18 PRESTRESSED CONCRETE

18.1 GENERAL

18.1.1 Scope

1 This section describes the requirements for prestressed post-tensioned concrete, including materials and procedures for installation, stressing and grouting.

2 Related Sections and Parts are as follows:

This Section

Part 2..... Aggregates
Part 3..... Cementitious Material
Part 4, ... Water
Part 5, ... Admixtures
Part 6, ... Property requirements
Part 7, ... Concrete Plants
Part 8, ... Transportation and placing of concrete
Part 9, ... Formwork
Part 10, ... Curing
Part 11, ... Reinforcement
Part 15, ... Hot weather concreting
Part 16, ... Miscellaneous

18.1.2 References

ACI 325.7R ---------- Recommendations for Designing Prestressed Concrete Pavements
ACI 343R ---------- Analysis and Design of Reinforced Concrete Bridge Structures
ACI 350.3R ---------- Seismic Design of Liquid-Containing Concrete Structures
ACI 358.1R ---------- Analysis and Design of Reinforced and Prestressed-Concrete Guideway Structures
ACI 372R ---------- Design and Construction of Circular Wire- and Strand-Wrapped Prestressed-Concrete Structures
ACI 373R ---------- Design and Construction of Circular Prestressed Concrete Structures with Circumferential Tendons
ACI 423.3R ---------- Recommendations for Concrete Members Prestressed with Unbonded Tendons

ASTM A881/A881M -- Standard Specification for Steel Wire, Deformed, Stress-Relieved or Low-Relaxation for Prestressed Concrete Railroad Ties
ASTM A882/A882M -- Standard Specification for Filled Epoxy-Coated Seven-Wire Prestressing Steel Strand
ASTM A641/A641M – Standard Specification for Zinc-Coated (Galvanized) Carbon Steel Wire
ASTM A416/A416M Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete

AWWA D110----------Wire- and Strand-Wound, Circular, Prestressed Concrete Water Tanks

BS 1881 .....Testing Concrete.

BS 5896, ...Specification for high tensile steel wire and strand for the prestressing of concrete

EN 12350, ...Testing fresh concrete

EN 12390, ...Testing hardened concrete

EN 1992 .....Eurocode 2: Design of concrete structures

ISO 1920, ... Testing of concrete

18.1.3 Submittals

1 Samples

(a) a 1 m length sample of strand shall be taken from every 1000 m of strand to be installed in the works with a minimum of one sample of strand per reel, on Site in the presence of the Engineer for strength test at an independent laboratory approved by the Engineer. A reel shall only be accepted if both the breaking load and the 0.1 % proof load of the sample exceed the characteristic load given in BS 5896 Table 6

(b) a minimum of three samples of strand shall be taken at random from each reel of prestressing steel on Site in the presence of the Engineer. The reels on Site shall only be accepted if the relaxation values determined by the tests are equal to or lower than the specified relaxation class of BS 5896.

(c) Sample requirements and frequency for prestressing wire shall meet the requirements of AWWA D110 and ACI 372R.

2 Technical details of the proposed materials and equipment shall be submitted. Details of the jack type and size shall be submitted to allow for clearances to be checked. A calibrated stress-recording device shall be used. Design Data. The Contractor shall submit:

(a) details of the proposed grout mix design

(b) tendon extension calculations

(c) vent pipe spacing and location details.

(d) detailed execution and shop drawings

(e) calculation notes

3 Other Submittals. The Contractor shall also submit:

(a) Curriculum vitae and experience record of the supervisor proposed, who shall have a minimum of five years experience in such a position

(b) Safety procedures, including warning signs, barricades and communication between different stressing locations

(c) The name of the proposed the prestressing company, giving details of previous projects.

18.1.4 Storage and Handling

1 Prestressing steel shall be stored on palettes at least 300 mm above the ground, and be protected from contamination by wind blown sand or rain.

2 Prestressing strand shall be in coils of sufficiently large diameter to ensure that the strand pays off straight.

18.2 PRESTRESSING

18.2.1 General

1 Prestressing operation shall be carried out only under the direction of an experienced and competent supervisor and all personnel operating the stressing equipment shall have been properly trained in its use.

2 In addition to the normal precautions against accident, which should be taken at all times for the whole of the Works, special care shall be taken when working with or near tendons which have been tensioned or are in the process of being tensioned.

3 The system of prestressing used shall be a system approved by the Engineer. Such system shall be used strictly in accordance with the recommendations of the system manufacturer.

4 Under no circumstances shall equipment or fittings designed for use with one system of prestressing be used in conjunction with equipment and fittings designed for use with another system.

5 Prestressing components shall be stored in clean dry conditions. They shall be clean and free form loose rust and lose mill scale at the time of fixing in position and subsequent concreting. Slight rusting of the steel, which can be removed by moderate rubbing, is acceptable, but the surface shall not show signs of pitting.

18.2.2 Wires and Strands

1 All prestressing strands shall be seven-wire super stabilised low relaxation strands with a Guaranteed Ultimate Tensile Strength (GUTS) of not less than 1770 MPa, complying with BS 5896 or relevant ASTM standards.

2 All prestressing wire shall be cold-drawn, high-carbon wire meeting the requirements of ASTM A821/A821M, Type B having a minimum ultimate tensile strength of 1,448 MPa (210,000 psi) prior to galvanizing. Zinc coating for galvanizing shall meet the requirements of ASTM A641/A641M, with a minimum weight per unit area of uncoated wire surface of 259 g/m2 (0.85 oz/ft2). The minimum ultimate strength of the wire after galvanizing shall be no less than 1,241 MPa (180,000 psi).

3 All wires or strands to be stressed at the same time shall be taken from the same parcel. The coil numbers of the steel used for each tendon shall be recorded.

4 Welding of tendons shall not be permitted.

5 All cutting of strands shall be carried out using a high-speed abrasive cutting wheel or friction saw at not less than one diameter from the anchor. Cutting shall take place only after the Contractor has submitted the stressing records and the Engineer has approved them in writing. Flame cutting will not be permitted.

6 Tendons shall be built into the Works strictly in accordance with the system which is being employed.

7 Sufficient strand shall project from the anchorage to allow jacking to take place at the stressing end of the tendon.

8 The cable (tendons) or individual strands comprising the cable shall not be kinked or bent. No strand that has become unravelled shall be used.

18.2.3 Sheaths, Cores and Ducts

1 Sheaths shall be accurately located both vertically and horizontally as described in the Specific Project Specification. Unless otherwise described in the Specific Project Specification the tolerance in the location of the centre line of the sheath shall be within ±5 mm.

2 All sheaths and cores shall be maintained in their correct positions during the placing of the concrete. Unless otherwise agreed with the Engineer, sheaths shall be rigidly supported at points not less than 50 mm and not more than 500 mm apart. The method of support shall be to the approval of the Engineer.

3 Where sheaths are used, the number of joints shall be kept to a minimum and sleeve connectors shall be used for jointing. Each joint shall be adequately sealed against the ingress of material. Joints in adjacent sheaths shall be staggered by at least 300 mm

4 Sheaths shall be kept free of matter detrimental to the bond between the grout and the sheath and, except for material sealing a sheath joint, between the sheath and concrete.

5 Within 24 hours of the concrete being placed the Contractor shall satisfy the Engineer that the tendons are free to move if they are in ducts or that the ducts are free from obstruction.

6 The number and position of grout vents for entry and outlet points and for checking that the entire length of duct has been adequately grouted, shall be agreed with the Engineer before the ducts are formed.

7 Vents shall be provided at low points in the tendon profile to allow the disposal of water that may have collected as a result of rain or curing, for example. The vents shall be sealed before grouting operations beginning.

18.2.4 Anchorages

1 Anchorages, end blocks and plates shall be positioned and maintained in position during concreting so that the centre line of the duct passes axially through the anchorage assembly.

2 All bearing surfaces shall be clean before concreting and tensioning.

3 Anchoring of prestressing wires shall meet the requirements of AWWA D110 and ACI 372R.

18.2.5 Jacking Equipment

1 All jacking equipment used for stressing operations shall be of the type applicable to the system adopted.

2 Jack and pumps shall be calibrated at an independent facility, in the presence of the Engineer, before beginning stressing operations. Calibration of the equipment shall take place at six-month intervals for equipment permanently present on Site. Whenever new equipment is brought to the Site, or equipment is removed and returned, or serviced, recalibration of the equipment as described will be required.

3 All gauges, load cells, dynamometers and other devices used for measurement shall have a reading accuracy of within ±2 %.

4 Stressing equipment for prestressing wires shall meet the requirements of AWWA D110 and ACI 372R.

18.2.6 Tensioning

1 The Contractor shall submit details of the proposed stressing loads and stressing sequence to the Engineer for approval.

2 Tensioning shall be carried out only in the presence of the Engineer or his representative unless permission has been granted to the contrary.

3 The Contractor shall ensure that personnel carrying out the stressing are provided with particulars of the required tendon loads, order of stressing and extensions.

4 Immediately before tensioning, the Contractor shall prove that all tendons are free to move between jacking points.

5 Unless otherwise permitted in the Contract, concrete shall not be stressed until it has reached at least the age at which two test cubes taken from it attain the specified transfer strength. The cubes shall be made and tested as described in BS 1881, EN 12350, EN 12390 or ISO 1920. They shall be cured in similar conditions to the concrete to which they relate to, and in a manner approved by the Engineer.

6 The friction factors assumed for the calculation of tendon extension shall be verified by on Site measurement of the force-extension relationship of a typical sample of installed tendons.

7 The Contractor shall establish the datum point for measuring extension and jack pressure to the satisfaction of the Engineer.

8 The tendons shall be stressed at a gradual and steady rate until they attain the force required.

9 The maximum force exerted on the shall not exceed 75 % of the GUTS of the strand. For the purposes of cable detensioning, where the installed strand is to be discarded the jacking force may be increased to 80 % GUTS.

10 The force in the tendons shall be obtained from the readings on a load cell or pressure gauge and the extension of the tendons measured. The two readings shall conform to the limits set by the Engineer but in all cases the force in the tendon as computed from the extension measurement shall be within +5 % to -2 % of the force indicated by the gauging system.

11 When stressing from one end only the pull in at the dead end shall be accurately measured and the appropriate allowance made in the measured extension at the live end.

12 If the calculated and measured extensions vary from each other by more than ±6 % then corrective action shall be taken. This may involve detensioning and retensioning of the tendons if required by the Engineer.

13 When the required force, including overloads of short duration, has been applied to the satisfaction of the Engineer, the tendons shall be anchored. The jack pressure shall then be relieved in such a way as to avoid shock to the anchorage or tendons.

14 If the pull-in of tendons at the completion of anchoring is greater than that acceptable to the Engineer, the tendons shall be detensioned and the tendon tensioned again.

15 The Engineer may direct that the force in any tendon be tested by rejacking. This will only be instructed if there is doubt that the calibration of tensioning equipment is accurate. Care shall be exercised by the Contractor during the retensioning to ensure that the jacking load does not exceed more than 80 % of the GUTS of the strand.

16 If it is necessary to crop the tendons to enable the ducts to be grouted, this shall be delayed as long as is practicable up to the time of grouting. In all other cases, unless otherwise agreed with the Engineer, the tendons shall not be cropped less than three days after grouting.

17 The Contractor shall keep full records of all tensioning operations, including the measured extensions, pressure gauge or load cell readings and the amount of pull-in at each anchorage. Copies of these records, on suitable forms, shall be supplied to the Engineer within 24 hours of each tensioning operation.

18 Tensioning prestressing wires shall meet the requirements of AWWA D110 and ACI 372R

18.2.7 Grouting

1 Grouting shall take place only with the written approval of the Engineer.

2 All ducts shall be thoroughly cleaned by means of compressed air and all anchorages shall be sealed before grouting.

3 Ducts shall be grouted as soon as practicable after the tendons in them have been stressed and the Engineer's written permission to commence has been obtained. Grout shall be injected in one continuous operation and allowed to flow from the vents until the consistency is equivalent to that being injected. The maximum time between mixing and injection shall not exceed 30 min.

4 The ducts shall be completely filled with grout.

5 Vents shall be sealed consecutively in the direction of flow and the injection tube sealed under pressure until the grout has set. The filled ducts shall be protected to the satisfaction of the Engineer to ensure that they are not subject to shock or vibration for one day.

6 Two days after grouting, the level of grout in the injection and vent tubes shall be inspected and made good if necessary.

7 The Contractor shall keep full records of grouting including the date each duct was grouted, the proportions of the grout and admixtures used, the pressure, details of interruptions and topping up required. Copies of these records shall be supplied to the Engineer within three days of grouting.

8 Prestressing wires shall be protected against corrosion and other damage by a shotcrete cover coat meeting the requirements of AWWA D110 and ACI 372R

18.2.8 Grout Mixer

1 The grout mixer shall produce a grout of colloidal consistency. The grout injector shall be capable of continuous operation with a sensibly constant pressure up to 0.7 MPa and shall include a system of circulating or agitating the grout whilst the actual grouting is not in progress. All baffles to the pump shall be fitted with sieve strainers size BS 14.

2 The equipment shall be capable of maintaining pressure on completely grouted ducts and shall be fitted with a nozzle which can be locked off without loss of pressure in the duct.

3 The pressure gauges shall be calibrated before they are first used in the Works and thereafter as required by the Engineer. All equipment shall be thoroughly washed with clean water at least once every three hours during grouting operations and at the end of use for each day.

4 The Contractor shall ensure that standby grouting equipment is available in the event of a breakdown.

18.2.9 Grout Trials

1 The Contractor shall carry out grouting trails to the satisfaction of the Engineer before actual grouting taking place.

2 Unless otherwise directed or agreed as a result of grouting trials, the grout shall:

(a) consist only of ordinary Portland cement, water and an approved expansion agent

(b) have a water: cement ratio as low as possible consistent with the necessary workability. Under no circumstances shall the water: cement ratio exceed 0.4

(c) not be subject to bleeding in excess of 2 % after 3 h or 4 % maximum when measured at 18 ^{o}C in a covered glass cylinder approximately 100 mm diameter with a height of approximately 100 mm and the water shall be reabsorbed after 24 h.

3 Admixtures containing chloride or nitrates shall not be used. Other admixtures shall be used only with the written permission of the Engineer and shall be used strictly in accordance with the manufacturer's instructions.

4 The grout shall be mixed for a minimum of 2 minutes and until a uniform consistency is obtained.

END OF PART