

TRANSPORT FOR NSW (TfNSW)
QA SPECIFICATION TS 02168.1 (R64)

SOIL NAILING

NOTICE

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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 TS 03356.1 (TfNSW 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
Ed 1/Rev 8	1.2.3 1.3 Table R64.1 Table R64.3 2.3.2 2.3.3 2,3,4 2.3.5 3.4.5.7 3.5.1 3.5.2 3.5.4.1 3.5.4.3 3,.5.4.4 C2 Annexure R6 4/M	New designation for Q5 & Q6 added. Term and definition for ASTM added. New designations added for TfNSW test methods. New designation added for TfNSW test method New designation for TfNSW B80 added. New designation for TfNSW R68 added. New designation for TfNSW R40 added. New designation for TfNSW 3557 added. New designation for TfNSW T375 added. New designations for TfNSW B80 & TfNSW R68 added. New designation for TfNSW R68 added. New designation for TfNSW R68 added. New designation for TfNSW R68 added. New designation for TfNSW Q5 & Q6 added New designations added. AS 2832.1, AS 4969.12, D2974 added	MGE	17/12/25

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:

- (a) it produces zinc alloy layers of similar thickness to hot-dip galvanizing, without being susceptible to hydrogen embrittlement; and
- (b) 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 A 1059M “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 the following:

- (a) The Drawings clearly detail the construction sequence for the soil nail walls.
- (b) The actual construction sequence by the Contractor conform strictly to the construction sequence specified in the Drawings and other requirements in this Specification.
- (c) 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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IC-QA-R64

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 the Specification	1
1.3 Definitions	2
1.4 Typical Soil Nail Details	4
1.5 Planning Documents	5
1.6 Design LIFE and Technical Maintenance Plan	5
2 MATERIALS	5
2.1 General	5
2.2 Soil Nails	6
2.3 Facing	12
3 CONSTRUCTION	13
3.1 General	13
3.2 Storage and Handling	14
3.3 Construction Sequence	15
3.4 Soil Nail Installation	16
3.5 Placement of Facing	20
3.6 Fitting of Galvanized Nuts and Bearing Plates	23
4 INSTRUMENTED SOIL NAIL	23
5 TESTING OF SOIL NAILS	24
5.1 General	24
5.2 Soil Nail Tests	24
5.3 Testing and Measuring Equipment	29
5.4 Records of Tests	30
6 RECORDS FOR INSTALLATION	30
ANNEXURE R64/A – PROJECT SPECIFIC REQUIREMENTS	32
ANNEXURE R64/B – MEASUREMENT AND PAYMENT	33
ANNEXURE R64/C – SCHEDULES OF HOLD POINTS, WITNESS POINTS AND IDENTIFIED RECORDS	35
C1 Schedule of Hold Points and Witness Points	35
C2 Schedule of Identified Records	35
ANNEXURE R64/D – PLANNING DOCUMENTS	36
ANNEXURE R64/E – INSTRUMENTED SOIL NAILS	37
ANNEXURES R64/F – LISTS OF APPROVED HOLLOW BAR SOIL NAIL SYSTEMS AND CONDITIONS OF USE	40

ANNEXURES R64/G TO R64/L – (NOT USED)..... 41

ANNEXURE R64/M – REFERENCED DOCUMENTS..... 42

LAST PAGE OF THIS DOCUMENT IS 43

FOREWORD

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REVISIONS TO PREVIOUS VERSION

This document has been revised from Specification TS 02168.1 (TfNSW R64) Edition 1 Revision 7.

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 TS 02168.1 (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 into the retained earth mass at nominated positions and levels shown on the Drawings. The retained earth mass may be soils, weathered rocks or a combination of both. The bonded length of soil nails may be embedded in soils, weathered rocks or combination of both.

It covers the requirements for supply and installation of soil nails including compliance testing, and the associated 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 TS 00118.1 (TfNSW Q5) or TS 01572.1 (TfNSW Q6) as applicable for the definitions of **HOLD POINTS** and **WITNESS POINTS**.

The records listed in Annexure R64/C are **Identified Records** for the purposes of TS 00118.1 (TfNSW Q5) or TS 01572.1 (TfNSW Q6) as applicable 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:

Acceptance Test Nail:	A soil nail which is subject to Acceptance Test.
Annulus:	Radial space between the soil nail and the drillhole wall.
Anchor bar:	A bar which holds facing’s reinforcement in place for application of shotcrete or concrete.
Asset Custodian:	The TfNSW Division accountable for the end-to-end life cycle management and performance of assets (including asset condition, risk and reporting) on behalf of the Asset Owner to achieve agreed customer and community outcomes.
ASTM:	ASTM International (formerly known as American Society for Testing and Materials).
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 or shotcrete until the concrete or shotcrete has developed required properties.
Ground type:	A stratum of ground within which materials have the same properties as proven by a geotechnical assessment substantiated by results of site investigation.
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.
Rebound:	Shotcrete material that bounces off the receiving surface.
Sealed curing:	Curing at ambient temperature in which the 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 drilled hole and grouted in place.
Standard moist curing:	Standard moist curing as defined in AS 1012.8.4.
Suitability Test Nail:	A soil nail specially installed on site for testing its ultimate pull out capacity through the Suitability Test procedure.
Technical Maintenance Plan:	Technical maintenance plan (refer to Specification TS 01517.1).
UTS:	Ultimate tensile strength.
Working Nail:	A soil nail that is not a Suitability Test Nail.
Wet curing:	Curing at ambient temperature in which the concrete/shotcrete 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

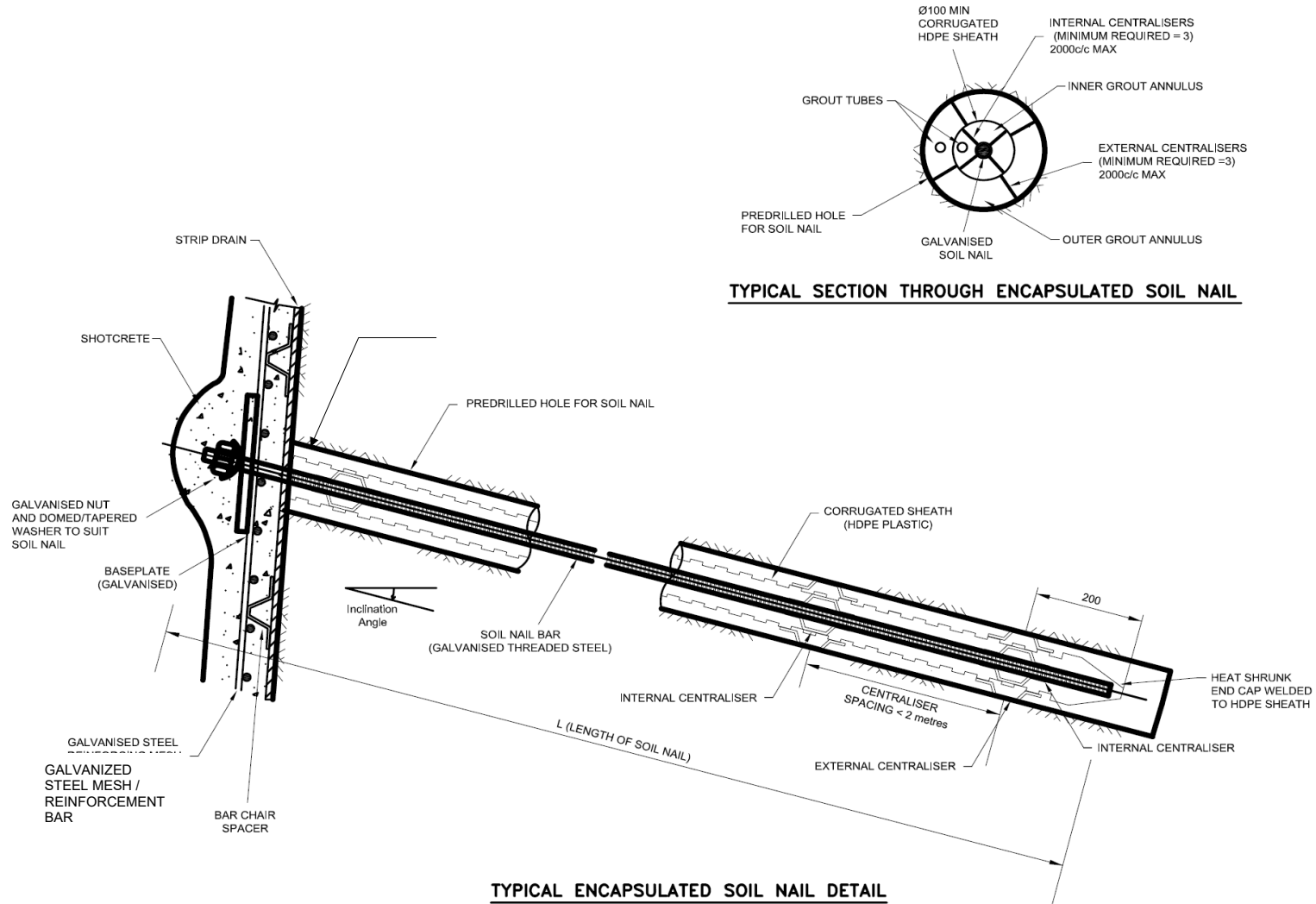


Figure R64.1 – Typical Soil Nail Details
(for illustration purposes only – refer to Drawings for construction details)

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.

1.6 DESIGN LIFE AND TECHNICAL MAINTENANCE PLAN

For soil nails with a design life of less than 100 years and required to function beyond the construction phase of a project, the design life must be approved by the Asset Custodian.

Project specific Technical Maintenance Plan (TMP) for the whole of design life must be prepared and approved according to Specifications TS 01517.1, TS 01517.2 and TS 01517.3 for soil nails which are required to function beyond the construction phase of a project.

2 MATERIALS

2.1 GENERAL

Materials used for manufacturing soil nails and 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 facing must be accompanied by a manufacturer’s certificate of conformity, verifying that the proposed materials comply with all the requirements of this Specification. The certificate of conformity must include the test certificates stipulated in 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 Reinforcement Bars

Soil nail reinforcement bars must be either solid steel bars, or hollow steel bars if specified in Annexure R64/A.

Solid steel bars must be Grade 500N or Grade 600N deformed bar to AS/NZS 4671.

Hollow steel bars must be one of the TfNSW registered proprietary hollow bar soil nail systems listed in Annexure R64/F. Maximum design life of hollow bar soil nail systems is 20 years.

You must provide test certificates to demonstrate 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, unless otherwise stated in the TfNSW approved Proprietary Hollow Bar Soil Nail Systems.

Reinforcement bars must be hot-dip galvanized complying with 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

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.

You must provide test certificates to demonstrate conformity. Each delivery of couplers must be accompanied by documentation showing the mill certificate and Lot number.

2.2.3 Nuts

Unless otherwise stated in the TfNSW approved Proprietary Hollow Bar Soil Nail Systems, 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/NZS 1214, or galvanized by an alternative process approved by the Principal.

You must provide test certificates to demonstrate conformity. Each delivery of nuts must be accompanied by documentation showing the mill certificate and Lot number.

2.2.4 Encapsulation and Sacrificial Steel Thickness

Encapsulate any soil nail in a corrugated plastic sheath unless:

- (a) the design life of the soil nail is less than 2 years; or

- (b) the ground types embedding the soil nail meet all requirements in Table R64.1 and the sacrificial steel thickness allowed in the design meets the requirements in Tables R64.2a to R64.2d.

For stray current, a thorough investigation must confirm the stray current voltage fluctuations meet the requirement in Table R64.1. For other properties, a minimum of 5 laboratory test results on each property is required and all results must meet the requirements in Table R64.1 for each ground type.

Table R64.1 – Requirements on Ground Type for Unencapsulated Soil Nails (Solid Steel Bars and Hollow Steel Bars)

Property	Test Method	Requirement
Resistivity (saturated)	TS 02795.43 (TfNSW T185)	> 30 ohm-m
pH	TS 02811.02 (TfNSW T1002)	5 to 10
Peroxide sulfur content	AS 4969.12	< 0.04%
Chloride ion content	TS 02811.10 (TfNSW T1010)	< 0.01%
Organic content	AS 1289.4.1.1	< 1%
Stray current voltage fluctuations	AS 2832.1	< 20 mV

Table R64.2a – Sacrificial Steel Thickness Across Diameter Of Unencapsulated Solid Steel Bars (mm)

Plasticity Index TS 02795.05 (TfNSW T109)	% passing 75 µm (AS 1289.3.6.1)	Design Life ⁽¹⁾			
		2 years	20 years	50 years	100 years
≤ 12	≤ 15	0	0.6	1.3	2.0
≤ 12	> 15	0	0.9	2.0	3.0
> 12	any	0	1.5	3.3	5.0

Note:

⁽¹⁾ Maximum design life of unencapsulated solid steel bars is 100 years.

Table R64.2b – Sacrificial Steel Thickness Across External Diameter of Unencapsulated Hollow Steel Bars (mm)

Plasticity Index TS 02795.05 (TfNSW T109)	% passing 75 µm (AS 1289.3.6.1)	Design Life ⁽¹⁾	
		2 years	20 years
≤ 12	≤ 15	0.4	1.2
≤ 12	> 15	0.6	1.8
> 12	any	1.0	3.0

Note:

⁽¹⁾ Maximum design life of unencapsulated hollow steel bars is 20 years.

Table R64.2c – Sacrificial Steel Thickness Across Internal Diameter of Unencapsulated Hollow Steel Bars (mm)

Design Life ⁽¹⁾	
2 years	20 years
0.4	1.2

Note:

⁽¹⁾ Maximum design life of unencapsulated hollow steel bars is 20 years.

For couplers in unencapsulated soil nails, sacrificial steel thickness allowed in the design meets the requirements in Table R64.2d:

Table R64.2d – Sacrificial Steel Thickness Across External and Internal Diameters of Couplers

Soil Nail Type	External/Internal Diameter	Sacrificial Steel Thickness
Solid bar soil nails	Across external diameter	100% of sacrificial steel thickness in Table R64.2a
	Across internal diameter	50% of sacrificial steel thickness in Table R64.2a
Hollow bar soil nails	Across external diameter	100% of sacrificial steel thickness in Table R64.2b
	Across internal diameter	50% of sacrificial steel thickness in Table R64.2b

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

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

- ASTM D 3350 for HDPE with cell classification 335530C, or
- ASTM D 1784 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, sheath joints must be provided by lapping 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.

You must provide test certificates to demonstrate conformity. Each delivery of corrugated plastic sheaths must be accompanied by documentation showing the mill certificate and Lot number.

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 to steel reinforcement interface.

Plastic slip-on devices must not be used as centralisers. The grout tube spirally wound around a soil nail must not be used as a centraliser.

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

Other than hollow bar soil nails, 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 or reinforcement bar, or between the bar and the drillhole.

For hollow bar soil nails, provide a centraliser for each segment of reinforcement bar with a maximum length of 3 m.

A minimum grout cover of 25 mm must be provided 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.

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/NZS 4131. Tubing must be of adequate strength to resist damage during both installation and grouting.

Grout tubes must be provided such that grout will be injected into the bottom of the intended grout sections directly from the grout tubes. Provide grout tubes in accordance with Table R64.3 below:

Table R64.3 – Required Grout Tubes

Soil Nail Types	Soil Nails subject to Suitability Tests or Acceptance Tests	Required Grout Tubes
Encapsulated solid bar soil nail	Yes	(a) one for grouting the bonded length outside the encapsulation; (b) one for grouting the bonded length inside the encapsulation; (c) one for grouting the debonded length outside the encapsulation; (d) one for grouting the debonded length inside the encapsulation.
	No	(a) one for grouting outside the encapsulation; (b) one for grouting inside the encapsulation.
Unencapsulated solid bar soil nail	Yes	(a) one for grouting the bonded length; (b) one for grouting the debonded length.
	No	(a) one for grouting the bonded and debonded length.
Hollow bar soil nail	Yes	(a) one for grouting the debonded length.
	No	Not required

For grouting of the bonded length of a soil nail, the grout tubes must be securely fixed to the steel reinforcement or encapsulation. Otherwise, the grout tubes must be securely fixed to the steel reinforcement or encapsulation or inserted after 24 hours upon completion of grouting of the bonded length.

2.2.7 Grout

Grouts must have high bleed resistance, low shrinkage and high fluidity and conform to Table R64.4 when tested as specified.

Table R64.4 – Performance Requirements for Grout

Property	Test Method	Criteria	Comments
Bleeding	ASTM C 940	Final bleeding < 0.5%	Measured when two successive readings show no further expansion or bleeding.
Volume Change	ASTM C 1090	Maximum height change @ 1 day & 28 days 0.1% and 0.3%	
Early Expansion	ASTM C 940	< 2% at 3 hours.	Temperature tolerances are 20 °C ±5 °C.
Fluidity	ASTM C 939 ⁽¹⁾	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	TS 02800.49 (TfNSW T375)	32 MPa at 7 days 40 MPa at 28 days	Use 75 mm cubes.

Note:

- ⁽¹⁾ 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 TS 03323.1 (TfNSW 3211). Only use cement free from any lumps. Cement must only be stored in dry weatherproof containers. Subject to the approval of the Principal, small stacks of bagged cement of agreed quantities may be held in the open. Such small stacks of bagged cement 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 admixtures without the approval of the Principal, and such 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 (SO₃) and chloride contents must be determined by the method described in AS 1012.20.1. The total nitrate content must be determined by the method described in ASTM D 4327.

The grout mix proportions and types of admixture (if used) together with test results must be submitted to the Principal for approval 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 admixtures 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

Nail heads and bearing plates must conform to the following:

- (a) Nail head and bearing plate components (including nuts, washers, etc) must be fabricated from Grade 250 steel in accordance with AS/NZS 3678;
- (b) 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/m² (equivalent to 85 microns thickness).

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.

Fully cover nail heads and bearing plates with shotcrete of 50 mm minimum thickness unless the design life of the soil nails is 2 years or less.

2.3 FACING

2.3.1 General

Where a diaphragm support is required to distribute the soil nail action over the surface of retained mass, a facing must be constructed with either formed concrete or shotcrete to the dimensions shown on the Drawings. The facing must be 150 mm thick minimum.

Where a diaphragm support is not required to distribute the soil nail action over the surface of retained mass, a concrete plinth must be provided for each soil nail to the dimensions shown on the Drawings.

The facing and concrete plinths must be constructed following preparation of the cut face. The surface to be sprayed must be devoid of loose or soft areas, overhangs, undercut zones or other voids, such that the facing will bond to the face and slippage at the interface will not occur.

2.3.2 Formed Concrete

All materials and workmanship for formed concrete must be in accordance with Specification TS 01733.1 (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 40 MPa.

2.3.3 Shotcrete

Materials and workmanship for shotcrete must comply with Specification TS 02170.1 (TfNSW R68). Exposure Classification must be B2 or more aggressive for the shotcrete mix design.

All shotcrete must be minimally reinforced with D500 SL81 steel mesh complying with AS/NZS 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 1627.0.

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/NZS 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 placed centrally within the 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 TS 02159.1 (TfNSW R40).

2.3.5 Flexible Strip Filter Drains

Unless otherwise specified on the Drawings, place flexible strip filter drains behind the facing at spacings no more than 3 m and inclination less than 60 degrees from horizontal.

Flexible strip filter drains must be in accordance with Specification TS 03356.1 (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

Construction Program and Method Statement must be provided to the Principal for agreement at least 10 working days before the commencement of the soil nailing works. The submission of the Construction Program and Method Statement constitutes a Hold Point.

HOLD POINT

Process Held:	Commencement of soil nailing work (including installation and testing of suitability test nails).
Submission Details:	At least 10 working days before the commencement of soil nailing 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:

- (a) names and resumes of suitably experienced personnel who will supervise and carry out the work;
- (b) method of installation of the soil nails, including drilling, cleaning, supporting the drillholes; and grouting and testing of the nails together with construction or excavation sequence;
- (c) 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;
- (d) proposed grout mix proportions and the method of grout production;
- (e) 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;
- (f) calibration certificates and documentation demonstrating your proposed testing and measuring equipment comply with the requirements specified in Clause 5.3;
- (g) templates for recording measurements of suitability tests and acceptance tests;
- (h) proposed endoscope camera and sample drillhole photos taken by it;
- (i) proposed method to fill up the debonded length with grout after completion of acceptance test;
- (j) detailed method of applying shotcrete;
- (k) proposed construction program and construction sequence; and
- (l) treatment of shotcrete lateral joints.

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 windblown dust. 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.

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

3.3 CONSTRUCTION SEQUENCE

Commence installation of working nails only after all suitability tests (refer to Clause 5) have been completed and the associated Hold Points have been released.

Unless otherwise shown on the Drawings or directed by the Principal, construct working nails and 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;
- (b) 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;
- (c) 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.

- (d) Installation of working nails and testing of acceptance test 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;
- (e) Construction of the 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;
- (f) Carry out construction of subsequent rows of soil nails and facing in a similar manner, one row at a time;
- (g) Excavation for subsequent rows of soil nails cannot commence until the installation of the preceding row is fully completed and the 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 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.

Construction sequence specified in the Contract Documents must not be changed without the approval of the Principal.

3.4 SOIL NAIL INSTALLATION

3.4.1 General

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

Assemble soil nails (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.

Soil nails must be installed at an inclination of 15° to horizontal or steeper.

3.4.2 Set Out And Drilling

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 length 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.

Holes for soil nails must be at least 100 mm in diameter or as shown on the Drawings, whichever is larger.

Use pneumatic, rotary or rotary-percussion drilling equipment for drilling to ensure minimal remoulding of insitu materials within the drillholes.

Do not use flushing agents other than air. Do not inject fluid (including grout) into drillholes during drilling.

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, remove all loose and deleterious material from the drillhole by air flushing and protect the drillhole opening from entry of foreign matter.

3.4.3 Collapsible Drillholes

For any drillhole which may collapse before completion of grouting, suitability test or acceptance test, install a casing to support the drillhole.

Alternatively, pre-grout the drillhole with a suitable grout mix and then re-drill the drillhole after the grout has gained sufficient strength to prevent collapse before completion of grouting, suitability test and acceptance test. Requirements in Clause 3.4.2 also apply to re-drilling.

3.4.4 Insertion

3.4.4.1 Solid Bar Soil Nails

Prior to insertion of solid bar soil nails, clean the drillholes by air flushing until all debris are extracted from the drillholes. Insert each soil nail 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.

Do not inject fluid (including grout) into drillholes during insertion.

Replace any soil nail if the galvanized coating is damaged during installation. Insertion must occur as soon as practicable following drilling, but in any event must be completed within 24 hours after completion of drilling.

3.4.4.2 Hollow Bar Soil Nails

Advance hollow bar soil nails into drillholes as drilling progress.

Do not inject fluid (including grout) into drillholes during insertion.

3.4.5 Grouting

3.4.5.1 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) a flow meter and pressure gauge to check the intake grout volume and grout pressure. The flow meter must be located at the grout delivery point at the nail and be calibrated to report to a precision of 1% of the volume of the nail hole or better.

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.

3.4.5.2 Grout Mixing

Batching of the dry materials must be by weight. Measure the amount of water used with a calibrated flowmeter. The calibrated flow metre must be calibrated to report to a precision of 1% of the batch volume or better.

Mix the grout by adding initially approximately two-thirds of cement to the water, followed by the admixtures, 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.

3.4.5.3 Grouting

Grouting must occur as soon as practicable following drilling and must be completed within 24 hours after completion of drilling.

Within an hour before commencement of grouting, clean the drillholes by air flushing until all debris are extracted from the drillholes.

Carry out grouting by use of supply lines directly connecting the pumps to the down-hole grout tubes or hollow bar soil nails.

Inject grout to the bottom of the intended grout section, at an injection pressure of not more than twice the overburden pressure measured at the top of the soil nail. The grout tubes and the hollow bar soil nails 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.

For each soil nail subject to suitability test or acceptance test:

- (a) Inject an amount of grout to completely fill up the bonded length as shown on the Drawings. The grout level must be controlled such that the grout tube for subsequent grouting of the debonded length will not be blocked. The grout level must then be checked by sitting for a minimum of 5 minutes and inject additional grout to top-up if necessary to ensure that the bonded length is fully grouted. Repeat the grout level check and top-up until the grout level has become stable such that the grouted length measure 24 hours after completion of grouting is within a range of +0.0m to -0.1m of bonded length specified on the Drawings. The grout must not extend to the debonded length as shown on the Drawings.
- (b) For encapsulated soil nails, inject grout in a controlled manner and 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. Both the inside and outside of the sheathing must be fully grouted along the bonded length.
- (c) After completing the suitability test or acceptance test, inject grout to 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 a minimum of 5 minutes and inject additional grout to top-up if necessary to ensure that the soil nail is fully grouted. Repeat the grout level check and top-up until grout level has become stable.
- (d) Plug the remaining void at the top of the drillhole flush to the slope faces using a dry-packed 3:1 sand to cement mix.

For working nails which are not acceptance test nails:

- (a) Inject grout to 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 inject additional grout to top-up if necessary to ensure that the soil nail is fully grouted. Repeat the grout level check and top-up until grout level has become stable.
- (b) For encapsulated soil nails, inject grout in a controlled manner and 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. Both the inside and outside of the sheathing must be fully grouted.
- (c) Plug the remaining void at the top of the drillhole flush to the slope faces using a dry-packed 3:1 sand to cement mix.

Catch and dispose of the grout that has overflowed from the hole as waste to the satisfaction of the Principal.

Grouting must not commence 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 to soil and grout to nail bond does not occur.

3.4.5.4 Loss or Leakage of Grout

During the grouting of any hole, the Principal must be informed immediately if the grout intake is 50% more than the theoretical volume of grout required.

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.

3.4.5.5 Bleed Testing

Provide one sample of grout from each batch of grout to determine the amount of bleeding in accordance with ASTM C 940 and the requirements specified in Clause 2.2.7. Collect grout samples from the grout mixer.

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 determining the amount of bleeding are carried out.

3.4.5.6 Fluidity Testing

One sample of grout must be provided from each batch of grout to determine the fluidity in accordance with ASTM C 939 and the requirements specified in Clause 2.2.7. Grout samples must be collected from the grout mixer.

For each soil nail, complete the fluidity test prior to commencement of grouting. If the immediate efflux time does not meet the requirement in Table R64.4, reject the grout and mix a fresh batch. Do not use non-conforming grout in the works.

3.4.5.7 Compressive Strength Test

During the production of grout, take representative test specimens comprising cubes in accordance with Test Method TS 02800.49 (TfNSW T375).

For each suitability test nail and acceptance test nail, collect 3 test specimens from the grout mixer during grouting of the bonded length and 3 test specimens from the grout emerged from the top of the drillhole during grouting of the debonded length.

For each working nail other than acceptance test nails, collect 3 grout test specimens from the grout emerged from the top of the drillhole.

For grouting of the debonded length of encapsulated soil nails, collect the test specimens from the grout emerged from the annulus between the encapsulation and drillhole's perimeter.

Store cubes under standard curing conditions of 23°C in accordance with Test Method TS 02800.49 (TfNSW T375) and a relative humidity in excess of 98%.

The first and second cubes of each set of grout cubes must be tested at 7 days and 28 days from the date of sampling in accordance with Test Method TS 02800.49 (TfNSW T375) and must achieve the compressive strength specified in Clause 2.2.7.

For any set of cubes, hold the third cube if compressive strength at either 7 days or/and 28 days does not meet the compressive strength specified in Clause 2.2.7 for testing at the Principal's direction.

If the result of any grout cube's compressive strength does not comply with the specified requirements in Clause 2.2.7, you must:

- (a) submit particulars of the proposed changes to the materials, grout mix or methods of production to the Principal for agreement. Further trial mixes and grouting trials must be carried out unless prior agreement is obtained from the Principal;
- (b) replace the corresponding soil nail.

3.5 PLACEMENT OF FACING

3.5.1 General

Construct the facing with formed concrete or shotcrete as required in Clause 2.3.

Place formed concrete in accordance with Specification TS 01733.1 (TfNSW B80).

Place shotcrete in accordance with Specification TS 02170.1 (TfNSW R68).

Present the slope area to the Principal for inspection before placement of facing.

3.5.2 Slope Surface Preparation

Carry out slope surface preparation in accordance with TS 02170.1 (TfNSW R68).

During placement of facing, 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. Measuring pins must be:

- (a) durable and non-corrosive;
- (b) made from galvanized steel with a with a minimum average coating weight of 600 g/m² (equivalent to 85 microns thickness) or fibre reinforced polymer;
- (c) protected by cold galvanisation coating as per manufacture’s recommendation for site cut steel pins;
- (d) of sufficient length to provide adequate fixity during application of formed concrete or shotcrete.

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

3.5.3 Drilling and Grouting of Steel Mesh Support Anchor Bars

You must give the Principal 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 any anchor bar into a drillhole, the wall of the drillhole must be cleaned such that all deleterious materials or accumulations, which would impair the effectiveness of the anchor bar, are removed. Following cleaning, the hole must be gauged 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.

3.5.4 Application of Shotcrete

3.5.4.1 General

Application of shotcrete must be in accordance with TS 02170.1 (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.

3.5.4.2 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.

Where the shotcrete application cannot be completed to full layer thickness at the end of a day, the following must apply:

- (a) The end-of-day joint must not be formed on the exposed (air) side of the reinforcement. The shotcrete must terminate behind the reinforcement, maintaining a minimum cover of 75 mm behind the mesh.
- (b) Feathered joints are not permitted. Taper the unfinished shotcrete edge sharply in accordance with TS 02170.2 (TfNSW D&C R68).
- (c) Before resuming shotcrete application, prepare the hardened surface in accordance with TS 02170.2 (TfNSW D&C R68) to ensure adequate bonding between layers.
- (d) The unfinished shotcrete surface must be terminated midway between adjacent soil nails.

3.5.4.3 Curing of Shotcrete

Carry out curing of shotcrete in accordance with TS 02170.1 (TfNSW R68).

3.5.4.4 Testing of Shotcrete

Carry out testing of shotcrete for conformity in accordance with TS 02170.1 (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.

3.5.4.5 Checking Integrity of Shotcrete

Unless otherwise approved by the Principal, 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.

3.6 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 40 MPa, lock tight the nuts on soil nails.

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 and 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 and acceptance test.

The purpose of suitability tests is to confirm that the bond strength is achieved and that the reinforcement will perform as designed prior to the installation of working nails. The acceptance test on working nails is a measure of quality control. Carry out tests for soil nails under the direction of a qualified and experienced engineer, who is your authorised representative and who must record the work.

Details of soil nails for suitability test and acceptance test, including locations, must be shown on the Drawings.

The number of suitability test nails must be the greater of:

- (a) the number specified on the Drawings; or
- (b) 1% of the working nails; or
- (c) 2 for each ground type within the anchorage zone of the working nails.

Subject a minimum of 3% of working nails to acceptance test (Clause 5.2.2).

5.2 SOIL NAIL TESTS

5.2.1 Suitability Test

Prior to the installation of working nails, install suitability test nails as shown on the Drawings and carry out suitability test 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 ground for each ground type within the anchorage zone of the working nails.

Each suitability test nail must have a minimum bonded length of 3 m, and the entire bonded length must be located within a single ground type. Provide a debonded length as shown on the Drawings. The debonded length must be long enough to prevent influence on the test result from the load test reaction system.

If the ground conditions encountered during drilling differ from those shown on the Drawings, adjust the debonded length such that the entire bonded length is located within the intended ground type. In any case, the debonded length must be 1 m long minimum.

The soil nails subject to suitability test are additional to the working nails shown on the Drawings.

You must give the Principal at least seven working days' notice of your intention to carry out each suitability test. Suitability tests must be carried out in the presence of the Principal.

WITNESS POINT

Process Witnessed: Suitability tests.

Submission Details: Advise the Principal, at least 7 working days before each suitability test and, your intended date of testing.

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 suitability test nails must be installed in an identical manner, including time delays between various operations, and at locations with ground conditions representative of those of the working nails.

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 increments and held at these loads for the period specified in Table R64.5 below:

Table R64.5 – Suitability Test: Load Increments and Minimum Periods of Observation

Load Cycle No.	Test Loads (% of Ultimate Geotechnical Strength as shown on the Drawings) ⁽¹⁾	Minimum Period of Observation at Peak Test Load (minutes)
1	10 → 30 → 10	10
2	10 → 50 → 10	60
3	10 → 70 → 10	10
4	10 → 100 → 10	180

Note:

⁽¹⁾ Ultimate geotechnical strength is the ultimate bond resistance along the bonded length of the suitability test nail.

Use the loading calibration to determine the applied loads for loading stages. Use the unloading calibration to determine the applied loads for unloading stages.

For each load cycle, increase the applied load smoothly to the peak test load within 1 to 5 minutes. For each load cycle, hold the load at the peak test load during the period of observation specified in Table R64.5. Top up the applied load whenever it drops to 1 kN below the peak test load. Record the soil nail head movements and applied loads at 0, 1, 2, 3, 5, 6, 10, minutes and thereafter every 10 minutes up to the end of the period of observation.

The field record must be signed by your authorised representative immediately after the test. You must provide a copy of the field record to the Principal within 24 hours upon completion of the suitability test.

Within 1 hour after completion of each suitability test, you must take photos along the debonded length of the drillhole with an endoscope camera. The photos must have a captured resolution of 1920 x 1080 or higher, illuminated with a suitable light source, and taken at intervals of 0.5 m or closer.

Determine the measured elastic extension (δe_m) for load cycles 1 to 4 as follows:

$$\delta e_m = \delta e_{\text{peak}} - \delta e_{\text{unload}}$$

Calculate theoretical elastic extensions (δe_t) for load cycles 1 to 4 as follows:

$$\delta e_t = (T_p - T_i) \times L_{fl} / (E \times A_c)$$

where

δe_{peak} : measured maximum soil nail head movement at peak applied loads for load cycles 1 to 4

δe_{unload} : measured soil nail head movement after unloaded to 10% of the ultimate geotechnical strength

T_p : peak applied loads for load cycles 1 to 4

T_i : applied load after unloaded (10% of ultimate geotechnical strength)

L_{fl} : length between top of bonded length and base of locking nut

E: elastic modulus of soil nail bar

A_c : cross sectional area of soil nail bar.

A suitability test will be considered successful if all the following are satisfied:

- (a) a creep movement of less than 2 mm between the 6 and 60 minutes readings in the period of observation of Cycle 4;
- (b) a creep movement of less than 1 mm between the 60 and 180 minutes readings in the period of observation of Cycle 4;
- (c) the creep rate is constant or decreasing, when plotted against the logarithm of time throughout the period of observation of Cycle 4;
- (d) δe_m is more than 90% δe_t .

For encapsulated soil nails, the photos taken by the endoscope camera must clearly show that:

- the annulus between the sheathing and drillhole circumference is free of grout, debris and any materials which may diminish the applied test load to the bonded length;
- the annulus between the sheathing and the soil nail steel bar is free of grout, debris and any materials which may diminish the applied test load to the bonded length.

For unencapsulated soil nails, the photos must clearly show that the annulus between the drillhole circumference and the soil nail steel bar is free of grout, debris and any materials which may diminish the applied test load to the bonded length.

For any suitability test which doesn't meet all the requirements above, repeat the suitability test on a replacement suitability test nail. Any modifications of construction procedures, replacement nails and associated tests must be at your cost.

Cut-off the bar flush with the finishing ground and grout the remaining part of the drillhole, or extract the entire suitability test nail from the drillhole for inspection if directed by the Principal.

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 suitability test nail. Any modifications of construction procedures, replacement nails and associated tests must be at your cost.

Unless otherwise directed by the Principal, fill the void caused by the extraction of the soil nail with grout.

Within 5 working days upon completion of a suitability test, submit the test records detailed in Clause 5.4 to the Principal.

Submission of the suitability test records stipulated in Clause 5.2.1 constitutes a Hold Point.

HOLD POINT

Process Held: Installation of working nails.

Submission Details: Suitability test records and documentation stipulated in Clause 5.4.

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 working nails, unless otherwise approved by the Principal, must be subjected to acceptance test. You must install acceptance test nails as shown on the Design Documentation Drawings. The Principal may direct additional acceptance tests if necessary.

You must provide a debonded length as shown on the Drawings. The debonded length must be 1 m long minimum and long enough to prevent influence on the test result from the load test reaction system. The bonded length must be entirely embedded in the anchorage zone of the most critical failure mechanism.

You must give the Principal at least seven working days' notice of your intention to carry out each acceptance test. You must carry out acceptance tests in the presence of the Principal prior to the construction of facing to the exposed ground.

WITNESS POINT

Process Witnessed: Acceptance tests.

Submission Details: Advise the Principal, at least 7 working days before each acceptance test and, your intended date of testing.

Injected grout must have achieved a compressive strength of 40 MPa before performing acceptance test.

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

Soil nails subject to acceptance tests must be loaded to the load increments and held at these loads for the periods specified in Table R64.6 below:

Table R64.6 – Acceptance Test: Load Increments and Minimum Periods of Observation

Load Increment (% of Working Load ⁽¹⁾ of each acceptance test nail as shown on the Drawings) ⁽¹⁾	Minimum Period of Observation (minutes)
25	5
50	5
100	5
150	180 (Creep Test)
100	5
50	5
25	5

Note:

⁽¹⁾ Working Load is the design bond resistance along the bonded length of the acceptance test nail.

Use the loading calibration to determine the applied loads for loading stages. Use the unloading calibration to determine the applied loads for unloading stages.

Increase the applied load smoothly to each load increment within 1 to 5 minutes. For each load increment, hold the applied load during the period of observation specified in Table R64.6. Top up the applied load whenever it drops to 1 kN below the load increment. Record the soil nail head movements and applied loads at the beginning and the end of the observation period. For the creep portion of the test, record the soil nail head movements and applied loads at 0, 1, 2, 3, 5, 6, 10, 20, 30, 50, 60, 90, 120, 150 and 180 minutes.

The field record must be signed by your authorised representative immediately after the test. You must provide a copy of the field record to the Principal within 24 hours upon completion of the acceptance test.

Within 1 hour after completion of each acceptance test, you must take photos along the debonded length of the drillhole with an endoscope camera. The photos must have a captured resolution of 1920 x 1080 or higher, illuminated with a suitable light source, and taken at intervals of 0.5 m or closer.

Determine the measured elastic extension (δe_m) as follows:

$$\delta e_m = \delta e_{\text{peak}} - \delta e_{\text{unload}}$$

Calculate theoretical elastic extension (δe_t) as follows:

$$\delta e_t = (T_p - T_i) \times L_n / (E \times A_c)$$

where

δe_{peak} : measured maximum soil nail head movement at peak applied load (150% of working load)

δe_{unload} : measured soil nail head movement after unloaded to 25% of the working load

T_p : peak applied load (150% of working load)

T_i : applied load after unloaded (25% of working load)

L_n : length between top of bonded length and base of locking nut

E: elastic modulus of soil nail bar

A_c : cross sectional area of soil nail bar.

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

- (a) a creep movement of less than 2 mm between the 6 and 60 minutes readings in the period of observation;
- (b) a creep movement of less than 1 mm between the 60 and 180 minutes readings in the period of observation;
- (c) the creep rate is constant or decreasing, when plotted against the logarithm of time throughout the period of observation;
- (d) δe_m is more than 90% δe_e .

For encapsulated soil nails, the photos taken by the endoscope camera must clearly show that:

- the annulus between the sheathing and drillhole circumference is free of grout, debris and any materials which may diminish the applied test load to the bonded length;
- the annulus between the sheathing and the soil nail steel bar is free of grout, debris and any materials which may diminish the applied test load to the bonded length.

For unencapsulated soil nails, the photos must clearly show that the annulus between the drillhole circumference and the soil nail steel bar is free of grout, debris and any materials which may diminish the applied test load to the bonded length.

Where an acceptance test nail does not meet the acceptance criteria, test an additional 2 nearby soil nails as directed by the Principal. 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.

Fill the entire debonded length by tremie grouting.

Within 5 working days upon completion of an acceptance test, submit the test records detailed in Clause 5.4 to the Principal.

Submission of the acceptance test records stipulated in Clauses 5.2.2 constitutes a Hold Point.

HOLD POINT

Process Held: Acceptance of working nails.

Submission Details: Within one week of completion, submit to the Principal acceptance test records and documentation stipulated in Clause 5.4.

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

5.3 TESTING AND MEASURING EQUIPMENT

Measure soil nail head movements using a calibrated dial gauge mounted on a tripod or fixed to a rigid support, both of which must be independent of the jacking system and the soil nail, and will not move during the test. The dial gauge must be capable of measuring to an accuracy of 0.01 mm. The dial

gauge must be set up in line and parallel to the direction of nail movement, so as to avoid any misalignment and eccentricity to the direction of movement of the soil nail. The dial gauge must be zeroed after aligning the longitudinal axis of the dial gauge with that of the soil nail and the initial load has been applied.

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 applied loads with a digital pressure gauge with an accuracy of ± 1 kN or better. Calibrate the hydraulic jack and digital pressure gauge as a set.

Alternatively, the applied loads may be measured by a load cell in series with the jack. The load cell must have a digital readout with an accuracy of ± 1 kN or better. Calibrate the load cell and digital readout as a set. Ensure that the load cell is properly aligned with the axis of the soil nail bar and the jack.

Calibration certificates must be less than 12 months old. 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.

The calibration certificate must be accompanied by the related calibration curve and tabulated record of true applied loads against measured loads.

Perform the calibration for the loading and unloading operations over its full working range.

5.4 RECORDS OF TESTS

The test records must include:

- (a) construction conformity record (Clause 6) of suitability test nails and acceptance test nails;
- (b) dates of drilling, grouting and testing;
- (c) time intervals between completion of test soil nail hole drilling and start of grout injection;
- (d) any variations from the specified procedure;
- (e) any unforeseen or unusual conditions encountered;
- (f) calibration certificates;
- (g) field records of suitability tests and acceptance tests;
- (h) theoretical elastic extensions between top of the bonded length and the locking nut;
- (i) plots and tables of soil nail head movements against applied loads;
- (j) plots and tables of soil nail head movements against time elapsed for each period of observation;
- (k) photos taken along the debonded length of the drillhole;
- (l) demonstrations that the test results comply with all the requirements in this Specification.

6 RECORDS FOR INSTALLATION

Conformity records for each soil nail must include the following:

- (a) soil nail identification number;

- (b) bearing, inclination, position, depth, and diameter of the formed drillhole;
- (c) soil and rock types encountered and casing (if any);
- (d) water levels;
- (e) drilling rates and drilling obstructions encountered;
 - (f) cleaning procedure;
 - (g) type and age of cement;
 - (h) concentration and types of admixture (if any);
 - (i) water to 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) date and time of completion of soil nail hole drilling;
 - (p) date and time of start of grout injection;
 - (q) date and time of completion of grout injection;
 - (r) volume of the drillhole, volume of grout injected in m³ and % of drillhole's volume;
 - (s) average injection pressure;
 - (t) times and details of any interruptions;
 - (u) results of bleeding tests, fluidity tests, and compressive strength tests.

For each soil nail, submit the above conformity records to the Principal within five working days after the full length of soil nail is grouted.

ANNEXURE R64/A – PROJECT SPECIFIC REQUIREMENTS

Project:

- (a) Design Life of soil nails: years
- (b) If Design Life of soils nails is less than 100 years and the soil nails are required to function beyond the construction phase of a project, insert approval of Design Life by Asset Custodian below:

Signature: _____

Name: _____

Position: _____

Date: _____

- (c) Solid bar and/or hollow bar soil nails⁽¹⁾: _____

Note:

⁽¹⁾ Maximum design life of hollow steel bar soil nails is 20 years.

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 Suitability Test Nails

The unit of measurement is “each” suitability 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 Working Nails, including Testing of Acceptance Test Nails

The unit of measurement is “each” working 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 working nail, as shown on the Drawings or directed by the Principal. This item is not applicable to working nails with strain gauges and cables attached.

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

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

The unit of measurement is “each” working 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 lineal 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 Working Nails

The unit of measurement is “each” acceptance test conducted on working 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 lineal 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, admixtures 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	Witness	Suitability tests
5.2.1	Hold	Submission of suitability test records
5.2.2	Witness	Acceptance tests
5.2.2	Hold	Submission of acceptance test records

C2 SCHEDULE OF IDENTIFIED RECORDS

The records listed below are Identified Records for the purposes of TS 00118.1 (TfNSW Q5) or TS 01572.1 (TfNSW Q6) as applicable Annexure Q/E.

Clause	Description of Identified Record
2.1	Certificates of conformity of all materials used for the Works, including test certificates
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 casing installation and pre-grouting
3.4.4	Conformity records for soil nail insertion
3.4.5	Conformity records for grouting
3.5.4	Conformity records for thickness of shotcrete applied as the facing
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

Clause	Description of Identified Record
6	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 3.4.5);
- (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 3.6).

ANNEXURE R64/E – INSTRUMENTED SOIL NAILS

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

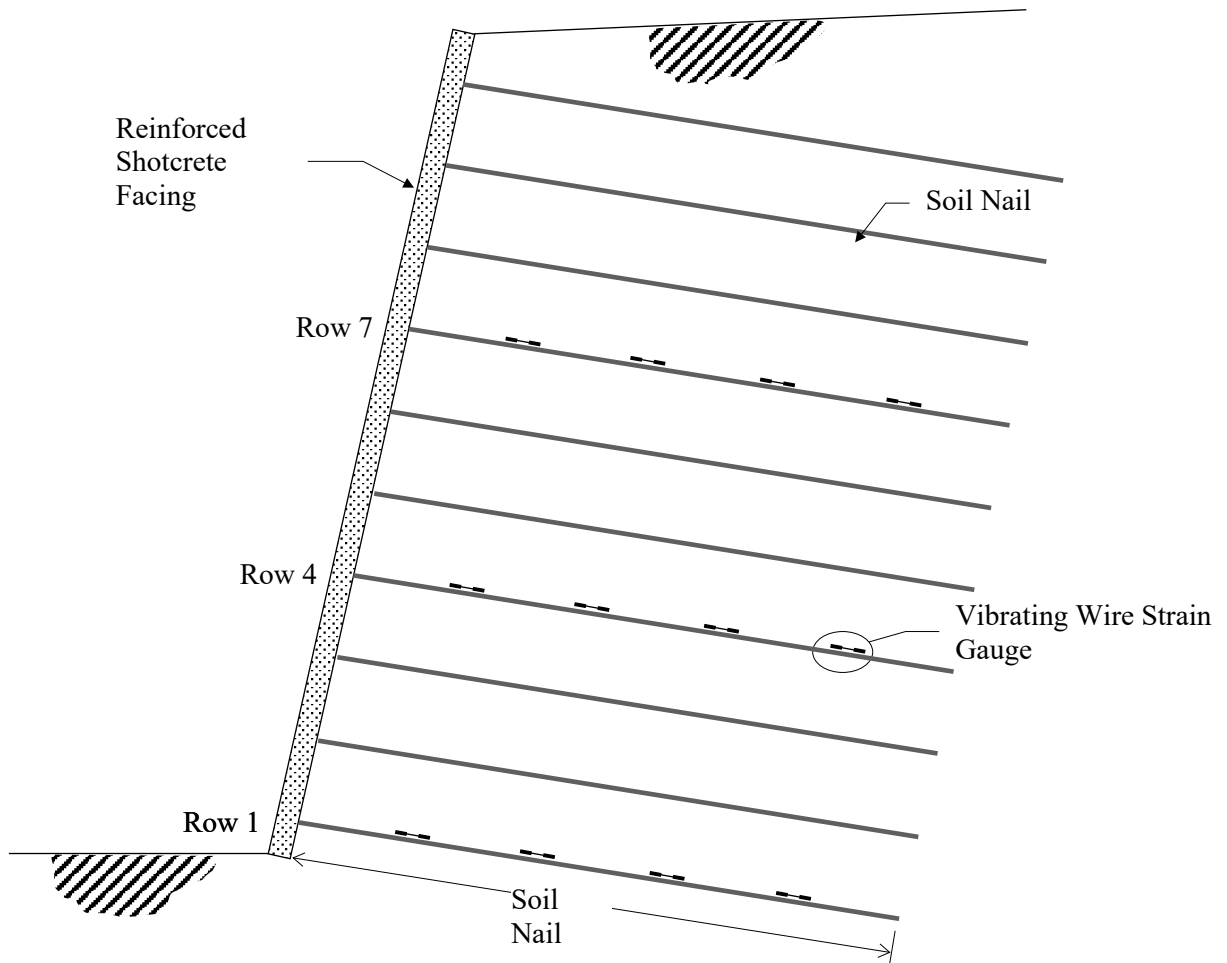


Figure R64/E.1 – Typical Soil Nail Structure with Instrumentation

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

Table R64/E.1 Typical Soil Nail Instrumentation Requirements

.	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 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 or 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 or 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>

.	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 channels) 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 or sensors every 6 hours. Multiplexing may be used.
14.	Datalogger power supply	Either dedicated 240 V 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 – LISTS OF APPROVED HOLLOW BAR SOIL NAIL
SYSTEMS AND CONDITIONS OF USE**

ANNEXURES R64/G TO R64/L – (NOT USED)

ANNEXURE R64/M – REFERENCED DOCUMENTS

Refer to Clause 1.2.5.

TfNSW Specifications

TS 00118.1 (TfNSW Q5)	Quality Management (Minor and Routine Maintenance Works)
TS 01517.1	Maintenance Requirements Analysis and Technical Maintenance Plans – Part 1: Development Process
TS 01517.2	Maintenance Requirements Analysis and Technical Maintenance Plans – Part 2 Blank TMP and Service Schedule Forms
TS 01517.3	Maintenance Requirements Analysis and Technical Maintenance Plans – Part 3 TMP Review and Authorisation Form
TS 01572.1 (TfNSW Q6)	Quality Management (Major Works)
TS 02159.1 (TfNSW R40)	Horizontal Drains
TS 02170.1 (TfNSW R68)	Shotcrete Work Without Steel Fibres
TS 01733.1 (TfNSW B80)	Concrete Work for Bridges
TS 03323.1 (TfNSW 3211)	Cementitious Materials, Binders and Fillers
TS 03356.1 (TfNSW 3557)	Flexible Strip Filter Drains

TfNSW Test Methods

TS 02795.05 (TfNSW T109)	Plastic limit and plasticity index of road construction materials
TS 02795.43 (TfNSW T185)	Resistivity of sands and granular road construction materials
TS 02800.49 (TfNSW T375)	Sampling and testing of grout
TS 02811.02 (TfNSW T1002)	Determination of the pH Value of water using a pH Meter
TS 02811.10 (TfNSW T1010)	Quantitative Determination of Chlorides in Soil

Other TfNSW documents

CQTD 2009/005 Construction Quality Technical Direction Quality Alert 5 – Soil nail walls
(This document is not publicly available. To obtain access email standards@transport.nsw.gov.au)

Australian Standards

AS 1012.8.4	Methods of testing concrete – Part 8: Method for making and curing concrete compression, indirect tensile and flexure test specimens, in the laboratory or in the field
AS 1012.20.1	Methods of testing concrete – Method 20.1: Determination of chloride and sulfate in hardened concrete and aggregates – Nitric acid extraction method
AS 1112.3	ISO metric hexagon nuts – Part 3: Product grade C
AS/NZS 1214	Hot-dip galvanized coatings on threaded fasteners (ISO metric coarse thread series) (ISO 10684:2004, MOD)
AS 1275	Metric screw threads for fasteners

AS 1289.4.1.1	Methods of testing soils for engineering purposes – Method 4.1.1: Soil chemical tests – Determination of the organic matter content of a soil – Normal method
AS 1478.1	Chemical admixtures for concrete, mortar and grout: Admixtures for concrete
AS 1627.0	Metal finishing – Preparation and pretreatment of surfaces: Method selection guide
AS 2832.1	Cathodic protection of metals – Pipes and cables
AS/NZS 3678	Structural steel – Hot-rolled plates, floorplates and slabs
AS/NZS 4131	Polyethylene (PE) compounds for pressure pipes and fittings
AS 4969.12	Analysis of acid sulfate soil – Dried samples – Methods of test – Complete suspension peroxide oxidation combined acidity and sulfur (SPOCAS) method
AS/NZS 4671	Steel for the reinforcement of concrete
AS/NZS 4680	Hot-dip galvanized (zinc) coatings on fabricated ferrous articles
AS/NZS ISO 9001	Quality management systems – Requirements

ASTM Standards

C 939	Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)
C 940	Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory
A 1059	Standard Specification for Zinc Alloy Thermo-Diffusion Coatings (TDC) on Steel Fasteners, Hardware, and Other Products
C 1090	Standard Test Method for Measuring Changes in Height of Cylindrical Specimens of Hydraulic-Cement Grout
D 1784	Standard Classification System and Basis for Specification for Rigid Poly (Vinyl Chloride) (PVC) Compounds and Chlorinated Poly (Vinyl Chloride) (CPVC) Compounds
D 3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
D 4327	Standard Test Method for Anions in Water Suppressed by Ion Chromatography