

SECTION 9 - CONCRETE WORK

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S9.01 CONTRACTOR PLACED AGAINST ROCK

- (1) The requirements of this clause apply to all concrete placed against rock on the surface and underground.
- (2) All spaces outside the minimum specified thickness of the concrete shall be filled completely and solidly with concrete and the Contractor shall ensure that concrete is forced into all irregularities in the excavated surfaces.
- (3) Where an appreciable quantity of water flows from the excavated surface against which the concrete is to be placed, it shall be excluded from the space to be filled by concrete by caulking, diverting by pipes, pans and other means, and pumped from sumps, until the concrete has set sufficiently to be unaffected by water through the action of percolation, hydrostatic pressure or abrasion.
- (4)
 - (a) The Contractor shall backfill grout all spaces between the rock remaining unfilled after placing of the concrete has been completed, provided that such grouting shall be performed after the concrete has attained sufficient strength, as determined by the Engineer, to resist the grouting pressures. The injection of the grout shall be done at a pressure determined by the Engineer, but in no case shall the pressure exceed 200kPa (2kg/cm²).
 - (b) The backfill grout shall be injected through drilled holes or through pipes set in the concrete. The size and location of the holes and pipes shall be as shown on the Drawings or as directed.
 - (c) The installation of the pipes and fittings, grout materials, and grout placing operations for this grouting requirement shall be in accordance with the applicable provisions of Section 6.(Not Applicable)

S9.02 DIVERSION TUNNEL CONDUIT PLUG (Not Applicable)

- (1) The Contractor shall furnish and install closure bulkhead gate in accordance with the provision of Clause S9.04. The second stage concrete in the diversion tunnel conduit plug shall be placed immediately after the bulkhead gate has been installed and all the work required by this Clause shall be completed as soon as is practicable thereafter.
- (2) Concrete shall be placed in sections with drainage pipes to allow the removal of percolated water, air vents, grout stops, and grouting system.

- (3) Grouting of joints between the first and second stage concrete in the conduit plug shall be in accordance with Clause 6.05(8), and shall not commence until the concrete has attained sufficient strength. Grout shall be forced through previously installed longitudinal feeder pipes along the conduit axis and lateral riser pipes with grout outlets.

S9.03 MASS CONCRETE PLACING AT WEIR CREST, CHUTE AND STILLING BASIN

- (1) The Contractor shall submit the concreting procedure and method of placing concrete for the mass concrete at structure for the Engineer's approval thirty (30) days prior to start the concrete placing.
- (2) The Contractor proposal for the concreting shall be based on the following criterion:
 - (a) Time and rate of placement.
 - (b) Control of concrete temperatures.
 - (c) Treating of the construction joints.
 - (d) Proposed method for the uniform concrete consistency and control of concrete slump.
- (3) The maximum size of coarse aggregate shall be 75 mm in accordance with Clause S8.02.
- (4) The slump of concrete shall be kept as low as practicable for vibrator consolidation so as to reduce excessive mortar breeding on the surface. Concrete of relatively dry consistency 1 to 2 inch slump shall be used and adequately and thoroughly vibrated into place.
- (5) Block diversion will be made to suit the capacity of concrete placing and production of concrete to avoid delay of placing which result in cold joints within a lift. Any imperfection and defective concrete shall be removed and replaced.
- (6) Care shall be taken to vibrate and consolidate concrete in the area where a newly place layer of concrete joins previously placed concrete. Procedures for vibration shall be established to eliminate the possibility of incomplete consolidation.
- (7) The concrete temperature shall be strictly control according to Clause S8.06.

S9.04 CONCRETE IN BLOCKOUTS AND UNDER BASEPLATES

(1) Requirement

- (a) The Contractor shall place blockout concrete blockouts, constructed as shown on the Drawings or as directed, after the installation and adjustment of metalwork furnished and installed has been completed. Blockout concrete, excludes concrete designated on the Drawings are considered as second stage concrete.
- (b) The Contractor shall also construct blockouts and place concrete in the blockouts to permit installation of items of structural steelwork, metalwork and hydromechanical equipment to be furnished and installed by the Contractor (or his subcontractor), and the cost of such work shall be included in the cost of the concrete in which the blockout is provided and the items installed respectively.

(2) Preparation and Placing Concrete in Blockouts

- (a) Before concrete is placed in the blockouts, the concrete surfaces of the blockouts shall be roughened by chipping or other approved methods and in such a manner as not to loosen, crack or shatter any part of the concrete beyond the roughened surface.
- (b) After being roughened, the surface of the concrete shall be cleaned in accordance with Clause S8.18 and shall be sound and hard and in such a condition as to ensure a good mechanical bond between the existing and the new concrete.
- (c) All concrete which is not hard, dense and durable, as determined by the Engineer, shall be removed to the depth required to secure a surface satisfactory to the Engineer.
- (d) The Contractor shall place the concrete in blockouts in such a way as to ensure satisfactory bond with the existing concrete, to secure complete contact with metalwork to be embedded in the blockout concrete and to avoid displacement of the metalwork being embedded. Where directed, concrete placed in blockouts shall contain an approved expanding agent in accordance with Clause S8.04(2) (C) or placing of mixed concrete shall be delayed to reduce subsequent shrinkage. The cost of preparing the surface of the concrete against which blockout concrete is to be placed, shall be included in the rate for concrete in the blockout.

S9.05 CONCRETE IN SURFACE WORK

- (1) The Contractor shall place all required concrete for the following surface works:
 - box culvert diversion

- . conduit pipe
- . river outlet
- . intake tower

(2) Concrete Surround for Steel pipe Conduit

- (i) The steel conduit shall be supported on steel or concrete cradles resting on the first stage concrete. The steel liners shall be braced internally to maintain their correct shape.
- (ii) The Contractor shall provide all external bracing and ties necessary to maintain the conduit pipes in their correct position during placement of the surrounding concrete.
- (iii) The Contractor shall not carry out any welding to the steel conduit except for the attachment by welding of steel reinforcing bars passing through the seep rings at the upstream end of the steel conduit. Welding of the reinforcing bars to the seep rings shall be carried out by qualified welders.
- (iv) Prior to the concrete embedment of the steel conduit, the Contractor shall provide grout pipes and outlets below the invert of the conduit pipe to enable any void in the concrete placed beneath the pipe to be subsequently grouted. The Contractor shall not weld any grout pipe or fitting to any part of the steel conduit. After completion of the concrete embedment, backfill grouting of all voids between the steel conduit and the concrete surround shall be carried out by the Contractor in accordance with the applicable requirements of the Specification.

S9.06 CONCRETE IN TUNNELS (Not Applicable)

- (1) The Contractor shall place all required concrete for the following tunnels as shown on the Drawings or directed:
 - . diversion tunnel and tunnel portals

(2) Placing Concrete in Tunnels

Concrete in tunnel linings shall be placed by a displacement type pump or by pneumatic placing equipment or by any other acceptable method. The equipment used in placing the concrete, and the method of its operation, shall be such as will permit introduction of the concrete into the forms without high-velocity discharge and resultant segregation. After the concrete has been built up over the arch of tunnel lining at the start of a placement, the end of the discharge line shall be kept adequately buried in the concrete during placement of the arch to ensure complete filling. The discharge line shall be marked so as to indicate the depth of burial at any time. Concrete shall be forced into all irregularities in the rock surface to fill completely the arch. Placing equipment

shall be operated by experienced operators only. Cold joints in tunnel linings shall be avoided where practicable. Where an appreciable quantity of water flows from the rock against which the concrete is to be placed, the water shall be excluded from the space to be filled with concrete by caulking, diverting by pipes, pans and other means, and the pumping from sumps, until the concrete has set sufficiently to be unaffected by action of the water through percolation, hydrostatic pressure or abrasion.

(3) Removal of Timber before Placing Concrete Lining

- (a) Unreinforced lined sections of tunnels and shafts: In unreinforced concrete lined sections of tunnels and shafts supported by steel rib supports all loose timber shall be removed as completely as practicable before concrete lining is placed. All timber spreaders shall be removed prior to placement of concrete lining. The Contractor shall securely brace the supports with the minimum practicable amount of blocking and wedging. No timber support accessories will be permitted between the outer face of the steel rib support and the minimum excavation line.
- (b) Circular lined sections of tunnels and shafts: No timber support accessories will be permitted in circular lined sections of tunnels and shafts supported by steel rib supports. Only steel support accessories shall be permitted to remain prior to connecting. All timber spreaders shall be removed prior to placement of concrete lining.

(4) Concreting Behind Steel Conduit Liners in Diversion Tunnel Plug

- (a) Before concreting behind steel conduit liners all objectionable material shall be removed from the outside surface which shall be maintained clean until concrete is placed. Field welding of any joint shall be completed before concreting. All temporary timber struts, loose material and debris shall be removed from outside the conduit liner before concreting.
- (b) The Contractor shall adequately support and anchor the steel conduit liners with effective steel or concrete cradles. Site welding of supports to the outside of the pipeshell will not be allowed. The temporary internal stiffeners of the tunnel liners shall not be removed for at least 24 hours after placing concrete backfill.

(5) Backfill Grouting

- (a) The Contractor shall backfill grout all spaces between the concrete lining and rock and between the concrete and steel liners remaining unfilled after placement of the concrete has otherwise been completed provided that such grouting shall be performed after the concrete has cooled and obtained sufficient strength as determined by the Engineer to resist the grouting pressures. The injection of the grout shall be done at a pressure

as determined by the Engineer but in no case shall the pressure exceed 200 kPa (2 ksc).

- (b) In unreinforced concrete lined sections the backfill grout shall be injected through holes drilled through the concrete or through pipes set in the concrete.
- (c) In reinforced concrete lined sections the grout shall be injected through pipes set in the concrete lining.
- (d) In steel lined sections, the grout shall be injected through holes drilled to rock at the location of the predrilled grout holes provided in the steel liners. At any point where inspection indicates that a cavity exists between the steel liner and the concrete, the Contractor shall drill and tap the liners to provide additional grouting points.
- (e) The size and location of the holes or pipes shall be as shown on the Drawings or as directed by the Engineer.
- (f) Composition of backfill grout
 - . cement and water
 - . cement, fine aggregate and water, or
 - . cement, filter and water.

The proportions of water to cement by weight shall be within the range 0.7 to 0.8. The proportion of fine aggregate to cement by weight shall be within the range 1.5 to 2.0. The fine aggregate for grout shall be clean 100 percent shall pass a 2.36 mm sieve and at least 30 percent shall pass at 0.30 mm sieve.

- (g) Grout plugs

After completion of the backfill grouting, the grout holes shall be sealed off with threaded steel plugs and a sealing compound, as shown on the Drawings or directed by the Engineer.

- (h) At any point where inspection indicates that a cavity exists between the steel liner and the concrete, the Contractor shall drill and tap the liners to provide additional grouting points. After completion of the backfill grouting, the grout holes shall be sealed off with threaded steel plugs and a sealing compound, as shown on the Drawings or directed by the Engineer.

(6) Exploratory Adits

- (a) The Contractor shall place concrete in the existing exploratory adits as shown on the Drawings or as directed by the Engineer. The exploratory adits shall be cleared of all timber supports and loose rock, clay rubbish and other objectionable material removed to the satisfaction of the Engineer. The floor of the adits shall be free of standing water immediately prior to concreting. All the exploratory adits shall be filled completely and solidly with concrete and the Contractor shall ensure that concrete is forced into all irregularities in the rock surface.

- (b) Backfill grouting

The Contractor shall backfill grout all spaces in the roofs and side walls of the adits remaining unfilled after placing of the concrete.

(7) Concrete in Tunnel Plugs

- (a) The Contractor shall place all required concrete for the tunnel plugs as shown on the Drawings or directed by the Engineer.

- (b) Placing Concrete in Tunnel Plugs

- (i) The Contractor's proposal for cooling of the concrete in the tunnel plug shall be submitted to the Engineer at least sixty (60) days prior to commencement of concreting. The cooling system and thermometer pipes shall consist of black steel pipes embedded in the concrete. Cooling shall commence at the time of placing the concrete in the plug and shall continue until the concrete temperature has been reduced to that of the surrounding rock.
 - (ii) The Contractor shall supply, install and test thermometers.
 - (iii) Grouting between concrete and rock and between the plug placements shall be carried out after the concrete has cooled to the surrounding rock temperature.
 - (iv) After the cooling and thermometer pipes have served their purpose, the embedded pipes shall be filled with grout. The grout shall be forced into the pipes with only sufficient pressure to ensure that the pipes are completely and solidly filled. All holes left at the grout connections shall be filled immediately and completely with dry-pack.

- (v) The Contractor shall furnish and install closure stop logs in accordance with the requirements for diversion. The second stage concrete in the diversion tunnel plug shall be placed immediately after the bulkheads have been installed and all the work required by this Clause shall be completed as soon as is practicable thereafter.
- (vi) Grouting of the joints between the first and second stage concrete in the tunnel plug shall not commence until the concrete has cooled to 25°C.

S9.07 CONCRETE IN POWERHOUSE

- (a) The Contractor shall place all required concrete in the Power House as shown on the Drawings or directed by the Engineer.

- (b) Tentative Features

The following features, as shown on the Drawings, are tentative only and the Contractor shall not be entitled to any additional compensation above the rates tendered in the priced Bill of Quantities for the items of concrete on account of changes to such features:

- (i) Levels of floors.
- (ii) Sizes of columns, girders and beams.
- (iii) Thickness of walls and floors.
- (iv) Location of walls, partitions, floors, columns, girders, beams and openings.
- (v) Numbers, locations and sizes of blockouts, holes, pipes, pits, trenches, cables, anchor bolts and embedded metal work for plant.

- (3) Details on Drawings

Blockouts, holes, pipes, pits, trenches, pedestals and embedded metalwork for machinery, pipes, cables, anchor bolts and other accessories are not fully detailed on the Drawings and may be changed in number, location or size when full details of the equipment and accessories become available. The Contractor will not be entitled to any increase in rates for such changes made before concrete placement around the relevant blockouts, holes, pipes, pits, trenches, pedestals or embedded metalwork commences.

- (4) Openings

Openings in floors and walls shall be formed before the concrete is placed.

(5) Allowance for Floor Tiles

Concrete slabs to be covered with a floor finish or tiles shall be left at a sufficient depth below the finished floor elevations to permit placing of the required thickness of floor finish or tiles, and proper allowance shall be made for the finish when anchor bolts, pipes and other metalwork are placed. Concrete slabs forming floors shall be carefully screeded to the design levels shown on the Drawings. Scrabbling or grinding to bring the floor to the correct levels will not be permitted after installation of mechanical or electrical equipment has commenced.

S9.08 BACKFILL CONCRETE

The Contractor shall place backfill concrete in the following locations:

- . filling seams and treating defects, below the general level of excavations
- . modifying abutment contact slopes
- . filling over excavations
- . bedding below the lining of surface drains
- . elsewhere as directed.

S9.09 MISCELLANEOUS CONCRETE

The Contractor shall place miscellaneous concrete in the following locations:

- . concrete surround, anchor blocks and pits for water supply, drainage and sewerage pipes
- . drainage junction sumps, manholes, cable pits and trenches valve boxes, hydrant boxes, septic tank and biological filter
- . inlet sumps, head walls, retaining walls, wing walls, concrete surround for culverts
- . terminal structures and instrument boxes
- . kerb paths, kerb drains, channel drains, gutters footpaths in parking areas and drainage inverts
- . backfill for drainage
- . base and associated valve pit for the water supply tank
- . foundations
- . rock traps
- . other miscellaneous concrete as shown on the Drawings or directed.

S9.10 MEASUREMENT AND PAYMENT

(1) General

- (a) Measurement, for payment, of concrete required to be placed directly upon or against surfaces of excavation will be made to the lines for which payment for excavation is made.
- (b) Measurement, for payment, of second stage concrete required as shown on the Drawings will be made of the actual volume of concrete directed to be placed.
- (c) Measurement, for payment, of backfill concrete, concrete placed in the cutoff wall, concrete placed in cavities, concrete placed in exploratory adits and concrete placed at upstream toe of the dam will be made of the batch volume of concrete placed in these locations.
- (d) Measurement, for payment, of all other concrete will be made to neat lines of the structures as shown on the Drawings unless otherwise prescribed in this Specification.
- (e) In measuring concrete for payment, deductions will be made for the volume of all ducts, embedded pipes, surface conduits and drains, recesses for rails and gate guides in first stage concrete, embedded metalwork and other blockouts having a cross-sectional area larger than 0.10 square meters as measured at right angles to their longitudinal axis. Deductions will also be made for all openings, recesses and blockouts with cross-sectional area less than 0.10 square meters but which have an individual volume larger than 0.5 cubic meters.
- (f) Measurement, for payment, of concrete required for treatment of defects outside the excavation pay lines other than in excavation for underground works, will be made of the actual volume of concrete directed to be placed in these locations.
- (g) Payment for concrete in the various parts of the Works will be made at the applicable rate per cubic meter bid in the Schedule. These rates shall include the cost of all labor, constructional plant and materials including cement required in the construction, except that payment for furnishing and handling joint filler, waterstops and reinforcement bars and fabric will be made at the applicable rates bid in the Schedule.
- (h) Except as provided in subcause (f) of this Clause, payment will not be made for concrete required to be placed outside specified or approved excavation pay lines due to over-breakage, excess excavation or wasted concrete, or for any other reason.

(2) Formwork

Measurement, for payment, of formwork, separate payment will not be made for formwork for concrete and all costs shall be included in the rates bid in the Schedule for the various items of concrete constructions.

(3) Reinforcing Bars

- (a) Measurement, for payment, of placing reinforcing bars will be made only of the calculated mass of the bars placed in the concrete in accordance with the Drawings or as directed by the Engineer.
- (b) Payment for placing grade SR 24 rounded reinforcing bars will be made at the rate per tonne bid therefor in the Schedule. Payment for placing grade SD30 and SD40 deformed reinforcing bars will be made at the rate per tonne bid therefor in the Schedule.
- (c) All joints or splices shown on the Drawings or directed by the Engineer will be measured for payment as laps, Mechanical compression couplings, approved by the Engineer, will be measured for payment in terms of length of equivalent lap joint. Additional joints or splices will not be measured for payment.
- (d) These rates shall include the cost of preparing reinforcement detail drawings, scheduling reinforcement and of furnishing and attaching wire ties and metal, concrete or other supports, of cutting, bending, cleaning, securing and maintaining in position all reinforcing bars. Payment will not be made for joints or splices nor for reinforcement used in miscellaneous precast and prestressed concrete units.

(4) Diversion Tunnel (Not Applicable)

- (a) Payment for concrete in the diversion tunnel closure gate structure, inlet and outlet structures and the circular sections of diversion tunnel will be made at the rate per cubic meter bid there for in the Schedule.
- (b) Payment for concrete in tunnel plug structure will be made at the rate per cubic meter bid therefor in the Schedule. This rate shall include the cost of the concrete cooling, thermometer pipes and thermometers and grouting of joint.

(5) Concrete Plug

In addition to works included as described in Clause S9.10(1), the entire cost of labor and material related to contact grouting between the plug concrete and the conduit walls shall be included in the rate bid in the Schedule for concrete plug in diversion conduit.

(6) Structure Concrete

- (a) Payment for concrete in structure: floor slabs, cantilever walls and bridge pier will be made at the rate per cubic meter bid therefor in the Schedule.
- (b) Payment for the precast prestressed beams for the bridge will be made in accordance with Clause S10.06.
- (c) Payment for concrete and concrete non-shrink compound will be made at the rate per cubic meter bid therefor in the Schedule.
- (d) Payment for concrete in the power house will be made at the rate per cubic meter bid therefor in the Schedule.

(7) Blockout and Second Stage Concrete

Payment for blockout and second stage concrete will be made at the rate per cubic meter bid therefor in the Schedule.

(8) Miscellaneous Concrete

Payment for miscellaneous concrete will be made at the rate per cubic meter bid therefor in the Schedule.

(9) Waterstops

- (a) Measurement, for payment, of furnishing and placing waterstops will be of the lengths placed in accordance with the Drawings or as directed by the Engineer. Waterstops installed by the Contractor in construction joints in locations other than those shown on the Drawings or directed by the Engineer will not be measured for payment.
- (b) Payment, of furnishing and placing waterstops will be made at the applicable rate per linear meter under the following types set forth in the Schedule.
 - (i) PVC waterstop type A, B and C

(10) Material Seals in Joints

Separate payment will not be made for material seals in joints and cost of materials shall be included in the rate bid in the Schedule for the various items of concrete joints.

(11) Joint Fillers and Sealer

- (a) Polysulphide and Bitumen-Rubber mastic joint filler
Measurement, for payment, of furnishing and placing mastic joint filler will be made of the dimensions shown on the Drawings Payment for

furnishing and placing polysulphide and bitumen-rubber mastic joint filler will be made at the rate per square meter bid therefor in the Schedule. This rate shall include the cost of the protective synthetic rubber membrane.

(b) Bituminous fiber sheet and expanded polystyrene joint filler

Measurement, for payment, of furnishing and placing bituminous fiber sheet and expanded polystyrene joint filler will be made to the dimensions shown on the Drawing of the area required to be covered with joint filler and deductions will not be made for openings required to be made in the joint filler. Joint filler required to be placed beyond the excavation pay lines will not be measured for payment. Joint filler required to be raked out of the joint will be measured for payment as expanded polystyrene. Payment for furnishing and placing bituminous fiber sheet joint filler, and for furnishing and placing expanded polystyrene joint filler will be made at the applicable rate per square meter bid therefor in the Schedule.

(c) Joint strips

Measurement, for payment, of furnishing and installing joint strips will be made of the length of joint strips as shown on the Drawings or directed by the Engineer. Payment for furnishing and installing joint strips will be made at the rate per linear meter bid therefor in the Schedule.

(d) Annular seal for pipes

Measurement, for payment, of furnishing and placing annular seal for pipes will be made of the length of joint sealed as shown on the Drawings or as directed by the Engineer. Payment for furnishing and placing annular seal for pipes will be made at the rate per linear meter bid therefor in the Schedule.

(e) Cork board

Measurement, for payment, of furnishing and placing cork board will be made of the area of joint sealed as shown on the Drawings or as directed by the Engineer. Payment for furnishing and placing cork board will be made at the rate per square meter bid therefor in the Schedule.

(f) Cork mastic

Measurement, for payment, of furnishing and placing cork mastic will be made of the volume of joint filled with mastic shown on the Drawings or directed by the Engineer. Payment for furnishing and placing cork mastic will be made at the rate per square meter bid therefor in the Schedule.

(g) Pipe wrapping material

Measurement, for payment, of furnishing and placing pipe wrapping material will be made of the area of pipe shall wrapped as shown on the Drawings. Payment for furnishing and placing pipe wrapping material will be made at the rate per square meter bid therefor in the Schedule.

(h) Epoxy mortar

Measurement, for payment, for epoxy mortar will be made of the actual volume of mortar placed in the blockout and under baseplates. Payment for furnishing and placing epoxy mortar will be made at the rate per cubic meter bid therefor in the Schedule.

(i) Joint for access road

Measurement, for payment, of furnishing and installing contraction joint, expansion joint and longitudinal joint will be made of the dimensions shown on the Drawings Payment for furnishing and installing all joint will be made at the rate bid therefor in the Schedule.

**SECTION 10 - PILING PRECAST AND
PRESTRESSED CONCRETE**

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S10.01 PILING WORK

(1) GENERAL

Piles shall be constructed, in accordance with the details shown on the Drawings, of concrete Class D, proportioned, mixed and placed in accordance with the provisions of Section 8 and this Section. Reinforcement shall comply with the provisions of Section 8. Main reinforcing bars shall be supplied in one complete length and should this prove impracticable separate lengths shall be effectively spliced by a method approved by the Engineer.

The pile shall be so straight that a line stretched from tip to butt on any face will not be more than 1/1000 of the length of the pile from the face of the pile at any point.

(2) PREPARATION FOR DRIVING

(a) Abutments

Abutment piles shall be driven from a working surface which extends up to the underside of the pile cap and out to the finished slopes around the abutment. The working surface shall form part of the permanent embankment and shall be constructed to the relevant specifications. Under no circumstances will the Contractor be permitted to complete this part of the embankment after the piles have been driven.

(b) Pile Caps

The heads of all concrete piles shall be protected by caps of approved design, preferably having a rope or other suitable cushion next to the pile head and fitting into a casting which in turn supports a timber shock block.

(c) Splicing Piles

Full length piles shall be used where practicable. In exceptional circumstances splicing of piles may be permitted.

Splices shall be made as follows:

After the driving is completed, the concrete at the end of the pile shall be cut away, leaving the reinforcement steel exposed for a length of 40 diameters. The final cut of the concrete shall be perpendicular to the axis of the pile. Reinforcement similar to that used in the pile shall be securely fastened to the projecting steel and the necessary form work shall be placed, care being taken to prevent leakage along the pile. The concrete shall be of the same quality as that used in the pile, just prior to placing concrete, the top of the pile shall be thoroughly wetted and covered with a thin coating of neat cement, retempered mortar or other suitable bonding material. The forms shall remain in place not less than seven days and shall then be carefully removed and the entire exposed surface of the pile finished as previously specified.

(3) METHOD OF DRIVING

(a) General

Reinforced concrete piles may be driven using a drop hammer, single or double acting steam hammer, or a diesel hammer. Drop hammers shall weigh not less than 80 percent of the pile weight and the drop shall be not more than one meter. Steam and diesel hammers shall produce an equivalent energy per stroke.

In case the required penetration is not obtained by the use of a hammer complying with the above minimum requirements, the Contractor shall provide a heavier hammer or resort to jetting at this own expense.

(b) Leads

Pile driver leads shall be of approved design and constructed in such a manner as to afford freedom of movement of the hammer, and they shall be held in position by guys or stiff braces to insure support to the pile during driving. Except where piles are driven through water, the leads shall be of sufficient length so that the use of a follower will not be necessary.

Inclined leads shall be used in driving battered piles, and shall provide sufficient lateral support for the pile so that no undue stresses are induced in the pile during driving.

(c) Followers

The driving of piling with followers shall be avoided if practicable and shall be done only under written permission of the Engineer.

(d) Water Jets

When water jets are used, the number of jets and the volume and pressure of water at the jet nozzles shall be sufficient to freely erode the material adjacent to the pile. The plant shall have sufficient capacity to deliver at all times at least 7 kilograms per square centimeter pressure at 20 mm jet nozzles. Before the desired penetration is reached, the jets shall be withdrawn and the piles shall be driven with the hammer to secure the final penetration.

(e) Accuracy of Driving

Piles shall be driven with a deviation of not more than 1° from the vertical or from the batter shown on the plans. After driving, the positions of the pile heads shall not deviate by more than 80 mm from the positions shown on the Drawings. The center of gravity of any row of piles shall be within 50 mm from its theoretical position in any direction.

(f) Defective Piles

The procedure incident to the driving of piles shall not subject them to

excessive and undue abuse producing crushing and spalling of the concrete. Manipulation of piles to force them into proper position, considered by the Engineer to be excessive, will not be permitted. Any pile damaged by reason of internal defects, or by improper driving or driven out of its proper location or driven below the elevation fixed by the Drawings or by the Engineer, shall be corrected at the contractor's expense by one of the following methods approved by the Engineer for the pile in question:

- The pile shall be withdrawn and replaced by a new and if necessary, a longer pile.
- A second pile shall be driven adjacent to the defective or low pile.
- The pile shall be spliced or build up as otherwise provided herein or a sufficient portion of the footing extended to properly embed the pile.

All piles pushed up by the driving of adjacent piles or by any other cause shall be driven down again to their previous elevations.

(g) Cutting Off Piles

Piles shall be cut off at such elevation that they will extend into the cap or footing as indicated on the Drawings. Reinforced concrete piles may be cast the full length of the reinforcing bars, provided that the concrete is cut off to expose the steel as shown on the Drawings after the piles have been driven.

All cut off lengths of piling shall become the property of the Contractor. Cut-off lengths of piling may be incorporated in the work if approved in writing by the Engineer, otherwise pile cut-off lengths shall be disposed off to the satisfaction of the Engineer.

(4) DETERMINATION OF BEARING CAPACITY

(a) General

All piles shall be driven to such depths or sets as may be required to obtain the necessary allowable bearing value. The Engineer will decide on the criteria for when this value has been achieved, based on the criteria for when this value has been achieved, based on load tests or the driving records. He will choose a factor of safety dependent on the uniformity of the foundation conditions, but the required ultimate load will generally be two and a half times the working load for loading tests, or three times the working loading when determining the final set of the pile according to the specified driving formula.

(b) Test Piles

The lengths of piles shown on the Drawings are based on information which it has been possible to obtain from a site investigation prior to the driving of test piles.

Before the driving criteria are finally settled, the Contractor shall construct to the lengths specified by the Engineer such pilot piles as may be found necessary and these piles shall be driven at the positions and to the set specified by the Engineer, who shall be notified in advance of the driving. The Contractor shall furnish the Engineer daily with a detailed record of the driving of pilot piles throughout the full depth of driving, as specified in clause (c) below.

Based on the results of the pilot piles, the Engineer will choose one or more locations for pile loading tests which shall be carried out prior to driving production piles.

(c) Loading Tests

The Engineer may require one or more loading tests at each building location. At the start of the Project, the Contractor shall therefore submit to the Engineer detailed Drawings of the equipment and arrangement he intends to use for loading tests. The equipment shall be designed to apply loads in smooth increments. If the Contractor proposes to use suspension piles for the load reaction, such tension piles shall be of the same type and size as the permanent piles and shall be driven in the location of permanent piles. Loads for the load test shall not be applied until 10 days or such times as directed by the Engineer have elapsed since the driving of the piles. Tension piles will require strengthening with extra steel to carry the tension loading. The Contractor shall submit Drawings to the Engineer showing the extra reinforcement and method of transferring the load between the piles and loading frame. A minimum of 3 pile diameters clear distance shall be allowed between the test pile and tension piles.

No particular payment will be made for any additional length supplied, cast or driven, or for any additional reinforcement of such piles that may be required for their use as tension piles, nor for any resumed driving that may be ordered by the Engineer, during or after the test, due to the piles having moved, or for repair of any damage caused during the test, such costs being considered incidental to load tests, and included in unit rate of Load Test.

Piles selected by the Engineer shall be tested as follows:

- The test load shall be applied by a method approved by the Engineer and shall be measured within the accuracy of 2 percent. Settlements shall be measured within an accuracy of 0.2 mm.
- The test load shall be applied in the increments of 25 percent of the working load of the pile.
- The load after each increment shall be kept constant until the rate of settlement does not exceed 0.2 mm per hour.
- The amount of settlement shall be recorded before the next increase of load.
- The load shall be reduced in stages equal to those in which it was applied.

- The amount of recovery shall be recorded before the next decrease of load.
- The Contractor shall, within 24 hours of the completion of the test, submit to the Engineer for each pile tested graphs showing load and settlement plotted above and below a common base line of time; settlement and recovery plotted vertically against a base line of load.

The ultimate bearing capacity of the pile shall be defined as the load where the gross settlement begins to exceed 1 mm per ton of additional load, or which cause a gross settlement of 25 mm, whichever occur first.

Other details of loading tests shall conform to method defined by the Engineer.

(d) Driving Records

A record of all piles installed shall be kept by the Contractor and a copy of the record of each day's work shall be given to the Engineer within 24 hours. The record shall contain the following information:

Date of driving
Date of casting and identification number Location of pile
Length of pile and cross section
Ground level before driving
Estimated tip elevation (as shown on the Drawings)
Actual tip elevation after driving
Number of blows for each 30 cm penetration from start of driving
Number of blows for each 10 cm penetration for last 100 cm
Hammer type, weight and rated energy
For drop hammer, the actual drop height
Details of interruptions to driving
Details of redriving
Details of condition of pile head.

On completion of piling, the Contractor shall deliver to the Engineer a drawing recording the final depths of all piles relative to project elevations.

(e) Driving Formula

To interpolate bearing capacities of piles between load test locations or at locations where load tests have not been earned out, the ultimate capacity of piles may be calculated from the following formula:

$$Q_{ult} = \frac{1000eWH}{S+0.5\sqrt{eWHL/A}}$$

Where Q_{ult} = Ultimate bearing capacity in t

W = weight of hammer in t

H	=	drop of hammer in m
L	=	length of pile in m
A	=	cross section of pile in sq.m
S	=	penetration per blow in mm, for the last 20 blows
e	=	efficiency factor:
		1.0 for drop hammer with free fall
		0.7 for drop hammer with wire drum hoist
		0.9 for single or double acting hammer

For piles driven with a diesel hammer, the bearing value may be calculated according to the formula given by the manufacturer of the hammer, subject to the Engineer's approval.

S10.02 PRECAST CONCRETE

(1) General

- (a) The Contractor shall construct and erect precast reinforced concrete units in accordance with this Clause where and as shown on the Drawings or directed by the Engineer.
- (b) Except as otherwise provided in this Clause, all units shall be constructed and erected in accordance with the applicable requirements of the Specification and ACI 318M-83.
- (c) The maximum size of the coarse aggregate for all precast concrete units shall be 20 mm.
- (d) All precast concrete units shall be cast in individual forms and may be cured by steam curing.
- (e) Where the use of immersion type vibrators is not practicable the Contractor shall consolidate thin precast concrete slabs and units on a vibrating table or by another effective method.
- (f) Precast concrete units shall not be branded or marked in any position which can be seen in the finished work or against which any concrete is to be placed.
- (g) The units may be supplied by a manufacturer or may be manufactured by the Contractor at an approved location. For units other than concrete blocks and precast units which are detailed on the Drawings, the Contractor shall also submit to the Engineer all details of the individual

units, including proposed reinforcement, proposed concrete strength and location of lifting points as hereinafter specified.

- (h) Repairing of damaged units will not be permitted except where such damage and repair will not impair the installation or the appearance of the units after installation.

(2) Submission of Proposed Methods

Thirty (30) days before commencing manufacture of all precast reinforced concrete units, the Contractor shall submit to the Engineer all details of the methods to be used in manufacture, handling, transport, storage and erection of the units.

(3) Handling

During transportation and storage, all precast reinforced concrete units shall be supported as in their final positions. Precast members shall be adequately braced and supported during erection to ensure proper alignment and safety. Such bracing or support shall be maintained until adequate permanent connections have been made.

(4) Tolerances

The dimensions of all finished precast reinforced concrete units shall be within the following limits at the time of placement of the units in the structure, unless otherwise shown on the Drawings:

- | | |
|---|----------------------------|
| (a) Overall dimensions of units | +/- 5 mm |
| (b) Cross-sectional dimensions | |
| (i) sections less than 75 mm | +/- 1.5 mm |
| (ii) sections over 75 mm | +/- 5 mm |
| (c) Deviation from straight line in long section | Not more than 5 mm per 6 m |
| (d) Deviation from specified camber | +/- 1.5 mm per 3 m of span |
| (e) Maximum differential in camber between adjacent units in erected position | 10 mm |

S10.03 PRESTRESSED CONCRETE

(1) General

- (a) The Contractor shall manufacture prestressed concrete units (or members) as shown on the Drawings or directed in accordance with this

Clause and the applicable provisions of the Specification. The work shall be supervised either by specialist staff experienced in prestressing or shall be carried out by a specialist subcontractor and shall comply with ACI 318M or AS 1481 except as otherwise specified in this Clause.

- (b) The Contractor shall construct and erect the prestressed concrete members to the lines, grades and dimensions shown on the Drawings or directed.

(2) Methods of Prestressing

- (a) The method of prestressing shall be as shown on the Drawings unless otherwise approved.
- (b) The Contractor may propose an alternative system to that specified herein and shown on the Drawings. The proposed alternative system shall provide means of:
 - (i) prestressing in stages, and destressing at any stage before grouting; and
 - (ii) measuring the load in the tendons.
- (c) All members of the Contractor's alternative system shall be designed for the prestress forces and eccentricities shown on the Drawings. Reinforcement behind prestressing anchor plates shall be designed for the anchor plate sizes and prestressing forces shown on the Drawings.
- (d) Any alternative prestressing systems proposed by the Contractor shall be such that the general arrangement, depth and outward shape of the members remain unaltered.
- (e) The Contractor shall submit to the Engineer, at least thirty (30) days before constructing any members, full details of anchorages, anchorage reinforcement, sheathing and relevant particulars of the proposed tendons, together with complete drawings of those parts of the structure affected by the change and all appropriate design calculations.
- (f) The Contractor shall precast the prestressed members at an approved location.
- (g) The Contractor shall at least thirty (30) days before commencement of manufacture of the prestressed members:
 - (i) Submit, to the Engineer, full details of his method of forming, placing and curing of the members and of his handling, transporting, erection, stressing and grouting methods. The Contractor shall not vary his methods without resubmitting full details of the proposed changes.

- (ii) Submit shop drawings and details of all metalwork, prestressing tendon anchorages to be embedded in the members, schedules of locations of material and marks by which individual items can be identified.

(3) Concrete Materials

Cement, admixtures, water and aggregates for prestressed concrete members shall comply with the applicable requirements of this Specification.

(4) Materials for Tendons

- (a) High tensile steel wire and strand shall conform to ASTM A416 - A421 or AASHTO M204.
- (b) High tensile alloy bars shall have the following physical properties:
 - (i) Minimum tensile strength – 1,080 MPa (11.0 tonnes/cm²)
 - (ii) Proof stress at a non-proportional strain of 5 percent, not less than 85% of the minimum tensile strength.
 - (iii) Percentage elongation at fracture, not less than 6 percent.
 - (iv) Relaxation at 1,000 hours from initial stress of 70 percent ultimate tensile strength, not more than 4 percent.
- (c) The Contractor shall state the secant modulus of the material proposed at the average tensioning stress shown on the Drawings together with the guaranteed limits of its variation. Values shall be substantiated by test results.
- (d) High tensile steel bars will be individually inspected for superficial tears, nicks, roller marks or any other form of surface imperfection. A bar with surface imperfections that range from 0.15 mm to 0.40 mm deep may be accepted for use at the discretion of the Engineer, provided the imperfections whose depths range from 0.15 mm to 0.40 mm are filed smooth with a fine cut half round file. A bar with surface imperfections that exceed 0.40 mm in depth will not be acceptable for use. Notwithstanding the above conditions of acceptance, any bar which has an imperfection that the Engineer considers detrimental to the strength of the bar shall not be used.
- (e) Three (3) test pieces selected by the Engineer shall be tested by the Contractor and manufacture of cables or placing of tendons shall not commence until satisfactory results have been received from these tests. Further test pieces, approximately one for each tonne of tendons used in the construction, will be taken during the progress of the work and shall be tested by the Contractor for conformity with the requirements of this

Specification. The ratio of length to diameter of test pieces will exceed 100:1. Test pieces will not be taken from the end 1.5 m of a coil of wire or strand.

- (f) All testing shall be carried out in an authorized and registered laboratory approved by the Engineer.

(5) Anchorage Devices and Couplings

- (a) All anchorages for high tensile steel strand tendons shall generally be in accordance with ACI 318M. All anchorages shall be provided with a positive centering device so that the anchorage heads shall not move during tensioning operation.
- (b) All high tensile steel bar tendons shall be anchored by means of rolled threads and nuts except that, for wholly embedded anchorages, tapped plates shall be used in conjunction with the rolled threads.
- (c) Anchorages and coupling devices shall be capable of withstanding a force of not less than 95 percent of the specified minimum ultimate tensile strength of the tendon without damage or excessive deformation or draw-in.
- (d) Swaging of strand and button-heading of wire shall be carried out only by approved methods and the swages/button-heads shall develop not less than 95 percent of the specified minimum ultimate tensile strength of the strand or wire.
- (e) At least thirty (30) days before the start of concreting operations, the Contractor shall supply, to the Engineer, details and results of tests carried out on the following:
 - (i) Two (2) complete anchorages and couplings for each type of tendon to be used in the Works.
 - (ii) Two (2) sample lengths of tendon with ends treated for anchorages and couplings.
- (f) Further anchorages and couplings shall be tested by the Contractor during the progress of the work at the rate of one anchorage of each size and one coupling for the strand prestress tendons and one complete high tensile steel bar tendon for each consignment delivered to the Works. Sufficient length of the appropriate made-up tendon shall be tested with each anchorage or coupling for the strand prestressed tendons to suit testing arrangements.
- (g) Anchorages and tendons shall not be installed until test results for the anchorages have shown that they meet the specified requirements.

- (h) Should any anchorage or coupling fail to comply with paragraph d. of this subclause, the quantity of anchorages or couplings represented by that specimen shall be replaced.
- (i) No damaged anchorage or coupling devices shall be used. All steel in the anchorages shall be protected from corrosion at all times. All threaded parts shall be protected by greased wrapping and all tapped holes shall be protected by suitable plugs until used. The devices shall be kept free from mortar, loose rust, grease, tar, paint, oil, mud or any other coating. The Engineer may direct the use of a suitable coating to protect the exposed faces of anchorages and anchorage plates after embedment in the precast girder segments but all such coating shall be removed immediately before the tendons are installed.

(6) Ducts

- (a) Ducts for the insertion of prestressing tendons shall be formed in the concrete members by means of light-gauge steel conduits, flexible steel sheathing or by other acceptable means except that bars may be cast in place after wrapping with a tape coating to prevent bonding with the concrete.
- (b) The ducts shall be strong enough to withstand the placing and the vibration of the concrete without suffering any damage or deformation. Internal and external diameters of the ducts shall be within the limits shown on the Drawings.
- (c) The ducts and any joints shall be mortar tight and the ducts shall be in one piece between the ends of each segment or placement. Curved pieces of duct shall be pre-bent to the dimensions shown on the Drawings and shall be checked with lengths of tendon for flattening and other distortions which might obstruct the free movement of the tendons.
- (d) Before the ducts are embedded in the concrete, they shall be accurately aligned and securely fixed in position by means of rigid supports spaced at intervals of not more than 1 m. Bar tendons to be cast in place shall be similarly aligned and fixed, but shall not be welded to the supports.
- (e) Grout holes shall be provided at both ends of ducts and shall be at least 10 mm in diameter. The grout holes shall be equipped with a plug, valve or similar device capable of withstanding a grout pressure of 700 kPa without loss of water or air. For ducts with high points along their length, additional vents with plug valves of similar diameter shall be provided at the high points to bleed air and water and to ensure that the duct is completely filled with grout after grouting.

(7) Handling and Storage of Tendons and Accessories

- (a) The Contractor shall receive all materials at the Site and store the materials under cover on suitable supports above the ground. High-tensile steel wire and strand shall be supplied in coils, which shall be supported so that they are free to rotate before lengths of tendons are drawn from them. Materials shall be kept free from loose or thick rust, oil, grease, tar, paint, mud, or any other deleterious substance but shall not be brought to a smooth polished condition. A slight film of rust will not be regarded as harmful, but the steel shall not be visibly pitted by rust.
- (b) The Contractor shall be responsible for checking that all dimensions and quantities shown on the manufacturers' schedules are correct and shall obtain copies of these schedules from the manufacturers for this purpose.
- (c) Before being assembled or worked in any way, the prestressing materials shall be clean and free from kinks or damage. All damaged materials shall be removed from the Site and replaced.

(8) Marking of Precast Prestressed Members

- (a) The date of casting, length of member and the identification number directed by the Engineer shall be marked on every precast prestressed member in an approved position which cannot be seen in the finished work. When directed the word "TOP" and/or lifting positions shall also be marked on the member.
- (b) Temporary identification and date of casting marking shall be scratched into the top surface of the member near an end immediately after screeding off.
- (c) The final marking shall be made by indelible marking material using letters approximately 75 mm high.

(9) Lifting, Handling and Stacking of Precast Prestressed Members

- (a) Post-tensioned members shall be fully stressed or stressed to the extent shown on the Drawings and all stressed tendons shall have been grouted for seven (7) days before lifting or handling of the member unless the moving of post-tensioned members off their casting beds before grouting stressed tendons is approved. If such approval is given each ungrouted tendon shall be adequately marked for possible slip and should any slip or damage occur, the tendon shall be replaced and/or restressed as directed.
- (b) At all times, during handling, members shall be secured in an upright position by means of suitable packing pieces and braces. Members shall not be braced against each other but shall be provided with independent bracing. Special care shall be exercised not to damage the flanges of members.

- (c) Members shall not be stacked on top of each other and no superimposed load shall be placed on a member.
- (d) Members shall be handled, lifted and supported carefully at the positions and in the manner shown on the Drawings. Where no method of lifting is shown on the Drawings, the Contractor shall submit details of his proposal for lifting the members.
- (e) No member which is manufactured away from the Site shall be delivered to the Site without prior approval.

(10) Dimensions and Tolerances

- (a) The dimensions and shape of prestressed concrete members stated on the Drawings shall be taken to apply to the members and structure at the time of their completion when under self weight alone.
- (b) Except where stated otherwise on the Drawings or approved by the Engineer, the dimensions and profile of the forms shall compensate for deformations caused by prestressing so that the dimensions and profile of the completed members shall conform to the Drawings. The Contractor shall submit, prior to construction of the forms, details of the magnitude of these deformations and how he proposes to allow for them.
- (c) Variation in the overall length and length centre to centre of bearings shall be accurate to within 5 mm or ± 0.06 percent of the length, whichever is the greater.
- (d) Deviation from profile in a vertical plane:

Sagging profiles will generally not be accepted but upward deviation (hog) from the required profile of up to 0.1 percent of the span length will be permitted.
- (e) The deviation of a member from the required profile in a horizontal plane shall not exceed 5 mm or ± 0.06 percent of the length of the member, whichever is greater.
- (f) Variation in location ducts and sheathing: ± 4 mm.
- (g) Cover to ducts and sheathing shall be not less than 50 mm.

S10.04 MANUFACTURE OF PRESTRESSED CONCRETE MEMBERS

(1) General

- (a) The Contractor shall manufacture precast prestressed concrete members to the dimensions shown on the Drawings or directed.

- (b) Care shall be taken during tensioning to ensure the safety of all personnel engaged on the work and of other persons in the vicinity.
- (c) Jacks shall be secured in such a manner that they will be restrained should they lose their grip on the tendons. No person shall be allowed to stand behind the jacks or close to the line of action in front while tensioning is in progress. The operation of the jacks, the measurement of the elongation and associated operations shall be carried out in such a manner and from such positions that the safety of all concerned is ensured.
- (d) Heavy stoppers made either of hardwood or sheet metal shall be provided and placed in such a manner as to prevent any tendon, which might become loose, recoiling unchecked. During actual stressing operations, warning signs in adequately large letters shall be displayed at both ends of the post-tensioned member.
- (e) Sheathing for all ducts shall be placed accurately in the formwork in the position shown on the Drawings and shall be adequately tied and held against movement during concreting. The sheathing shall be fixed so as to ensure the alignment as well as the position of ducts at joints is accurate. The joint between the sheathing and anchorage plates shall be mortar tight. Ducts shall be stiffened during concreting by means of an internal strand of diameter equal to or greater than the final strand tendons. Immediately after the whole of the concrete has been placed in a precast member, all duct internal stiffeners shall be pulled back and forth for about 300 mm to ensure they are perfectly free inside the ducting.
- (f) High tensile steel bar tendons shall be located as shown on the Drawings and suitable devices shall be provided to ensure that the tendons are maintained in their correct position, both laterally and vertically, during casting. When bar tendons are being placed, particular care shall be taken that the tendons shall not come into contact with the oiled surface of the forms or be otherwise contaminated. Any oil or other contamination which might collect on the tendons shall be removed by cleaning the affected tendons with clean rags soaked in mineral spirit or by other approved methods. Welding of high tensile steel bar or plate will not be permitted. High tensile steel bars or plates splashed by weld splatter shall be removed and replaced at the expense of the Contractor. After installation of the bar tendons in the forms, the exposed parts of the rolled threads on the bars shall be protected and such protection shall be kept over the threads until just before tensioning the tendon.
- (g) All anchorage plates for prestressing tendons shall be accurately positioned square to the line of action of the tendons and held firmly during concreting. Any mortar adhering to the exposed faces of the anchorages shall be removed.
- (h) Placing of concrete shall be performed only in the presence of the Engineer.

(2) Tensioning Equipment

- (a) All tensioning equipment shall be preferably power driven. The power unit shall be adjusted so that the rate of extension of the tendon is within recommended limits or as directed by the Engineer.
- (b) Dynamometers and each set of equipment comprising pump, jack and pressure gauges shall be calibrated immediately prior to delivery to the site and every six months thereafter unless otherwise directed and the true force determined from the calibration curve. Calibration certificates shall be submitted to the Engineer prior to the equipment being delivered to the Site. Dynamometers and scales shall permit force and elongation respectively, to be determined within an accuracy of 2 percent.
- (c) Pressure gauges shall be concentric scale gauges accurate to within 1 per cent of their full capacity. They shall be selected so as to be used between 50 and 90 percent of their full capacity. Where pressure gauges are used, a snubber, or similar device, shall be fitted so as to protect the gauge against sudden release of pressure. Provision shall also be made, by such means as a Tee connection, for the attachment of a second gauge to be used as a check whenever so requested by the Engineer.

(3) Required Strength and Age of Concrete for Prestressing

- (a) The prestressing force shall not be applied to a member until all the concrete in the member has attained the compressive strength stated on the Drawings, nor shall it be applied at an earlier age than 60 hours after casting (or repair) or 36 hours after casting (or repair) when steam cured, provided that when steam cured the temperature of the concrete has returned to the ambient temperature. The use of excess cement to obtain high early strength will not be permitted.
- (b) The age at which the prestressing force is to be applied shall take into consideration the modulus of elasticity of the concrete. Variations in atmospheric temperature and humidity may make it desirable to vary the age at which members are prestressed so that the modulus of elasticity, and hence the resulting deformations, are as alike as possible.

(4) Tensioning Force Required

- (a) The tensioning force applied to any tendon shall be measured both directly by measurement of the force or jacking pressure and indirectly by measurement of the elongation of the tendon. Where not stated on the Drawings, the Engineer will direct which of these methods is to be regarded as determining the tensioning force and which is to be regarded as checking it.

- (b) The Contractor shall measure tensioning force required for the elongation and for the force in the tendon at the jack. Allowance shall be made for the anticipated draw-in at the anchorage devices on release of the jacks. Any difference in the force determination from each measurement greater than 5 percent shall be ascertained and corrected.
 - (c) Determination of the tensioning force by means of elongation will only be accepted when the limits of variation of the secant modulus, at the tensioning stress guaranteed by the Contractor, are approved. Should the secant modulus of batches of tendons differ by more than 3 percent, the required elongation shall be adjusted accordingly.
 - (d) Every endeavor shall be made to obtain the force shown on the Drawings or directed. A tolerance of 5 percent will be permitted for individual tendons provided that the total prestress load being applied at that time is within 2 percent of the required value.
 - (e) If, on completion of tensioning of a tendon, the requirements of this Clause and ACI 318M are not satisfied, the Engineer may direct the Contractor to adopt special methods overcoming friction loss, such as lubricating the tendon with a water soluble oil, and may direct the tendon to be stressed simultaneously from both ends in the restressing operation if this is physically possible.
- (5) Placing and Tensioning of Tendons
- (a) Strand prestressing tendons shall be placed in the sheathing in accordance with the recommendations of the prestressing system supplier and this Clause.
 - (b) The method of placement shall be such as to ensure that neither the tendon nor the sheathing shall be damaged during the operation.
 - (c) Immediately before placing each tendon, the Contractor shall ensure that all water is driven out of the duct and that the strand tendon, once placed, shall be completely protected against weather, in the period between placing in the duct and grouting, by covering and sealing openings in the duct. In the period between placing in the duct and grouting of the tendon, ends exposed to weather shall be provided with weatherproof coverings. The Engineer may direct the Contractor to dry any tendon in a duct or to fill the duct with a saturated lime solution before fitting the weatherproof covers and seals.
 - (d) The tensioning procedure for all tendons shall be in accordance with ACI 318M. Tensioning shall be performed only in the presence of the Engineer and only by technicians trained for and experienced in this type of work. Special care shall be taken to apply the tensioning force smoothly and at an even rate and to release the jack smoothly. Members

shall be prestressed in accordance with the best practice applicable to the particular prestressing method.

- (e) The process of prestressing shall be continuous, the tendons being stressed in the sequence and to the loads shown on the Drawings and the operation completed without interruption in as short a time as possible, unless otherwise specified or directed by the Engineer.
 - (f) The protruding ends of tendons shall be cleaned of any contamination which may have accumulated since placing. Tendons shall be checked before tensioning to ensure that they are free to move inside the duct, and anchorages shall be thoroughly cleaned before commencement of tensioning. Special care shall be taken to set the jack or jacks accurately in the line of the tendon. The force which is applied initially to take up the slack of the tendon shall be chosen so as to seat the jack firmly but shall not exceed the force normally associated with the particular method of prestressing. During the tensioning of each tendon, after taking up the slack, the jack force (or pressure) shall be read and an elongation reading made. Subsequent similar readings of force and elongation shall be made at intervals directed by the Engineer and plotted to determine the total tendon elongation. The draw-in on anchoring shall also be measured.
 - (g) In the case of slipping of one or more components or tendons of a group tensioned together, the Engineer may approve a compensating increase in the elongation of the remaining tendons of the group provided that the jacking force does not exceed 85 percent of the minimum ultimate strength of each of the tendons. If a tendon breaks or slips during or after tensioning, so that the allowable tolerances are exceeded, the tendon shall be released, replaced if necessary and prestressed.
 - (h) Unless otherwise shown on the Drawings or directed, strand tendons shall be stressed from one end only. When stressing a tendon from both ends is directed, the jacking forces shall not differ by more than 10 percent throughout the tensioning operation. The tensioning operation shall continue until the required force in the tendon at each jack is reached. Where tendons are shown on the Drawings to be stressed simultaneously, the force shall be increased in each tendon so that the maximum jacking force for each tendon is reached and tendons are anchored at approximately the same time.
- (6) Data to be recorded
- (a) The following data, where applicable, shall be recorded by the Contractor:
 - (i) Identification number of dynamometers, gauges, pumps and jacks.
 - (ii) Identification particulars of tendons.

- (iii) Initial force (or pressure) when tendons are marked for measurement of elongation.
 - (iv) Final force (or pressure) and elongation obtained on completion of tensioning.
 - (v) Elongations remaining after release of jacks.
 - (vi) Ramming pressures.
 - (vii) Elongation obtained at suitable intervals during tensioning together with corresponding force (or pressure).
- (b) All forms shall be forwarded to the Engineer on completion.
- (7) Grouting of Prestress Tendons
- (a) The Contractor shall completely fill with grout each prestressed tendon duct in accordance with ACI 318M and this Clause.
 - (b) Tendons shall be grouted within 24 hours of tensioning unless otherwise directed by the Engineer.
 - (c) The ratio of water to cement by weight in the cement grout shall not be more than 0.45 and the compressive strength on 150 mm by 75 mm diameter cylinders of cement grout, cured for twenty eight (28) days at $20^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and 97 to 100 percent relative humidity, shall be at least 27.5 Mpa (280 ksc.). Before injection, the grout mixture shall be mixed for a minimum of three minutes by means of a high speed mechanical stirrer and sieved through a 1.4 mm sieve and, unless otherwise directed, the flow time through a standard flow cone shall be not greater than 30 seconds.
 - (d) The grout shall be prepared using a mixture and additives which prevent shrinkage and bleeding. Neither aluminum powder nor chloride compounds shall be used as an additive. A methyl cellulose additive may be used to improve fluidity and control bleeding. Water used in the grout mixture shall be substantially free of either chloride or sulphate compounds.
 - (e) At least sixty (60) days before grouting any prestressing tendons, the Contractor shall prepare in the presence of the Engineer a trial mix of his proposed grout mixture including admixtures which shall then be sampled and tested by the Contractor to verify its compliance with this Clause.
 - (f) As the work progresses, the Contractor shall take further samples for testing when directed. The Engineer may direct that grout mixtures to be varied so as to achieve the specified properties.

- (g) The grout shall be used within one hour of commencing to mix the ingredients.
 - (h) The grouting equipment shall be arranged to provide a supply line and a return line from the grout pump to the grout connection. Provision shall be made to permit accurate control of grouting pressures and of grout flow at the grout connection, and continuous circulation of grout within the grouting system.
 - (i) The duct to be grouted shall first be filled with water under pressure of 700 kPa (7 ksc.) for at least one hour before grouting. All ducts shall be flushed with clean water followed by compressed air immediately before grouting until all loose particles are removed. Grout shall then be injected by means of a grout pump of either the piston displacement type or screw or impeller type. An even, slow, continuous flow of grout shall be maintained until the duct is completely filled and pure grout of the consistency being injected issues from all vents and until all entrapped air has been expelled. The vents shall be progressively closed until the duct is completely filled. The grout shall then be held at 700 kPa (7 ksc.) pressure for at least one minute after which the grouting end shall be plugged. All care shall be taken to prevent loss of grout immediately after grouting. The grouting tubes shall be topped up with grout if a wastage or subsidence of grout occurs when disconnecting the pump. Unless otherwise directed, all vents and other openings shall be kept closed until regrouting commences.
 - (j) Sufficient grout shall be available for immediate use to enable the grouting of a whole duct without interruption, refilling of the grout tank or the necessity of mixing further quantities.
 - (k) Regrouting of prestress tendons, in accordance with this subclause, shall be carried out by the Contractor during the second hour after the first grouting of the tendon has been completed but in any case before the grout begins to set. Grout shall be injected in such a way as to prevent air being introduced into the duct with the grout. The Engineer will direct the locations at which grout is to be injected into any duct. The Engineer may direct the use of a mineral pigment in the grout to help determine when grout from the second grouting operation is beginning to flow through vent openings.
- (8) Cutting and Protection of Anchorages
- (a) After the grout in any tendon duct has set, the wire or strand ends shall be cut to the prestressing system supplier's requirements with a cutting disc.
 - (b) All anchor heads for strand tendons shall be protected by grout or concrete with a minimum clear cover of 25 mm.

S10.05 PRESTRESSED BEAMS FOR BRIDGE

The Contractor shall manufacture and erect the precast prestressed concrete beams for the bridge shown on the Drawings or directed by the Engineer.

S10.06 MISCELLANEOUS PRECAST CONCRETE

The Contractor shall furnish and install miscellaneous precast concrete not specifically included elsewhere, including but not limited to:

- (1) Precast covers for the sewerage stilling chambers and miscellaneous manhole covers.
- (2) R.C. pile and R.C. box beam for bridge.
- (3) R.C. pipe and guard post for access roads.

S10.07 MEASUREMENT AND PAYMENT

(1) Piling Works

(a) Measurement of piling works

When concrete piles are extended, the length of the extension from the cut-off to the top of the extension shall be considered as concrete piling and will be added to the original length for measurement.

The cut-off elevation will be considered to extend five centimeters into the pile cap and no deduction of concrete volume of the pile cap will be made.

If after driving of test piles or completing the pile tests for a particular structure the Contractor desires for his own convenience of pile rig utilization to drive the other piles of the particular structure, before their tip elevations have been calculated and agreed upon, he may apply in writing to the Engineer to do so. The Engineer may approve this application provided that the Contractor agrees to redrive the piles so driven at a later date if the calculated pile tip elevations fall lower than the elevations to which the piles were driven or, if the piles were over driven to a lower elevation than those calculated from the pile load test, to accept payment to the pile tip elevation established by the pile load tests.

In the case of extending the pile bent above the lateral braced beam, the cut-off elevation will be considered to be at the bottom elevation of the braced beam if the Contractor chooses the option to cut-off piles at this level. The concrete and reinforcing steel in the braced beam as well as in the extended piles will in this case be measured and paid for under the respective unit rates of concrete.

The quantities of bar reinforcing steel required in concrete piling, including the length extending into caps or footings, will not be paid for as a separate item and full compensation therefore will be considered as included in the unit rate price said per lineal meter for concrete piling, unless otherwise specified by the Engineer.

(b) Payment

It not otherwise specified as lump sum contract, reinforced concrete or prestressed concrete pile of specified cross-section shall be paid for at the respective unit rate per linear meter complete in place and accepted.

The price shall include all materials, labor, equipment including reinforcement, hardware, furnishings, formwork, driving, casting, cutting-off, splicing, welding, tools and incident" necessary for the completion of works.

Pay items shall be as follows:

Item No.	Description	Unit
-	Provide and Drive R.C. Pile, Size.....	Linear meter
-	Provide and Drive R.C. Pile, Size.....	Linear meter
-	Load Test R.C. Pile, Size.....	Each

(2) Prestressed Beams for Bridge

- (a) Measurement, for payment, of prestressed beams for bridge will be made of the set of prestressed concrete in the bridge beam installed.
- (b) Payment for furnishing and installing prestressed beams for the spillway bridge will be made at the rate per set bid therefor in the Bill of Quantities. This rate shall include the cost of all labor, equipment and materials to perform the work specified including the supply and installation of the prestressing cables or bars except that payment for in situ concrete, reinforcing steel, jointing materials, bearings and metalwork placed in situ concrete bridge decks will be made at the applicable rates bid in the Schedule.

(3) Miscellaneous Precast Concrete

- (a) Measurement, for payment, for furnishing and installing miscellaneous precast concrete will be made of the quantities of concrete in the precast units.
- (b) Payment for furnishing and installing miscellaneous precast concrete will be made at the rate per unit bid therefor in the Schedule.