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Specification

Post-tensioned Ground Anchors

(ATS 5140-23, Ed 1.0 MOD)

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Preface

This document is the first issue as TS 02163, which adopts and modifies ATS 5140-23. It sets out the requirements for the supply, assembly, installation, grouting, stressing and monitoring of ground anchors which are post-tensioned. It includes drilling, grouting and water testing, and sealing of the boreholes.

This document supersedes TS 02163 (IC-QA-R56) *Ground Anchors (Schedule Of Rates) – QA* and TS 01737.1 (IC-QA-B114) *Ground Anchors (Lump Sum) – QA* and TS 01737.2 (IC-DC-B114) *Ground Anchors.*

For the purposes of this document, where TfNSW has identically adopted, or adopted and modified, an ATS document as a Transport Standard, the corresponding Transport Standard should be applied.

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1. Scope

1.1 This Specification sets out the requirements for the supply, assembly, installation, grouting, stressing and monitoring of ground anchors which are post-tensioned. It includes drilling, grouting and water testing, and sealing of the boreholes.

1.2 This Specification:

a. applies to both temporary and permanent ground anchors with appropriate corrosion protection systems installed into soil or rock;

b. applies to anchors with or without prestressing; and

c. applies to both strand and bar tendons.

2. Referenced documents

2.1 The following documents are referenced in this Specification:

Australian Standards

AS/NZS 1314	Prestressing anchorages
AS 1349	Bourdon tube pressure and vacuum gauges
AS 2758.1	Aggregates and rock for engineering purposes – Part 1: Concrete aggregates
AS/NZS 3678	Structural steel – Hot-rolled plates, floorplates and slabs
AS/NZS 4672	Steel prestressing materials
AS/NZS 4672.1	General requirements
AS/NZS 4672.2	Testing requirements
AS/NZS 4680	Hot-dip galvanized (zinc) coatings on fabricated ferrous articles
AS 5100.3	Bridge design – Foundations and soil-supporting structures
AS 5100.5	Bridge design – Part 5: Concrete
AS/NZS ISO 9001	Quality management systems – Requirements

ASTM International

ASTM B117	Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM C939	Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)
ASTM C940-98a	Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory
ASTM C1090-01	Standard Test Method for Measuring Changes in Height of Cylindrical Specimens of Hydraulic-Cement Grout
ASTM D92	Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester

ASTM D94	Standard Test Methods for Saponification Number of Petroleum Products
ASTM D127	Standard Test Method for Drop Melting Point of Petroleum Wax Including Petrolatum
ASTM D130	Standard Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
ASTM D217	Standard Test Methods for Cone Penetration of Lubricating Grease
ASTM D566	Standard Test Method for Dropping Point of Lubricating Grease
ASTM D937	Standard Test Method for Cone Penetration of Petrolatum
ASTM C939	Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)
ASTM C940	Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory
ASTM D972	Standard Test Method for Evaporation Loss of Lubricating Greases and Oils
ASTM C1090	Standard Test Method for Measuring Changes in Height of Cylindrical Specimens of Hydraulic-Cement Grout
ASTM D1248	Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable
ASTM D1264	Standard Test Method for Determining the Water Washout Characteristics of Lubricating Greases
ASTM D1742	Standard Test Method for Oil Separation from Lubricating Grease During Storage
ASTM D1743	Standard Test Method for Determining Corrosion Preventive Properties of Lubricating Greases
ASTM D1784	Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
ASTM D3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
ASTM D4048	Standard Test Method for Detection of Copper Corrosion from Lubricating Grease
ASTM D4101	Standard Specification for Polypropylene Injection and Extrusion Materials ASTM
ASTM D6184	Standard Test Method for Oil Separation from Lubricating Grease (Conical Sieve Method)

British / International standards

BS 8081	Code of Practice for Ground Anchorages (British Standard Institution)

TfNSW Standards

TS 01621	Lists of Transport for NSW (TfNSW) Pre-Approved Proprietary Bridge Components and Systems
TS 01642 (T HR CI 12002 ST)	Durability Requirements for Civil Infrastructure

TS 02800.49 (T375)	Sampling and Testing of Grout
TS 03323.1	Cementitious Materials, Binders and Fillers

Other references

ACI 423.7-14 *Specification for unbonded single-strand tendon materials*

International Federation for Structural Concrete (fib) Fédération internationale du béton, FIB Bulletin 75 *Polymer-duct systems for internal bonded post-tensioning*

Geotechnical Engineering Handbook Volume 2 – Procedures; published by Ernst & Sohn 2003

3. Definitions

3.1 The following definitions apply to this Specification:

Anchor Supervisor:	Nominated employee of the Ground Anchor System Supplier who is responsible for the supervision of Critical Anchor Activities and certification of installation operations.
Anchorage:	The anchor component at the top of a tendon that transfers the tendon load to the ground or structure, comprising the prestressing head, bearing plate or anchorage casting, protective cover and all associated seals, fittings and materials (refer Annexure B: Figure 2).
Bleed:	The separation of water from the grout paste.
Centraliser:	A corrosion proof component fixed to the outside of an anchor duct to support and centralise the anchor in its borehole and ensure adequate external grout cover
Coupler:	A device for joining lengths of bar or strand which comprise an anchor tendon.
Critical Anchor Activity:	The critical activities listed in Clause 7.3.
Duct:	A semi-rigid tube generally corrugated both inside and outside to isolate the tendon from the environment and to transfer load between the inner and outer grout annuli in the tendon bond length. Corrugated or smooth tubes may be used over the tendon unbonded length (refer Annexure B: Figures 1, 3, 4, and 5).
Effective tendon free length:	The length of tendon between the connection of the tendon to the stressing jack and a point along the tendon, which acts elastically during stressing. It is calculated from the measured load / extension of the ground anchor.
Fixed anchor length:	The design length of borehole over which the load is transferred to the ground (refer Annexure B: Figure 1).
Ground Anchor System Supplier:	The owner, or agent of the owner, of an approved ground anchor system responsible for its supply and installation.
Ground anchor (or rock anchor):	An installation that is capable of transmitting an applied tensile load to a load bearing stratum of rock or soil, comprising an anchorage, free anchor length and fixed anchor length (refer Annexure B: Figure 1).

Grout:	Cementitious material complying with TS 03323.1 that transfers load from the tendon to the ground over the fixed anchor length.
Monitorable anchor:	A ground anchor assembled and installed to allow inspection and measurement of anchor loads at some time after completion of stressing.
Multiple anchor:	A single borehole containing multiple unit strands or bars with bonded lengths at staggered depths, to provide ultra-high load capacities in soils and weak rocks (refer Annexure B: Figure 4c).
Nonconforming anchor:	A ground anchor system or its parts that do not conform with this Specification but with prior application for acceptance and Proof Tests may be approved by the Principal.
Nose cone:	A component at the lower end of the anchor that retains and seals the end of the duct to assist insertion of the anchor into the borehole.
Overhead zone:	The zone of the anchorage lying above the bearing plate and including the protective cap (refer Annexure B: Figure 2).
Permanent ground anchor:	An installation that ensures the stability and satisfactory performance of the permanent structure or supported excavation for its design life.
Prestressing head:	A steel block with tapered holes and wedges capable of transferring the entire capacity of the tendon to the structure. Bars may use threaded nuts instead of wedges.
Principal's Registration Scheme:	Any scheme for the prequalification, registration or approval of products, manufacturers, suppliers and/or Professional Engineers in operation in the jurisdiction where the concrete is to be placed.
Professional Engineer:	A person who: a) Has least 5 years of experience relevant to the design of ground anchors b) is registered on any scheme of registration of engineers prescribed by legislation in the applicable jurisdiction; c) is appropriately registered or prequalified if the Principal has implemented an applicable registration or prequalification scheme; and d) satisfies at least one of the following requirements: i) is a Chartered Professional Engineer; or ii) holds a 4-year civil engineering degree from a university that is accredited under the Washington Accord and is registered in a relevant area of practice on the National Engineering Register.
Proof anchor:	A ground anchor on which a Proof Test is carried out prior to ground anchor work commencing at the site.
Protective cap:	A non-corroding sealed cap of galvanized steel or strong plastic containing a corrosion inhibiting compound that surrounds the prestressing wedges or nuts and tendon ends; it may be capable of being removed (refer Annexure B: Figures 2 and 3).
Restressable prestressing head:	A prestressing head similar to a normal prestressing head that permits the tendon force to be measured by lift-off tests throughout the life of the structure. Small load losses of up to 20% of working load may be recovered by restressing and shimming or thread-turning.
Sheath:	A generally smooth flexible tube which isolates each strand or bar and does not bond with the surrounding grout (refer Annexure B: Figures 1, 3, 4 and 5).

Spacer:	A corrosion proof component fixed to the tendon elements inside the anchor duct to space them centrally inside the duct and ensure adequate internal grout cover.
Strand node:	The controlled deformation of strand wires to form a tight “birdcage” to enhance the pull-out capacity of the tendon from the grout.
Suitability anchor:	A ground anchor on which a Suitability Test is carried out prior to installation of the remaining ground anchors it represents.
Temporary ground anchor:	An installation often used during the construction phase of a project to carry loads for a known short period of time, usually less than 2 years.
Tendon:	That part of a ground anchor that transmits the tensile load from the fixed anchor length to the anchorage, typically comprising a bundle of identical strands or a single high tensile steel bar.
Tendon bond length:	The length of tendon bonded directly to the grout capable of transmitting the ultimate tensile capacity of the tendon (refer Annexure B: Figure 3).
Tendon node:	In multi-strand anchors the strands are spaced apart at tendon nodes and typically at 1 m to 2 m away from these nodes the strands are banded tightly together; this enhances the bond between the tendon and the grout (refer Annexure B: Figures 1 and 3).
Tendon unbonded length:	The length of tendon between the prestressing head and the proximal end of the tendon bond length that is specifically isolated from direct contact with the grout (refer Annexure B: Figure 3).
Underhead zone:	The zone of the anchorage lying between the prestressing head and the seal which overlaps the corrosion protection applied to the tendon free length (refer Annexure B: Figure 2).
Unit tendon:	A tendon component of a multiple anchor that has its own prestressing wedge or nut, free length and bonded length. The bonded lengths of each Unit are located at a staggered depth in the borehole.
Virgin material	Unused raw material that has never been subjected to any processing other than for its production. Pipe products made of virgin materials generally show better durability and have better mechanical and chemical properties

Loads and Force

Initial or Datum Load (T_A):	Initial load applied to the tendon prior to any testing.
Initial Residual Load (T_{RI}):	Measured load in the tendon immediately after lock-off assessed by a Lift-off Test.
Jacking Force (T_J):	The jacking force that produces the lock-off load, taking into account any anchorage friction and draw-in losses.
Lock-off Load (T_O):	The load required to be transferred to an anchor head immediately on completion of a stressing operation.
Minimum Breaking Load (T_U):	The product of the number of strands in an anchor and the characteristic minimum breaking load of the strand, or the minimum characteristic breaking load of a bar tendon.
Residual Load (T_R):	Measured load in the tendon after lock-off assessed by a Lift-off Test.

Test Load (T_P):	The maximum load to which a tendon is subjected during Suitability or Acceptance Tests (see Clause 5.3).
Working Load (T_D):	Residual load in the tendon after all losses that provides the required restraint to the structure or the ground.

Tests

Acceptance Test:	A single load cycle to Test Load (T_P) then reduced to a lock-off load to verify that each working ground anchor conforms to the anchor acceptance criteria. It applies to all working anchors not subject to a Suitability Test.
Lift-off Test:	Determination of the force in a tendon that causes a small lift of the anchor head away from the bearing plate, generally confirmed using a 0.5 mm (or thin as practical) feeler gauge.
Proof Test:	A multi-cycle stressing test carried out to a non-working anchor in advance of the installation of working ground anchors for investigation or verification purposes.
Suitability Test:	A multi-cycle stressing test ending by a lock-off load to verify the ground anchor design and installation and to establish reference test values for other anchors represented by the tested anchor. It applies to 1%-2%of the working anchors.

See Annexure for explanatory diagrams.

Symbols

A_t	Cross-sectional area of tendon (mm²)
E_t	Modulus of elasticity of tendon (MPa)
L_b	Bond length (mm)
L_{ef}	Effective free length (mm)
L_{fr}	Free length (mm)
R_a	Anchor resistance calculated in accordance with AS 5100.3
S^*	Design action loads calculated in accordance with AS 5100.3
T	Anchor load (kN)
T_A	Initial Datum Load (kN)
T_J	Jacking Force (kN)
T_O	Lock-off Load (kN)
T_P	Test Load (kN)
T_R	Residual Load (kN)
T_{RI}	Initial Residual Load (kN)
T_U	Minimum Breaking Load of tendon (kN)
d_L	Measured total extension of tendon relative to a datum (mm)
δL_e	Measured elastic extension of tendon at each load stage (mm)

A_t	Cross-sectional area of tendon (mm²)
δL_r	Calculated elastic extension of tendon at each test load stage (mm)
δL_{pl}	Measured plastic or non-recoverable extension of tendon at each test load stage (mm)
$ø_g$	Geotechnical reduction factor selected in accordance with AS 5100.3
$ø_n$	Importance category reduction factor selected in accordance with AS 5100.3

4. Quality System Requirements

4.1 The Contractor must prepare and implement a Quality Plan that includes the documentation in Table 4.1.

Table 4-1 – Quality Plan

Clause	Description of document
5.6	Criteria for a satisfactory rock surface and procedures for installing the bearing plate on its pad when stressing anchorages directly against rock.
5.9	Details of supplementary additional corrosion protection required in a specific environment.
5.12	Details of method of sealing base and head of underhead zone duct or trumpet.
9.1	Fully detailed drawings including cross-sections and longitudinal sections showing all ground anchor components, method of assembly and provisions for monitoring.
9.10	Procedure for preventing tendon strands from crossing within the free length.
9.21	Demonstration of adequacy of joints in sheaths and ducts.
9.25	Details of sheaths at tendon couplers
9.31	Detailed procedures for fixing lower end of tendon to the internal nose cone and details at the bottom of corrugated duct and its sealing with a nose cone.
10.4, 10.13	Drilling procedures including method of supporting the borehole during drilling, procedures for maintaining and checking the borehole alignment during drilling, procedure for dealing with variations in subsoil conditions, method of cleaning, installation and grouting when penetrating material other than rock.
10.28	Procedures for inserting assembled anchors into boreholes.
10.34	Procedures for repairing damage to factory grouted anchors.

HOLD POINT 1	
Process held	Installation of ground anchors
Submission Details	The Quality Plan must be provided to the Principal at least 10 working days prior to the commencement of work on site.
Release of Hold Point	The Principal must consider the submitted documents and may carry out surveillance and audit, prior to authorising the release of the Hold Point.

5. Design

General

5.1 Unless specified otherwise in the Contract documents, the Contractor must design the ground anchor system and the design must conform to AS 5100.3, as amended by this Specification.

5.2 The design (and any subsequent modification to the design) must be certified by a Professional Engineer.

5.3 The Test Load T_P must be greater than the design action loads, S*, on the ground anchor under the worst load combination divided by the relevant geotechnical reduction factor, $ø_g$, and importance category reduction factor, $ø_n$, selected in accordance with AS 5100.3.

5.4 The tendon bond length must be not less than 3 m.

5.5 Ground anchors where wedges are to be reseated during monitoring or for any other reason must not be stressed more than 75% of T_U.

5.6 When stressing the anchorage directly against the rock, the Quality Plan must include the proposed criteria for a satisfactory rock surface and procedures for installing the bearing plate on its pad.

5.7 For guidelines to good practice in the design of ground anchors with reference to site investigation data, refer to:

a. BS 8081

b. Geotechnical Engineering Handbook Volume 2 Procedures – Chapter 2.5.

Corrosion Protection

General

5.8 Unless specified otherwise in the Contract documents, the design life of a permanent anchor is 100 years.

5.9 If the Contractor cannot conclusively demonstrate that the corrosion protection performance of a ground anchor system in a specific environment will achieve the 100-year design life, supplementary additional protection must be included in the design. Details of the additional protection must be included in the Quality Plan.

5.10 The design of the system must:

a. include measures to eliminate corrosion and loss of capacity of the load carrying elements of the ground anchor over the anchor's design life;

b. include corrosion protection by containing the steel elements of the tendon within anchor sheaths and ducts over the entire length within the ground or structure;

c. in the fixed anchor length, supplement the isolation provided by the duct with an outer annulus of cementitious grout not less than 20 mm thick (this grout is not considered to provide corrosion protection because the grout will crack during testing and stressing); and

d. in the free anchor length, supplement this isolation with corrosion inhibiting compounds (CICs), which are an integral part of the ground anchor's corrosion protection system.

Underhead Zone Protection

5.11 The design of the protection of the Underhead Zone (the length of tendon between the top of the CIC filled sheath and the base of the prestressing head) must:

a. include special precaution to address its vulnerability to corrosion because of the difficulty of inspecting the effectiveness of the protection provided after the completion of stressing;

b. include a steel duct or trumpet around the tendon in this zone that contains either the CIC or a resinous grout, both of which must be fully sealed to prevent leakage; and

c. be consistent with BS 8081.

5.12 The Quality Plan must include details of the method of sealing the base and head of this duct or trumpet.

Temporary Anchors

5.13 Unless environmental conditions indicate a given exposure class at and below which cementitious grout alone is appropriate (a non-aggressive environment), cementitious grout alone is appropriate corrosion protection for tendons of temporary anchors with a design life of up to two years. The tendons must be spaced, centralised and have a grout cover of not less than 20 mm. In the absence of specific exposure classification guidelines, AS 5100.5 and TS 01642 may be used for guidance.

6. Materials

General

6.1 Materials must be sourced from suppliers that have a quality management system which is certified to AS/NZS ISO 9001 by an organisation which is accredited by JAS-ANZ or another Accreditation Body Member of the International Accreditation Forum.

6.2 Where a Principal's Registration Scheme is in place for the supply of System Components, and/or post-tensioning systems, the System Components and/or systems must comply with that scheme for anchors installed in that jurisdiction.

6.3 Prior to the installation of the prestressing components and tendons, the Contractor must submit to the Principal:

a. evidence that the suppliers of the materials have the specified quality management systems in place;

b. evidence that the prestressing materials are certified by ACRS in accordance with Clause 6.5 (or an equivalent scheme acceptable to the Principal);

c. details of the proposed materials and evidence that their properties conform to this Specification, including approval under any applicable Principal's Registration Scheme;

d. certification and Lot numbers in accordance with Clause 6.9; and

e. test reports in accordance with Clause 6.12

6.4 The anchorages and tendons must conform to a TfNSW approved ground anchor system. Refer to TS 01621 for approved ground anchor systems.

Tendons

6.5 In addition to AS/NZS ISO 9001 certification, prestressing materials must be certified under an Australian Certification Authority for Reinforcing Steels (ACRS) conformity assessment scheme, or an equivalent scheme accepted by the Principal.

6.6 Tendons must conform to AS/NZS 4672.1. If the Contractor proposes to use tendons conform to standards other than AS/NZS 4672.1, it must provide evidence to the Principal that the tendons are of equivalent quality.

6.7 Strand must be Class 2 relaxation (Relax 2) to AS/NZS 4672.1 or equivalent unless specified otherwise.

6.8 The capacity of any bar connections must not be less than the capacity of the bar.

6.9 With each delivery, the Contractor must provide documentation to the Principal listing the Lot numbers from which each coil or bar is taken, and NATA endorsed test certificates demonstrating conformity with AS/NZS 4672.

6.10 Testing must conform to AS/NZS 4672.2.

6.11 During manufacture in the mill, at least one sample from each coil of wire and strand must be tested and at least 3 bars from each Lot and each delivery must be tested.

6.12 The following test reports must be submitted to the Principal

a. Breaking force;

b. Yield strength and elongation;

c. Load-elongation curve;

d. Cast analysis of the steel;

e. Cross-sectional area of tendon; and

f. 1000-hour isothermal relaxation, with evidence that the tendon tested represents the tendons supplied.

6.13 In addition to the supplier's testing prior to delivery, for strand tendons, at least 3 site samples (1.5 m each) of strand per coil used (at different locations within each coil – start, middle and end) must be taken during tendon manufacturing. These samples must be labelled and stored securely to enable later testing if anomalies are observed during the testing and stressing operations. The Principal may then direct these samples to be tested at an approved laboratory if unusual results are observed. These additional strand samples must be held by the Contractor for at least 7 days after satisfactory stressing operations.

Anchorages

6.14 Anchorages must conform to AS/NZS 1314.

6.15 Anchorage components must form part of an approved ground anchor system and be of adequate size and shape to safely transfer the force from the tendon from the anchorage to the supporting surface without overstress, either directly through the anchor head or indirectly through a chair under the stressing jack.

6.16 Unless approved otherwise by the Principal, bearing plates must be Grade 250 steel to AS/NZS 3678. Subject to the Principal's prior approval, higher strength steels may be used, provided that evidence is submitted demonstrating an adequate factor of safety.

6.17 Bearing plates for anchors stressed directly to rock must be the size shown on the Drawings, dimensioned to transfer tendon forces uniformly without overstressing the rock or the bearing plate.

6.18 All bearing plates not fully covered with concrete and isolated from the environment must be hot-dip galvanized to AS/NZS 4680.

6.19 The bearing stress at the steel contact surfaces must not exceed 400 MPa. The bearing stress at the concrete surface must not exceed 30 MPa.

6.20 Submit calculations or other evidence from the supplier of the ground anchor system substantiating the design of the bearing plates supplied for the Works.

6.21 The manufacturing tolerances for each component must not impair the gripping efficiency of the assembled anchorage.

6.22 A device to centre the anchorage must be provided so that the tendon force is applied uniformly to the contact surface between the prestressing head and the bearing plate or anchorage casting.

6.23 The prestressing head must permit the monitoring of accurate extension measurements without indeterminate losses between loading increments.

6.24 Draw-in losses associated with the wedges must be uniform and allow presentation of draw-in versus load plots where appropriate.

6.25 Injection nipple/s for the corrosion inhibiting compound (CIC) must be incorporated to fill and eliminate cavities above and around the prestressing head and its wedges. Any protection / cover cap must be fully filled with CIC unless otherwise approved. CIC injection systems must ensure that no air voids are present after injection and additional care must be taken to ensure no water is trapped within the anchor head zone.

6.26 Provisions must be made in either the bearing plate and / or anchor head to enable effective CIC injection at completion of stressing into any voids that may exist either under the anchor head or within the anchor head. Details of injection processes must be provided to the Principal.

6.27 Any permanent anchor that will have a permanent load cell fitted must incorporate an externally threaded anchor head should the load cell fail, enabling a later mechanical connection to the anchor for alternative load monitoring equipment to be fitted. Similarly, any anchor that is to be later monitored (without a permanent load cell) should incorporate external threads to its anchor heads as this is the preferred mechanism to reconnect to the anchor.

Grout

6.28 The following must be satisfied for the grout to be used for anchor installations:

a. Cement for grout must conform to TS 03323.1;

b. Fine aggregate, if used, must have a maximum nominal size of 1.0 mm and conform to AS 2758.1 for normal weight, concrete exposure classification B2, and maximum water absorption of 2.0%;

c. Mixing water must be clean and free of oil, acid, alkali, organic or vegetable matter, not be harmful to steel or grout, and have a chloride ion content less than 500 mg/l;

d. Methylcellulose lignosulphonate based superplasticisers and aluminates must not be used as admixtures. Expansive admixtures where used must be the pre-hardening type and not include iron or aluminium powders. The chemical reactions between grout constituents or materials in contact with the grout must not produce gases;

e. Grout mixes may be pre-packaged so that only water and admixtures need to be added to the dry mix on-site, or mixes may be designed to meet project specifications for site batching; and

f. Grout mix must conform to the performance requirements given in Table 11.7.

Sheaths and Ducts

6.29 Individual strand sheaths (minimum 1.5mm thick) and tendon anchor ducts must be robust, abrasion and corrosion resistant, waterproof, non-biodegradable and sufficiently flexible to allow insertion of the anchor into the borehole without damage. They must be strong and provide enough support to prevent excessive deformation, crushing, causing friction or rupture under loads imposed during anchor installation and grouting.

6.30 The Contractor must maintain and check the integrity of the sheaths and ducts during assembly, installation, grouting and testing.

Strand/Bar Sheaths

6.31 The following must be provided for both temporary and permanent anchors:

a. a strong smooth virgin material plastic sheath (HDPE or PP), minimum 1.5mm thick closely surrounding (but not gripping) the steel strand/bar over the unbonded length of the tendon;

b. a corrosion inhibiting grease or lubricant conforming to Clause 6.40 completely filling the annulus between the strand/bar over the full free length and the sheath such that during anchor stressing operations the frictional forces over the unbonded length of the tendon are minimized; and

c. CIC filled sheaths fitted around tendon element to be sealed from both ends using an approved sealant.

6.32 If a sheathed tendon has any voids within the free length strand or bar where the CIC is not 100% filling the internal cavity, these tendons must be rejected. In the case of strands, this includes the small interstitial voids around the central king wire where it meets the six external helical wires forming the seven-wire strand.

6.33 Pre-greased factory strands can only be used if both the internal and external walls of the HDPE / PP sheath are truly circular and constant over the full free length and exhibit no “rifling” or following in a spiral / helix manner similar to the lay of the strand. Greased strands with any tight to strand or helix type HDPE / PP sheath must not be used.

Tendon Unbonded Length Ducts

6.34 Ducts for the tendon unbonded length may be smooth or corrugated and, unless otherwise approved by the Principal, must be one of the following:

a. HDPE conforming to ASTM D1248 designation 111C5-P33; or

b. PP conforming to ASTM D4101 designation PP0210B55542.

Bond Length Ducts

6.35 Ducts for the bonded length must be corrugated virgin material and unless otherwise approved by the Principal must be HDPE conforming to ASTM D3350 cell classification 335533C or polymer compliant with FIB Bulletin 75 requirements. Low Density (LD) and Medium Density (MD) HDPE must not be used.

6.36 Unless approved otherwise by the Principal, corrugations must be uniform and generally sinusoidal in shape, conforming to the following:

a. Wall thickness (w) of ducts: $w \geq 2$ mm

b. Pitch of corrugations (p): $12\,w \geq p \geq 6\,w$

c. Amplitude of corrugations (a): $a \geq 5\,w$

6.37 The profile must not allow voids to be formed in the rising grout column.

6.38 The base of the duct must be sealed and contain a nose cone to assist insertion into the borehole. The nose cone must not inhibit grouting of the tendon and must be robust and corrosion resistant.

6.39 The Contractor must demonstrate, using Proof Tests, the capability of the duct to:

a. provide adequate bond capacity between the inner grout annulus and the tendon equal to the tensile capacity of the tendon;

b. provide adequate bond capacity between the duct and the outer grout annulus equal to the tensile capacity of the tendon;

c. accommodate the elastic behaviour of the tendon; and

d. satisfy other anchor acceptance criteria.

Corrosion Inhibiting Compound (CIC)

6.40 The corrosion inhibiting compound (CIC) used for the sheaths of individual strands or bars and corrosion protection of the Underhead and Overhead zones of the anchor must be a chemically stable, non-reactive grease or wax compatible with tendons, sheaths and grout conforming to Table 6.41. Alternatively, a CIC material that complies with the requirements outlined in ACI 423.7-14 Table 7.2.1 is acceptable, subject to Principal's approval.

6.41 The Contractor must submit a NATA endorsed test report certifying that the CIC conforms to Table 6.41.

Table 6.41 – Performance criteria for grease/wax corrosion inhibiting compound

Property	Grease – Test Method*	Grease – Requirement	Wax – Test Method	Wax – Requirement	Comments
Consistency with cone penetration	D217	265 – 295 dmm	D937	150 – 350 dmm	Pumpability and application compatibility to be confirmed
Corrosion protection	D1743	Pass	D1743	Pass	
Copper corrosiveness	D4048	1a	D130	1a	
Salt spray corrosion (5% salt fog @ 38ºC, 0.127 mm, Q Panel Type S)	B117	Rust Grade 7 or better after 1000 h	B117	Rust Grade 7 or better after 1000 h	
Oil separation maximum	D1742	3%	ASTM D6184	0.5% @ 38ºC	
Drop pt. minimum	D566	150ºC	D127	65ºC	
Flash pt. minimum	D92	200ºC	D92	200ºC	
Evaporation maximum	D972	0.5%	D972	0.5% @ 38ºC	
Saponification	D94	< 2 mg KOH/gm	D94	< 2 mg KOH/gm	
Water washout	D1264	< 5% at 38ºC	D1264	< 5% at 38ºC	

Note: * All tests are to ASTM unless stated otherwise.

Protective Caps

6.42 The protective caps and inspection lids must:

a. be watertight;

b. allow complete draining and refilling of the CIC;

c. cover the prestressing head and protruding tendon ends in accordance with Clause 14; and

d. unless approved otherwise, be manufactured from steel which is hot-dipped galvanized to AS/NZS 4680 with a minimum thickness of 7 mm.

6.43 A system to check the CIC level must be included (e.g., a removable screwed sealing plug with a probe).

6.44 Where the anchorage is fully isolated from the environment by a thick dense cover of concrete not subject to cracking through the lifetime of the permanent anchor, then protective caps may be omitted, subject to the prior approval of the Principal.

7. Supply and Supervision

General

7.1 The Contractor must supply and install each ground anchor at the specified location and alignment in accordance with the Drawings and this Specification using a tendon with the specified minimum breaking load and minimum bond length prestressed to achieve the specified Lock-off Load (T_O).

7.2 The ground anchor system used must be one included in TS 01621.

Critical Anchor Activities

7.3 The Critical Anchor Activities include:

a. All on-site activities for Proof and Suitability Testing (Clause 8);

b. Borehole drilling, cleaning and testing (Clause 10);

c. Insertion of each anchor into the borehole (Clause10);

d. Grouting (Clause 11);

e. Load testing (Clause 12);

f. Stressing (Clause 13); and

g. Cutting off tendon and applying corrosion protection to the anchorage and underhead zone (Clause 14).

Anchor Supervisor

7.4 The Contractor must ensure that the Ground Anchor System Supplier appoints a suitably experienced and qualified Anchor Supervisor. The Anchor Supervisor must be approved by the Principal and be experienced in anchors of the nature being installed, in respect to corrosion protection, length and anchor capacity.

7.5 The Anchor Supervisor must supervise the Critical Anchor Activities.

7.6 The Anchor Supervisor must certify that the following items conform to this Specification:

a. Quality Plan (Clause 4.1);

b. Each tendon coil or bar (Clause 6.9);

c. Ground anchor system (Clause 6.14);

d. Grout (Clause 6.28);

e. Tendons sheaths, anchor sheaths and ducts (Clause 6.29);

f. Corrosion inhibiting compound (Clause 6.40);

g. Testing of Proof and Suitability anchors (Clause 8);

h. Assembled anchor (Clause 9);

i. Borehole drilling, cleaning and testing (Clause 10);

j. Anchor insertion and water testing (Clause 10);

k. Experience and qualifications of all grouting personnel (Clause 11.2);

l. Grouting (Clause 11);

m. Stressing (Clause 13);

n. Assessment of anchors (Clause 12);

o. Application of corrosion protection to underhead zone and protective cap (Clause 14);

p. Monitoring (Clause 15).

Factory Grouted Tendons

7.7 For light weight ground anchor systems with up to 10 strands up to 6 m long, anchors may be grouted under factory conditions with either cementitious or resinous grout with unconfined compressive strength not less than 40 MPa at 28 days.

7.8 Grout must have reached a compressive strength of not less than 20 MPa before removing the anchors from the pouring frames following grouting.

7.9 Precautions must be taken during handling and transportation to maintain the integrity of the factory grouted tendons and no damage occurs to the corrugated / external duct.

8. Installation of Proof and Suitability Anchors

8.1 All on-site activities for Proof and Suitability Testing are Critical Anchor Activities which must be carried out under the supervision of the Anchor Supervisor.

HOLD POINT 2	
Process Held	Drilling boreholes for and assembly of Proof and Suitability anchors.
Submission Details	All details of relevant Proof and Suitability anchors (Clauses 4 and 12) must be submitted at least 5 working days prior to before drilling or assembly.
Release of Hold Point	The Principal must consider the submitted documents and may carry out surveillance and audit, prior to authorising the release of the Hold Point.

8.2 Proof anchors must be assembled and tested taking into consideration the nature of the investigation and include some or all of the following:

a. to provide information for the final design (refer Clause 12.11 to 12.22) i.e., anchor capacity at the grout/ground, grout/tendon or the duct/grout interfaces;

b. to establish precisely the supply, assembly, installation and grouting operations to be used for the working anchors; and

c. to demonstrate the performance of the corrosion protection system (e.g., split gun-barrel tests allowing inspection after loading (refer Annexure B: Figure 6).

8.3 Suitability anchors must be supplied, assembled, installed and grouted using identical materials and methods to those for working anchors, but a more severe test regime will be applied (refer Clause 12.23 to 12.31).

8.4 After successful testing, only Suitability anchors may be used as working anchors. The load capacity of proof anchors must be disregarded. Suitability anchors which do not comply with Clause 12 must not be used as working anchors.

9. Assembly

HOLD POINT 3	
Process Held	Assembly of working anchors.
Submission Details	Evidence proving conformity with Clauses 4 (quality plan), 5, 6, 7.7, 7.8, 7.9, 8 and certification of conformity of Suitability Anchors at least five (5) working days before assembly.
Release of Hold Point	The Principal must consider the submitted documents and may carry out surveillance and audit, prior to authorising the release of the Hold Point.

General

9.1 The Quality Plan must include:

a. fully detailed proposals, with drawings including cross-sections and longitudinal sections showing all anchor components,

b. details of the method of assembly preventing damage to the anchor components and corrosion protection system;

c. If anchors are to be assembled off-site, the procedures proposed for assembly and transport and identify precautions required to maintain the integrity of the tendon, sheath, duct, grout tubes and joints during loading, transportation and unloading to ensure no reduction in anchor performance; and

d. if applicable, the provisions for monitoring specified in Clause 15.

9.2 An assembly schedule tracing the source of each tendon in each anchor e.g., for strand, each coil from which each strand in each anchor was taken must be made available to the Principal.

9.3 Prior to commencement, or during the early stages in the anchor works, if directed by the Principal, the Contractor must demonstrate the resistance of the duct to damage during installation by inserting and withdrawing an assembled anchor from the borehole and inspecting its condition.

9.4 The Principal may consider systems developed to confirm the total isolation of the tendon from the environment using electrical conductivity test techniques.

9.5 If factory grouted anchors are provided, the above controls must be maintained and make the manufacturing facilities made available for the Principal’s inspection.

9.6 A minimum of 20 mm grout thickness must be provided between the sheath/duct and the borehole wall.

Tendons

9.7 Any damaged or kinked tendons must be rejected.

9.8 Welding must not be carried out at a distance less than 3 m from any tendons. Any tendon affected by arc strikes must be rejected.

9.9 Tendons must be cut with high-speed carborundum disk cutters. Flame cutting must not be used under any circumstances.

9.10 The Quality Plan must include a procedure for avoiding crossing of strands within the tendon unbonded length. Tendons must be arranged uniformly without oblique crossing over the anchor cross-section

9.11 If strand is used, it must be supplied in coils in conformity with AS/NZS 4672.1. When removing strand from coils, the resulting twisting forces must not loosen the lay of the strand. The lay of the strand wires may only be modified with the intent of forming strand nodes.

9.12 Corrosion inhibitors applied by the manufacturer of the tendons for protection during transport are permitted, provided that the inhibitors do not reduce the bond between the tendons and the grout.

Grout Tubes

9.13 Unless otherwise specified, provide for each anchor, a minimum of two independent grout tubes, one in each annulus, extending to the bottom of the anchor and the base of the borehole that, if left in place, must not reduce the bond between the tendon and the grout.

9.14 Grout tubes must be appropriate for the volume of grout and size of anchor with a minimum internal diameter of 16 mm and sufficient wall thickness and strength to prevent damage during handling, installation and grouting.

9.15 Tendons must be assembled so that any external grout tubes will not be damaged during installation and the specified grout thickness between the sheaths and duct and the sides of the borehole will be provided.

9.16 Grout tubes, spacers and centralisers must be arranged so that grout will flow freely to provide complete grout cover around all anchor components, without entrapping pockets of grout, bleed water or air.

Spacers and Centralisers

9.17 Spacers must be provided to separate the tendon elements and provide the required grout cover. Use star-shaped or serrated spacers of interrupted circular perimeter to minimise contact with the ducts and allow free flow of grout.

9.18 Centralisers and spacers must be provided at not less than 1 m intervals in the bonded length and 3 m intervals in the unbonded length between the duct and the borehole wall to ensure complete filling of the outer annulus with grout of the minimum specified thickness and to prevent damage.

9.19 Centralisers and spacers must be manufactured from materials that can withstand installation forces without damage and that will not corrode or damage the anchor components.

9.20 Centralisers must be sized and spaced to protect external grout tubes from being damaged. Grout tubes must not be used as centralisers or spacers.

Joints

9.21 The Quality Plan must include details of the method of demonstrating the adequacy of joints in sheaths and ducts.

9.22 Where a corrugated duct joins with a smooth or corrugated duct above the tendon bond length, the joint must be sufficiently strong to withstand installation and unbalanced water and grout pressures.

9.23 Joints must be provided at the bottom of the corrugated duct to the nose cone, that are strong, watertight and able to withstand loads from all anchor operations without damage.

9.24 Joints between lengths of sheaths and ducts must be made using hot plate welding by experienced operators, unless approved otherwise. Demonstrate the adequacy of the welds or alternative joints. Include sampling and testing of field joints in the Inspection and Test Plan and the Proof Tests (refer Clause 9.3).

Unbonded Length

9.25 The Quality Plan must include details of the sheaths at tendon couplers (applicable to bar tendons only).

9.26 Overlap the unbonded length duct with the underhead zone trumpet. The joint between the trumpet and the duct must be sealed.

9.27 Where the use of coupler(s) within the tendon unbonded length cannot be avoided, the bar coupler(s) must be surrounded with a coupler isolation sheath of sufficient length of equal or better performance than the remainder of the unbonded length sheath that allows the coupler to move freely within the surrounding grouted annulus during cyclic loading of the anchor without damage to the integrity of the unbonded length.

9.28 Close attention must be paid to the coupler isolation during sheath fusion welding or use bonded heat shrink systems for watertight overlaps. Since the diameter of the coupler isolation sheath is generally greater than that of the remaining unbonded length sheath, use sheaths which accommodate bar and coupler movement, maintain integrity and avoid damage to the unbonded length, as approved by the Principal prior to use, and demonstrate satisfactory performance if required using Proof Tests.

9.29 For strand tendons the friction loss between the smooth sheath and strand and internal grease / void filling must not exceed 5 kg/m per strand.

9.30 Where specified for strand anchors, a staggered transition length must be introduced to accommodate the localized tendon bundle girth that would otherwise occur should all strands terminate between the free and bond length at a common location. By having the strands stagger at their junctions, the overall bundle diameter is reduced. However, the stagger length must be as short as practical. This is to minimize the variance in stress between strands within the bundle and is particularly crucial for anchors with shorter free lengths. The Contractor must calculate the nominal variance in stress levels as a result of the transition length and submit these to the Principal.

Bond Length

9.31 The Quality Plan must include detailed procedures for fixing the lower end of the tendon to its nose cone and as applicable the bottom of the corrugated duct and its seal to the external nose cone.

9.32 A nominal minimum 5 mm space must be provided between adjacent strands of multistrand tendons at bond length internal spacers for complete grout penetration. Provide similar grout cover to bar couplers.

9.33 At the midpoints between bond length internal spacers of multistrand tendons, tight bands must be fitted to provide a minimum 20 mm grout cover between the strands and the duct wall and to enhance the bond between tendon and grout.

9.34 Bar tendons must be centralized within the duct to provide a minimum 20 mm grout annulus.

9.35 Where transition lengths are used, the joints between each unbonded length and bond length must be staggered to avoid abrupt changes in the load transfer mechanism (refer clause 9.30).

Marking

9.36 The upper ends of tendons and sheaths must be clearly marked with reference marks prior to installation and provide in the assembly schedule for each anchor details of the following lengths in metres from the reference marks to an accuracy of 0.1 m:

a. Depth of borehole;

b. Location of reference marks;

c. Ends of tendon, duct and sheath;

d. Start of bond length duct;

e. End of bond length duct;

f. Start of debonding for each individual strand or bar;

g. End of debonding for each individual strand or bar;

h. End of each grout tube.

Conformity Records

9.37 Shop drawings and conformity records must be submitted for each type of anchor, including tendon materials and anchorage components and the assembly schedule at least 5 working days before the proposed date of installation.

10. Installation

General

10.1 When anchoring new concrete structures, the anchor must be installed through formed holes constructed to the tolerances shown on the Drawings, unless specified otherwise.

10.2 When anchoring existing concrete structures, holes must be drilled in the structure using diamond core drills or the like to a tolerance of –0, +25 mm on the diameter, unless specified otherwise. Percussion hammer or impact type drills or similar must not be used to drill through the structure without the prior approval of the Principal.

10.3 During borehole drilling, cleaning, testing, tendon installation and grouting, the Contractor must ensure that:

a. the complete tendon bond length is in ground of the specified quality and strength;

b. the complete tendon bond length is filled with the same grout as that pumped to the borehole;

c. the grout does not become diluted by ingress of water into the tendon bond length;

d. the grout does not leak from the borehole prior to setting;

e. the tendons are grouted to the surface then flushed back to a depth to allow for the necessary strand pattern divergence; and

f. the grout is not in contact with the anchored structure until after completion of stressing because the free length grout column in compression can behave like a strut on the back of the structure; provide packers to prevent this if necessary.

Drilling

10.4 The Quality Plan must include procedures for managing the drilling process, including:

a. managing variations in subsoil condition;

b. when penetrating material other than rock, details of the proposed drilling procedure and method of supporting the borehole during drilling, installation and grouting; and

c. maintaining and checking the specified borehole alignment and deviation from straight during drilling.

10.5 The use of bentonite, or other products that may reduce anchor bonding, is prohibited.

10.6 Drilling of boreholes is a Critical Anchor Activity that must be carried out under the supervision of the Anchor Supervisor.

10.7 Boreholes must be drilled at the locations and to the minimum diameter shown on the Drawings, providing for the minimum grout thicknesses specified in Clause 9.6. To ensure that the sides of the hole are sufficiently rough for bonding, diamond core drilling must not be used for the borehole in the tendon bond length.

10.8 Boreholes must be drilled to at least to the depths specified on the Drawings or as directed by the Principal. Extra length must be provided as required by the tendon size with a minimum of 500 mm below the tendon bond length for deposition of cuttings that cannot be flushed out. The borehole “overdrill” length may be a function of the tendon size and the nature of material being drilled.

10.9 The Contractor must:

a. use a rigid drilling rig assembly and working platform to achieve the specified borehole alignment;

b. check the positioning of the rig regularly during drilling to maintain the specified alignment; and

c. use rigid, large diameter drill rods and associated casings to minimise borehole deviations resulting from obstructions or inclined bedding planes.

10.10 Boreholes must comply with the following:

a. deviation from alignment must not exceed 1 in 20;

b. deviation from straight must not exceed 20 mm in any 3 m length;

c. entry point must be positioned within a tolerance of ±75 mm for retaining walls and of ±100 mm for structures; and

d. initial alignment when setting up the drilling rig should not deviate by more than 2° from the specified axis of the borehole to reduce interaction between tendon bond lengths, (particularly where the anchorages are in close proximity and/or anchors are long).

10.11 Suitable equipment to facilitate measurement of borehole deviation must be used.

10.12 In ground likely to collapse, temporary or permanent lining tubes or steel casings must be used to support the sides of the tendon bond length of the borehole. Drilling fluid that may reduce tendon bond must not be used at any stage of drilling operations. Temporary casing may only be withdrawn after the borehole is supported by grout.

Cleaning

10.13 The Quality Plan must include the methods of cleaning the boreholes.

10.14 Cleaning of boreholes is a Critical Anchor Activity that must be carried out under the supervision of the Anchor Supervisor.

10.15 On completion of drilling or reaming, the borehole must be cleaned and then covered securely to prevent contamination.

10.16 Cleaning must be carried out by flushing the borehole at least 3 times with water and air until the emerging water is clear. Any smearing and flushable drill cuttings from the borehole walls and bottom that may be detrimental to the performance of the anchor must be removed by the flushing.

Borehole Testing

10.17 Testing of boreholes is a Critical Anchor Activity that must be carried out under the supervision of the Anchor Supervisor.

10.18 Borehole testing is carried out to ensure that during grouting uncontrolled grout leakage does not take place and on completion of grouting the bond length is fully grouted.

10.19 Borehole testing must be carried out in conformity with Clauses 10.21, 10.22 or 10.24 or by a combination of these tests.

10.20 The tests must be applied over the bond length of the anchor and, if requested by the Principal, over the free length also.

Pressure Grouting

10.21 If pressure grouting (which is primarily suited to anchors founded in weak or fissured rocks and soils) is required or specified on the Drawings, it must be carried out as follows:

a. Grout the borehole under a pressure of 1 MPa, reduced as necessary to remove the drill casing from the fixed length.

b. During grouting, check the efficiency of the grouting by monitoring the response of the ground to further grout injection and restore the grout pressure quickly if it falls by injecting more grout.

c. If the grout pressure cannot be maintained, redrill the borehole after the grout sets.

d. If required, isolate the borehole length to be tested and control the withdrawal of lining tubes or use a packer or tube-a-manchette system.

e. During pressure grouting of fully cased boreholes where casings are progressively removed, such as for anchors in soil, maintain the casing rotation during the application of the pressure.

Falling Head Grout Test

10.22 When pressure grouting is not carried out as part of routine anchor construction, the Falling Head Grout Test may be carried in accordance with the following procedure:

a. Fill the borehole with grout prior to insertion of the anchor and observe the grout level until it becomes steady.

b. If the grout level falls, top it up with more grout and after sufficient stiffening of the grout, redrill and retest the borehole.

10.23 Where repeat tests in a particular ground condition demonstrate a steady grout level, the test may be replaced by confirmation of a steady grout level after anchor installation, if approved by the Principal.

Water Testing

10.24 Where water testing is carried out, the following procedure applies:

a. Subject the borehole to a water test to determine the likelihood of grout loss over the anchor length. If agreed by the Principal, grout the borehole prior to water testing.

b. Borehole packers may be used to seal off the length of borehole under test or fill the borehole to the required level with water and test under a constant water head.

c. Test by applying a net pressure of 100 kPa, or a lower pressure if agreed to by the Principal and maintain this pressure for at least ten (10) minutes with a water loss in this

period of not more than 50 litres. The net pressure is the difference between the applied pressure and the pressure in the borehole.

d. If the water loss exceeds 50 litres in ten minutes, grout the bond length, redrill the borehole and test again. Should the test again fail, repeat the process.

10.25 If, after two grouting operations the water test fails, but no grout loss occurred during the second grouting operation, the borehole may be accepted and no further attempt to waterproof the borehole is needed. Where a grout loss occurs during the second grouting operation, the Contractor must give consideration to multistage grouting and/or use of sanded mixes or abandon the borehole for use for drainage or filling with grout.

10.26 If any water outflow occurs from the borehole collar due to water inflow into the borehole, the Contractor must waterproof, and water test the borehole as above. If, after two successive grouting operations, outflow of water from the collar continues, the Contractor must implement a means of providing sufficient backpressure to stop the outflow of water during grouting of the anchor.

Conformity Records

10.27 Conformity records for the borehole must be submitted to the Principal prior to inserting the anchor.

Anchor Insertion

General

10.28 The Quality Plan must include procedures for inserting assembled anchors into boreholes.

10.29 Insertion of each anchor into the borehole is a Critical Anchor Activity which is required to be carried out under the supervision of the Anchor Supervisor.

10.30 The Anchor Supervisor must inspect the anchor assemblies prior to insertion and certify the integrity of the sheaths, duct, tendon and grouting tubes.

10.31 Unless specified otherwise (such as for temporary anchors) tendons must be fully encapsulated and placed in sheaths or ducts as part of their final assembly in the borehole.

HOLD POINT 4	
Process Held	Insertion of working anchors
Submission Details	All details in Clauses 9.36, 9.37, and 10.27 must be submitted to the Principal at least 5 working days prior to inserting the anchors.
Release of Hold Point	The Principal must consider the submitted documents and may carry out surveillance and audit, prior to authorising the release of the Hold Point.

Insertion of Permanent Anchors Grouted In-situ

10.32 The insertion of permanent anchors grouted in-situ must be carried out in accordance with the following:

a. Keep each borehole sealed until the assembled anchor is ready to be inserted.

b. Before inserting the anchor, clean the walls and bottom of the borehole in accordance with Clause 10.16 and gauge it to confirm that it is unobstructed and of the required diameter over its full depth.

c. Just prior to inserting the anchor, completely fill the borehole with water.

d. To eliminate damage to the duct and centraliser during anchor insertion, use a removable funnel with a rounded entrance at the collar of the borehole or at the casing head.

e. Fill the duct with water as it is lowered into the water-filled borehole to assist its insertion and to minimise differential water pressure.

f. Control the descent of the anchor using a braking device. Suspend the anchor during and after insertion so that it is not compressed or displaced from the centre of the borehole.

g. Control the curvature of the anchor during insertion to prevent kinking or crumpling of the sheaths and duct.

h. Test the integrity of the grout tubes after insertion of the anchor or prior to grouting by pumping water through each tube.

i. Take measures immediately after anchor insertion to protect the borehole from contamination e.g., from waste grout, that could adversely affect subsequent grouting.

Water Testing of Inserted Anchor

10.33 After insertion or immediately prior to grouting, the Contractor must:

a. Water test to demonstrate the integrity of the corrosion protection system of the assembled anchor by topping up the inner annulus with water and extracting water from the outer annulus.

b. Provide a differential water head between the inner and outer annulus of at least 2 m for at least 30 minutes. If any leakage occurs, withdraw the anchor from the borehole, repair or replace it and water test again until it is watertight. Some minor expansion of the duct is possible during water testing. The aim of the test is to confirm that there is no leakage; i.e., a constant water height inside the duct.

Insertion of Factory Grouted Anchors

10.34 The integrity of semi-rigid factory grouted anchors must be thoroughly inspected immediately prior to insertion in the borehole and any damage repaired by applying a heat shrink sleeve, as approved by the Principal. The Quality Plan must include procedures for repairing damage to factory grouted anchors.

10.35 Where damage is severe or repeated, the anchors must be rejected and the entire fabrication, transportation and storage procedures must be reviewed.

10.36 Factory grouted anchors must be spaced off the borehole wall to eliminate insertion damage.

10.37 Where a multiple anchor system is used, the Contractor must ensure that each unit length, (typically 2.5 m long), is correctly staggered at the designed depth and provide appropriate spacers within the system.

11. Grouting

General

11.1 Grouting of ground anchors is a Critical Anchor Activity that must be carried out under the supervision of the Anchor Supervisor.

11.2 All personnel involved in grouting must be acceptable to the Anchor Supervisor and have relevant training and experience or be subject to supervision that will produce conforming grout.

11.3 Grouting must commence immediately after approval of insertion of the anchor in a single stage operation, filling the borehole in such a manner that the hardened grout does not come in contact with the structure. This time delay should not exceed 24 hours. Where more than 24 hours have passed since insertion, the anchor must be flushed and potentially removed, then the process repeated, unless otherwise approved by the Principal.

11.4 The inner annulus inside the duct must be grouted with the same grout used in the outer annulus between the duct and wall of the borehole.

11.5 The internal and external grouts must be injected via independent grouting tubes simultaneously in a manner that minimises the differential grout head to avoid damaging the sheathing.

11.6 Corrosion protection of the prestressing head must be in accordance with Clause 6.42 of this Specification.

HOLD POINT 5	
Process Held	Grouting of anchors.
Submission Details	Conformity records of grout materials and mix design (Clauses 6.28, 11.8 and 11.9), grout tubes (Clause 9.13 to 9.16), anchor assembly (Clause 9), and anchor installation (Clause10) to be provided to the Principal prior to grouting.
Release of Hold Point	The Principal must consider the submitted documents and may carry out surveillance and audit, prior to authorising the release of the Hold Point.

Performance

11.7 Cementitious grout for grouting of a ground anchor must:

a. in permanent anchors that are grouted in-situ, fill the internal and external annuli of the complete bond length and the majority of the free length;

b. after curing, provide adequate strength to prevent bond failure in the bond length between tendon and grout, duct and grout, and borehole and grout;

c. contribute to the protection of the tendon against corrosion, even though it is likely that tensile cracking of the grout will take place during stressing of the tendon;

d. have fluid characteristics to penetrate and fill all voids in the assembled anchor and surrounding ground to protect the tendon and develop the required anchor load capacity; and

e. have high bleed resistance, low shrinkage and high fluidity and conform to the values in Table 11.7

Table 11.7 – 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.
Volume change	ASTM C1090	Maximum height change at 1 and 28 days 0.1% and 0.3%	
Early expansion	ASTM C940	< 2% at 3 hours	Temperature tolerances are 20°C ± 5°C.

Property	Test method	Criteria	Comments
Fluidity	ASTM C939 [2]	Immediately after mixing Efflux time < 20 s 45 minutes after mixing Change in efflux time < ± 3 s	Target efflux time for the site conditions must not vary from nominated value by more than ± 2 s.
Minimum compressive strength	TS 02800.49	32 MPa at 7 days 40 MPa at 28 days	Use 75 mm cubes.

Notes:

1 The test method must be modified to simulate wicking of strands as follows:

Cut a 1000 mm long piece of 12.7 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.

Mix Design and Testing

11.8 Grout must be supplied and tested in accordance with the Clause 11.7.

11.9 The Contractor must:

a. not use additives unless it can demonstrate that the additives will not harm grout performance or anchor components;

b. carry out preliminary testing and prove that the grout mix conforms to Table 11.7 prior to grouting the Suitability anchor; and

c. in the event of nonconformity, stop grouting and implement corrections to the mix and retest to achieve the specified bleed and strength.

Mixing

11.10 The Contractor must:

a. hold adequate stocks of cement or bagged mixes at the grout mixer to ensure continuity of grouting. Use only fresh cement and bagged mixes less than 1 month old;

b. use only fresh cement that is free of lumps;

c. carry out preliminary low volume mixing and discharge to waste all surplus water from the mixer;

d. batch into mixers by mass for all mix constituents except liquids which may be by volume;

e. use whole bags of cement or approved packaged grout mixes clearly marked with the bag mass;

f. supply additives in individual doses to suit each batch size;

g. ensure the water temperature measured in the mixer prior to addition is not less than 5°C nor more than 27°C;

h. monitor the grout consistency using a mud balance and flow cone once mixed.

i. keep the grout continuously agitated after mixing;

j. where required, demonstrate the grout will pass through 2.36 mm nominal apertures;

k. utilise for grout pumping a recirculating system where the grout is continuously discharged back into the agitation tank;

l. use the grout as soon as possible after mixing and in any case within 45 minutes of adding cement to the mixing water;

m. maintain a continuous supply of grout by mixing the next batch of grout whilst pumping the previous batch; and

n. keep the grout temperature between 5°C and 30°C during mixing or pumping which may require heating or cooling of the mixing water.

Pumping Equipment

11.11 Grout pumps must be of a type approved by the Principal, with an outlet pressure of at least 1.0 MPa and be capable of pumping the grout at a rate appropriate to the required rate of rise.

11.12 The grout pump must be run continuously for the duration of the grouting of each anchor. The grout pump must be equipped to independently pump at different rates into the inner and outer annuli. For anchors longer than 20m or those with ultimate capacity exceeding 5,000kN, separate pumps with variable flow must be used to independently grout the inner and outer annuli.

11.13 Provide backup grouting equipment and submit procedures for controlling and handling interruptions to grouting operations i.e., interruptions either to continuous grout injection or to continuous efflux of water from the borehole.

11.14 Grouting must be carried out using supply lines directly connecting the pump to the down-hole tubes. All connections, valves and lines must be pressure rated to at least 1.0 MPa.

11.15 Grout fittings and pressure gauges must be located to enable control and monitoring of pressure during injection of the grout to the down-hole tubes. Pressure gauges must be calibrated and fittings at the tops of boreholes must allow discharging to waste.

Procedure

General

11.16 All discharged water and grout to be collected and treated in accordance with the environmental management requirements included in the Contract documents.

11.17 Grouting must be carried out in accordance with the following procedure:

a. Circulate sufficient water through the grout tubes to ensure all air has been displaced and continue circulating the water until the emerging water is clear.

b. Keep the outer and inner annulus discharge tubes and grout hoses filled with water at the commencement of grout injection.

c. Prior to commencing grouting, measure the fluidity which must not vary from the target fluidity by more than ± 2 sec, and in any case must not be more than 22 sec. Ensure that grout tubes and discharge hoses and equipment can sustainably withstand the resistance pressure generated during the grouting operation, being critically aware that the time post mixing as the grout ages will make the grout less “pumpable”.

d. Prior to commencing injection of grout, measure the density using a mud balance of the grout which will enable verification of the approximate w/c ratio. The SG of grout will be anticipated to be in the 1.90 – 2.00 range dependent upon the w/c ratio. Do not inject grout that is outside the required criteria.

e. Inject the grout through the feeder tubes commencing at the level at the lowest elevation, moving though progressively to higher level injection tubes if fitted. Do not commence injection into the next level of grout tube prior to the grout reaching that level. Inject simultaneously into both inner and outer annuli, taking care to ensure the grout levels are common to both, and perhaps with a slight bias to the inner grout level being slightly higher than the external.

f. Where the bottom of the borehole is at a level more than 300 mm below the bottom of the anchor, grout the bottom section of the hole to approximately the level of the bottom of the anchor and then commencing the internal grout so to simultaneously grout both the external hole and anchor internal annuli. In critical applications and also for long anchors measuring boxes to measure displaced water or flow meters may be appropriate to keep the relativity of the grout between the two chambers within a short distance of each other to avoid rupture of the duct due to differential pressures caused by the density of the grout relative to the water being displaced during the tremie grouting process. Keeping the head

of grout within the duct is balanced with the head of grout in the borehole annulus during grouting is critical.

g. inject the grout continuously until all the water is displaced from the outlet vents.

h. Continue grouting until the emerging grout density measured is within ± 5% of that of the injected grout.

i. Alternatively, continue grouting until the emerging grout's measured fluidity is within ± 20% of that of the injected grout.

j. Once the emerging grout has complied with the above, continue observation of the process by an experienced operator, and continue discharging the grout until there is no doubt that all zones of low-quality grout have been displaced.

k. Within 30 minutes of completion of grouting, flush out the top of the grout column to a depth sufficient to allow the strands to be spread to accommodate the prestressing head. This depth must be at least equal to the deviation length specified for the anchorage of the ground anchor system used.

l. Flush out to avoid excessive compressive stresses in the grout column from strut action between the grout column and the bearing plate or anchorage and the structure.

m. Support the anchor for a minimum of 24 hours following completion of grouting.

Temporary and Factory Grouted Anchors

11.18 Grouting of the entire borehole length must be carried out using typically a single grout tube that extends to the base of the borehole.

11.19 Where end of casing pressure grouting is used, on completion of grouting the borehole, the drill head must be coupled to the drill casing and the casing withdrawn gradually. During withdrawal, a grout pressure of up to 1 MPa must be applied at the drill head flush inlet passage of the drill casing to inject grout into the ground within the bond length.

11.20 Where post grouting is used, supplementary grout pipes must be installed alongside the duct with valves at specific locations and apply between 2 MPa and 4 MPa of pressure to the grout to break through the in-situ grout column into the ground. Post grouting must be carried out between 2 hours and 24 hours after borehole grouting.

Permanent Anchors with In-situ Grouted Ducts

11.21 Separate feeder pipes musty be installed, one to the base of the borehole in the outer grout annulus and the other in the inner grout annulus to the base of the duct. If necessary additional level(s) of grout tubes must be added for longer anchors.

11.22 Prior to grouting, the volumes of the grout required to fill the inner annulus must be determined, deducting the volume occupied by the tendon and other anchor components, and the volume needed to fill the outer annulus. These volumes must be used to assess the effectiveness of the grouting.

11.23 During grouting, the head differential between the inner and outer grout annuli must be kept to less than that equivalent to 2 m of grout, unless the sealed duct has adequate capacity to resist this head differential without damage or leaks.

11.24 Typically, the volume per metre of the outer annulus is greater than that of the inner annulus by a factor of between 2.0 and 2.5. These volume differentials must be used to control the grouting, and grout using:

a. For anchors up to 15 m long – operator estimate;

b. For anchors over 15 m long – calibrated water return tanks or flow gauges.

Conformity Records

11.25 Conformity records for the grouting of each anchor must be submitted to the Principal. The Contractor must provide evidence that no voids are present in the annuli between the anchor and any sheathing. Any void will result in rejection of the anchor.

12. Load Testing

General

12.1 Load testing of ground anchors is a Critical Anchor Activity that must be carried out under the supervision of the Anchor Supervisor.

12.2 The Anchor Supervisor must approve the test method and the monitoring system used for each test. For each test, load the anchor in stages in accordance with the specified test procedure.

12.3 The Contractor must undertake the following types of on-site load tests, as specified:

a. Proof (where specified, refer Clause 12.11 to 12.22);

b. Suitability (refer Clause 12.23 to 12.31); and

c. Acceptance (refer Clause 12.32 to 12.34).

12.4 Load testing must be undertaken at the frequency specified in Annexure C, unless specified otherwise in the Contract documents.

Loading and Monitoring

12.5 Loads must be applied and released smoothly to prevent shock or dynamic loading of the anchor.

12.6 During all tests, the applied load and tendon extension at each load increment and each load/extension observation must be monitored and recorded.

12.7 The Contractor must:

a. Load the anchor in a single unmonitored load cycle up to Test Load T_P and return to Initial or Datum Load T_A. This preload cycle is intended to:

   i. accommodate draw-in of reusable jack wedges gripping the tendon;

   ii. overcome initial friction forces;

   iii. achieve bedding of the bearing plate or cast-in anchorage;

   iv. achieve displacement of the structure;

   v. reduce the contribution of extraneous displacements;

   vi. allow a more accurate determination of elastic extension during the monitored cycle.

b. The theoretical elastic extension δL_r of the tendon at Test Load T_P must be calculated using the Equation 1 and the data from the anchor assembly schedule prepared in conformity with Clause 9.36:

$$\delta L_r = \frac{(T_P - T_A) L_{fr}}{A_t E_t}$$

Equation 1 – Theoretical elastic extension of the tendon

Where:

A_t = area of steel in the tendon (mm^2)

E_t = elastic modulus of the tendon (MPa)

L_{fr} = free length of tendon between top of bond length and wedges at rear of jack (mm)

δL_r = calculated elastic extension of tendon (mm)

T_A = Initial or Datum Load (N)

T_P = Test Load (N)

c. The values of 90% and 110% elastic extension at Test Load T_P from Initial or Datum Load T_A must be calculated to provide criteria for assessing anchor conformity. The measured extension δLe between 0.9 δL_r and 1.1 δL_r will be conforming.

d. When the measured extension is outside the limits as specified in item c. in this list, carry out as appropriate, while the stressing equipment is in place, two additional load cycles to verify load/extension repeatability (refer to item i. in this list).

e. For Suitability Tests and Acceptance Tests, carry out a program of cyclic loading and unloading using load increments and minimum periods of observation given in Annexure C. After the peak load in each cycle is reached, take measurements of the load loss with the deformation held constant for a time interval of 5 minutes, but this time may be subsequently increased to 15 minutes and then to 50 minutes to obtain compliance to a limiting value in Table 12.7.

Table 12.7 – Limiting values of load loss/creep movement with time

Observation period (minutes)	Maximum time interval between recordings (minutes)	Relaxation test: maximum load loss within observation period	Creep test: maximum deformation change within observation period
0 to 5	1	2% of cycle peak load	2% of δL_e
5 to 15	2	1% of cycle peak load	1% of δL_e
15 to 50	5	1% of cycle peak load	1% of δL_e

f. For a relaxation test, the tendon extension must not vary by more than 0.5% of the extension recorded at 0 min throughout the observation period.

g. For a creep test, the applied load must not vary by more than 0.5% of the load recorded at 0 min throughout the observation period.

h. Based on the load/extension results, calculate the effective tendon free length L_{ef} (equation 2) at Test Load T_P using data from the anchor assembly schedule prepared in conformity with Clause 9.36 and the load test records and calculate the limits for acceptance (equation 3 or 4) as follows:

$$L_{ef} = \frac{\delta L_e A_t E_t}{(T_p - T_A)} \times 10^{-3}$$

Equation 2 – Effective tendon free length

and

$$0.9L_{fr} \leq L_{ef} \leq \left(L_{fr} + 0.5L_b\right)$$

Equation 3 – Limits of effective tendon free length: case 1

or

$$0.9L_{fr} \leq L_{ef} \leq 1.1\ L_{fr}$$

Equation 4 – Limits of effective tendon free length: case 2

Where:

A_t = area of steel in the tendon (mm^2)

E_t = elastic modulus of the tendon (MPa)

L_b = tendon bond length (mm)

L_{ef} = effective tendon free length between top of bond length and wedges at rear of jack (mm)

L_{fr} = free length of tendon between top of bond length and wedges at rear of jack (mm)

T_A = Initial or Datum Load (kN)

T_P = Test Load (kN)

δL_e = measured elastic extension of the tendon (mm)

i. If the anchor does not satisfy either of these limits then reload the anchor in two cycles to Test Load T_P. Provided that recalculated $L_{ef} \geq L_{fr} + 0.6\ L_b$ and the anchor has repeatable load/extension behaviour in the second cycle as demonstrated by the extension in the second cycle being within ± 5% of that in first cycle, this criterion is satisfied.

If this criterion is not satisfied, then extend the test with the approval of the Principal or replace or down rate the anchor.

j. The Initial Residual Load T_{RI} measured by Lift-off Test immediately after lock-off must not be less than 110% and not greater than 115% of specified Design Working Load T_O. If the Initial Residual Load T_{RI} is less than 110% of the specified Lock-off Load T_O, increase the jacking force T_J and repeat the test cycles.

k. The Residual Load T_R measured by Lift-off Test at 48 hours after lock-off must not be less than 96% of the initial Residual Load T_{RI}.

l. Where the Residual Load T_R at 48 hours after lock-off is less than 96% of the Initial Residual Load T_{RI}, the test may be repeated for two further 48-hour periods.

If the Residual Load T_R at 96 hours after lock-off is greater than 94% of T_{RI} or at 144 hours is greater than 93% of T_{RI}, the Residual Load Criterion is satisfied.

If this criterion is still not satisfied, extend the test with approval of the Principal, or replace the anchor.

12.8 To assess the behaviour of the anchor at peak load, the performance must be monitored by the following tests:

a. Relaxation Test: i.e. measurement of load loss while the extension is kept constant; or

b. Creep Test: i.e., measurement of the change in extension while the load is kept constant.

12.9 Anchor performance at lock-off must be monitored by carrying out lift-off tests at specified periods after lock-off (load monitoring).

12.10 Where proven accurate load cells are part of the anchor system, they may be used for both determining load losses and load monitoring at Test Load T_P and Lock-off Load T_O to verify anchor performance. Refer Clause 13.17 for load cell calibration.

Proof Tests

12.11 Where specified, a Proof Test is a load test carried out in advance of the installation of the working ground anchors to:

a. establish for the designer the anchor resistance R_a in relation to the ground conditions;

b. allow the designer to determine criteria for anchor acceptance;

c. verify the performance of proposed materials and components e.g., ducts;

d. prove the competence of the Contractor; and

e. determine the bond capacity of an anchor by inducing a failure at the grout/ground interface.

12.12 Proof Tests must be carried out in advance of the installation of working anchors to verify for the designer that the failure load or the bond capacity of an anchor at the grout/ground interface provides the required resistance in the working anchor.

12.13 The resistances achieved relate to the ground conditions, anchor materials used, and the construction methods adopted.

12.14 Proof Tests may be specified where anchors are to be used in ground conditions not yet tested by previous Proof Tests or where greater design loads are to be used than those adopted in similar ground conditions.

12.15 At a site where variable ground conditions are expected, Proof Tests may be used to assess the performance of anchors founded in different strata.

12.16 Anchors for Proof Tests are loaded more rigorously than working anchors, so it is generally necessary to increase the area of the tendon to accommodate the higher load requirements, or to test shorter bonded lengths if the test is specified to induce a grout/ground interface failure.

12.17 The anchor must be loaded to failure or to a maximum test load which must not exceed 80% of the minimum breaking load of the tendon (T_U), whichever is lower.

12.18 Throughout Proof Tests, the Contractor must investigate the characteristics of load loss or creep (as applicable) at each load cycle peak (see Annexure C). Failure is deemed to be reached when the following occurs over a 5-minute period:

a. at constant extension, the load loss exceeds 2% of the maximum test load (Relaxation Test)

b. at constant load, the change in extension exceeds 2% of measured elastic extension of the tendon (for the Creep Test.)

12.19 The anchorage resistance R_a must be assessed in accordance with AS 5100.3.

12.20 Proof Tests may be extended as required to verify the actual performance of any component of the anchor, these being typically:

a. bond capacity at the tendon to grout interface;

b. bond capacity of the duct to grout interface;

c. integrity of corrosion protection system during and after completion of testing; and

d. performance of new anchor systems e.g., multiple anchor, removable anchor or carbon fibre tendon systems etc.

12.21 Proof Tests may be carried out on site or under controlled laboratory conditions using gun-barrel type tests (refer Annexure B: Figure 6) which allow component inspection after testing, this being preferred when the integrity of the duct of a ground anchor system is being investigated.

12.22 Anchors subjected to Proof Tests must not be used as working anchors.

Suitability Tests

12.23 A Suitability Test is a test on an anchor which is identical to the working anchors to:

a. verify the ground anchor design and installation; and

b. establish reference test values for other anchors represented by the tested anchor.

12.24 Prior to carrying out a Suitability Test, the Contractor must take into account the results of Proof Tests or of relevant prior published data that will form the basis of or validate the design of working ground anchors, the required resistance at each interface and the ability of the anchor to sustain load.

12.25 Tendons, drilling, grouting and construction methods for Suitability Tests must be identical to those proposed for the working anchors.

12.26 Suitability Tests must demonstrate that:

a. load/extension behaviour of the anchor under cyclic loading and the magnitude of the elastic extension and permanent displacement of the tendon are acceptable;

b. the tendon extensions, following corrections for head movement etc, lie between 90% and 110% of the values calculated using design load, tendon area, tendon elastic modulus and design free anchor length (see Clause 12.7 list item c.);

c. the calculated value of apparent tendon free length lies between 90% and 110% of the design free anchor length, calculated using the measured elastic extension values (see Clause 12.7 list item i.);

d. in the event of nonconformity with design values, the repeatability of load/extension characteristics can be verified using extra test cycles (see Clause12.7 list item j.); and

e. the load losses/creep movement characteristics following Acceptance Testing (see Clause 12.7 list item e. and Clause 12.7 list item h.) are acceptable.

12.27 The results of Suitability Tests must be used to verify the performance of represented working anchors constructed in exactly the same way and under identical ground conditions at the frequency specified in Annexure C. Where varying ground conditions are known or are encountered, then additional anchors must be installed, and additional Suitability Tests carried out.

12.28 Suitability anchors, subject to satisfactory performance as assessed by conformity with the relevant acceptance criteria of Clause 12.7, may be used as working anchors.

12.29 The Test Load T_P for Suitability anchors must be selected in accordance with Section 5, but must not exceed 0.8 T_u. for strands or 0.75 T_u for bars.

12.30 Unless specified otherwise by the designer or in the Contract documents, the loading cycles and minimum periods of observation must comply with the recommended values in Annexure C.

12.31 Suitability anchors must be test loaded to T_P in a minimum six load cycles. Where relevant Proof Tests have previously been carried out, load cycles 1 to 3 in Annexure C Table C.3 may be omitted.

Acceptance Tests

12.32 An Acceptance Test is a single load cycle to Test Load T_P to verify that each working ground anchor conforms to the anchor acceptance criteria.

12.33 An Acceptance Test must be carried out on any working anchor which has not been subjected to a Suitability Test. For anchors up to 15 m long, one unmonitored preliminary loading cycle to Test Load T_P must be carried out.

12.34 Acceptance tests must be carried out as follows:

a. load in 4 equal increments from Initial or Datum Load T_A to Test Load T_P;

b. unload in 4 equal increments from T_P to T_A (see Annexure C Table C 4 for observation and recording periods);

c. observe and record load losses at Test Load T_P or creep deformation at Test Load T_P (as applicable);

d. observe and record Lock-off Load T_O; and

e. apply the relevant acceptance criteria of Clause 12.35 to assess conformity.

Assessment and Acceptance Criteria

12.35 The Contractor must:

a. assess all ground anchors covered by this Specification at Test Load T_P and Lock-off Load T_O;

b. assess anchor performance by carrying out Suitability Tests on Suitability anchors before testing the working anchors using Acceptance Tests;

c. conform to all the acceptance criteria of Clause 12.7, and

d. only accept a working load for an anchor that conforms to all the acceptance criteria of Clause 12.7.

13. Stressing

Commencement of Stressing Operations

13.1 Stressing of ground anchors is a Critical Anchor Activity that must be carried out under the supervision of the Anchor Supervisor.

HOLD POINT 6	
Process Held	Stressing of anchors
Submission Details	All details proving conformity with Clauses 11.25 and 12, including equipment calibration certificates (Clauses 13.18 and 13.20) must be provided to the Principal at least 2 working days before commencing stressing.
Release of Hold Point	The Principal must consider the submitted documents and may carry out surveillance and audit, prior to authorising the release of the Hold Point.

13.2 Both the Anchor Supervisor and Stressing Technician must be suitably experienced with the equipment in use and scale of anchor being tested.

13.3 Anchors must not be stressed against a concrete member until testing of cylinders representing all the concrete in the member confirms the specified transfer strength has been achieved and the concrete has reached the age of 7 days, if moist cured, or 2 days if steam cured, and the concrete has cooled to ambient temperature unless otherwise shown on the Drawings. If the specified transfer strength is not achieved, the tendons must not be stressed until the concrete represented by the cylinder is estimated to have attained 105% of the transfer strength.

13.4 Anchors must not be stressed until all the grout of the anchor is at least 14 days old or as accepted by the Principal and the average compressive strength of all the grout in the borehole is at least 32 MPa. For anchors > 10,000 kN capacity the minimum grout age is 21 days and minimum compressive strength is 45MPa.

WITNESS POINT 1	
Process	Stressing of each anchor
Notification Period	At least 1 working day (not less than 24 hours) the stressing of each anchor.

Safety Precautions

13.5 In addition to the safety requirements specified elsewhere in the Contract documents, the Contractor must:

a. take care during stressing to ensure the safety of all personnel engaged on the work and of other persons in the vicinity;

b. ensure personnel are excluded from the risk area in the event that the grip on the tendon is lost;

c. not allow any person to stand behind the jack while tensioning is in progress;

d. operate the jacks, measure the extensions and carry out any associated operations in a manner and from positions which ensure safety; and

e. erect “stressing in progress” signs and barricade off hazardous areas.

Stressing Equipment

13.6 The stressing equipment must have a rated load capacity greater than 90% of the specified minimum breaking load and at least 120% of the maximum predicted stressing extension of the ground anchor tendon.

13.7 The design of the jacking system must allow the taking of accurate measurements conforming to Clause 13.19

13.8 The pump must be equipped with a site-regulated pressure overload relief valve to prevent tendon damage from over tensioning.

13.9 All connections between the pump and the jack must have a bursting pressure of at least four times the maximum pump pressure rating.

13.10 Pressure gauges must conform to the requirements of AS 1349. The diameter of the gauge of the analog type must not be less than 150 mm and must be of such a type which will allow visual reading to the nearest 0.5 MPa or 5 bar and has a readout resolution specified in Clause 13.20, whichever is more stringent. Digital transducer pressure gauges may be used as the primary gauge; however, an analog gauge must also be used as a secondary gauge and verify readings are in parallel on both gauges. There is no need to record the second gauge values. Stressing or test loading must stop if there is a mismatch between the gauges and an investigation to be carried out to determine which if either of the gauges appears to be

unreliable. Such a finding will require the faulty gauge to be removed from the system. At least two gauges must be supplied calibrated to each jack to be used.

13.11 When the tendon is stressed to 75% of its breaking load, the indicator must be between 50% and 75% of the full-scale reading. If outside of this range, the Contractor must investigate the circumstances and if appropriate, a Hold Point will apply.

13.12 Gauges must be fitted with a snubber or similar device to protect them against sudden release of pressure. If possible, the primary gauge must be mounted at the jack to enable the highest accuracy of pressure recording.

13.13 When required for audit purposes, a master gauge for checking the gauge accuracy must be made available and provision for attaching this gauge for audit purposes made.

13.14 The gauges must be inspected before starting each stressing operation and if defective, replaced immediately with another calibrated gauge. Any gauge that has sustained hydraulic or other shock must be replaced with another calibrated gauge.

13.15 Where a discrepancy occurs between the two pressure gauges, the defective gauge must be identified using the master gauge and dispatched for re-calibration or replacement.

13.16 Alternatively, a pressure gauge as above may be provided and a digital load readout unit with up-to-date calibration to safeguard against load monitoring errors.

13.17 For electrical load cells, calibration must be undertaken using the leads that will be used on-site.

13.18 Current NATA accredited calibration certificates for each load cell, jack, pump and gauge or their combinations which conform to Table 13.18 must be provided to the Principal.

Table 13.18 – Calibration certificates

Equipment	Calibration certificates
Jack and gauge combinations	Not more than six months old for digital and analog gauges respectively. Jack and gauges must be calibrated as a set. Separate certificates must be provided for each jack and gauge combination. Each certificate accompanied with a pressure versus load curve for loading and unloading over the full operating range.
Load cells	Issued within the last fifty (50) stressing operations or not more 28 days old, whichever is less.
Dial gauges	Not more than 12 months old.
Flowmeters and pressure gauges used during water testing or grouting	Issued within the last 200 operations or not more than 90 days old, whichever is less.

Measurement

13.19 Movements of the jack relative to a datum must be measured within an accuracy of ± 2%. Tendon loads must be measured within an accuracy of ± 2%.

13.20 The instruments for measuring load and deformation must have a readout resolution of 0.5% of T_P and 0.5% of δL_r respectively. At least 4 instruments must be used for measuring the anchor head movement.

13.21 Measurements of extensions must be checked using the movement of the jack, both before and after lock-off.

Wedges

13.22 Wedges must not damage the tendons during successive loading and unloading of the tendons. Regripping in the same strand location is not permitted. Draw-in to the permanent prestressing head must take place only at lock-off.

13.23 During the testing or stressing of working anchors, allow no indents resulting from tendon gripping to form in the tendon below the prestressing head and protect against damage to the corrosion protection.

13.24 Wedges must be assembled or fitted on each strand prior to commencing stressing. Slippage of individual strands within each anchorage must be detected by marking the strands with spray paint after applying the initial load, unless approved otherwise by the Principal.

Preparatory Operations

13.25 The cavity in the underhead zone at the top of the anchor must be filled with corrosion inhibiting compound (CIC) as part of installing the bearing plate. Final CIC injection must take place after stressing is completed.

13.26 After positioning the bearing plate, the prestressing head must be installed making sure that wire or strand tendons are not crossed within the free length. The bearing plate and tendon must not be in contact. Locate the prestressing head and tendon at the centre of the anchorage and borehole.

13.27 Where the bearing plate or anchorage has previously been cast in the concrete, purpose made shims must be used to compensate for any misalignment of the plate or anchorage prior to stressing using below the prestressing head.

Control of Stressing Operations

13.28 Stressing operations must be carried out only by personnel with training and experience in this type of work.

13.29 The anchors must be stressed in the order indicated in the Drawings or as directed by the Principal and in accordance with the applicable load test of Clause 12.

13.30 All strands or wires in a tendon must be stressed simultaneously and uniformly using a single jack. The tension must be applied smoothly at an even rate and on completion of stressing, the jack released gradually.

13.31 For multiple anchors, multiple jacks must be used for stressing, one at the head of each unit tendon, which must be hydraulically synchronised so that identical loads are applied simultaneously to each unit while allowing different extensions of the multiple units of the anchor.

13.32 The unit anchor load must be the total ground anchor load divided by the number of unit anchors. Each unit anchor must satisfy the general anchor acceptance criteria.

13.33 All anchor stressing must be completed without interruption in as short a time as possible.

13.34 The jacking force T_J must be estimated from the summation of:

a. loss in prestress force due to elastic shortening (where applicable);

b. draw-in; and

c. anchorage and hydraulic jack friction.

13.35 The jacking force T_J must not exceed 80% of the nominal minimum breaking load of the tendon or 75% for bars or the rated capacity of the stressing equipment, whichever is less, under any circumstances.

13.36 The Contractor must complete and make available to the Principal stressing forms for each ground anchor, providing the following:

a. identification of anchor;

b. identification of jack and gauge;

c. identification of load readout unit where applicable;

d. Minimum Breaking Load of the tendon T_U;

e. Lock-off Load T_O;

f. Jacking Force T_J;

g. maximum applied load 0.8 T_U for strands or 0.75 T_U for bars;

h. calculated theoretical elastic extension of tendon δL_r at Test Load T_P; including correction to include for actual tendon area and Youngs modulus values, which may involve averaging in the case where strand from multiple coils has been incorporated into the tendon;

i. loads recorded during stressing with corresponding gauge pressures, i.e., Initial or Datum Load T_A, Test Load T_P and maximum load;

j. measured tendon extensions corresponding to all recorded loads;

k. measured bearing plate settlement corresponding to all recorded loads;

l. corrected tendon extensions, making due correction for bearing plate settlement at each recorded load;

m. measured load loss or creep (as applicable) at each specified load and time period (2, 5, 10, 15 minutes etc.);

n. Initial Residual Load T_{RI} immediately after lock-off and Residual Load T_R at 48 hours etc;

o. graph showing extensions versus loads for cyclic loading;

p. assessment of compliance with acceptance criteria.

13.37 Accompany stressing forms with graphs showing measured loads versus extensions δL, δL_e and δL_{pl} showing whether anchor behaviour is elastic or elastic / plastic.

14. Cutting Off of Stressed Tendons

14.1 Cutting off of tendon and applying corrosion protection to the anchorage and underhead zone are Critical Anchor Activities which must be carried out under the supervision of the Anchor Supervisor.

HOLD POINT 7	
Process Held	Tendon cutting off.
Submission Details	The following must be provided to the Principal prior to cutting off: • All details in Clauses 12.35, 13.28 to 13.37, and where applicable, details in Clauses 15.2, 15.10 and 15.11 • The proposed length of protruding excess tendon from the prestressing head
Release of Hold Point	The Principal must consider the submitted documents and may carry out surveillance and audit, prior to authorising the release of the Hold Point.

14.2 As appropriate, the excess tendon protruding above the prestressing head must be trimmed to a length compatible with monitoring requirements and fitting of protective caps.

14.3 Stressed tendons must be cut off with a high-speed abrasive disc or wheel.

14.4 The protective cap must be fitted and filled (at the same time as the underhead zone) with Corrosion Inhibiting Compound.

15. Monitoring

General

15.1 Where specified, install ground anchors to enable short-term or long-term monitoring. Ground anchors with reseated wedges must not be stressed to more than 75% of T_U.

15.2 In addition to the information specified in Clause 9.1, drawings and cross-sections for monitorable anchors, detailing the bearing plate or anchorage casting, prestressing head, protective cap, provisions for corrosion protection and for carrying out Lift-off Tests must be submitted to the Principal.

15.3 Protective caps must be provided on all monitorable anchors to enable monitoring and increasing the tendon loads at any time after installation.

15.4 For anchors requiring controlled destressing, protruding strand lengths equal to the recorded strand extension plus approximately 300 mm must be provided with extended protective caps.

15.5 Provisions of access to measure residual load and inspection must be provided to all ground anchors, unless:

a. Sufficient number of such non-monitorable anchors are fitted with robust electrical load cells with capacity greater than the nominal ultimate capacity of the tendon. The load cells must be calibrated to cope with changes in environmental conditions such as large temperature variations and grounded to protect against damage from lightning strikes for the whole design of the anchors;

b. Approved by the Principal.

15.6 Short-term monitoring must be carried out where specified from the date of installation up to the Date of Completion. If required, the Principal will arrange for long-term monitoring after that date.

15.7 The extent of monitoring required must be as specified in the Contract documents. The number and/or position of the anchors specified for short term or long-term monitoring may be modified by the Principal following anchor assessment, excavations showing sub-surface conditions or other reasons.

15.8 Lift-off Tests on monitorable anchors must be carried out by one of following methods:

a. If the circular prestressing head has an external thread allowing fitting of equipment for jacking, comprising a threaded tube, stressing jack and stressing stool, carry out at least three 0.5 mm lift-offs and record the lift-off loads from the calibrated jack and pressure gauge combination. If required, or if specified in the Contract documents, lift the prestressing head and fit purpose-made shims to increase anchor load;

b. If adequate strand length beyond the prestressing head is provided within an extended protective cap, fit a stressing stool and jack the tendon using the same procedure used during the Works. Replace the extended protective cap following the testing to permit continued monitoring or to fit purpose-made shims or to carry out tendon distressing;

c. If at least 150 mm strand has been left beyond the prestressing head beneath the protective cap, check loads in individual strands using a coupler, stressing stool and calibrated mono jack.

15.9 Note that controlled destressing of anchors is only possible using Method b.

Short-Term Monitoring

15.10 The Contractor must:

a. monitor residual loads in the specified anchors at the frequency specified by the Principal (see Annexure C for details of testing and frequencies);

b. inspect and report on the condition of the ground or structure at the anchor, the protection cap and corrosion protection, the prestressing head and the tendon;

c. after the inspection, measure the Residual Load T_R by Lift-off Test or direct reading of load cells;

d. recalibrate, repair or replace any load cell and associated equipment that is defective and/or results in unreliable readings;

e. measure by Lift-off Test the residual load where readings from a load cell are not reliable;

f. reinstate the corrosion protection and replace the protective cap;

g. if the Residual Load T_R varies by more than ± 10% of the Initial Residual Load T_{RI} measured immediately after lock-off, inform the Principal immediately and submit a remediation proposal to ensure the loss of anchor residual load at the end of design life would not compromise the design. The remedial works must be carried out after obtaining approval from the Principal; and

h. Submit monitoring records for each anchor to the Principal within 3 working days of completing the monitoring.

Long-Term Monitoring

15.11 If specified in the Contract documents, the Contractor must submit to the Principal, all information from load indicators and read-outs, together with measurement units and range, reading accuracy, long-term error, and the calibration procedures and sites for each item of the monitoring equipment.

15.12 Where permanent load cells are integrated as non-replaceable / non removable items; the anchorage system must be designed with provision to enable a later mechanical lift off checking system to undertake load verification should the load cell results be in question. All permanent anchors incorporating a permanent load cell, must have the anchor head externally threaded and suited to being able to mechanically transfer at least 100% of the tendon capacity via the anchor head threads.

Annexure A Summary of Hold Points, Witness Points and Records

a. The following is a summary of the Witness Points / Hold Points that apply to this Specification and the Records that the Contractor must submit to the Principal to demonstrate compliance with this Specification.

Clause	Hold point	Witness point	Identified Records
4.1	1. Installation ground anchors		Quality Plan in accordance with Clause 4
8.0	2. Drilling boreholes for and assembly of proof and suitability anchors		All details of relevant proof and suitability anchors in Clauses 4 and 12
9	3. Assembly of working anchors		Conformity records for each assembled anchor
4			Quality Plan in accordance with Clause 4
5			Records for design conformity
6			Conformity records for materials and components
7.7, 7.8, 7.9			Conformity records for factory grouted tendons
8			Conformity records relevant to proof and suitability anchors
10.31	4. Insertion of working anchors.		Conformity records for each assembled anchor and assembly schedule.
9.36, 9.37			Shop drawings and conformity records
10.27			Conformity records for drilling, cleaning and testing of each borehole.
10.33			Anchor insertion and water testing records
11.6	5. Grouting of anchors.		Conformity records of grout materials and mix design and other details
6.28, 11.8, 11.9			Conformity records of grout materials and mix design
9.13 to 9.16			Grout tubes
9 and 10			Anchor assembly and installation

Clause	Hold point	Witness point	Identified Records
13.1	6. Stressing of anchors		Details proving conformity with Clauses 11.25 and 13
13.18, 13.20			Equipment calibration certificates
13.4		1. Stressing of each anchor	
14.1	7. Tendon Cut off		All details in Clauses 12.7, 13.28 to 13.37
15.2			Drawings and details for monitoring
15.10			Short term monitoring records
15.11			Long term monitoring records

Annexure B Explanatory Diagrams

The following diagrams are informative and provided to assist with the interpretation of the definitions.

Figure B.1 – Ground anchor nomenclature

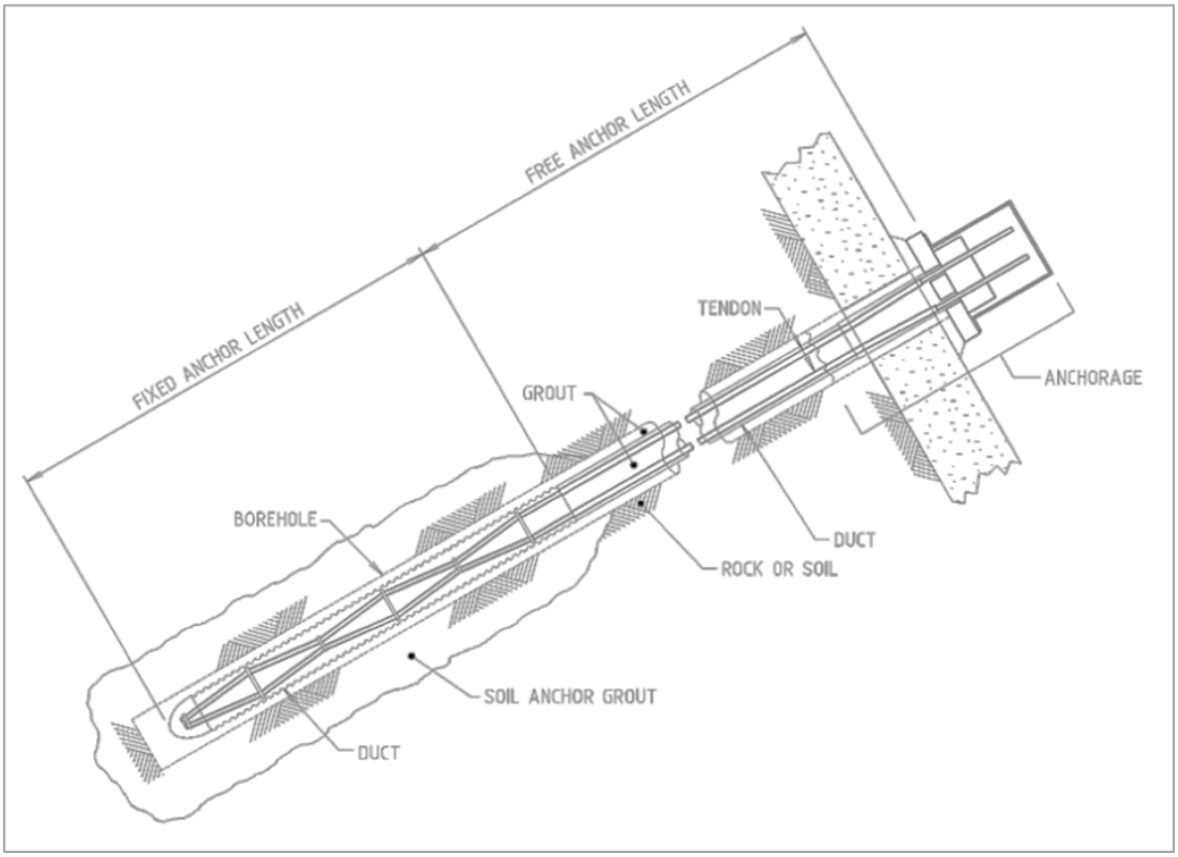


Figure B.2 – Monitorable permanent anchorage

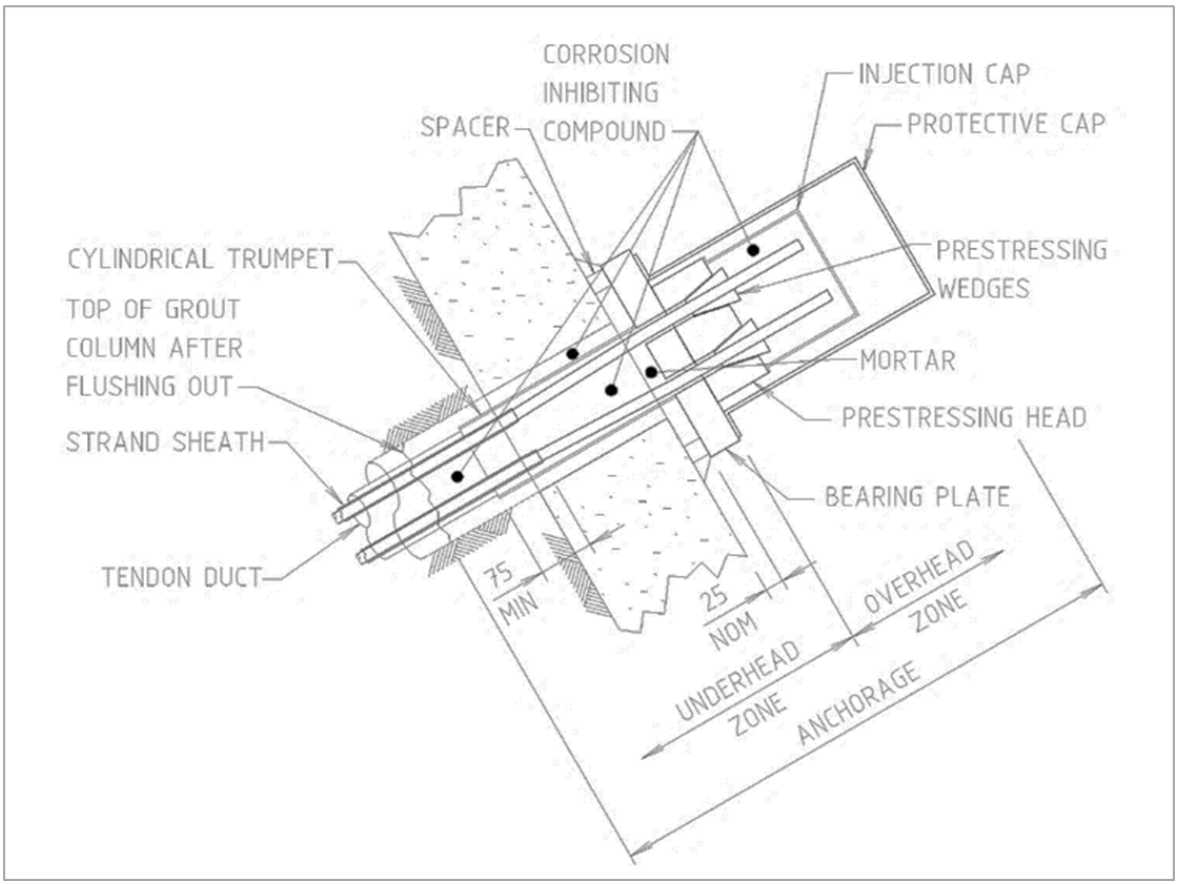


Figure B.3 – Tendon nomenclature

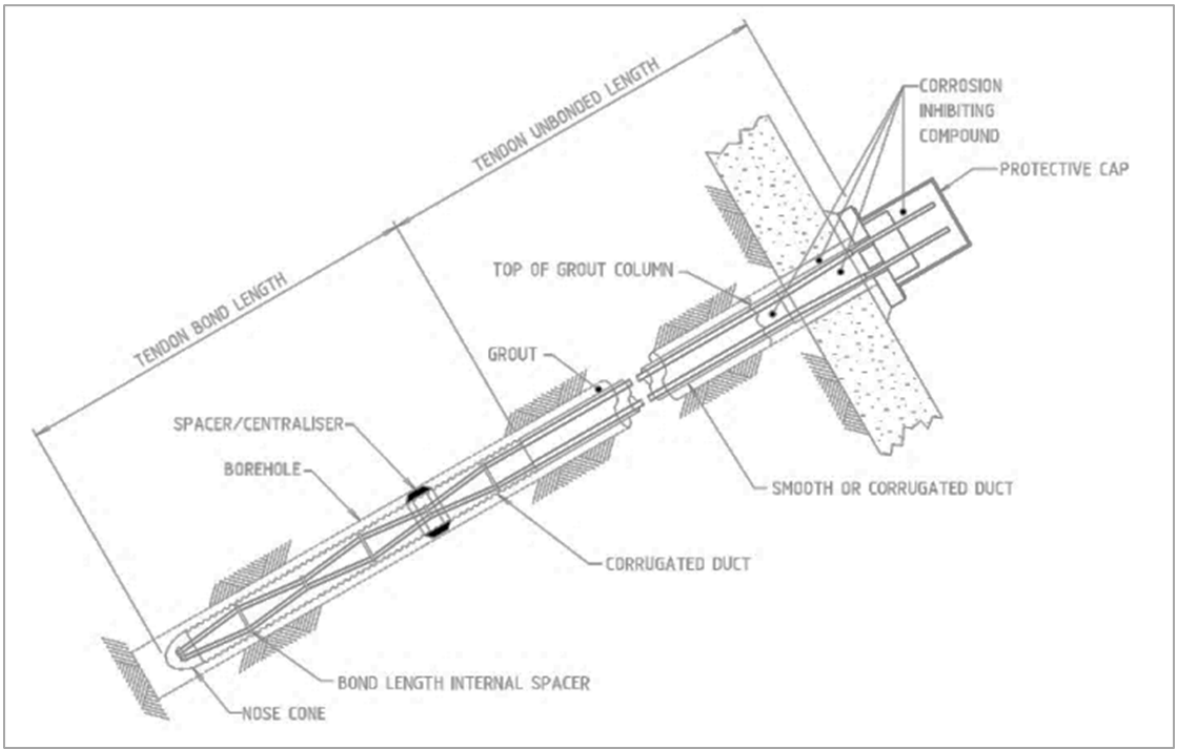


Figure B.4 – Typical factory grouted tendon bond lengths

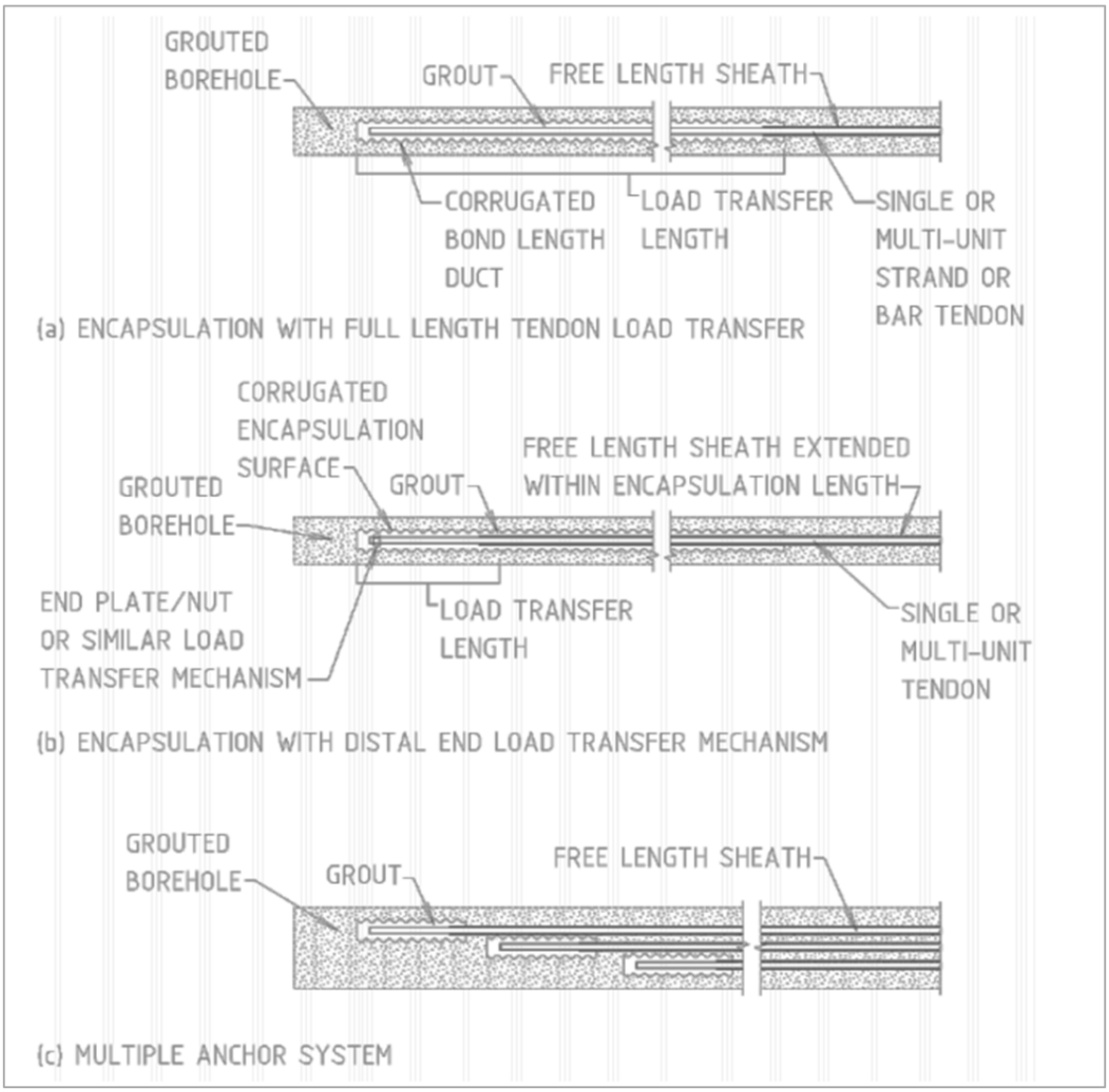


Figure B.5 – Grouted in-situ tendon bond length

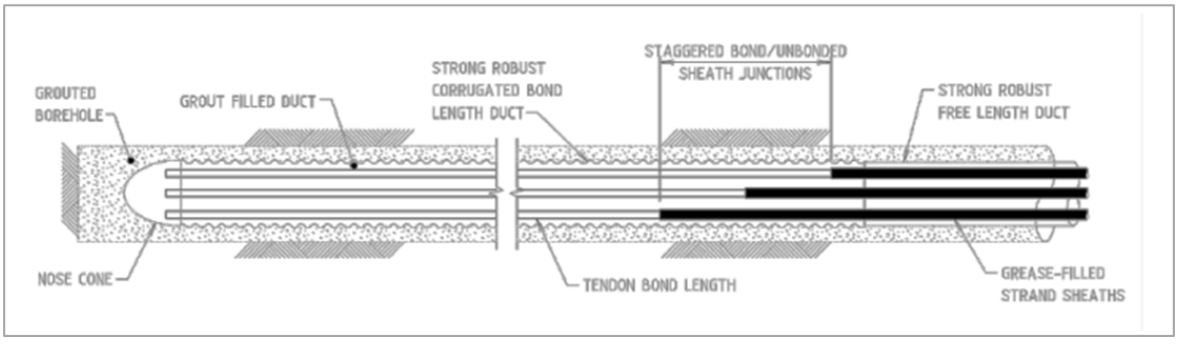
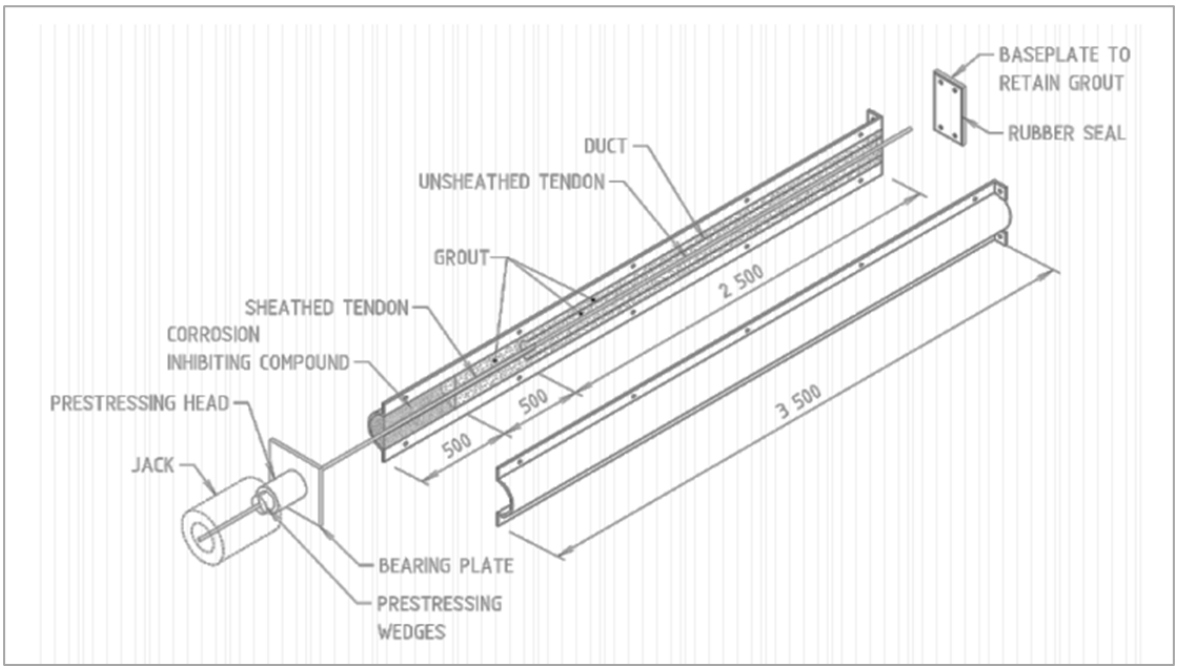


Figure B.6 – Split gun-barrel test arrangement



Annexure C Load Testing

a. Minimum Frequency of Testing

See Clause 12.3.

Table C.1 – Minimum load testing frequency

Clause	Type of test	Type of ground anchor*	Minimum frequency of testing for each type of ground anchor and each ground condition
12.11 to 12.22	Proof	Exploratory or investigation	As required by the designer or as specified on the Drawings
12.23 to 12.31	Suitability	Low risk and temporary	The greater of: • 1% of installed anchors; • 1; or • as specified on the Drawings
12.23 to 12.31	Suitability	High risk and temporary. Normal risk and permanent	The greater of: • 2% of installed anchors; • 2; or • as specified on the Drawings
12.23 to 12.31	Suitability	Critical and permanent	The greater of: • 2% of installed anchors; • 3; or • as specified on the Drawings
12.32 to 12.34	Acceptance	All	All remaining anchors

Note: For guidance to classification of ground anchors, refer to AS 5100.3 and this Specification

b. Proof Test

See Clause12.11 to 12.22.

Table C.2 – Recommended load increments and minimum periods of observation for proof tests

Load Increments (% of T_U) – Cycle 1	Load Increments (% of T_U) – Cycle 2	Load Increments (% of T_U) – Cycle 3	Load Increments (% of T_U) – Cycle 4	Load Increments (% of T_U) – Cycle 5	Load Increments (% of T_U) – Cycle 6	Load Increments (% of T_U) – Cycles 7 & 8	Minimum period of observation (minutes)
5	5	5	5	5	5	5	1
10	20	30	40	50	60	70 (65*)	1
15	25	35	45	55	65	75 (70*)	1
20	30	40	50	60	70	80 (75*)	5
15	20	30	40	40	50	50	1
10	10	15	20	20	30	30	1
5	5	5	5	5	5	5	1

Notes:

Plot load-displacements as the test proceeds. At an early stage observe trends and, in particular, yield of the bond length as failure approaches.

* For bars

c. Suitability Test

See Clause12.23 to 12.31.

Table C.3 – Recommended load increments and minimum periods of observation for suitability tests

Load Levels (% of Test Load T_P) – Cycle 1	Load Levels (% of Test Load T_P) – Cycle 2	Load Levels (% of Test Load T_P) – Cycle 3	Load Levels (% of Test Load T_P) – Cycle 4	Load Levels (% of Test Load T_P) – Cycle 5	Load Levels (% of Test Load T_P) – Cycle 6	Minimum period of observation (minutes)
10	10	10	10	10	10	1
	25	40	55	70	85	1
25	40	55	70	85	100	5
	25	40	55	70	85	1
10	10	10	10	10*	10	1

Note: * Full unloading is permitted for installation of the permanent wedges

d. Acceptance Test

See Clause12.32 to 12.34.

Table C.4 – Recommended load increment and minimum periods of observation for acceptance tests

Load levels (% test load T_P)	Minimum period of observation (minutes)
10	1
40	1
70	1
100	5
70	1
40	1
10	1