

TRANSPORT FOR NSW (TfNSW)

QA SPECIFICATION R56

GROUND ANCHORS (SCHEDULE OF RATES)

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REVISION REGISTER

Ed/Rev Number	Clause Number	Description of Revision	Authorised By	Date
Ed 1/Rev 0		First Issued	GM,CMS	04 Mar 91
Ed 2/Rev 0	2	Clause numbers and lists restructured to suit new format. Hold point has been restructured and rewritten.	GM,CEC J Woodward	27 Mar 95
Ed 2/Rev 1	Pay item R56P5	Specification Number changed from R85 to R56. Converted to MS Word 6.0c. References to RTA Specifications changed. Specification Title changed. Pay Item reworded for clarity	GM, RNIC (J Woodward)	13 Jan 97
Ed 2/Rev 2	Title Various 1.2 1.3, 2 1.4 1.6 1.6, 4.1 4.1 4.1.2	“Supply, Installation and Stressing” deleted. Minor editorial changes Tender requirements transferred to Annexure R56/4. RTA acceptance required for system, design calculation requirements changed. Components to be supplied by system supplier. New clauses New definitions. Delete AS 3902, add AS 1012 Change ISO 9001 to ISO 9002 Suppliers may be independent of system owner. Clause deleted, refer to RTA Q.	GM, RNIC	31.07.98

Ed/Rev Number	Clause Number	Description of Revision	Authorised By	Date
Ed 2/Rev 2 (cont'd)	4.2, 7.2, 8.1.1 4.3 5.1 5.2, 5.3, 6.1, 7.1, 8.1.1 7.3 11.1 12 Annexures R56/1, R56/3, R56/4	Grout strength changed from 30 MPa to 32 MPa Relaxation loss test changed. Drilling through concrete added Identified Critical Post- Tensioning Activities Grout to be tested as cylinders Reference to Annexure R56/1 added Additional records required New annexures listing supplementary information, acceptable systems to replace prequalification and tender information.		
Ed 3/Rev 0	Title Global	Specification title changed. Specification reformatted. “Contractor” replaced by “you”. “Superintendent” replaced by “Principal”. “PROJECT PLAN” changed to “PROJECT QUALITY PLAN”. Text revised to direct imperative style. Cross references updated. Extensive changes to technical content. Figures added. Minor and major changes to clauses; some transferred to other clauses.	GM, IC	15.12.08
Ed 3/Rev 1	1.3.1 4.1	Definitions of “you” and “your” added. Added: NPER registration as equivalent to CPEng, Engrs Aust, for certification purposes.	GM, IC	14.12.09
Ed 3/Rev 2	2.4 4.1 Annex E Annex M	“AS 3972” changed to “RTA 3211”. Approved Proprietary Ground Anchor Systems changed from listing in Annex E to RTA Internet website. Deleted. Referenced documents updated.	GM, IC	26.11.10
Ed 3/Rev 3	10.3	Requirements for gauges for stressing jacks clarified.	GM, IC	30.05.11
Ed 3/Rev 4	Table R56.1 9.2, 9.3, 9.4 & 9.5 9.6 10.7	Oil separation test method revised. Creep replaced by relaxation. Load used in calculation of extension revised to be in (N). Creep displacement replaced by load loss.	GM, IC	05.04.12

Ed/Rev Number	Clause Number	Description of Revision	Authorised By	Date
Ed 3/Rev 4 (cont'd)	Tables R56/L2.2, L2.3 & L2.4 Annexure R56/M	Minimum period of observation at peak load revised. Reference to FTMS 719C replaced by ASTM D6184.		
Ed 3/Rev 5	Global	References to “Roads and Maritime Services” or “RMS” changed to “Transport for NSW” or “TfNSW” respectively.	DCS	22.06.20



GROUND ANCHORS (SCHEDULE OF RATES)

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VERSION FOR: DATE:

CONTENTS

CLAUSE	PAGE
FOREWORD	III
TfNSW Copyright and Use of this Document.....	iii
Revisions to Previous Version.....	iii
Project Specific Changes	iii
1 GENERAL.....	1
1.1 Scope	1
1.2 Structure of Specification.....	1
1.3 Definitions	2
1.4 Notation	5
1.5 Figures	6
2 MATERIALS AND COMPONENTS	9
2.1 General	9
2.2 Tendons	9
2.3 Anchorages	10
2.4 Grout.....	11
2.5 Sheaths and Ducts	11
2.6 Corrosion Inhibiting Compound (CIC)	12
2.7 Protective Caps.....	13
3 DESIGN.....	13
3.1 General	13
3.2 Corrosion Protection	14
4 SUPPLY AND SUPERVISION	15
4.1 General	15
4.2 Anchor Supervisor.....	15
4.3 Factory Grouted Tendons.....	16
5 PROOF AND SUITABILITY ANCHORS	17
6 ASSEMBLY.....	17
6.1 General	17
6.2 Tendons	18
6.3 Grout Tubes.....	18
6.4 Spacers and Centralisers.....	19
6.5 Joints.....	19
6.6 Unbonded Length	19
6.7 Bond Length	20
6.8 Marking	20
6.9 Conformity Records	20
7 INSTALLATION.....	20
7.1 General	20
7.2 Drilling	21
7.3 Cleaning.....	22
7.4 Borehole Testing	22
7.5 Anchor Insertion.....	23

8	GROUTING	25
8.1	General.....	25
8.2	Performance.....	25
8.3	Mix Design and Testing	26
8.4	Mixing	27
8.5	Pumping Equipment	27
8.6	Procedure.....	28
8.7	Conformity Records.....	29
9	LOAD TESTING	29
9.1	General.....	29
9.2	Loading and Monitoring.....	29
9.3	Proof Tests.....	30
9.4	Suitability Tests	31
9.5	Acceptance Tests	31
9.6	Assessment and Acceptance Criteria.....	32
10	STRESSING.....	34
10.1	Commencement of Stressing Operations.....	34
10.2	Safety Precautions	35
10.3	Stressing Equipment.....	35
10.4	Measurement	36
10.5	Wedges	36
10.6	Preparatory Operations.....	36
10.7	Control of Stressing Operations	37
11	CUTTING OFF OF STRESSED TENDONS	38
12	MONITORING	38
12.1	General.....	38
12.2	Short-Term Monitoring	39
12.3	Long-Term Monitoring.....	39
	ANNEXURE R56/A – PROJECT SPECIFIC REQUIREMENTS	40
	ANNEXURE R56/B – MEASUREMENT AND PAYMENT	40
	ANNEXURE R56/C – SCHEDULES OF HOLD POINTS, WITNESS POINTS AND IDENTIFIED RECORDS	43
	C1 Schedule of Hold Points and Witness Points	43
	C2 Schedule of Identified Records.....	44
	ANNEXURE R56/D – PLANNING DOCUMENTS.....	45
	ANNEXURES R56/E TO R56/K – (NOT USED).....	45
	ANNEXURE R56/L – TESTING PROCEDURES	46
	L1 Grout Testing.....	46
	L2 Load Testing.....	46
	ANNEXURE R56/M – REFERENCED DOCUMENTS AND ABBREVIATIONS	49
	M1 References	49
	M2 Abbreviations.....	50
	LAST PAGE OF THIS DOCUMENT IS	50

FOREWORD

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REVISIONS TO PREVIOUS VERSION

This document has been revised from Specification TfNSW R56 Edition 3 Revision 4.

All revisions to the previous version (other than minor editorial and project specific changes) are indicated by a vertical line in the margin as shown here, except when it is a new edition and the text has been extensively rewritten.

PROJECT SPECIFIC CHANGES

Any project specific changes are indicated in the following manner:

- (a) Text which is additional to the base document and which is included in the Specification is shown in bold italics e.g. ***Additional Text***.
- (b) Text which has been deleted from the base document and which is not included in the Specification is shown struck out e.g. ~~Deleted Text~~.

TfNSW QA SPECIFICATION R56

GROUND ANCHORS (SCHEDULE OF RATES)

1 GENERAL

1.1 SCOPE

This Specification sets out the requirements for the supply, assembly, installation, grouting, stressing and monitoring of post-tensioned ground anchors including drilling, grouting and water testing, and sealing of the boreholes. It applies to both temporary and permanent ground anchors with appropriate corrosion protection systems installed into soil or rock. It may also be applied to anchors which are stressed directly to ground and to unstressed or lightly stressed tie-downs which anchor structures to rock or soil through intervening unsound stratum.

Unless otherwise specified, such as for temporary anchors, tendons must be fully encapsulated and placed in sheaths or ducts before insertion in the borehole. Carry out borehole grouting in a single stage operation, filling the borehole in such a manner that the hardened grout does not come in contact with the structure. If alternatives are proposed, state this clearly in the tender and provide full details proving conformity with all other requirements of this Specification.

This Specification applies primarily for strand-type tendons, but conforming bar tendons may be used.

The Specification applies to ground anchors included as part of a Schedule of Rates Contract. Specification TfNSW B114 is applicable to Lump Sum Contracts or the Lump Sum parts of Combined Contracts.

1.2 STRUCTURE OF SPECIFICATION

This Specification includes a series of annexures that detail additional requirements.

1.2.1 Project Specific Requirements

Project specific details of work are shown in Annexure R56/A.

1.2.2 Measurement and Payment

The method of measurement and payment is detailed in Annexure R56/B.

1.2.3 Schedules of HOLD POINTS, WITNESS POINTS and Identified Records

The schedules in Annexure R56/C list the **HOLD POINTS** and **WITNESS POINTS** that must be observed. Refer to Specification TfNSW Q for the definitions of **HOLD POINTS** and **WITNESS POINTS**.

The records listed in Annexure R56/C are **Identified Records** for the purposes of TfNSW Q Annexure Q/E.

1.2.4 Planning Documents

The PROJECT QUALITY PLAN must include each of the documents and requirements stated in Annexure R56/D and must be implemented.

1.2.5 Minimum Frequency of Testing

The Inspection and Test Plan must nominate the proposed testing frequency to verify conformity of the item, which must not be less than the frequency specified in Annexure R56/L. Where a minimum frequency is not specified, nominate an appropriate frequency. Frequency of testing must conform to the requirements of TfNSW Q.

1.2.6 Referenced Documents and Abbreviations

Unless specified otherwise or is specifically supplied by the Principal, the applicable issue of a referenced document, is the issue current at the date one week before the closing date for tenders, or where no issue is current at that date, the most recent issue.

Standards, specifications and test methods are referred to in abbreviated form (e.g. AS 1234). For convenience, the full titles are given in Annexure R56/M. Whenever a part of a standard is referenced, the common title is given separately and the part referred to only by its title.

1.3 DEFINITIONS

1.3.1 General

Anchor Supervisor: Nominated employee of the Ground Anchor System Supplier approved by the Principal responsible for 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 (see Figure 2).

Bleed: The separation of water from the grout paste.

Coupler: A device for joining lengths of bar or strand which comprise an anchor tendon.

Critical Anchor Activity: Construction activities including test anchors; anchor assembly; borehole drilling, cleaning and testing; anchor insertion, grouting and stressing; load testing; cutting off tendon and application of corrosion protection to anchorage and underhead zone.

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. Extensions may be either corrugated or smooth over the tendon unbonded length (see Figures 1, 3, 4, 5 and 6).

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 load/extension characteristics of the ground anchor.

Fixed anchor length: The design length of borehole over which the load is transferred to the ground (see Figure 1).

Free anchor length: The design length of borehole between the anchorage and the start of the bonded length along which no prestressing force is transferred to the ground (see Figure 1).

Ground Anchor System Supplier: The owner, or agent of the owner, of a TfNSW approved ground anchor system responsible for its supply and control, and for performance of its components.

Ground 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 (see Figure 1).

Grout: Cementitious material that transfers load from the tendon to the ground over the fixed anchor length; it may fill the remainder of the borehole and/or contribute to corrosion protection of the steel tendon.

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 (see Figure 4c).

Non-conforming anchor: A ground anchor system or its parts that do not conform to 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 (see 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, usually 100 years.

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.

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 (see 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 (see Figures 1, 3, 4 and 5).

Spacer/centraliser: A corrosion proof component that supports the tendon or sheath/duct to ensure adequate 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 (see 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 (see 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 (see 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 (see 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.

The terms “you” and “your” mean “the Contractor” and “the Contractor’s” respectively.

1.3.2 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 (refer to Clause 3.1).

Working Load (T_D): Residual load in the tendon after all losses that provides the required restraint to the structure.

1.3.3 Tests

Acceptance Test: A single load cycle to Test Load T_P to verify that each working ground anchor conforms to the anchor acceptance criteria.

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 thick feeler gauge.

Proof Test: A load test carried out in advance of the installation of the working ground anchors to:

- (i) establish for the designer the anchor resistance R_a in relation to the ground conditions;
- (ii) allow the designer to determine criteria for anchor acceptance;
- (iii) verify the performance of proposed materials and components e.g. ducts;
- (iv) prove the competence of the Contractor;
- (v) determine the bond capacity of an anchor by inducing a failure at the grout/ground interface.

Suitability Test: At least six load cycles followed by lock-off to verify the rock anchor design and installation and to establish reference test values for other anchors represented by the tested anchor.

1.4 NOTATION

A_t	=	Cross-sectional area of tendon (mm ²)
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)
dL	=	Measured total extension of tendon relative to a datum (mm)
δL_e	=	Measured elastic extension of tendon at each load stage (mm)
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)
ϕ_g	=	Geotechnical reduction factor selected in accordance with AS 5100.3
ϕ_n	=	Importance category reduction factor selected in accordance with AS 5100.3

1.5 FIGURES

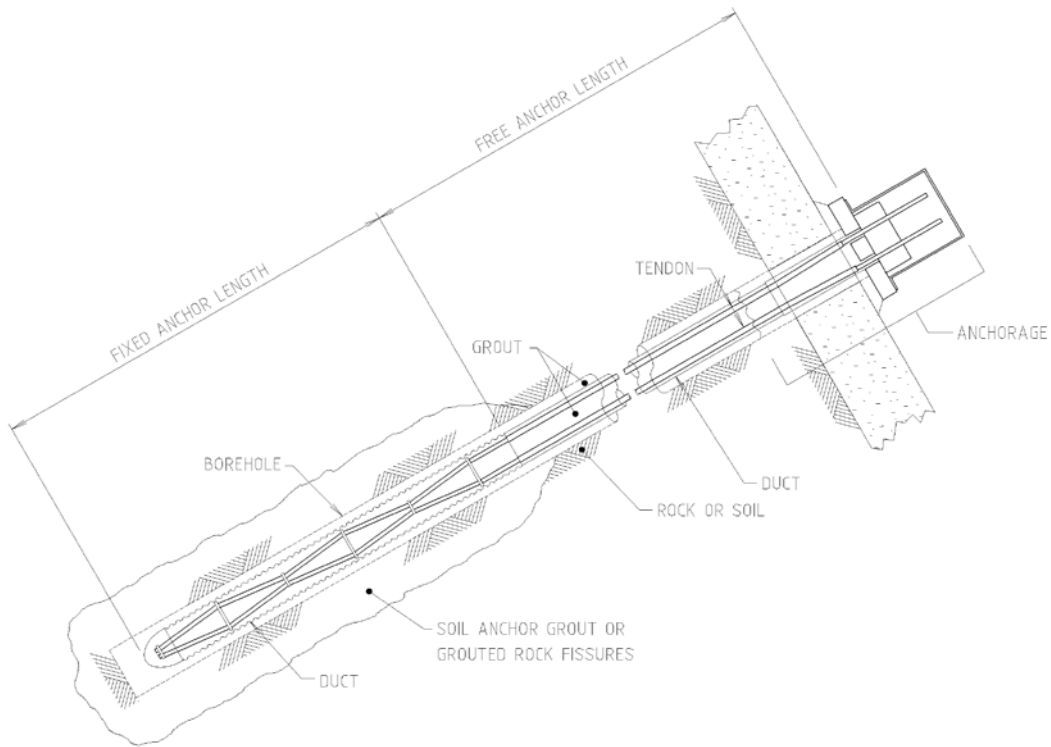


Figure 1 – Ground Anchor Nomenclature

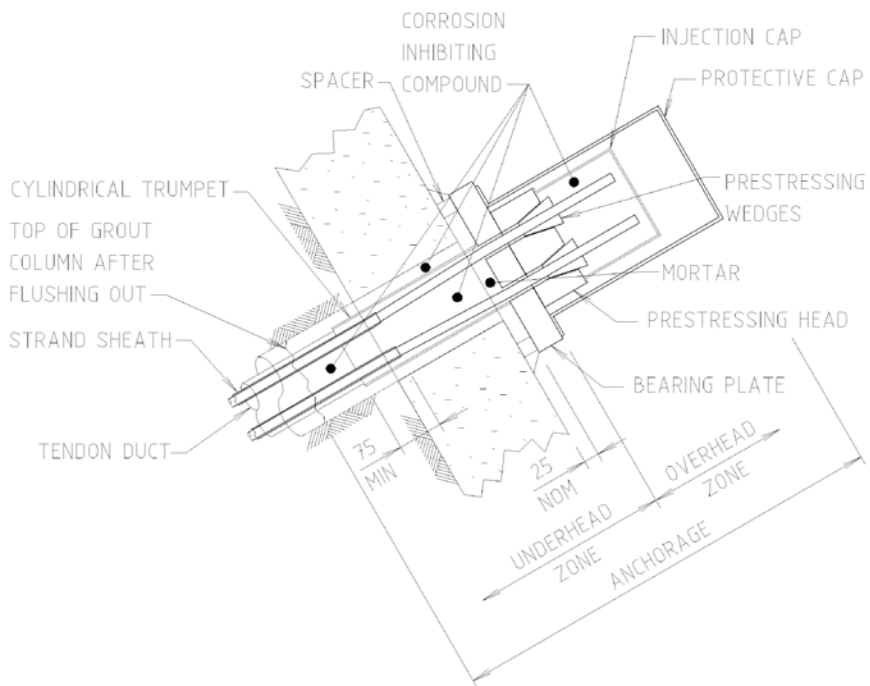


Figure 2 – Monitorable Permanent Anchorage

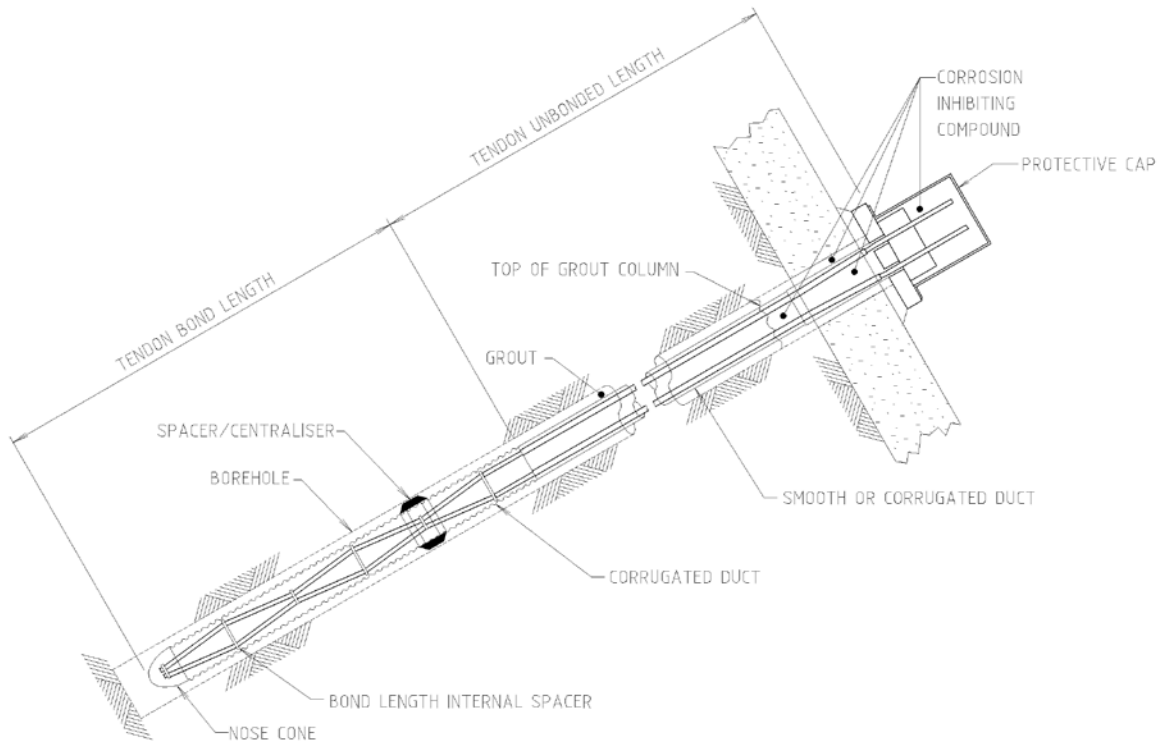


Figure 3 – Tendon Nomenclature

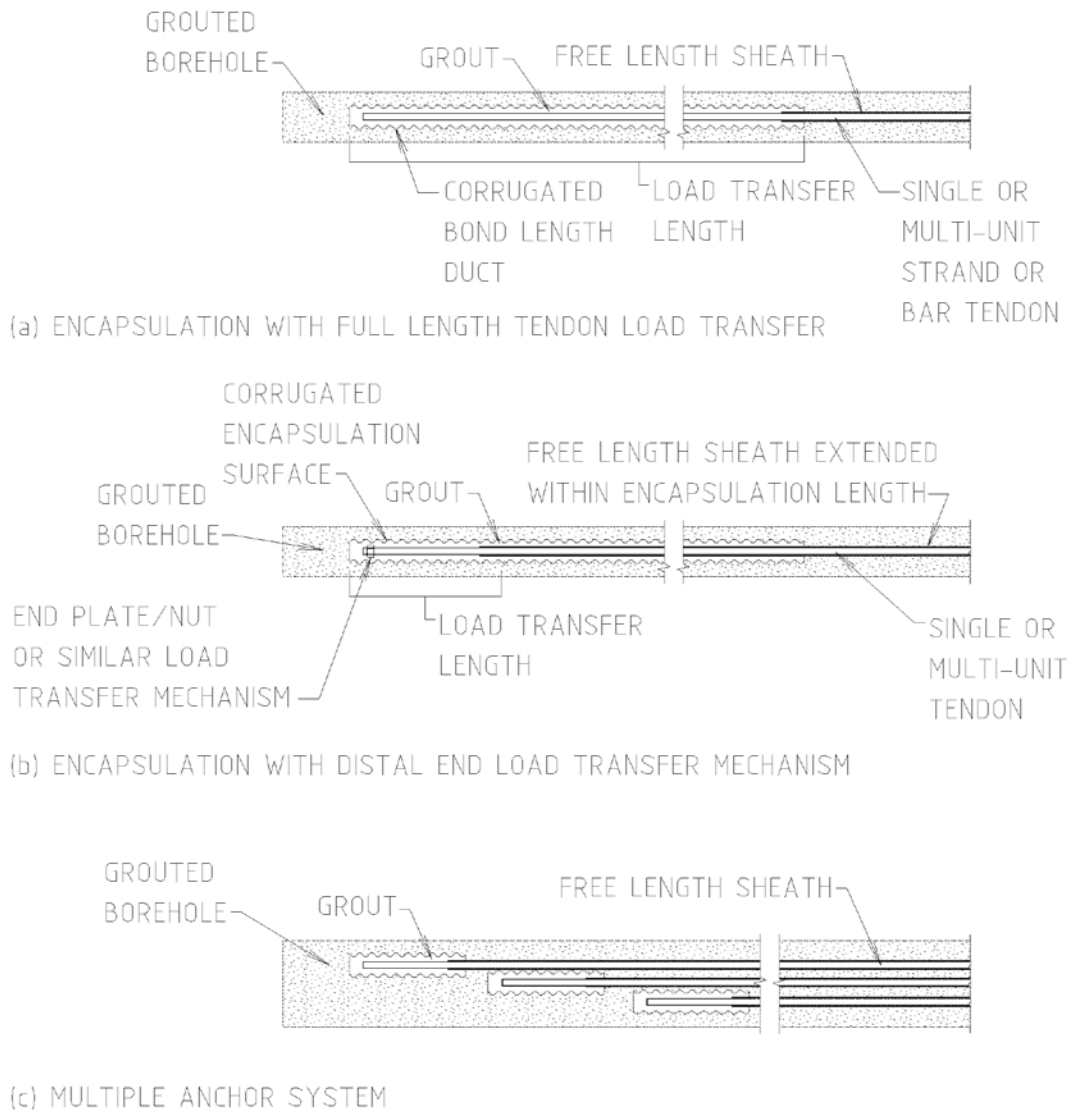


Figure 4 – Typical Factory Grouted Tendon Bond Lengths

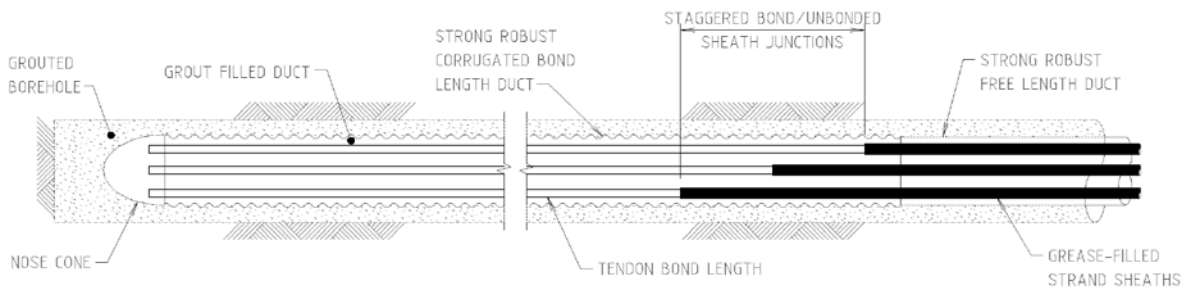


Figure 5 – Grouted In-situ Tendon Bond Length

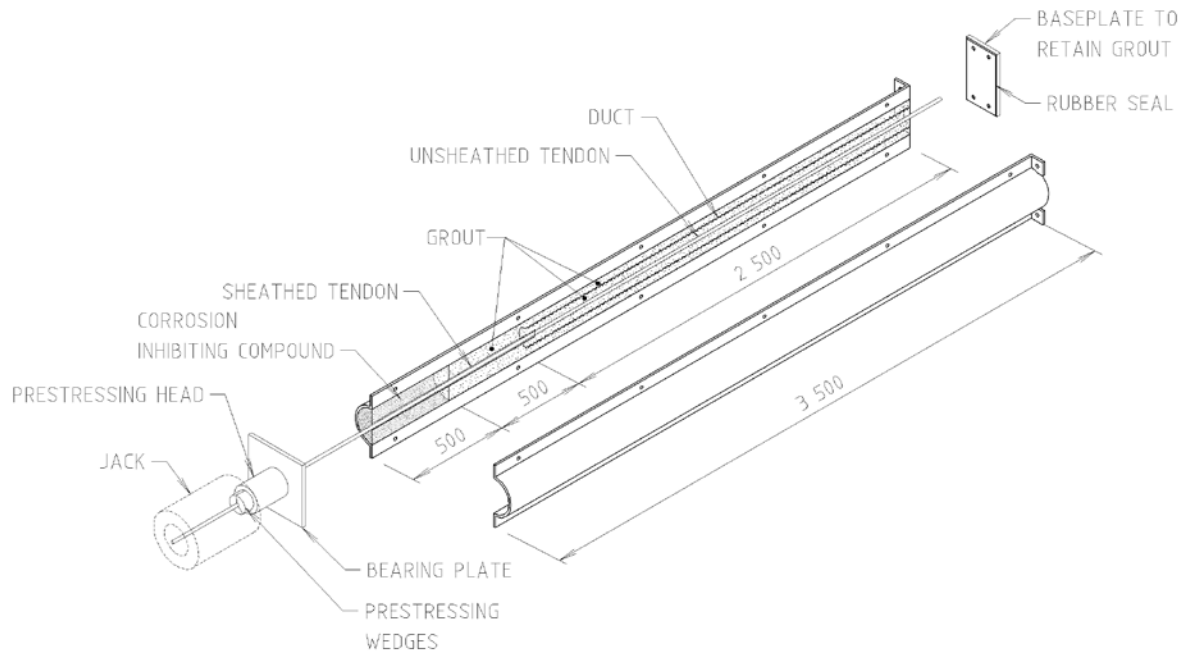


Figure 6 – Split Gun-Barrel Test Arrangement

2 MATERIALS AND COMPONENTS

2.1 GENERAL

Obtain materials only from suppliers that have implemented quality management systems to AS/NZS ISO 9001, with third-party certification accredited or accepted by JAS-ANZ.

Provide evidence demonstrating that each supplier of prestressing components and tendons has the specified quality management systems in place, and prove the conformity of the supplied materials with the requirements of this Specification.

2.2 TENDONS

Obtain prestressing materials only from suppliers that have implemented quality management systems to AS/NZS ISO 9001, with third-party certification accredited or accepted by JAS-ANZ. Australian Certification Authority for Reinforcing Steels Ltd's (ACRS) certification of product compliance to AS/NZS 4672 will be accepted as conformity with this requirement.

Provide evidence demonstrating that each supplier of prestressing materials has the specified quality management systems in place, and provide proof of conformity of the supplied materials with the requirements of this Specification.

Tendons must conform to AS/NZS 4672.1. If tendons conform to standards other than AS/NZS 4672, provide to the Principal evidence that the tendons are of equivalent quality.

Strand must be Relaxation Class 2 unless specified otherwise.

Tendons must conform to TfNSW's approved ground anchor system.

Provide, with each delivery, documentation listing the Lot numbers from which each coil or bar is taken and NATA endorsed test certificates in accordance with TfNSW Q as evidence of conformity with AS/NZS 4672.

Testing must conform to AS/NZS 4672.2.

Test at least one sample from each coil of wire and strand.

Test at least 3 bars from each Lot and each delivery.

Submit the following test reports:

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

2.3 ANCHORAGES

Anchorage must conform to AS 1314.

Submit for all anchorage components certification of conformity with the nominated TfNSW approved ground anchor system.

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

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

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.

Hot-dip galvanize to AS/NZS 4680 all bearing plates not fully covered with concrete and isolated from the environment.

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.

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

Manufacturing tolerances for each component must not impair the gripping efficiency of the assembled anchorage.

Provide a device to centre the anchorage so that the tendon force is applied uniformly to the contact surface between the prestressing head and the bearing plate or anchorage casting.

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

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

Incorporate injection nipple/s for the corrosion inhibiting compound (CIC) to fill and pressurise cavities above and around the prestressing head.

2.4 GROUT

Cement for grout must conform to Specification TfNSW 3211.

Fine aggregate if used must have 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%.

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.

Methocell, ligno-sulphonate 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.

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.

2.5 SHEATHS AND DUCTS

Individual strand sheaths 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 or rupture under loads imposed during anchor installation and grouting.

Maintain and check the integrity of the sheaths and ducts during assembly, installation, grouting and testing.

2.5.1 Strand/Bar Sheaths

Provide for both temporary and permanent anchors:

- (i) a strong smooth plastic sheath closely surrounding the steel strand/bar over the unbonded length of the tendon; and
- (ii) a corrosion inhibiting grease or lubricant conforming to Clause 2.6 completely filling the annulus between the strand/bar and the sheath such that during anchor stressing operations the frictional forces over the unbonded length of the tendon are minimised.

2.5.2 Tendon Unbonded Length Ducts

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

- (i) HDPE conforming to ASTM D1248 designation 111C5-P33; or
- (ii) PP conforming to ASTM D4101 designation PP0210B55542.

2.5.3 Bond Length Ducts

Ducts for the bonded length must be corrugated and unless otherwise approved by the Principal must be HDPE conforming to ASTM D3350 cell classification 335533C.

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

- (i) Wall thickness (w) of ducts: $w \geq 2 \text{ mm}$
- (ii) Pitch of corrugations (p): $12 w \geq p \geq 6 w$
- (iii) Amplitude of corrugations (a): $a \geq 3 w$

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

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.

Demonstrate using Proof Tests the capability of the duct to:

- (i) provide adequate bond capacity between the inner grout annulus and the tendon equal to the tensile capacity of the tendon;
- (ii) provide adequate bond capacity between the duct and the outer grout annulus equal to the tensile capacity of the tendon;
- (iii) accommodate the elastic behaviour of the tendon; and
- (iv) satisfy other anchor acceptance criteria.

2.6 CORROSION INHIBITING COMPOUND (CIC)

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 R56.1.

Submit a NATA endorsed test report in accordance with TfNSW Q certifying conformity of the CIC with Table R56.1.

Table R56.1 Performance Criteria for Grease/Wax Corrosion Inhibiting Compound

Property	Grease		Wax		Comments
	Test Method*	Requirement	Test Method	Requirement	
Consistency	D217	265-295 dmm	D937	150-350 dmm	Pumpability & application compatibility to be confirmed
Corrosion protection	D1743	Pass	D1743	Pass	Test substrate to be vertical 7-wire prestressing strand
Copper corrosiveness	D4048	1a	D130	1a	
Salt spray corrosion	B117	1000h	B117	1000h	
Oil separation maximum	D1742	3%	ASTM D6184	0.5% @ 38°C	Test temp for wax is 38°C
Drop pt. minimum	D566	150°C	D127	65°C	Test temp for wax is 38°C
Flash pt. minimum	D92	200°C	D92	200°C	
Evaporation maximum	D972	0.5%	D972	0.5% @ 38°C	
Saponification	D94	< 2 mg KOH/gm	D94	< 2 mg KOH/gm	
Water washout	D1264	< 5% at 38°C	D1264	< 5% at 38°C	

* All tests are to ASTM unless stated otherwise

2.7 PROTECTIVE CAPS

Provide protective caps that are watertight, allow complete draining and refilling of the CIC and cover the prestressing head and protruding tendon ends in accordance with Clause 11. Caps also must allow visual inspection of the CIC level using a watertight inspection lid without removal of the cap.

Unless approved otherwise by the Principal, the protective cap and inspection lid must be minimum 7 mm thick steel hot-dipped galvanized to AS/NZS 4680.

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

3 DESIGN

3.1 GENERAL

Design of ground anchors must conform to AS 5100.3.

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, ϕ_g , and importance category reduction factor, ϕ_n , selected in accordance with AS 5100.3.

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

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

When stressing the anchorage directly against the rock, include in the PROJECT QUALITY PLAN, the proposed criteria for a satisfactory rock surface and procedures for installing the bearing plate on its pad.

For guidelines to good practice in the design of rock and soil anchors with reference to site investigation data, see:

- (i) British Standard Code of Practice for Ground Anchorages BS 8081 published by the British Standards Institute;
- (ii) Geotechnical Engineering Handbook Volume 2 Procedures – Chapter 2.5 Ground Anchors published by Ernst & Sohn 2003.

3.2 CORROSION PROTECTION

3.2.1 General

The design life of permanent anchors conforming to this Specification is 100 years in typical aggressive NSW environments.

Where doubt exists with regard to the corrosion protection performance of a ground anchor system in a specific environment, provide supplementary additional protection.

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

Provide corrosion protection by containing the steel elements of the tendon within anchor sheaths and ducts over the entire length within the ground or structure. 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 must not be considered as providing corrosion protection as the grout may crack during stressing. In the free anchor length, supplement this isolation with corrosion inhibiting wax or grease compounds, which are an integral part of the ground anchor's corrosion protection system.

3.2.2 Underhead Zone Protection

The length of tendon between the top of the CIC filled sheath and the base of the prestressing head is particularly vulnerable to corrosion, and, on completion of stressing, it is rarely possible to inspect the effectiveness of the protection provided. Special precautions for corrosion protection of this zone are specified in this Specification. Refer also to BS 8081 for guidance to good ground anchor corrosion protection practice.

Provide 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 contained to prevent leakage.

Provide details of the method of sealing the base and head of this duct or trumpet for approval by the Principal.

3.2.3 Temporary Anchors

Unless environmental conditions are particularly aggressive, cementitious grout alone is appropriate corrosion protection for tendons of temporary anchors with a design life of up to two years in a non-aggressive environment, provided the tendons are spaced, centralised and have a grout cover of not less than 20 mm.

4 SUPPLY AND SUPERVISION

4.1 GENERAL

The ground anchor system used must be one of the TfNSW approved Proprietary Post-tensioned Ground Anchor Systems listed in TfNSW Internet website:

<http://www.rms.nsw.gov.au/business-industry/partners-suppliers/documents/tenders-contracts/listofapprovedbridgecomponentssystems.pdf>.

Tender on the number and arrangement of ground anchors with the design working load shown on the Drawings.

The submission of an alternative tender can only be accepted by the Principal.

Where any modifications are necessary to the concrete reinforcement and/or dimensions to suit a TfNSW approved ground anchor system for the number and arrangement of ground anchors shown on the Drawings, submit at your own cost to the Principal working drawings, drawn to the same scale and drawing standard as the Drawings, showing all modifications necessary to accommodate the system, together with design calculations carried out and certified by a chartered professional engineer with membership of Engineers Australia (or equivalent) practising in the field of structural engineering and experienced in this type of work. One equivalent would be an Engineer registered on the National Professional Engineers Register (NPER) in the general area of practice of Structural Engineering.

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_0).

4.2 ANCHOR SUPERVISOR

Critical Anchor Activities must be carried out under the supervision of the Anchor Supervisor.

The Bridge Engineer (Policy & Specifications), TfNSW Engineering Technology (ph 02 8837 0875; fax 02 8837 0054) maintains the list of Anchor Supervisors acceptable to the Principal.

Critical Anchor Activities include:

- (a) All on-site activities for Proof and Suitability Testing (Clause 5);
- (b) Borehole drilling, cleaning and testing (Clause 7);
- (e) Insertion of each anchor into the borehole (Clause 7.5.1);
- (f) Grouting (Clause 8.1);
- (g) Load testing (Clause 9.1);

- (h) Stressing (Clause 10.1);
- (i) Cutting off tendon and applying corrosion protection to the anchorage and underhead zone (Clause 11).

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

- (i) Information to be supplied (Annexure R56/D);
- (ii) Each tendon coil or bar (Clause 2.2);
- (iii) Ground anchor system (Clause 2.3);
- (iv) Grout (Clause 2.4);
- (v) Tendons sheaths, anchor sheaths and ducts (Clause 2.5);
- (vi) Corrosion inhibiting compound (Clause 2.6);
- (vii) Testing of Proof and Suitability anchors (Clause 5);
- (viii) Assembled anchor (Clause 6);
- (ix) Borehole drilling, cleaning and testing (Clause 7);
- (x) Anchor insertion and water testing (Clause 7.5);
- (xi) Experience and qualifications of all grouting personnel (Clause 8.1);
- (xii) Grouting (Clause 8);
- (xiii) Stressing (Clause 10);
- (xiv) Assessment of anchors (Clause 9);
- (xv) Application of corrosion protection to underhead zone and protective cap (Clause 11);
- (xvi) Monitoring (Clause 12).

4.3 FACTORY GROUTED TENDONS

For relatively 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.

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

Take precautions during handling and transportation to maintain the integrity of the factory grouted tendons.

5 PROOF AND SUITABILITY ANCHORS

HOLD POINT

Process Held:	Drilling boreholes for and assembly of Proof and Suitability anchors.
Submission Details:	All details in Annexure R56/D relevant to Proof and Suitability anchors at least five (5) working days before drilling or assembly.
Release of Hold Point:	The Principal will consider the submitted documents and may carry out surveillance and audit prior to authorising the release of the Hold Point.

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.

Proof anchors must be assembled and tested taking into consideration the nature of the investigation, i.e.

- (a) to provide information for the final design (see Clause 9.3) 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;
- (c) to demonstrate the performance of the corrosion protection system (e.g. split gun-barrel tests allowing inspection after loading (see Figure 6)).

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 (see Clause 9.4).

After successful testing, only Suitability anchors may be used as working anchors. Proof anchors must not be incorporated into the Works.

6 ASSEMBLY

HOLD POINT

Process Held:	Assembly of working anchors.
Submission Details:	Evidence proving conformity with Clauses 2, 3, 4.3, 5 and Annexure R56/D and certification of conformity of Suitability anchors at least five (5) working days before assembly.
Release of Hold Point:	The Principal will consider the submitted documents and may carry out surveillance and audit, prior to authorising the release of the Hold Point.

6.1 GENERAL

For all ground anchor assemblies, submit your comprehensive proposals for the complete assembly to prevent damage to the anchor components and corrosion protection system during handling.

Include in the PROJECT QUALITY PLAN fully detailed proposals, with drawings including cross-sections and longitudinal sections showing all anchor components, including details of the method of assembly and if applicable the provisions for monitoring specified in Clause 12.

If anchors are to be assembled off-site, submit for approval by the Principal 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.

Provide and make available to the Principal 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.

Prior to commencement, or during the early stages in the anchor works, demonstrate the duct's resistance to damage during installation by inserting and withdrawing an assembled anchor from the borehole and inspecting its condition.

Consideration may be given to systems developed to confirm the total isolation of the tendon from the environment using electrical conductivity test techniques.

If factory grouted anchors are provided, maintain the above controls and make the manufacturing facilities available for the Principal's inspection.

Provide for a minimum of 20 mm grout thickness between the sheath/duct and the borehole wall.

6.2 TENDONS

Supply strands in coils in conformity with AS/NZS 4672. When removing strands 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.

Reject any damaged or kinked tendons.

Do not carry out welding at a distance less than 3 m from any tendons. Reject any tendon affected by arc strikes.

Cut tendons with high-speed carborundum disk cutters. Do not use flame cutting under any circumstances.

Arrange tendons uniformly without oblique crossing over the anchor cross-section. Include in the PROJECT QUALITY PLAN a procedure for avoiding severe crossing of strands within the tendon unbonded length.

6.3 GROUT TUBES

Provide for each anchor, a minimum of two independent grout tubes in each annulus extending to the bottom of the anchor that, if left in place, must not reduce the bond between the tendon and the grout.

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.

Assemble tendons 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.

Arrange grout tubes, spacers and centralisers so that grout will flow freely to provide complete grout cover around all anchor components, without entrapping pockets of grout, bleed water or air. Provide 300 mm above the bottom of the grout supply tube additional cut-outs, to minimise blockages.

6.4 SPACERS AND CENTRALISERS

Provide internal spacers to centralise the tendon and provide the required cover.

Provide spacers 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.

Manufacture centralisers and spacers from materials that can withstand installation forces without damage and that will not corrode or damage the anchor components.

External spacers must be sized and spaced to protect external grout tubes from being damaged.

Do not use grout tubes as spacers.

6.5 JOINTS

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

Provide joints at the top and bottom of the corrugated duct, to the smooth free length and to the nose cone respectively, that are strong, watertight and able to withstand loads from all anchor operations without damage.

Joints between lengths of sheaths and ducts must be made using hot plate welding by experienced operators, unless approved otherwise by the Principal. 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 (see Clause 9.3).

6.6 UNBONDED LENGTH

Overlap the duct with the corrosion protection at both the connection with the tendon bond length and with the underhead zone.

Where the use of coupler(s) within the tendon unbonded length cannot be avoided, then surround the strand or bar coupler(s) 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.

Pay close attention 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 strand/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.

6.7 BOND LENGTH

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

At the midpoint between bond length internal spacers, provide 20 mm minimum grout cover between the strands and the duct wall.

Centralise bar tendons within the duct to provide a minimum of 20 mm grout annulus.

Where transition lengths are used, stagger the joints between each unbonded length and bond length to avoid abrupt changes in the load transfer mechanism.

Fix the lower end of the tendon to the bottom of the corrugated duct and seal it using a nose cone in accordance with Clause 2.5.3; provide detailed procedures for this in the PROJECT QUALITY PLAN.

6.8 MARKING

Clearly mark the upper ends of tendons and sheaths 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.

6.9 CONFORMITY RECORDS

Submit shop drawings and conformity records for each type of anchor, including tendon materials and anchorage components and the assembly schedule at least five (5) working days before the proposed date of installation.

7 INSTALLATION

7.1 GENERAL

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

When anchoring existing concrete structures, drill holes in the structure using diamond core drills or the like to a tolerance of $-0, +25$ mm on the diameter, unless specified otherwise. Do not use percussion hammer or impact type drills or the like without approval of the Principal.

During borehole drilling, cleaning, testing, tendon installation and grouting 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 grout of the same quality 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;
- (f) when required, the grout is not in contact with the back of 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.

When penetrating material other than rock, provide full details in the PROJECT QUALITY PLAN of the proposed drilling procedure and method of supporting the borehole during drilling, installation and grouting.

7.2 DRILLING

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

Drill boreholes at the locations and to the minimum diameter shown on the Drawings, providing for the minimum grout thicknesses specified in Clause 6.1. Do not use diamond core drilling for the borehole in the tendon bond length, as the sides of the hole must be rough for bond.

Drill boreholes at least to the depths specified on the Drawings or as directed by the Principal. Provide an extra length 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.

Use a rigid drilling rig assembly and working platform to achieve the specified borehole alignment. Check the positioning of the rig regularly during drilling to maintain the specified alignment. Use rigid, large diameter drill rods and associated casings to minimise borehole deviations resulting from obstructions or inclined bedding planes.

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;
- (d) initial alignment when setting up the drilling rig must not deviate by more than 2° from the specified axis of the borehole.

Conform to borehole tolerances to avoid difficult homing, undesirable friction during stressing and interaction between bonded anchors. Use suitable equipment to facilitate measurement of borehole deviation. Include in the PROJECT QUALITY PLAN procedures for maintaining and checking the specified alignment and deviation from straight.

Conform to the angular tolerances or better to reduce interaction between tendon bond lengths, particularly where the anchorages are in close proximity and/or anchors are long.

In ground likely to collapse, use temporary or permanent lining tubes or steel casings to support the sides of the tendon bond length of the borehole.

Provide in the PROJECT QUALITY PLAN methods of dealing with variations in subsoil condition.

7.3 CLEANING

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

On completion of drilling or reaming, clean and then seal the boreholes to prevent contamination.

Carry out cleaning by flushing the borehole at least three (3) times with water and air until the emerging water is clear, to remove all smearing and drill cuttings from the borehole walls and bottom.

Provide in the PROJECT QUALITY PLAN methods of cleaning the boreholes.

7.4 BOREHOLE TESTING

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

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.

Borehole testing must be carried out in conformity with Clauses 7.4.1 or 7.4.2 or 7.4.3 or a combination of the Clauses.

Apply the tests over the bond length of the anchor. Apply the tests over the free length also, if required by the Principal.

7.4.1 Pressure Grouting

Pressure grouting is particularly suited to anchors founded in weak or fissured rocks and soils.

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

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.

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

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.

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.

7.4.2 Falling Head Grout Test

When pressure grouting is not carried out as part of routine anchor construction, the borehole may be filled with grout prior to insertion of the tendon and the grout level observed until it becomes steady.

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

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 tendon installation, if approved by the Principal.

7.4.3 Water Testing

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.

Borehole packers may be used to seal off the length of borehole under test, or fill the complete borehole with water and test.

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.

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.

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, give consideration to multistage grouting and/or use of sanded mixes, or abandon the borehole for use for drainage or filling with grout.

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

7.4.4 Conformity Records

Submit conformity records for the borehole prior to inserting the anchor.

7.5 ANCHOR INSERTION

7.5.1 General

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.

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

HOLD POINT

Process Held:	Insertion of working anchors.
Submission Details:	All details in Clauses 6.9 and 7.4.4 at least five (5) working days before commencement.
Release of Hold Point:	The Principal will consider the submitted documents and may carry out surveillance and audit, prior to authorising the release of the Hold Point.

Give at least one working day's notice prior to inserting each anchor. Submit insertion procedures as part of the PROJECT QUALITY PLAN.

7.5.2 Insertion of Permanent Anchor Tendons Grouted In-situ

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

Before inserting the anchor, clean the walls and bottom of the borehole in accordance with Clause 7.3 and gauge it to confirm that it is unobstructed and of the required diameter over its full depth.

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

The use of a removable funnel with a rounded entrance at the collar of the borehole or at the casing head during tendon insertion should eliminate damage to the duct and external spacers during insertion.

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

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.

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

Test the integrity of the grout tubes by pumping water through each tube.

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

7.5.3 Water Testing of Inserted Anchor

After insertion or immediately prior to grouting, water test to demonstrate the integrity of the corrosion protection system of the assembled anchor by topping up with water and extracting water from the outer annulus. Provide a differential water head between the inner and outer annulus of at least two (2) m for at least thirty (30) minutes. If any leakage occurs, withdraw the anchor from the borehole, repair or replace it and water test again until it is watertight.

7.5.4 Insertion of Factory Grouted Anchors

Inspect the integrity of semi-rigid factory grouted anchors immediately prior to insertion in the borehole, and repair any damage by applying a heat shrink sleeve, as approved by the Principal.

Where damage is severe or repeated, review the entire fabrication, transportation and storage procedures.

Space factory grouted anchors off the borehole wall to eliminate insertion damage.

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

8 GROUTING

8.1 GENERAL

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

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.

Commence grouting immediately after approval of insertion of the anchor. This time delay must not exceed 24 hours. Where more than 24 hours have passed since insertion, remove the anchor and repeat the operations specified in Clause 7.5, unless approved otherwise by the Principal.

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

Inject the grout with an independent tremie pipe.

Corrosion protection of the prestressing head must be in accordance with Clause 2.7 of this Specification.

HOLD POINT

Process Held: Grouting of anchors.

Submission Details: Conformity records of grout materials and mix design (Clauses 2.4 and 8.3), grout tubes (Clause 6.3), anchor assembly (Clause 6), and anchor installation (Clause 7).

Release of Hold Point: The Principal will consider the submitted documents and may carry out surveillance and audit, prior to authorising the release of the Hold Point.

8.2 PERFORMANCE

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.

Grouts must have high bleed resistance, low shrinkage and high fluidity and conform to Table R56.2 when tested as specified.

Table R56.2 – 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 @ 1 & 28 days 0.1% and 0.3%	
Early Expansion	ASTM C940	< 2% at 3 hours.	Temperature tolerances are 20°C ± 5°C.
Fluidity	ASTM C939 ²	Immediately after mixing: Efflux time < 20 s 45 minutes after mixing: Change in efflux time < ± 3 s	Your target efflux time for the site conditions must not vary from nominated value by more than ± 2 s.
Minimum compressive Strength	TfNSW T375	32 MPa at 7 days 40 MPa at 28 days	Use 75 mm cubes

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.

8.3 MIX DESIGN AND TESTING

For grout materials, refer to Clause 2.4.

Do not use additives unless you can demonstrate that the additives will not harm grout performance or anchor components.

Carry out preliminary testing and prove that the grout mix conforms to Table R56.2 prior to grouting the Suitability anchor.

Carry out tests for bleeding, fluidity and compressive strength tests conforming to Table R56.2 at the frequency specified in Table R56/L.1 of Annexure R56/L.

In the event of non-conformity, stop grouting and modify operations to achieve the specified bleed and strength.

8.4 MIXING

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.

Use only fresh cement that is free of lumps.

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

Batch into mixers by mass for all mix constituents except liquids which may be by volume. Use whole bags of cement or approved packaged grout mixes clearly marked with the bag mass. Supply additives in individual doses to suit each batch size.

Water temperature measured in the mixer prior to addition must not be less than 5°C nor more than 27°C.

Keep the grout continuously agitated after mixing.

Where required, feed the grout by gravity from the mixer through a screen with 2.36 mm nominal apertures attached to the grout pump.

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

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

Maintain a continuous supply of grout by mixing the next batch of grout whilst pumping the previous batch.

Keep the grout temperature between 5°C to 30°C during mixing or pumping. Heat or cool the mixing water if necessary to achieve this.

8.5 PUMPING EQUIPMENT

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.

Run the grout pump continuously for the duration of the grouting of each anchor.

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.

Carry out grouting 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.

Locate grout fittings and pressure gauges to enable control and monitoring of pressure during injection of the grout to the down-hole tubes. Ensure that pressure gauges are calibrated and fittings at the tops of boreholes allow discharging to waste.

8.6 PROCEDURE

8.6.1 General

Arrange for all discharged water and grout to be collected and treated in accordance with Specification TfNSW G36.

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.

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

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. Do not use any grout which is nonconforming.

Inject the grout through the feeder tubes to the bottom of the hole and anchor. Where the bottom of the drill hole 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 simultaneously grout both the hole and anchor.

Inject the grout continuously until all the water is displaced from the outlet vents and the emerging grout has the same fluidity as the grout entering the feeder tubes. Continue grouting until the measured fluidity is within $\pm 20\%$ of that of the injected grout. Carry out fluidity testing until the emerging grout complies.

Once the emerging grout has reached the fluidity of the injected grout, 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.

Where ducts are particularly long, ensure that the head of grout within the duct is balanced with the head of grout in the borehole annulus during grouting.

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. Flushing out is also required 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.

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

8.6.2 Temporary and Factory Grouted Anchors

Carry out grouting of the entire borehole length using a single grout tube that extends to the base of the borehole.

Where end of casing pressure grouting is used, on completion of grouting the borehole, couple the drill head to the drill casing and withdraw the casing gradually. During withdrawal, apply grout pressure of up to 1 MPa at the drill head flush inlet passage of the drill casing to inject grout into the ground within the bond length.

Where post grouting is used, install supplementary grout pipes 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. Carry out post grouting between 2 hours and 24 hours after borehole grouting.

8.6.3 Permanent Anchors With In-situ Grouted Ducts

Install two separate feeder pipes, 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.

Prior to grouting, determine the volumes of the grout required to fill the inner annulus, deducting the volume occupied by the tendon and other anchor components, and the volume needed to fill the outer annulus. Use these volumes to assess the effectiveness of the grouting.

During grouting, keep the head differential between the inner and outer grout annuli 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.

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. Use these volume differentials 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.

8.7 CONFORMITY RECORDS

Submit conformity records for the grouting of each anchor.

9 LOAD TESTING

9.1 GENERAL

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

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.

In this Specification, three types of on-site load tests are specified:

- (i) Proof;
- (ii) Suitability;
- (iii) Acceptance.

For the definitions of each test, see Clause 1.3.3.

Load test at the frequency specified in Clause L2.1 of Annexure R56/L, unless specified otherwise.

9.2 LOADING AND MONITORING

Apply and release loads smoothly to prevent shock or dynamic loading of the anchor.

During all tests, monitor and record the applied load and tendon extension at each load increment.

To assess the behaviour of the anchor at peak load, monitor performance by measurement of load loss while the extension is kept constant as verified by measurements i.e. relaxation test.

Monitor anchor performance at lock-off by carrying out accurate lift-off tests at specified periods after lock-off, i.e. load monitoring.

Where proven accurate load cells are part of the jacking system, both these tests may be carried out at Test Load T_P and Lock-off Load T_O to verify anchor performance.

9.3 PROOF TESTS

Proof Tests are 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.

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

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.

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

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 to induce a grout/ground interface failure.

Load the anchor to failure or to a maximum test load which must not exceed 80% for strands or 75% for bars of the minimum breaking load of the tendon (T_U), whichever is lower.

Throughout Proof Tests, investigate the characteristics of load loss at each load cycle peak (see Table R56/L.2.2). Failure is deemed to be reached when at constant extension the load loss due to relaxation exceeds 2% of the maximum test load over a 5 minute period.

Assess the anchorage resistance R_a in accordance with AS 5100.3.

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.

Proof Tests may be carried out on Site or under controlled laboratory conditions using gun-barrel type tests (see 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.

Do not use anchors subjected to Proof Tests as working anchors.

9.4 SUITABILITY TESTS

Prior to carrying out a Suitability Test, 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.

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

Suitability Test must demonstrate:

- (1) acceptable load/extension behaviour of the anchor under cyclic loading and the magnitude of the elastic extension and permanent displacement of the tendon;
- (2) that 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 9.6.2.c);
- (3) that 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 9.6.2.g);
- (4) that in the event of nonconformity with design values, the repeatability of load/extension characteristics can be verified using extra test cycles (see Clause 9.6.2.h);
- (5) that relaxation characteristics following Acceptance Testing (See Clause 9.6.2(e) and (f)) are acceptable.

Use the results of Suitability Tests to verify the performance of represented working anchors constructed in exactly the same way and under identical ground conditions at the frequency specified in Clause L2.1 of Annexure R56/L. Where varying ground conditions are known or are encountered, then install and carry out Suitability Tests on additional anchors.

Suitability anchors, subject to satisfactory performance as assessed by conformity to the relevant acceptance criteria of Clause 9.6.2, may be used as working anchors.

The Test Load T_P for Suitability anchors must be selected in accordance with Clause 3 but must not exceed $0.8 T_U$ for strands or $0.75 T_U$ for bars.

Loading cycles and minimum periods of observation are given in Table R56/L.2.3 of Annexure R56/L.

Load Suitability anchors to Test Load T_P in a minimum of six load cycles.

Where relevant Proof Tests have previously been carried out, load Suitability anchors using one initial unmonitored cycle and 3 repeat cycles to Test Load T_P .

9.5 ACCEPTANCE TESTS

Carry out an Acceptance Test on any working anchor not subjected to a Suitability Test.

For anchors up to 15 m long carry out one unmonitored preliminary loading cycle to Test Load T_P .

Load in 4 equal increments from Initial or Datum Load T_A to Test Load T_P and then unload in 4 equal increments from T_P to T_A (see Table R56/L.2.4 of Annexure R56/L for observation and recording periods).

Observe and record relaxation test results and relaxation to Lock-off Load T_O and apply the relevant acceptance criteria of Clause 9.6.2 to assess conformity.

9.6 ASSESSMENT AND ACCEPTANCE CRITERIA

9.6.1 General

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

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

Anchors must conform to all the acceptance criteria of Clause 9.6.2.

Only accept a working load for an anchor that conforms to all the acceptance criteria of Clause 9.6.2.

9.6.2 Assessment Criteria and Mode of Application for all Suitability Anchors and all Acceptance Tests

- (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 wedge draw-in of tendon gripping system;
 - (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) Calculate the theoretical elastic extension δL_r of the tendon at Test Load T_P from Initial or Datum Load T_A using data from the anchor assembly schedule prepared in conformity with Clause 6.8:

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

Where:

A_t = area of steel in the tendon (mm²)

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) Calculate values of 90% and 110% elastic extension at Test Load T_P from Initial or Datum Load T_A to provide criteria for assessing anchor conformity i.e. measured extensions δL_e between $0.9 \delta L_r$ and $1.1 \delta L_r$ will be conforming.
- (d) When the measured extension is outside these limits, carry out as appropriate, while the stressing equipment is in place, two additional load cycles to verify load/extension repeatability (see Item g).
- (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 Table R56/L.2.3 and Table R56/L.2.4 respectively. 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 R56.3.

Table R56.3 – Limiting Values of Load Loss with Time

Observation Period (Minutes)	Limiting Load Loss Within Observation Period
0 to 5	Max. 2% of T_P
5 to 15	Max. 1% of T_P
15 to 50	Max. 1% of T_P

- (f) Based on the load/extension results, calculate the effective tendon free length L_{ef} at Test Load T_P using data from the anchor assembly schedule prepared in conformity with Clause 6.8 and the load test records and calculate the limits for acceptance as follows:

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

or

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

and

$$L_{ef} = \frac{\delta L_e A_t E_t}{(T_P - T_A)} \times 10^{-6}$$

Where:

A_t = cross-sectional area of steel in the tendon (mm²)

E_t = elastic modulus of the tendon (MPa)

L_b = tendon bond length

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

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

T_A = Initial or Datum Load (N)

T_P = Test Load (N)

δL_e = measured elastic extension of the tendon (mm)

If the corrected elastic extension lies within these limits, the effective free length satisfies the acceptance criteria.

- (g) If the anchor does not satisfy either of these limits then reload the anchor in two cycles to Test Load T_P . Provided $L_{ef} \geq L_{fr} + 0.6 L_b$ and the anchor has repeatable load/extension behaviour in the second cycle as demonstrated by the extension in the second cycle being within $\pm 5\%$ 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.

- (h) 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 Lock-off 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.
- (i) 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} .
- (j) 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 or down rate the anchor.

10 STRESSING

HOLD POINT

Process Held:	Stressing of anchors.
Submission Details:	All details proving conformity with Clauses 8.7 and 10 at least two (2) working days before commencing stressing.
Release of Hold Point:	The Principal will consider the submitted documents and may carry out surveillance and audit, prior to authorising the release of the Hold Point.

10.1 COMMENCEMENT OF STRESSING OPERATIONS

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

Do not stress anchors until all the grout of the anchor is at least fourteen (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.

WITNESS POINT

Process to be Witnessed:	Stressing of each anchor.
Submission Details:	At least one (1) working day's notice of stressing an anchor.

10.2 SAFETY PRECAUTIONS

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

Secure the jack in such a manner that it will be restrained should the grip on the tendon be lost. Do not allow any person to stand behind the jack while tensioning is in progress. Operate the jacks, measure the extensions and carry out any associated operations in a manner and from positions which ensure safety.

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

10.3 STRESSING EQUIPMENT

The stressing equipment must have rated load and travel capacities greater than 90% of the specified minimum breaking load and corresponding extensions of the ground anchor tendon.

The design of the jacking system must allow the taking of accurate measurements conforming to Clause 10.4.

Equip the pump with a site-regulated pressure overload relief valve to prevent tendon damage from over tensioning.

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

Pressure gauges must conform to the requirements of AS 1349. The diameter of the gauge 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.

When the tendon is stressed to 75% of its breaking load, the indicator must be between 50% and 75% of the full-scale reading.

Fit gauges with a snubber or similar device to protect them against sudden release of pressure.

When required for audit purposes, make available a master gauge for checking the gauge accuracy. Make provision for attaching this gauge for audit purposes.

Inspect gauges before starting each stressing operation and, if defective, replace immediately with another calibrated gauge. Replace any gauge that has sustained hydraulic or other shock with another calibrated gauge.

Where a discrepancy occurs between the two pressure gauges, identify the defective gauge using the master gauge and dispatch for re-calibration or replacement.

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

For electrical load cells, calibrate using the leads that will be used on-site.

Provide current NATA accredited calibration certificates for each load cell, jack, pump and gauge or their combinations conforming to the following:

- (a) Jack, pump, and gauge combinations:

- (i) Not more than six months old;
 - (ii) Separate certificates for each combination;
 - (iii) Each certificate accompanied with a pressure versus load curve for loading and unloading over the full operating range.
- (b) Load cells:
Issued within the last fifty (50) stressing operations or not more 28 days old, whichever is less.
- (c) Dial gauges:
Not more than 12 months old.
- (d) 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.

10.4 MEASUREMENT

Measure movements of the jack relative to a datum within an accuracy of $\pm 2\%$ of the calculated elastic extension of the tendon δL_r at Test Load T_P and measure tendon loads within an accuracy of $\pm 2\%$ of Test Load T_P using instruments graduated or with digital readouts to achieve these accuracies.

Check measurements of extensions using the movement of the jack, both before and after lock-off.

10.5 WEDGES

Wedges must not damage the tendons during successive loading and unloading of the tendons. Draw-in to the permanent prestressing head must take place only at lock-off.

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 allow no damage to the corrosion protection.

Seat wedges on each strand prior to commencing stressing. Detect slippage of individual strands within each anchorage by marking the strands with spray paint after applying the initial load, unless approved otherwise by the Principal.

10.6 PREPARATORY OPERATIONS

Fill the cavity in the underhead zone at the top of the anchor with corrosion inhibiting compound (CIC) before installing the bearing plate.

After positioning the bearing plate, install the prestressing head, 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.

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

10.7 CONTROL OF STRESSING OPERATIONS

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

Stress the anchors in the order indicated on the Drawings or as directed by the Principal and in accordance with the applicable load test of Clause 9.

Stress all strands or wires in a tendon simultaneously and uniformly using a single jack. Apply the tension smoothly at an even rate. On completion of stressing, release the jack gradually.

For multiple anchors, stress using multiple jacks, one at the head of each unit tendon. Hydraulically synchronise the multiple jacks so that identical loads are applied simultaneously to each unit anchor. 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.

Complete all anchor stressing without interruption in as short a time as possible.

Estimate the jacking force T_J from the required Lock-off Load T_O based on the summation of:

- (a) loss in prestress force due to elastic shortening (where applicable);
- (b) draw-in; and
- (c) anchorage friction.

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

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 ;
- (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 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.

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.

11 CUTTING OFF OF STRESSED TENDONS

HOLD POINT

Process Held: Tendon cutting off.

Submission Details: All details in Clauses 10.7 and 9.6.2 before commencement.

Release of Hold Point: The Principal will consider the submitted documents and may carry out surveillance and audit, prior to authorising the release of the Hold Point.

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.

Trim as appropriate the excess tendon protruding above the prestressing head to a length compatible with monitoring requirements and fitting of protective caps.

Cut off stressed tendons with a high-speed abrasive disc or wheel.

Fit the protective cap and fill it and the underhead zone with Corrosion Inhibiting Compound.

12 MONITORING

12.1 GENERAL

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

Submit, in addition to the information specified in Clause 6.1, 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.

Provide protective caps on all monitorable anchors to enable monitoring and increasing the tendon loads at any time after installation.

For anchors requiring controlled destressing, provide protruding strand lengths equal to the recorded strand extension plus approximately 300 mm, and provide extended protective caps.

Where access is difficult, fit anchors specified for long-term monitoring with robust electrical load cells with capacity greater than the nominal ultimate capacity of the tendon, calibrated to cope with changes in environmental conditions such as large temperature variations and grounded to protect against damage from lightning strikes.

Carry out short-term monitoring 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.

The extent of monitoring required must be as per Annexure R56/A but the type, 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.

Carry out Lift-off Tests on monitorable anchors by one of following methods:

- (1) 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, lift the prestressing head and fit purpose-made shims to increase anchor load.
- (2) 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 destressing.
- (3) 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 monojack.

Note that controlled destressing of anchors is only possible using method 2.

12.2 SHORT-TERM MONITORING

Monitor residual loads in the specified anchors at the frequency specified by the Principal.

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.

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

Recalibrate, repair or replace at your expense any load cell and associated equipment that is defective and/or results in unreliable readings. Measure by Lift-off Test the residual load where readings from a load cell are not reliable.

Reinstate the corrosion protection and replace the protective cap.

Should the Residual Load T_R vary by more than $\pm 10\%$ of the Initial Residual Load T_{RI} measured immediately after lock-off, inform the Principal immediately.

Submit monitoring records for each anchor within three days of completing the monitoring.

12.3 LONG-TERM MONITORING

Submit for all the anchors specified in Annexure R56/A or by the Principal 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.

ANNEXURE R56/A – PROJECT SPECIFIC REQUIREMENTS

Refer to Clause 1.2.1.

(Insert Project Specific Requirements)

ANNEXURE R56/B – MEASUREMENT AND PAYMENT

Payment will be made for all costs associated with completing the work detailed in this Specification in accordance with the following Pay Items.

Where no specific pay items are provided for a particular item of work, the costs associated with that item of work are deemed to be included in the rates and prices generally for the Work Under the Contract.

Unless specified otherwise, a lump sum price for any of these items will not be accepted.

Pay Item R56P1 Proof Anchors (when specified)

The unit of measurement must be per Proof Anchor and per metre length, for each size of anchor.

The scheduled rate must include all costs associated with drilling, cleaning, casing, grouting, supply, assembly, installation, stressing and Proof Tests of the Proof Anchors before other anchors are manufactured and drilled.

Pay Item R56P2 Drilling to Contract Level

The unit of measurement must be per metre of borehole drilled.

The scheduled rate must include all costs associated with setting up for drilling and cleaning out of holes. The measured length must include 500 mm beyond the tendon bond length required under Clause 7.2.

Pay Item R56P3 Drilling Below Contract Level (Provisional)

The unit of measurement must be per metre of hole drilled beyond the levels shown on the Drawings, but not including the 500 mm beyond the tendon bond length required under Clause 7.2.

The scheduled rate must include all costs associated with drilling below Contract Level.

Pay Item R56P4 Casing of Boreholes in Other Than Rock

The unit of measurement must be per metre of borehole drilled through material which is other than rock and which requires casing to enable drilling in rock to proceed and/or to provide containment for the grout protecting the free length of the anchor.

The scheduled rate will be additional to that under Pay Item R56P2 and must include all costs associated with the supply and installation of the casing and the additional costs associated with drilling through non-rock material.

Pay Item R56P5 Water Testing (Provisional)

The unit of measurement must be per metre of hole.

The scheduled rate must include all costs associated with grouting, redrilling and water testing (excluding water testing of the sheath).

This item is not applicable to water testing of the sheath, the costs of which must be included in Pay Item R56P2.

Each time a hole must be subject to a water test (due to failing previous water test), it must be considered as a new hole for the purpose of payment under this pay item.

Pay Item R56P6 Supply Assembly and Installation of Anchors

The unit of measurement must be per ground anchor and per metre, for each size of anchor.

The scheduled rate must include the costs of:

- (a) supply of tendon, sheathing, spacers, centralisers, grease, nose cone, grout tubes, associated components (not including anchorages) and testing associated with the supply of materials;
- (b) assembly and installation of rock anchors; and
- (c) water testing of sheathing.

The length must be measured from the underside of the bearing plate to the end of the nose cone.

Pay Item R56P7 Grouting

The unit of measurement must be per "each" anchor grouted.

The scheduled rate must include all costs associated with the supply and handling of cement and other grout constituents and supply of water, power and equipment for batching, mixing and placing of grout.

Pay Item R56P8 Supply and Installation of Anchorages

The unit of measurement must be per "each" anchorage.

The scheduled rate must include all costs associated with the supply and installation of anchor heads, barrels, wedges and bearing plates. It must also include the supply and installation of special anchor heads or protruding tendon for anchors requiring provision for monitoring, restressing and/or destressing.

Pay Item R56P9 Stressing of Anchors

R56P9.1 Anchors subject to Suitability Test

R56P9.2 Anchors subject to Acceptance Test

The unit of measurement must be per "each" ground anchor for each size of anchor and each stressing procedure i.e. Suitability Test or Acceptance Test as specified.

The scheduled rate must include all costs associated with the stressing of the ground anchors and recording and submission of stressing data.

Pay Item R56P10 Anchorage Protection

The unit of measurement must be per "each" anchor.

R56P10.1 Non-restressable Anchors

The scheduled rate must include all costs associated with cutting off the tendon and applying an approved protective treatment with concrete or epoxy.

R56P10.2 Monitorable, Restressable and/or Destressable Anchors

The scheduled rate must include all costs associated with cutting off the tendon and supply and installation of protective cap and grease filling with the specified Corrosion Inhibiting Compound.

Pay Item R56P11 Monitoring of Anchors (when specified)

The unit of measurement must be per "each" inspection for each anchor monitored.

The scheduled rate must include all costs associated with inspection, provision and setting up of equipment, measurement of residual load, reinstatement of protection, recording and submission of monitoring data and associated activities.

Pay Item R56P12 Provision of Load Cells (when specified)

The unit of measurement must be per "each" load cell.

The scheduled rate must include all costs associated with the supply and fitting of the load cells.

ANNEXURE R56/C – SCHEDULES OF HOLD POINTS, WITNESS POINTS AND IDENTIFIED RECORDS

Refer to Clause 1.2.3.

C1 SCHEDULE OF HOLD POINTS AND WITNESS POINTS

Clause	Type	Description
5	Hold	Drilling boreholes for and assembly of Proof and Suitability anchors
6	Hold	Assembly of working anchors
7.5.1	Hold	Insertion of working anchors
8.1	Hold	Grouting of anchors
10	Hold	Stressing of anchors
10.1	Witness	Stressing of each anchor
11	Hold	Tendon cutting off

C2 SCHEDULE OF IDENTIFIED RECORDS

The records listed below are Identified Records for the purposes of TfNSW Q Annexure Q/E.

Clause	Description of Identified Record
2.1	Evidence that each supplier of prestressing components and tendons has in place a third-party certified quality management system to AS/NZS ISO 9001.
2.2	Documentation with Lot numbers for each tendon coil or bar, and NATA accredited certification of conformity with supply standards.
2.3	Certification and evidence of conformity with the nominated TfNSW approved ground anchor system and supply standards for all anchorage components.
2.4	Certification and evidence of conformity of grout.
2.5	Certification and evidence of conformity of tendon sheaths and anchor ducts.
2.6	NATA test report certifying conformity of corrosion inhibiting compound.
4.1	Working drawings and Engineer's certification of necessary modifications to accommodate the approved ground anchor system.
4.2	Certification from Anchor Supervisor that work conforms to the Specification.
5	Results of testing of Proof and Suitability anchors.
6.1	Detailed drawings showing anchor system, including provisions for monitoring, and completed assembly schedule.
6.9	Conformity records for each assembled anchor, and assembly schedule.
7.4.4	Conformity records for drilling, cleaning and testing of each borehole.
7.5	Anchor insertion and water testing records.
8.7	Records of grouting of each anchor.
9	Load testing calculations and records.
9.6	Anchor assessment records.
10.7	Set of completed stressing forms for each anchor.
12.1	Drawings and cross-sections for monitorable anchors, with details of bearing plate or anchorage casting, prestressing head, protective cap, provisions for corrosion protection and provisions for carrying out Lift-off Tests.
12.2	Monitoring records for each monitorable anchor.

ANNEXURE R56/D – PLANNING DOCUMENTS

Refer to Clause 1.2.4.

The following documents are a summary of documents that must be included in the PROJECT QUALITY PLAN. The requirements of this Specification and others included in the Contract must be reviewed to determine additional documentation requirements.

The information to be submitted as part of the PROJECT QUALITY PLAN includes, but is not limited to, the following:

- (a) Full details proving conformity with the Specification of alternative corrosion protection systems to that specified (Clause 1.1);
- (b) Criteria for a satisfactory rock surface and procedures for installing the bearing plate on its pad when stressing anchorages directly against rock (Clause 3.1);
- (c) Details of supplementary additional corrosion protection required in a specific environment (Clause 3.2.1);
- (d) Details of method of sealing base and head of underhead zone duct or trumpet (Clause 3.2.2);
- (e) Fully detailed drawings including cross-sections and longitudinal sections showing all ground anchor components, method of assembly and provisions for monitoring (Clause 6.1);
- (f) Procedure for preventing tendon strands from crossing within the free length (Clause 6.2);
- (g) Demonstration of adequacy of joints in sheaths and ducts (Clause 6.5);
- (h) Details of sheaths at tendon couplers (Clause 6.6);
- (i) Detailed procedures for fixing lower end of tendon to the bottom of corrugated duct and sealing with nose cone (Clause 6.7);
- (j) Full details of proposed drilling procedure and method of supporting the borehole during drilling, installation and grouting when penetrating material other than rock (Clause 7.1);
- (k) Procedures for maintaining and checking the specified borehole alignment and deviation from straight during drilling (Clause 7.2);
- (l) Procedure for dealing with variations in subsoil condition when drilling boreholes (Clause 7.2);
- (m) Methods of cleaning the boreholes (Clause 7.3);
- (n) Procedures for inserting assembled anchors into boreholes (Clause 7.5.1);
- (o) Procedures for repairing damage to factory grouted anchors (Clause 7.5.4).

ANNEXURES R56/E TO R56/K – (NOT USED)

ANNEXURE R56/L – TESTING PROCEDURES

Refer to Clauses 1.2.5, 8 and 9.

L1 GROUT TESTING**L1.1 Minimum Frequency of Testing****Table R56/L.1 Minimum Grout Testing Frequency**

Clause	Characteristic Analysed	Test Method	Minimum Frequency of Testing
8.2	Bleeding	ASTM C940	One test or one test each 4 hours, whichever is the greater
8.2	Fluidity	ASTM C939	One test per batch
8.2	Compressive Strength Test*	TfNSW T375	Three cubes per anchor or batch, whichever is the lesser

* Additional cubes should be taken if grout strength is required at other than seven day's age

L2 LOAD TESTING

Refer to Clause 9.

L2.1 Minimum Frequency of Testing

Refer to Clause 9.1.

Table R56/L.2.1 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
9.3	Proof	Exploratory or investigation	As required by designer or as specified on the Drawings
9.4	Suitability	Low risk and temporary	≥ 1% of installed anchors or 1, whichever is greater
9.4	Suitability	High risk and temporary Normal risk and permanent	≥ 2% of installed anchors or 2, whichever is greater
9.4	Suitability	Critical and permanent	≥ 2% of installed anchors or 3, whichever is greater
9.5	Acceptance	All	All remaining anchors

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

L2.2 Proof Test

Refer to Clause 9.3.

Table R56/L.2.2 - Recommended Load Increments and Minimum Periods of Observation for Proof Tests

Load Increments (% of T_U)							Minimum Period of Observation (Minutes)
1 st Cycle	2 nd Cycle	3 rd Cycle	4 th Cycle	5 th Cycle	6 th Cycle	7 th & 8 th Cycles	
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

NOTE. 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

L2.3 Suitability Test

Refer to Clause 9.4.

Table R56/L.2.3 - Recommended Load Increments and Minimum Periods of Observation for Suitability Tests

Load Levels (% of Test Load T_P)						Minimum Period of Observation (Minutes)
Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6	
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

* Full unloading is permitted for installation of the permanent wedges

L2.4 Acceptance Test

Refer to Clause 9.5.

Table R56/L.2.4 - 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

ANNEXURE R56/M – REFERENCED DOCUMENTS AND ABBREVIATIONS

Refer to Clause 1.2.6.

M1 REFERENCES

TfNSW Specifications

TfNSW G36	Environmental Protection
TfNSW Q	Quality Management System
TfNSW B114	Ground Anchors (Lump Sum)
TfNSW 3211	Cements, Binders and Fillers

TfNSW Test Methods

TfNSW T375	Sampling and Testing of Grout
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Australian Standards

AS/NZS 1314	Prestressing anchorages
AS 1349	Bourdon tube pressure and vacuum gauges
AS 2758.1	Aggregates and rock for engineering purposes - 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/NZS ISO 9001	Quality management systems – Requirements

ASTM Standards

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 D972	Standard Test Method for Evaporation Loss of Lubricating Greases and Oils
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 Standard

BS8081	British Standard Code of Practice for Ground Anchorages
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Other References

Geotechnical Engineering Handbook Volume 2 Procedures

– Chapter 2.5 Ground Anchors, published by Ernst & Sohn 2003

M2 ABBREVIATIONS

CIC	Corrosion Inhibiting Compound
HDPE	High Density Polyethylene
JAS-ANZ	Joint Accreditation System for Australia and New Zealand
NATA	National Accreditation and Testing Agency
PP	Polypropylene
PVC	Polyvinylchloride