Main Roads
Technical Standard

MRTS89

Post-tensioned Concrete

June 09

Queensland Government

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June 09

Table of Contents

Page

Post-Tensioned Concrete

1 INTRODUCTION

This Standard sets out the requirements for the supply, installation, stressing, grouting and corrosion protection of post-tensioned, internal prestressing tendons and their anchorages and other components for post-tensioned concrete bridge elements.

This Standard does not fully specify post-tensioning systems comprising ungrouted internal tendons or stay cables.

This Technical Standard shall be read in conjunction with MRTS01 *Introduction to Technical Standards*, MRTS50 *Specific Quality System Requirements* and other Technical Standards as appropriate.

This Technical Standard forms part of the Main Roads Specifications and Technical Standards Manual.

The construction of post tensioned concrete elements shall use suppliers and products for the items listed in Table 1 that are registered by Transport and Main Roads.

Table 1 – Items Requiring Use of Registered Suppliers and Products

Clause	Category of Work
7.1.1	Prestressing Strand.
7.1.3	Anchorages for Prestressing Strand.
7.1.4	Couplers.
8	Wet to Dry Epoxy Adhesive.

For the requirements for registration and information regarding registered suppliers and products for the above items refer to –

Department of Transport and Main Roads
Bridge Design
GPO Box 1412
Brisbane, Qld, 4001

2 DEFINITION OF TERMS

The terms used in this Standard shall be as defined in Clause 2 of MRTS01 *Introduction to Technical Standards*.

3 REFERENCES

Table 3 lists documents referenced in this Technical Standard.

Table 3 – Referenced Documents

Reference	Title
AS 4672.1	Steel prestressing materials general requirements.
AS 4672.2	Steel prestressing materials testing requirements.
AS/NZS 1314	Prestressing Anchorages
AS 1349	Bourdon tube pressure and vacuum gauges
AS 1761	Helical Lock-Seam Corrugated Steel Pipes.
AS/NZS 2312	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings
AS 3600	Concrete Structures
AS/NZS 4680	Hot-dip galvanized (zinc) coatings on fabricated ferrous articles
ISO 9001	Quality management systems - requirements

4 STANDARD TEST METHODS

The standard test methods used in this Standard shall be as stated in MRTS70 *Concrete*.

5 QUALITY SYSTEM REQUIREMENTS

5.1 Hold Points, Witness Points and Milestones

General requirements for Hold Points, Witness Points and Milestones are specified in Clause 5.2 of MRTS01 *Introduction to Technical Standards*.

The Hold Points and Witness Points applicable to this Standard are summarised in Table 5.1. There are no Milestones defined.

Table 5.1 –Hold Points and Witness Points

Clause	Hold Point	Witness Points
6.2.3	1. Void restraints.	
7.1.1	2. Prestressing Strand.	
7.1.4	3. Couplers.	
7.2.1	4. Stressing.	
7.2.3	5. Transfer strength.	
7.2.3.4	6. Variation in elongation.	
7.3.1		Grouting.
7.3.5	7. Grouting trial mix.	
7.3.6.2	8. Grouting operations.	

5.2 Construction Procedures

The Contractor shall prepare documented procedures for all construction processes in accordance with the quality system requirements of the Contract.

Procedures for those activities listed in Table 5.2 shall be submitted to the Administrator in accordance with the quality system requirements of the Contract.

Table 5.2 – Construction Procedures

Clauses	Category of Work
7.2	Stressing procedures.

5.3 Testing Frequency

The minimum testing frequency for work covered by this Standard is one per each post-tensioning operation.

6 CONCRETE

6.1 Construction Materials

This Standard is in addition to the requirements of MRTS70 *Concrete*.

6.2 Formwork and Falsework

6.2.1 Superstructure Falsework

Stiffness of different falsework types shall be compatible in order to avoid differential settlement. Stiffness of falsework shall be such as to minimise vertical deflections resulting from the concrete weight. Superstructure shall be preset to allow for these deflections.

6.2.2 Superstructure External Formwork

Formwork to be used for external faces of the superstructure shall be either purpose made metal-faced forms or plywood in as new condition. Any form surface defect shall be repaired prior to each concrete placement operation.

Formwork shall be set to a smooth curve between the given co-ordinate points.

To prevent loss of water and cement fines during vibration, all form joints shall be sealed watertight. Such sealing and its effects shall not be visible on the finished face of the concrete.

6.2.3 Void Former

Non-recoverable void former may be required for the Superstructure. The Contractor shall use helical lock seam corrugated steel pipe of 1.6 mm minimum sheet thickness to construct voids. The void former material shall be galvanised and manufactured in accordance with the relevant sections of AS 1761. Helical seam joints and end stops shall be watertight.

Each length of void former shall be inspected by the Contractor to ensure that there are no defects such as distortions in the circular shape, ripples or dents in the corrugations, or holes for grout leakage into voids.

Void former shall be adequately supported and tied down to prevent movement during concreting operations.

Holding down details for the void former shall be such that the ties exert a uniform radial pressure on the pipe. Care shall be taken to prevent slackening of these ties such as by slipping into corrugation valleys. Care shall also be taken to ensure that the void former supports do not move or distort during tensioning of void tie-downs. Hold downs for voids shall be added to falsework beams and shall not bear directly on the form sheeting.

The Contractor shall be responsible for setting the void formwork to such tolerances as may be necessary to ensure that the finished concrete voids do not infringe the tolerances set out below –

a) departure from specified alignment ± 5 mm;

b) departure from specified profile ± 5 mm; and

c) variation in cross-sectional dimensions ± 5 mm.

Voids outside these tolerances shall be rejected. The restraint systems for void formers shall be approved by the Administrator prior to placing the concrete. Hold Point 1

6.3 Positioning

6.3.1 Tendon Ducts

All tendon ducts shall be temporarily stiffened during concreting. Strands may be placed in the ducts prior to concreting to provide stiffening.

Tendons shall be carefully located and securely held in the positions shown in the Drawing. The method of supporting and fixing the tendons or ducts in position shall be such that they shall not be displaced by heavy and prolonged vibration, by pressure of the concrete being placed, by workmen or by construction traffic. Before starting work, the Contractor shall detail the methods proposed for positioning and restraining the ducts during concreting.

Sections of ducts shall be joined together using sleeves that prevent grout leakages into the ducts. A heat shrink type sleeve is the preferred method of sealing. Ducts shall be so located and secured that, after casting, the displacement from the specified position shall not exceed 6 mm. Care shall be taken to ensure that post-tensioning ducts are positioned to maintain this tolerance. The means of supporting and locating the ducts shall not give rise to excessive friction when the tendon is being tensioned.

6.3.2 Anchorages

Anchorages shall be positioned within tolerances of ± 6 mm across and vertically and ± 15 mm along the tendon. The face of an anchorage shall be square to within 0.5º to the line of the tendon.

Any anchorages outside this tolerance shall be deemed non-conforming.

6.4 Construction Methods

Construction methods shall conform to the requirements of MRTS70 *Concrete*.

6.5 Concreting

6.5.1 General

The Contractor shall ensure that all sections of formwork are adequately supported and braced during the progress of the concrete pour to ensure that the finished concrete is within the specified tolerances.

Sufficient labour shall be retained on site until all concrete has achieved initial set so that any necessary surface finishing may be carried out.

Unstressed tendons shall not lie in a duct longer than 5 weeks prior to stressing.

6.5.2 Voided slab decks

When placing concrete around void formers it is essential that every precaution be taken to avoid settlement cracking.

The Contractor shall place concrete around the void formers in four successive layers such that –

a) the first pour reaches the bottom third of the void former;

b) the second pour reaches the centre of the void formers;

c) the third pour is level with the top of the void formers; and

d) the fourth pour is level with the finished surface shown in the Drawing.

The time delay between each layer shall be such as to permit any settlement of the previous layer to take place but in no case shall it bring about a situation wherein internal vibrators shall not readily penetrate the previous layer under their own weight. The Contractor shall determine by test a delay time between successive layers that is appropriate to the concrete mix and the weather conditions.

6.5.3 Completion of concreting

At the completion of concreting, on the same day, any water within ducts shall then be blown out as much as is practical with compressed air with all low point drains opened at first and progressively closed from the pressure end after water flow ceases at each drain.

7 STRESSING

7.1 Materials and Equipment

7.1.1 Prestressing Strand

Tendons used for longitudinal stressing shall comply with AS/NZS 4672.1, AS/NZS 4672.2-7 wire ordinary-12.7-1870-Relax 2 and AS/NZS 4672.2-7 wire ordinary-15.2-1750-Relax 2, except that the maximum projected relaxation loss at 10,000 days shall be 5.0% when stressed to 80% of minimum Ultimate Tensile Strength specified in AS/NZS 4672.1.

Physical testing of prestressing strand shall be carried out by a NATA registered laboratory as deemed necessary.

Registered prestressing strand (refer Clause 1) shall be used in the Works.

At least 28 days prior to the date on which the prestressing strand is to be used on Site, the Contractor shall supply the Administrator with the Manufacturer's Certificates that certify;

a) the prestressing strand complies with this Standard; and

b) the load extension curves and the measured area of the strand for each batch of coils of prestressing steel to be used on the Site.

All coils of material shall be capable of being identified with the relevant test certificates.

Prestressing strand shall not be used in the Works until the Administrator has verified that the strand complies with the requirements of this Clause 7.1.1. Hold Point 2

The Contractor shall store samples of prestressing strands received from the manufacturer before the use of that coil of strand. These samples shall be used for check testing if considered necessary. Stored sample quantities shall be adequate for testing if required.

7.1.2 Post-tensioned Bar Stressing Units

Post-tensioned bar stressing units shall consist of stressing bars, nuts, washers, anchor plates and couplers. Stressing units shall be lifted, handled, transported and stored in a manner that no damage is incurred to them. Threads on the ends of the units shall be covered and protected during transportation and placing. They shall be stored in a place where they shall not be subject to damage by welding, weld splatter, accidental heating or passage of electric currents. Stressing bars shall not be nicked. Stressing units shall be well supported clear of the ground and shall be protected from mud splatter and corrosive effects of dust and materials.

Stressing bars shall comply to AS/NZS 4672.1 and AS/NZS 4672.2. Bars shall have a coarse thread.

Anchor plates shall be hot dip galvanised to AS/NZS 4680.

Physical testing of bars shall be carried out by a NATA registered laboratory.

Certification shall be obtained from the stressing bar Manufacturer that the bar complies with this Standard.

Manufacturer's test certificates with load extension curves shall be supplied by the Contractor to the Administrator not less than 28 days prior to use on the Site of the relevant material. All bars shall be capable of being identified with the relevant test certificates.

7.1.3 Anchorages for Prestressing Strand

Anchorages for strand shall comply with AS/NZS 1314 and Transport and Main Roads Technical Note 25. Registered anchorages (refer Clause 1) shall be used.

7.1.4 Couplers

Tendons shall be joined only by registered couplers (refer Clause 1) designed to develop 100% of the specified minimum breaking load of the tendon. Couplers shall pass efficiency testing to AS/NZS 1314 to prove they develop greater than 95% of the specified minimum breaking load for strand tendons, and greater than 100% for bar tendons. Couplers shall not be used in the Works until the Administrator has verified that the couplers comply with the requirements of this Clause 7.1.4. Hold Point 3

Couplers shall be provided where shown in the Drawing.

7.1.5 Swaging and button-heading

Swages and button-heads shall develop not less than 95% of the specified minimum breaking load of the strand or wire. Onion head anchors for slab anchors shall not be used.

7.1.6 Ducts

Internal ducts shall conform to either -

a) ASTM D3350 for HDPE with cell classification 335533C; or

b) ASTM D1784 for rigid PVC with classification 13464B.

Ducts shall have a corrugated profile with an allowance in the wall thickness to account for abrasion during stressing of the tendon.

Sheaths and removable formers used to form ducts shall maintain their original cross section and profile during construction. The friction coefficient between the duct and the tendon shall not be higher than 0.20 unless shown otherwise on the Drawings.

Ducts with spring joints and holes shall not be used.

7.1.7 Bleed/Grout Holes, Vents and Caps

Grout inlets and outlets shall be provided at each anchorage. Grout vents shall be provided at each high point.

Grout vents shall be at least 0.5 m higher than the grout inlet, to ensure effective head of grout.

Grout inlets shall be fitted with a pressure gauge for measuring pressures independent of pressures observed at the grout pump or air compressor. Unless otherwise specified, all pressures specified for testing shall be measured at the grout inlet.

Anchorages shall be fitted with grout caps and sealed for grouting and venting operations.

Grout inlets, outlets and vents shall be fitted with a metal valve which can be closed and opened several times, or another equivalent method provided for maintaining pressure during air testing, and for controlling the grout flow during grouting. Exposed grout vents shall be in the shut position.

The pressure rating for inlets, outlets and vents shall not be less than 1.0 MPa. All tubing shall be of plastic or other non-metallic materials with 20 mm minimum inside diameter, and with sufficient strength to withstand the applied pressures without distortion or damage. Tubing shall be protected from accidental damage during construction operations. Tubing shall be securely fastened to the duct and all joints shall be made airtight.

7.1.8 Stressing Jacks

Jacks shall be suitable for the prestressing system to which they shall be applied. Where clearances for jacks are insufficient, extended stressing stools, either straight or deflected, shall be used. Such stools shall be purpose made as is necessary to clear obstructions.

Jacks and gauges shall be calibrated as a whole. Pressure gauges shall be concentric scale complying with AS 1349 and shall be accurate within 1% of their full capacity. Jacks and gauges shall be recalibrated at periods not exceeding 12 months. The equipment shall be recalibrated if an inaccuracy in the gauges is suspected at any time.

The Contractor shall supply to the Administrator a copy of the current load / pressure calibration graph from a NATA laboratory.

7.1.9 Conditions of Prestressing Steel

a) **Degreasing and Cleaning**

Strand and bar shall be free of loose mill scale, surface grease, dirt or any foreign matter likely to affect bonding and shall not be exposed to stray heat from flame torches or welders before stressing.

Loose rust shall be removed from strand and bar before use. Badly rusted or pitted steel shall not be used. All foreign matter shall be removed prior to drawing the tendon. Strand and bars shall not be allowed to come in contact with dirt, and shall be kept on a specially prepared clean surface;

b) **Straightening not permitted**

Tendons supplied by the manufacturer shall be in coils large enough to be self straightening.

Kinked or damaged strand or bars shall not be used and shall be removed from the Site; and

c) High tensile steel bars shall be individually inspected for superficial tears, nicks, roller marks or any other form of surface imperfection. A bar with surface imperfections that range up to 0.40 mm deep may be accepted provided that imperfections ranging from 0.15 mm to 0.40 mm in depth are filed smooth with a fine cut half round file. A bar with surface imperfections that exceed 0.40 mm in depth shall be treated as non-conforming.

7.2 Post-Tensioning

7.2.1 General

No stressing shall be done without adequate prior notice being given to the Administrator. Upon receipt of satisfactory test certificates or results from test samples, the Contractor shall complete stressing schedules setting out elongation and jacking forces to be used in tensioning and shall supply a copy of the stressing schedule to the Administrator prior to commencing stressing. The stressing operations shall be performed under the supervision of a competent person provided by the Contractor and in the presence of the Administrator. Hold Point 4

Under no circumstances shall the maximum jacking force exceed 85% of the specified minimum ultimate strength of a tendon, or the rated capacity of the jacking equipment used, whichever is the lesser.

Results and data relating to the tensioning operations shall be recorded on the stressing schedules.

The Contractor shall be responsible for the safety of all personnel during stressing and shall provide any safety equipment necessary in accordance with the relevant Codes and Acts.

7.2.2 Data to be Recorded

The following data relating to the prestressing operations shall be recorded by the Contractor –

a) Identification number of dynamometers, gauges, pumps and jacks;

b) Initial stressing force (or pressure) when tendons are marked for measurement of elongation;

c) Force applied if a dynamometer is used or, alternatively, the pump or jack pressure and area of the piston;

d) Elongation before anchoring; and

e) Elongation remaining after anchoring.

The fully completed stressing schedule shall be made available to the Administrator if requested.

7.2.3 Procedure

7.2.3.1 General

Prestressing shall not commence until the specified transfer strength of the concrete has been obtained and the Administrator has verified the obtaining of the transfer strength. Stressing shall generally comply with the requirements of AS 3600.

7.2.3.2 Strand

Strands shall be individually pulled snug to ensure seating on the couplers at swaged ends. Tendons shall be stressed initially to a jack pressure nominated by the Contractor as a basis for measuring elongation.

All strands in a common duct shall be stressed simultaneously. Tendons shall be stressed from either one end or two ends as shown in the Drawing. Wedges shall be driven tight in a uniform manner on all strands in an anchorage.

7.2.3.3 Post-tensioned bar

An initial force shall be applied to the bar to seat the end and ensure the bar is pulled snug.

7.2.3.4 Jacking- Strand and Post-Tensioned Bar

Jacking forces shown in the Drawing are the forces in the tendon/bar prior to jack off and include allowance for draw in. Tendon Extension may be modified by the Administrator as required to allow for variations in the duct friction characteristics. Jacking forces shall exceed initial forces by the amount of friction loss in the jack. Prior to stressing, tendons shall be match marked at a point clear of the jack, so that any slip of a strand can be detected.

Correlation between the jacking force and extension during a stressing operation shall be checked. If the correlation is outside the limits of Clause 19.3 of AS 3600, the Contractor shall cease use of the product until additional physical tests have been made at a NATA registered laboratory. In such cases, two samples shall be tested for ultimate tensile strength, 0.1% proof stress, 0.2% proof stress, secant modulus of elasticity at the stressing load and the percentage of elongation at rupture on a 600 mm gauge length. Hold Point 6

7.2.4 Trimming Ends of Strands and Finishing

Trimming of ends shall be carried out with high speed cutting discs to within 50 mm of the anchor block.

7.3 Grouting

7.3.1 General

The Contractor shall provide the Administrator 3 days notice prior to the commencement of grouting. Grouting of prestressing tendons shall be performed in the presence of the Administrator. Witness Point

Precast elements shall not be lifted within 3 days of grouting and shall not be transported within 7 days of grouting.

7.3.2 Air Testing of Ducts before Grouting

Air testing of ducts before grouting is a Critical Post-Tensioning Activity that shall be carried out under the supervision of a Post-Tensioning Supervisor.

Before air testing, the volume of air in the duct shall be determined taking into account the internal dimensions of the duct and the space taken up by the tendon.

Before testing, any water in the duct shall be blown out with compressed oil-free air.

After sealing the anchorage ends, each duct shall be tested as follows –

a) With all valves closed, the duct shall be pressurised at the grout inlet with oil-free air to 250 kPa to confirm that the installed system has sufficient integrity for grouting;

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

c) The pressure shall be reduced to 100 kPa;

d) The air source shall be locked off; and

e) The air pressure loss over time shall be recorded. Maximum allowed pressure loss is 40% within a duration of –

$$D = (1.1 \times V + 5) / 60$$

where –

D = duration in minutes; and

V = the volume of the duct minus the strand volume in litres.

If the pressure loss over time is greater than 40%, a thorough inspection shall be made for any evidence of leakage from, or between, ducts. Leakages shall be rectified and the duct retested before grouting.

The Post-Tensioning Supervisor shall make an assessment of the entire tendon to determine whether grouting can proceed if the air loss criterion cannot be achieved after rectifying detected leakages.

Where air testing detects leakage between two adjacent ducts that cannot be practically rectified, both ducts shall be air tested as a single system and the two ducts shall be grouted simultaneously with two lines controlled by individual lock off valves.

7.3.3 Operations

Grouting is a Critical Post-Tensioning Activity and shall be carried out under the supervision of a Post-Tensioning Supervisor.

All personnel involved in grouting shall be appropriately trained and experienced, and shall be acceptable to the Post-Tensioning Supervisor.

A standby grout pump shall be available for use on Site at all times.

Tendons shall be grouted as soon as practicable after stressing and in any case no later than –

a) one week under severe corrosivity level;

b) two weeks under moderate corrosivity level; or

c) three weeks under low corrosivity level,

as defined in AS/NZS 2312.

Safety precautions shall be taken to prevent injury to operators and other workmen in the vicinity during grouting operations.

Grouting operations shall be carried out so that the ducts are completely filled with a dense and uniform grout.

7.3.4 Performance Requirements

Grouts shall have high bleed resistance, low shrinkage and high fluidity. Grouts shall comply with the performance requirements of Table 7.3.4 when tested as specified.

Table 7.3.4 - Performance Requirements for Grout

Property	Test Method	Criteria	Comments
Bleeding	ASTM C940[1]	Final Bleeding < 0.5%.	Measured when two successive readings show no further expansion or bleeding.
Early Expansion	ASTM C940	< 2% at 3 hours.	Temperature tolerances are 20ºC ± 5ºC.
Fluidity	ASTM C939[2]	Immediately after mixing: Efflux time < 20 s. 45 minutes after mixing: Change in efflux time < ± 3 s.	Contractor's target efflux time for the Site conditions shall not vary from nominated value by more than ± 2 s.
Minimum compressive Strength	Q476	32 MPa at 7 days.	

1. Modify the test method to simulate wicking of strands as follows:

   Cut a 1000 mm long piece of 15.2 mm 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. A modification may be introduced to the test method 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.

7.3.5 Materials and Mix Design

All material suppliers for the grout shall have a third party certified quality system to ISO 9001.

The Contractor shall undertake a trial mix for the grout as specified in MRTS70 *Concrete*. Hold Point 7

Materials for grout shall comply with the requirement of MRTS70 *Concrete*. Where fine aggregate is used in the grout it shall have a maximum nominal aggregate size of 1.0 mm.

Only fresh cement or fresh packaged grout mixes less than 1 month old shall be used.

Only clean water free from oil, acid, alkali, organic or vegetable matter and from any ingredients harmful to steel or the grout shall be used in the mix. The water shall not contain more than 500 mg/l of chloride ions.

Grout mixes may be pre-packaged when only water and admixtures are added to the dry grout mix on Site, or may be designed to meet specific project requirements where different grout mix ingredients are batched on Site.

Where a grout mix is commercially confidential, a full submission for the approval of such mixes shall be forwarded, in confidence, to;

Department of Transport and Main Roads
Bridge Design
GPO Box 1412
Brisbane, Qld, 4001

The Contractor shall also advise the Administrator.

The water/cement ratio shall not be greater than 0.40 by mass.

Expansive admixtures where used shall –

a) be of the pre-hardening type;

b) not contain iron or aluminium powder; and

c) not generate gases from chemical reaction between grout mix constituents or other materials in contact with the grout.

All performance tests shown in Table 7.3.4 shall be carried out for the trial mix.

7.3.6 Grouting Systems

7.3.6.1 Mixing and Pumping Equipment

Grout pumps shall be of the positive displacement type with an outlet pressure of at least 1.0 MPa. The pumps shall be capable of pumping the grout at the required rate and be capable of continuously grouting the largest tendon in no more than 20 minutes.

Grouting supply lines shall connect the pumps directly to the grout inlets. All pumps, lines, tubes, connections, and valves shall be pressure rated to at least 1.0 MPa.

Pumps shall be fitted with seals to prevent oil and air contamination of the grout or the loss of constituent materials during the grouting operation.

Pumps shall be capable of operating continuously with little pressure variation, and shall have a system for recirculating the grout while actual grouting is not in progress.

Pumps and grout inlets shall be fitted with pressure gauges capable of reading grout pressures up to 1.0 MPa. Pressure gauges shall have a full scale reading less than 1.5 MPa and shall be maintained in calibration.

Flowmeters and pressure gauges used during air testing or grouting shall have NATA accredited calibration certificates issued within the last 100 operations for which the device was used or within the last six months, whichever is less.

Any gauge that has sustained hydraulic or other shock shall be replaced immediately with another gauge.

7.3.6.2 Grouting Systems – Verification Process

A minimum of 14 days prior to grouting operations, the grouting system including mixing equipment shall be verified as adequate to undertake grouting of tendons in the Works by successfully grouting ducts in the verification test.

The same make and type of mixing equipment used for approval of the grouting system shall be used for grout production. Equipment different to that used for approval shall not be used unless specifically approved by the Administrator. Grouting operations shall not be undertaken prior to successful completion of the verification test. Hold Point 8

The verification test is designed to demonstrate and verify the effectiveness of the grouting system.

The verification test shall comprise –

a) a fully assembled mock-up tendon shall be assembled comprising one peak located a minimum of 750 mm above the anchors and two valleys located a minimum of 1000 mm below the anchors;

b) the two end anchorages shall be located a minimum of 12 m apart fitted with grout inlets and outlets. The tendon shall be secured to a supporting frame capable of taking the stressing force required to take up the slack;

c) the duct shall be the dominant size used shown in the Drawing and shall be filled with the maximum number and size of strand shown in the Drawing;

d) the mock-up tendon shall be grouted;

e) the tendon shall be protected from shock and vibration for 48 hours;

f) the tendon shall be stripped and sliced at specified locations;

g) the extent of air/bleed voids in the duct and the integrity of the grout shall be determined; and

h) additional test specimens for all the performance tests of Table 7.3.4 shall be prepared during the grouting of the mock-up tendon.

All performance tests shown in Table 7.3.4 shall be carried out for the grout verification test.

Full details of the procedures for verification testing and/or grouting system approval are available on request from;

Department of Transport and Main Roads
Bridge Design
GPO Box 1412
Brisbane Qld 4001

7.3.7 Routine Production Testing of Grout

Tests for bleeding, fluidity and compressive strength in accordance with Table 7.3.4 shall be carried out at the frequency specified in Table 7.3.7 and the results reported to the Administrator.

Compliance of each batch of grout delivered to Site with the approved grout shall be verified by submitting a certificate of uniformity testing for the supplied grout, supported by evidence of the grout manufacturer's quality management system accreditation.

Table 7.3.7 - Frequency of Acceptance Tests for Grout

Test	Sample
Bleeding Test	One test per day.
Fluidity	One test per day.
Compressive Strength Test*	Three cubes per day or lot whichever larger.

* Additional cubes may be taken if testing of strength is required at other than seven days,

Conformity of the batch is achieved when the acceptance tests of the grout comply with the performance requirements specified in Table 7.3.4.

7.3.8 Mixing

Batching of grout shall be carried out by mass for all mix constituents except liquids, which may be measured by volume.

Only whole bags of cement or pre-packed grout mix shall be used.

Bags of cement or grout shall be weighed before batching.

Accurate control of the water/cement ratio and additives shall be provided for each batch of grout. Admixtures for the grout mix shall be supplied in single dose containers made up to suit each grout batch size.

The water and premixed additive shall be placed in the agitator tank first. The cement shall then be dispersed uniformly within the agitator tank. The mixing water shall be heated or cooled if necessary to keep the grout temperature between 5°C and 30°C during mixing and grouting.

The grout shall be mixed at a minimum of 1000 rpm in a high-speed mixer capable of imparting a high shear to the grout components so that a colloidal grout of uniform consistency is produced in a mixing time of less than five minutes.

7.3.9 Grouting of Ducts

Grouting of ducts shall not be carried out when the temperature of the concrete is below 10ºC or above 30ºC.

Adequate stocks of cement or pre-packaged grout mixes shall be held at the grout mixer to ensure no interruptions to the continuity of grouting operations.

Before grouting, the volume of grout required for each duct shall be determined and used as a basis for control of volumes and rates of grout injection.

Before commencing grouting, sampling for production acceptance testing shall be carried out in accordance with Clause 7.3.5 and Table 7.3.7. Where fluidity testing is required the efflux time shall be determined before proceeding with grouting. The efflux time shall not vary from the target efflux time by more than ± 2 seconds.

The mixed grout shall be fed to the pump by gravity from a hopper attached to and directly over the pump. The hopper shall be kept at least partially full of grout at all times during grouting operations.

The mixed grout shall pass through a screen with 2.36 mm nominal apertures during its progress between the hopper and the pump.

The grout shall be used as soon as possible after mixing and in any case within 45 minutes of adding cement to mixing water.

The grout shall be injected from a low point or the low end of a tendon. An even, slow, continuous flow of grout shall be maintained until the duct is completely filled with pure grout and all entrapped water and air has been expelled.

The grout flow shall be such as to fill the duct at a rate between 10 m and 15 m of duct per minute. Filling rates for vertical ducts shall not be more than 5 m/minute.

Vents and drains shall be closed off progressively once pure grout issues from them except for vents located less than 1 m downstream of a high point. The downstream vent shall be closed off before the high point vent.

In the event that a high point grout vent shall be used as an inlet, procedures shall be implemented to vent the grout from that vent to ensure that no air is entrapped in the duct.

The grouting pressure shall not exceed 400 kPa. Where the maximum grouting pressure is not sufficient to grout the duct, then the grout injection point shall be moved to the next downstream vent which is closed off, or ready to be closed off, to reduce injection pressures whilst maintaining one way flow.

7.3.9.1 Grouting Procedure

The grouting procedure described in this Clause 7.3.9.1 shall be followed.

a) Either a single metal valve, or a single use plastic valve before a reusable metal valve, shall be used on all grout lines, inlets, outlets, vents and drains. If only single metal valves are used, these shall be left in place undisturbed until the following day;

b) With all vents and valves open, the grout shall be injected at a rate of 10-15 m/min through the inlet in the anchorage casting or at the tendon low point using a suitable grouting pressure dependent on grout properties and tendon geometry. This pressure is termed the operational grouting pressure (OGP);

c) Vents shall be closed off progressively using the metal control valves when consistent grout flows from each vent. The quality of the grout may be checked visually. A fluidity test shall be carried out if there is any doubt as to the quality of the grout issuing from the vent. The fluidity shall be no less than 3 seconds less than that measured during the acceptance testing;

d) After initial grouting is completed and all the vents have been closed off under OGP –

   i) The duct shall be checked for any grout leaks while maintaining the minimum OGP for 1 minute;

   ii) The pressure shall be reduced to 100 kPa, and this pressure maintained for 5 minutes. This may require opening of a high point vent metal control valve to reduce the pressure, closing that vent's metal control valve, then reinjecting a very small quantity of grout at 100 kPa;

   iii) Using the minimum possible OGP, grout injection shall be maintained whilst slowly discharging any water, air and diluted grout from each vent by opening and subsequently closing the vent's metal control valve, successively working in the direction of grout injection starting with the inlet vent in the grout cap or the closest vent to the grout injection point; and

   iv) The OGP shall be reduced and the grout inlet closed off at 100 kPa pressure, if necessary utilising the pressure reducing procedure set out in (ii) above,

e) Any plastic valves shall be closed off and their associated metal valves removed for cleaning and re-use.

Grouted ducts shall not be subjected to shock, vibration, construction traffic or similar loads, until 24 hours after completion of grouting.

Grout inlets, outlets and vents shall be removed the following day and the completed grouting inspected.

Any voids within anchorages shall be filled with epoxy.

Any voids within the ducts at anchorages shall be filled using vacuum injected grouting. Large voids shall be referred to the Administrator. The reasons for the formation of any voids shall be determined and steps shall be taken to avoid such voids in subsequent grouting operations.

If, due to blockages, equipment breakdowns, or for other reasons, a duct is not filled with grout, all voids shall be located. The Administrator shall be notified together with a disposition for filling the voids.

8 PROTECTION OF ANCHORAGES

For exposed anchorages, recesses shall be concreted with a minimum of Class 40 MPa/10 concrete cast in the anchorage recess. Prior to such concreting, the concrete around the anchorage and the anchor plate shall be thoroughly cleaned by abrasive blasting and the contact surfaces of the anchorage and anchorage recess shall be coated with a registered wet to dry epoxy adhesive (refer Clause 1).