

S.06: PRESTRESSED CONCRETE

Structural concrete containing prestressed steel reinforcement to introduce pre-compression is termed as prestressed concrete.

6.1 General

The work shall be carried out in accordance with the drawings and these specifications or as approved by the Engineer.

Concrete and un-tensioned steel for the construction of pre-stressed concrete members shall conform to the requirements of sections respectively in so far as the requirements of these Sections apply and are not specifically modified by requirements set forth herein.

Contractor shall ensure that different components of pre-stressing system such as jacks, bearing plates, wedges, anchorages, strands and HDPE ducts are compatible to each other and the data regarding the same shall be exchanged in between all the suppliers **to ensure the same.**

6.2 Materials**A. Sheathing**

Material for all pre-stressing sheathing duct shall be HDPE in the form of corrugated. The thickness of the HDPE sheathing ducts shall conform to IRS Concrete Bridge Code-1997 & IRC -112:2020).

- i. The minimum wall thickness of the duct as manufactured shall be 2.0 mm, 2.5 mm, 3.0 mm and 4.0 mm for ducts of internal diameter upto 50 mm, 85 mm, 100 mm and 125 mm respectively. Linear interpolation may be done for any intermediate values.
- ii. Tolerance for duct diameter is $\pm 1\%$ or ± 1 mm, whichever is greater. Tolerance for wall thickness shall be $-0/+0.5$ mm.
- iii. The minimum residual wall thickness after loss in the compression test as per clause B1-2 at Appendix B1 of IRS CBC-1997 with latest correction slips, shall not be less than 1.5 mm for ducts upto 160 mm outer Diameter.
- iv. The material for the ducts shall be high-density polyethylene with more than 2 percent carbon black to provide resistance to ultra-violet degradation and shall have the following properties as mentioned in table below unless otherwise specified:

Property	Unit	Applicable Standard	Temperature	Acceptance Values	
				Min	Max
Carbon content	%			e	
Density	gm/cc	IS2530	23 ° C	0.94	0.96
Tensile strength at Yield	MPa	BS EN ISO 527-3		20	
Shore 'D' Hardness		IS 13360 (Part 5 /Section 11)		a. 3 Sec b. 15 Sec	: 60 : 58
Elongation at Yield	%	BS EN ISO 527-3		7	
Melt Flow Index (MFI)	g/10 minutes	IS:2530	190 ° C under a mass of 5 kg	0.5	1.2

Environmental Stress Crack Resistance	Hrs	ASTMD-1693	70 ° C	192	
Coefficient of Thermal Expansion for 20 °C - 80 ° C	/ ° C	DIN 53 752		1.50×10^{-4}	
Charpy impact strength of notched specimen (i) at 23 ° C (ii) at -40 ° C	kJ/m ²	BS EN ISO 179		1.0kJ/m ² 4 kJ/m ²	

- v. The ducts shall be corrugated on both sides. The duct shall transmit full tendon strength from the tendon to the surrounding concrete over a length not greater than 40 duct diameters. Material and formulation of sheathing ducts shall conform to test and acceptance criteria of IRC-112:2011.
- vi. The sheaths shall be sufficiently watertight to prevent concrete laitance penetrating in them in quantities likely to increase friction. Special care shall be taken to ensure water-tightness at the joints
- vii. The alignment of all sheaths and extractable cores shall be correct to the requirements of the drawings and maintained securely to prevent displacement during placement and compaction of concrete. The permissible tolerance in the location of the sheaths and extractable cores shall be 5 mm. Any distortion of the sheath during concreting may lead to additional friction.
- viii. Sheathing ducts shall be joined by adopting any one or more of the following methods, as convenient to suit the individual requirements of the location, subject to satisfactory pressure tests before adoption and approval of Engineer.
 - Using Corrugated threaded sleeved couplers which can be tightly screwed together with male and female threads
 - Jointing with thick walled HDPE shrink couplers with glue. This can also be used for connection with trumpet etc.
 - Welding with electro fusion couplers/Heat Shrink Couplers..
- ix. The joints shall be able to withstand an internal pressure of 0.5 bar(0.05 Mpa) for 5 minutes as per **water loss test procedure** given in Clause-B-7 at Appendix-B of IRS Concrete Bridge Code- 1997
- x. The initial acceptance tests such as bond test, compression test for loss of wall thickness are required to be performed as part of acceptance criteria for system.
- xi. In addition to above, the HDPE ducts supplier must have conducted friction test at least once as given in FIP bulletin No-7 to establish/confirm the friction values (K & u) using the HDPE ducts produced by them, submit the test details and obtain approval prior to commencing supplies .
- xii. The routine test such as workability test, transverse load rating test, tension load test and water loss test shall be applicable for both post threading and pre - threading system of cables.
- xiii. Loads to be imparted on the 107mm ID sheathing during transverse load rating test and tension load test shall be extrapolated from values given for smaller dia sheathing as per IRC 112:2020 with latest amendments. At least 3 samples for one lot of supply (not exceeding 7000 meter length) shall be tested.
- xiv. In viaduct constructed by precast segmental construction, cables shall be threaded after application of temporary prestressing..
- xv. In such cases a temporary flexible PVC/HDPE tube of suitable O.D shall be homed through sheathing which will provide adequate stiffness to sheathing during concreting and also prevent blockage of sheathing in case of possibility of leakage. The temporary PVC/HDPE tube shall be pulled out before threading of the permanent cables.

B. Anchorages

- I. Anchorages shall be procured from authorized manufacturers only. Anchorages shall conform to BS: 4447.

Load transfer test and anchorage efficiency shall be conducted as defined in FIP-1993.

Engineer- in-charge shall select at random, the required anchorages / wedges sample from completed lots for testing by the manufacturer.

The concrete unit of required size/R/F will be made by contractor using same design mix of concrete which will be required for the load transfer test.

The load transfer test shall be conducted only when the concrete unit attains sufficient strength required for stressing activity as proposed in the drawings.

No damaged anchorages shall be used. Steel parts shall be protected from corrosion at all times. Threaded parts shall be protected by greased wrappings and tapped holes shall be protected by suitable plugs until used. The anchorage components shall be kept free from mortar, loose rust and any other deleterious coating.

After completion of pre-stressing and grouting of cables in PSC members, the extra length of stressed strands projecting outside the anchorage are required to be cut as per approved methodology and the anchorage ends are to be sealed as per the relevant specifications approved by Engineer-in-Charge.

- II. Swages of prestressing strand shall develop strength of at least 95 per cent of the specified breaking load of the strand.
- III. Untensioned steel reinforcements, around anchorages shall be furnished by prestressing system supplier. Requirement of the same should be job specific and based on edge distance of anchorage and strength of concrete at the time of stressing of cables as defined in drawings. The same R/F shall be provided in unit required for load transfer test.

Minimum 3 tests each are required to be conducted for load transfer test and anchorage efficiency test. The manufacturer shall complete the required testing and determine compliance of the obtained results with FIP-1993 recommendations before transporting the lot to site.

C. Prestressing Steel

- i. Uncoated, stress relieved, low relaxation steel conforming to IS: 14268:2017, class - 2 shall be used. Nominal dia shall be 15.2 mm with minimum breaking strength of 260.7 KN and minimum 0.2 % proof load of 234.6 KN.
- ii. Various test as recommended in IS: 14268 shall be conducted before transporting the lot to site. Apart from 1000 hrs relaxation test conducted by manufacturer, at least two such tests are required to be conducted by approved independent (third party) agency in the beginning of project.
- iii. All strands to be transported to the site shall be assigned a lot number and tagged for identification purposes.

D. Prestressing Strands/Wires Storage

All high tensile steel for prestressing work shall be stored about 30 cm above the ground in a suitably covered and closed space to protect it from dampness. It shall also be invariably wrapped in gunny cloth or tar paper or any other suitable material, as per approval of Engineer. Even if it is to be stored in an area at the site for short time during transit it shall be suitably covered. Protection during storage and repacking or application of washable protective coating to the H.T. steel shall be given by the contractor at no extra cost, if the packing of H. T. Strands/wires during unloading and storage / handling in the stores gets damaged.

Stock piling of HTS wires on the work site shall not be allowed any time, especially before and during the monsoon.

Engineer-in-Charge or his authorized representative shall always have an easy access to the store-yard for inspecting the H. T. Wires/strands/Bars and satisfying themselves regarding the condition thereof. Any modifications regarding storage suggested by Engineer shall scrupulously be followed by the contractor. During monsoon days, H.T wires/strands shall be kept in a reasonably air tight store, if required by the Engineer, at no extra cost.

6.3 Testing of Prestressing Steel and Anchorages

All strand from each manufactured reel and all bars of each size from each mill heat to be shipped to the site shall be assigned a lot number and shall be tagged in such a manner that each lot can be positively identified at the job site. Each reel of prestressing reinforcement shall be accompanied by a manufacturer's certificate of compliance, a mill certificate, and a test report. Samples from each size and each heat of prestressing bars and from each manufactured reel of prestressing steel strand shall be furnished to the Engineer for testing.

Samples shall be submitted in ample time to allow for testing, for tabulating results and, if necessary, in case of unsatisfactory finds, to call for and retest substitute samples. The Contractor shall have no claim for additional compensation because of delay while awaiting approval of the materials furnished for testing.

- i. Testing of Prestressing Steel as per IS 14268:2017 is included in the scope of work. Nothing Extra shall be payable in this regard.
- ii. All 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.
- iii. Anchorage assemblies to be transported shall be like-wise identified.
- iv. All samples submitted shall be representative of the lot to be furnished and in the case of strands, samples shall be taken from the same master roll. The Contractor shall furnish samples of at least 5.0m length selected from each lot for testing. Also, two anchorage assemblies, complete with distribution plates of each size or types to be used, shall be furnished along with short lengths of strands as required.

6.4 Workmanship**A. Cleaning**

Tendons shall be free from loose rust, oil, grease, tar, paint, mud or any other deleterious substance. Cleaning of the high tensile steel wires may be carried out by immersion in suitable solvent solutions, wire brushing or passing through a pressure box containing Carborundum powder. However, the tendons shall not be brought to a polished condition.

B. Straightening

High tensile strands shall be supplied in coils of sufficiently large diameter such that tendons shall retain their physical properties and shall be straight as it unwinds from the coil. Tendons of any type that are damaged, kinked or bent shall not be used.

The packing of prestressing strands shall be removed only just prior to making of cable for placement. Suitable stands shall be provided to facilitate uncoiling of strands without damage to steel. Care shall be taken to avoid the possibility of steel coming into contact with the ground.

C. Positioning**I. Post-Tensioning**

- i. Prestressing tendons shall be accurately located and maintained in position, both vertically and horizontally, as per drawings.
- ii. Tendons shall be so arranged that they have a smooth profile without sudden bends or kinks. The location of prestressed cables shall be such as to facilitate easy placement and vibration of concrete in between the tendons.
- iii. Sheathing shall be placed in correct position and profile by providing suitable ladders and spacers. Such ladders may be provided at intervals of approximately 1.0 m. Sheathing shall be tied rigidly with such ladders/spacer bars so that they do not get disturbed during concreting.
- iv. The method of supporting and fixing shall be such that profile of cables is not disturbed during vibrations, by pressure of wet concrete, by workmen or by construction traffic.

- II. Each anchorage device shall be set square to the line of action of the corresponding prestressing tendon and shall be positioned securely to prevent movement during concreting.

The anchorage devices shall be cleaned to the satisfaction of the Engineer prior to the placing of concrete. After concreting, any mortar or concrete which adheres to bearing or wedging surfaces shall be removed immediately.

Tendons shall be placed only prior to stressing. Tendons shall be handled with care to avoid damage or contamination, to either the tendon or the sheathing. Any tendons which are damaged or contaminated shall be cleaned or replaced as directed by the Engineer.

D. Cutting

Cutting and trimming of H.T.S wires or strands shall be done by suitable mechanical cutters. In post-tensioning, the ends of prestressing steel projecting beyond the anchorages, shall be cut by suitable means Before grouting operation.

E. Protection of Pre-stressing Steel

Pre-stressing steel shall be continuously protected against corrosion, until grouted. The corrosion protector shall have no deleterious effect on the steel or concrete or on the bond strength of steel to concrete. Grouting shall conform to these specifications or as directed by the Engineer.

F. Sheathing

The joints of sheathing pipes shall be water-tight. Special attention shall be paid to the junction at the anchorage end, where the sheathing must tightly fit on the protruding trumpet end of anchorage and thereafter sealed preferably with adhesive water proof tape as per approved manufacturer's specifications.

The sheathing and all joints shall be water tight. Any temporary opening in the sheathing shall be satisfactorily plugged and all joints between sheathing and any other part of the prestressing system shall be effectively sealed to prevent entry of mortar, dust, water or other deleterious matter. Sheathing shall be neatly fitted at joints without internal projection or reduction of diameter.

Sheathing shall be firmly tied so that while concreting they should not float up. Sheathing shall be aligned accurately with respect to vertical and horizontal coordinates (profile).

Enlarged portions of the sheathing at couplings or anchorages shall be of sufficient length to provide for the extension of the tendons.

G. Grout Vents

Grout vents of at least 20 mm diameter shall be provided at both ends of the sheathing.

H. Anchorages

All bearing surfaces of the anchorages shall be cleaned prior to concreting and tensioning.

Anchor cones, blocks and plates shall be securely positioned and maintained during concreting such that the centre line of the duct passes axially through the anchorage assembly.

The anchorages shall be recessed from the concrete surface as per drawings.

After the prestressing operations are completed and pre-stressing strands are cut, **the surface shall be painted with two coats of epoxy of suitable formulation having a dry film thickness of 80 microns per coat and entire recess shall be filled with concrete or non-shrink/pre-packaged mortar or epoxy concrete as approved by Engineer-in-Charge.**

6.5 Supervision

All pre-stressing and grouting operations shall be undertaken by trained and qualified personnel only.

All prestressing accessories shall be procured from authorized manufacturers with in-house testing facilities. The Contractor shall be required to engage specialized agencies who should also be entrusted with the total service contract for fabrication of cables to required Length, protection of cables during concreting, prestressing and grouting.

Necessary certificates shall be accorded by such specialized agencies that the work has been carried out in accordance with prescribed specifications.

A representative of supplier of the pre-stressing system shall be present during all tensioning and grouting operations and shall ensure, monitor and certify their correctness.

6.6 Tensioning Equipment

All tensioning equipment shall be procured from authorised manufacturers only and shall be approved by the Engineer prior to use. Where hydraulic jacks are used, they shall be power-driven unless otherwise approved by the Engineer. The tensioning equipment shall satisfy the following requirements:

- (i) The means of attachments of the pre-stressing steel to the jack or any other tensioning apparatus shall be safe and secure.
- (ii) Where two or more wires/strands constitute a tendon, a single multi pull stressing jack shall be used, which is capable of tensioning simultaneously all the wires/strands of the tendon. Suitable facilities for handling and attaching the multi-pull jack to the tendons shall be provided.

- (iii) In special cases where usage of multistrand jack is not feasible, Contractor may use mono strand jack on specific approval of Engineer.
- (iv) The tensioning equipment shall be such that it can apply controlled total force gradually on the concrete without inducing dangerous secondary stresses in steel, anchorage or concrete;
- (v) Means shall be provided for direct measurement of the force by use of dynamometers or pressure gauges fitted in the hydraulic system itself to determine the pressure in the jacks. Facilities shall also be provided for the linear measurement of the extension of prestressing steel to the nearest mm and of any slip of the gripping devices at transfer

All dynamo meters and pressure gauges including a master gauge shall be calibrated by approved laboratory immediately prior to use and then at intervals not exceeding 3 months and the true force determined from the calibration curve.

Pressure gauges shall be concentric scale type gauges accurate to within two per cent of their full capacity. The minimum nominal size of gauge shall be 100 mm. The gauge shall be so selected that when the tendon is stressed to 75 per cent of its breaking load, the gauge is reading between 50 percent and 80 percent of its full capacity. Suitable safety devices shall be fitted to protect pressure gauges against sudden release of pressure.

Provision shall be made for the attachment of the master gauge to be used as a check whenever requested for by the Engineer.

Jack efficiency test shall be conducted at suppliers factory as well as at site prior to first use at site and then at intervals not exceeding three months

pump shall be calibrated from an approved laboratory prior to use and then at intervals not exceeding three months.

6.7 **Post Tensioning**

Tensioning force shall be applied in gradual and steady steps and carried out in such a manner that the applied tensions and elongations can be measured at all times. The sequence of stressing, applied tensions and elongations shall be in accordance with the approved drawing or as directed by the Engineer.

It shall be ensured that in no case, the load is applied to the concrete before it attains the strength specified on the drawing or as stipulated by the pre-stressing system supplier, whichever is more.

After pre-stressing steel has been anchored, the force exerted by the tensioning equipment shall be decreased gradually and steadily as to avoid shock to the pre-stressing steel or anchorage.

The tensioning force applied to any tendon shall be determined by direct reading of the pressure gauges or dynamo-meters and by comparison of the measured elongation with the calculated elongation. The calculated elongation shall be invariably adjusted with respect to the modulus of elasticity of steel and area of strand for the particular lot as given by the manufacturer.

The difference between calculated and observed tension and elongation during prestressing operations shall be regulated as follows:

- a) If the calculated elongation is reached before the specified gauge pressure is obtained, continue tensioning till attaining the specified gauge pressure, provided the elongation does not exceed 1.05 times the calculated elongation. If 1.05 times the calculated elongation is reached before the

specified gauge pressure is attained, stop stressing and inform the Engineer for proper remedial measure.

- b) If the calculated elongation has not been reached at the specified gauge pressure, continue tensioning by intervals of 5kg/sq. cm until the calculated elongation is reached provided the gauge pressure does not exceed 1.05 times the specified gauge pressure. If the elongation at 1.05 times the Specified gauge pressure is less than 0.95 times the calculated elongation, the following measures must be taken, in succession, to determine the cause of this lack of discrepancy:
 - I. Check the correct functioning of the jack, pump and leads.
 - II. De-tension the cable. Slide it in its duct to check that it is not blocked by mortar which has entered through holes in the sheath. Re-tension the cable if free.
 - III. Re-establish the modulus of elasticity of steel for the particular lot from an approved laboratory. Contractor may suggest other remedial measure for approval of the Engineer.

If the required elongation is still not obtained, further finishing operations such as cutting or sealing, should not be undertaken without the approval of the Engineer.

When stressing is taken up from one end only, the slip at the end remote from the jack shall be accurately measured and an appropriate allowance made in the measured extension at the jacking end.

A complete record of prestressing operations along with elongation and jack pressure data shall be maintained in the format given in Appendix 1800/II of MOST Specification or as per format approved by Engineer.

Any breakage of individual strand / groups of strands during tensioning shall require immediate de-stressing of all strands and replacement of the all the strands by fresh strands.

6.8 Grouting of Pre-stressed Tendons

Post tensioned tendons shall be bonded to concrete of the prestressed member as well as protected from corrosion by cement grout which shall fill the ducts fully, without leaving any entrapped air or water pockets, voids created by evaporation of excess water in the grout and bleeding.

Prior to grouting, all cables shall be tested with water pressure of 0.3 MPa for approximately 3 minutes, to investigate leakages and connectivity of ducts.

Since the epoxied joint (in precast segmental construction) is of paramount importance to ensure long-term durability of prestressing cables, this field test shall be taken as an indication of the Contractor's quality of work in general and effectiveness of the epoxy joint executed by him. The approval / rejection of such span shall depend on the decision of Engineer. However, no extra payment shall be made to the contractor for such epoxy injection.

Grouting of pre stressed tendons should be carried out as early as possible but not later than 2 weeks from the date of prestressing. Whenever this stipulation cannot be complied with for unavoidable reason, adequate temporary protection of the steel against corrosion by methods or products which will not impair the ultimate adherence of the injected grout should be ensured till grouting.

All other aspects of grouting of cables shall be governed by latest MORTH- Specification and IRC-112:2020. If there is any discrepancy of clauses between them, IRC 112:2020 shall prevail. A record of grouting operations shall be maintained in the format as given in Appendix 1800/III of MORTH Specifications.

6.9 **Safety Precautions during Tensioning**

Care shall be taken during tensioning to ensure the safety of all persons in the vicinity.

Jacks shall be secured in such a manner that they will be held in position, should they lose their grip on the tendons.

No person shall be allowed to stand behind the jacks or close to the line of the tendons while tensioning is in progress.

The operations of the jacks and the measurement of the elongation shall be carried out in such a manner and such a position that the safety of all concerned is ensured.

A safety barrier shall be provided at both ends to prevent any tendon, which might become loose from recoiling unchecked.

Safety net shall be placed below the End segment during prestressing to avoid any falling of any broken concrete pieces of segment on the road in case of any cracks in End segment during prestressing.

During actual Prestressing operation, warning signs shall be displayed at both ends of tendon and below the jack location at ground level.

After pre-stressing, concrete shall neither be drilled nor any portion cut nor chipped away nor disturbed, without approval of the Engineer.

No welding shall be permitted on or near tendons nor shall any heat be applied to tendons. Any tendon which has been affected by welding, weld spatter or heat shall be rejected.

6.10 **Tolerances**

Permissible tolerances for positional deviation of Pre-stressing tendons in cast-in-situ construction shall be limited to the following

Variation from the specified horizontal profile	:	5 mm
Variation from the specified vertical profile	:	5 mm
Variation from the specified position in member	:	3 mm

6.11 **Transportation and Storage of Unit:**

Precast girders shall be transported in an upright position. Points of support and the direction of reactions with respect to the girder shall approximately be the same during transportation and storage as when the girder is placed in final position.

When members are to be stacked, they shall be firmly supported at such bearing positions as it will ensure that the stresses induced in them are always less than the permissible design stresses. Further, inclined side supports shall be provided at the ends and along the length of a precast girder to prevent lateral movements or instability.

Care shall be taken during storage, hoisting and handling of the precast units to prevent their cracking or being damaged. Units damaged by improper storing or handling shall be replaced by the Contractor at his expense.

6.12 Tests and Standards of Acceptance

The materials shall be tested in accordance with these Specifications and shall meet the prescribed criteria.

The work shall conform to these Specifications and shall meet the prescribed standards of acceptance.

6.13 DELETED

6.14 Pre-cast Pre-tensioned Girders

General

This section generally applicable to precast pre-tensioned girder.

a. Construction sequences

Sequence of Operations for pre-tensioned girders.

For pre tensioned girders of standard length, the sequence of operation, starting from erection of formwork, shall be as follows:

- (i) Erection of formwork
- (ii) Placement of reinforcement cage
- (iii) Threading of HT strands from movable bulkhead to fixed anchor through individual casting beds, end shuttering and reinforcement cages. De-bonding tubes are to be placed in position for strands to pass through. The de-bonding tubes shall be 25mm internal dia, hollow, rigid HDPE pipes and the same shall be provided as per detailed drawing/approval of engineer without any extra cost.
- (iv) Removal of initial slackness in the strands by using J-20 mono-strand jack or equivalent up to 20KN force.
- (v) Complete the balance pre-stressing by using mono-strand jacks of desired capacity and lock individual strands. Locking plate to be inserted between the movable bulkhead and fixed bulkhead. Mark individual strands for checking the slip of strands.
- (vi) Seal the ends of de-bonding tubes and close the formwork to correct dimension.
- (vii) Pour concrete. Keep test cubes in the same environment as that of the girder concrete.
- (viii) Allow concrete to set for 3-4 hours before steam curing if required is started.
- (ix) Once steam curing (if required) is over as per direction of the Engineer, remove covers and allow the girders to cool to ambient temperature. Test the cubes for determining compressive strength of concrete in girders.
- (x) If adequate compressive strength is obtained, release the strands and check the slip of strands. Releasing shall be done by displacement of one side of the anchor supports, or both supports alternatively. Releasing shall be done on every strands simultaneously. Releasing shall be smooth and progressive. Sudden releasing by rupture is prohibited.
- (xi) Cut the strands, remove the formwork and lift the girders to inspection bay for removal of end plate and bending of projected bars.
- (xii) Cut the projected strands from girder ends and apply epoxy coating to strands. Mark the girders.
- (xiii) Wet curing.
- (xiv) Arrange for stacking, lock handling and transportation to site.

b. Concreting for Precast Girders

Unless otherwise mentioned hereunder, the concrete shall be prepared, mixed and placed in position in accordance with the particular specifications given earlier. The Contractor shall maintain a record of the proportions of mix at the batching plant and produce the same for checking by the Engineer whenever required. Casting of girder shall be done in a single pour.

The contractor shall take care in placing reinforcement cage so that cables/strands are not disturbed and the minimum cover as recommended in the drawing is available. The girder shall be cast with specified camber and curvature.

c. Forms for Precast Pre-stressed Girders

The pre-tensioned girders shall be cast at casting yard. The contractor shall clean, thoroughly, the steel forms of all dirt, mortar and other matter such as chips, blocks etc. prior to using them. The contractor shall check the accuracy of alignment and rectify the inconsistencies, if any, of the forms and steel casting bed. Contractor shall also take care of bulkheads including positioning of jacks who may become necessary to suit the design requirement of the precast girders or as instructed by the Engineer. Forms shall be specifically suited to external form vibrators.

Some of the precast pre-tensioned girders are curved. The moulds in the precast yard shall be adjustable to construct these curved beams as per the Construction drawings.

d. Permissible tolerances

The formwork for precast girder shall be so made that it produces a finished concrete true to shape, lines, levels, plumb and dimension shown on the drawings subject to the following tolerance unless otherwise specified in these documents or directed by Engineer.

Length of Girder

Per 3 m length	-	±3 mm
Maximum for entire length	-	±10 mm

Cross-sectional Dimension

Web	-	±3mm
Flange/Slab	-	± 3 mm
Depth	-	± 3 mm
Plumb	-	1 in 1000
Location of Strand	-	± 3 mm

e. Quality Control and Testing Materials

The contractor shall carry out all tests of materials in order to guarantee the specified quality in accordance with the relevant clauses of this specification.

f. Steam Curing of Precast girders**g. Marking of Precast Elements**

Precast Elements shall be marked immediately after removing the side forms with paint of approved quality. The elements shall be marked at minimum four places on outer faces of webs and at the ends with the following details:

- a) Girder Number.
- Date of casting the girder.

h. Tests of Precast Pre-tensioned Elements

Precast units shall be load tested at service load after erection on site and up to failure at precast yard, as approved by the Engineer.

Prior to carrying out load tests, if required, the contractor shall submit arrangement of testing, loading etc. and shall carry out any modifications, if needed, on the existing testing arrangement to the satisfaction of the Engineer at no extra cost. The contractor shall submit a report containing test results and observations etc. to the department.

i. **Handling, Stacking, Transportation and Placing of Precast Element**

All aspects of casting, pre-tensioning, handling, transportation and erection shall be proposed by contractor in detailed method of statements along with calculations and submitted for approval of the Engineer. Detailed fabrication drawings of each element to be submitted by contractor for approval of the Engineer.

All handling, lifting and erection equipment shall be load-tested prior to their use and also when ordered by the Engineer.

Handling of precast members shall be allowed only after the same have attained the specified strength.

The members shall be lifted only from the positions specified for this purpose. Precast members are to be lifted, stacked and/or handle such that self-weight is mobilized and supports are located as per their final bearing conditions.

Lifting inserts are to be proposed by the contractor for approval of the Engineer.

For precast pre-tensioned members arrangements would be required for de bonding of strands for part length towards end of members. All exposed edges of precast elements should have chamfers of 10mm x 10mm. All necessary safety precautions will be taken to avoid any accident and damage during handling of the precast units. Special precautions shall be taken during and after erection for stability of the precast elements.

The contractor shall submit detailed plan showing stacking of precast elements at casting yard and at site and shall obtain approval of the Engineer.

The precast girders shall be stacked on timber or any other suitable supports provided over the firm ground/base. The girders shall be placed side by side on these supports. Care shall be taken to avoid any undue loading of girders during stacking.

The girders shall be transported in an upright position and points of support and the direction of reaction with respect to the girders shall approximately be the same during storage as when the girder is placed in final position. The transportation of precast units to position or to lifting position (to the deck) shall be done during night unless otherwise permitted by the Engineer.

The contractor shall obtain necessary permission from the concerned departments for transporting the precast girders. The contractor should study the problems likely to arise in the transportation of long girders on heavy traffic road. The road movements shall be possible only from 12.00 midnight to 6.00 AM. Mode of transportation, proposed by Contractor, shall be approved by the Engineer before commencing the transportation operation. Proper precautions should be taken during handling of precast units during transportation and all traffic safety measures taken.

The contractor shall be required to execute all handling and re handling of girders including interim storages etc., till these are finally erected, within his quoted rate. Contractor can plan the activities in advance to

reduce such handling if practicable. The contractor should plan for emergencies in case of failure of a trailer. Adequate standby arrangements will have to be made. Transport, handling and storage operations must:

- Ensure the security of all personnel by avoiding any risk of instability of the members or of the lifting or handling equipment,
- Avoid any unexpected stress and excessive deformation,
- Eliminate every risk of deterioration capable to alter the aspect or the durability of the structure.
- Avoid any thermal shock during storage.

When placing the precast units in position, care should be taken to place the right unit in the right position with minimum handling of units. Care should also be taken to prevent any damage to the precast units. Units damaged by improper storing or handling/rehandling shall be replaced by the contractor at his own expense. The methodology proposed by the Contractor for placing these units, shall be approved by the Engineer, before commencement of the work. The rate for the reinforcement in the girders shall also include cutting of temporary handles (rebar), if required. The contractor shall prepare and submit a form for each span indicating the location and girder number of each girder.

j. **Shop Drawings and Design Calculations for Construction Procedures**

General

The Contractor shall submit according to a schedule, complete details and information concerning the method, materials, equipment and procedures he proposes to use. These shall be called "Method Statements". Method Statements shall be submitted sufficiently in advance of the start of superstructure field construction operations, so as to allow the Engineer adequate review period, which shall not be less than 30 days. The submittals shall invariably include step-by-step casting, lifting, curing, stacking, transportation and erection procedure. The Contractor's Method Statements shall also include all calculations, drawings and information as may be relevant. The following points are specifically highlighted:

- Accommodating block-outs, openings and protrusions. Protruding re-bars may be needed (track starter rebar, for example). Anchorages and inserts for OHE poles, signalling equipment and cable routing supports shall also be included where needed in precast beams.
- Adjusting to changes in girder length, curve, inclination and camber as shown in Detailed Design Drawings.
- Adjusting the profile to take into account design camber values
- Stripping without damage to the concrete.
- The form design shall provide a tapered portion at both end for bearing of elastomeric bearing.
- Forms shall not be removed until the concrete has attained adequate strength. Care should be exercised in removing the forms to prevent spalling and chipping of the concrete.
- All side, bottom and end forms for precast beams shall be constructed of steel.
- Forms shall be of sufficient thickness, with an adequate external bracing and stiffeners, and shall be sufficiently anchored to withstand the forces due to placement and vibration of concrete. No tie bolt is permitted for casting of precast beam. Joints in the forms shall be designed and maintained for mortar tightness. The grade and alignment of forms shall be checked each time they are set and shall be maintained during the casting of concrete.

k. **Design Calculations for Construction Procedures**

Design assumptions and calculations shall be submitted for temporary pre-stressing, false work, erection devices, formwork or other temporary construction which may be required to complete the work.

- Assumptions and Calculations shall also be submitted to substantiate the system and method of permanent and temporary pre-stressing proposed by the Contractor.

- In the sections that follow, specific recommendations for precast full span construction for superstructure are given apart from certain special aspects of construction.
- Shop Drawings for Precast Full Span Construction
- The Contractor shall submit detailed shop drawings for approval. The shop drawings shall be based on Final Design Drawings issued by the Client to the Contractor and shall include:
 - Fully and accurately dimensioned views showing the geometry of precast units including all projections, recesses, notches, openings, block-outs, blister if any and where acceptable, as well as other pertinent details.
 - Details of any special reinforcing required for handling of precast units or for other purposes. Also all bar bending schedules shall be presented based on reinforcement schedules given in Final Drawings issued by the Client.
 - Details and locations of all other items to be embedded in the precast units such as inserts, lifting devices shall be shown.
 - Pre-stressing system details shall include sizes and properties of strands, assemblies and stressing procedure, de bonding tubes and locations of additional reinforcement necessary to resist pre-stressing stresses.
 - Graphs, charts or tables showing the theoretical location of each precast units, as erected or placed shall be furnished to the Engineer for his use in checking the erection of the superstructure. Detailed procedures for making geometry correction shall be designed.
 - Details of sealing of de bonding tubes and protection of strands.
 - Method of installing bearings and expansion joints shall be given including approved manufacturer's recommendations.
- Forms For Precast Full Span Construction
- Forms for precast units construction shall be metal form work only. Shop drawings shall be submitted for all formwork. The precast units during storing /curing shall always be supported as shown in tender drawings or as approved by Engineer only.
- In addition to the requirements of the Standard Specifications, the forms used for precasting shall be capable of:
 - Producing the precast units within the tolerances permitted in this section.
 - Accommodating block-outs, openings and protrusions. Protruding re-bars will be needed at least for second-pour plinths. Anchorages and inserts for OHE poles, signaling equipment and cable routing supports shall also be included where needed in precast units.
 - Adjusting to changes in precast units geometry as shown in Final Design Drawings issued by the Client, or for correcting previous minor casting errors to prevent accumulation.
 - Adjusting the profile to take into account design camber values
 - Stripping without damage to the concrete.
 - Joints in external formwork shall be avoided as far as possible. Where sections of forms are for some reason to be joined on the exterior face of the precast units, an offset in excess of
 - 0.5mm for flat surfaces and 1 mm for comers and bends will not be permitted.
 - Forms shall not be removed until the concrete has attained adequate strength Care should be exercised in removing the forms to prevent spading and chipping of the concrete.
 - All side, bottom, inside and header forms for precast units construction shall be constructed of steel.
 - Forms shall be of sufficient thickness, with an adequate external bracing and stiffeners, and shall be sufficiently anchored to withstand the forces due to placement and vibration of concrete. Internal bracing and holding devices in forms shall be limited to stay bolts in webs, which can be removed from the concrete surface to permit patching following form

removal. Joints in the forms shall be designed and maintained for mortar tightness. The grade and alignment of forms shall be checked each time they are set and shall be maintained during the casting of concrete.

- Metal forms shall be reasonably free from rust, grease or other foreign materials. All forms shall be cleaned thoroughly prior to each casting operation. End headers shall be maintained to smooth casting surface.
- All formed surfaces for casting members shall be constructed and maintained to provide precast units tolerances.
- The faces of all forms, other than end headers, shall be properly cleaned and treated with form oil or other bond breaking coating prior to placing concrete. The oil or other materials used shall be of a consistency and composition to facilitate form removal. Materials, which stain or react with concrete, shall not be used. Care shall be exercised to facilitate formwork and precast units removals without damage to the concrete.

6.15 Precast Pretension/Post Tensioned I Girders:

- a. Additional specification for I-girder structure Concrete I-girder deck structure / station beams shall be made of precast pre-tensioned / post-tensioned I-girder, and cast in-situ slab , If applicable.

Slabs on top of concrete I-girder, shall be reinforced concrete,

6.16 Measurements for Payment (Not applicable for Lumpsum Schedule A, B & C):

Prestressed Concrete shall be measured in -cubic metres based on theoretical cross- sectional area and length. The volume occupied by mild steel reinforcement / HYSD bars; high tensile steel, sheathing and anchorages shall not be deducted. Measurement for transportation of precast member/segment shall be measured in metric tonnes based on standard density of concrete equivalent to 2.5 t/cum including the weight of rebars, sheathing ducts, embedments etc.

Supplying, fixing and tensioning steel HT wires/strands/cables (measured between anchorages) shall be measured in metric tonnes on theoretical basis based on the standard weight per metre length. Each size shall be measured separately. No allowance shall be made for extra lengths in anchorages or elsewhere.

HDPE sheathing, grouting operations, couplers for sheathing, anchorages, epoxy protection of anchorages, stressing using Multi strand stressing jacks, samples for testing including testing, sealing of anchorage recess with concrete (same grade as structure) and all related operations to complete the work shall all be deemed to be included in the main item of HT strand and shall not be paid for separately. The rate shall also include payments, if any to be made to the supplier of the prestressing system who has to monitor, ensure and certify the correctness of all the arrangements/operations.