CONSTRUCTION REQUIREMENTS

6.5.1 GENERAL

Unless otherwise ordered by the Engineer-in-Charge, the Contractor shall certify for the Engineer-in-Charge's approval that a technician skilled in the approved pre-stressing method will be available to the Contractor to give aid and instruction in the use of the pre-stressing equipment to obtain the required results.

The tensioning process shall be conducted so that the tension being applied and the elongation may be measured at all times.During the pre-stressing operations, standing behind or under jack will not be allowed in order to ensure that no one is injured by the flying spindle, tendon or the jack in the event of a break occurring.

6.5.2 PRE-STRESSING METHOD

The pre-stressing system shall be as shown on drawings and indicated in the tender. The Contractor may opt for the alternate method of pre-stressing to be used, provided he introduces no change in the position of centroid of the total pre-stressing force over the length of the member and in the magnitude of the final effective pre-stressing force as prescribed in the Drawings. The alternate option shall be subject to all requirements hereinafter specified.

a. The safety of the anchorage of the pre-stressing tendons and their suitability for the transmission of forces to the concrete under all loads whatsoever.
b. That the actual losses due to friction coincide with the calculated ones for the pre-stressing.
c. The suitability of the proposed steel for the chosen pre-stressing system.
d. The length of transmission of the force to the concrete and the minimum strength of the latter necessary for pre-stressing in systems, where the pre-stressing elements are fully or partially anchored to the concrete through bond and friction.
e. The suitability of measures taken to protect pre-stressing tendons from corrosion until the final tensioning is carried out.

The Contractor shall submit well in advance to the Engineer-in-Charge for approval complete details of the methods, materials, and equipment he proposes to use in the pre-stressing operations. Such detail shall outline the method and sequence of stressing, complete specifications and details of the pre-stressing steel and anchoring devices

proposed for use, anchoring stresses, type of enclosures, and all other data pertaining to the pre-stressing operation, including the proposed arrangement of the pre-stressing units in the members.

An agreement certificate for the pre-stressing system shall be submitted and approved by the Engineer-in-Charge before any structural member to be pre-stressed may be tensioned, this agreement certificate must be issued by an authorized testing laboratory otherwise the Engineer-in-Charge may order such an agreement certificate from a laboratory of his choice at the cost of the Contractor. All rules referring to this agreement certificate here in after are subject to the approval of the Engineer-in-Charge.

6.5.3 PRETRESSING EQUIPMENT

Hydraulic jacks shall be equipped with accurate pressure gauges. The contractor may elect to substitute screw jacks or other types for hydraulic jacks. In that case, proving rings or other approved devices shall be used in connection with the jacks. All devices, whether hydraulic jack gauges or otherwise, shall be calibrated so as to permit the stress in the pre-stressing steel to be computed at all times. A certified calibration curve shall accompany each device. Safety measures shall be taken by the Contractor to prevent accidents due to possible breaking of the pre-stressing steel or the slipping of the grips during the pre-stressing process. All equipments shall be thoroughly washed with clean water at least once every three (3) hours during the grouting operations and at the end of use for each day.

6.5.4 ENCLOSURES

Enclosures for pre-stressing steel shall be accurately placed at locations shown on the plans or approved by the Engineer-in-Charge.

All enclosures shall be of ferrous metallic material and shall be completely mortar-tight with the exception that the contractor, at his option, with the approval of the Engineer-in-Charge, may form the enclosures by means of cores or ducts composed of rubber or other suitable material which can be removed prior to installing the pre-stressing reinforcement. Enclosures shall be strong enough to maintain their shape under such forces as will be imposed upon them. They shall be six (6)mm larger in internal diameter than the bar, cable, strand or group of wires, which they enclose. Where pressure grouting is specified, cores or ducts shall be provided with the pipes or other suitable connection for the injection of grout after the pre-stressing operations have been completed.

6.5.5 PLACING STEEL (WIRES)

All steel units shall be accurately placed in the position shown on the Drawings or required by the Engineer-in-Charge and firmly held during the placing and setting of the concrete.

Distance from the forms shall be maintained by stays, blocks, ties, or hangers approved by the Engineer-in-Charge. Blocks for holding units from contact with the forms shall be precast mortar blocks of approved shape and dimensions. Layers of units shall be separated by mortar blocks or other equally suitable devices. Wooden blocks shall not be left in the concrete.

Suitable horizontal and vertical spacers shall be provided, if required, to hold the wires in place in true position in the enclosure.

6.5.6 PLACING CONCRETE

Concrete shall be controlled, mixed, and handled as specified in Section 5 - Plain & Reinforced Concrete unless otherwise specified herein.

Concrete shall not be poured in the forms until the Engineer-in-Charge has inspected the placing of the reinforcement, conduits, anchorages, and pre-stressing steel and has given his approval thereof.

The concrete shall be vibrated internally or externally, or both as ordered by the Engineer-in-Charge. The vibrating shall be done with care in such a manner as to avoid displacement of reinforcement, conduits, or wires.

6.5.7 PRETENSIONING

The pre-tensioning elements shall be accurately held in position and stressed by jacks. A record shall be kept of the jacking force and the elongation produced thereby. Several units may be cast in one continuous line and stressed at one time. Sufficient space shall be left between ends of units, if necessary, to permit access for cutting after the concrete has attained the required strength. No bond stress shall be transferred to the concrete, nor end anchorages released, unit the concrete has attained a compressive strength, as shown by cylinder tests, of at least two hundreds and eighty (280) Kg/sq.cm, and as approved by the Engineer-in-Charge. The elements shall be cut or released in such an order that lateral eccentricity of pre-stress will be minimum.

6.5.8 POST-TENSIONING

Tensioning shall be carried out only in the presence of the Engineer-in-Charge or his representative unless permission has been obtained to contrary. Immediately before tensioning, the contractor shall prove that all tendons are free to move between jacking points and that members are free to accommodate the horizontal and vertical movements due to the applications of pre-stress.

Tensioning of pre-stressing reinforcement shall not be commenced until tests on concrete cylinders, manufactured of the same concrete and cured under the same conditions, indicate that the concrete of the particular member to be pre-stressed has attained a compressive strength of at least 280 Kg/sq.cm by cylinder tests.

After the concrete has attained the required strength, the pre-stressing reinforcement shall be stressed by means of jacks to the required tension and stress transferred to the end anchorage(s). Stressing shall be from both ends unless otherwise required in the Contract or agreed by the Engineer-in-Charge. The tensioning process shall be so conducted that the tension being applied and the elongation of the pre-stressing elements may be measured at all times. The friction loss in the elements, i.e. the difference between the tension at the jack and the minimum tension in the pre-stressing steel shall be determined by the formula.

$$F\mathrm{T} = 2\left(1 - \frac{a.c.E}{d}\right)$$

Where

F_T = total friction loss

F1 = observed tension at the jack

a = cross sectional area of the pre-stressing element

c = observed elongation of the element when the force at the jack is F1.

E = secant modules of elasticity of the element for stress F1 as determined from the stress-strain diagram of the element.

D = Distance from the jack to the point of lowest tension in the element. Where jacking is done from both ends of the members, the point ofminimum tension

is the center of the member. Where jacking isdone from one end only. D is the distance to the other end of the member.

Any surplus length of tendon shall be cut off by an approved method which will not affect the strength of the stressed tendon, with particular care if the use of spark erosion or oxyacetylene burning methods of cutting are approved by the Engineer-in-Charge.
A record shall be kept of gauge pressures and elongation at all times and submitted to the Engineer-in-Charge for his approval within twenty four (24) hours of each tensioning operation. The tendons shall be maintained in such a condition that they can be re-stressed until the Engineer-in-Charge has given final approval after inspecting the tensioning log.

6.5.9 GROUTING OF BONDED STEEL

Post-tensioned pre-stressed bridge members preferably shall be of the bonded type in which the tensioned steel is installed in holes or flexible metal ducts cast in the concrete and bonded to the surrounding concrete by filing the tubes or ducts with grout. The grout shall be a mixture of cement and fine sand (passing a No. 30 sieve) in the approximate proportion of one part cement to 0.75 part sand or as specified, the exact proportions to be adjusted to form a grout having the proper consistency and under no circumstances, shall be the water cement ratio exceed 0.45. The compressive strength of the hardened grout shall not be less than one hundred and seventy (170) Kg/sq.cm after seven (7) days at a temperature of 18^{o}C, when making preliminary trials for quality. The grout shall be mixed for a minimum of two (2) minutes and until a uniform consistency is obtained.

All pre-stressing reinforcement to be bonded shall be free of dirt, loose rust, grease, or other deleterious substance. Before grouting, the ducts shall be free of water, dirt or any other foreign substance. The ducts shall be blown out with compressed air until no water comes through the duct. For long members with draped strands an open tap at the low point of the duct may be necessary.The grout shall be fluid (consistency of thick paint) but proportioned so that free water will not separate out of the mix. Unpolished aluminum powder may be added in an amount per sack of cement as approved by the Engineer-in-Charge. Commercial plasticizers in accordance with the manufacturer's recommendation may be used provided they contain no ingredients that are corrosive to steel. Sufficient pressure shall be used in grouting to force the grout completely through the duct, care being taken that rupturing of the ducts does not occur.

6.5.10 HANDLING

Precast pre-stressed concrete members shall be transported in an upright position and the points of support with respect to the member shall be approximately the same during transportation and storage as when the member is in its final position. In the event that the Contractor deems it expedient to transport or store precast girders in other than this position it should be done at his own risk.Care shall be taken during storage, hoisting, and handling of the pre-casting units to prevent cracking or damage. Units damaged by improper storing or handling shall be replaced by the Contractor at his expense.

Pre-stressed structural members shall be constructed in conformity with the drawings governing the particular type of structure to be built or as required by the Engineer-in-Charge.

6.5.11 MANUFACTURE OF PRESTRESSED MEMBERS OFF THE SITE

i) The details of the method of manufacture shall be approved by the Engineer before work is started. When the method has been approved, no changes shall be made without the consent of the Engineer-in-Charge.

ii) The Contractor shall inform the Engineer-in-Charge in advance of the date of commencement of manufacture and the dates when tensioning of tendons, casting of members and transfer of stress will be undertaken for the first time for each type of beam.

iii) The Contractor shall send to the Engineer-in-Charge not more than seven (7) days after the transfer of stress, a certificate showing the force and strain in the tendons immediately after they were anchored, the strength and age of the test cubes in accordance with specified procedure and the minimum age in hours of the concrete at the time the stress was applied to the member. A copy of all twenty eight (28) days cube or cylinder test results relating to the work shall be sent to the Engineer-in-Charge as these become available. Records shall be kept so that the identity of those who stress the tendons, cast the concrete and transfer the stress on any member or line of members can be traced.

iv) Where the Engineer-in-Charge's Representative requires tests to be carried out, no beams to which the test relate shall be dispatched to the site until the tests have been satisfactorily completed.

6.5.12 Composite Slab Bridges

a) The manufacturing tolerances for the precast members shall nowhere exceed those given for the length, cross section and straightness in BS Code of Practice CP 116 (1969),"the structural use of precast concrete". In addition, where beams are laid side by side in a deck:

   i. The difference in soffit level between adjacent units before the in situ concrete is placed shall nowhere exceed five (5) mm for units up to five (5) meters nor ten (10) mm for longer units.
   ii. The width of the deck soffit shall be within plus twenty five (+ 25) mm of that described in the Contract.
   iii. In adjacent spans, the continuity of line of the outside beams shall be maintained.
   iv. The width of the gap between individual beams shall not exceed twice the nominal gap described In the Contract.
   v. The alignment of transverse holes shall permit the reinforcement or pre-stressing tendons to be placed without distortion.

b) The in-situ concrete shall be placed in such a sequence that the advancing edge of the freshly deposited concrete over the full width of deck or between longitudinal construction joints is approximately parallel to the deck supports.

c) Beams shall be prevented from moving laterally during the placing of the in-situ concrete.

6.5.13 SAMPLING AND TESTING

a) **Testing of Pre-tensioned Beams**

i) Any beam required by the Engineer-in-Charge to be subjected to a load test will be selected after transfer and wherever possible before the beam has been removed from the casting yard to the storage area. The Contractor shall not proceed with a load test until he has obtained the approval of the Engineer-in-Charge to the detailed arrangement. Except where otherwise agreed by the Engineer-in-Charge, the load test shall be carried out not less than twenty eight (28) days after casting. The cost of the load test shall be borne by the Contractor.

ii) The beam shall be supported at its design points of bearing. The specified test loads shall be applied equally at the third points of the span in not less than ten (10) approximately equal stages. The maximum load shall be sustained for five (5) minutes and then removed in not less than five (5) approximately equal stages. The mid-span deflection relative to a straight reference line joining the points of support shall be measured for each value of the load and five (5) minutes after removal of the load.

iii) Loads shall be measured with an accuracy of ± two (2) percent or 50 Kg and deflections with an accuracy of ± decimal five (0.5) millimeter.

iv) The load deflection graph shall be plotted from these values and shall show no appreciable variation from a straight line. If after five (5) minutes of removal of the load the beam does not show a recovery of at least ninety (90) per cent of the maximum deflection recorded during the test, the test loading shall be repeated. The beam shall be considered to have failed the test if the recovery five (5) minutes after removal of the test load for the second time is not at least ninety (90) per cent of the maximum deflection recorded during the second test.

v) The result of the test shall be deemed to apply to the other beams cast in the same production line but in the event of failure any additional beam may be separately tested at the contractor's option.

vi) The contractor shall supply to the Engineer-in-Charge record sheets of the test showing the age of the beam at the time of the test, loads, deflections, load-deflection curves and calculated value of Young's Modules of Elasticity (E).

vii) In addition, the record sheets supplied by the Contractor to the Engineer-in-Charge shall show the temperatures of the top and bottom surfaces of the beam measured at the time of the test.

b) **Testing of Pre-stressing Anchorages**

Anchorages for post tensioning shall be tested in accordance with the procedure described in BS4447 or as approved by the Engineer-in-Charge. For each anchorage system used in the Works, the characteristic value for anchorage efficiency shall be not less than ninety (90) percent.

6.5.14 CURING CONCRETE

a) **General**

For all pre-stressed concrete operations the curing procedures shall be well established and properly controlled. Curing shall be commenced immediately following initial set or completion of surface finishing Members shall be kept wet during the entire period of curing.

b) The curing shall conform to the procedure referred in Sub-clause 5.3.7 of Section 5 – Plain & Reinforced Concrete and as approved by the Engineer-in-Charge.

6.6 MEASUREMENT AND PAYMENT

6.6.1 COMPOSITE RATE

The measurement and payment for the items of the work of Brickwork hereof shall be made corresponding to the applicable CSR items as provided in Contract Agreement and shall constitute full compensation, for procurement, transportation, performance in all respects and completion of work as specified including the site clearance as approved by the Engineer-in-Charge.

6.6.2 LABOUR RATE

The measurement and payment for the items of the work of Brickwork hereof shall be made corresponding to applicable CSR item as provided in Contract Agreement and shall constitute full compensation for procurement transportation, performance in all respects and completion of work as specified including site clearance, as approved by the Engineer-in-Charge except the cost of materials to be provided by Department at designated location as defined in the Contract Agreement.

6.6.3 QUANTIFICATION

The unit of measurement shall be measured as mentioned below in accordance with corresponding CSR items.

1. For Volumetric items, the unit of measurement shall be cubic meter or cubic foot
   Item No.:6-4(d& e), 6-15, 6-17 and 6-18
2. For surface area items, the quantity of work shall be measured by surface area. The unit of measurement shall be Square Meter or Square foot. Following items of CSR are measured according to this criteria;
   Item No.:6-13 and 6-14
3. For linear items, the quantity of work shall be measured linearly along centre line of structure. The unit of measurement shall be running meter or running foot. Following items of CSR are measured according to this criteria;
   Item No.: 6-1 to 6-3, 6-5, 6-7, 6-9 and 6-10
4. For bulk items, the quantity of work shall be measured in units of weight i.e. Tonne or Tons. Following items of CSR are measured according to this criteria;
   Item No.: 6-A, 6-5, 6-11 and 6-12;
5. Following item of CSR shall be measured as Cable;
   Item No.: 6-6
6. Following item of CSR shall be measured as Cable End;
   Item No.: 6-8
7. Following item of CSR shall be measured as One Job;
   Item No.: 6-16
8. Following items of CSR shall be measured as Wire;
   Item No.: 6-19 and 6-20
9. Following items of CSR shall be measured as Set;
   Item No.: 6-4(a,b &c)