

TRANSPORT FOR NSW (TfNSW)

QA SPECIFICATION R64

SOIL NAILING

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REVISION REGISTER

Ed/Rev Number	Clause Number	Description of Revision	Authorised By	Date
Ed 1/Rev 0		First issue	GM, IC	23.04.09
Ed 1/Rev 1	1.4	Fig 1 – definition of length of soil length changed.	GM, IC	26.06.09
	2.2.1	Requirement for reinforcement bar couplers changed.		
	3, 4	Clause on instrumented soil nail relocated to after “Construction”; clauses renumbered.		
	3.3 (a)	Requirement for “Geotechnical Engineer” to be engaged by designer of soil nail structure added. Witness Point – Process witnessed reworded.		
	3.3 (e)	Wording changed to clarify intent. Time period for excavation of subsequent lift after completion of concrete facing of the previous lift changed from “48 hours” to “72 hours”.		
	5.2.1	Individual sub-clauses within clause reordered.		
	5.2.1, 5.2.2	Debonding and test load requirements for soil nail testing clarified. Test load increments and test load duration for Suitability and Acceptance Tests to determine creep characteristics under sustained loading revised. Creep movement and creep rate criteria for assessing Suitability and Acceptance Test results changed. Acceptance criteria clarified.		

Ed/Rev Number	Clause Number	Description of Revision	Authorised By	Date
Ed 1/Rev 1 (cont'd)	5.2.2 5.4 6.3 6.4.2 Pay Item R64P1 Annex R64/C	Note added to Table R64.4 clarifying that load sequence is one full cycle of testing. Contents duplicating Hold Point details deleted. Requirement for sealing of holes for anchor bar supporting the steel mesh changed from mandatory to optional. Purpose of sealing of anchor bar holes clarified. Wording of 30° taper requirement changed to clarify intent. Wording changed to emphasise that scope includes carrying out Suitability Testing Schedule of Hold and Witness Points – Description of Clause 4 Witness Point updated. Schedule of Identified Records - Clause references updated.		
Ed 1/Rev 2	Guide Notes 3.3	Measures to minimise problems during construction of soil nail walls added. Statement added that no change to construction sequence be made without the approval of the Principal.	GM, IC (M Andrew)	15.03.12
Ed 1/Rev 3	Guide Notes 2.2.1 2.2.2 2.2.2, 2.2.3, 2.2.8 2.3.5 Annex M	Added the following guide notes: G.1 - thermal diffusion galvanizing permitted as an alternative to hot-dip galvanizing for nuts, washers and bearing plates. G.2 - alternative to steel deformed bars and different thread types permitted. G.3 on adherence to specified construction sequence reworded. Alternative to Grade 500N steel deformed bars and different thread profiles permitted. New sub-heading “Couplers” inserted; subsequent clauses renumbered. Alternative process to hot-dip galvanizing permitted for couplers, nuts, soil nail heads and bearing plates permitted, subject to Principal’s approval. Strip filter drains changed to flexible type, reference changed to new Materials spec 3557. Strength requirements for strip drain filter deleted (duplicated in 3557, or superfluous). Referenced documents updated.	GM, IC	21.11.12
Ed 1/Rev 4	2.2.4, 2.2.6 Annex M	References to AS 4130 changed to AS 4131. Referenced documents updated.	MCQ	28.06.16

Ed/Rev Number	Clause Number	Description of Revision	Authorised By	Date
Ed 1/Rev 5	1.4	Figure 1 amended.	MCQ	31.07.18
Ed 1/Rev 6	Global	References to “Roads and Maritime Services” or “RMS” changed to “Transport for NSW” or “TfNSW” respectively.	DCS	22.06.20
Ed 1/Rev 7	2.2.7 Annex M	“AS 1478” changed to “AS 1478.1”. Referenced documents updated.	MCQ	04.11.20

GUIDE NOTES

(Not Part of Contract Document)

G.1 Protective Treatment of Couplers, Nuts, Washers and Bearing Plates

Refer Clauses 2.2.2, 2.2.3 and 2.2.8.

Thermal diffusion coating (TDC) galvanizing may be used as an alternative to hot-dip galvanizing for couplers, nuts, washers and bearing plates.

Thermal diffusion galvanizing has the following advantages over hot-dip galvanizing:

- (i) it produces zinc alloy layers of similar thickness to hot-dip galvanizing, without being susceptible to hydrogen embrittlement; and
- (ii) it produces more consistent coating thickness compared with hot-dip galvanizing, resulting in more reliable bolt preloads when tensioned using torque wrenches.

The thickness of the thermal diffusion galvanizing must not be less than the hot-dip galvanizing. Tapping of nuts following thermal diffusion galvanizing is not usually done because of the hardness of the coating.

Thermal diffusion galvanizing must meet the requirements of ASTM A1059M-08 “Standard Specification for Zinc Alloy Thermo-Diffusion Coatings (TDC) on Steel Fasteners, Hardware, and Other Products”.

Hot-dip galvanizing must still be used for galvanizing of soil nail steel bars.

G.2 Soil Nail Thread

Refer Clauses 2.2.1 and 2.2.2.

Alternative to deformed bars and different thread profiles may be permitted provided that the threaded nut assembly of the soil nail exceeds the minimum breaking load of the bar.

Soil nail bar couplers using such threaded profiles may be permitted provided that the same requirements stated above are met.

G.3 Soil Nail Wall Design and Construction Sequence

Refer Construction Quality Technical Direction CQTD 2009/005.

In order to minimise problems during the construction of soil nail walls, TfNSW Project Managers should ensure that:

- (i) The Drawings clearly detail the construction sequence for the soil nail walls.
- (ii) The actual construction sequence by the Contractor conform strictly to the construction sequence specified in the Drawings and other requirements in this Specification.
- (iii) No change to the construction sequence specified in the Drawings is made without the approval of the designer or TfNSW Manager Geotechnical Engineering (Ground Engineering).

G.4 Contact for Technical Queries

Any technical queries regarding the specifications can be referred to:

Manager Geotechnical Engineering (Ground Engineering)

Telephone: (02) 8837 0764 Facsimile: (02) 8837 0059



SOIL NAILING

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VERSION FOR: DATE:

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FOREWORD

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REVISIONS TO PREVIOUS VERSION

This document has been revised from Specification TfNSW R64 Edition 1 Revision 6.

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 R64

SOIL NAILING

1 GENERAL

1.1 SCOPE

This Specification sets out the requirements for soil nailing for the strengthening of earth slopes using grouted steel dowels (soil nails) installed at shallow inclination into the retained soil mass at nominated positions and levels shown on the Drawings.

It covers the requirements for supply and installation of soil nails including compliance testing, and the associated concrete facing work on the slope surface.

A reinforced, formed concrete or shotcrete facing, acting as 'diaphragm support' for the retained structure, forms part of the works.

1.2 STRUCTURE OF THE 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 R64/A.

1.2.2 Measurement and Payment

The method of measurement and payment is detailed in Annexure R64/B.

1.2.3 Schedules of HOLD POINTS, WITNESS POINTS and Identified Records

The schedules in Annexure R64/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 R64/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 shown in Annexure R64/D and must be implemented.

1.2.5 Referenced Documents

Unless specified otherwise, the applicable issue of a referenced document, other than a TfNSW Specification, 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 2350). For convenience, the full titles are given in Annexure R64/M.

1.3 DEFINITIONS

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

The following definitions apply to this Specification:

Annulus: Radial space between the soil nail and the drillhole wall.

Batch of Grout: Any quantity of grout used for grouting in one continuous operation in one day.

Curing: The control of temperature and moisture in the concrete until the concrete has developed required properties.

Grout: A mixture, similar to mortar, but more workable and possibly without any sand or fine aggregate, proportioned to produce a pourable liquid which does not readily segregate into its constituents during pouring or pumping.

Instrumented Nail: A specially made soil nail in which strain gauges are installed to monitor the stress/ strain behaviour of the nail steel bar.

Mortar: A mixture of cement, water and sand (fine aggregate), with or without chemical admixtures with a characteristic compressive strength at 28 days of not less than 25 MPa.

Nail Head: The upper part of the nail composed of a bearing plate, nut and washer, and the portion of steel reinforcement protruding above the bearing plate. For permanent nails in certain projects, the nail head may consist of a bent reinforcement bar to be covered by concrete facing.

Permanent Nail: A soil nail installed on site as the permanent work of the site and will be selectively tested under 1.5 time design load via the Acceptance Test procedure.

Rebound: Shotcrete material that bounces off the receiving surface.

Sealed Curing: Curing at ambient temperature in which the concrete surface is sealed by at least two coats of a curing compound conforming to this Specification.

Shotcrete: A structural sprayed concrete containing fine and coarse aggregates, water and cement, with or without the addition of set accelerators. Compaction of the material is achieved by the force of the jet impacting on the surface. The shotcrete is reinforced by galvanized steel mesh.

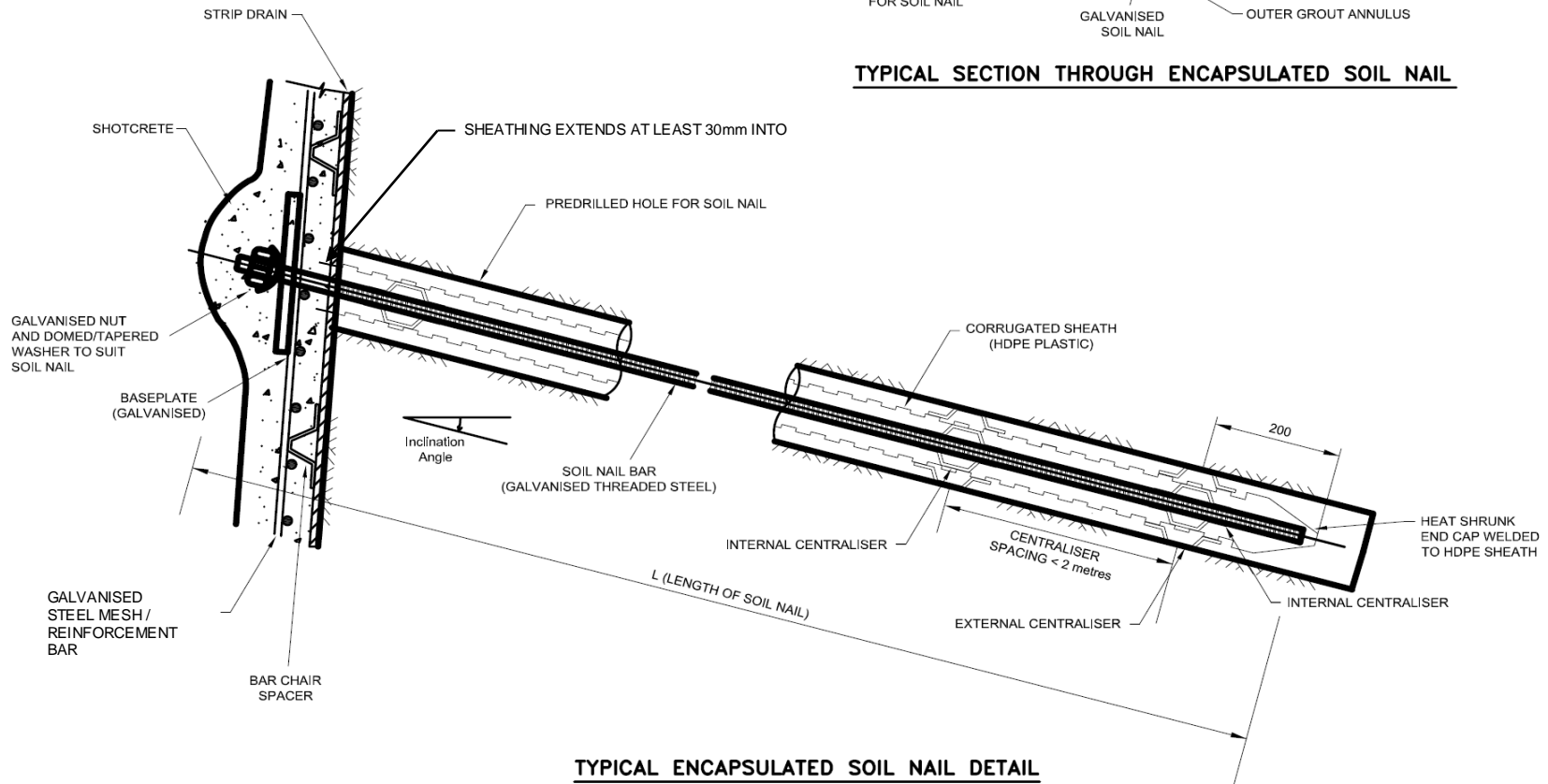
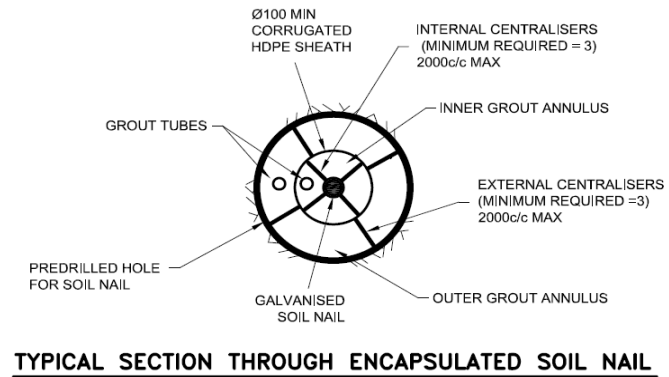
Soil Nail: A steel reinforcement bar inserted centrally into a pre-drilled hole and grouted in place.

Standard Moist Curing: Standard moist curing as defined in AS 1012, Part 8.

Test Nail: A soil nail specially installed on site for testing its ultimate pull out capacity through the Suitability Test procedure. It does not form part of the permanent works for the contract.

Wet Curing: Curing at ambient temperature in which the concrete surface is effectively covered with water or placed in a fog room/chamber with a relative humidity exceeding 98%.

1.4 TYPICAL SOIL NAIL DETAILS



TYPICAL ENCAPSULATED SOIL NAIL DETAIL
(for illustration purposes only – refer to Drawings for construction details)

1.5 PLANNING DOCUMENTS

The PROJECT QUALITY PLAN must include each of the documents and requirements listed in Annexure R64/D and must be implemented.

If the Contract does not require you to implement a PROJECT QUALITY PLAN, the documents listed in Annexure R64/D must be submitted to the Principal for consideration at least 5 working days prior to work commencing and must be implemented.

In all cases where this Specification refers to the manufacturer's recommendations, these must be included in the PROJECT QUALITY PLAN.

2 MATERIALS

2.1 GENERAL

Materials used for manufacturing soil nails and concrete facing must be produced by manufacturers operating under a quality management system, which satisfies the requirements of AS/NZS ISO 9001.

All materials used for the construction of soil nails and concrete facing must be accompanied by a manufacturer's certificate of conformity, verifying that the proposed materials comply with all the requirements of this Specification.

Submit the certificate of conformity to the Principal at least 10 working days before the commencement of Works. Submission of this certificate constitutes a Hold Point.

HOLD POINT

Process Held:	Commencement of Works.
Submission Details:	At least 10 working days prior to the commencement of Works, submit to the Principal certificate of conformity for the materials used in the soil nailing works.
Release of Hold Point:	The Principal will consider the submitted documents prior to authorising the release of the Hold Point.

2.2 SOIL NAILS

2.2.1 Soil Nail Steel Bars

Steel reinforcement bars for soil nails must be Grade 500N deformed bar to AS 4671, or other carbon steel grades with a minimum characteristic yield strength of 500 MPa and which meet the requirements for ultimate strength and elongation for Grade 500N steel bars shown in Table 2 of AS 4671. Provide the relevant test certificates demonstrating conformity.

Each delivery of steel bars must be accompanied by documentation showing the mill certificate and Lot number.

The bars must be threaded at one end. The thread must be ISO coarse pitch thread to AS 1275, or other thread profiles where approved by the Principal.

The steel reinforcement bar must be hot-dip galvanized to AS/NZS 4680, except that the minimum average coating weight must be 600 g/m² (equivalent to 85 microns thickness).

Inspect all steel reinforcement bars carefully to ensure that it is true to size and free from defects that may impair strength and durability.

2.2.2 Couplers

Steel reinforcement bars longer than 12 m must be joined using mechanical couplers. The use of couplers to extend the steel reinforcement bars must not result in a decrease in the tensile strength of the joined bar assembly.

All couplers must be hot-dip galvanized to AS/NZS 4680, or galvanized by an alternative process approved by the Principal.

The couplers must be of dimensions that do not interfere with the grouting and installation of soil nails.

2.2.3 Nuts

Nuts for soil nails must be grade C complying with AS 1112.3 and property Class 5 complying with AS 4291.2 or equivalent to suit the threaded end of the soil nail. The thread must conform to the ISO coarse pitch thread in accordance with AS 1275.

All nuts must be hot-dip galvanized in accordance with AS 1214, or galvanized by an alternative process approved by the Principal.

2.2.4 Encapsulation (Corrugated Plastic Sheath)

Where specified on the Drawings, encapsulate soil nails in a corrugated plastic sheath sealed at the buried end.

The corrugated plastic sheath must be manufactured from high density polyethylene complying with AS 4131, with a minimum uniform wall thickness of 2.0 mm.

The corrugated sheathing must meet the requirements of either of the following:

- ASTM D3350 for HDPE with cell classification 335533C, or
- ASTM D1784 for rigid PVC with classification 13464B.

The pitch of corrugations must be within six to twelve times the sheath wall thickness, and amplitude of corrugations must be not less than three times the wall thickness.

The finished internal and external surfaces of the corrugated plastic sheath must be clean and free from flaws, pin holes, bubbles, cracks and other defects.

Where possible, corrugated plastic sheath must be unjointed for the full length of soil nail.

Where joints cannot be avoided, provide sheath joints by lapping of at least 100 mm together with liberal use of solvent glues appropriate for the sheathing material or with heat-shrink sealing. The strength of the joint must be at least 90% of the parent material. Joints must be such that the continuity of the protective system over the whole length of the nail is unimpaired with respect to the physical and electro-chemical barrier.

A screw-on cap or a heat-shrink boot must be placed on the end of the sheath in contact with the ground and bonded with an appropriate solvent glue or heat shrink sealing.

Provide a manufacturer's certificate of conformity to the Principal, which includes the following information about the corrugated plastic sheath to be used:

- (a) manufacturer's name and current address;
- (b) full product name;
- (c) style, merge, or product code number;
- (d) outer and inner diameter;
- (e) wall thickness;
- (f) amplitude and pitch.

2.2.5 Centralisers

Manufacture centralisers from materials which have no deleterious effects to the reinforcing system and will not corrode. The centralisers must be of a shape that permits the free flow of grout but still performs the centralising function. They must not be compressible, bulky or cause decoupling of the grout or de-bonding of the grout/steel reinforcement interface.

Do not use plastic slip-on centralisers, or rely on the grout tube spirally wound around the soil nail to act as centraliser.

Centralisers must be firmly fixed to the nails and to the encapsulation and must be provided both inside and outside of nail assemblies.

Provide centralisers at intervals not exceeding 2 m along the corrugated plastic sheath or reinforcement bar, with the first and last centraliser 0.3 m from the end of each nail, to ensure that it is centred within the drillhole. Provide a minimum of three (3) centralisers for each nail for the annulus between the drillhole and the corrugated plastic sheath/reinforcement bar, or between the bar and the drillhole.

Subject to the results of the soil nail design, maintain a minimum grout cover of 25 mm between the corrugated plastic sheath and the drillhole; and 20 mm between the reinforcement bar and the encapsulation sheath at any location along the length of the bar or sheath. Where reinforcement bars are not encapsulated, the minimum cover between the bar and the drillhole must be 30 mm at any location, unless otherwise specified on the Drawings.

2.2.6 Grout Tubes

Grout tubes must have a minimum internal diameter of 12 mm for the core and outer annulus grouting and must be made from high-density polyethylene with a wall thickness of at least 2.0 mm or its equivalent to AS 4131. Tubing must be of adequate strength to resist damage during both installation and grouting.

Grout tubes must extend to the lowest portion of the drilled hole to ensure thorough grout penetration and must be securely fixed to the steel reinforcement to prevent displacement or dislodging.

Provide separate grout tubes for grouting the inside and outside of the encapsulated soil nail and for likely second stage grouting.

2.2.7 Grout

Grouts must have high bleed resistance, low shrinkage and high fluidity and conform to Table R64.1 when tested as specified.

Table R64.1 – Performance Requirements for Grout

Property	Test Method	Criteria	Comments
Bleeding	ASTM C940	Final bleeding < 0.5%	Measured when two successive readings show no further expansion or bleeding.
Volume Change	ASTM C1090	Maximum height change @ 1 day & 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 *	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

* 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.

Cement for grout must be Type GP cement complying with Specification TfNSW 3211. Only use cement free from any lumps. Store cement in dry weatherproof containers. Small stacks of bagged cement may be held in the open, but such stacks must be thoroughly protected from the weather by tarpaulins and must be placed on timber platforms above the ground. Hold adequate stocks of cement at the mixers to ensure continuous and uninterrupted grouting operations.

Do not use additives or admixtures without the approval of the Principal, and such additives or admixtures must comply with the requirements of AS 1478.1, and must not be deleterious to the properties of the grout or any other soil nail components. Admixtures containing calcium chloride, methocell, ligno-sulphonate and aluminates must not be used. Expansive admixtures where used must be of the pre-hardening type and not include iron or aluminium powders. In general, do not use admixtures of more than 0.005% by weight of cement.

Any chemical reactions between grout constituents or materials in contact with the grout must not produce gases.

Water used in grout must be clean and free from oil, acid, alkali, organic or vegetable matter and from any ingredients harmful to steel or cement grout. Water must not contain more than 500 mg/l of chloride ions. Water temperature measured at the mixer must not be less than 5°C nor more than 27°C.

The total sulphate (SO₃), chloride and nitrate contents of the grout must not exceed 4%, 0.1% and 0.1% respectively, expressed as a percentage between the respective ion content and the cement

content by mass in the grout. The total sulphate (SO_3) and chloride contents must be determined by the method described in AS 1012.20. The total nitrate content must be determined by the method described in ASTM D 4327-03.

Submit the grout mix proportions and types of additive or admixture (if used) together with test results for approval by the Principal at least 10 working days prior to the commencement of grouting. Submission of these documents constitutes a Hold Point.

HOLD POINT

Process Held:	Commencement of grouting
Submission Details:	At least 10 working days prior to the commencement of grouting, submit to the Principal the grout mix proportions, details of any additive or admixture proposed to be used and test certificates
Release of Hold Point:	The Principal will consider the submitted documents prior to authorising the release of the Hold Point

The above requirements are in general also applicable to the grouting for anchor bars used for holding the reinforcing mesh.

2.2.8 Nail Heads and Bearing Plates

Where shown on the Drawings, nail heads and bearing plates must conform to the following:

- (i) Nail head and bearing plate components (including nuts, washers, etc) must be fabricated from Grade 250 steel in accordance with AS 3678;
- (ii) All nail head components and the bearing plates must be hot-dip galvanized to AS/NZS 4680, or galvanized by an alternative process approved by the Principal, with a minimum average coating weight of 600 g/m^2 (equivalent to 85 microns thickness).

Where indicated, provide the bearing plate with holes for the secondary grout injection and the return flow which ensure that no void exists between the primary grout surface and the bearing plate.

For permanent protection, fully cover nail heads and bearing plates with shotcrete of 50 mm minimum thickness.

2.3 CONCRETE FACING

2.3.1 General

Construct the concrete facing with either formed concrete or shotcrete to the dimensions shown on the Drawings. The facing must be constructed following preparation of the cut face to the extent that the surface to be sprayed is devoid of loose or soft areas, overhangs, undercut zones or other voids, such that the facing will bond to the face and slip at the interface will not occur.

2.3.2 Formed Concrete

All materials and workmanship for formed concrete must be in accordance with Specification TfNSW B80. Unless specified on the Drawings or otherwise directed by the Principal, the 28 day compressive strength of concrete must be not less than 32 MPa.

2.3.3 Shotcrete

Materials and workmanship for shotcrete must comply with Specification TfNSW R68. Use Exposure Classification B2 for the shotcrete mix design.

2.3.3.1 Steel Reinforcement

(i) Steel Mesh Reinforcement

All shotcrete must be reinforced with steel reinforcing mesh using D500 SL81 mesh type (or as shown on the Drawings) complying with AS 4671 and hot-dip galvanized in accordance with AS/NZS 4680 except that minimum average coating weight must be 600 g/m² (equivalent to 85 microns thickness). Degreasing and abrasive blast cleaning or acid pickling of metal surfaces prepared for galvanizing must be in accordance with AS 1627.

(ii) Anchor Bar and Centralisers

Anchor bars for fixing the steel mesh reinforcements must be 800 mm long (which includes a 300 mm long cog), grade 500N, 16 mm deformed steel reinforcing bars complying with AS 4671. The anchor bars must be hot-dip galvanized in accordance with AS/NZS 4680 after bending.

Grout the anchor bars into holes with the cog end placing centrally within the concrete facing.

Provide not less than two centralisers along the full length of each anchor bar to maintain the bar centrally located within the drilled hole. Centralisers must be:

- (a) positioned to provide an even spacing between consecutive centralisers;
- (b) firmly fixed to the bar;
- (c) of a form that will not impair the free flow of the grout.;
- (d) manufactured from material that is not corrodible and will not have deleterious effects on the anchor bar and the grout.

2.3.4 Slotted Pipe Drains

Materials and workmanship for slotted pipe drains must be in accordance with Specification TfNSW R40.

2.3.5 Flexible Strip Filter Drains

Where specified on the Drawings, place flexible strip filter drains behind the concrete facing, at the spacing shown, which must not be more than 3 m.

Flexible strip filter drains must be in accordance with Specification TfNSW 3557.

The minimum one-third flow capacity of the core at 1% slope must be 60 litres per minute.

3 CONSTRUCTION

3.1 GENERAL

Provide the Principal for agreement with your full Construction Program and Method Statement at least 10 working days before the commencement of the works. The submission of the Construction Program and Method Statement constitutes a Hold Point.

HOLD POINT

Process Held:	Commencement of soil nailing work
Submission Details:	At least 10 working days before the commencement of works, submit to the Principal full Method Statement and Construction Program
Release of Hold Point:	The Principal will consider the submitted documents prior to authorising the release of the Hold Point.

The Method Statement and Construction Program must include, but not be limited to, the following information:

- (i) names and resumes of suitably experienced personnel who will supervise and carry out the work;
- (ii) method of installation of the soil nails, including drilling, cleaning, supporting the drillholes; and grouting and testing of the nails together with construction/excavation sequence. Only pneumatic, rotary and rotary percussion drilling with air as fluid and flushing agent are permitted;
- (iii) method for installing instrumented soil nails with strain gauges if any, providing conduits for wires and avoiding damage to wires between soil nails and readout box;
- (iv) proposed grout mix proportions and the method of grout production;
- (v) results of the trial grouting mix for anchor bars and soil nails that verify your proposed grout mix proportions and the method of grout production;
- (vi) detailed method of applying shotcrete; and
- (vii) proposed construction program and construction sequence.

3.2 STORAGE AND HANDLING

Suitably protect steel reinforcement, UPVC pipes, nail head components and bearing plates against mechanical damage, weld splash, contamination by marine spray, gross industrial atmospheric contamination and aggressive wind blown sands. Store steel reinforcement and UPVC pipes in straight lengths.

Store all soil nail components in clean and dry conditions.

Handle galvanized steel reinforcement carefully to avoid punctures, fractures or wear of the galvanizing. Do not drag bare or galvanized steel reinforcement across abrasive surfaces or through deleterious materials such as surface soil.

When lifting long steel reinforcement and encapsulation, use cradles to prevent excessive bending.

3.3 CONSTRUCTION SEQUENCE

Installation of permanent nails can commence once testing of the Test Nails (refer to Clause 5) has been completed and associated Hold Points have been released. Unless otherwise shown on the Drawings or directed by the Principal, construct soil nail slopes in an incremental, “top-down” manner in accordance with the following sequence:

- (a) For each construction stage, excavate the face of the cut over the width and depth as approved in the Method Statement.

Excavation of individual “lifts” must not exceed a total depth of 2 m, and must also not exceed a depth of 0.5 m below the row of soil nails to be installed, or the full depth of excavation in the case of the lowest row of soil nails.

The exposed slope face after each excavation “lift” must be inspected by a qualified Geotechnical Engineer engaged by the designer of the soil nail structure. This inspection constitutes a Witness Point.

WITNESS POINT

Process Witnessed: Exposed slope face after each excavation “lift”.

Submission Details: At least 2 working days before completion of excavation of a “lift”, advise the Principal of the availability of the excavated face for inspection by a qualified Geotechnical Engineer

- (b) Installation and testing of soil nails together with installation of horizontal drains and flexible strip filter drains must commence immediately after excavation is completed. The time the exposed excavated face is left unsupported must be kept to a minimum to prevent any deterioration of the excavated face.
- (c) Construction of the concrete facing over the exposed face at the current construction stage may commence once the soil nails and drainage have been installed. Make allowance for support of the facing during placement and for lapping of facing reinforcement to ensure a continuously reinforced face.
- (d) Carry out construction of subsequent rows of soil nails and concrete facing in a similar manner, one row at a time.
- (e) Excavation for subsequent rows of soil nails cannot commence until the installation of the preceding row is fully completed and the concrete facing has attained sufficient strength to be self-supporting to permit further excavation to proceed. Excavation of subsequent lifts can only take place when the completed concrete facing of the previous lift has achieved sufficient strength to be self supporting. This time period must not be less than 72 hours, unless otherwise approved by the Principal.

Do not change the construction sequence specified in the Contract Documents without the approval of the Principal.

3.4 SOIL NAIL INSTALLATION

3.4.1 General

Installation of the soil nails must be carried out by qualified and experienced personnel.

Assemble the soil nail (with or without encapsulation) in a workshop, or on site under cover, by trained personnel. Identify the assembled soil nails using clear markings and handle them with care.

3.4.2 Set Out and Drilling

Use rotary or rotary-percussion drilling equipment for drilling to ensure minimal remoulding of insitu materials within the drillholes. Do not use drilling fluids other than air, unless otherwise approved by the Principal.

Holes for galvanized soil nails must be at least 100 mm in diameter or as shown on the Drawings.

During the drilling operation, record the ground conditions encountered on a drillhole log together with all changes in ground type and notes on water levels encountered and drilling rates. Record also on the drillhole log the bearing and inclination of the formed drillhole as well as geometric details and the cleaning procedure.

On completion of drilling, clean the drillhole of all loose and deleterious material and protect or seal the drillhole opening to prevent the entry of foreign matter. Carry out cleaning by flushing with air or compressed air using side jet bits, so as to ensure removal of all drill cuttings from the walls and bottom of the drillhole and to avoid excessive air pressure. Reinforcement may only be installed in a clean hole free of debris and foreign matter.

The drillholes for the soil nails must have adequate clearance from the nearby structures and be constructed within the following tolerances:

- (a) Deviation in alignment of the drillhole must not exceed 5°. Deviation from straight must not exceed 25 mm in any 1.5 m length of hole. Locate the entry point of the drillholes within ± 50 mm of its design position on the cut face;
- (b) The depth of the holes must be within a tolerance of $-0, +100$ mm;
- (c) An allowance for overdrilling (300 mm maximum) must be added to the depth where debris cannot be removed from the bottom of the hole;
- (d) The maximum deviation of the diameter of the drillholes from the design diameter is $-0, +10$ mm.

3.4.3 Insertion and Grouting

3.4.3.1 Insertion of Soil Nails

Prior to soil nail installation, clean the drillhole of debris by air flushing methods.

Insert soil nails in one careful operation at a controlled rate to avoid dislodgment of material from the wall of the drillhole and to ensure that centralisers and spacers are not displaced. Replace any soil nail or its galvanized coating which is damaged during installation. Insertion and grouting must occur as soon as practicable following drilling, but in any event must be completed within 24 hours after completion of drilling.

Do not carry out grouting without the prior approval of the Principal.

3.4.3.2 Grouting Equipment

Grouting equipment for soil nail installation must be of a type, quantity and size which is suitable for the grouting required and is approved by the Principal. Keep the equipment clean and in good working order.

The equipment must include:

- (a) a purpose designed high speed mechanical stirrer capable of producing grout free of lumps within a mixing time of 2 minutes. Mixers must be fitted with a water volume measuring device for batching purposes;
- (b) a holding tank fitted with an agitator to provide continuous agitation of the grout at 100 rpm. The tank must be fitted with a dipstick to allow continuous measurement of the volume of grout in the tank;
- (c) flow meter and pressure gauge to check the intake grout volume and the required pressure.

The pump used for grout injection must be of the positive displacement type (i.e. it must be actuated by a piston or screw) fitted with a bypass back to the agitator tank to allow a standby pump to be brought into operation immediately in the event of breakdowns during grouting operations.

3.4.3.3 Grout Mixing

Batching of the dry materials must be by weight. Measure the amount of water used with a calibrated flowmeter or a measuring tank.

Mix the grout by adding initially approximately two-thirds of cement to the water, followed by the additive if any, and then the remaining one-third of cement. Mix the grout for a sufficient time to produce a grout of uniform consistency.

The grout mixing process must utilise a recirculating system where the grout is continuously discharged and recharged into the mixing unit during the mixing period. After mixing, keep the grout continuously agitated.

Pass the grout through a nominal 1.2 mm wire cloth to ensure a uniformly mixed grout prior to injection. Use the grout as soon as possible after mixing and in any case within 30 minutes of adding cement, unless approved retarding agents are used.

Grout pumps must be efficient and capable of running continuously for the duration of the grouting operation. They must be capable of pumping the specified grout at a rate appropriate to that required for the operation.

Any alternative mixing procedures proposed by you must be agreed with the Principal.

3.4.3.4 Grouting

Carry out grouting by use of supply lines directly connecting the pumps to the down-hole grout tubes. Inject grout through a grout tube to the bottom of the hole, at an injection pressure of not more than twice the overburden pressure measured at the top of the soil nail. The grout tubes must have a minimum internal diameter of 12 mm to ensure that blockages will not occur during grouting operations and must also be sufficiently robust to ensure that they are not damaged during handling.

During the grouting operation, the grout must displace all air and water and fill the hole in a continuous operation until the emerging grout is of the same consistency as the grout being pumped in. The grout level must then be checked by sitting for 5 minutes and top-up grout introduced if necessary to ensure that the soil nail is fully grouted.

Plug the remaining void at the top of the drillhole flush to the slope faces using a dry-packed 3:1 sand:cement mix. Discard and dispose of the grout that has overflowed from the hole as waste to the satisfaction of the Principal.

Alternative methods to ensure that soil nails are fully grouted may include overpouring the grout using a PVC tube extended sufficiently to allow for grout losses and prevent the formation of a horizontal construction joint in the grout. The choice of method must be adapted to the geology of the material and the extent of grout loss encountered. The degree of rock fracturing or presence of fill will affect grout loss.

During grouting of encapsulated soil nail, install a separated grout tube extending to the bottom of the assembly both inside and outside the encapsulation. Inject grout in a controlled manner from the bottom to the top both outside and inside until the encapsulation is completely filled without separation. Maintain the grout level between the outside and the inside sheathing to not greater than 1 m to ensure minimal pressure variation across the sheathing.

Discontinue grouting if the ambient and grout temperature falls below 5°C.

Protect the soil nail from accidental disturbance after grouting has been completed to ensure that damage of the grout/soil and grout/nail bond does not occur.

3.4.3.5 Loss or Leakage of Grout

If, during the grouting of any hole, the grout take increases suddenly by a significant amount, inform the Principal immediately.

If, during the grouting of any hole, grout is found to flow from adjacent grout holes in quantities which in the opinion of the Principal are sufficient to interfere seriously with the grouting operation or to cause appreciable loss of grout, cap the adjacent holes temporarily and remove the steel reinforcement bar from the grouted hole. Grout, re-drill and re-grout the hole.

If, during the grouting of any hole, grout is found to flow from joints in the geological formation at the Site or any other locations, plug or caulk the leaks in a manner agreed by the Principal.

3.4.3.6 Bleed Testing

Provide one sample of grout from each batch of grout to determine the amount of bleeding in accordance with ASTM C940 and the requirements specified in Clause 2.2.7.

Samples must be provided not more than 30 minutes after the grout has been mixed and must be protected from moisture content changes before the tests for amount of bleeding are carried out.

3.4.3.7 Fluidity Testing

Provide one sample of grout from each batch of grout to determine the fluidity in accordance with ASTM C939 and the requirements specified in Clause 2.2.7.

3.4.3.8 Compressive Strength Test

During the production of grout, take representative test specimens comprising cubes in accordance with Test Method TfNSW T375 at the frequencies shown in Table R64.2 below,

and additional cubes if testing is required at ages other than seven days. Store cubes under standard curing conditions of 23°C and 100% relative humidity, in accordance with Test Method TfNSW T375.

Table R64.2 – Sampling Frequency of Test Specimens

Grout Batches	Sampling Frequency
1 batch/day	1 pair of cubes
2 batches/day	2 pairs of cubes
3 – 5 batches/day	3 pairs of cubes
6 – 10 batches/day	4 pairs of cubes

Grout cubes must be tested at 7 days in accordance with Test Method TfNSW T375 and must achieve the compressive strength specified in Clause 2.2.7.

If the result of any test for compressive strength of grout does not comply with the specified requirements, submit particulars of the proposed changes to the materials, grout mix or methods of production to the Principal, make further trial mixes and carry out further grouting trials unless prior agreement is obtained from the Principal. Down-rate the capacity of the soil nails comprising the batch and install additional nails if necessary.

3.4.3.9 Fitting of Galvanized Nuts and Bearing Plates

Fit the bearing plate at the head of the soil nail concentrically to the steel reinforcement with a tolerance of 5 mm and perpendicular to the steel reinforcement with a tolerance of 3°.

The methods used for bedding the bearing plate must ensure void-free contact over the full area of the plate.

After the grout has attained a minimum compressive strength of 32 MPa, lock tight the nuts on soil nails.

3.4.3.10 Construction Conformity Record

Submit conformity records for each soil nail installation. The record must include the following:

- (a) soil nail identification number;
- (b) bearing, inclination, position, depth, and diameter of the formed drillhole;
- (c) soil/rock type encountered with depth during drilling;
- (d) water levels;
- (e) drilling rates;
- (f) cleaning procedure;
- (g) type and age of cement;
- (h) concentration and type of additive (if any);
- (i) water/cement ratio;
- (j) bleed characteristics of grout;
- (k) mixing equipment used;

- (l) mixing time;
- (m) size of grout pipe and length;
- (n) method of grouting;
- (o) time intervals between completion of soil nail hole drilling and start of grout injection;
- (p) time of completing grout injection;
- (q) volume of grout injected;
- (r) average injection pressure,
- (s) times and details of any interruptions;
- (t) test specimens taken and 7 day grout strength obtained;
- (u) estimated elastic extension for Suitability Test and Acceptance Tests.

4 INSTRUMENTED SOIL NAIL

Where specified on the Drawings or where directed by the Principal, install instrumented soil nails with attached strain gauges. Refer to Annexure R64/E for a diagram of a typical soil nail structure with instrumentation, and typical soil nail instrumentation requirements.

Instrumented soil nails with attached strain gauges are installed to measure axial forces on the nails. The objective of the instrumentation is to ensure that the structure performs within the design requirements by measurement of tensile forces on selected soil nail bars.

The work must be carried out by a third party geotechnical instrumentation specialist with proven experience in this type of work.

Where appropriate, submit your proposed instrumentation plans for review by the Principal prior to purchase of the materials (i.e. datalogger or gauges).

Supply the instrumented soil nails at least 21 days before the commencement of soil nail installation. Protect and store these soil nails to prevent any damage to the gauges or associated cabling. Properly label each instrumented soil nail and identify its location (row and cross section detail).

Agree with the Principal a suitable location for the terminal box and concrete foundation pad if the location is not shown on the Drawings.

Provide 7 working days notice to the Principal of your intention to install a particular instrumented soil nail. Insert the instrumented soil nail into the borehole carefully to avoid damaging the strain gauges and do not grout the borehole until the Principal has tested the strain gauge circuits at the readout box.

WITNESS POINT

Process Witnessed: Installation of instrumented soil nail

Submission Details: Advise the Principal, at least 7 working days before the commencement of installation, your intended date of commencement

Progressively install 100 mm PVC tubes (containing the draw wires) in a trench to the readout box, as shown on the Drawings. Connect the clearly labelled wires to the readout box with the correct soil nail number and strain gauge location. Provide electric power necessary to operate the readout box for

the monitoring of soil nail instrumentation installed. Provide unrestricted and safe access throughout the Contract for the Principal or his representative for testing the instrumentation.

5 TESTING OF SOIL NAILS

5.1 GENERAL

Soil nails must undergo two types of testing, namely, Suitability Test for test nails and Acceptance Test for permanent nails.

The purpose of Suitability Test on test nails is to confirm that the bond strength is achieved and that the reinforcement will perform as designed prior to permanent soil nail installation. The Acceptance Test on permanent nails is a measure of quality control. Carry out tests for soil nails under the direction of a qualified and experienced engineer provided by you in the presence of your authorised representative who must record the work.

The number of test nails to be assessed by Suitability Test must be the greater of:

- (i) the number specified on the Drawings; or
- (ii) 1% of the permanent nails but not less than 2.

Subject a total of 3% of permanent nails to Acceptance Test (Clause 5.2.2).

The locations of the test nails must be approved by the Principal.

5.2 SOIL NAIL TESTS

5.2.1 Suitability Test

Prior to the installation of permanent nails, install Suitability Test nails to the satisfaction of the Principal. The tests must establish adequacy of the soil nail installation with respect to bond stresses between the nail and soil for the various ground conditions which apply and must involve subjecting soil nails to axial pull-out loads until failure occurs, or to 80% of the ultimate tensile strength (UTS) of the soil nail bar.

These nails must have a minimum bond length of 3 m unless otherwise shown on the Drawings. Provide a minimum debonded zone of 1 m length of soil nail immediately behind the facing in order to prevent influence on the test result from the load test reaction system. This debonded length requirement may be waived if the load test reaction system will not exert any pressure on the slope surface within a metre radius from the circumference of the test nail drill hole.

The soil nails subject to Suitability Test are additional to the permanent nails shown on the Drawings.

Submit to the Principal testing arrangements to suit your particular working method and equipment, and calculations to verify load transfer, reactions and load testing programme, in conjunction with actual Suitability Test bar extensions and adjusted extensions deducting the calculated elastic bar extension.

Give the Principal at least one working day notice of your intention to carry out Suitability Test.

Test the soil nails subject to Suitability Test to pull-out failure or to 200% of the design working load, whichever is lower.

Adjust the reinforced bar diameter or strength grade, if necessary, at your cost to ensure that the test load does not exceed 80% of the UTS of the soil nail bar. The test nails must be installed in an identical manner, including time delays between various operations, and at locations with ground conditions representative of that of the permanent nails and as approved by the Principal.

Injected grout must have achieved a compressive strength of 40 MPa before performing the Suitability Test.

Soil nails subjected to Suitability Tests must be loaded in the working load increments and held at these loads for the period specified in Table R64.3 below:

Table R64.3 – Suitability Test: Load Increments and Minimum Periods of Observation

Load Cycle No.	Test Loads (% of Design Working Load)	Minimum Period of Observation at Peak Test Load (minutes)
1	10 → 60 → 10	10
2	10 → 100 → 10	60
3	10 → 150 → 10	10
4	and thereafter the load is 200% of the Design Working Load. The test load must be limited to 80% of the ultimate tensile strength of soil nail bar.	180

The rate of load application must be in the range of 3 to 5 kN/minute. At each load cycle, hold the load at the peak test load for the period of observation as specified in Table R64.3. Record the head movement at 1, 2, 3, 5, 6, 10, 20, 30, 50, 60, 90, 120, 150 and 180 minutes.

The Suitability Test will be considered successful if all the following are satisfied:

- (a) A total creep movement of less than 2 mm between the 6 and 60 minutes readings is measured during Cycle 4; and
- (b) A total creep movement of less than 1mm between the 60 and 180 minutes readings is measured in Cycle 4; and
- (c) The creep rate is linear or decreasing, when plotted against the logarithm of time throughout Cycle 4.

If the test nail cannot be pulled out within 80% of the ultimate tensile stress of the soil nail bar, cut-off the bar flush with the finishing ground and grout the remaining part of the drillhole.

When directed by the Principal, extract the entire test nail from the drillhole for inspection. Unless otherwise directed by the Principal, fill the void caused by the extraction of the soil nail with grout.

If the extracted soil nail indicates that full penetration of grout into the drillhole has not been achieved, or any other test result indicates that the soil nail has not been constructed in accordance with this Specification, submit revised soil nail construction procedures (such as drilling method, grout mix design and grouting techniques) to the Principal for approval.

Repeat the Suitability Test on a replacement test nail. Any modifications of construction procedures, replacement nails and associated tests must be at your cost.

The submission of the Suitability Test record as stipulated in Clause 5.4 constitutes a Hold Point.

HOLD POINT

Process Held: Installation of permanent nails

Submission Details: Suitability Test record

Release of Hold Point: The Principal will consider the submitted documents prior to authorising the release of the Hold Point

5.2.2 Acceptance Test

A total of 3% of permanent nails, unless otherwise approved by the Principal, must be subjected to Acceptance Test. Of these, half must be in the top row, a quarter in the middle row and a quarter in the bottom row. The Principal will nominate the locations of soil nails subject to Acceptance Test. The Principal may direct additional locations for Acceptance Test if necessary.

Provide a minimum debonded zone of 1 m length of soil nail immediately behind the facing in order to prevent influence on the test result from the load test reaction system. This debonded length requirement may be waived if the load test reaction system will not exert any pressure on the slope surface within a metre radius from the circumference of the test nail drill hole.

Carry out Acceptance Test in the presence of the Principal prior to the application of concrete facing to the exposed ground.

Injected grout must have achieved a compressive strength of 40 MPa before performing Acceptance Test.

The maximum applied load during the acceptance test must not exceed 80% of the ultimate tensile strength of the soil nail bar.

Provide actual acceptance test bar extensions and adjusted extensions deducting the calculated elastic bar extension.

Soil nails subject to acceptance tests must be loaded to the load increments and held at these loads for the periods specified in Table R64.4 below:

Table R64.4 - Acceptance Test: Load Increments and Minimum Periods of Observation

Load Increment (% of Working Load of each test nail as shown in Drawings)	Minimum Period of Observation (minutes)
25	5
50	5
100	5
150	180 (Creep Test)
100	5
50	5
25	5

Note: The above stages constitute one full cycle of testing.

The rate of load application must be in the range of 3 to 5 kN/minute. At each load increment, hold the load at the test load for the period of observation as specified in Table R64.4. Record the displacement at the beginning and the end of the observation period. For the creep portion of the test, record movements at 1, 2, 3, 5, 6, 10, 20, 30, 50, 60, 90, 120, 150 and 180 minutes.

The acceptance test will be considered successful if all of the following are satisfied:

- (a) A total creep movement of less than 2 mm between the 6 and 60 minutes readings is measured in Creep Test hold period; and
- (b) A total creep movement of less than 1 mm between the 60 and 180 minutes readings is measured in Creep Test hold period; and
- (c) The creep rate is linear or decreasing, when plotted against the logarithm of time throughout Creep Test hold period.

Where a test nail does not meet the acceptance criteria, test an additional 2 soil nails in the vicinity of the nonconforming soil nail. If any soil nail fails an Acceptance Test, abandon the soil nail and completely remove it from the drillhole by a method acceptable to the Principal. Unless otherwise instructed by the Principal, fill the drillhole by grouting. If the failed soil nail cannot be pulled out within 80% of the UTS of the soil nail bar, cut-off the bar flush with the finishing ground and grout the remaining part of the drillhole. Install another soil nail adjacent to the abandoned one for additional test at your cost.

5.3 TESTING AND MEASURING EQUIPMENT

Measure displacements using two dial gauges mounted on a tripod or fixed to a rigid support that is independent of the jacking mechanism and the soil nail. The dial gauge must be capable of measuring to an accuracy of 0.01 mm. Dial gauges must be set up so as to avoid any misalignment and eccentricity to the direction of movement of the soil nail, and zeroed after alignment and initial load has been applied.

Establish a stable datum to measure the movement at the bar head. Measure movements of the bar head relative to the datum to an accuracy of ± 0.1 mm.

Use a hydraulic jack, with a minimum travel of 150 mm, to apply the load. Apply the load to the soil nail via a load bridge to ensure that the surface reaction is clear of the soil nail. Measure the test load with an accuracy of ± 1 kN. Add a centre hole load cell in series with the jack for use during tests.

Calibrate the hydraulic jack, pressure gauge and load cell as a set. Submit to the Principal the calibration certificates, which must be less than 12 months old, for the jack, pressure gauge and load cell prior to the soil nail testing. The calibration must be undertaken by a registered NATA laboratory. The identification numbers on the field test equipment must match the identification numbers on the calibration data sheets. Take care to ensure that the load cell is properly aligned with the axis of the soil nail bar and the jack.

The calibration certificate must be accompanied by the related calibration curve and tabulated record of hydraulic pressure against jack load. Perform the calibration for the loading and unloading operations of the jack over its full working range.

Submit details of the installation, load measuring and movement measuring devices and the method of calculating/defining the bar elastic extension, to the Principal for approval.

5.4 RECORDS OF TESTS

Keep records of any Suitability Test and Acceptance Test carried out. These records must include:

- (a) Date;
- (b) Soil nail number;
- (c) Number of tests carried out;
- (d) Load/ extension measurements;
- (e) Any variations from the specified procedure;
- (f) Details of test results;
- (g) Any unforeseen or unusual conditions encountered;
- (h) Time intervals between completion of test soil nail hole drilling and start of grout injection;
- (i) Actual and calculated bar extensions, including and excluding elastic bar extension.

Tabulate and plot the soil nail head and bearing plate movements on a graph for assessment together with all other relevant information.

Submission of the testing records for the test nails constitutes a Hold Point.

HOLD POINT

Process Held: Acceptance of permanent nails

Submission Details: Within one week of completion, submit to the Principal test results on permanent nails in a prior agreed format

Release of Hold Point: The Principal will consider the submitted documents prior to authorising the release of the Hold Point

6 PLACEMENT OF CONCRETE FACING

6.1 GENERAL

Construct the concrete facing either from formed concrete or shotcrete, and reinforced with galvanized steel mesh/bars as shown on the Drawings.

Place formed concrete in accordance with Specification TfNSW B80.

Place shotcrete in accordance with Specification TfNSW R68.

6.2 SLOPE SURFACE PREPARATION

Carry out slope surface preparation in accordance with TfNSW R68.

During placement of concrete, protect the drainage system against contamination to ensure proper functioning.

Install thickness measuring pins on a 1.5 m square grid with a minimum 75 mm cover to reinforcement. These must be durable, non-corrosive and of sufficient length to provide adequate fixity during application of formed concrete or shotcrete.

Alternative methods for ensuring that the required minimum thickness of concrete is being applied may be approved by the Principal. Firmly fix steel reinforcement to prevent movement and vibration while the shotcrete is being applied.

6.3 DRILLING AND GROUTING OF STEEL MESH SUPPORT ANCHOR BARS

Give at least one working day notice of your intention to commence drilling of the steel anchor bar holes to support steel mesh.

Each anchor bar hole may be sealed until the anchor bar is ready to be installed to prevent the entry of foreign matter.

Immediately prior to installing the bar, clean the walls of the drillhole into which it is to be installed of all deleterious materials or accumulations, which would impair the effectiveness of the anchor bar. Following cleaning, gauge the hole to confirm that it is unobstructed for the full depth and diameter.

The anchor bar and centralisers must be assembled and positioned in the hole in accordance with the requirements of this Specification.

All grouting operations must be carried out by personnel skilled and experienced in this type of work.

The grouting supervisor must inspect the anchor bars assemblies prior to installation and verify that bars and grouting tubes have been correctly installed.

6.4 APPLICATION OF SHOTCRETE

6.4.1 General

Application of shotcrete must be in accordance with TfNSW R68.

Apply shotcrete in successive layers not exceeding 75 mm in thickness and with adequate adhesion to the surface or previous layers of shotcrete to prevent slumping or sagging. Unless approved otherwise, complete shotcreting to a whole panel (preferably not less than 10 m in length) prior to shotcreting the next panel.

Protect adjoining rock areas not required to be shotcreted from splash and spray rebound. Remove splash or rebound material on these adjoining surfaces by air-water jet or other suitable means as work proceeds.

Shotcrete must not cover or impair the function of slotted pipe drain or strip drain outlets which protrude through the shotcrete layer. You may use temporary plugs to protect such outlets during the shotcreting process.

6.4.2 Construction Joints

Keep construction joints to a minimum, and their types and locations must be approved by the Principal.

Form construction joints by one of the following methods:

- (a) Placing or trimming the joint edge not more than 45° with the base;

- (b) Forming an approximately square joint to part depth by placing the shotcrete against a former or making a cut to the depth of the reinforcement; or
- (c) Forming a full-depth square joint placed against a former.

Where a 30° taper is adopted for a construction joint, it must not be used as an end of day joint. Such tapered joints must be thoroughly cleaned and wetted by air water jet before continuing application of the adjoining shotcrete layer.

Taper the shotcrete over approximately 500 mm from the edges of the mesh (where used). Completely backfill any cut back areas with the final layer of shotcrete flush with the adjacent slope face.

6.4.3 Curing of Shotcrete

Carry out curing of shotcrete in accordance with TfNSW R68.

6.4.4 Testing of Shotcrete

Carry out testing of shotcrete for conformity in accordance with TfNSW R68.

Holes created by removal of cores must be thoroughly cleaned and dampened and reinstated with mortar (or other approved product) to achieve the same durability as the shotcrete.

6.4.5 Checking Integrity of Shotcrete

Check the integrity of the shotcrete for hollow areas by sounding with a hammer not more than 24 hours after placement.

Alternative methods may be used with the approval of the Principal.

Rectify defective areas by removal and replacement with fresh material with the area to be treated being a minimum of 300 mm x 300 mm and subject to the approval of the Principal. Remove and replace shotcrete which lacks uniformity, exhibits segregation, honeycombing, or lamination or shows evidence of other defects (e.g. dry patches, sand pockets or sagged slumped material) with fresh shotcrete.

7 RECORDS FOR INSTALLATION

Submit records for the installation of anchor bars, strip drains, steel reinforcement and shotcrete test records within three working days of completion of installation. Within the said three working days from completion of installation and after submission of conformity records, present the slope area to be covered by shotcrete to the Principal for inspection.

ANNEXURE R64/A – PROJECT SPECIFIC REQUIREMENTS

Insert any project specific requirements here. If there are none, delete this comment and replace the title with “(NOT USED)”

ANNEXURE R64/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 R64P1 - Supply, Installation and Testing of Test Nails

The unit of measurement is “each” test nail installed and tested, for each length nominated.

The schedule rate must include all materials and work associated with drilling holes, supply, installation and grouting of the soil nail and **conducting of Suitability Test**, as shown on the Drawings or directed by the Principal.

Pay Item R64P2 – Supply and Installation of Permanent Nails

The unit of measurement is “each” permanent nail installed, for each length nominated.

The schedule rate must include all materials and work associated with drilling holes, supply, installation and grouting of the permanent nail, as shown on the Drawings or directed by the Principal. This item is not applicable to permanent nails with strain gauges and cables attached.

Pay Item R64P3 – Permanent Nails with Strain Gauges and Cables (where directed)

Pay Item R64P3.1 – Supply and Installation of Permanent Nails with Strain Gauges and Cables

The unit of measurement is “each” permanent nail installed with strain gauges and cables attached, for each length nominated.

The schedule rate must include all materials and work associated with drilling holes, supply of soil nails, strain gauges, cables and readout box, attaching strain gauges and cables to soil nails, numbering of the cables, installation and grouting of the soil nails with strain gauges and cables attached, as shown on the Drawings or directed by the Principal.

Pay Item R64P3.2 – Supply and Installation of PVC Pipe for Strain Gauges

The unit of measurement is the linear metre of 100 mm PVC pipe installed.

The schedule rate must include all materials and work associated with excavation of slot into rock to house the PVC pipe in the cut face, excavation of surfaces trench to run pipes to readout

box, connecting and placing the pipe, and backfilling around the pipe, as shown on the Drawings or directed by the Principal.

Pay Item R64P3.3 – Other Miscellaneous Works for Instrumentation

This is a Lump Sum item.

This Pay Item covers the miscellaneous works necessary for the monitoring of soil nail instrumentation installed, including wiring connection to the readout box, concrete pad and the supply of electric power necessary to operate the readout box.

Pay Item R64P4 – Acceptance Tests of Permanent Nails

The unit of measurement is “each” acceptance test conducted on permanent nails, in accordance with Clause 5.2.2 and as directed by the Principal.

Pay Item R64P5 – Supply and Placing of Shotcrete

The unit of measurement is per square metre of surface covered by the full thickness of shotcrete, as shown on the Drawings or directed by the Principal.

The schedule rate must include all materials and work associated with surface preparation, supply and fixing of reinforcement, supply, application and curing of shotcrete and provision of drainage holes through the shotcrete facing from strip drains.

Pay Item R64P6 – Strip Drains

The unit of measurement is per linear metre of strip drain installed behind the shotcrete facing, as shown on the Drawings or directed by the Principal.

The schedule rate must include all materials and work associated with installation of the strip drains and their connection to the existing or newly constructed site drainage system as shown on the Drawings.

ANNEXURE R64/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
2.1	Hold	Submission of material certificates
2.2.7	Hold	Submission of grout mix proportions, additives and test results
3.1	Hold	Submission of Construction Program and Method Statement
3.3	Witness	Exposed slope face after each excavation “lift”
4	Witness	Installation of instrumented soil nail
5.2.1	Hold	Submission of Suitability Test record
5.4	Hold	Submission of test results on permanent nails

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	Certificates of conformity of all materials used for the Works
2.2.1	Test certificates for soil nail steel bars
2.2.4	Documentary evidence from manufacturer that proposed sheathing complies with requirements
2.3	Conformity records for the supply of either the formed concrete facing or shotcrete materials used for the facing
3.3	Conformity records for the construction sequence
3.4.2	Details of hole set out, drilling method using specialised equipment, hole depth, description of materials drilled and method of ensuring hole cleanness
3.4.3	Conformity records for soil nail installation and grouting
4	Drawings and other information detailing instrumented soil nails for monitoring the performance of the completed works
5.4	Conformity records for soil nail tests
6.4	Conformity records for thickness of shotcrete applied as the facing
7.0	Set of fully completed records including details of any changes to the Drawings, additional soil nails installed or changes to the configuration of the soil nails such as spacing or length

ANNEXURE R64/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 must include, but is not limited to, the following:

- (a) Nominated personnel to supervise and carry out the work together with evidence of relevant training and experience (Clause 3.1);
- (b) Details of method of installation, grouting and testing of soil nails (Clauses 3.1, 3.4 and 5);
- (c) Details of method of installation of instrumented soil nails with strain gauges (if any) (Clauses 3.1, 4 and Annexure R64/E);
- (d) Proposed grout mix proportions, the method of grout production and the results of trial grouting mix (Clauses 2.2.7, 3.1 and 3.4.3.3);
- (e) Details of method of applying shotcrete (Clause 3.1);
- (f) Construction program and construction sequence including method of excavation and staging of works (Clauses 3.1 and 3.3);
- (g) Details of method of storage and handling of soil nail components (Clause 3.2);
- (h) Details of method of fitting of galvanized nuts and bearing plates (Clause 3.4.3.9).

ANNEXURE R64/E – INSTRUMENTED SOIL NAILS

A typical soil instrumented nail configuration is shown below in Figure R64/E.1.

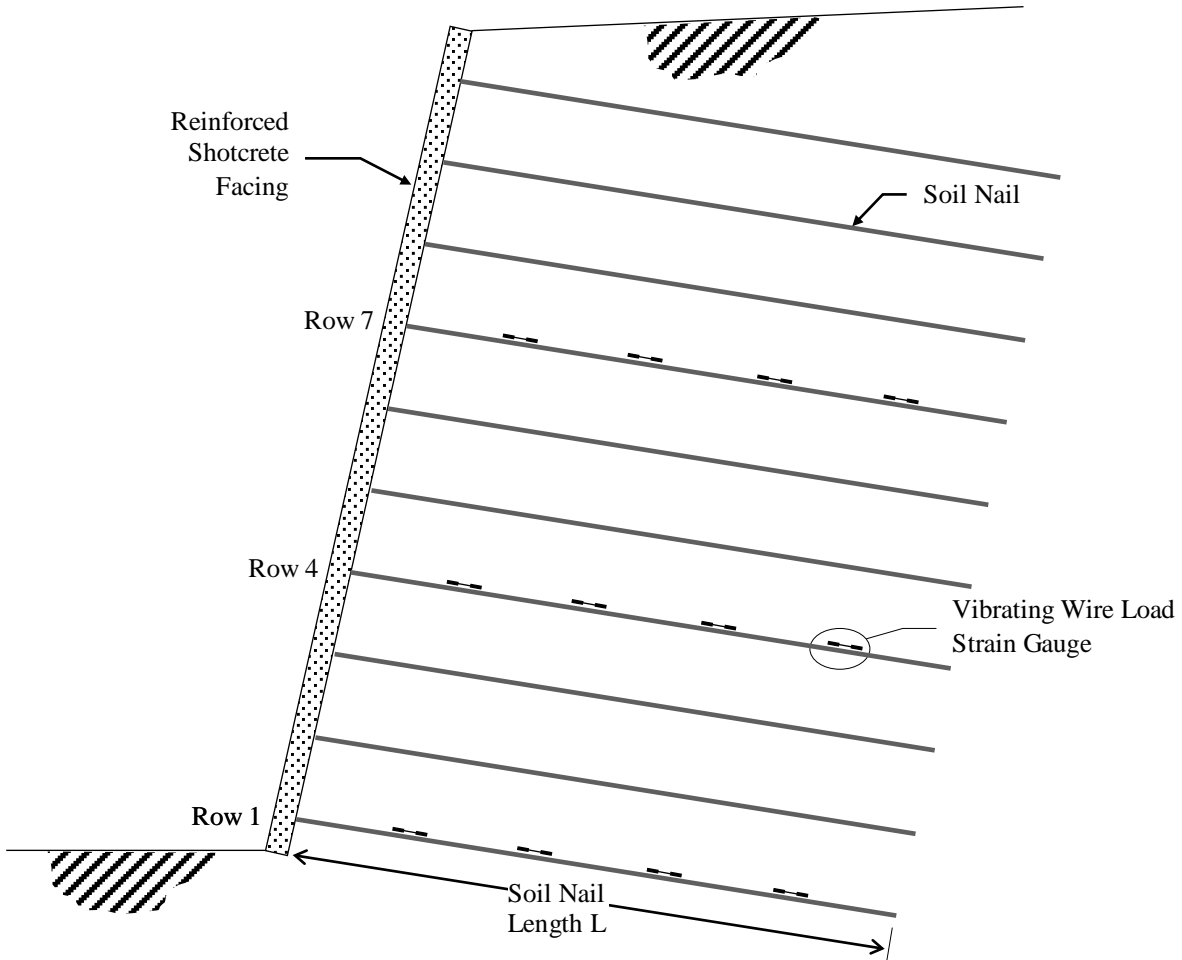


Figure R64/E.1 – Typical Soil Nail Structure with Instrumentation

Typical soil nail instrumentation requirements are given in Table R64/E.1 below.

Table R64/E.1 Typical Soil Nail Instrumentation Requirements

Item	Instrumentation	Details
1.	Strain gauge type	<p>Weldable vibrating wire type strain gauges to measure directly axial tensile forces.</p> <p>Vibrating wire gauges to be calibrated over the expected range of forces to the soil nail bars calculated by the Designer.</p> <p>Output of the vibrating wire gauges to be in terms of frequency calibrated to load.</p>
2.	Location of gauges	<p>For each instrumented cross section, gauges must be installed on rows of soil nails as shown on the Drawings. Each nominated soil nail must have strain gauges installed along the bar at locations shown on the Drawings.</p> <p>A typical arrangement is shown in Figure R64/E.1.</p>
3.	Temperature sensors	<p>For each cross section one temperature sensor must be installed in the soil nailed structure approximately 3 metres behind the facing. The temperature sensor may be a thermocouple device</p>
4.	Number of instrumented cross sections	<p>The Designer will nominate the number of instrumented cross sections depending on the Project and the criticality of the structure.</p>
5.	Total number of gauges	<p>The Designer will nominate the number of vibrating wire type load – strain gauges. In addition, one pair of strain gauges must be installed near the front end of the soil nail to measure shotcrete facing effects.</p>
6.	Gauge calibrations	<p>Strain gauges must be calibrated on an instrumented soil nail test bar in the laboratory to determine the axial load/strain frequency response of the system.</p>
7.	Sheath protection of gauges	<p>All gauges must be waterproofed by protective heat shrink plastic and electrical tape.</p>
8.	Installation of gauges	<p>Gauges must be micro- welded securely onto the soil nail bars to ensure correct readout of load/strain.</p> <p>Gauges and wiring must not interfere with the installation or grouting process of the soil nails.</p>
9.	Installation of instrumented soil nails	<p>Instrumented soil nails must be carefully installed using dedicated lifting slings to eliminate bending or flexing of the soil nails during insertion into the drill holes. Flexing or mishandling of the instrumented soil nails may induce unwanted tension into the gauges which must be avoided.</p>
10.	Installation gauge checks	<p>After installation but prior to grouting for the particular soil nail, all gauges must be checked for correct readout and electrical continuity.</p>

Item	Instrumentation	Details
11.	Monitoring of gauges during construction	Gauge readings must be taken at the following stages: (i) 24 hours after grouting, (ii) Prior to shotcreting, (iii) 24 hours after shotcreting, and (iv) 2 days after each excavation stage as shown on the PROJECT QUALITY PLAN.
12.	Ducts and cabling	Cabling must be housed in electrical PVC ducting placed under the shotcrete or concrete facing. The ducting must be waterproof. Sufficient cabling is required for all gauges to reach the datalogger device.
13.	Data logger	A multichannel datalogger device (48 channel) is required. The number of channels may vary depending on the actual instrumentation requirements of the Designer. The datalogger must be capable of continuously recording gauge data up to 6 months in internal memory. The datalogger must be capable of being programmed to taking readings from all gauges/sensors every 6 hours. Multiplexing may be used.
14.	Datalogger power supply	Either dedicated 240V mains voltage or power from solar cell panels is required. Solar cell panels must be installed on a separate mast above the readout box and vandal proof.
15.	Datalogger output	The datalogger must be supplied with modem facility for remote downloading of monitoring information.
16.	Datalogger labelling	All cabling from gauges must be clearly labelled to the datalogger to indicate gauge number, soil nail location and cross section details.
17.	Terminal box	A heavy duty steel terminal box (lockable and vandal proof) must be supplied to house the datalogger. The box must have a front door opening with steel hinges. Cabling must run in PVC ducting from the underside of the terminal box.
18.	Concrete pad	A reinforced concrete pad must be supplied as a foundation for the terminal box.
19.	Trenching requirements	All cabling from the instrumented sections must run through 100 mm PVC ducting to the terminal box. Trenching is required to lay the ducting to a depth of 300 mm. Trench backfill must be compacted to cover the ducting.

ANNEXURES R64/F TO R64/L – (NOT USED)

ANNEXURE R64/M – REFERENCED DOCUMENTS

Refer to Clause 1.2.5.

TfNSW Specifications

TfNSW Q	Quality Management System
TfNSW R40	Horizontal Drains
TfNSW R63	Geotextiles (Separation and Filtration)
TfNSW R68	Shotcrete Work Without Steel Fibres
TfNSW B80	Concrete Work for Bridges
TfNSW 3211	Cements, Binders and Fillers
TfNSW 3557	Flexible Strip Filter Drains

TfNSW Test Methods

TfNSW T375	Sampling and Testing for Grout
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Australian Standards

AS 1012	Methods of testing concrete
AS 1112.3	ISO metric hexagon nuts – Product grade C
AS 1214	Hot-dip galvanized coatings on threaded fasteners (ISO metric coarse thread series)
AS 1275	Metric screw threads for fasteners
AS 1379	Specification and supply of concrete
AS 1478.1	Chemical admixtures for concrete, mortar and grout – Admixtures for concrete
AS 1627	Metal finishing – Preparation and pretreatment of surfaces – Method selection guide
AS 2758.1	Aggregates and rock for engineering purposes – Concrete aggregates
AS 3678	Structural steel – Hot-rolled plates, floorplates and slabs
AS 4131	Polyethylene (PE) compounds for pressure pipes and fittings
AS 4671	Steel reinforcing materials
AS/NZS 4680	Hot-dip galvanized (zinc) coatings on fabricated ferrous articles
AS/NZS ISO 9001	Quality management systems – Requirements

ASTM Standards

C939	Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)
C940	Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory

C1090	Standard Test Method for Measuring Changes in Height of Cylindrical Specimens of Hydraulic-Cement Grout
D1784	Standard Specification for Rigid Poly (Vinyl Chloride) (PVC) Compounds and Chlorinated Poly (Vinyl Chloride) (CPVC) Compounds
D3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
D4327	Standard Test Method for Anions in Water by Chemically Suppressed Ion Chromatography