PART S25

POST-TENSIONED CONCRETE

CONTENTS

1. GENERAL

.1 This Part specifies the requirements for the production of post-tensioned prestressed concrete.

.2 Unless specified otherwise, the definitions in AS5100: Bridge Design Part 5: Concrete apply to this Part.

.3 The following documents are referenced in this Part:

AS 1012:	Methods of Testing Concrete
AS 1314:	Prestressing Anchorages.
AS 1349:	Bourdon Tube Pressure and Vacuum Gauges
AS 2312:	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings
AS 3972:	Portland and Blended Cements
AS 4672.1:	Steel Prestressing Materials – General Requirements
AS 4672.2:	Steel Prestressing Materials – Testing Requirements
AS 5100:	Bridge Design.
AS 9001:	Quality Management Systems – Requirements
ASTM C940-98:	Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory
ASTM C939-:2	Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)

2. QUALITY REQUIREMENTS

.1 Prestressed concrete members must be manufactured under a quality system certified to AS 9001.

.2 All testing and certification required under this Part must be carried out by a NATA accredited laboratory.

.3 The Contractor must prepare and implement a Quality Plan that at a minimum includes the documents, procedures and/or instructions listed below. If not provided beforehand, the procedures must be submitted at least 28 days prior to the commencement of tensioning.

.4 Provision of the documentation listed in this Clause shall constitute a **HOLD POINT**.

Safety

(a) Procedures / Safety Plan to ensure the safety of all persons during production, including details of no-go zones and protective barriers to prevent injury in the event of equipment failure.

(b) For precast bridge beams, full details of how the requirements of Section 4 “Manufacture” of the Worksafe Victoria publication: “Construction and Erection of Bridge Beams” will be addressed.

Personnel

(c) Details of experience of personnel supervising tensioning activities.

Tensioning Of Tendons

(a) Details of proposed tensioning equipment to be used and proof of its ability to carry out the work.

(b) Calibration of equipment.

(c) Recording of data.

(d) Stressing sequence.

(e) Method of determination of the initial force.

(f) Checking for slippage and friction loss.

(g) Handling and storage of tendons both in the coiled and made up states.

(h) Safety precautions during tensioning.

Pretensioning - Associated Works

(a) Fabrication and placing of tendons:

i) ensuring traceability of tendons

ii) method of placing

iii) layout of tendons at anchorages

iv) method of deflecting tendons, if appropriate

v) protection against corrosion.

(b) Method of tensioning tendons:

i) sequence of tensioning (for deflected strands)

ii) calculation of forces at anchorages and at member mid points

iii) estimated friction losses.

(c) Method of transfer of prestress.

i) release of tendons at end of stressing bed, including sequence of release

ii) release of tendons between members.

Post Tensioning - Associated Works

(d) Placing of ducts:

i) method of fixing

ii) treatment at joints

iii) temporary stiffening

iv) details of grout vents

v) method of sealing ducts, anchorages and grout vents

vi) method of ensuring ducts and grout vents remain clear of obstructions.

(e) Assembly of precast segments:

i) method of supporting segments for jointing

ii) measures to prevent damage to ducts at joints

iii) measures to prevent obstructions occurring the ducts.

(f) Fabrication and placing of tendons:

i) ensuring traceability of tendons delivered to site

ii) method of placing

iii) method of corrosion protection.

(g) Grouting of tendons:

i) method of grouting

ii) mix design, documentation and testing

iii) details of mixing and pumping equipment and evidence of its ability to meet the requirements of this Specification

iv) method of recording quantity of grout usage.

3. MATERIALS

Tendons

.1 The manufacturer / processor of the tendons must hold a valid certificate of approval issued by the Australian Certification Authority for Reinforcing Steel (ACRS). Refer to http://www.acrs.net.au

.2 The Contractor must provide:

(a) details of the composition of the tendons;

(b) test results in accordance in accordance with AS 4672.2 demonstrating compliance with AS 4672.1; and

(c) load-extension graphs covering each coil to be used, taken from 3 representative samples, each 1.4 m long, from each coil.

.3 Provision of the ACRS certification, details of tendon composition, evidence of compliance with AS 4672.2 and load extension graphs shall constitute a **HOLD POINT**.

.4 Welding is not be permitted on or near tendons nor must any heat be applied to tendons. Tendons which have been affected by welding, weld splatter and/or heat will be considered as non-conforming. Flame cutting of wire or tendon within 75 mm of where the tendon will be gripped by the anchorage or jacks is not be permitted.

Anchorages

.5 Anchorages must comply with AS 1314. Provision of the test certificates demonstrating compliance shall constitute a **HOLD POINT**.

.6 Spiral or other reinforcement specified by the manufacturer for use in conjunction with anchorage devices must be of the size and dimensions recommended by the manufacturer for the post-tensioning system.

.7 25 mm minimum diameter grout holes must be provided at both anchorages and must be placed at the highest point of the anchorage. Each of the grouting holes must be equipped with a plug valve or similar device capable of withstanding a pressure of 1.0 MPa without loss of water, air or grout.

Ducts

.8 Ducts must be of a type suitable for the nominated post-tensioning system and must be strong enough to withstand the placing and compaction of the concrete without suffering damage or deformation. The duct and any splices must be sealed to resist the entry of grout.

.9 Steel duct must have a corrugated profile and must be galvanized. Plastic duct must be corrugated and must have sufficient thickness to resist abrasion during installing and stressing of the tendon.

.10 Enlarged portions of the duct at couplings or anchorages must be of sufficient length to provide for the extension of the tendons. Vents, with plug valves, must be provided at intervals not greater than 10 metres along the duct. Additional vents with plug valves must be provided at high and low points in the duct.

Traceability

.11 Wire, strand, bars and anchorages must be labelled in accordance with the requirements of AS 4672 or AS 1314. Individual lengths of wire, strand or bar must be traceable from the point of manufacture of coils or lots to their final location by a unique identification number. Each coil must be clearly identified by use of a durable metal label to enable matching with the appropriate test certificates and load-extension graphs. Wire or strand not clearly identified must not be used.

.12 Anchorages must be traceable from the place of manufacture to their final location by a unique identification number.

Handling, Storage and Fabrication of Materials

.13 Materials must be stored and handled in such a manner so that they are not damaged, contaminated or their physical properties altered. This includes:

(a) storage under a waterproof shelter,

(b) being supported above ground level; and

(c) kept free of all foreign matter on the surface.

.14 Tendons must free of surface pitting, kinks and other damage. Ducts must not be damaged or kinked. Anchorage steel components including threads must be protected from corrosion by greased wrappings or plugs until required for use.

4. TENSIONING EQUIPMENT

.1 Dynamometers and each set of equipment comprising, pump, jack and pressure gauges must be calibrated by an approved laboratory immediately prior to first use and then at intervals not exceeding 6 months and the true force at the jack determined from the calibration curve.

.2 Pressure gauges must:

(a) be concentric scale type gauges complying with AS 1349;

(b) not be less than a nominal size of 150 mm;

(c) read between 50% and 80% of its full capacity when the tendon is stressed to 75% of its breaking load; and

(d) be fitted with safety devices to protect pressure gauges against sudden release of pressure.

.3 The measuring equipment used must permit tendon force and elongation to be determined to an accuracy of ± 2%.

5. SAFETY

.1 The Contractor's Safety Plan and / or procedures must identify and manage the hazards to site personnel, other persons who might be affected by the stressing operation and nearby property and must take the highest standard of care to ensure the safety of all affected persons and property in accordance with the provisions of the *Work Health and Safety Act (SA) 2012* and the *Work Health and Safety Regulations (SA) 2012*.

.2 The Contractor must establish no-go zones with warning signs and substantial barricades in order to provide a protective barrier for site personnel, other persons and property and to prevent the entry of unauthorised persons into the hazard zone around and behind the jacking equipment.

.3 Jacking and other site personnel must not be permitted to stand behind the jack or close to the line of the tendons while stressing is in progress. During stressing operations, warning signs that conform to AS 1319 must be displayed at both ends of the member being tensioned. The stressing jack must be adequately supported and restrained in order to ensure that it cannot cause injury to personnel operating the jacking equipment should the jack lose its grip on the tendons or should the tendon fail.

6. TENSIONING OF TENDONS

General

.1 The Contractor must provide at least:

(a) 14 days notice of the day that tensioning will commence; and

(b) 24 hours notice of the time that tensioning of each member will commence.

.2 Provision of the above notices shall constitute a **HOLD POINT**.

.3 Tensioning must be performed only by personnel experienced in this type of work and in accordance with the Quality Plan. Concrete must not be drilled or any portion cut or chipped away or otherwise disturbed after prestressing, unless prior approval has been obtained.

Ducts and Grout Vents

.4 Ducts, grout vents and their connections must be mortar tight and strong enough to withstand the forces normally encountered in the placing, vibration of concrete and stressing without suffering any damage or deformation.

.5 Grout vents must be provided at all high and low points in the ducts. Additional vents must be provided beyond each high point in the direction of grout flow at the point where the duct is ½ a diameter lower than the high point, but no further than 1 m. Additional vents must also be supplied at the highest point of each anchorage.

.6 Vents must be at least 20 mm in internal diameter and must extend a minimum height of 1 m from the top of the concrete surface. Grout vents must be equipped with a plug valve or similar device, capable of withstanding a pressure of 1 MPa without the loss of air pressure or grout.

.7 Where tendons are installed in ducts after concreting, grout vents must be checked for blockages and cleared if necessary at the following times:

(a) during and immediately after placing of concrete, and

(b) prior to installation of tendons.

.8 Ducts in which the permanent tendon will not be in place during concreting must have a temporary tendon inserted or must be stiffened by some other approved method.

Couplings

.9 Couplings must be housed such that complete grout encasement of all coupling components will be accomplished during grouting of the tendons.

Concrete Placement

.10 Care must be taken during placing and compaction of concrete to avoid damage to ducts, grout vents and their connections.

.11 When the permanent tendons are inserted in the ducts before all concreting has been completed, the tendons must be moved backwards and forwards approximately 300 mm after the concrete has hardened, and within 24 hours of placing of concrete, in order to ensure that the tendons are free to move during tensioning operations.

.12 Where a permanent tendon is not used and prior to reeving tendons, a wooden or steel dolly must be drawn through the ducts before the concrete hardens to check for obstructions. Any obstructions which may impede the passage or movement of the tendons in the ducts must be removed.

Placing Tendons

.13 Where possible, tendons must not be placed until immediately prior to stressing. When installing tendons, care must be taken to ensure that each strand or wire maintains its relative position with respect to all other strands or wires throughout the length of the tendon.

.14 Where strands are fabricated into a tendon as a group and subsequently pulled through the ducts the groups of strands or wires must be pulled simultaneously through a comb. When steam curing is used tendons must not be installed until steam curing is completed.

Tensioning Procedure

.15 Tendons must be checked before tensioning to ensure that they are free to move inside the duct.

.16 Tendon ducts must be cleaned out by blowing oil-free compressed air through them and anchorages must be thoroughly cleaned prior to commencement of tensioning. The protruding ends of tendons must be cleaned of any coating, such as rust, mortar, oil or mud which would lessen the grip of wedges or anchorage devices. The jack must be set accurately in the line of the tendons.

.17 Prior to the commencement of each post-tensioning operation, a **HOLD POINT** shall apply.

.18 The prestressing force must not be applied to a member until all the concrete in the member has attained the compressive strength shown on the Drawings. If a member has been steam cured, the prestressing force must not be applied until the temperature of the concrete has cooled to ambient air temperature.

.19 Once commenced, a tendon stressing operation must be completed without interruption. No tendon must be left in a partially stressed condition. The application and release of the prestressing force must be carried out in such a sequence that produces the minimum of eccentric force in the member.

.20 The tensioning force applied to any tendon must be measured by direct reading of the pressure gauges and checked by comparison of the measured elongation with the elongation calculated by the Contractor from the load-extension graphs supplied.

Multi-strand Tensioning

.21 Anchor blocks must be set parallel to the anchorage prior to any force being applied to the tendon. The force which is applied initially to take up the slack of the tendon must be sufficient to seat the jack firmly but must not exceed the amount normally associated with the particular method of prestressing.

.22 After taking up the slack, individual strands must be accurately marked at both ends so that any slip may be observed. The strands located on the perimeter of the tendon must be used to measure draw-in. Allowance must be made for any draw-in of the tendon at the anchored end.

.23 Where the tendons are required to be tensioned by jacks at each end operating simultaneously, arrangements must be made to keep almost identical forces at each jack throughout the tensioning operation which must continue until the required force in the jacks is reached.

Monostrand Tensioning

.24 All strands must be accurately marked prior to any force being applied to the tendon. An initial force equal to 10% of the final force must be applied to take up the slack of the tendon.

.25 After taking up the slack and where applicable the tendon must be marked at the anchored end so that any slip or draw-in may be measured. Readings of force and elongation must be taken at the initial and final stage of tensioning of each tendon. Elongations must be recorded from the jack ram.

.26 If, during tensioning, the check measurement of any individual strand elongation differs from its required value by +10% or -5%, a **HOLD POINT** shall apply. If the average measured extension of a group of tendons anchored at the same anchorage differs by more than ± 7%, a **HOLD POINT** shall apply.

Requirements after Stressing

.27 The maximum jacking force must not exceed:

(a) 80% of the rated capacity of the jacking equipment used;

(b) 85% of the specified minimum ultimate strength of the tendon; or

(c) 75% of the minimum ultimate strength of the bar.

.28 If, during tensioning, the check measurement of elongation differs from its required value by ±7% a **HOLD POINT** shall apply.

.29 After stressing of a member has been completed, and prior to grouting and cutting back tendons at anchorages, a **HOLD POINT** shall apply.

.30 Subject to prior approval, a precast, post-tensioned member may be lifted from the assembly bed before the stressed tendons have been grouted but all ungrouted tendons must be marked for measurement of slip. Tendons which slip or become damaged must be considered as non-conforming.

Friction Loss Check

.31 The friction coefficient of the tendons within the ducts must be established as directed or as required on the Drawings. The Contractor must have on site the appropriate equipment to enable the friction loss to be measured between anchorages.

Tendon Failure

.32 Where one or more components or tendons of a group stressed together slips or breaks during stressing operations, a **HOLD POINT** shall apply.

.33 Subject to prior approval, a compensating increase in the force of the remaining tendons of the group may be permitted, provided that the jacking force does not exceed 85% of the minimum ultimate tensile strength of the remaining tendons. If this cannot be achieved the tendon must be considered as non-conforming.

Data to be Recorded

.34 The following data, where applicable, must be recorded during the stressing process:

(a) Identification number of each dynamometer, gauge, pump and jack.

(b) Identification particulars of tendons.

(c) Initial forces/pressures and elongations.

(d) Final forces/pressures and elongations.

(e) Elongations obtained at all stages during tensioning, together with corresponding forces/pressures.

(f) Elongations and forces/pressures when resetting of jacks is required.

(g) Draw-in at both ends of tendons (where applicable).

(h) Draw-in of auxiliary wedges at the rear of the jack (where applicable).

7. GROUTING

General

.1 All cable ducts containing stressed cables are to be grouted unless otherwise shown on the drawings. Grouting must be carried out as soon as practical after stressing and in any case no later than:

(a) one week under severe corrosivity level;

(b) two weeks under moderate corrosivity level;

(c) three weeks under low corrosivity level.

.2 Corrosivity is as defined in AS 2312.

.3 The grouting must be carried out in such a manner that the cable ducts are completely filled with a dense and uniform grout. Grouting must not be performed if:

(a) the air temperature is greater than 29o C when the shade temperature is rising;

(b) the air temperature is greater than 32o C when the shade temperature is falling; or

(c) the temperature of the concrete is below 10^{o} C or above 30^{o} C.

Properties of Grout

.4 The grout must be a mixture of Type GP Portland Cement to AS 3972 and water having a water/cement ratio of not more than 0.40 by mass. Cement and water must conform with the requirements for these materials given in Division CC "Concrete", except the water must not contain more than 500 milligrams per litre of chloride ions and cement must be less than 21 days old.

.5 No additives will be permitted in the grout mixture unless the Contractor can demonstrate that they have no harmful effect whatsoever on the prestressing steel, do not contain iron or aluminium powder and do not generate gases from chemical reaction between grout mix constituents or other materials in contact with the grout. Grout must have high bleed resistance, low shrinkage and high fluidity.

.6 Grout must comply with the requirements of Table 7.6.

TABLE 7.6 PERFORMANCE REQUIREMENTS FOR GROUT

Property	Test Method	Criteria	Comments	Frequency
Bleeding	ASTM C9401[1]	Final bleeding < 0.5%	Measured when two successive readings show no further expansion or bleeding	One test per day
Early Expansion	ASTM C940	< 2% at 3 hours	Temperature tolerances are 20 ^{o} C + 5 ^{o} C	One test per day
Fluidity	ASTM C9392[2]	Immediately after mixing: Efflux time < 20 s 45 minutes after mixing: Change in efflux time < + 3 s	Contactor's target efflux time for the site conditions must not vary from nominated value by more than + 2 s	One test per day
Minimum Compressive Strength[3]	AS 1012	32MPa at 7 days		Three cubes per day or lot, whichever is larger

Notes:

1. ASTM C9401 must be modified to simulate wicking of strands as follows:

Cut a 1000mm long piece of 15.2mm 7-wire prestressing strand (wrap strand at cuts with suitable tape to prevent splaying the wires when it is cut). Degrease and clean the cut strand. Insert the piece of strand vertically and centrally into the grout cylinder using a centraliser and secure in position. Introduce the grout into the graduated cylinder as per the test method. Take readings as per the test method.

2. ASTM C9392 may be modified as follows:

Fill the flow cone to the top instead of to the standard level. Measure the efflux time as the time measured to fill the one litre container placed directly under the flow cone.

3. Additional cubes may be taken if testing is required at other than seven days

Trial Mix

.7 The Contractor must provide details of the grout mix design, prepare grout trial mixes and undertake the tests listed in Table 7.2 on the trial mixes.

.8 Provision of conforming test results shall constitute a **HOLD POINT**.

Air Testing of Ducts before Grouting

.9 Air testing of ducts before grouting must be carried out under the supervision of the specialist stressing personnel. Any water in the duct must first be blown out with oil-free air. After sealing the anchorage ends, each duct must be tested as follows:

(a) With all valves closed, pressurise the duct at the inlet with oil-free air to 250kPa to confirm the installed system has sufficient integrity for grouting.

(b) Hold the pressure at 250kPa for 30 seconds. A sudden drop in pressure of more than 100kPa, or a need to continuously inject compressed air to maintain pressure indicates that the system is not sufficiently sealed for grouting. All leaks must be located and repaired and the test repeated.

(c) Reduce the pressure to 100kPa.

(d) Lock off the air source.

(e) Record the air pressure loss over time. A pressure loss greater than 40% must not be permitted within a duration of $D = (1.1V + 5)/60$, where D = duration in minutes and V = volume of the duct minus the strand volume, in litres.

.10 If the pressure loss over time is greater than 40%, a thorough inspection and repairs must be undertaken prior to re-test. Where air testing detects leakage between two adjacent ducts that cannot be practically rectified, both must be air tested together as a single system and then must be grouted simultaneously with two lines controlled by individual lock off valves.

.11 If the air loss criterion cannot be achieved after rectifying all detected leakages, assessment must be undertaken by the specialist stressing personnel who must provide a recommendation whether grouting should proceed.

.12 Provision of conforming test results shall constitute a **HOLD POINT**.

Grouting Equipment

.13 The mixing equipment must be of a type capable of producing a uniform suspension of cement in water.

.14 The injection must be capable of continuous operation with minimum variation of pressure and must include a system for recirculating the grout whilst grouting is not in progress.

.15 The grout pump must be capable of delivering grout at a rate of 1800 litres per hour at pressures up to 1.0MPa. All piping to the grout pump must have a minimum of bends and valves and changes in diameter. All baffles to the pump must be fitted with 1.18mm sieve strainers.

.16 The equipment must have sufficient capacity to continuously fill a tendon, without interruption, at the required rate of injection.

.17 During grouting the Contractor must have available adequate flushing-out plant to facilitate complete removal of the grout in the event of a breakdown of the grouting equipment or other disruption before the grouting operation has been completed. This equipment must be ready for operation during grouting.

.18 Piping to the grout pump must have a minimum of bends, valves and changes in diameter. Pipes and fittings must have a minimum internal diameter of 20 mm.

.19 A standby grout pump must be made available on site for use at all times during grouting operations. All equipment must be thoroughly washed through with clean water after every series of operations and more frequently if necessary. The intervals between washings must not exceed three hours.

Grout Mixing

.20 Water must be added to the mixer first then Portland cement. Mixing must continue for at least two but not more than four minutes until a uniform consistency is obtained. Only as much grout as may be used in one hour must be mixed in any batch. The Contractor must ensure that each batch of grout is mixed to the same consistency.

Grout Placement

.21 Before grouting, the volume of grout required for each duct must be determined for use as a basis for control of volumes and rates of grout injection. Grout must be injected into the duct from the lowest

anchorage in an even continuous flow so that it moves along the duct at a rate of between 6-12 metres per minute. Filling rates for vertical ducts must not exceed 5 metres per minute.

.22 When the grout reaches the first grout vent it must be allowed to flow out until all excess water and air has been expelled from the first portion of the duct and it is of the same consistency as the injected grout. This grout vent must then be sealed off and the procedure repeated at the remaining vents until the duct is completely filled. The vents must be progressively closed from the pumping end except that at the intermediate high points the vents immediately downstream must be closed before their associated high point.

.23 In cases where the ducts are longer than 100 metres an alternative grouting procedure may be required.

.24 The Contractor must supply attachments suitable for injecting grout at the anchorages and all intermediate grout outlets for use as required if a blockage occurs during grouting. After a period of not less than two days the plugs at grout outlets must be removed and any necessary topping up carried out.

.25 All grout outlet pipes must be cut off or drilled out as necessary to maintain the specified cover to any metal surfaces. The recess so formed must be made good with epoxy to give a smooth surface flush with the concrete.

.26 The Contractor must maintain records of the amount of grout injected into each duct and test results demonstrating compliance with Table 7.2 “Performance Requirements for Grout”.

8. TREATMENT OF ANCHORAGES AND COUPLINGS

.1 Tendons must not be cut back at anchorages until the Hold Point in Clause 6.6.4 "Requirements after Stressing" has been released. Ends of tendons must be cut with a high speed abrasive disc or wheel to give the cover as required by AS 5100.5 or as specified in the Drawings. Flame cutting of tendons must not be used.

.2 Prior to placing anchorage encasing concrete or concreting an end beam, the roughened end surface of the beams must be coated with an approved wet-to-dry epoxy resin bonding agent.

.3 Anchorage encasing concrete that will be visible in the final condition (such as diaphragms) must be of the same colour as the surrounding concrete. Recesses for stress bars must be concreted within 7 days of grouting.

9. HOLD POINTS

.1 The following is a summary of Hold Points referenced in this Part:

CLAUSE REF.	HOLD POINT	RESPONSE TIME
2.	Submission of procedures	7 days
3.3	Supply of tendons	14 days
3.5	Supply of anchorages	14 days
6.2	Notification of Tensioning	1 day
6.17	Prior to each post-tensioning operation	2 hours
6.26	Monostrand tensioning	2 hours
6.28	Excessive elongation	1 day
6.29	Prior to grouting and cutting back of tendons	2 hours
6.32	Failure of a tendon	Refer clause
7.7	Grout trial mix test results	7 days
7.11	Air test of ducts results	2 hours

10. VERIFICATION REQUIREMENTS AND RECORDS

.1 In addition to the records provided with the Hold Points, the Contractor must supply the following records:

CLAUSE REF.	SUBJECT	RECORD TO BE PROVIDED
6.34	Tensioning Data	Refer clause
7.6	Properties of Grout	Refer clause