

Prestressing

1800

Prestressing

1801. DESCRIPTION

Structural concrete containing prestressed steel reinforcement to introduce precompression is termed as prestressed concrete.

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

Concrete and untensioned steel for the construction of prestressed concrete members shall conform to the requirements of sections 1700 and 1600 for Structural Concrete and Steel Reinforcement respectively in so far as the requirements of these Sections apply and are not specifically modified by requirements set forth herein.

1802. MATERIALS

1802.1. All materials shall conform to Section 1000.

1802.2. Sheathing

1802.2.1. The sheathing ducts shall be of the spiral corrugated type. Unless otherwise specified, the material shall be Cold Rolled Cold Annealed (CRCA) Mild Steel conforming to IS:513 intended for mechanical treatment and surface refining but not for quench hardening or tempering.

The material shall normally be bright finished. However, where specified, as in case of use in aggressive environment, galvanised or lead-coated mild steel strips shall be used.

The thickness of sheathing shall be as shown on the drawing, but shall not be less than 0.3 mm, 0.4 mm and 0.5 mm for sheathing ducts having internal diameter of 50 mm, 75 mm and 90 mm respectively. For bigger diameter of ducts, thickness of sheathing shall be based on recommendations of prestressing system supplier or as directed by the Engineer.

The sheathing shall conform to the requirement as per tests specified in *Appendix 1800/I*.

For major projects, the sheathing ducts should preferably be manufactured at the project site utilising appropriate machines. With such an arrangement, long lengths of sheathing ducts may be used with consequent reduction in the number of joints and couplers. Where sheathing duct joints are unavoidable, such joints shall be made

slurry tight by the use of corrugated threaded sleeve couplers which may be tightly screwed onto the outer side of the sheathing ducts.

The length of the coupler should not be less than 150 mm but should be increased upto 200 mm wherever practicable. The joints between the ends of the coupler and the duct shall be sealed with adhesive sealing tape to prevent penetration of cement slurry during concreting. The couplers of adjacent ducts should be staggered wherever practicable. As far as possible, couplers should not be located in curved zones. The corrugated sleeve couplers are being conveniently manufactured using the sheath making machine with the next higher size of die set.

1802.2.2. The internal area of the sheathing duct shall be in accordance with the recommendations of the system manufacturer and shall be about three times the area of the tendons. In case of 6T13, 12T13 and 19T13 sizes of tendons comprising 12/13 mm dia strands, the inner diameter of the sheathing shall not be less than 50 mm, 75 mm and 90 mm respectively or those shown in the drawing, whichever is greater.

Where prestressing tendons are required to be threaded after concreting the diameter of sheathing shall be about 5 mm larger than that required as above.

1802.2.3. In severe environment, cables shall be threaded after concreting. In such cases a temporary tendon shall be inserted in the sheathing or the sheathing shall be stiffened by other suitable method during concreting.

1802.3. Anchorages

1802.3.1. Anchorages shall be procured from authorised manufacturers only. Anchorages shall conform to BS:4447. Test certificates from a laboratory fully equipped to carry out the tests shall be furnished to the Engineer. Such test certificates shall not be more than 12 months old at the time of making the proposal for adoption of a particular system for the project.

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 and loose rust and any other deleterious coating.

1802.3.2. Swages of prestressing strand and button-heads of prestressing wire, where provided shall develop a strength of at least 95 per cent of the specified breaking load of the strand or wire as the case may be. Where swaging/button-heading is envisaged, the Contractor shall furnish details of his methodology and obtain approval of the Engineer, prior to his taking up the work.

1802.3.3. Untensioned Steel reinforcements, around anchorages shall conform to the details of prestressing system and as shown on the drawing.

1803. TESTING OF PRESTRESSING STEEL AND ANCHORAGES

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.

All wire, strand or bars to be shipped to the site shall be assigned a lot number and tagged for identification purposes. Anchorage assemblies to be shipped shall be like-wise identified.

All samples submitted shall be representative of the lot to be furnished and in the case of wire or strand, shall be taken from the same master roll. The Contractor shall furnish samples of at least 5.0 m 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 alongwith short lengths of strands as required.

1804 WORKMANSHIP

1804.1. Cleaning

Tendons shall be free from loose rust, oil, grease, tar, paint, mud or any other deleterious substance.

Cleaning of the steel 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.

1804.2. Straightening

High tensile steel wire and strand 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 wire/strand shall be removed only just prior to making of cable for placement. Suitable stands shall be provided to facilitate uncoiling of wires/strands without damage to steel. Care shall be taken to avoid the possibility of steel coming into contact with the ground.

1804.3. Positioning

1804.3.1. Post-Tensioning

Prestressing tendons shall be accurately located and maintained in position, both vertically and horizontally, as per drawings.

Tendons shall be so arranged that they have a smooth profile without sudden bends or kinks.

The locationing of prestressed cables shall be such as to facilitate easy placement and vibration of concrete in between the tendons. High capacity tendon shall be used to reduce the number of cables thereby eliminating the necessity of grouping. The selected profiles of the tendons shall be such that their anchorages are not located in the top deck surface. Where two or more rows of cables have to be used, the cables shall be vertically in line to enable easy flow of concrete. The clear vertical and horizontal distances between any two cables shall in no case be less than 100mm anywhere along the length of the superstructure. Where precast segments are used, the clear distance shall be at least 150 mm.

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.

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.

Sheathing in which the permanent tendon will not be in place during concreting shall have a temporary tendon inserted or shall be stiffened by some other method to the approval of the Engineer. The temporary tendon shall be pulled out before threading the permanent tendon into place by a special threading machine or other contrivance.

Where possible tendons shall not be placed until immediately

prior to stressing. Tendons shall be handled with care to avoid damage or contamination, to either the tendon or the sheathing. Any tendons damaged or contaminated shall be cleaned or replaced.

1804.3.2. Pre-Tensioning. Prestressing steel shall be accurately located and maintained in position, both vertically and horizontally, as per drawings.

1804.3.3. 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.

1804.4. Cutting

Cutting and trimming of wires or strands shall be done by suitable mechanical or flame cutters. When a flame cutter is used, care shall be taken to ensure that the flame does not come in contact with other stressed steel. The location of flame cutting of wire or strand shall be kept beyond 75 mm of where the tendon will be gripped by the anchorage or jacks.

In post-tensioning the ends of prestressing steel projecting beyond the anchorages, shall be cut after the grout has set.

1804.5. Protection of Prestressing Steel

Prestressing 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.

In the case of external prestressing, steel shall be encased in suitable polyethylene pipes before grouting.

1804.6. Sheathing

The joints of all sheathings 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 heat shrink tape, to make it water-proof.

The heat-shrink tape is supplied in the form of bandage rolls which can be used for all diameters of sheathing ducts. The bandage is coated on the underside with a heat sensitive adhesive so that after heating the bandage material shrinks on the sheathing duct and ensures formation of a leak-proof joint. The heating is effected by means of a soft gas flame.

A sheath making machine should be positioned at the site of work for large projects so that sheathing can be prepared as and when it is required for construction.

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.

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

1804.7. Grout Vents

Grout vents of at least 20 mm diameter shall be provided at both ends of the sheathing and at all valleys and crests along its length. Additional vents with plugs shall also be provided along the length of sheathing such that the spacings of consecutive vents do not exceed 20 m. Each of the grout vents shall be provided with a plug or similar device capable of withstanding a pressure of 1.0 MPa without the loss of water, air pressure or grout.

1804.8 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 by a minimum cover of 100 mm.

After the prestressing operations are completed and prestressing wires/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.

1804.9. Structural Concrete

Structural concrete shall conform to Section 1700. The formwork shall conform to Section 1500.

1805. SUPERVISION

All prestressing and grouting operations shall be undertaken by trained personnel only. A representative of supplier of the prestressing system shall be present during all tensioning and grouting operations and shall ensure, monitor and certify their correctness.

1806. TENSIONING EQUIPMENT

All tensioning equipment shall be procured from authorised manufacturers only and 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 prestressing 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 multipull 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 multipull jack to the tendons shall be provided.
- (iii) 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; and
- (iv) 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 an 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 per cent and 80 per cent 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.

1807. 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 prestressing system supplier, whichever is more.

After prestressing steel has been anchored, the force exerted by the tensioning equipment shall be decreased gradually and steadily so as to avoid shock to the prestressing 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 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.
- b) If the calculated elongation has not been reached at the specified gauge pressure, continue tensioning by intervals of 5 kg/sq. c.m. until the calculated elongation is reached provided the gauge pressure does not exceed 1.05 times the specified gauge pressure.
- c) 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) Detension the cable. Slide it in its duct to check that it is not blocked by

mortar which has entered through holes in the sheath. Retension the cable if free.

- iii) Re-establish the modulus of elasticity of steel for the particular lot from an approved laboratory.

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.

- d) When stressing 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/III*. The number of stages of prestressing and grouting shall be reduced to a minimum, preferably 2 in the case of simply supported girders.

1808. GROUTING OF PRESTRESSED TENDONS

Grouting shall conform to *Appendix 1800/III*. A record of grouting operations shall be maintained in the format given in *Appendix 1800/IV*.

1809. PRE-TENSIONING

1809.1. General

The planning and construction aspects of the tensioning bed, tensioning bench, abutments at location of anchorage, steam curing system, formwork of the concrete elements and arrangements for de-moulding, lifting, stacking and transportation of the pre-tensioned concrete elements are all specialised items and shall be entrusted to engineers specifically experienced in this type of work.

1809.2. Stressing Bed for Pre-tensioning

The abutments and bed for pre-tensioning of tendons shall be designed to withstand the total tensioning force.

A notice shall be displayed adjacent to the stressing bed showing the maximum tensioning force permitted.

Where concrete elements are cast and prestressed individually, the stressing bench or moulds shall be rigid enough to sustain the reaction of the prestressing force without distortion.

In the long line method of prestressing, sufficient locator plates should be distributed throughout the length of the bed to ensure that

the wires are maintained in their proper position during concreting. The moulds shall be free to slide in the direction of their length and thus permit the transfer of the prestressing force to all the concrete elements along the whole line.

Sufficient space shall be left in between the ends of concrete elements to permit access for cutting the strands/wires after transfer. Hold-downs or deflectors shall be used for holding or deflecting the tendons in required position firmly. Deflectors which are in contact with the tendon shall have a diameter not less than the tendon or 15 mm, whichever is greater.

The tensioning force required to be applied as stated on the drawings shall be the force remaining in the strands/wires after all strands/wires have been anchored to the abutments of the stressing bed and after the anchorage slip has already taken place. The tensioning force shall be determined by direct reading of the pressure gauges or dynamo-meters and by the measured elongation after slip.

The Contractor shall submit method of tensioning the tendons including the arrangement and layout of prestressing beds and all tendon deflection points to the Engineer for approval before manufacture commences.

The Contractor shall carry out trial stressing operations to establish the frictional resistance offered by the hold-downs and the slip during anchoring.

Where sheathing of pre-tensioned tendons is required to prevent bond over a specified length, it shall consist of plastic tubing or other material approved by the Engineer and shall be of a quality, diameter and thickness such that bond shall be effectively prevented. The tubing shall be fastened to the tendon in such a manner that cement mortar cannot enter. The Engineer may order that the pull-in of the tendon be measured during the transfer of prestress.

The Contractor shall also submit calculations showing that the hold-downs have been designed and constructed to withstand concentrated loads resulting from the application of the tensioning force.

1809.3. Tensioning Procedure

The tensioning of the wires and strands shall be done not too much in advance of concreting.

The tensioning force shall be applied gradually and uniformly.

In order to remove slack and to lift tendons off the bed floor, an initial force approved by the Engineer shall be applied to the tendons. Allowance shall be made for this force in calculating the required elongation.

Tendons shall be marked for measurement of elongation after the initial force has been applied. When required by the Engineer, tendons shall be marked at both the jacking end and dead end of the stressing bed and at couplers if used so that slip and draw-in may be measured.

Where deflected strands have been specified, the Engineer may direct the elongation or strain gauge measurements be taken at various positions along the tendon to determine the force in the tendon at those positions.

1809.4. Transfer of Prestress

While the process of tensioning can be accomplished by means of hydraulic jacks, some positive mechanical means shall be provided to maintain the tension during the entire period between the tensioning of the wires/strands and transfer of the prestressing force to the concrete element.

Transfer of prestress shall not proceed until the Engineer has approved the proposed method. Tendons and deflection devices shall be released in such a pre-determined order that unacceptable tensile stresses are not induced in the concrete.

Prior to transfer of the force to the units, all tendons shall be tested for tightness and any loose tendon shall be reported to the Engineer who will decide whether the units affected shall be rejected.

The Engineer may require that tendons be marked at each end of any unit to allow measurement of the pull-in of the concrete.

Tendons shall be released gradually and preferably simultaneously.

Under no circumstances shall tendons be cut while under tension.

On completion of the transfer of prestress, the projecting lengths of tendon shall be cut off flush with the end surface of the unit, unless otherwise shown, by a method approved by the Engineer.

In no case shall the transfer of prestressing force to the concrete elements take place before concrete attains the strength specified in the drawings. To determine the specified strength, additional cube testing shall be undertaken at the Contractor's cost. In case steam curing is employed, the cubes shall be placed in the same environment as the

concrete elements to obtain an accurate assessment of concrete strength at the time of transfer.

The sequence of transfer of prestressing force shall be done strictly as indicated in the drawings and ensuring that eccentricities of the prestressing force in the vertical and horizontal directions of the concrete element is a minimum during the entire sequence.

The maximum slip of any tendon during transfer shall not exceed 3 mm at any end of the concrete element. In case this slip is exceeded, the concrete element in question shall be rejected.

1809.5. Protection of Ends

The exposed ends of the tendons and the concrete surfaces of the ends of the units shall be wire brushed clean of all rust, loose mortar, grease and dirt.

The exposed ends of the tendons and concrete surface within 50 mm of tendons shall be then abraded to provide a clean sound surface. An epoxy tar paint suitably formulated to give a dry film thickness of 80 microns per coat shall then be immediately applied over the ends of the tendons unless otherwise directed.

A second coat of paint shall be applied prior to the drying out of the first coat.

1810. 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 and associated operations shall be carried out in such a manner and from 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.

During actual tensioning operation, warning sign shall be displayed at both ends of the tendon.

After prestressing, concrete shall neither be drilled nor any portion

cut nor chipped away nor disturbed, without express 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.

1811. TRANSPORTATION AND STORAGE OF UNITS

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 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

1812. TOLERANCES

Permissible tolerances for positional deviation of Prestressing tendons shall be limited to the following

- a) Variation from the specified horizontal profile : 5 mm
- b) Variation from the specified vertical profile : 5 mm
- c) Variation from the specified position in member : 5 mm

1813. 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.

1814. MEASUREMENTS FOR PAYMENT

Prestressed Concrete shall be measured in cubic metres. The volume occupied by mild steel reinforcement / HYSD bars, high tensile steel, sheathing and anchorages shall not be deducted.

High tensile (prestressing) steel shall be paid for separately and its length shall be measured as actually incorporated in the finished work.

From the length so measured its weight shall be calculated in tonnes on theoretical basis and paid for.

Anchorage devices, additional length of cables for attaching jack, ducts or sheathing, grout, non-prestressed steel reinforcement fixed to the anchorage devices, making of recesses and filling the same, protection by painting with epoxy and furnishing samples for testing shall all be deemed to be included in the item of high tensile steel and shall not be measured separately.

1815. RATE

The contract unit rate for cast-in-place prestressed concrete shall cover the cost of all materials, labour, tools and plant required for mixing, placing in position, vibrating and compacting, finishing as per directions of the Engineer, curing and other incidental expenses for producing concrete of specified strength to complete the structure or its components as shown on the drawings and according to specifications. The contract unit rate shall also include the cost of making, fixing and removing of all centring and forms required for the work unless otherwise specified in the Contract.

For precast prestressed concrete members, the rate in addition to above shall also include the cost of all materials, labour, tools and plant required to transport and place these members in their final position as shown on the drawings and as directed by the Engineer.

The contract unit rate for high tensile steel shall cover the cost of material, labour, tools and plant required for manufacturing, placing, tensioning, anchoring and grouting the high tensile steel in the prestressed concrete as shown on the drawings and as per specifications herein above or as directed by the Engineer.

The cost of anchorage devices, additional length of cables for attaching jack, ducts or sheathing, grout, non-prestressed steel reinforcement fixed to the anchorage devices, making of recesses and filling the same, protection by painting with epoxy and furnishing samples for testing shall all be included in the unit rate. 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 operations.