Geotechnical Design Report and Specification for Slope Stabilisation Works

Ponsharden Cemeteries

Penryn

Jubb

PREPARED BY:
Jubb Consulting Engineers Ltd.

FOR:
Falmouth Town Council

DATE:
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REFERENCE:
21287-GDR-01

Contents

1. Project Information

1.1 Project Information

Client	Falmouth Town Council

1.2 Project Details

Project Name	Ponsharden Cemeteries Slope Stabilisation
Location	Penryn
Jubb Project Number	21287

1.3 Report Details

Version	C
Status	Final
Date	23/02/2022

1.4 Project Authorisation

ISSUE HISTORY: AUTHORISATION:

Version	Date	Detail	Prepared By	Checked By	Approved By
A	16/12/2021	Preliminary	M Temlett	M Campbell	M Campbell
B	10/01/2022	Draft for Client Review	M Temlett	M Temlett	P Webber
C	23/02/2022	Final Issue	M Temlett	M Temlett	P Webber

2. Introduction

2.1 Commission

Jubb Consulting Engineers (Jubb) have been appointed by Falmouth Town Council to undertake geotechnical design for the permanent works cutting stabilisation slope solution for a site at Ponsharden Cemeteries, located near Penryn in Cornwall. The site comprises the northern boundary of the Ponsharden Cemeteries site forming a cutting to the A39 (Falmouth Road), which runs parallel to the site boundary. The works comprise the stabilisation of the northern lower boundary of the Jewish and Congregationalist Cemetery site, which currently comprises an unretained soil and rock cutting slope (of angles up to 80°), which is currently suffering from erosion and undercutting. At the crest of the slope is a Cornish hedge with trimmed trees and tree roots, largely holding together the upper portion of the slope. It is understood a client requirement of the project is to not alter or remediate the Cornish hedge. A section of access stairs to the west of the site (used to access A39 footway below through a stone archway) lined with stonework also requires repair works.

Areas adjacent to the site (to the east) comprise of vertical stone masonry walls, which the proposed slope stabilisation works are required to tie into. Works proposed within proximity to the existing masonry walls and archways will consider the potential for destabilisation of these areas and existing structures.

This report constitutes the Geotechnical Design report (GDR) for the proposed permanent works to include temporary works requirements and provides advice for the geotechnical design of soil nails, mesh and reno-facing. This report and design are limited to only areas between the existing stonework archway and the gas sub-station, as well as a section of stonewall along the steps into the site.

Permanent works design has been carried out by Jubb on behalf of Falmouth Town Council. The current failing slopes sit at between approximately 55° to near vertical, covered with low vegetation on the lower face and a tree stump towards the crest where a Cornish hedge runs along the crest of the slope. It is understood the tree stumps and Cornish hedge are to remain wherever possible as instructed by the client.

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2.2 Objectives

The key objectives of this report are to:

- Review of all existing information available at the site, including, but not limited to:
  - Site investigation and reports from the previous proposed slope stabilisation works to the adjacent site available (site investigation results and site observations from adjacent site);
- Carry out temporary works design checks where required, integrated with construction sequence analysis (undertaken routinely as part of detailed design of the permanent works);
- Carry out detailed design analysis of slope stability, construction sequencing, calculations for soil nails reinforcement;
- Development of a CDM Design Risk Assessment;
- Preparation of drawings to construction issue, including; General Arrangement, Plan Layout, Elevation, Sections, Details and drawing notes;
- Preparation of specification drawing/s including Bill of Quantities; and
- Preparation of a Geotechnical Design Report

The primary design objective is to provide an adequate long-term factor of safety and protection against future erosion and undercutting to the proposed cutting.

2.3 Design Life

The permanent works associated design will have a design working life of 60 years in accordance with Manual of Contract Documents for Highway Works Volume 1 Specification for Highway Works - Series 600 – Clause 624 Ground Anchorages.

2.4 Geotechnical Category

The scheme has been classified as Category 2 as described within EC7. Category 2 includes conventional geotechnical structures; shallow and piled foundations, retaining walls and earthworks constructed without exceptional geotechnical risks, loading or difficult ground conditions. Designs for Category 2 should normally include quantitative geotechnical data and analysis to ensure the fundamental requirements are satisfied. A CAT2 'Design Check' has been carried out independently by Jubb.

2.5 Previous Reporting

The following previous reports have been made available to Jubb upon which this report and associated design are reliant on:

- AGS Ground Solutions Ltd – Ponsharden Cemeteries – Geotechnical Report (Ref: A2292-1), dated March 2021; and
- Platipus Earth Anchoring Systems – Ponsharden Cemeteries – Conceptual Proposal (Ref: PAL_CP_21_15320_001, dated 9th April 2021).

Of the above documents, a full geotechnical investigation was carried out by AGS ground Solutions Ltd in March 2021.The investigation comprised 6 no. hand-portable window sampling holes were drilled to between 2.23 m and 4.44 m depth below ground level along the crest of the subject slope. The findings of the investigation are discussed further within Section 4.0 of this report.

In addition to the above, a conceptual design proposal for soil anchors was prepared by Platipus Earth Anchoring Systems. Characteristic soil parameters derived within this assessment will be reviewed by Jubb within Section 5.0 of this report.

3. Site Synopsis

3.1 Site Location

The site (Ponsharden Cemeteries) is located on the west bound lane of the A39 (Falmouth Road) at the Jewish and Congregationalist Cemeteries, in Penryn on the town limits of Falmouth. The site forms the northern site boundary of the cemetery, adjacent to the A39, which runs east-west below the site.

The Ordnance Survey (Landranger) grid reference of the centre of the site is SW 79468 33861.

The location of the site has been presented in **Appendix A**.

3.2 Site Description

The site comprises a ~25 m length northern boundary of the cemetery site, with the A39 running parallel. At the northern boundary of the site, a low (~0.5 m high) Cornish hedge sits on top of an unsupported road cutting. The road cutting forms a part vegetated slope and rock slope, which is locally undercut and subject to slope instability and erosion. Slope angles along the face vary from 55° to near-vertical. Undercut areas generally comprise of root balls of trees located within the Cornish hedge.

The site itself is occupied by a Congregationalist and Jewish Cemetery that is currently under restoration. The Congregationalist site is located to the eastern half of the site, with the Jewish Cemetery occupying the west. The site gently slopes from east to west with elevations to the west at 14.55 mAOD, reducing to 9.06 m AOD to the west. To the far east of the site is a stone masonry lined stairway which leads down to the level of the highway at 8.9 mAOD (although varies along the length of the slope) through a stone archway (currently in need of minor repair works), which adjoins to an existing stone wall which continues to the adjacent site to the east.

Below the site, the A39 highway forms a 2-lane carriageway with a 40-mph speed limit, which falls downhill to the west and generally has an elevation of 8.98 mAOD to the east and 7.93 mAOD to the west.

To the far west of the cutting, a gas sub-station is present, < 2m from the cutting comprising a green metal structure.

Graves are expected to be present up to a depth of 2 m below the existing ground level within the cemetery and are expected to be present as close as the inner boundary of the Cornish hedge.

4. Ground Investigation

4.1 Site Investigation

A ground investigation was along the crest of the slope of the site by AGS Ground Solutions Ltd between 2nd and 3rd March 2021, which was planned and scoped by others. The investigation comprised the following activities:

- 6 no. window sample holes (WS01 and WS06).

Representative soil sampling of each stratum was undertaken to allow for geotechnical testing.

The factual ground investigation works are detailed in the following report:

- AGS Ground Solutions Ltd – Ponsharden Cemeteries – Geotechnical Report (Ref: A2292-1), dated March 2021.

Window sample holes were extended to between 2.23 m and 4.44 m depth below ground level (bgl). The samples recovered were photographed and representative soils samples were obtained for further laboratory testing.

4.2 Soil Nail Testing

At the time of writing this report, no soil nail testing had been carried out. It is recommended for soil nail testing to be carried out in accordance with BS EN ISO 22477-5: Test Method 1 to include suitability testing and acceptance testing.

It is recommended for 3 no. 'Suitability' soil nail tests to be carried out (2 no. within the main cutting face and 1 no. within the section of failed stone wall) where soil nails have been proposed, with tests extending 4m. The aim of the testing is to determine the characteristics of the soil nail in the working load range. Once testing has been completed, the results will be reviewed ahead of commencing the soil nail installation to determine acceptability testing requirements.

4.3 Geotechnical testing

Geotechnical testing for the previous geotechnical investigation was carried out by Babtie Engineering Laboratory in accordance with BS1377: Methods of test for soils for civil engineering purposes, as listed in the table below.

Table 1: Geotechnical Testing

No. of Tests	Test	Test Method
	Classification Tests	
12	Natural moisture content	BS1377: Part 2.
13	Particle Size Distribution	BS1377: Part 2.
13	Particle Size Distribution with sedimentation	BS1377: Part 2.
13	Atterberg Test (4-point)	BS1377: Part 2.

5. Ground Conditions

5.1 Geology

During the investigation of the riverbank at the adjacent site, the following ground conditions were encountered:

- Made Ground/Topsoil;
- Residually weathered Mylor Slate Formation; and
- Moderately to slightly weathered Mylor Slate Formation.

Table 2 provides a summary of ground conditions encountered to the west of the site.

Table 2: Ground Conditions Summary

Description	Stratum	Encountered in	Typical depth to top of stratum (m bgl)	Typical depth to base of stratum (m bgl)	Average thickness (m)
Brown gravelly topsoil with tree roots/gravelly clayey topsoil. Gravel is fine to medium sub-rounded imported granite.	Made Ground/Topsoil	All locations	0.0	0.3	0.375
Stiff brown/grey gravelly CLAY. Gravel is fine to coarse sub-angular to sub-rounded slate and flint.	Residually weathered bedrock	All locations	0.3	1.6	1.225
Moderately weak brown/grey META-MUDSTONE. Very weak thin laminae 1 to 4 mm	Moderately weathered Bedrock	All Locations	1.6	3.27	1.67
Moderately strong brown/grey META-MUDSTONE. Very weak thin laminae 1 to 4 mm	Slightly weathered Bedrock	All Locations	3.27	Unproven	Unproven

Boreholes were progressed through the made ground/topsoil into the underlying weathered bedrock. Made ground/topsoil was generally found to be 0.3 m thickness, with the exception of WS04 to the far east of the site, where made ground was found to be up to 0.75 m thickness.

The made ground/topsoil was found to be underlain by a residually weathered stiff brown/grey gravelly CLAY, generally encountered to 1.6 m depth (average), which gradated into a moderately weathered moderately weak META-MUDSTONE, becoming moderately strong below 3.2 m depth. The bedrock weathering profiled was generally found to be consistently dipping to the west, which follows the general topographic trend of the site.

5.2 Groundwater

Groundwater was not encountered within any of the borehole locations. It should be noted, during a recent site inspection by Jubb, no signs of groundwater seepage were observed within the cutting.

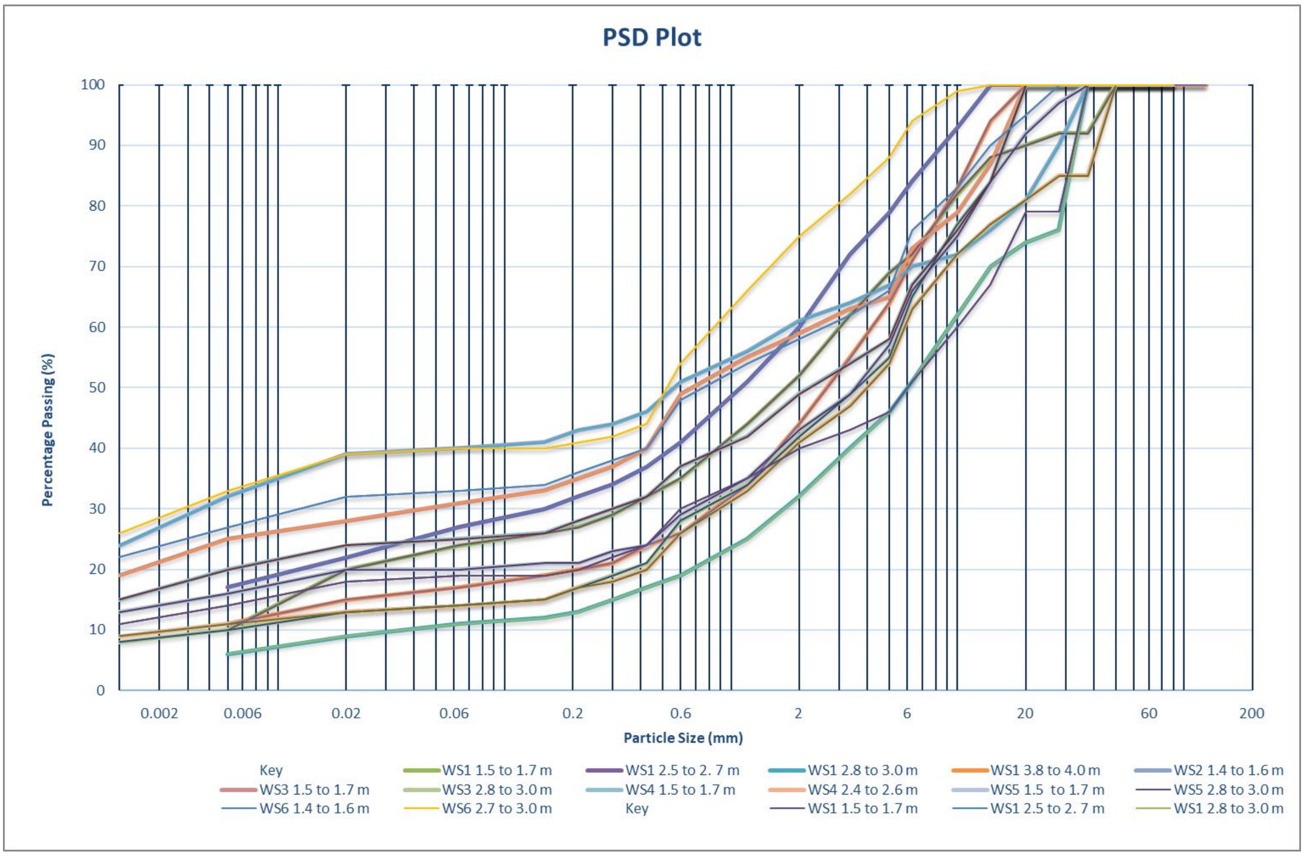
5.3 Material Properties

Laboratory testing was carried out on samples obtained from the residually weathered bedrock.

5.3.1 Classification Properties

6 no. samples from the residually weathered deposits and 7 no. from the moderately weathered bedrock were submitted for grading testing as part of the previous investigation works. The results have been presented in Figure 1, which confirm the variation in composition with depth described in Section 5.1, whereby deposits become less cohesive with depth (below ~4 m depth).

Figure 1. Particle Size Distribution Plot



6 no. samples were tested for natural moisture content within the residual soils, which ranged between 12% and 16%. Within the moderately weathered bedrock, natural moisture contents ranged between 6.4% to 15%.

Figure 2. Atterberg Plot - Residual Soil and Moderately Weathered Bedrock

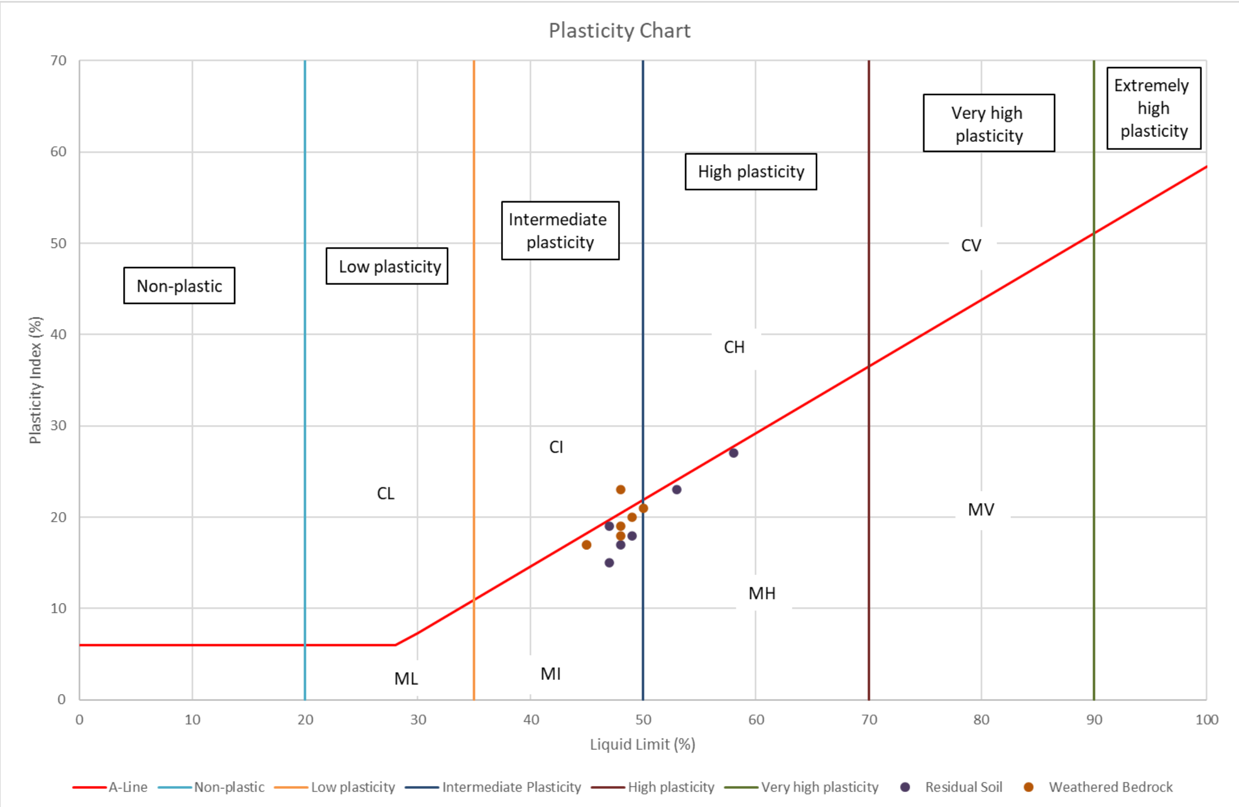


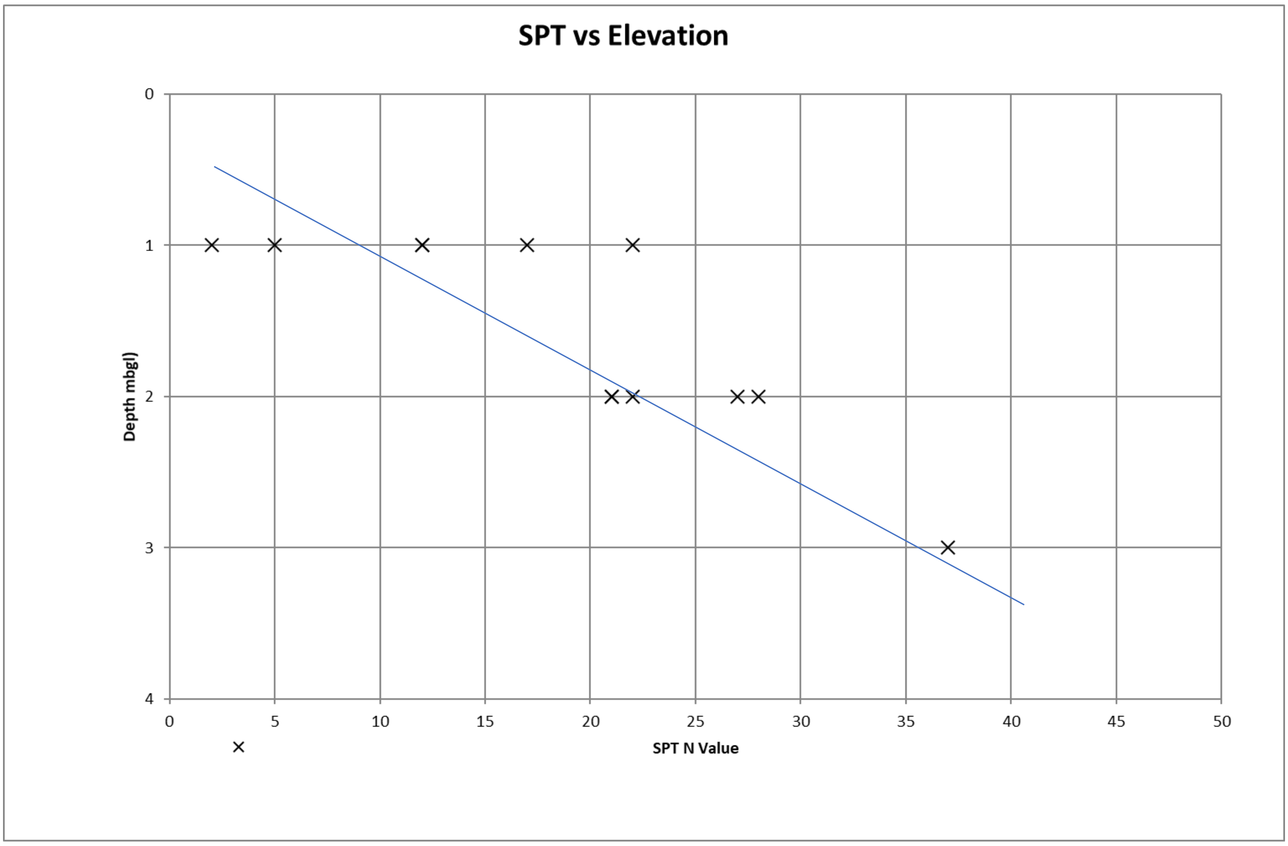
Table 3. Atterberg Limits Tests

Summary Geotechnical Data: Residual Soil			
	Minimum	**Maximum**	**Average**
Natural Moisture Content	12	16	13.7
Liquid Limit	47	58	50.3
Plastic Limit	30	48	33.8
Plasticity Index	15	27	19.8
Summary Geotechnical Data: Moderately Weathered Bedrock			
	Minimum	**Maximum**	**Average**
Natural Moisture Content	6.4	15	9.4
Liquid Limit	45	50	47.6
Plastic Limit	25	30	28.3
Plasticity Index	17	23	19.3

5.3.2 *In-situ* Testing

Standard Penetration Testing (SPT) was carried out within each borehole position across the adjacent site. The results indicate extrapolated SPT N-values generally ranging between 13 and 45 (but locally as high as 105 and 200 - likely to be on encountering refusal on cobbles and boulders). Relevant to the top 5 m of the riverbank slope, the lower quartile SPT value is 22.

Figure 3. SPT Plot Vs Depth (m bgl)



5.3.3 Chemical Properties

No chemical testing has been carried out to date on the site.

Table 4: Geotechnical Characteristics Properties

Characteristic Property	Symbol	Units	Made Ground / Topsoil	Residual Soil	Moderately Weathered Bedrock	Slightly Weathered Bedrock
Unit Weight	γ	kN/m³	15	19	20	21
Effective Angle of Shearing Resistance ^	Ø'	Degrees	15	26	34	-
Effective Cohesion	c'	kPa	-	-	-	-
Intact Uniaxial Compressive Strength (UCS)*		MPa	-	-	-	8.3
Hoek and Brown Criterionª	m	-	-	-	-	1.678
	s	-	-	-	-	0.012
Permanent Works pore Water Pressure Ratio	Ru_P	-	0.1	0.1	0.1	0.1

Note:
^ - Soil parameters derived from Gibson, Experimental Determination of the True Cohesion and True Angle of Internal Friction in Clays, Proc. of the Third Int. Conf. on Soil Mechanics and Foundation Engineering, Zurich, 1953.
* - UCS strength estimated from extrapolated SPT N-values
ª – Hoek and Brown Criterion estimated using Rocscience Rocdata5.0

these values seem really low.

6. Proposed Works

6.1 General

The proposed works comprise the stabilisation and remediation of the currently unstable and eroding section of cutting along the northern and north-eastern boundary of the Ponsharden Cemetery. The original concept of the stabilisation works comprised slopes being formed to between 60 to 70° slopes with Class 6 material, a grid of Platipus soil anchors to be progressed through the reformed cutting, a Maccaferri MacMAT R Steel reinforced Geomat as the facing, attached to the soil anchors affixed to the face using 300 mm x 300 mm x 10 mm galvanised load plates.

Given the presence of shallow bedrock, Jubb consider the use of Platipus anchors unsuitable. In addition, the placement of Class 6I material at angles in excess of 60° is considered impractical from a buildability perspective. Jubb have therefore, provided an optimised detailed design of the above. Based on the above design, Jubb have proposed the following:

- Soil nails as per the previous designs. Number of nails, lengths angle of installation to be decided based on the outcome of the design analyses;
- High tensile steel mesh with matting to tie-in with soil nails and create a facing for the temporary works; and
- Reno mattress facing to be attached to soil nail heads, infilled with a combination of Class 6G material and topsoil. Any gaps between the rear of the cutting and the reno-mattress are to be packed with site won material. The mattresses are to be lined with jute with topsoil seeded with wildflower.

The nail design has been undertaken in accordance with the following standards:

Soil nails:

- BS EN 1997, Part 1: Geotechnical Design : General Rules;
- UK National Annex to Eurocode 7: Geotechnical Design;
- BS 8006-2:2011+A1:2017, Code of practice for strengthened/reinforced soils – Part 2: Soil Nail Design); and
- BS EN 16907 Earthworks 2018.

6.2 Eurocode & BS8006 Partial Factors

The partial factors to be applied to determine the Design Parameters for the characteristic soil properties and actions as set out in BS 8006-2:2011+A1:2017 – Code of practice for strengthened / reinforced soils Part 2: Soil nail design as Ultimate Limit State for Set 1 and Set 2 design conditions and are show in Table 5.

Table 5: BS8006-2 Partial Factors

BS8006-2 Partial Factors				
			Set	
Item		Notation	Set 1	Set 2
Permanent Actions	Favourable	γ_{Gfav}	1.00	1.00
	Unfavourable	γ_G	1.35	1.00
Variable Actions	Favourable	γ_{qfav}	0.00	0.00
	Unfavourable	γ_Q	1.50	1.30
Coefficient of shearing resistance		γ_Φ	1.00	1.30
Effective Cohesion		$\gamma_{C'}$	1.00	1.30
Undrained Strength		γ_{cu}	1.00	1.40
Unconfined Compressive Strength		γ_{qu}	1.00	1.40
Weight Density		γ_γ	1.00	1.00

During the works, it is assumed no plant or machinery will be located above the cut slope during the temporary slope condition and all construction works will be completed from the toe of the slope.

Following construction of the new stabilised cutting, Jubb have assumed small maintenance plant/equipment will be used on the slope above the works assuming up to a 3.5 tonne vehicle, which will have a characteristic uniformly distributed variable unfavourable load of 5 kN/m^2, which will be assumed to be applied to the crest of the slope.

Table 6. Surcharge Load Factors - Eurocode 7

Eurocode 7 Surcharge Load Partial Factors				
Surcharge	**Unfactored Load (kN/m^2)**	**Load Action**	**Set 1 (kN/m^2)**	**Set 2 (kN/m^2)**
Small maintenance plant/equipment above cutting (assumed up to 3.5 tonnes)	5	Variable unfavourable	7.5	6.5

7. Global Slope Stability Assessment

A global slope stability assessment has been carried out using Rocscience, Slide software, version 8.026. The slope stability model has been based on Set 1 and 2 Partial Factors using the following limit state equilibrium methods:

- Spencer;
- Janbu;
- Modified Bishop; and
- GLE/Morganstern-Price.

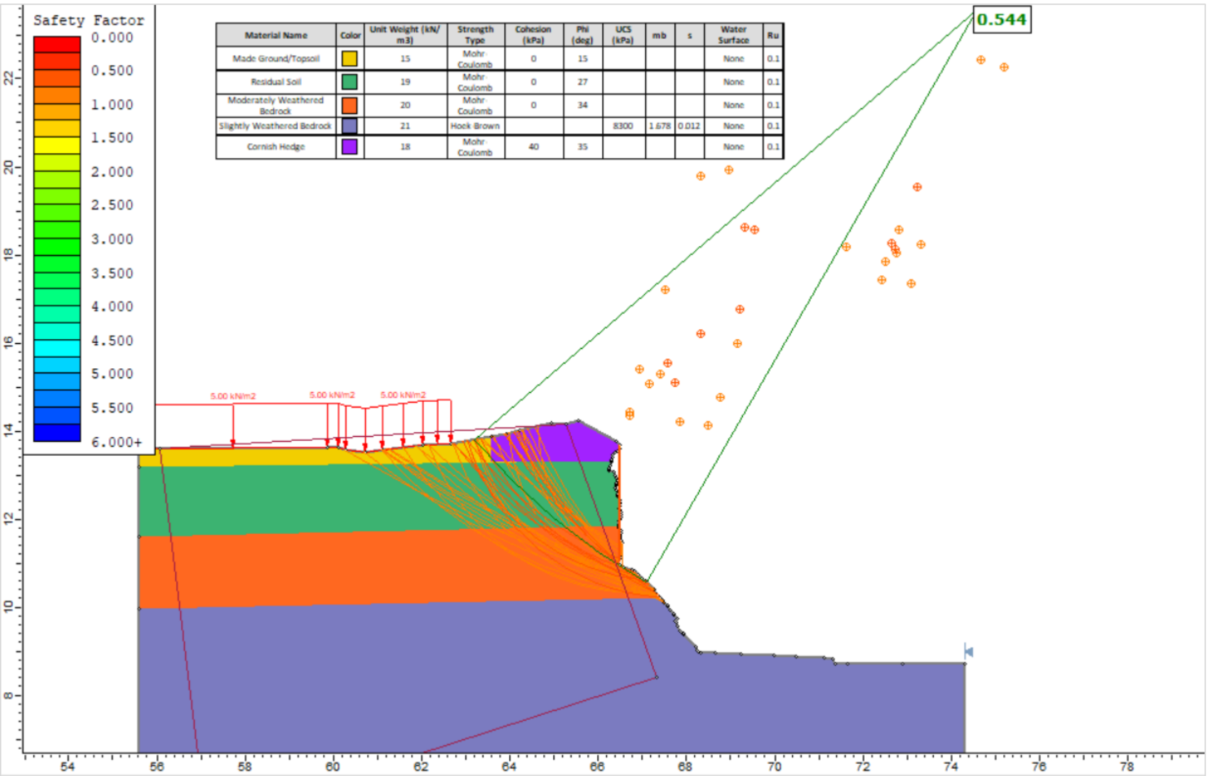
The results of the analysis have been presented in **Appendix B**. As part of the analysis, the current slope conditions were modelled to represent present day conditions of the slopes. In doing so, a Pore Water Pressure Ratio (Ru) of 0.1 has been assumed for weathered materials assuming a minimum slip plane depth of 0.5 m below surface level. For the purpose of the design, the Cornish hedge has been assumed to effectively held together by roots.

Table 7. Preliminary Slope Stability Assessment of Unsupported Slopes (unprofiled)

Preliminary Slope Stability Model - Unsupported						
Section	**Set**	**Ordinary - Fellenius**	**Spencer**	**Janbu**	**Modified Bishop**	**Morganstern - Price**
Section 1	Set 1	1.18	1.1	1.1	1.1	1.1
	Set 2	0.911	0.858	0.858	0.862	0.858
Section 2	Set 1	0.645	0.604	0.587	0.594	0.604
	Set 2	0.496	0.460	0.451	0.457	0.459
Section 3	Set 1	0.671	0.751	0.551	0.212	0.715
	Set 2	0.516	0.575	0.427	0.165	0.554
Section 4	Set 1	0.750	0.686	0.686	0.593	0.686
	Set 2	0.594	0.544	0.544	0.480	0.544
Section 5	Set 1	0.795	0.804	0.714	0.789	0.803
	Set 2	0.612	0.619	0.549	0.607	0.624
Section 6	Set 1	0.374	0.409	0.280	0.330	0.350
	Set 2	0.348	0.319	0.298	0.313	0.315

Based on the above results, conservative factors of safety were observed using the Janbu method, whereby both Set 1 and Set 2 under the Janbu method produced the lowest factor of safety. However, Bishop methodology will also be considered and checked in accordance with BS 8006-2:2011+A1:2017. This method is considered appropriate for modelling the slopes for the proposed works for global factors of safety. With the exception of Set 1 on Section 1, all slope stability models returned a Factor of Safety <1.

Figure 4. Section 4 slope stability model – Set 2 (Janbu Method) – Filtered for FOS <1



8. Soil nail Design

This section provides details of the soil nail design to ensure global and local (mantle) stability for the temporary and permanent works. Additional details of soil nails and facing design have also been provided within the soil nail drawings in **Appendix E - Drawing 600, 601, 602, 650 and 651.**

Soil nails are to be used on the project where their purpose on site are as follows:

- Main Cutting Permanent works – Between 3 no. to 5 no. rows of soil nails (depending on the height of the cutting) are to be drilled into the permanent works cut slope, to provide global and local slope stability during the permanent works activities at an angle of 30° from horizontal with the exception of the top row of soil nails which will be angled at 40° from horizontal. The soil nails are to be secured to the face using a mesh and spike plates; and

  Stairway Permanent works – 4 no. rows of soil nails (varies depending on the profile of the stairs) are to be drilled into the permanent works cut slope, to provide global and local slope stability during the permanent works activities at an angle of 30° from horizontal with the exception of the top row of soil nails which will be angled at 40° from horizontal. The soil nails are to be secured to the face using a mesh and spike plates.

8.1 Tendon Strength

DYWIDAG soil nail systems are recommended for use at the site, with the intended use to control overall global stability of the cutting slope and combined with the proposed mesh covered surface to ensure local stability (slope mantle) during temporary works conditions for temporary slope conditions and permanent works. The type of tendon has been selected in conjunction with Geobrugg Ruvolum software to select a product which is both suitable for controlling the local and global stability requirements, but also a product which is compatible with the permanent facing mesh design. On this basis a DYWIDAG R38-420 with a sacrificial corrosion allowance has been selected for the main face along Falmouth Road and a DYWIDAG R25-200 along the stairway cutting, which assumes the following criteria:

Table 8. Tendon Properties and Strength Parameters

	Units	Main Cutting – Falmouth Road	Stairway Cutting
Bar Type		DYWIDAG R38-420	DYWIDAG R25-200
Nominal thread diameter	**mm**	38	25
Effective external diameter	**mm**	36.4	23.8
Internal diameter	**mm**	21	14
Cross-section area	**mm2**	660	290
Ultimate Strength	**kN**	420	200
Yield Strength	**kN**	350	150
Steel Grade (Yield/Ultimate)	**N/mm2**	510/610	520/690

Given the design life of 60 years is assumed, the sheltered coastal location of the proposed works and in accordance with BS 8006-2:2011+A1:2017: Code of practice for strengthened/reinforced soils Part 2: Soil Anchor Design, an atmospheric corrosivity category of C3 (medium) has been considered appropriate. In addition, due to the lack of soil geochemical data, the soil and rock at the site has been assumed to have a 'high' aggressivity condition. Based on the DYWIDAG technical data for such soil types, the following has corrosion parameters been assumed within the design:

Table 9. Tendon Properties and Strength Parameters

	Units	Main Cutting – Falmouth Road	Stairway Cutting
Bar Type		DYWIDAG R38-420	DYWIDAG R25-200
Sacrificial Thickness	**mm**	4.9	4.9
Cross-sectional Area (with rusting away)	**mm2**	406	126
Ultimate Strength	**kN**	256	86
0.2% Yield Strength	**kN**	214	65

8.2 Global Slope Stability Assessment

Based on the worst-case slope profiles, a slope stability assessment was carried out using Rocscience Slide based on reprofiling the slope to form maximum slope angles of 70°. Based on the outcome of the facing design using Geobrugg's Ruvolum software, a soil nail angle of 30° was required to satisfy soil nail facing design, with the exception of Row 1, which requires a soil nail angle of 40° to prevent intersection with potential grave sites. The following slope stabilisation assumptions between Sections 3 to 5:

- 1 no. row (Row 1) of 3.0 m length R38-420 DYWIDAG galvanised hollow bar installed at an angle of 40° from horizontal, with P33 galvanised and spike plate within a 115 mm diameter hole;
- 1 no. row (Row 2) of 4.5 m length R38-420 DYWIDAG galvanised hollow bar installed at an angle of 30° from horizontal, with P33 galvanised and spike plate within a 115 mm diameter hole;
- 1 row (Row 3) of 3.5 m length R38-420 DYWIDAG galvanised hollow bar installed at an angle of 30° from horizontal, with P33 galvanised and spike plate within a 115 mm diameter hole;
- 1 row (Row 4) of 3.0 m length R38-420 DYWIDAG galvanised hollow bar installed at an angle of 30° from horizontal, with P33 galvanised and spike plate within a 115 mm diameter hole; and
- 1 row (Row 5) of 3.0 m length R38-420 DYWIDAG galvanised hollow bar installed at an angle of 30° from horizontal, with P33 galvanised and spike plate within a 115 mm diameter hole.
- On construction of the reno-mattress facing, the soil nail shall be attached to the rear face of the mattress with an addition P33 galvanised spike plate.

Between Sections 1 and 2, the following soil nail arrangement has been assumed:

- 1 no. row (Row 1) of 3.0 m length R38-420 DYWIDAG galvanised hollow bar installed at an angle of 40° from horizontal, with P33 galvanised and spike plate within a 115 mm diameter hole;
- 1 no. row (Row 2 – on Section 2 only) of 3.5 m length R38-420 DYWIDAG galvanised hollow bar installed at an angle of 30° from horizontal, with P33 galvanised and spike plate within a 115 mm diameter hole;
- 1 row (Row 3) of 3.0 m length R38-420 DYWIDAG galvanised hollow bar installed at an angle of 30° from horizontal, with P33 galvanised and spike plate within a 115 mm diameter hole;
- 1 row (Row 4) of 3.0 m length R38-420 DYWIDAG galvanised hollow bar installed at an angle of 30° from horizontal, with P33 galvanised and spike plate within a 115 mm diameter hole; and
- On construction of the reno-mattress facing, the soil nail shall be attached to the rear face of the mattress with an addition P33 galvanised spike plate.

For the access stairs, the following soil nail configuration has been assumed:

- 1 no. row (Row 1) of 2.5 m length R25-200 DYWIDAG galvanised hollow bar installed at an angle of 40° from horizontal, with P33 galvanised and spike plate within a 50 mm diameter hole;
- 3 no. row (Row to 4) of 2.5 m length R25-200 DYWIDAG galvanised hollow bar installed at an angle of 30° from horizontal, with P33 galvanised and spike plate within a 50 mm diameter hole;

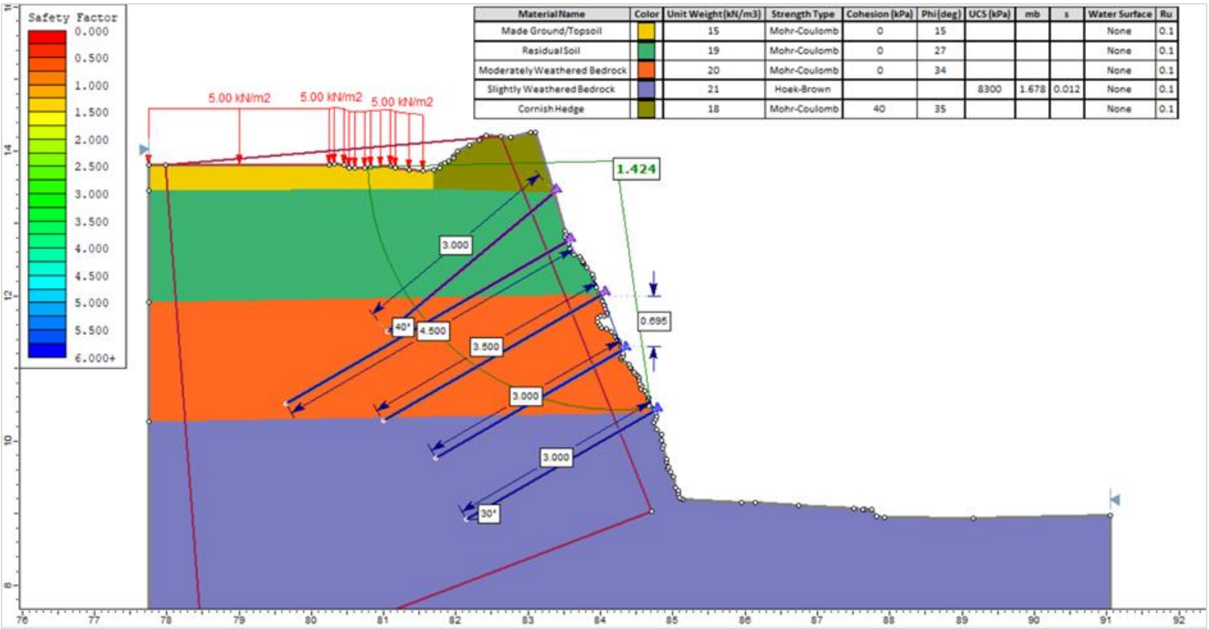
Between Section 1 to 2 all soil nails are to be installed with a vertical spacing (nail distance in line of slope) 1.0 m and a 2.0 m out of plane spacing. Between Section 3 to 5, Rows 1 to 3 soil nails are to be installed with a vertical spacing (nail distance in line of slope) 1.0 m and a 1.0 m out of plane spacing, with rows 4 to 5 to be increased to a 2.0m out of plane spacing. Within Section 6 all nails are to be installed with a vertical spacing (nail distance in line of slope) 0.75 m and a 0.75 m out of plane spacing.

For the purpose of this study, pore water pressure ratios (Ru) have been assumed as 0.1.

The general proposed nail layout has been presented in Figure 5.

Soil nails are to be installed on an offset diamond grid pattern across the slope, which will ensure Rows 1 and 2 do not clash due to the steeper nail angle of Row 1.

Figure 5. Typical Temporary Works Soil nails Arrangement - Section 5



8.2.1 Permanent Works

Under permanent conditions, a global slope stability assessment has been undertaken, with the results presented in Table 10, which assumes the reno-mattress facing has been attached to the soil nail head to form the slope facing. Any void behind the reno-mattress has been assumed to be backfilled with site won weathered bedrock material. With regards to the stairway reinstatement (Section 6), the stone wall has been assumed to be reconstructed, with the gap between the cutting and the wall backfilled with Select Fill material.

On this assumption, permanent works slope a FOS > 1.065 is achieved for Set 1 and >1.054 for Set 2, which is based on the minimum number of rows and vertical spacing of nails required to achieve global stability.

Table 10. Slope Stability Assessment of Permanent Works Supported Slopes – Circular Failures

Section	Scenario	Set	Janbu	Bishop simplified
Section 1	Slope Regrading and Soil Nailing	Set 1	1.558	1.065
		Set 2	1.296	1.291
	Facing Installation	Set 1	2.878	3.999
		Set 2	2.27	3.01
Section 2	Slope Regrading and Soil Nailing	Set 1	1.558	1.065
		Set 2	1.296	1.291
	Facing Installation	Set 1	2.878	3.999
		Set 2	1.872	2.322
Section 3	Slope Regrading and Soil Nailing	Set 1	1.91	1.409
		Set 2	1.47	1.054
	Facing Installation	Set 1	3.4	3.03
		Set 2	2.27	2.34
Section 4	Slope Regrading and Soil Nailing	Set 1	4.73	2.8
		Set 2	5.27	1.63
	Facing Installation	Set 1	4.62	3.89

		Set 2	3.36	2.7
Section 5	Slope Regrading and Soil Nailing	Set 1	2.54	3.2
		Set 2	1.87	2.09
	Facing Installation	Set 1	3.28	4.63
		Set 2	2.36	3.19
Section 6	Slope Regrading and Soil Nailing	Set 1	1.917	1.63
		Set 2	1.73	1.85
	Facing Installation	Set 1	1.739	2.29
		Set 2	1.650	5.08

In addition, the stability of the slopes without facing design (absence of reno-mattress) has been assessed for non-circular failures using a block search methodology. The results of the slope stability assessment have been presented in Table 11.

Table 11. Slope Stability Assessment of Permanent Works Supported Slopes –Non-Circular Failures

Section	Scenario	Set	Janbu	Bishop simplified
Section 1	Slope Regrading and Soil Nailing	Set 1	2.58	2.36
		Set 2	2.06	1.845
Section 2		Set 1	1.4	1.496
		Set 2	1.413	1.535
Section 3		Set 1	2.38	2.35
		Set 2	1.67	1.64
Section 4		Set 1	6.49	6.814
		Set 2	3.84	3.84
Section 5		Set 1	2.6	2.86
		Set 2	1.58	1.73
Section 6		Set 1	2.36	2.73
		Set 2	1.48	1.69

8.3 Pull-Out Resistance

Although no Investigation (pull-out) testing has been carried out at the time of writing this report, the following analysis has been carried out to check the tendon resistance, resistance between the interaction of the grout and tendon and the resistance between the grout and the ground (surrounding soil):

MAIN FACING:

- **Tendon Resistance**;
  - Bar diameter – 38 mm
  - Reduced cross-sectional area of bar at end of design life – 406 mm^2;
  - Ultimate tensile strength at start of design life – 610 N/mm^2;
  - Steel grade yield at start of design life – 510 N/mm^2;
  - Resistance factor for tendon (γT) – 1.15;
  - Characteristic yield strength of tendon (Rtk) – 115 kN; and
  - Design Tensile Resistance (Rtd) – 100 kN.
- **Grout-Tendon Resistance;**
  - Bar diameter – 38 mm;
  - Free length of nail – 0.75 m;
  - Fixed length of nail varies between 2.25 m for 3.75 m length nail; and
  - Ultimate bond or skin friction at the tendon/grout interface – 5000 kN/m^2.
- **Grout-Ground Resistance**;
  - Ref Table 11 for grout:ground stress;
  - 115 mm diameter of fixed anchor; and
  - Fixed length of nail varies between 2.25 m for 3.75 m length nail.

STAIRWAY:

- **Tendon Resistance**;
  - Bar diameter – 25 mm;

- Reduced cross-sectional area of bar at end of design life – 127 mm^2;
- Ultimate tensile strength at start of design life – 690 N/mm^2;
- Steel grade yield at start of design life – 250 N/mm^2;
- Resistance factor for tendon (ɣT) – 1.15;
- Characteristic yield strength of tendon (Rtk) – 117 kN; and
- Design Tensile Resistance (Rtd) – 102 kN.

- **Grout-Tendon Resistance;**
  - Bar diameter – 25 mm;
  - Free length of nail – 0.75 m;
  - Fixed length of nail varies between 2.25 m for 2.75 m length nail; and
  - Ultimate bond or skin friction at the tendon/grout interface – 5000 kN/m^2.
- **Grout-Ground Resistance**;
  - Ref Table 11 for grout:ground stress
  - 50 mm diameter of fixed anchor; and
  - Fixed length of nail varies between 2.25 m for 2.75 m length nail.

Table 12 provides a summary of the expected effective stress pull-out resistance which varies based on nail fixed lengths, with values ranging between 8.0 kN to 42.2 kN for the main face and 4.4 kN to 14.6 kN, for the stairway. Given the design tendon resistance is 100 to 102 kN, the grout-ground resistance is considered the limiting factor for nail design and shall be used for design purposes.

Table 12. Effective Stress Pull Out Resistance – BS8006-2 2011 method (unfactored)

Element	Nail Row	Entry Level (m below embankment crest)	Nail Length (m)	Nail Free Length (m)	Embedment (m)	Effective Stress Pull Out Resistance (kN)
						Unfactored
Main Facing	1	0	3	0.75	1.875	8.0
	2	1	4.5	0.75	2.625	32.9
	3	2	3.5	0.75	2.125	32.0
	4	3	3	0.75	1.875	33.6
	5	4	3	0.75	1.875	42.2
Stairway	1	0	3	0.75	1.875	4.4
	2	1	3.5	0.75	2.2125	9.3
	3	2	3	0.75	1.875	10.9
	4	3	3	0.75	1.875	14.6

8.4 Grout

No geochemical testing has been carried out at the site to date. The Mylor Slate Formation is not known to contain pyrite and the geological setting is distal from contact with granitic bodies. Therefore, the risk of high sulphate content is considered low. Given the anchors are to be driven to a shallow depth of 6 m, some degree of weathering of the Mylor Slate Formation is expected, further reducing the risk of pyritic mineralogy interacting with the grout.

8.5 Nail Layout

The nails are to be installed at 1.0 m vertical spacing (measured along slope). The nails are all to be inclined by 30° (with the exception of Row 1 which will be installed at 40°) within the residual soil and weathered bedrock, where modified cut slope angles reside at no greater than 70°. Where slopes are currently near vertical, slopes will be anchored in their current condition. Between Section 1 to 2 all soil nails are to be installed with a vertical spacing (nail distance in line of slope) 1.0 m and a 2.0 m out of plane spacing. Between Section 3 to 5, Rows 1 to 3 soil nails are to be installed with a vertical spacing (nail distance in line of slope) 1.0 m and a 1.0 m out of plane spacing, with rows 4 to 5 to be increased to a 2.0m out of plane spacing. Within Section 6 all nails are to be installed with a vertical spacing (nail distance in line of slope) 0.75 m and a 0.75 m out of plane spacing.

A layout plan and indicative nails schedule is indicated in **Appendix E - Drawing 600.**

8.6 Mesh

The cutting face for temporary works for soil nailing shall be prepared to form a smooth face not exceeding slope angles of 70°. Where slopes are currently in excess of 70°, to prevent undercutting of the Cornish hedge, slopes will be anchored in their current condition.

To protect against shallow mantle failure in the cut between soil nails, a Tecco mesh system will be installed during soil nailing works. The mesh selected is super coated Tecco G65/3 manufactured by Geobrugg, with a P33 spike plate. The Tecco mesh will be installed to the base of the cut and draped over the crest of slope, terminating at either end in anchor trench no shallower than 300 mm. The mesh shall be underlain by TECMAT®. A technical datasheet for the Tecco mesh is provided in **Appendix C.**

The mesh suitability has been checked using Geobrugg's Ruvolum software. The software has calculated that the Tecco mesh is appropriate for the slope when used in combination with the proposed anchor arrangement, which assumes a 1.0 m maximum thickness layer of mantle and an out of plane nail spacing of 2.0 m and a vertical nail spacing of 1 m (nail distance in line of slope).

Ruvolum calculation sheets are provided in **Appendix D.**

8.7 Head Plate

The soil nails will be attached to the mesh and cut slope facing using a head plate, which bolts onto the end of the soil nail. The head design has been carried out in accordance with BS8006 and through the use of Geobrugg Ruvolum software, to ensure compatibility of the mesh with the spike plate. The head plate design will comprise a Geobrugg P33 super coated spike plate with lock-nut fitting. An additional head plate will be attached to the soil nail to secure the reno-mattress to the face.

Based on the slope configuration, the ultimate bearing resistance of the mesh shearing off in the nail direction at the upslope of the slope plate has been calculated at 90 kN, which is derived through Ruvolum. Ruvolum also takes care of corrosion over the lifetime of the project.

8.8 Slope Final Facing

The slope will be faced using a 0.3 m depth reno-mattress, with the soil nails attached to the rear of the mattress using an additional P33 spike plate. The reno-mattress will comprise Enviromesh Biaxial Weld Mesh (GABION ENV-P38 – Polymer Powder Coated Grey, 3.8 mm diameter mesh) with a 120-year design life (and BBA certificate). Product details have been provided in **Appendix C**.

The mattress will be lined with a Green-tech GTCoir on the rear and side walls.

The reno-mattress itself will be infilled with placed stone with voids infilled with topsoil, documented within the Jubb specification (Ref: 21287-SPEC-01). A modified Class 6G material will be used for the filling of the reno-mattress to maintain the aesthetic requirements of the finished facing.

The modified reno-mattress fill material will comprise the following:

- Fill material to be placed within the reno-mattress will comprise tabular locally sourced slightly weathered to fresh grey limestone or similar to match the neighbouring walls.
- The stones will be placed with a stone:void ratio of approximately 80%:20%.
- The remaining voids will be infilled progressively with Class 5 clean topsoil.
- The stone will comprise a minimum Uniaxial Compressive Strength UCS of >30MPa.
- The stone will have an approximate dimension of 1H:3L:1W and > 200 mm but < 300 mm length.
- Source of stone to be inspected and approved by the geotechnical engineer.

Reno-mattresses are to be filled in accordance with manufacturing recommendations not exceeding 340 mm layer heights. Filling shall be staged so that no adjacent cells have more than a half difference in levels of filling for units of greater height than 500 mm.

<u>The final finish of the wall is yet to be confirmed.</u>

8.9 Construction Sequence

The construction sequence of the soil nail stabilised slopes, in summary, is as follows, which includes the cut slope, soil nail and mesh temporary cut slope, installation of reno-mattress facing:

- Establish work area including road closures
- Commence regrading and removal of unstable slope materials and vegetation to form slope angles not exceeding those identified during detailed design;
- Installation of first top 2 no. rows of soil nails to lengths as those identified during detailed design and confirmed during inspection. Fixed length to be grouted. Soil nails are to be tested in accordance with BS EN 1997-1 (including UK National Annex) and BS8006-2;
- Drape mesh and erosion protection mesh over remainder of the slope and pin in place, fixing with head plates and the crest of the slope and j-pins towards the base;
- Installation of soil nails progressively during excavation works to the slope and installation of mesh facing using a top-down construction method;
- Installation of reno-mattress with attachment of reno mesh to the soil nails using an additional head plate. Once attached and cages of the reno- mattress are secured, the mattress can be progressively infilled with stone and topsoil.
- Any voids behind the cut slope and the rear of the reno-mattress can be packed and infilled with site won weathered rock and soil fill.
- Final facing finish to be confirmed;
- Demobilisation from site and removal of traffic management requirements.

During the installation of the soil nails, the Tecco mesh facing is to be progressively draped over the soil cut surface with each row of soil nails installed, including the installation of headworks and the Tecco tensioned to ensure no inter-nail failures to occur during construction. Prior to the excavation of the next level of nails, the nail/grout bond should be tested to reach > 30N/mm2.

9. Summary

The design of the slope remediation works is to comprise in summary of the following elements:

- Cutting and forming of the existing cutting to not exceeding 70° including excavation of the reno-mattress embedment
- Soil nail of the main cutting face as follows:

  <u>SECTION 1-2</u>

  - 1 no. row (Row 1) of 3.0 m length R38-420 DYWIDAG galvanised hollow bar installed at an angle of 40° from horizontal, with P33 galvanised and spike plate within a 115 mm diameter hole;
  - 1 no. row (Row 2 – on Section 2 only) of 3.5 m length R38-420 DYWIDAG galvanised hollow bar installed at an angle of 30° from horizontal, with P33 galvanised and spike plate within a 115 mm diameter hole;
  - 1 row (Row 3) of 3.0 m length R38-420 DYWIDAG galvanised hollow bar installed at an angle of 30° from horizontal, with P33 galvanised and spike plate within a 115 mm diameter hole;
  - 1 row (Row 4) of 3.0 m length R38-420 DYWIDAG galvanised hollow bar installed at an angle of 30° from horizontal, with P33 galvanised and spike plate within a 115 mm diameter hole; and
  - On construction of the reno-mattress facing, the soil nail shall be attached to the rear face of the mattress with an addition P33 galvanised spike plate.

  <u>SECTION 3-5</u>

  - 1 no. row (Row 1) of 3.0 m length R38-420 DYWIDAG galvanised hollow bar installed at an angle of 40° from horizontal, with P33 galvanised and spike plate within a 115 mm diameter hole;
  - 1 no. row (Row 2) of 4.5 m length R38-420 DYWIDAG galvanised hollow bar installed at an angle of 30° from horizontal, with P33 galvanised and spike plate within a 115 mm diameter hole;
  - 1 row (Row 3) of 3.5 m length R38-420 DYWIDAG galvanised hollow bar installed at an angle of 30° from horizontal, with P33 galvanised and spike plate within a 115 mm diameter hole;
  - 1 row (Row 4) of 3.0 m length R38-420 DYWIDAG galvanised hollow bar installed at an angle of 30° from horizontal, with P33 galvanised and spike plate within a 115 mm diameter hole; and
  - 1 row (Row 5) of 3.0 m length R38-420 DYWIDAG galvanised hollow bar installed at an angle of 30° from horizontal, with P33 galvanised and spike plate within a 115 mm diameter hole.

ACCESS STAIRS:

- 1 no. row (Row 1) of 2.5 m length R25-200 DYWIDAG galvanised hollow bar installed at an angle of 40° from horizontal, with P33 galvanised and spike plate within a 50 mm diameter hole;
- 3 no. row (Row 2 to 4) of 2.5 m length R25-200 DYWIDAG galvanised hollow bar installed at an angle of 30° from horizontal, with P33 galvanised and spike plate within a 50 mm diameter hole;

- All soil nails on the main face are to be installed with a vertical spacing 1.0 m (nail distance in line of slope) and between 1.0 and 2.0 m out of plane spacing in a diamond arrangement. Soil nails installed along the stairway are to be installed with a vertical spacing 0.75 m (nail distance in line of slope) and 0.75 m out of plane spacing in a diamond arrangement;
- Installation of super coated steel Tecco G65/3 mesh over the cutting face using a top-down construction approach. Installation of reno-mattress is to be carried out from the base upwards, with the rear of the mattress attached to the soil nail tendon using an additional nail spike plate.

Earthworks are to be carried out in general accordance with Specification for Highway Works – Series 600 with regards to suitability of backfilled materials, material chemical requirements and compaction requirements.

A Geotechnical Risk Register is a method of identifying hazards which may arise during the construction phase of works based on the data currently obtained for the site. The register is a work in progress and as further information arises, it should be updated in order to quantify the risk. At this stage, the aspects covered by the register are attributed to Cost and Health and Safety, although as site works commence, programme may become a prominent factor, which is contained within **Appendix F**.

Appendix A: Site Location Plan

Appendix A: Site Location Plan

Jubb

Appendix B: Slope Stability Assessment (ULS)

Figure 6. Section 1 Current site Condition BS8006 Set1

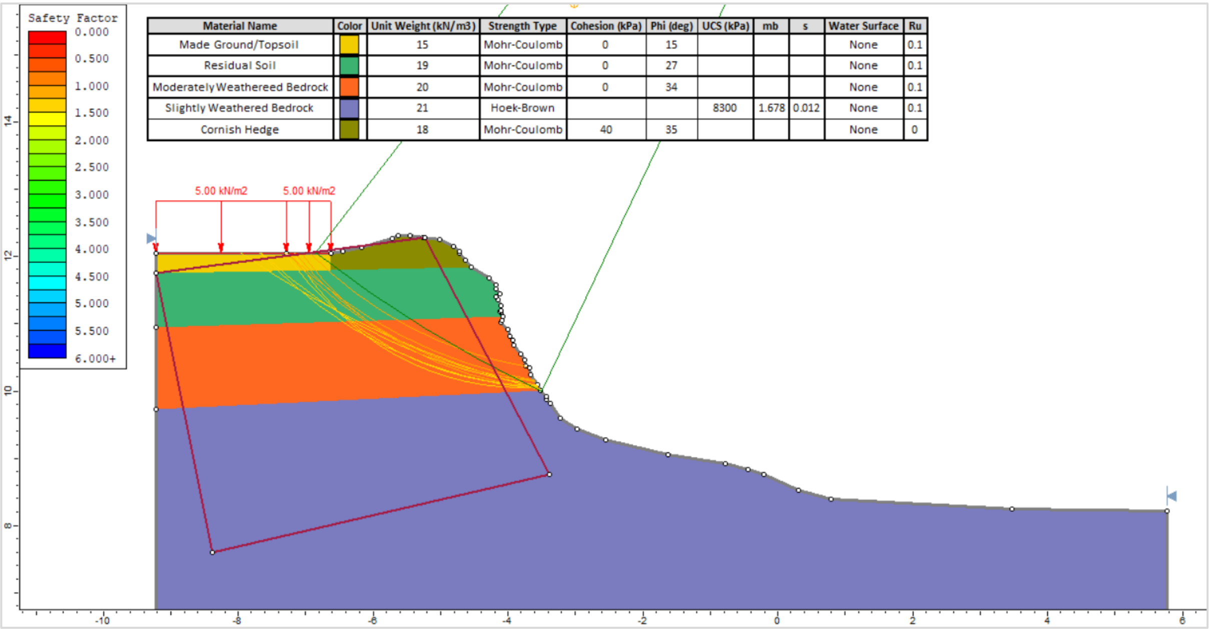


Figure 7. Section 1 Current site Condition BS8006 Set2

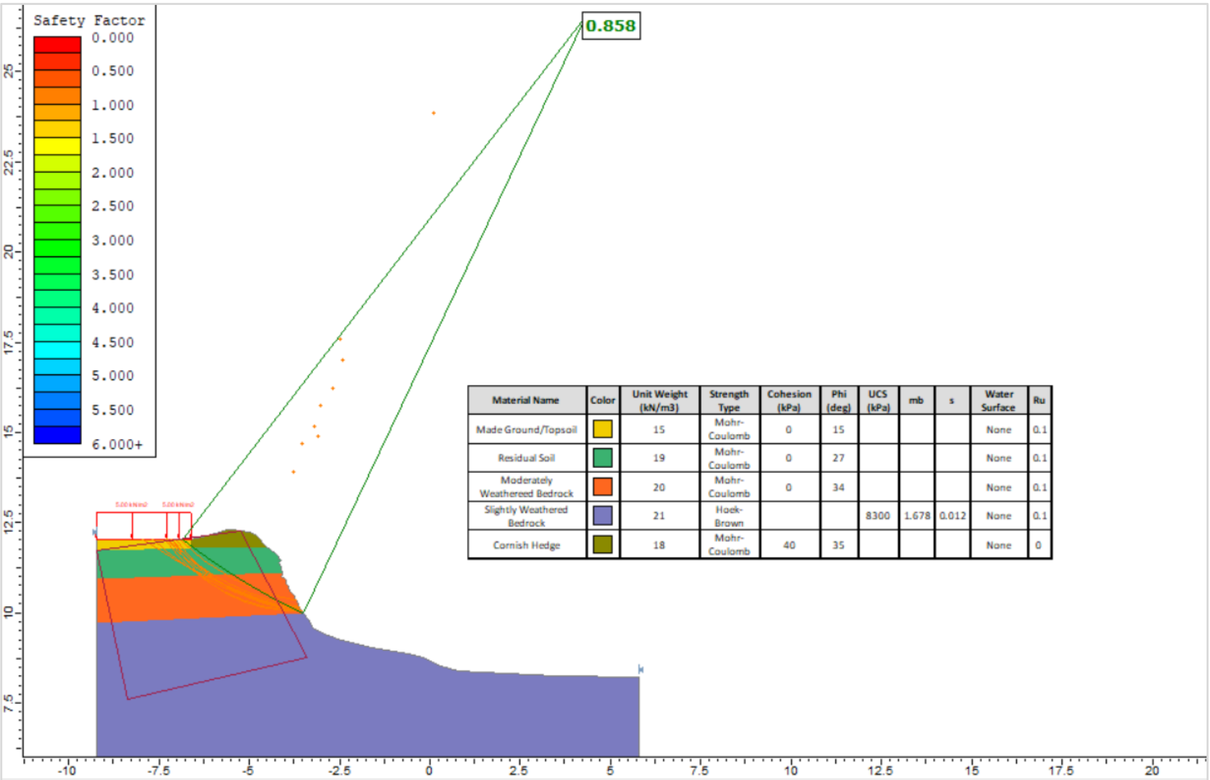


Figure 8. Section 1 – Soil Nailing - BS8006 Set1

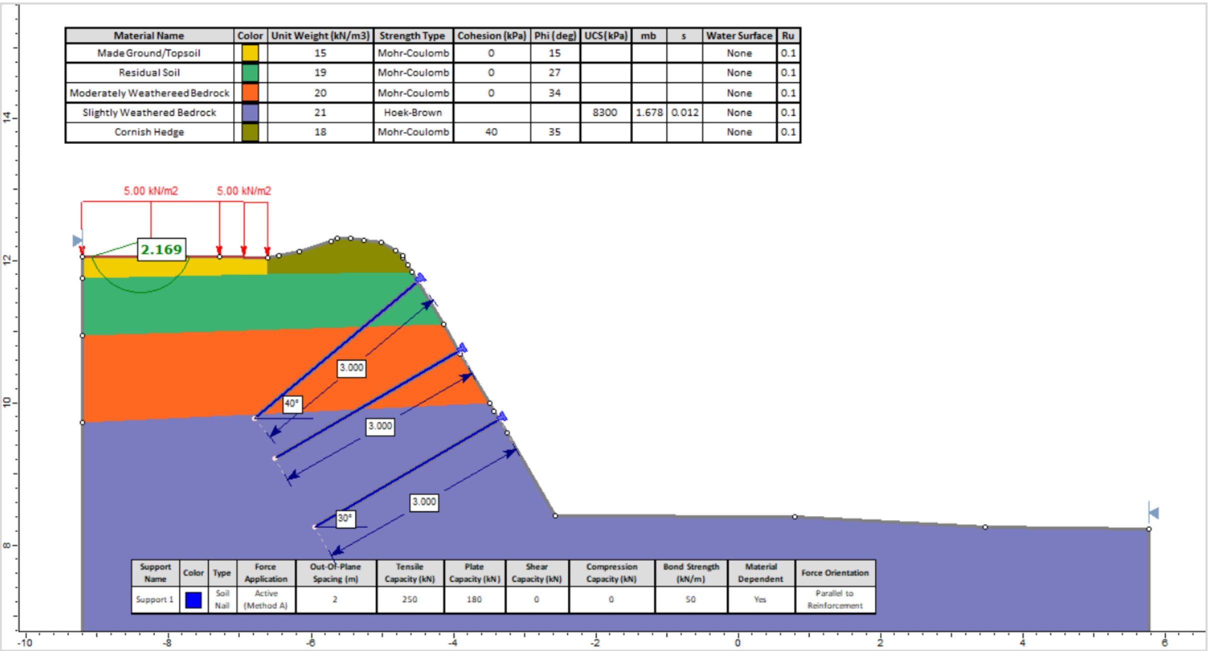


Figure 9. Section 1 – Soil Nailing - BS8006 Set2

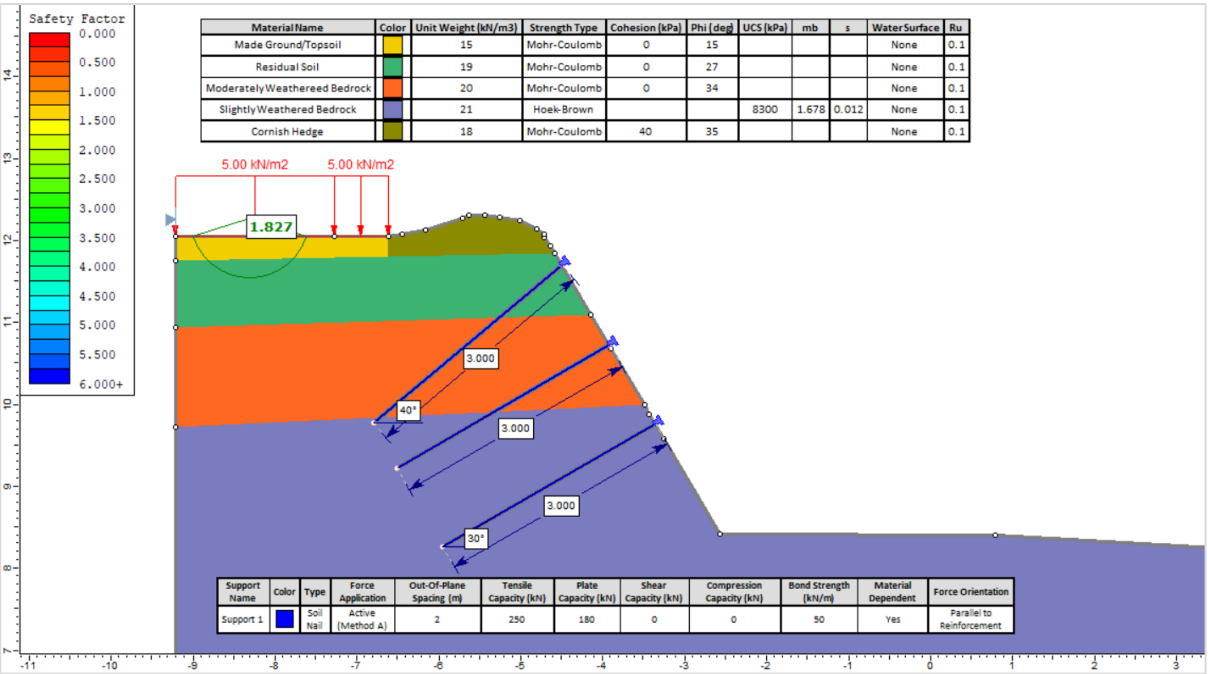


Figure 10. Section 1 – Facing Installation - BS8006 Set1

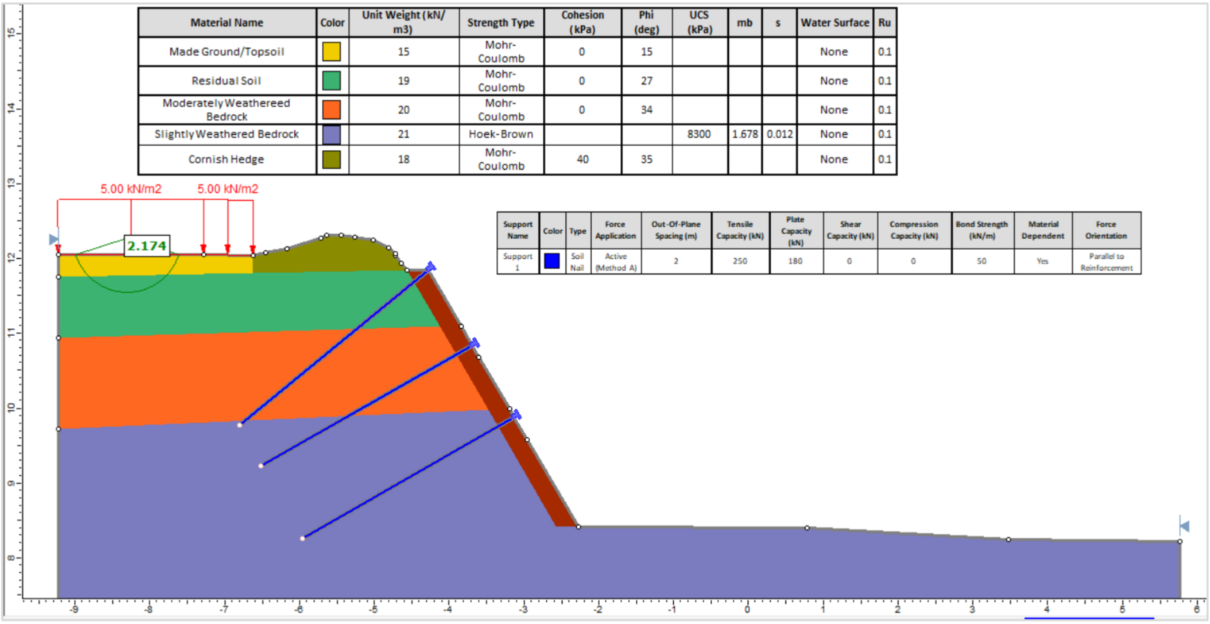


Figure 11. Section 1 – Facing Installation - BS8006 Set2

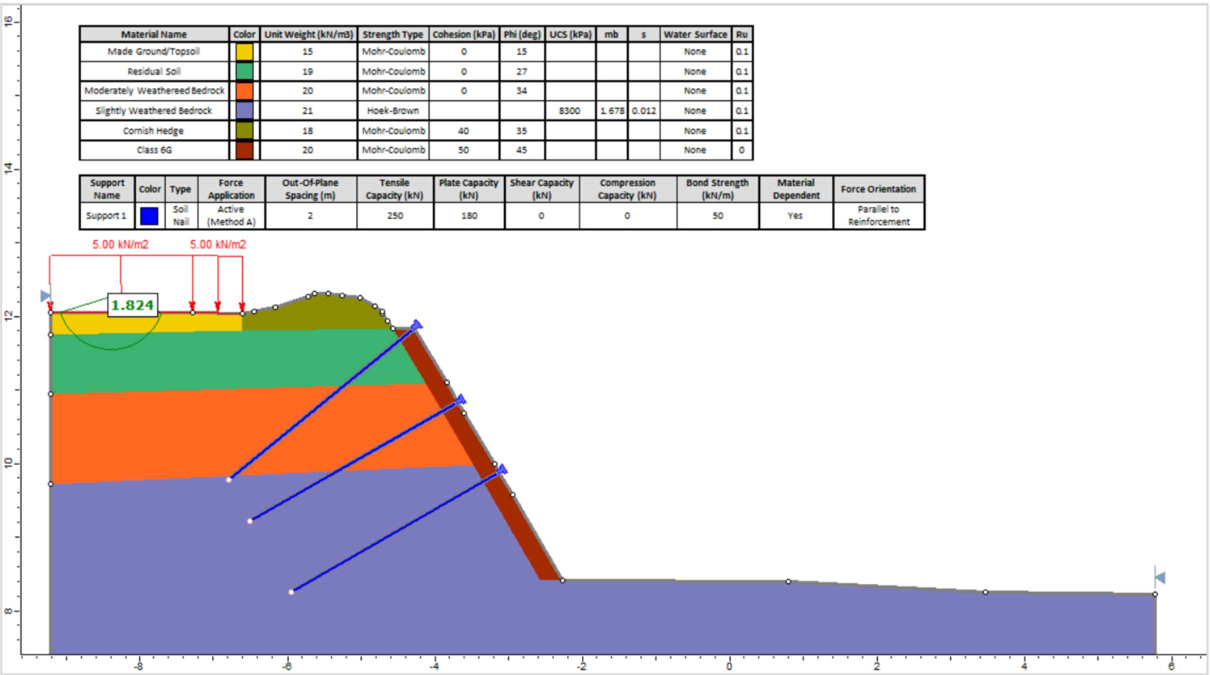


Figure 12. Section 2 Current site Condition BS8006 Set1

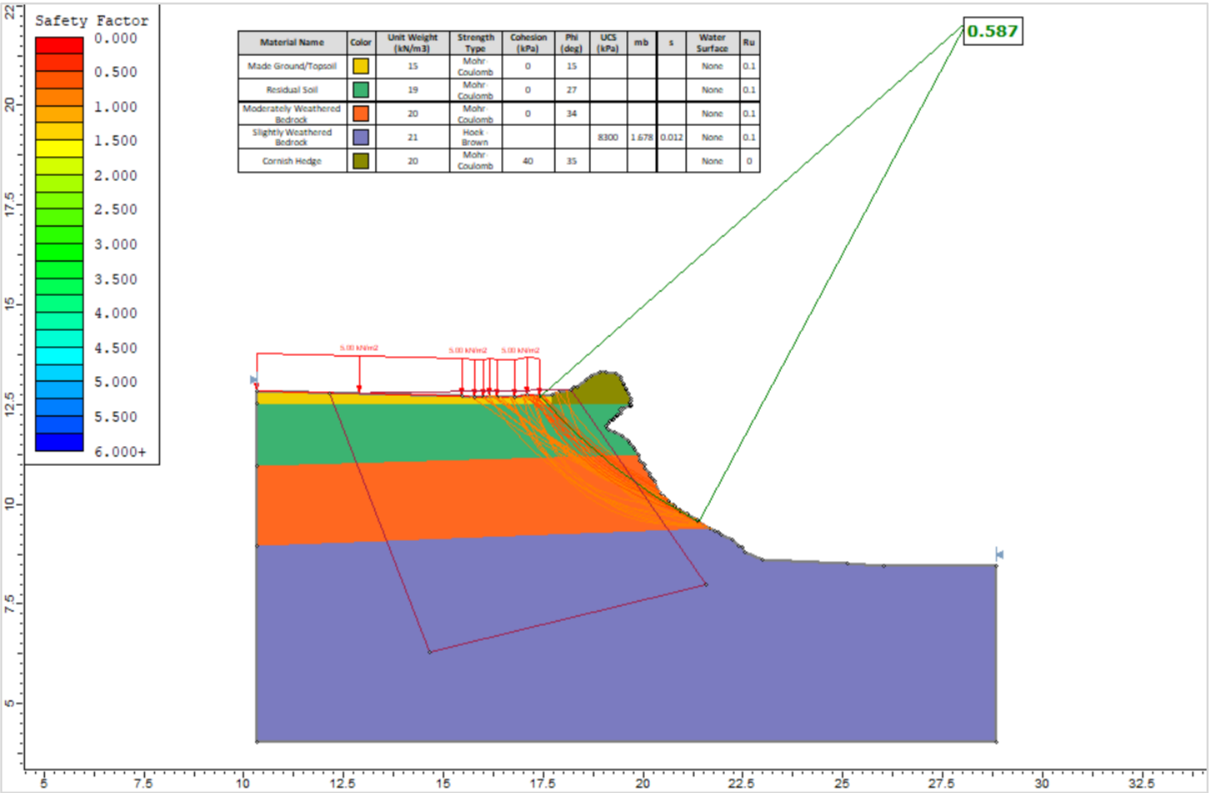


Figure 13. Section 2 Current site Condition BS8006 Set2

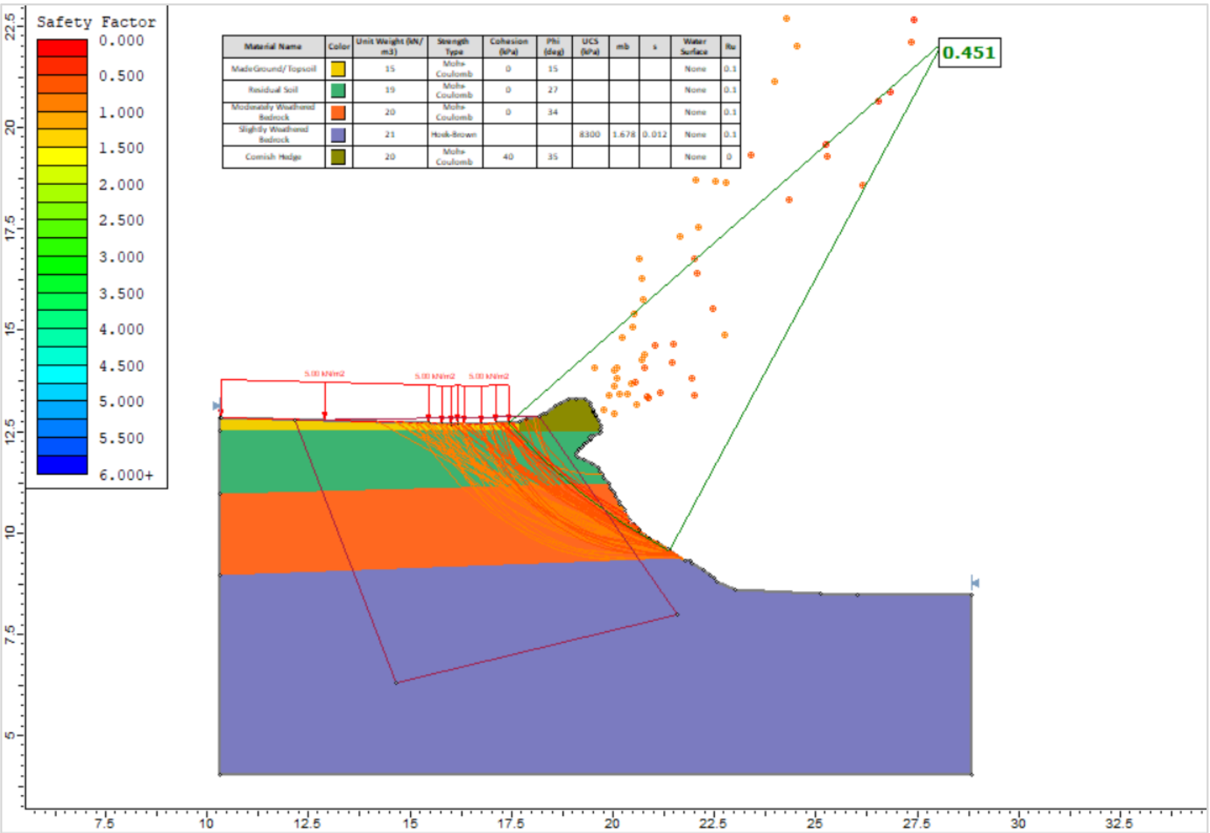


Figure 14. Section 2 – Soil Nailing - BS8006 Set1

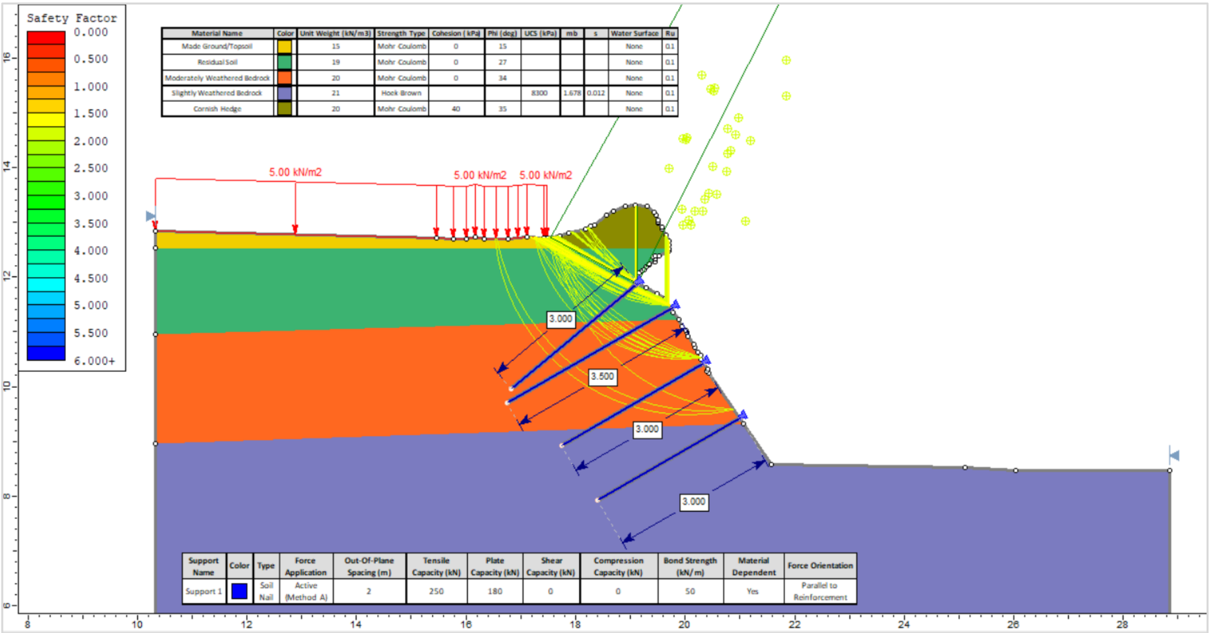


Figure 15. Section 2 – Soil Nailing - BS8006 Set2

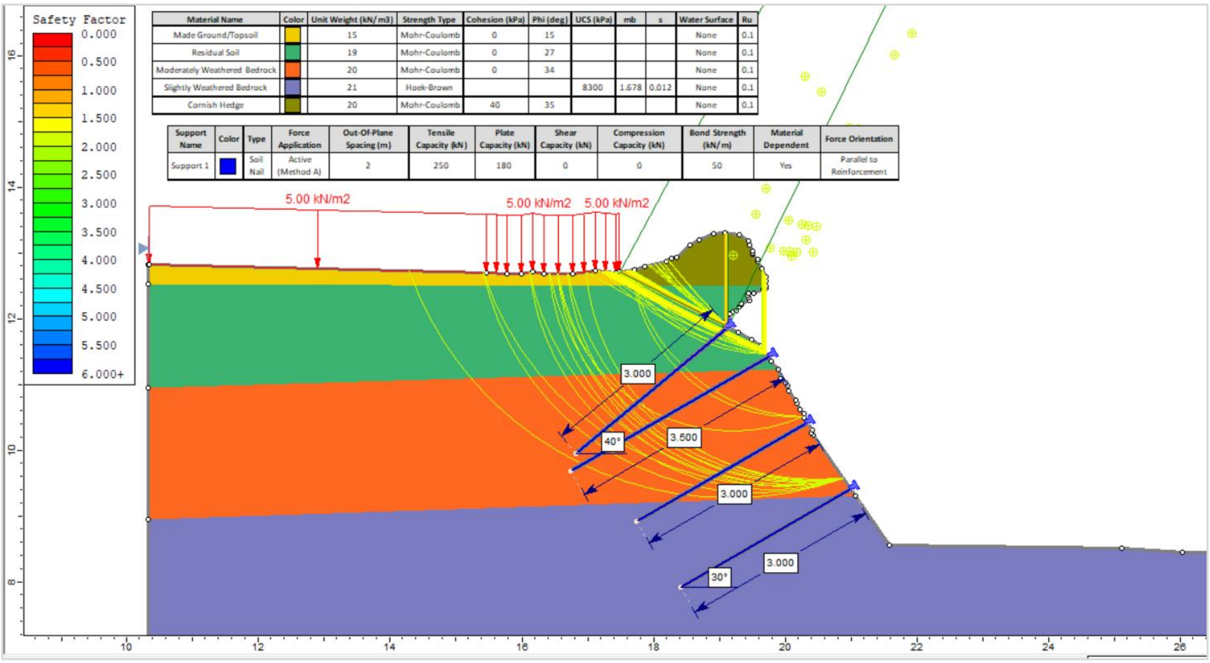


Figure 16. Section 1 – Facing Installation - BS8006 Set1

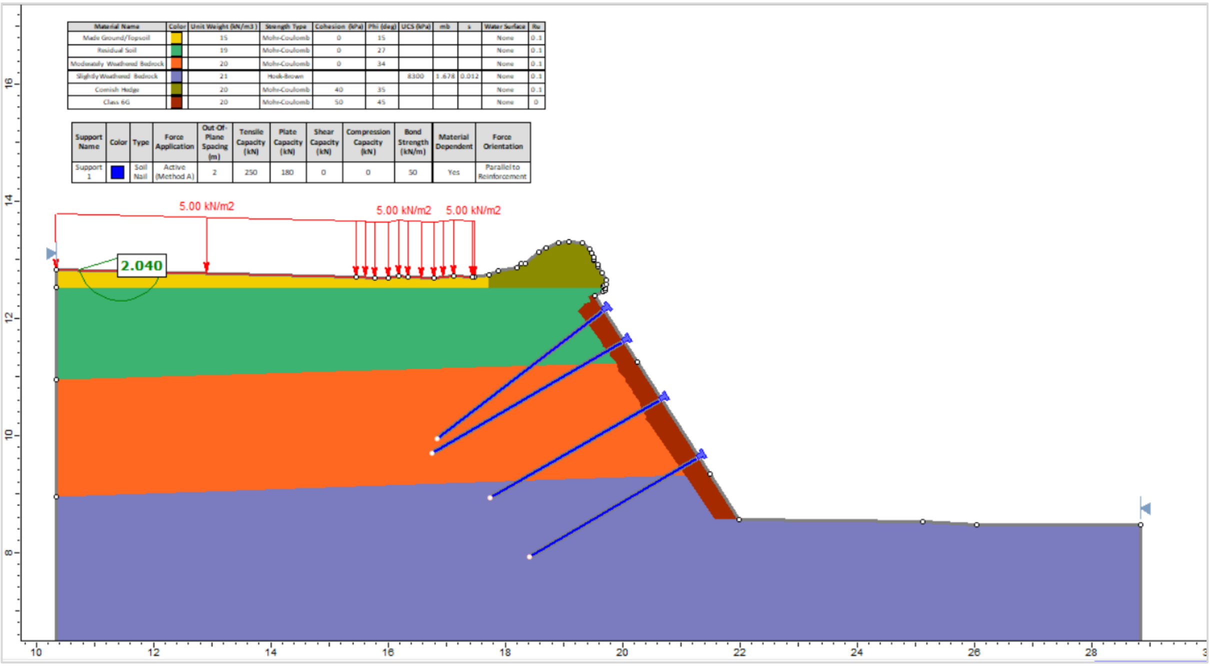


Figure 17. Section 2 – Facing Installation - BS8006 Set2

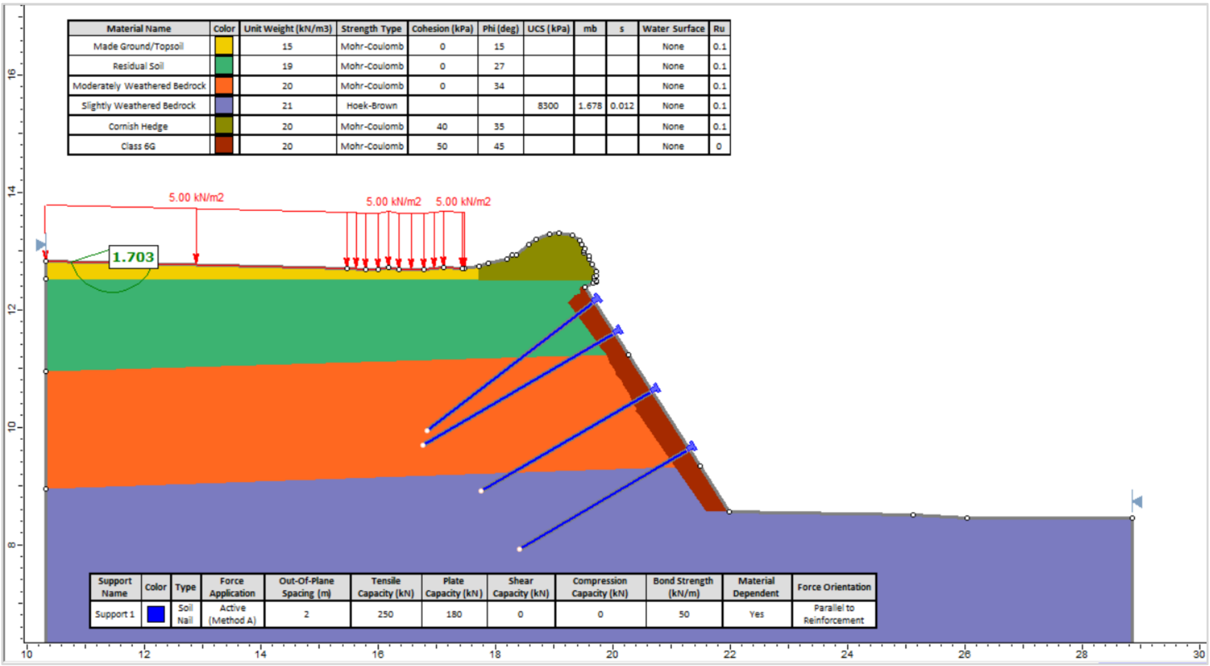


Figure 18. Section 3 Current site Condition BS8006 Set1

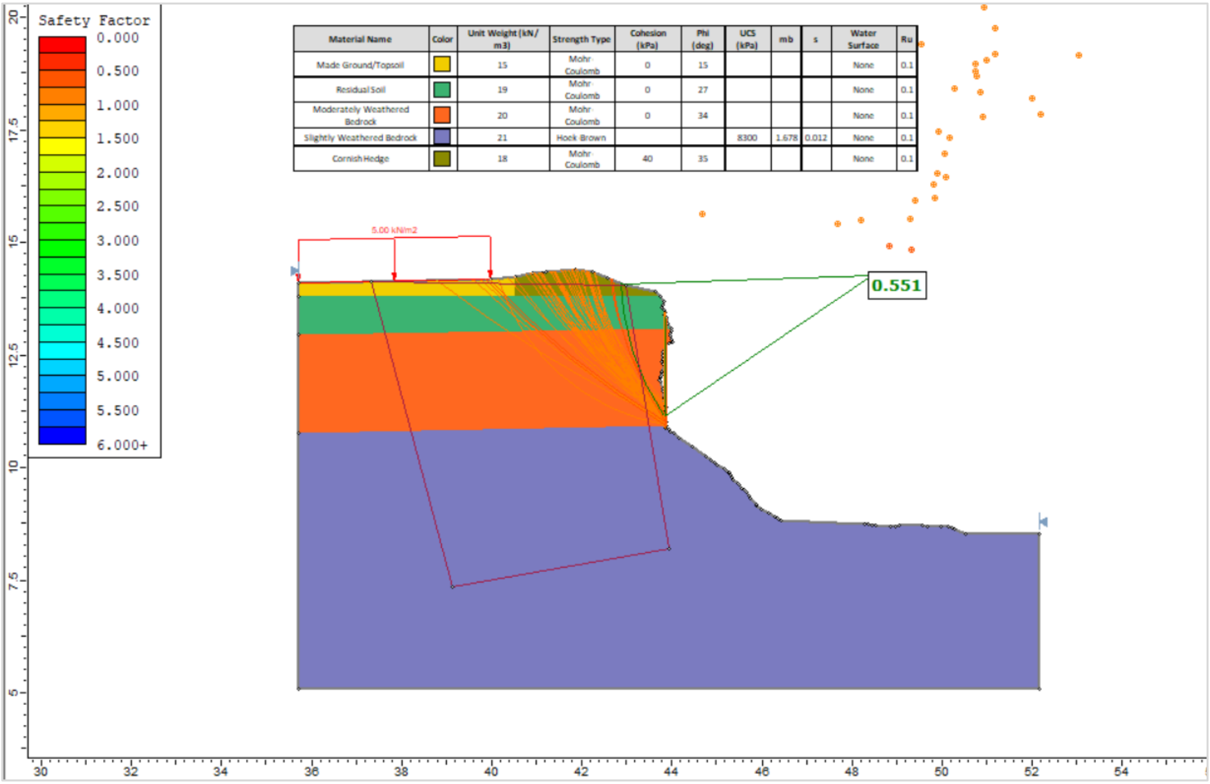


Figure 19. Section 3 Current site Condition BS8006 Set2

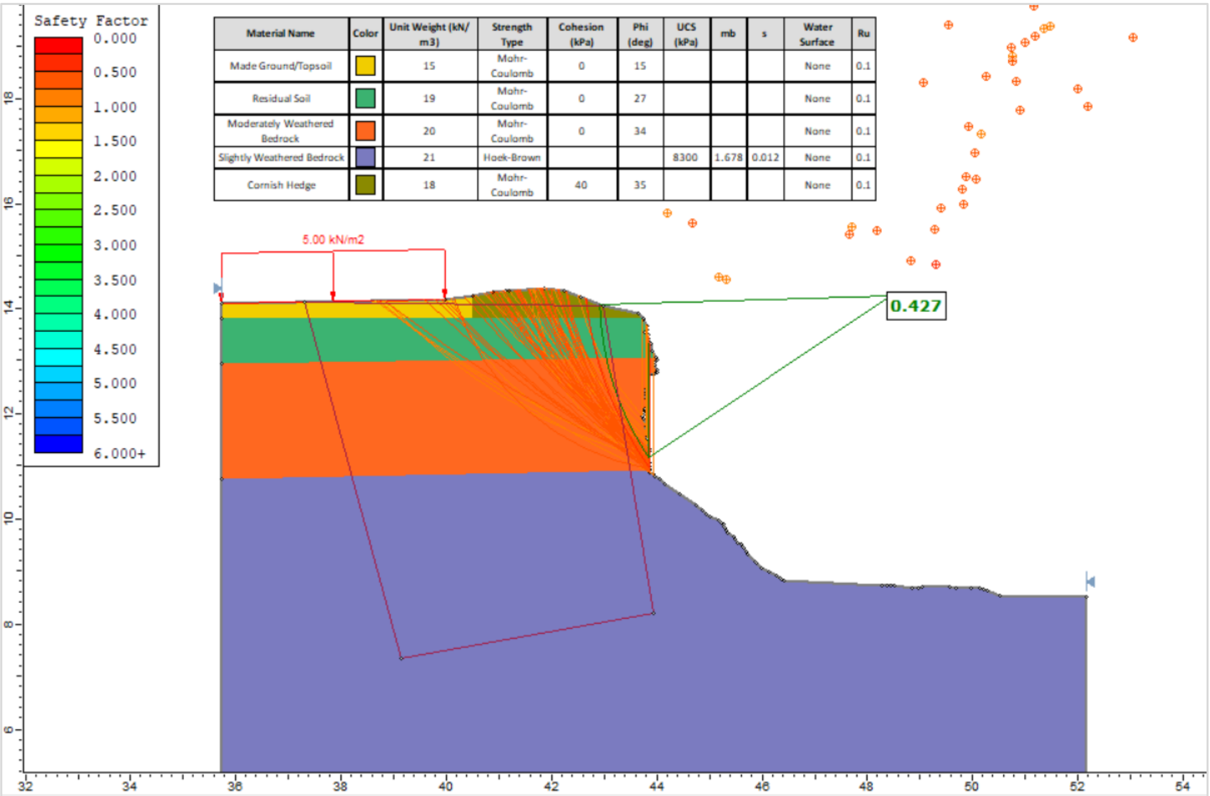


Figure 20. Section 3 – Soil Nailing - BS8006 Set1

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	UCS (kPa)	mb	s	Water Surface	Ru
Made Ground/Topsoil		15	Mohr-Coulomb	0	15				None	0.1
Residual Soil		19	Mohr-Coulomb	0	27				None	0.1
Moderately Weathered Bedrock		20	Mohr-Coulomb	0	34				None	0.1
Slightly Weathered Bedrock		21	Hoek-Brown			8300	1.678	0.012	None	0.1
Cornish Hedge		18	Mohr-Coulomb	40	35				None	0.1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Shear Capacity (kN)	Compression Capacity (kN)	Bond Strength (kN/m)	Material Dependent	Force Orientation
Support 1		Soil Nail	Active (Method A)	2	250	180	0	0	50	Yes	Parallel to Reinforcement
Support 2		Soil Nail	Active (Method A)	1	250	180	0	0	50	Yes	Parallel to Reinforcement

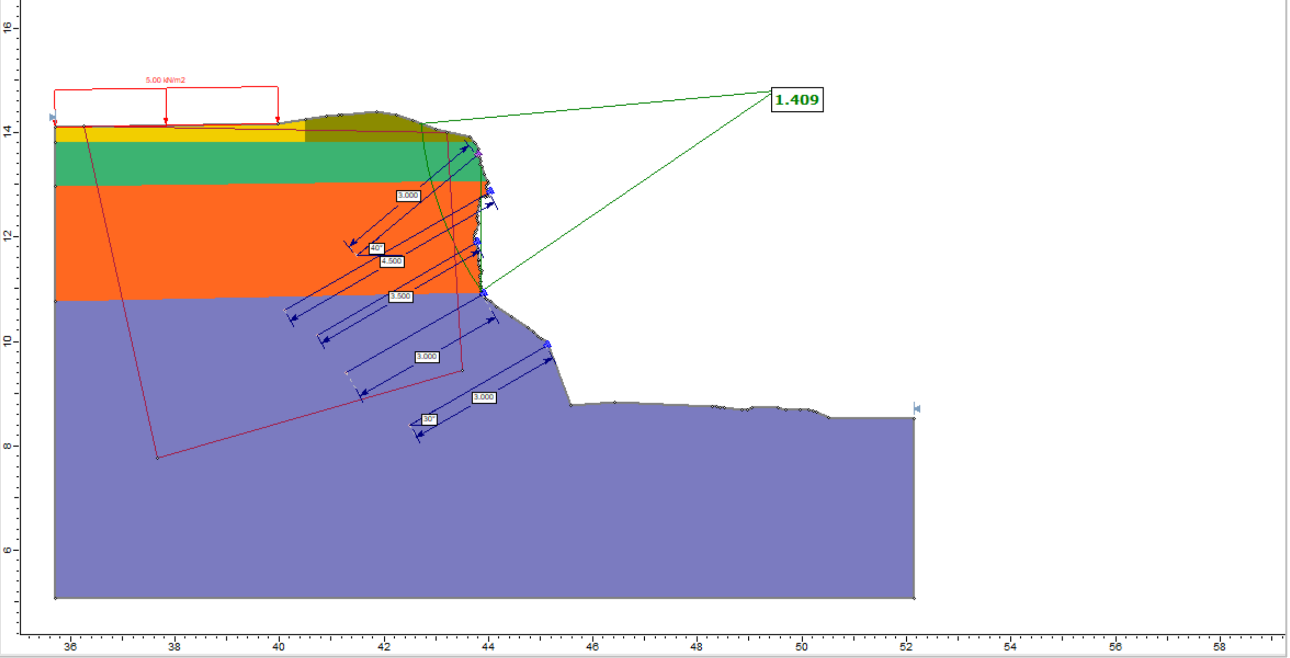


Figure 21. Section 3 – Soil Nailing - BS8006 Set2

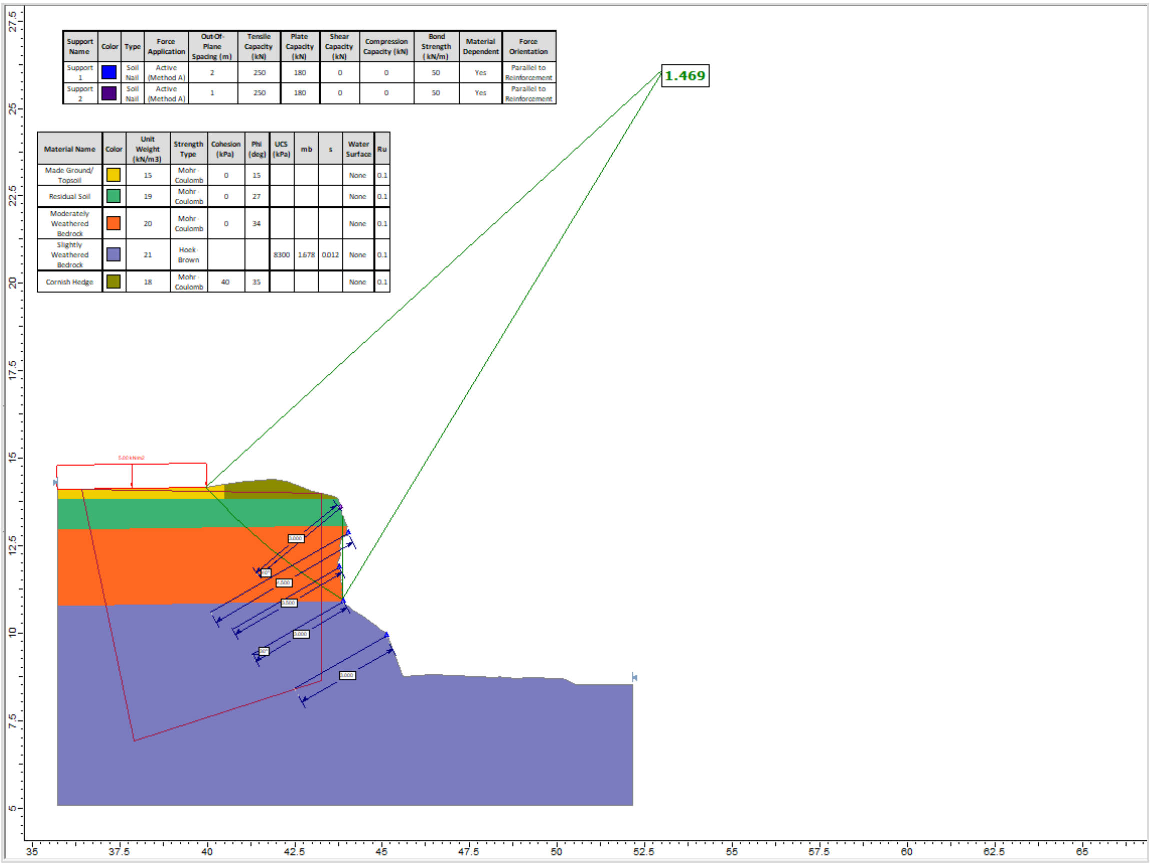


Figure 22. Section 3 – Facing Installation - BS8006 Set1

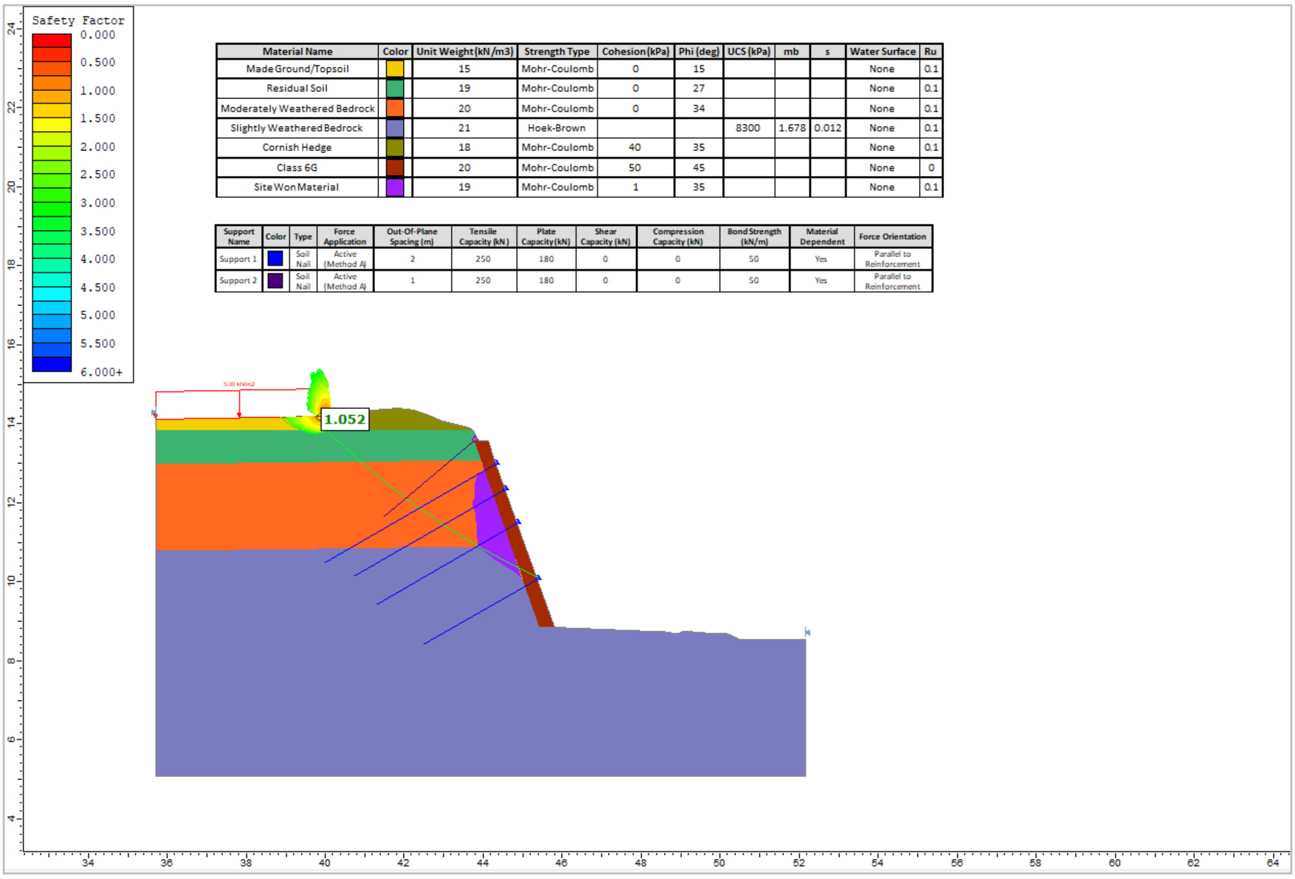


Figure 23. Section 3 – Facing Installation - BS8006 Set2

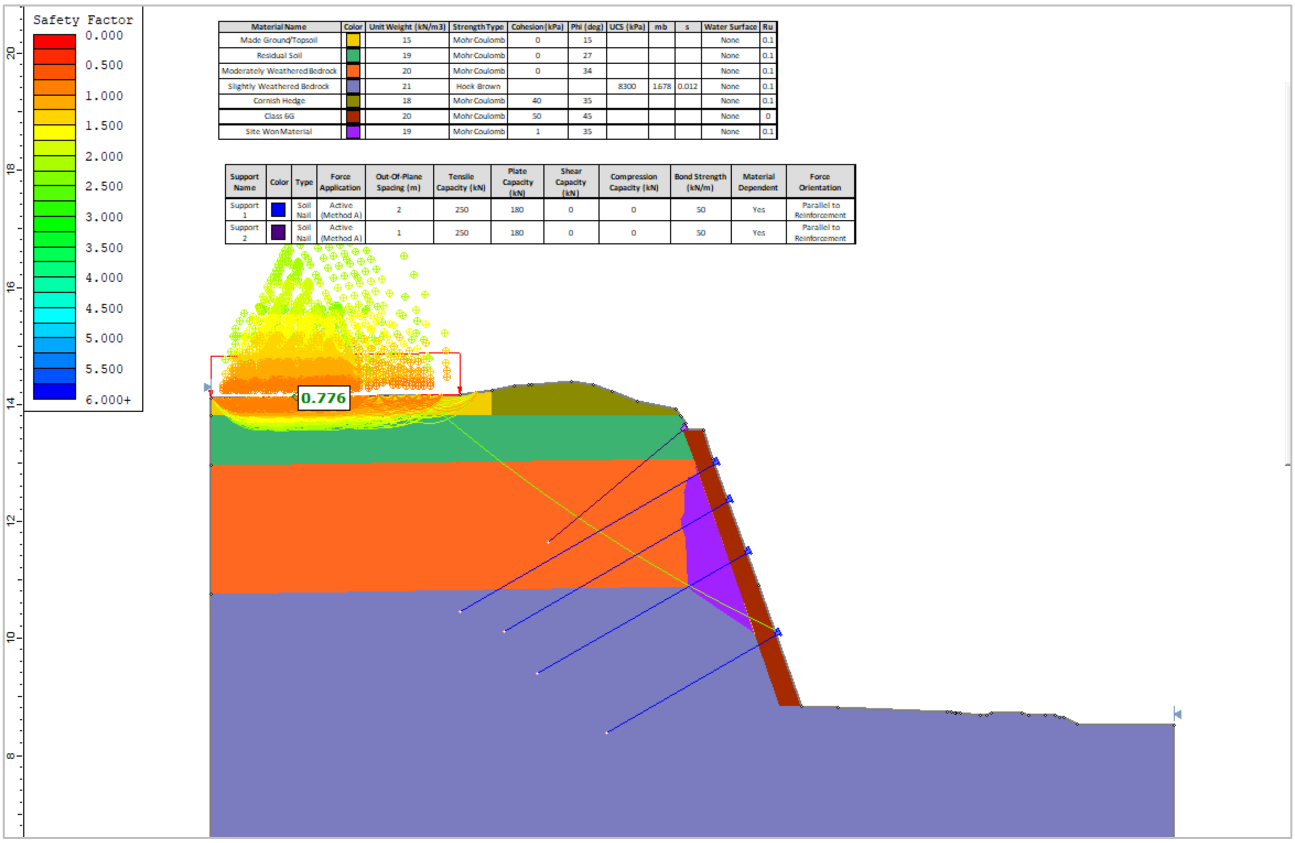


Figure 24. Section 4 Current site Condition BS8006 Set1

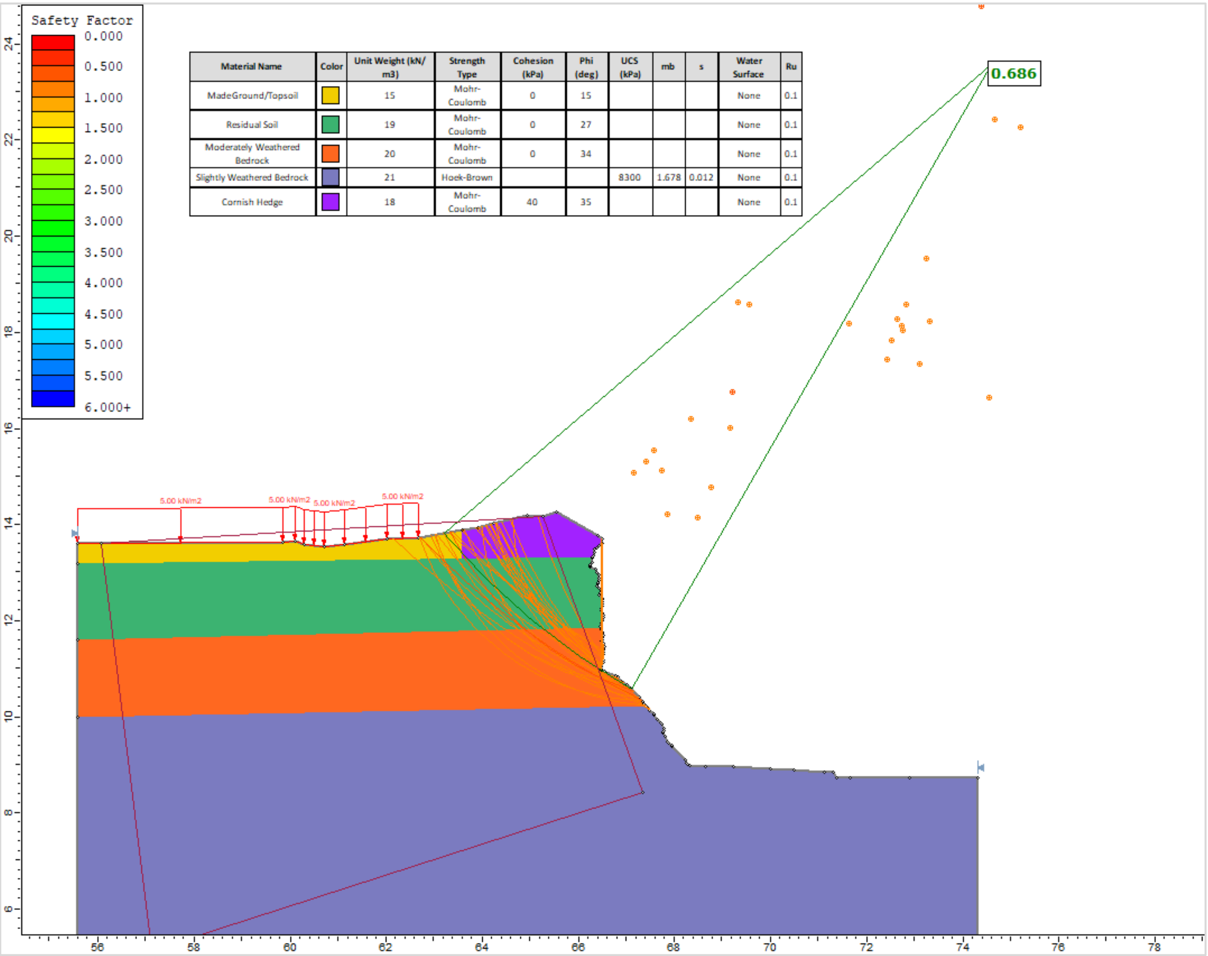


Figure 25. Section 4 Current site Condition BS8006 Set2

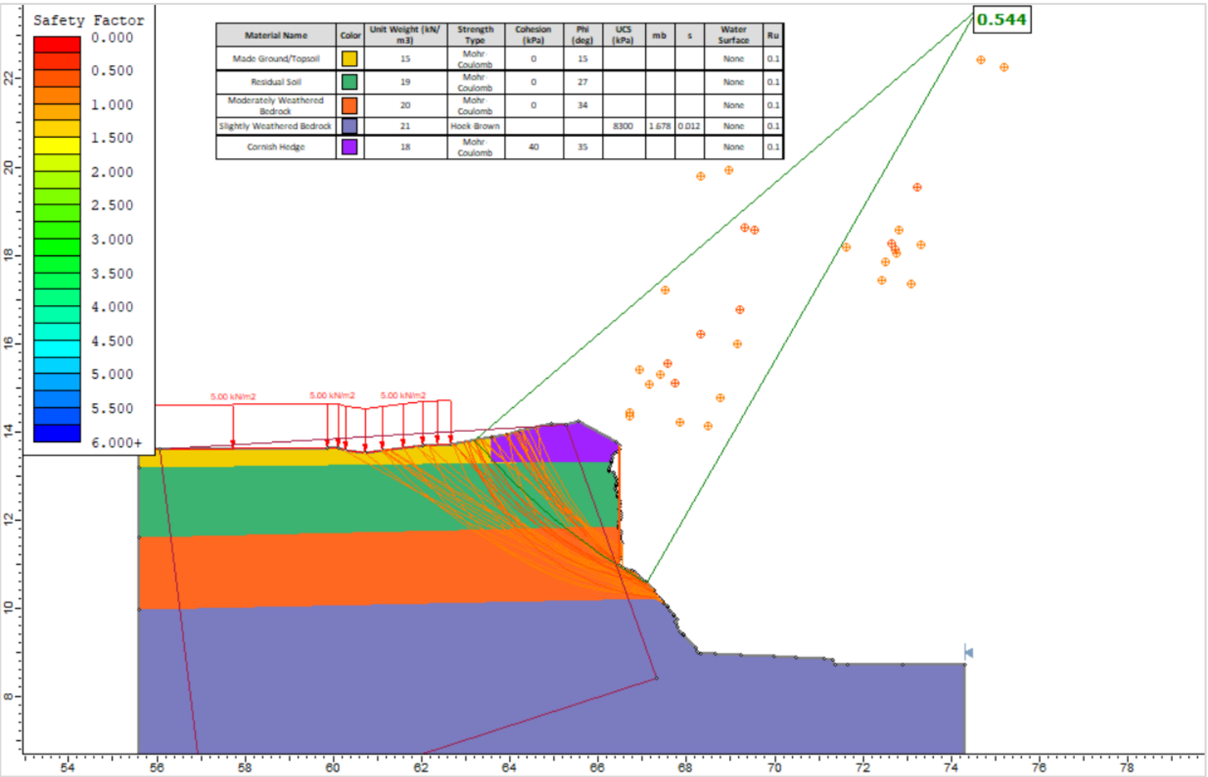


Figure 26. Section 4 – Soil Nailing - BS8006 Set1

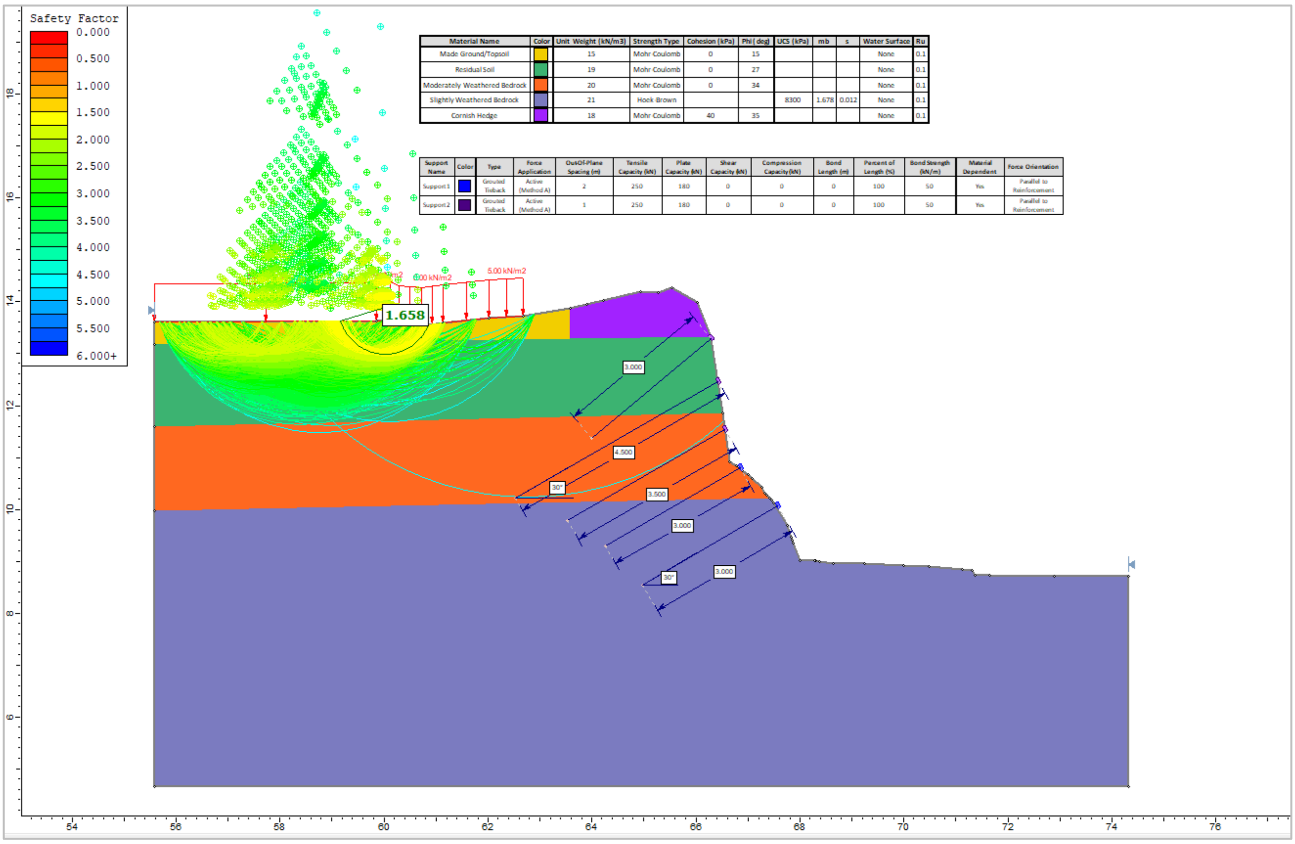


Figure 27. Section 4 – Soil Nailing - BS8006 Set2

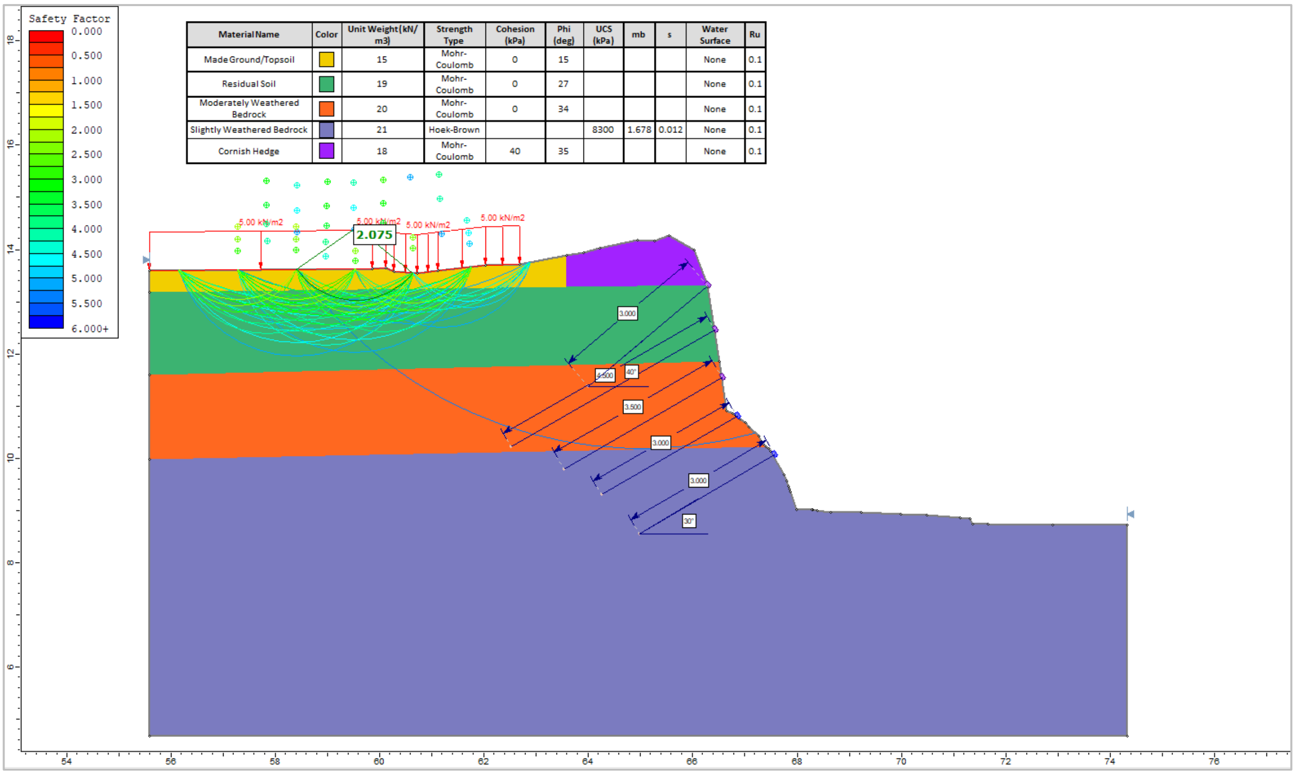


Figure 28. Section 4 – Facing Installation - BS8006 Set1

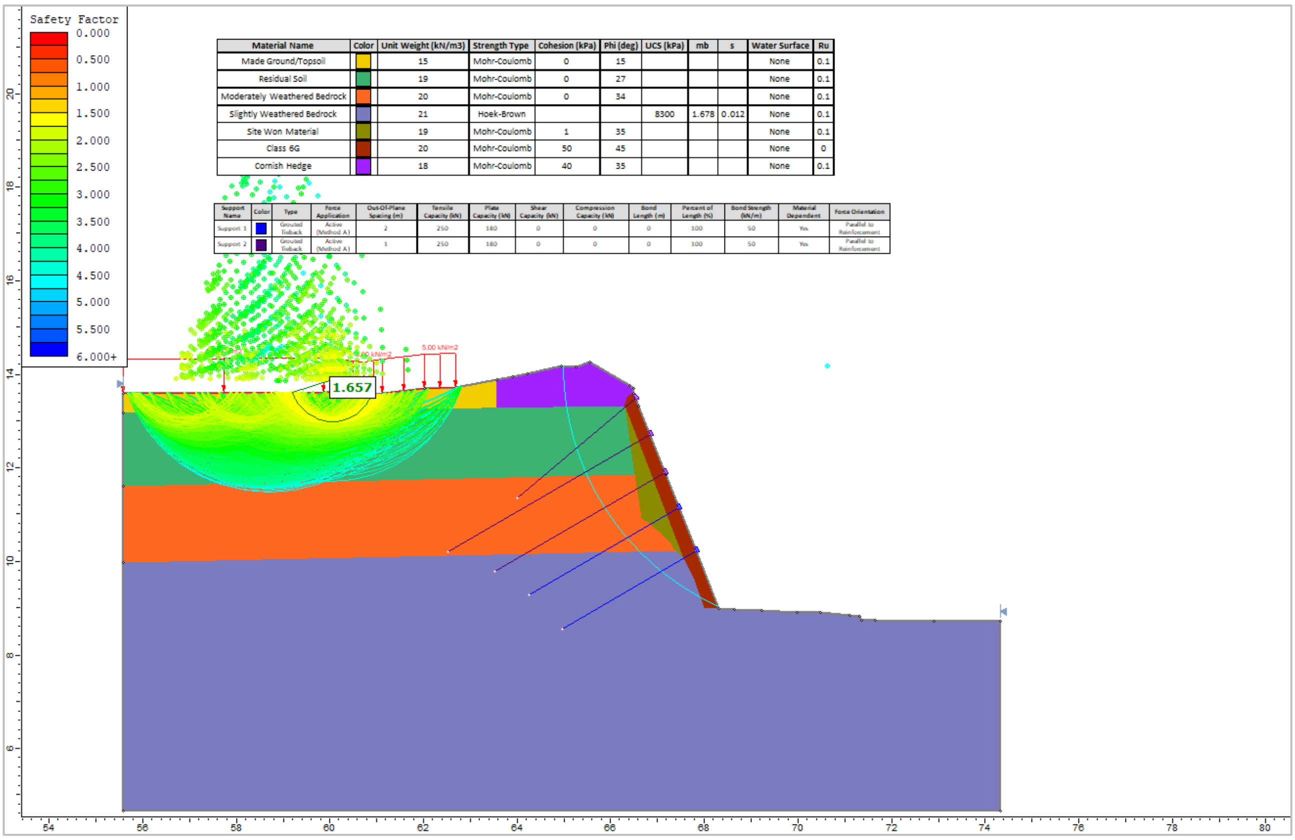


Figure 29. Section 4 – Facing Installation - BS8006 Set2

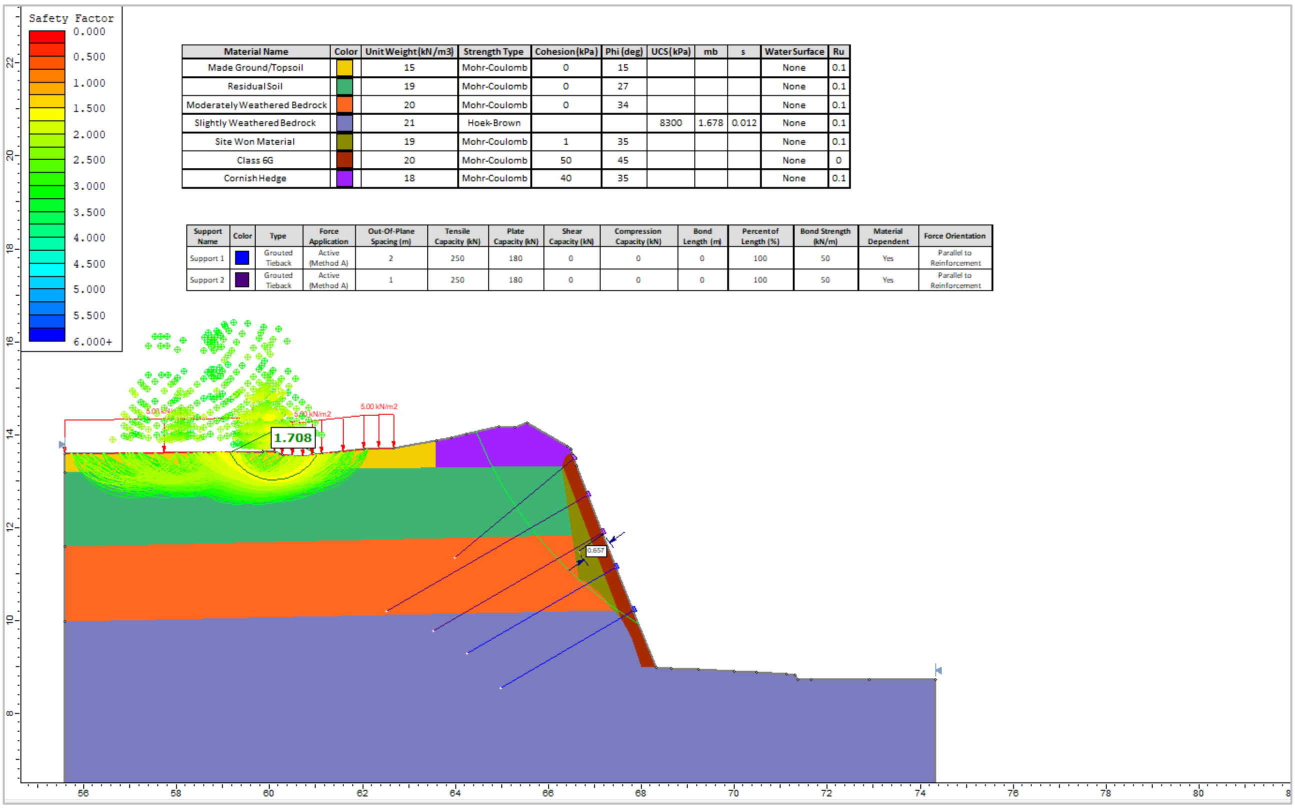


Figure 30. Section 5 Current site Condition BS8006 Set1

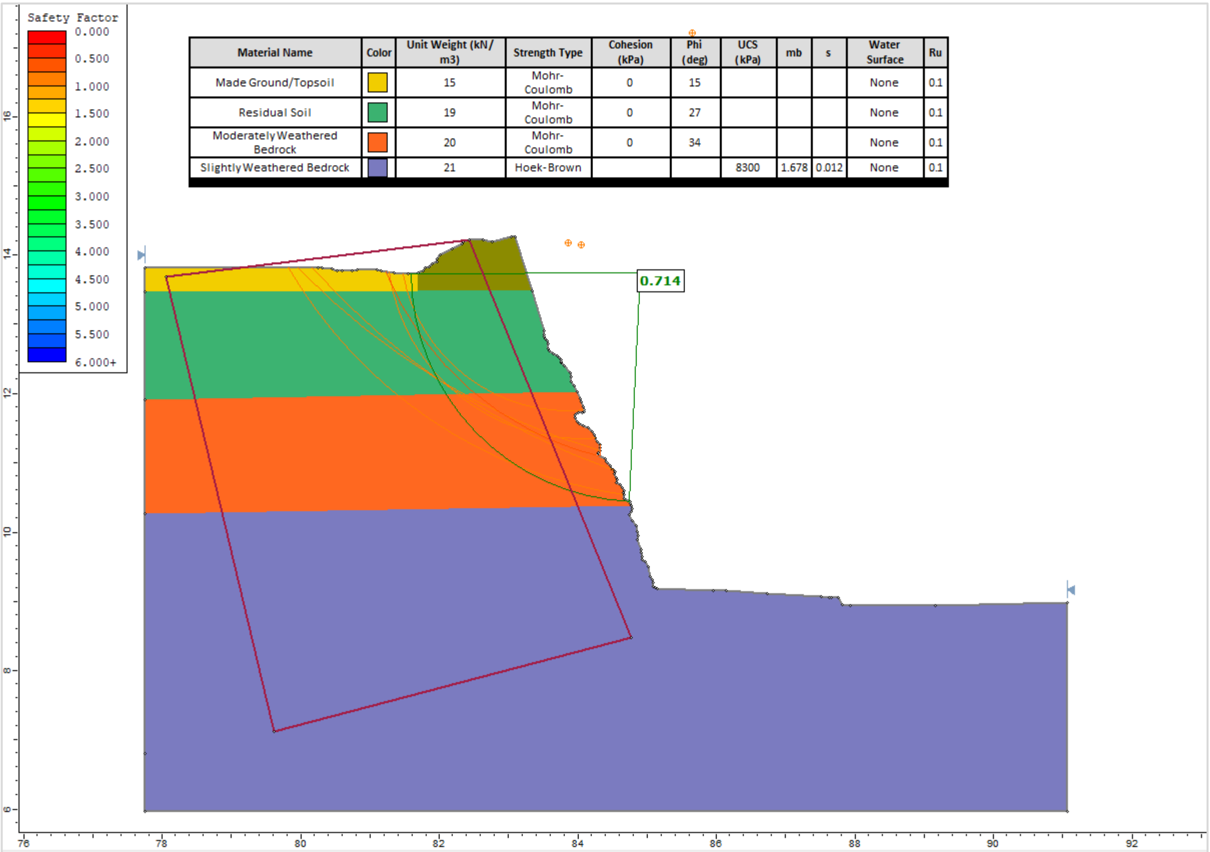


Figure 31. Section 5 Current site Condition BS8006 Set2

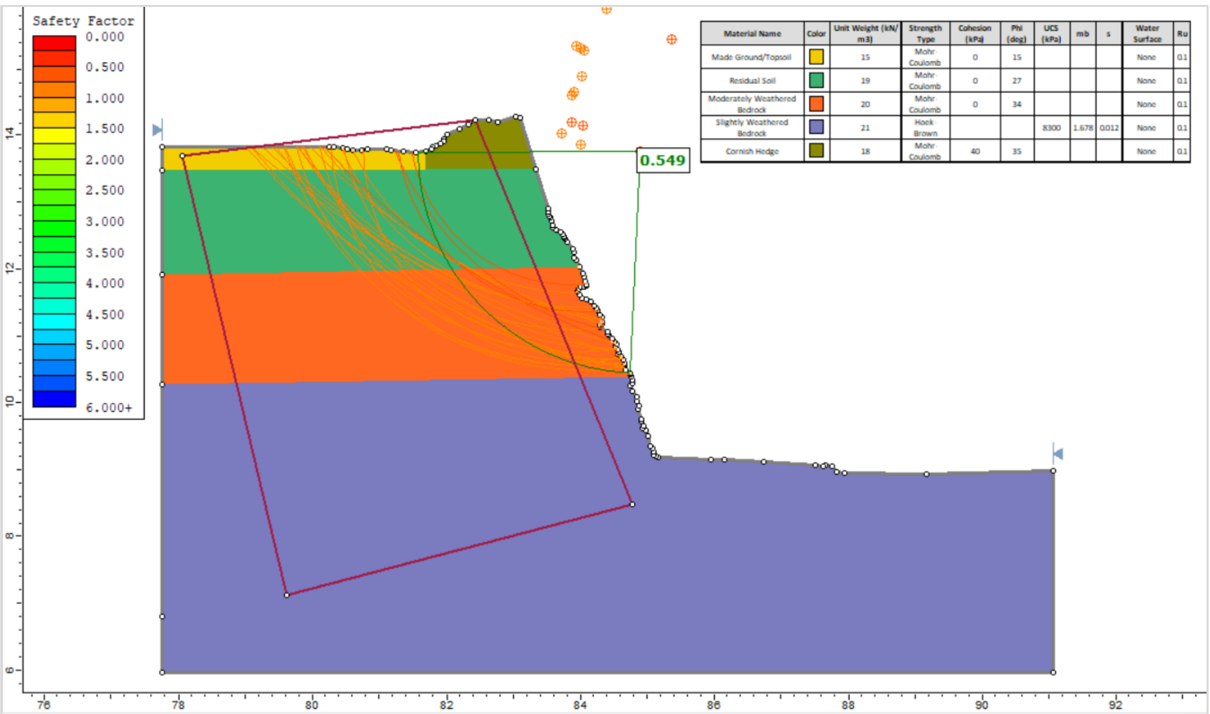


Figure 32. Section 5 – Soil Nailing - BS8006 Set1

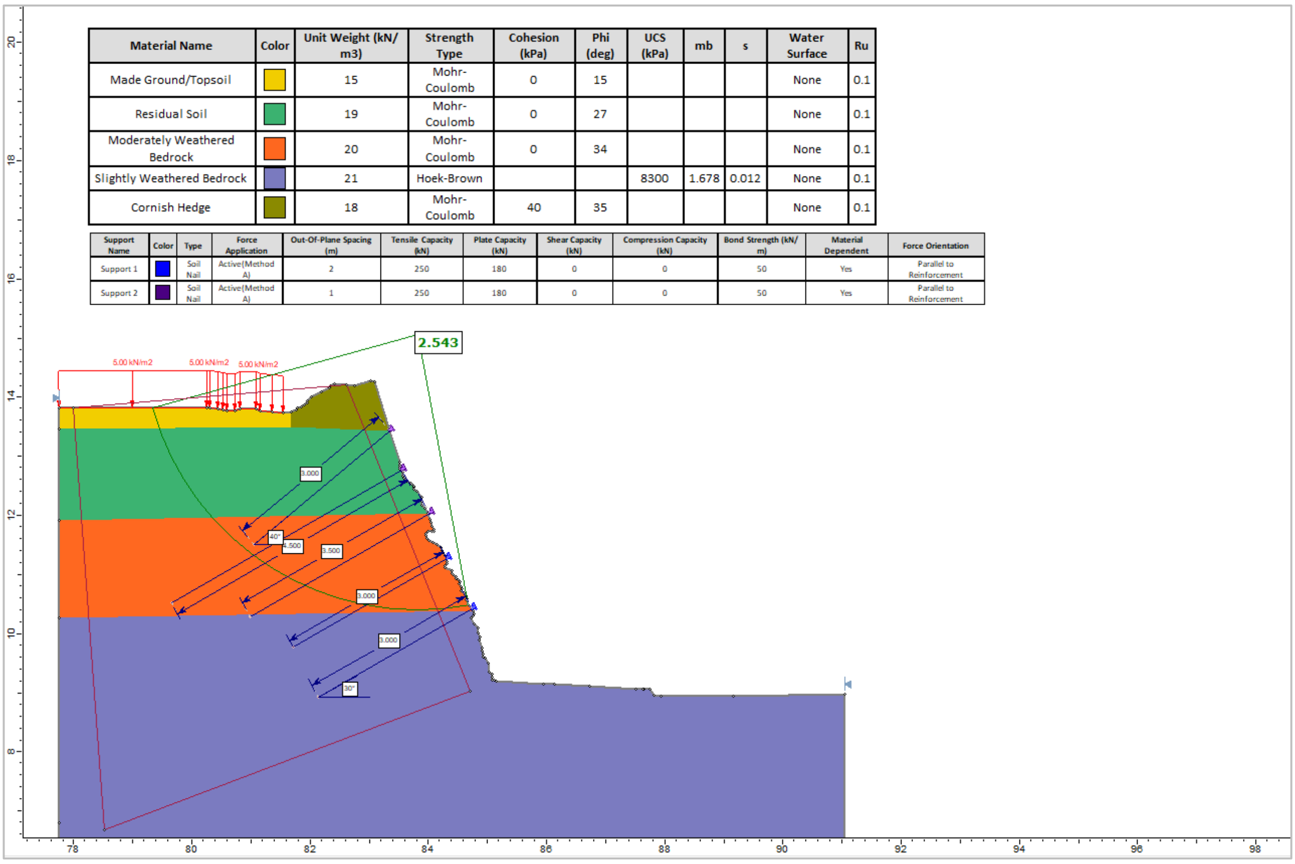


Figure 33. Section 5 – Soil Nailing - BS8006 Set2

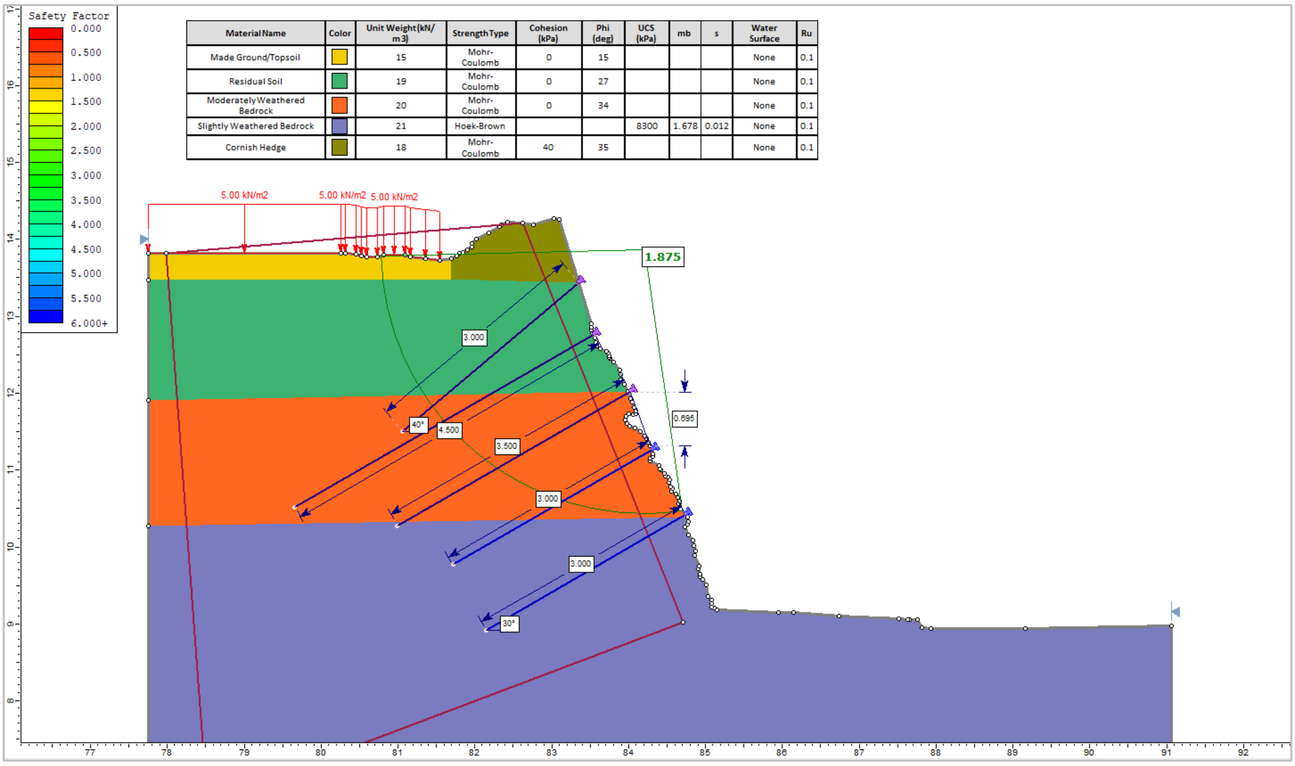


Figure 34. Section 5 – Facing Installation - BS8006 Set1

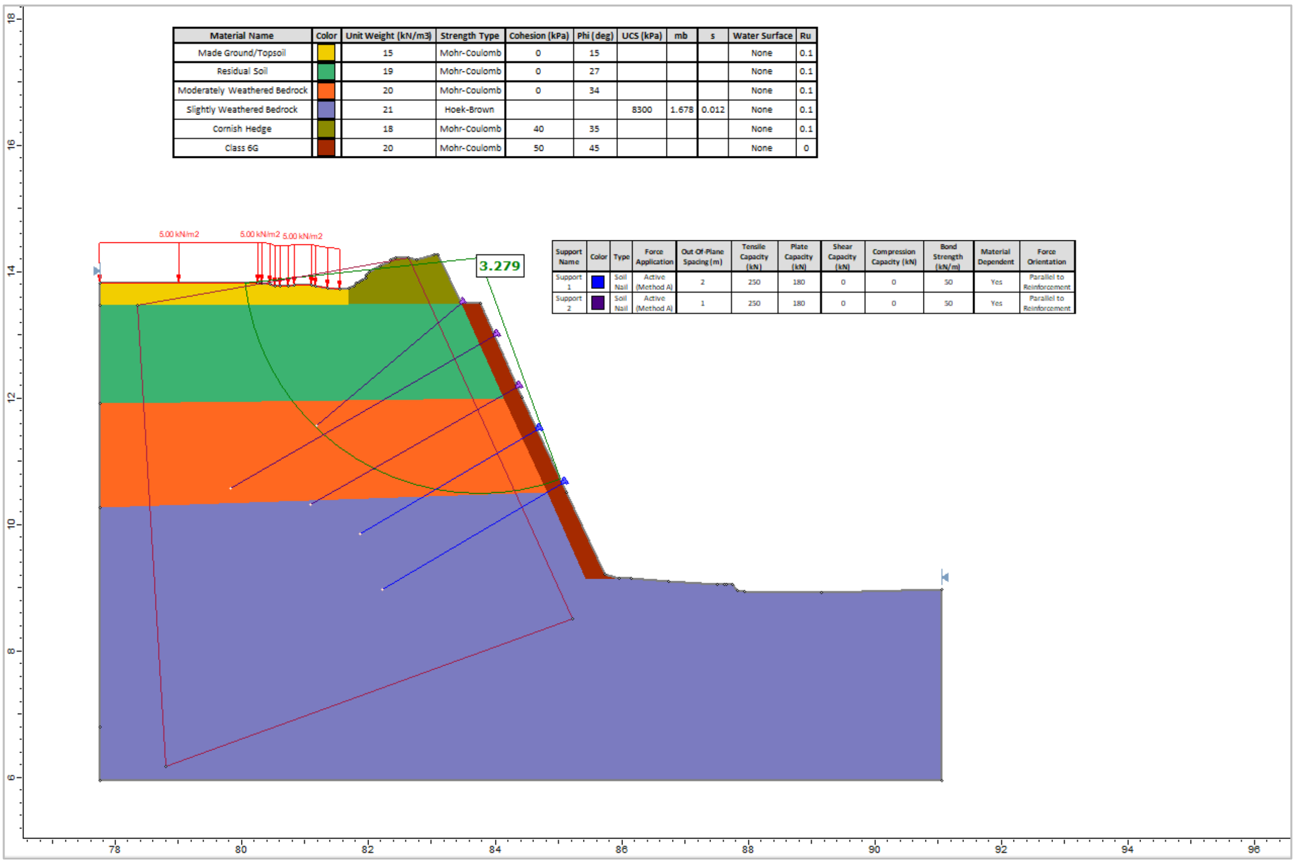


Figure 35. Section 5 – Facing Installation - BS8006 Set2

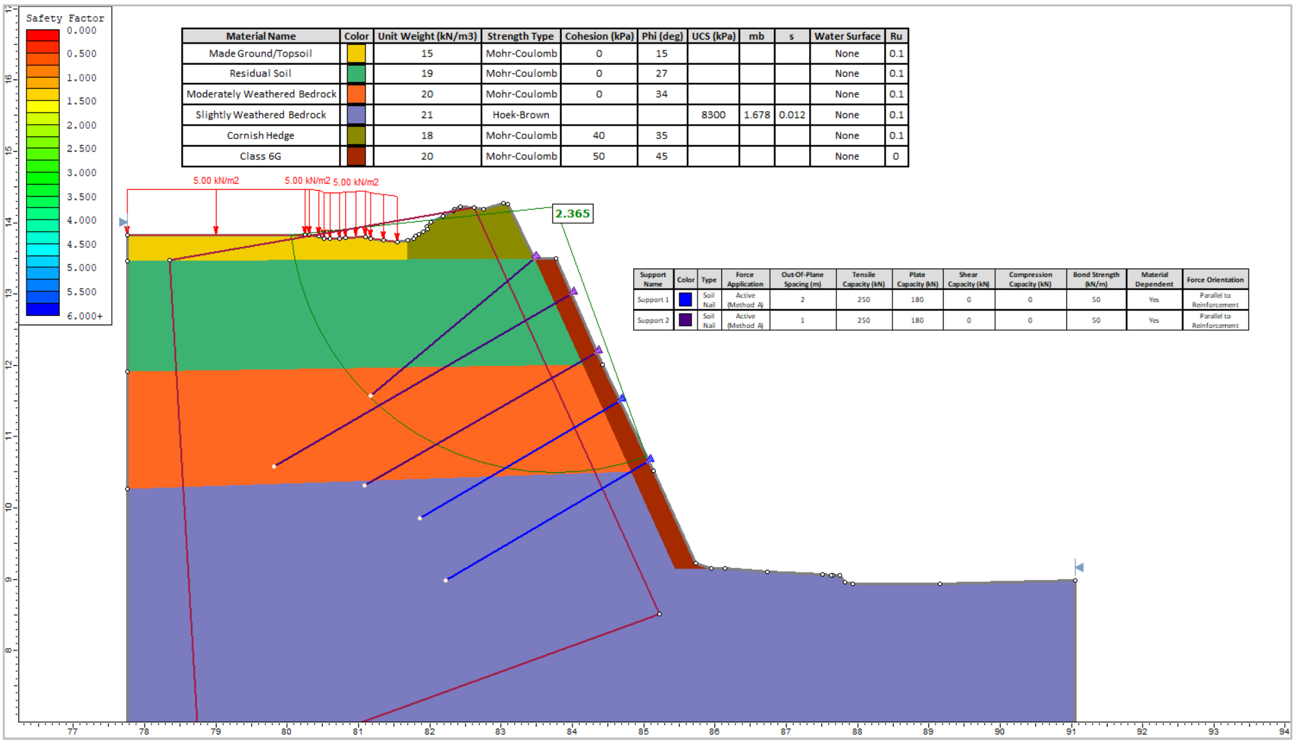


Figure 36. Section 6 Current site Condition BS8006 Set1

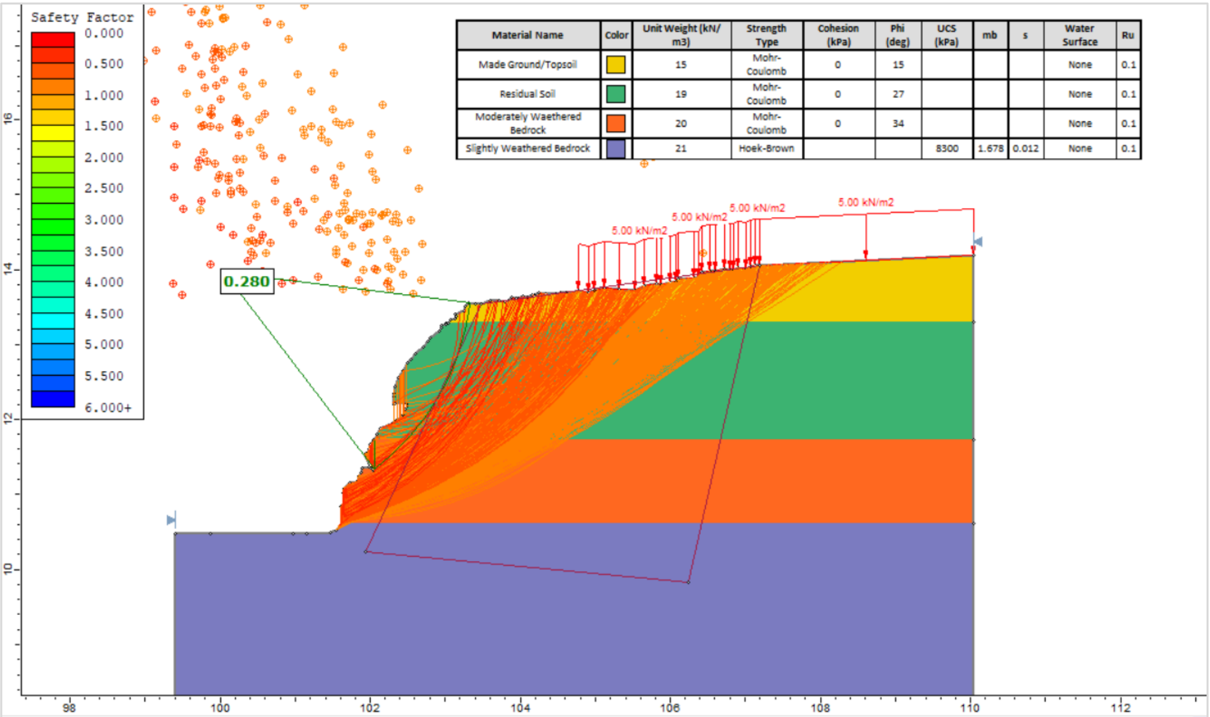


Figure 37. Section 6 Current site Condition BS8006 Set2

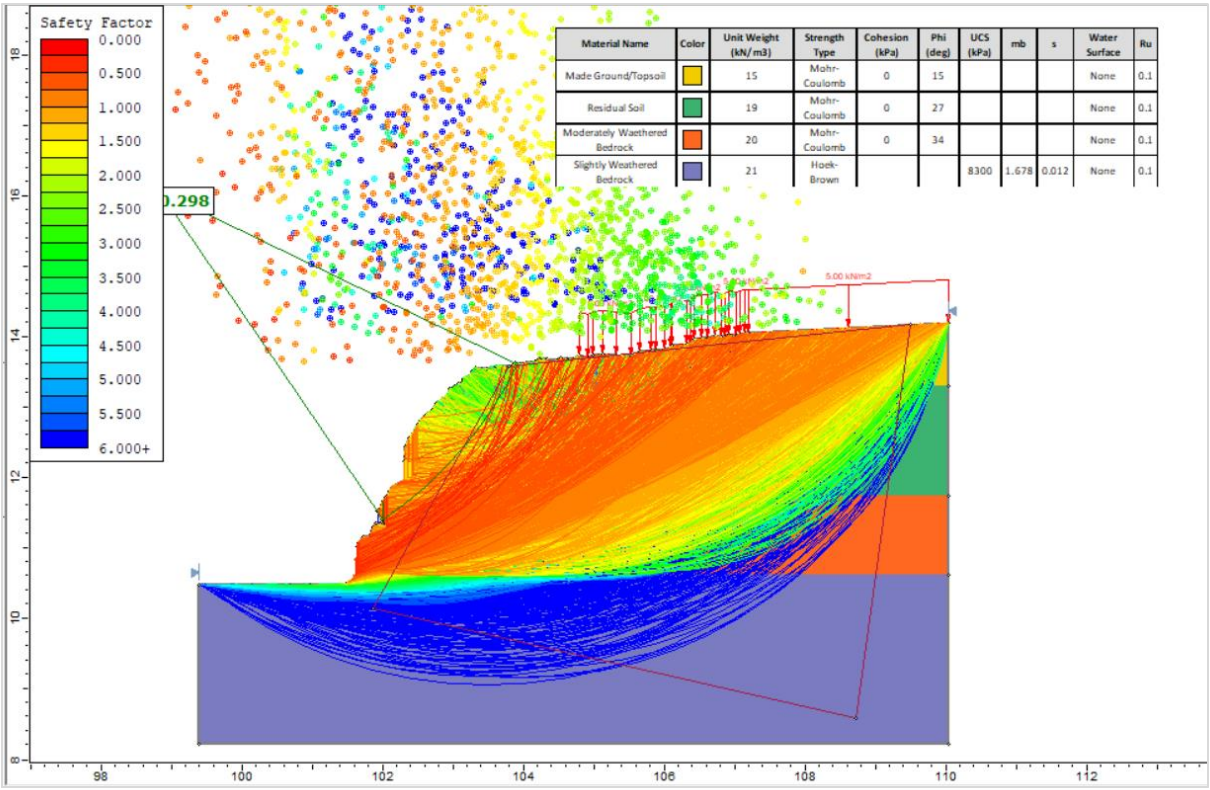


Figure 38. Section 6 – Soil Nailing - BS8006 Set1

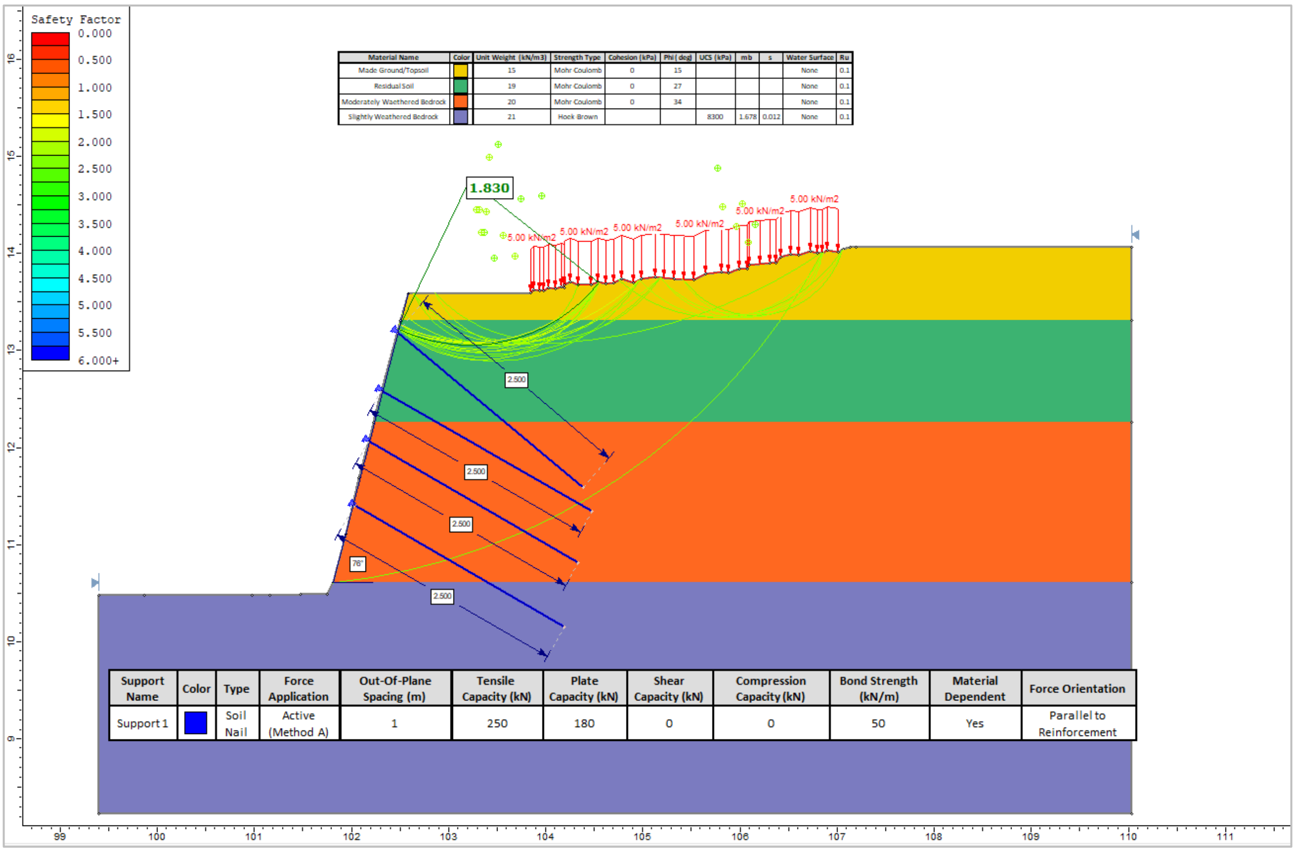


Figure 39. Section 6 – Soil Nailing - BS8006 Set2

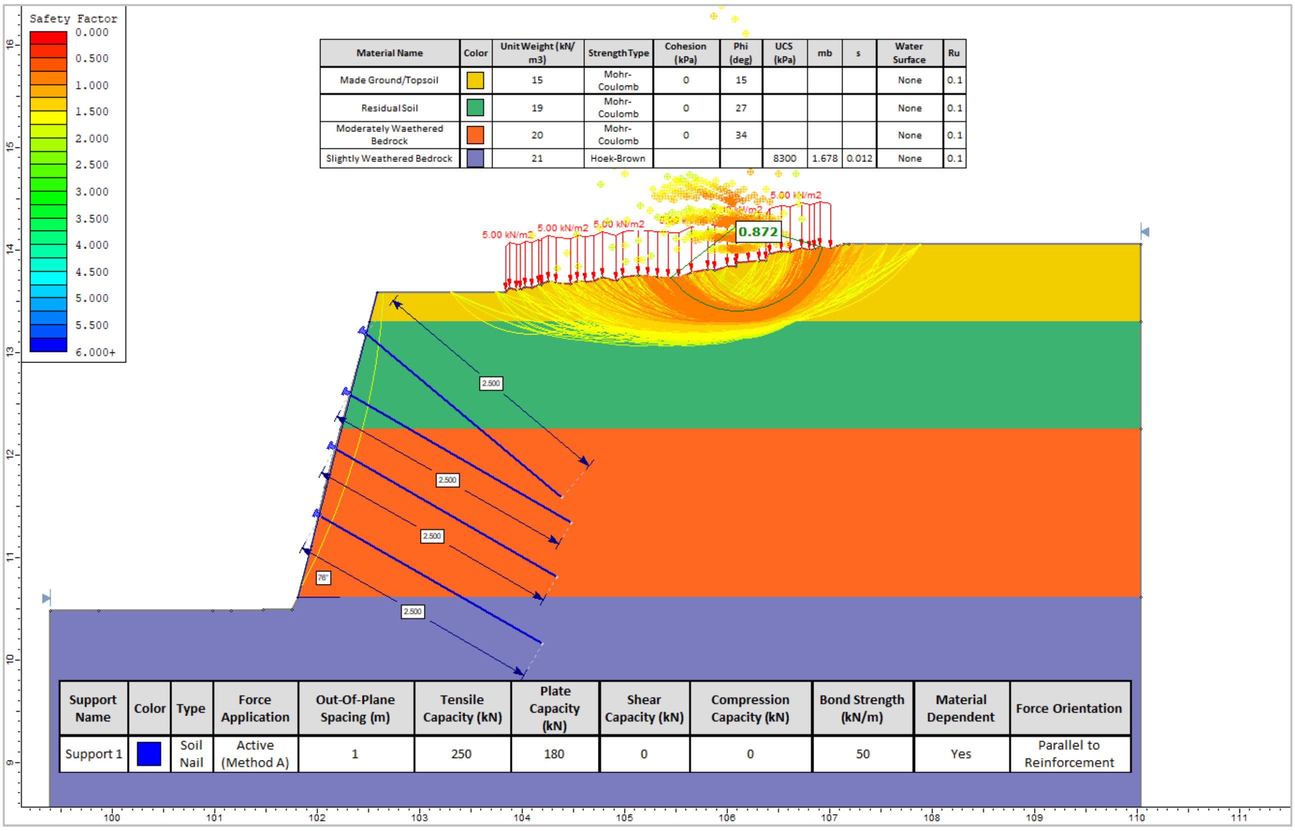


Figure 40. Section 6 – Facing Installation - BS8006 Set1

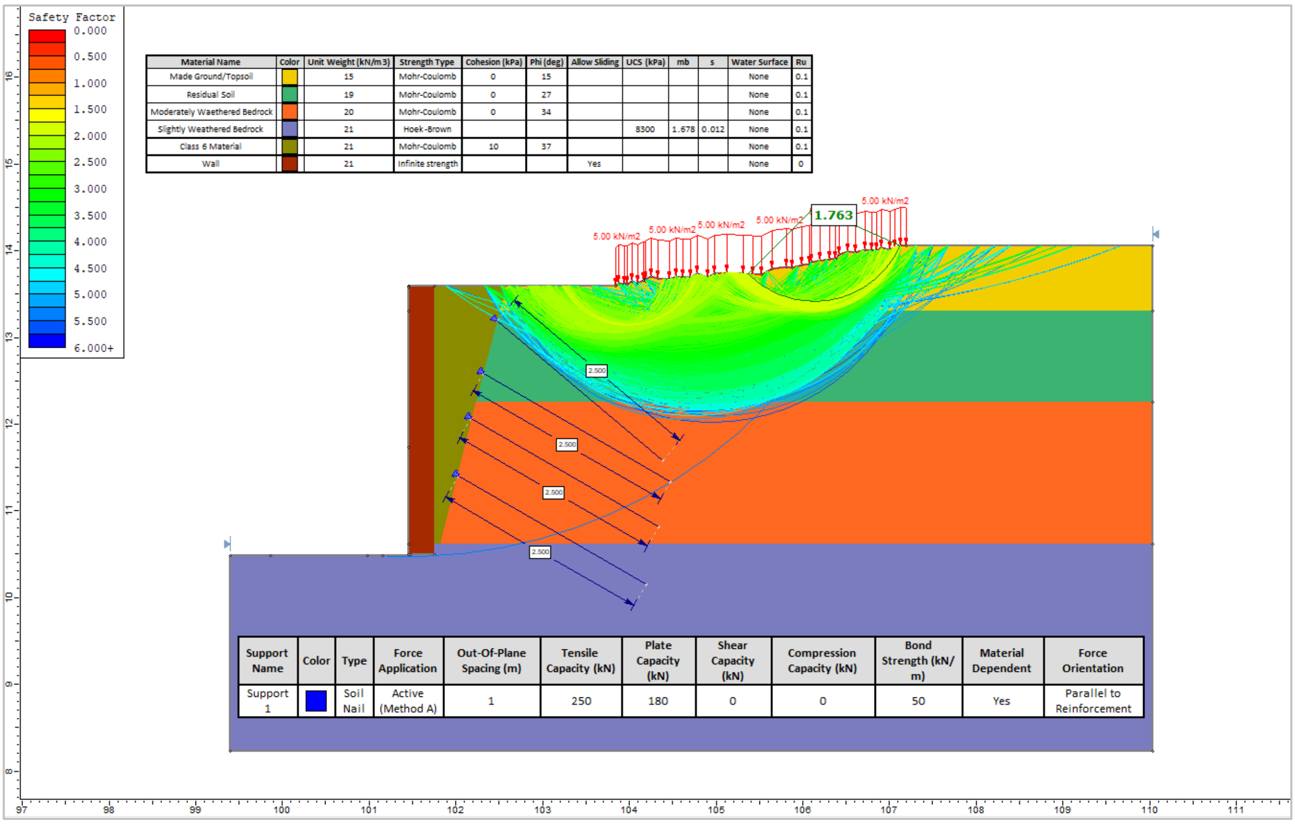
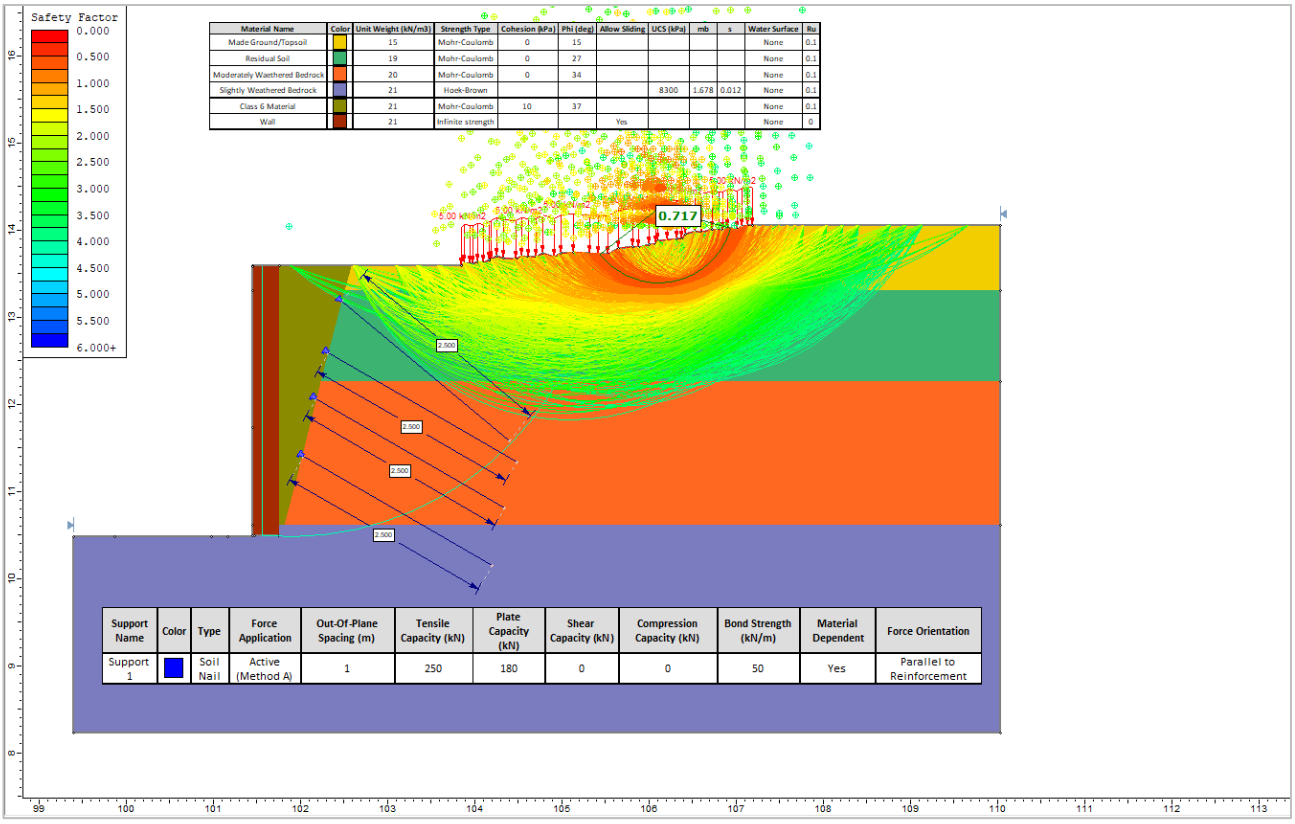


Figure 41. Section 6 – Facing Installation - BS8006 Set2



Appendix C: Product Data Sheets

DYWIDAG-SYSTEMS INTERNATIONAL

DYWI® Drill Hollow Bar System

Contents

Introduction

DYWI® Drill Hollow Bar is a fully threaded self-drilling system installed into loose or collapsing soils without the need for casing. The bar features a hollow bore which enables it to be simultaneously drilled and grouted. The hollow bar incorporates a left-hand thread for standard rotary percussive drilling.

Manufactured from high grade steel tubing to EN 10083-1, DYWI® Drill Hollow Bar is cold rolled to form standard rope thread or “T” thread profiles. The DYWI® Drill rolling process refines the grain structure of the steel, increasing the yield strength and producing a robust drill steel suitable for a range of drilling and grouting applications.

The DYWI® Drill Hollow Bar System includes a full range of drill bits, adaptor sleeves, couplers, nuts and bearing plates. In addition, the range of DYWI® Drill injection adaptors and drill tooling enables the hollow bar to be used with a wide range of drilling equipment.

Key Features

- **European Technical Approval**
  - The DYWI® Drill Hollow Bar System has a full European Technical Approval covering all bars and accessories **ETA-12/0603**
- **Manufactured in Europe**
  - DYWI® Hollow Bars are produced in a specialist facility in Pasching, Austria
- **No Casing Required**
  - Bars can be drilled into loose or collapsing soils without the need for a casing to support the borehole.
- **Fully Threaded Rod Sections**
  - Continuous thread ensures that rods can be cut and coupled at any point, or extended.
- **Simultaneous Drill and Grout Installation**
  - Grout is injected at all points of the borehole as drilling is advanced, permeating the local strata for increased bond performance and producing bulbing in softer sections of the soil.
- **Rotary Percussive Drilling**
  - This drilling technique is highly efficient, ensures good directional stability of the drill string and helps to consolidate the grout within the borehole.
- **High Strength Threads**
  - Both the Rope threads and “T” threads provide a strong and robust thread ensuring a high level of bond with the borehole grout.
- **Self-Drilling System**
  - The self-drilling function enables bars to be drilled into most ground conditions for both tension or compression applications, and is also used as an injection conduit.
- **Left-Hand Thread**

Bar/Grout bond

Research & Development - DYWI® Drill Hollow Bar drilled into sand and exhumed to measure the diameter and consistency of grout cover

Technical Data

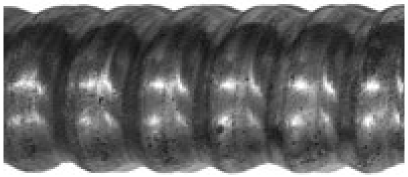
Typically used for Soil Nails

Bar Type	Nominal Thread Diameter [mm]	Effective External Diameter [mm]	Internal Diameter [mm]	Cross Section Area [mm²]	Ultimate Strength [kN]	Yield Strength [kN]	Steel Grade Yld / Ult [N/mm²]	Weight [kg/m]
R25-200	25	23.8	14	290	200	150	520/690	2.30
R32-210	32	29.5	21.5	340	210	170	530/660	2.80
R32-250	32	29.5	19.7	370	250	190	510/670	3.00
R32-280	32	29.5	18	410	280	220	520/670	3.40
R32-320	32	29.5	16.5	470	320	280	590/680	3.90
R32-360	32	29.5	15	510	360	300	590/710	4.10
R32-400	32	29.5	12.5	560	400	330	590/710	4.40
R38-420	38	36.4	21	660	420	350	510/610	5.30
R38-500	38	36.4	19	750	500	400	530/660	6.00
R38-550	38	36.40	18.2	780	550	430	550/710	6.2

Typically used for Micropiles

Bar Type	Nominal Thread Diameter [mm]	Effective External Diameter [mm]	Internal Diameter [mm]	Cross Section Area [mm²]	Ultimate Strength [kN]	Yield Strength [kN]	Steel Grade Yld / Ult [N/mm²]	Weight [kg/m]
R51-550	51	48.4	35	810	550	450	510/630	7.10
R51-660	51	48.4	33	970	660	530	540/670	7.80
R51-800	51	48.4	30.5	1,150	800	630	570/720	9.00
R51-925	51	48.4	27.5	1,275	925	730	595/775	9.60
T76-1300	76	73.5	57.5	1,590	1,300	1,000	630/820	12.5
T76-1650	76	73.5	54.1	1,975	1,650	1,200	610/835	15.5
T76-1900	76	73.5	49.4	2,360	1,900	1,500	640/810	18.5
T103-2300	103	94	78	3,200	2,300	1,800	560/710	25
T103-3700	103	94	51	5,200	3,700	2,700	560/710	40

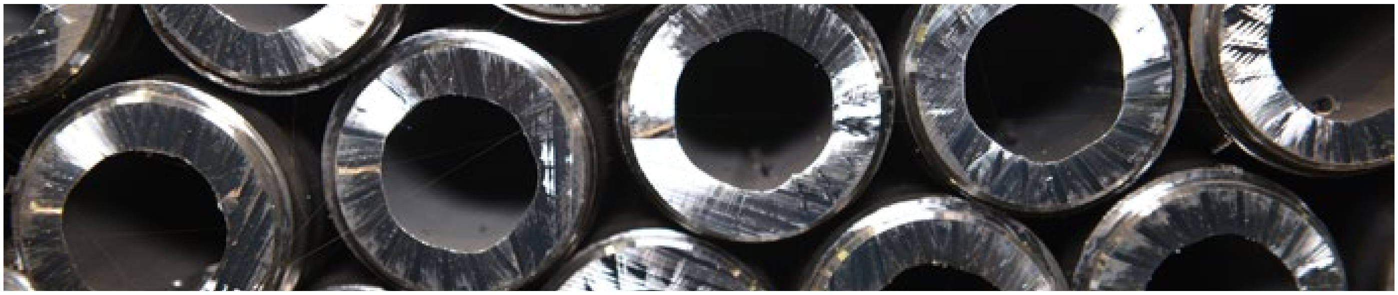
DYWI® Drill Rope Thread (R)



DYWI® Drill "T" Thread

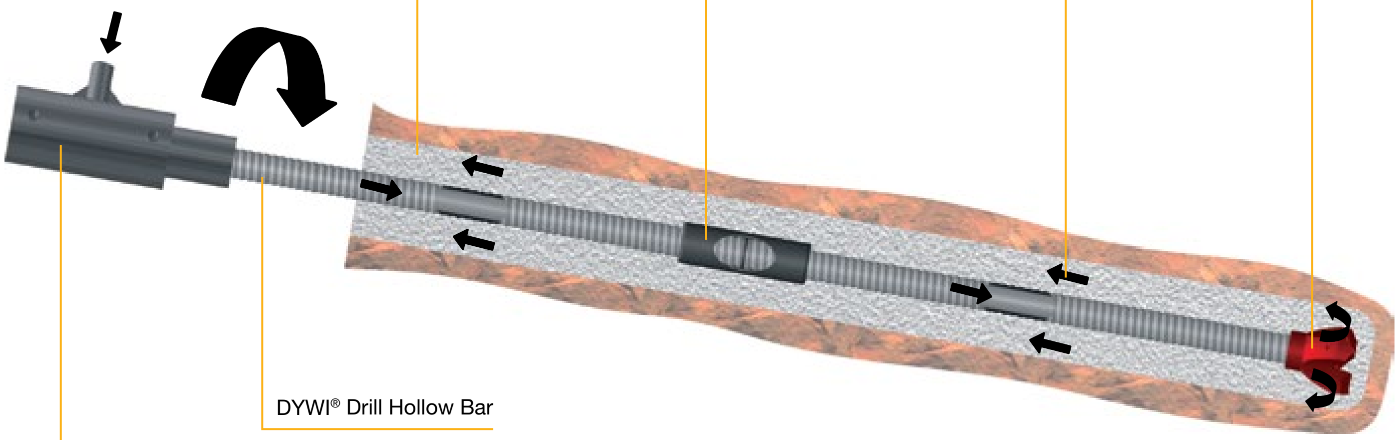
Technical Notes

- Bar lengths
  - 3m or 4m.
- Bar finishes
  - Plain or galvanized to EN 1461
- E Value
  - 205,000 N/mm². Strain at ultimate load (Agt.) ≥ 2.50%. Fractile value of strain UTS R_m / $R_{p\,0.2}$ ≥ 1.5.



DYWI® Drill Hollow Bar Installation

The DYWI® Drill Hollow Bar offers high rates of installation, as drilling and grouting can be combined as a single cycle. To achieve these benefits, it is important that the correct equipment is selected to ensure efficient drilling.



Drilling Technique

The three main drilling functions are:

- Rotation: 120-150 RPM. This is the key drilling function to ensure the full diameter of the borehole is cut as drilling advances
- Percussion: 300-600 BPM, for directional stability and drilling efficiency
- Fine Feed: Feed pressures should be regulated to match the achievable drilling rate
  - See DYWIDAG-Systems International Technical Note, TN 104

Rotary Percussive Top Hammer

This is the essential piece of equipment for hollow bar drilling. Rotary percussive drilling ensures efficiency in most ground conditions, provides good directional stability for the drilled bar and helps consolidate the placed grout. The hammer should have sufficient torque and rotation speed.

Although it may be desirable to maximise the size of the drill bit, it should always be compatible to the bar used to drill.

Simultaneous Drilling and Grouting

This method ensures grout is placed at all points of the borehole as drilling is advanced, permeating the local soil strata and producing bulbing in the softer sections of the borehole.

Reaming (extracting and re-inserting whilst under rotation) of the bottom rod section at full depth will further enhance bond performance, as the ground strength is typically highest at this point due to overburden pressure.

A Frame drilling at Watford Cutting

Excavator mounted rig at HoTV A465

Anti-Corrosion Protection

Durability

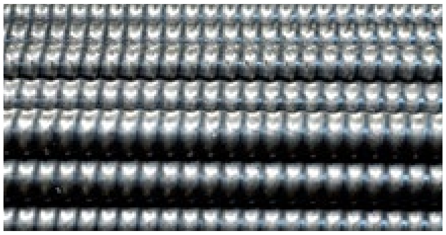
Borehole grout, whilst beneficial, is not the primary basis for ensuring durability of the soil nail over its design life.

Corrosion protection for hollow bar soil nails is achieved through:

1. **Sacrificial Corrosion Allowance;** This technique calculates the loss of steel over the proposed design life of the soil nail or micro pile based on the total surface area of the bar. The residual strength of the bar is then calculated based on the remaining cross sectional area of steel, this can then be assessed against the required working load of the bar. The quantity of steel loss is based on research in accordance with TRL 380, EN14199, CIRIA C637. Corrosion rates are determined by the aggressive levels of the soil in accordance with the values outlined in the standards. In most cases, highly aggressive ground conditions don't occur naturally and are only present in locations formerly used for industrial processes which have contaminated the soil
2. **Supplementary Galvanizing**; in accordance with EN1461 hot dipped galvanizing will provide an additional 5-15 years lifespan, depending on aggressive of the soil, for buried installations. This method when applied to the top bar, located at the soil / air interface ,the most corrosive area, provides a practical basis for increasing lifespans but minimises additional cost. Corrosion in the deeper parts of the borehole is less prevalent due to the lack of oxygen. A fully galvanized system can be adopted if the project specification requires it.
3. **Duplex Coatings;** comprises an additional Epoxy Powder coating (80-90 µm) over the hot dipped galvanizing. Although the coating can be damage during rotary percussive installation the remaining Epoxy Coating will provide an additional protective benefit especially in the valleys between the threads, where the Epoxy coating generally remains intact. Loss of Epoxy at the crest of the thread is common, but this part of the bar tends to have a greater wall thickness forming the thread ridge and has greater resistance to corrosion. Any visible damage to the Epoxy coating can be repaired with a two-pack Epoxy paint "touch-up" kit.

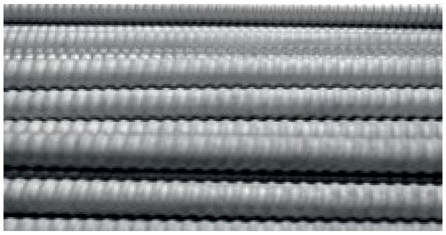
Increasing Durability

Sacrificial Corrosion Protection



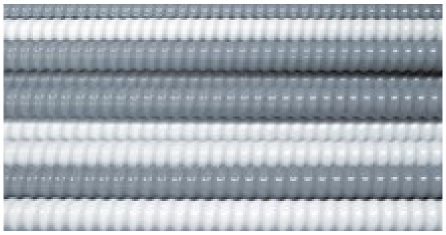
Plain Steel

Galvanizing / Sheradizing



Hot-Dip Galvanizing

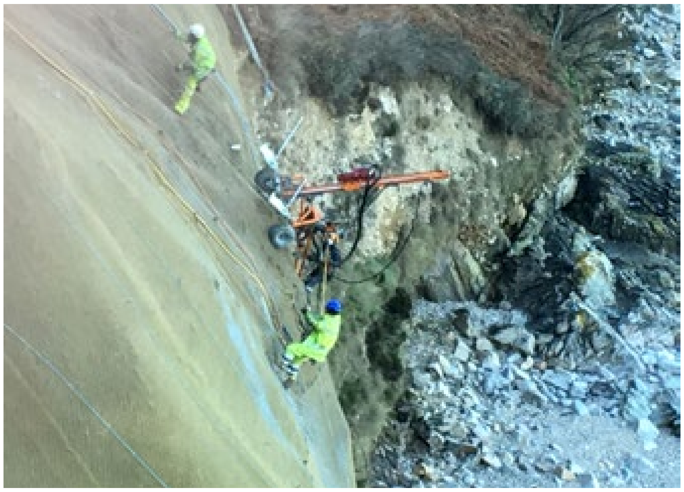
Duplex Coating



Duplex Coating

Soil Nailing using DYWI® Drill Hollow Bar at Filton Banks, Bristol

Initial Slip early 2017



Installation of DYWI® Drill Hollow Bar Soil Nails through GREENAX®

Spoil at toe left in place as erosion control and slope buttressing, DYWI® Mat Green used to prevent erosion.

GREENAX® enables vegetation to establish on steep slopes, providing further reinforcement to the cliff face.

Sacrificial Corrosion – Technical Data

Bar Size	Soil aggressivty	Sacrificial Corrosion – 60 Years				Sacrificial Corrosion – 120 Years			
		Sacrificial Thickness $\Delta_{s,60}$ [mm]	Cross Sectional Area $A_{s,60}$ [mm²]	Ultimate Strength $F_{t,k,60}$ [kN]	0.2 % Yield Strength $F_{0.2,k,60}$ [kN]	Sacrificial Thickness $\Delta_{s,120}$ [mm]	Cross Sectional Area $A_{s,120}$ [mm²]	Ultimate Strength $F_{t,k,120}$ [kN]	0.2 % Yield Strength $F_{0.2,k,120}$ [kN]
R32-210	low	0.8	301	187	143	1.4	274	171	130
	middle	1.5	269	168	128	2.5	226	141	107
	high	2.8	214	133	101	4.9	129	80	61
R32-250	low	0.8	333	225	171	1.4	306	207	157
	middle	1.5	302	204	155	2.5	258	175	133
	high	2.8	246	166	126	4.9	161	109	83
R32-280	low	0.8	378	255	201	1.4	351	237	186
	middle	1.5	347	234	184	2.5	304	205	161
	high	2.8	291	197	154	4.9	206	139	110
R32-320	low	0.8	433	295	231	1.4	406	277	216
	middle	1.5	402	274	214	2.5	359	244	191
	high	2.8	346	236	184	4.9	261	178	139
R32-360	low	0.8	470	334	260	1.4	443	315	245
	middle	1.5	439	312	243	2.5	396	281	219
	high	2.8	383	272	212	4.9	299	212	165
R32-400	low	0.8	524	374	308	1.4	497	355	293
	middle	1.5	493	352	290	2.5	450	321	265
	high	2.8	437	312	257	4.9	353	251	207
R38-420	low	0.8	621	392	326	1.4	588	371	309
	middle	1.5	583	367	306	2.5	529	333	278
	high	2.8	513	324	270	4.9	406	256	214
R38-500	low	0.8	701	470	376	1.4	668	448	358
	middle	1.5	662	444	355	2.5	608	408	326
	high	2.8	593	397	318	4.9	486	326	261
R38-550	low	0.8	757	519	425	1.4	724	496	406
	middle	1.5	719	493	403	2.5	665	456	373
	high	2.8	649	445	364	4.9	542	372	304
R51-550	low	0.8	830	513	420	1.4	785	485	397
	middle	1.5	778	481	393	2.5	705	436	357
	high	2.8	684	423	346	4.9	538	332	272
R51-660	low	0.8	909	619	507	1.4	865	589	482
	middle	1.5	858	584	478	2.5	785	534	437
	high	2.8	764	520	425	4.9	617	420	344
R51-800	low	0.8	1,104	759	607	1.4	1,060	728	583
	middle	1.5	1,052	723	579	2.5	980	673	539
	high	2.8	958	659	527	4.9	812	558	446
R51-950	low	0.8	1,171	904	694	1.4	1,126	869	668
	middle	1.5	1,119	864	664	2.5	1,046	808	621
	high	2.8	1,025	791	608	4.9	879	678	521
T76-1300	low	0.8	1,530	1,228	944	1.4	1,463	1,174	903
	middle	1.5	1,452	1,165	896	2.5	1,342	1,077	828
	high	2.8	1,309	1,050	808	4.9	1,084	870	669
T76-1650	low	0.8	1,891	1,575	1,145	1.4	1,824	1,519	1,105
	middle	1.5	1,813	1,510	1,098	2.5	1,703	1,418	1,031
	high	2.8	1,670	1,390	1,011	4.9	1,444	1,202	874
T76-1900	low	0.8	2,280	1,828	1,443	1.4	2,213	1,774	1,400
	middle	1.5	2,202	1,765	1,393	2.5	2,092	1,676	1,323
	high	2.8	2,059	1,650	1,303	4.9	1,833	1,469	1,160
T103-2300	low	0.8	2,935	2,206	1,777	1.4	1,824	1,519	1,105
	middle	1.5	2,826	2,124	1,711	2.5	1,703	1,418	1,031
	high	2.8	2,627	2,187	1,590	4.9	1,444	1,202	874
T103-3700	low	0.8	5,670	4,545	3,588	1.4	2,213	1,774	1,400
	middle	1.5	5,562	4,458	3,519	2.5	2,092	1,676	1,323
	high	2.8	5,362	4,298	3,393	4.9	1,833	1,469	1,160

Grouting

The grout injection technique used for the installation of DYWI® Drill Hollow Bars is dependent on the type of drilling and the respective application. The most popular method is simultaneous drill and grout. This method ensures that all points of the borehole are homogeneously grouted as drilling is advanced.

For simultaneous drilling and grouting, pressure requirements are not high (up to 7 bar), but constant supply is necessary to ensure that grout circulates within the borehole during drilling. For granular soils, a small return of grout at the mouth of the borehole is all that is required; for cohesive soils, greater flush is necessary.

Typical Grouting Volumes

DYWI® Drill Hollow Bar	Drill Bit Ø [mm]	Grout [kg/m]	Drill Bit Ø [mm]	Grout [kg/m]
R32	75	30-40	100	32-42
R38	110	32-42	130	35-45
R51	115	35-45	150	38-48
T76	130	38-48	200	40-50

Grout consumption is dependent on:

- Amount of flush used - simultaneous drill and grout is a part flush/part injection technique
- Ground being drilled – granular soils or fractured ground with voids will result in increased grout take
- Rate of drilling advance

Grout Mixes

- 0.40 w/c ratio (water: cement ratio) = 40 liters water: 100kg cement
- 0.45 w/c ratio (water: cement ratio) = 45 liters water: 100kg cement

Grout Yields

- One 25kg bag of cement, mixed at 0.40 w/c cement ratio, will give 17.5 liters of grout
- Four 25kg bags of cement, mixed at 0.40 w/c cement ratio, will give 70 liters of grout

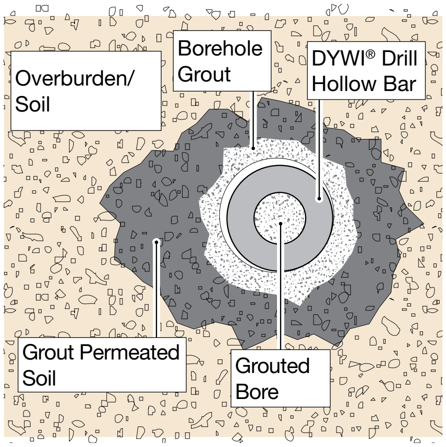
DYWI® Drill Hollow Bar grout column crack width analysis

DYWI® Drill Hollow Bar installed with simultaneous drill & grout HoTV A465 South Wales

Grout Pumps

These units typically comprise of a mixer and a pump. The choice of grout pump is dependent upon the application; Concrete Colloidal mixing pumps, Hani, Putzmeister or Turbosol are all suitable. The key requirement is full mixing of the grout and a steady pumping pressure.

Typical grout plant set-up



Typical section of grouted DYWI® Drill Hollow Bar

Grouted soil nails on shotcrete face

Drill Bits

Bar Type	Available Drill Types and Diameters								
	CRC Two-Stage RS-Flush (Retro & Side Flush), Hardened	**EY** Arc-Shaped Button, Hardened	**EYY** Arc-Shaped Button, Carbide Inserts	**EC** Arc-Shaped, Hardened	**ECC** Arc-Shaped, Carbide Inserts	**EX** Cross, Hardened	**EXX** Cross, Carbide Inserts	**ES** Button, Hardened	**ESS** Button, Carbide Inserts
									
R25						42	42	42	42
R32	75,100	51, 76	51, 76	76, 90	76, 90	51, 76	51, 76	51, 76	51, 76
R38	110,130	76		76, 90, 115	76, 90, 115	76, 90, 115	76, 90, 100, 115	76, 90, 100, 115	76, 90, 100, 115
R51	150, 175			76, 90, 115, 130	76, 90, 115	100, 115	100, 115	76, 100, 115	76, 100, 115
T76				130, 150	130, 150	130, 150	130	130, 150	130, 150
T103	220						175	175	175

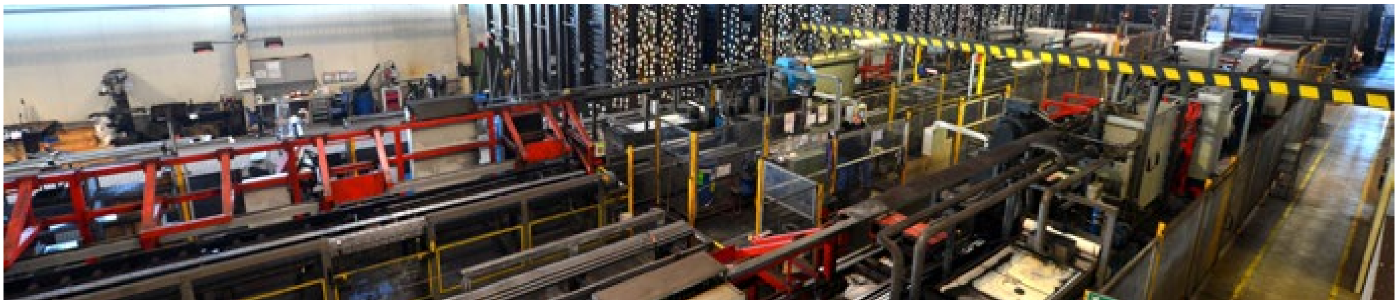
Use R25 / R32 adapter sleeve to fit R32 drill bit to R25 hollow bar.
Use R32 / R38 adapter sleeve to fit R38 drill bit to R32 hollow bar.
Other diameters available. Drill bit is a welded fabrication, therefore, cutting Ø can be enlarged to suit borehole requirements.

Drill Bit Adaptor Sleeves

Drill Bit Adaptors can be supplied to allow larger bits to be used with smaller bar.

Couplers and Nuts

N.B Lifting eye as standard do not necessarily provide the full load capacity of the DYWI® Drill Hollow Bar. Full capacity eye pieces can be manufactured upon request



DYWI® Drill Hollow Bar production plant, Austria

DYWI® Drill Hollow Bar System

DYWI® Drill Hollow Bar soil nails are ideal for loose or collapsing soils, as they can be installed without the need for a casing. The system is used for mixed fills, granular material and loose overburden. The DYWI® Drill hollow bar system allows drilling and grouting to be combined as a single operation and complies fully with EN 14490 (European standard for soil nails).

Soil nails are typically classified as lightly loaded (30-150 kN), passive installations. The fully bonded feature enables the loose wedge at the surface to be tied into the deeper stable zone. Soil nails are normally regarded as low risk installations, with an element of redundancy existing in the stabilized face. The design of soil nailed faces should incorporate a diamond grid layout to ensure efficient distribution of the reinforcement. Suitable drainage must be incorporated within the nailed face to prevent build up of water within the slope. Water ingress can negate the effects of the soil nails by increasing the bulk weight of the soil, decrease the internal angle of friction and may cause a slope failure.

Soil Nailing using DYWI® Drill Hollow Bar, DYWI® Mat Green & TECCO® G45/2 Cockermouth

Slope stabilisation at Phoenix Park, Dublin

A465 HoTV DYWI® Drill Hollow Bar & DYWI® Mat Green

Drilling in the snow at Kinghorn, Fife

DYWI® Drill Hollow Bar & TECCO® G45/2 stabilising a new cut in Halifax

Bearing Plates and Facings

Soil nail facings are split into three categories:

- Soft – Erosion Control Matting
- Flexible – Hi Tensile Steel Meshes
- Rigid – Shotcrete

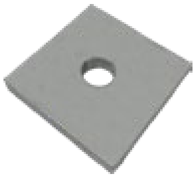
Facing systems provide a combination of structural facing and erosion control. The factors considered when determining the type of facing are slope geometry, geotechnical characteristics and environmental effects such as surcharge at crest and desired design life.

The use of different facings can have a significant effect on the soil nail design influencing spacing & shape of the nail pattern as well as the strength and size of the bar selected.

Bearing plates are used primarily to secure facings. Plates also provide an element of confinement, in conjunction with the retention effect of the fully bonded nail in the wedge zone. Centres for and lengths of soil nails should be defined by assessing the global stability of the slope first and then the internal checks including the superficial failures on the slope surface can be considered.

Angle compensation between the bearing plate and the soil nail must be addressed to ensure full seating of the plate against the face. For flatter slopes (25° to 30°), the amount of angle compensation is significant and can be up to 50°. See below for angle compensation options.

Erosion control matting offers a practical solution for most slopes up to 45°; above this angle facings with structural stiffness to resist bulging are required such as High Tensile Steel Mesh systems or for some vertical faces sprayed concrete may be required.

Flat Plate	Formed Plate	Slotted Plate
up to 15°	up to 20°	up to 55°
		

DYWI® Drill Hollow Bar & TECCO® overlaid with Geocell to retain topsoil on the face

DYWI® Drill Hollow Bar shotcrete used to create a ridged face to a stabilised slope.

Meshes

DYWIDAG-Systems International through partnership with specialist Swiss Geo-hazards solution provider GEOBRUGG offer a range of high-tensile steel, flexible facing meshes.

GEOBRUGG have vast experience in reducing the impact of rock fall and developed their first Avalanche Protection Structure made of wire rope net in 1951. These avalanche prevention structures were exposed to rockfalls during snow-free periods, and they succeeded in holding these rocks.

Following the success of the Avalanche Barriers, GEOBRUGG developed the TECCO® SYSTEM³. The first mesh was made from High Tensile Strength Steel wire. This then evolved into more discrete, lighter meshes such as DELTAX® and more robust cable nets designed to resist large angular blocks known as SPIDER®.

The synergy between DYWIDAG-Systems International & GEOBRUGG allows the supply of an entire Rock Fall Protection System from one source.

	Roll Size [m]	Roll Area [m²]	Tensile Strength [kN/m]	Punching Strength [kN]*	Wire Diameter [mm]	Corrosion Protection	Weight per Roll [kg]
DELTAX®	3.9 x 30	117	53	25.7 / 39 ***	2	ULTRACOATING®	76
TECCO® G45/2	3.5 x 30	105	85	80 / 110	2	ULTRACOATING®	121
TECCO® G65/3	3.9 x 30	117	150	180 / 240	3	SUPERCOATING®	193
TECCO® G65/4	3.5 x 20	70	250	280 / 370	4	SUPERCOATING®	231
SPIDER® S-130	3.5 x 20	70	220	230 /300 **	3 x 3 mm	SUPERCOATING®	182

* using spike plate P25/P33
** using spike plate P33/P66
*** using 150 x 150 / 200 x 200 square plate

	Roll Size [m]	Roll Area [m²]	Tensile Strength [kN/m]	Punching Strength [kN]	Wire Diameter [mm]	Corrosion Protection	Weight per Roll [kg]
Stainless Steel DELTAX®	3.9 x 55	214.5	45	60	2	INOX	76
TECCO® G65/3 STAINLESS	3.5 x 30	105	140	170	3	INOX	175

* using spike plate P33

	Roll Size [m]	Roll Area [m²]	Tensile Strength [kN/m]	Punching Strength [kN]*	Wire Diameter [mm]	Corrosion Protection	Weight per Roll [kg]
GREENAX®	3.9 x 30	117	53	25.7 / 39 *	2	ULTRACOATING®	123
TECCO® GREEN	3.9 x 25	97.5	150	180 / 240**	3	SUPERCOATING®	200

* using square plate 150 x 150 / 200 x 200
** using spike plate P33/P66


DELTAX® mesh being laid over tree stumps in Hove

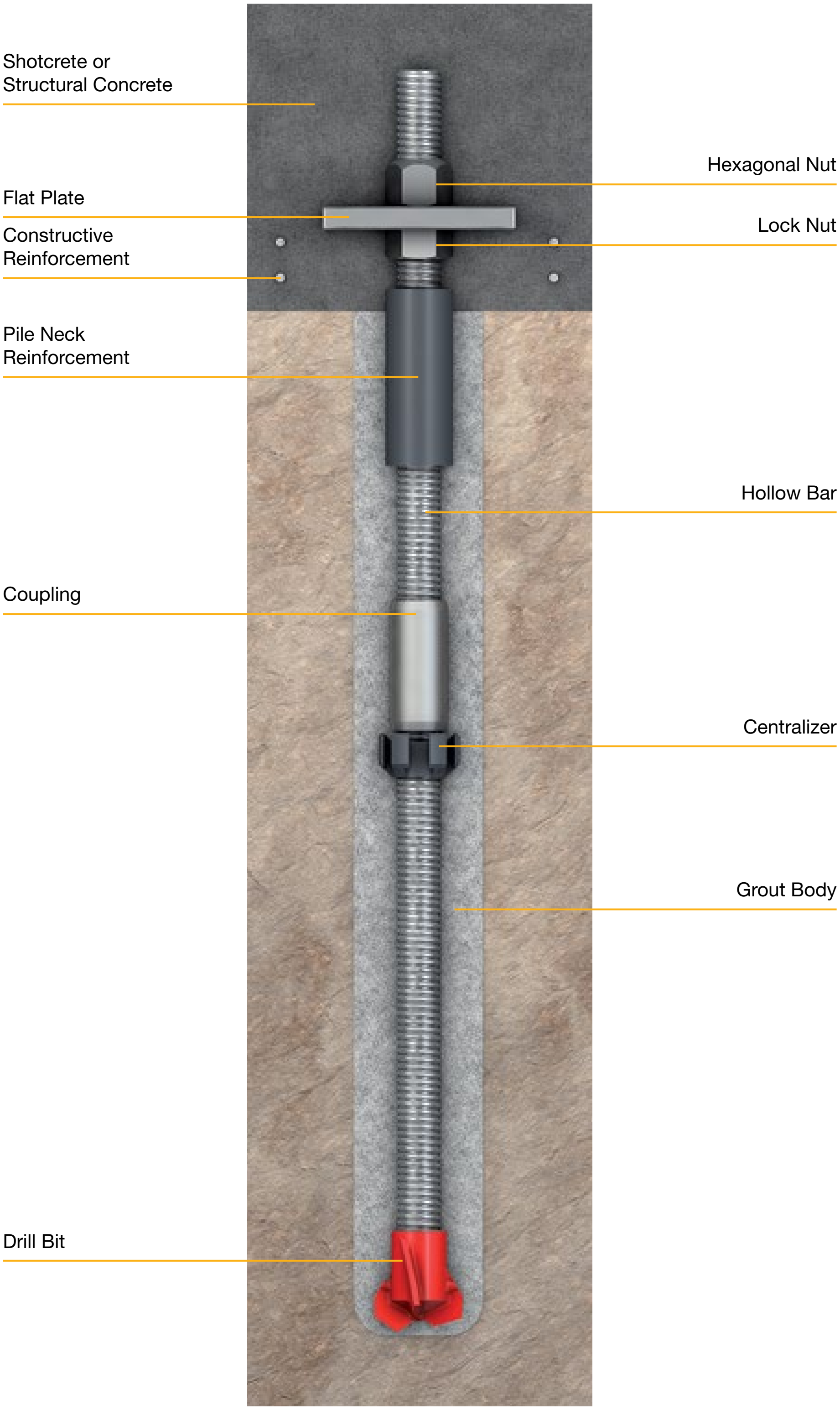

DELTAX® can be manually handled and moved into position

Micropiles

DYWI® Drill Hollow Bar Micropiles can be installed in restricted access areas or within the close proximity of buildings. Due to the fully threaded system, the micropile can be extended and grouted in areas where the founding level is deeper than expected.

The rotary percussive drilling method ensures minimal disturbance is caused during installation compared to driven piling systems, enabling the foundations of old structures or buildings to be upgraded without damage. Pile stiffness can be increased by placing a steel tube over the top 2m of bar and grouting the annulus.

Applications for DYWI® Drill injection piles, in accordance with EN 14199, include: retained facade bases, foundation upgrades, pylon bases, wind turbines, refurbishment of old structures and gantry bases for rail electrification. Larger diameter DYWI® Drill bars can be used to form contiguous piled retaining walls.




Raking T76 Micro Piles


T76 Micro Piles forming a contentious wall

Ground Anchors

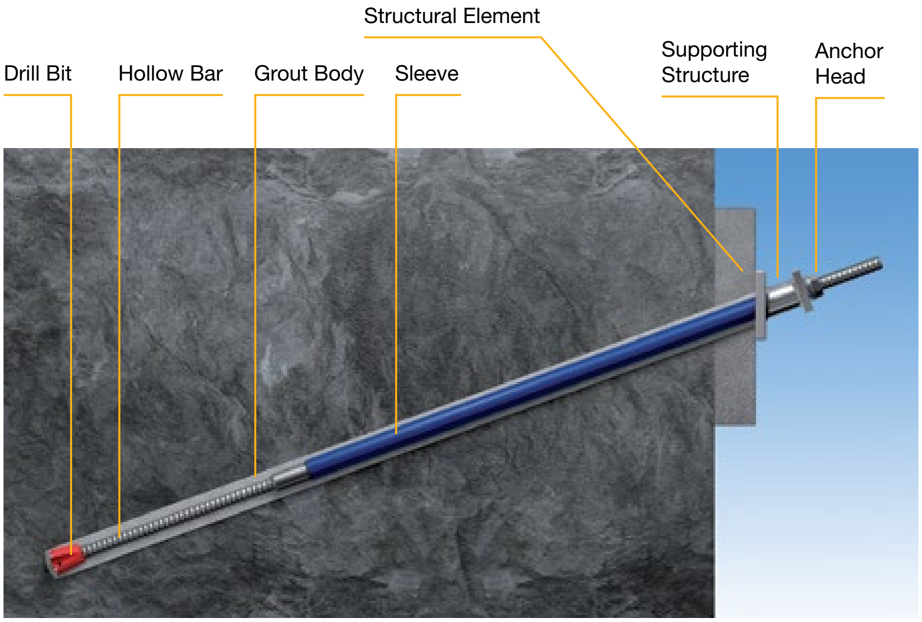
DYWI® Drill Injection Anchors are used extensively in temporary works, as the anchor can be drilled into a range of difficult ground conditions or collapsing soils without the need for a casing. The bond stress of both rope thread and “T” thread bars is high and compares favourably with reinforcing bars of similar diameter (this has been proved by tests carried out by the Technical University of Munich).

The DYWI® Drill free length system incorporates a special de-bond sleeve and compression collar so that the self-drilled anchors remain de-bonded in the free length for stressing.

The stressing operation and acceptance tests ensure that each anchor is fully tested and that additional extension will not occur during its service life.

Irrespective of threadform, hollow bar systems are only suitable as temporary anchors. The high impact energy during rotary percussive drilling prevents the use of an adequate corrosion protection system approved by the building authorities.

However, corrosion protection is mandatory for stressed (active) permanent anchors, in accordance with the design standards for permanent anchors (EN 1537).



DYWI® Drill R51 Duplex coated Hollow Bar is installed on the River Dargal Flood Aleviation Scheme, Ireland

Testing and Monitoring

On-site testing ensures the performance of the DYWI® Drill Hollow Bar System. This demonstrates both the quality and adequacy of the proposed design. Depending on the application, the appropriate test method should be chosen. Some tests may be more rigorous and are therefore conducted on sacrificial trial elements, installed as replicas of the working tendons.

The testing of ground anchors generally involves three categories of tests:

- Investigation Tests
  - Conducted on trial anchors and tested to failure to ascertain the expected performance of the design.
- Suitability Tests
  - Conducted on either sacrificial or working anchors to provide a data reference against which the working anchors can be measured.
- Acceptability Tests
  - Conducted on working anchors to ensure construction methods and safety.

For micropiles and soil nails, investigation and suitability tests are generally utilised.

Investigation tests are used to assess design parameters, verify the pile design, prove the ultimate load resistance and creep characteristics of the grout ground interface and the system within its working range.

Suitability tests prove the construction methods and that the micropile or nail complies with the Specification.

Pull-out tests are the default on-site testing procedure for all tensile elements such as ground anchors and soil nails.

Depending on the loading mechanism (tensile, compression or aalternating), micropiles can be tested by either pull out tests or static load tests. Spiles and injection lances are generally not tested.

Testing and monitoring features economic advantages during the service life of the tendon. With information gained from in-situ tests and trials, an optimised assessment of the construction design may be possible. Monitoring and regular inspection increase the service life of both the tendon and therefore the entire retaining structure, as defects or damage can be detected at an early stage.

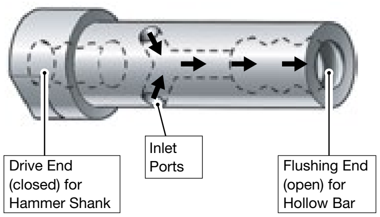
More information is given in the relevant codes and standards associated with these applications.

DYWI® Drill Injection Adaptors

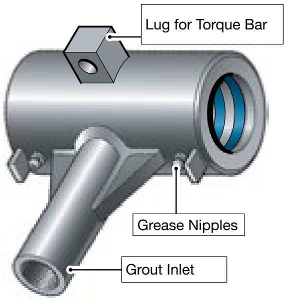
DYWI® Drill Injection Adaptors enable grout to be pumped into the bore of a rotating bar during drilling, ensuring the hollow bar is simultaneously grouted as drilling advances. The injection adaptor is a three component unit consisting of a flushing shaft, grout bottle and a seal kit.

For the connection between the hammer shank and the hollow bar, the selection of the correct injection flushing shaft within the injection adaptor unit is important. This will ensure the connection is sufficiently strong to endure the demands of rotary percussive drilling and withstand any temporary misalignment if obstructions are encountered during drilling.

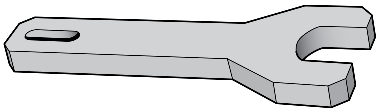
Tightening of the flushing shaft onto the hammer shank is essential to ensure that this joint remains tight during drilling and does not release during rod changes. The seals within the grout bottle should be greased approx. every 20 minutes.



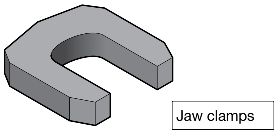
Flushing Shaft



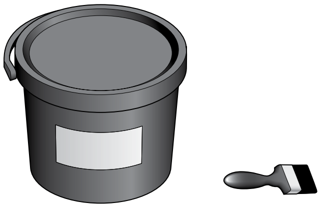
Grout Bottle



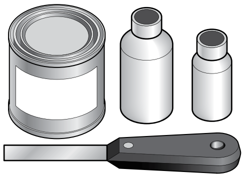
Drill Spanner (drill boom)



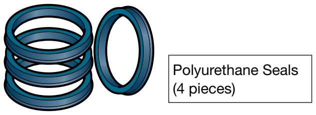
C Spanner



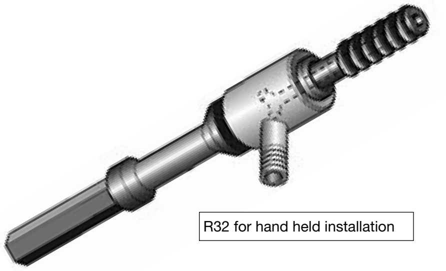
Thread Sealant – TF15, Teflon grease



Thread Lock Kit – Jet Lok



Seal Kit



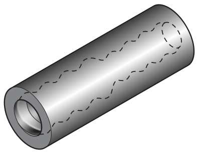
Rotary Injection Adaptor

Drill head with simultaneous drill & grout feed

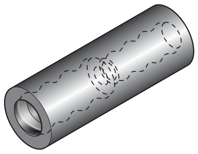
Drill Tooling

Drilling equipment often has to be adapted at short notice to accommodate unforeseen conditions. The DYWI® Drill tool range offers the driller the flexibility to make changes, ensuring limited down time and efficient drilling.

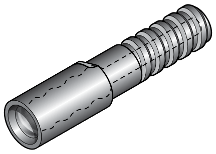
In addition to the tool range, drill spanners are supplied for lock-up of the flushing shaft on the shank adaptor and torque wrenches for the seating of bearing plates on the slope face, by torquing up the nut.



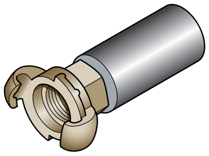
Reducing Coupler



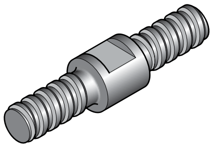
Reducing Coupler,
complete with centre bridge



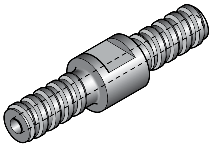
Box/Pin Adaptor
(hollow)



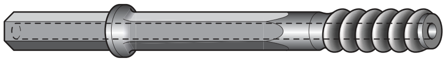
Grout Injection Coupler
(for subsequent grouting)



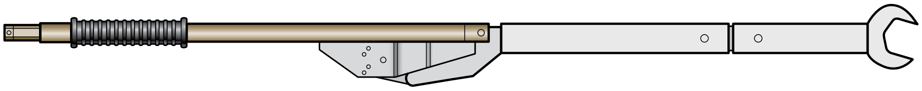
Pin/Pin Adaptor
(solid)



Pin/Pin Adaptor
(hollow)



Air Flush Shank



Torque Wrench

Hand drilling through DELTAX® at Hove

United Kingdom
DYWIDAG-Systems International Ltd.
Northfield Road
CV47 0FG Southam
Warwickshire
United Kingdom
Phone +44-1926-81 39 80
E-mail sales@dywidag.co.uk

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www.dywidag.co.uk

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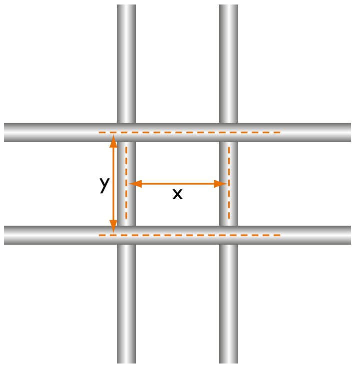
Gabion Design Specification : Bi-Axial Welded Mesh

GABION ENV-P38 (Polymer Powder Coated Grey)



SPECIFIED MESH BI-AXIAL WELDED
Nominal dimensions (x) and (y) : Gabions, 75mm Mattresses, 75mm

Gabions are to be manufactured and / or supplied by:
Enviromesh, Unit 4 Cartwright Industrial Estate, Spring Garden Road, Longton, Staffordshire, ST3 2TE.
Telephone +44 (0)1782 692310 Fax +44 (0)1782 692318 Email: enquiries@enviro-mesh.com Online: www.enviro-mesh.com

The certification, materials, manufacture, assembly and installation of the above-mentioned product shall comply with all of the following criteria:

Certification

1. All gabion materials and accessories must be certified in accordance with **British Board of Agrément (BBA)** certificate no. 05/4215. This is for current General Building Regulations.

2. All gabion products are manufactured in accordance with the requirements of BS EN 10223-8:2013 where the gabions are considered to have a life expectancy of **120 years.**

3. Evidence of current BBA certification and relevant certificates of conformity with respect to wire strength, weld strength and coating weights used in the manufacture of the mesh fabric and wire products are to be issued upon request.

Materials

The wire used in the manufacture of the gabions and installation accessories shall comply with the following:

Mesh Fabric
The mesh fabric shall be formed by electrically welding at each and every intersection, hard drawn steel line and cross wires into a dimensionally stable bi-axial square metric mesh of size **75mm x 75mm.**

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The weld strength shall be **75%** of the minimum ultimate tensile strength of the wire.

The nominal wire diameter for the mesh fabric shall be **3.80mm** for the base, front, rear, end, diaphragm panels and lid, all within the tolerances specified in BS EN 10218-2:2012 and shall have a tensile strength that falls within a range of **540-770 N/mm².**

Lacing Wire
The lacing wire used for site assembly shall be of a nominal **2.2mm** wire diameter in accordance with BS EN 10218-2:2012 and shall have a tensile strength that falls within a range of **350 to 550 N/mm².**

Corrosion Resistance
All wire used in the mesh fabric or accessories shall be Galfan coated (95% Zn/5% Al) in accordance with BS EN 10244-2:2009 (Class A). An additional nominal thickness is applied of **0.25mm** organic polymer powder coating (grey) for the mesh fabric and a nominal **0.5mm** organic polymer powder coating (grey) for the lacing wire. This coating being in accordance with BS EN 10245-1:2011 and BS EN 10245-2:2011

Manufacture

Unit Formation
The gabion is to be formed from mesh panels such that the front, rear, ends and diaphragm panels are connected to the base panel with either **Stainless Steel CL35 clips** or **Stainless Steel CL50 'C' rings** at a maximum spacing of 225mm for all joints. This process must be undertaken in a factory-controlled environment. The lid may be supplied loose or fixed in the same manner to the rear or face panel. Diaphragm (partitioning panels) spacings should not exceed 1.050m on units oriented as stretchers and 1.65m oriented as headers.

Should units be required to be pre-filled and lifted as opposed to filling in situ, additional clips, rings and mesh panels may be required. In such circumstances the manufacturer must be consulted prior to supply to ensure product is suitable for application.

Gabion Sizes
It should be noted that it is industry standard for gabions to be quoted as overall nominal sizes. The actual gabion sizing is dependant upon the physical mesh configuration.

Clarification should always be sought from the manufacturer in relation to gabion sizing.

Designation of sizes **length x width x height**

Gabion standard unit lengths: 975mm or 2025mm
Gabion standard unit widths: 450mm, 675mm, 975mm, 1350mm, 1500mm or 1650mm
Gabion standard unit heights: 300mm, 450mm or 975mm

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Non-standard sizes available in multiples of 75mm on request.

Assembly and Installation

Note Please also refer to manufacturer's installation instructions, which are available upon request in either electronic or hard copy format.

Jointing

Gabions are supplied with lacing wire as standard for horizontal and vertical jointing of adjacent units whilst empty. Lacing is to be continuous along all joints using alternate single and double loops at a maximum spacing of 100mm ensuring that it forms a tight joint. Start or termination of lacing is formed by three turns ensuring the free end is turned into the unit.

If CL50 'C' rings are to be used for final jointing as an alternative to lacing then these must be installed at every other mesh opening to achieve the required joint strength.

Internal Bracing

Internal bracing is formed by creating a continuous windlass tie between the face and rear of the exposed cells within the structure.

For 1m high units, two internal windlass bracings are required at third widths and at each third height of the gabion.

In all cases the windlass tie is to span two or three mesh openings on the front and rear cells to spread the load. The exposed end gabions to the wall should also be braced in both directions to prevent end face deformation.

The same is required to the rear cell of each course (rear panel to side panels).

Geotextile Separators

Where a geotextile separator between the rear of the gabion and backfill is to be used, refer to the engineer's design proposal and specification.

Foundations

Reference to the engineer's design proposal must be made with respect to foundation requirement, wall inclination, face configuration (stepped, flush or combination thereof), drainage and backfilling requirements. Any soft areas in the sub grade should be excavated and replaced with a granular material to the engineer's requirements.

Filling

Units are to be filled with a hard, durable, non-frost susceptible rock, stone or clean crushed concrete as specified by design. The grading of the fill is to be 100 to 150mm or 100 to 200mm (6G). Where dual fills of the same grading are specified a separation panel is optional. Where the secondary fill grading is less than the mesh aperture size, it is necessary for the fills to be separated using pre-cut correx panels or geo-textile that is

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inserted into the gabion on site. If this is the case then this will require the fitting of an additional longitudinal diaphragm set back from the face. In such instances it is important to refer to the engineer's design proposal with respect to additional drainage that may be required. It is also important to note that cohesive fills are not to be used as a secondary fill within gabions.

The units shall be filled in layers not exceeding 340mm, if large voids are present then the stone must be re-orientated to minimise voids. Where specified the gabions are to have a hand placed front face.

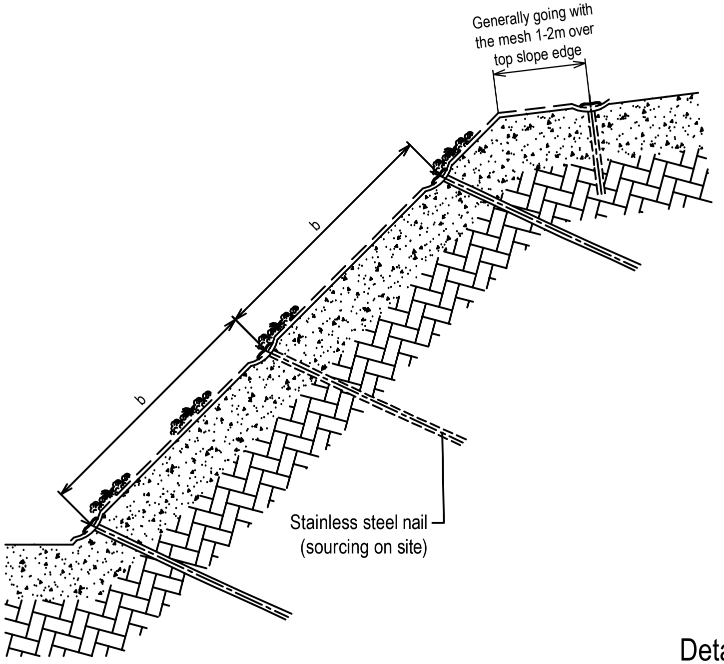
The units shall be filled such that the mesh lid bears down onto the gabion filling material. It may be beneficial to blind the top of the filled unit with a 20 to 50mm aggregate.

Filling should be staged so that no adjacent cells have more than a half difference in the level of filling for units of greater height than 500mm.

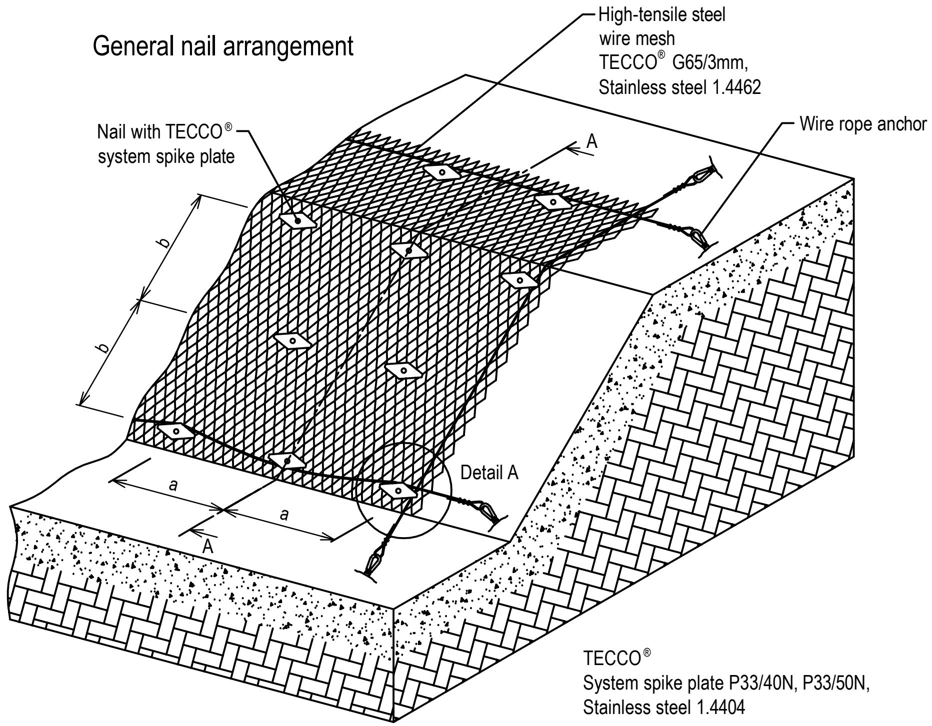
To assist in maintaining face alignment and reduce deformation, the use of external formwork i.e. timber or scaffold tubes can be tied onto the external face of the structure at third heights and then removed upon completion.

Cerana Limited registered office Garner Street Business Park Etruria Stoke-on-Trent Staffordshire ST4 7BH UK
Enviromesh is a trading name of Cerana Limited Registered in England Company No. 05065615 VAT No. GB 151 1046 61

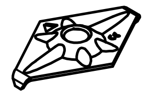
Cross section A-A



General nail arrangement

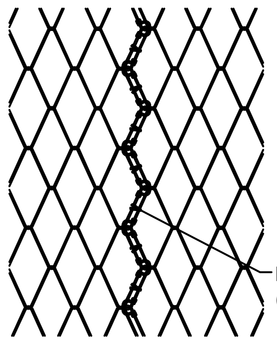


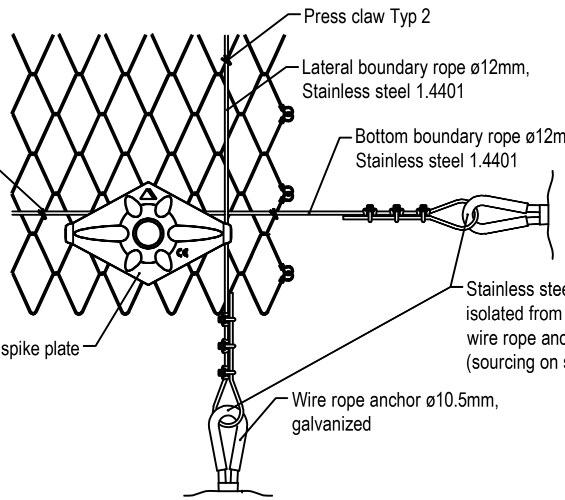
TECCO®
System spike plate P33/40N, P33/50N,
Stainless steel 1.4404



Detail A

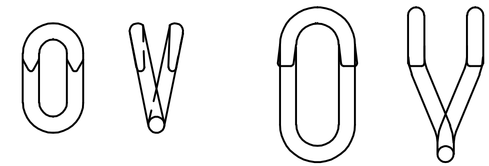
TECCO® mesh connection vertical
normally without overlap





Press claw Typ 1,
Stainless steel 1.4401

Press claw Typ 2,
Stainless steel 1.4401



modification: 194	M:%	substitute for: GE-1013e ed. 20.06.19 replaced by:		
TECCO® G65/3 STAINLESS **System drawing**		drawn	02.09.19	BIH
		checked	02.09.19	BIH
		approved	02.09.19	ROA1
GEOBRUGG AG CH-8590 Romanshorn	GEOBRUGG	**GE-1013e**		

CE European Technical Approval ETA-17/0118

GEOBRUGG BRUGG
Safety is our nature

TECHNICAL DATA SHEET

High-tensile steel wire mesh TECCO® G65/3

TECCO® high-performance steel wire mesh	
Mesh shape:	rhomboid
Diagonal:	x · y = 83 · 143 mm (+/- 3%)
Mesh width:	D_i = 65 mm (+/- 3%)
Angle of mesh:	ε = 49°
Total height of mesh:	h_{tot} = 11.0 mm (+/- 1 mm)
Clearance of mesh:	h_i = 5.0 mm (+/- 1 mm)
Number of meshes longitudinal:	n_l = 7 pcs/m
Number of meshes transversal:	n_q = 12 pcs/m

TECCO® steel wire	
Wire diameter:	d = 3.0 mm
Tensile strength:	$f_t \geq$ 1'770 N/mm^2
Material:	high-tensile steel wire
Tensile resistance of a wire:	Z_w = 12.5 kN

TECCO® corrosion protection **)	
Corrosion protection:	GEOBRUGG SUPERCOATING® A
Compound:	95% Zn / 5% Al
Coating:	min. 255 g/m^2
≤ 5% dark brown rust in salt spray test according to EN ISO 9227:	4200 hours (ETA-17/0118)

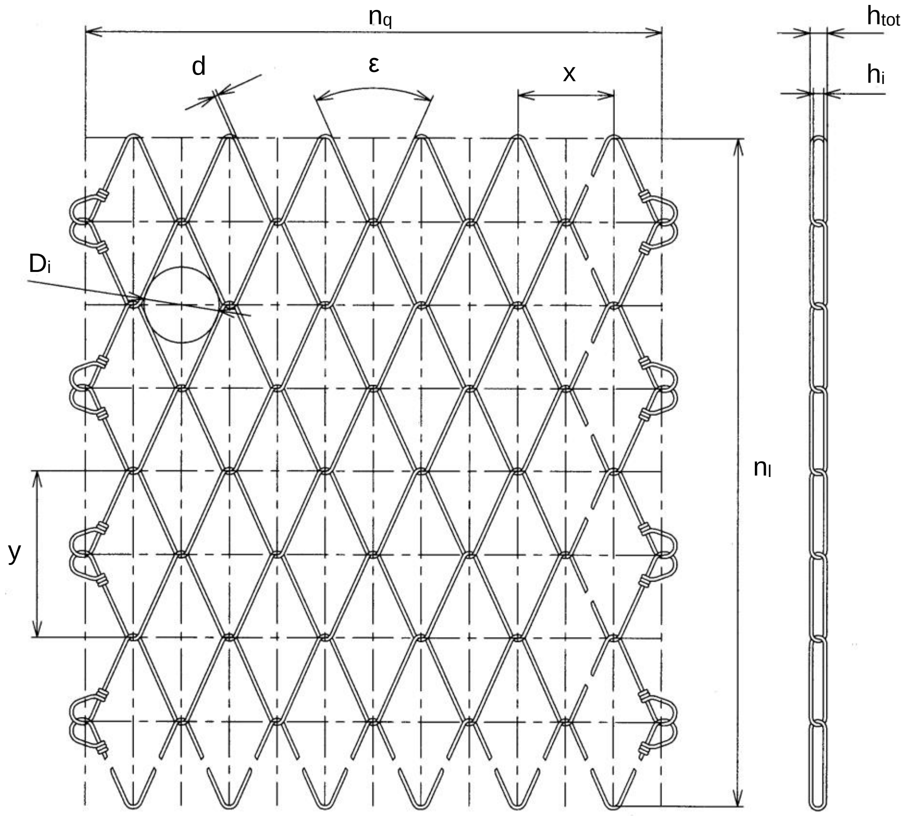
Load capacity (standard version)	
Tensile strength of mesh:	$z_k \geq$ 150 kN/m' *)
Bearing resistance against puncturing:	$D_R \geq$ 180 kN / 240 kN *)
Bearing resistance against shearing-off:	$P_R \geq$ 90 kN / 120 kN *)
Bearing resistance against slope-parallel tensile stress:	$Z_R \geq$ 30 kN / 45 kN *)
Elongation in longitudinal tensile strength test:	δ < 6.0 % *)
Classification according to EAD 230025-00-0106	group 2, class A (P33 and P66)

TECCO® mesh roll	
Roll width:	b_{Roll} = 1.75 m
Roll length:	l_{Roll} = 30 m
Total surface per roll:	A_{Roll} = 52.5 m^2
Weight per m^2:	g = 1.65 kg/m^2
Weight per mesh roll:	G_{Roll} = 87.5 kg
Mesh edges:	mesh ends knotted

*) As in EAD 230025-00-0106 and referring to TÜV Rheinland LGA test report 01/2014 using spike plate P33 / P66

**) Next to the standard version with Zn/Al coating, the high-tensile steel wire mesh is also available in stainless steel (INOX) in 1.4462 (AISI 318) sea water resistant quality.

TECCO® G65/3



TECHNICAL DATA SHEET

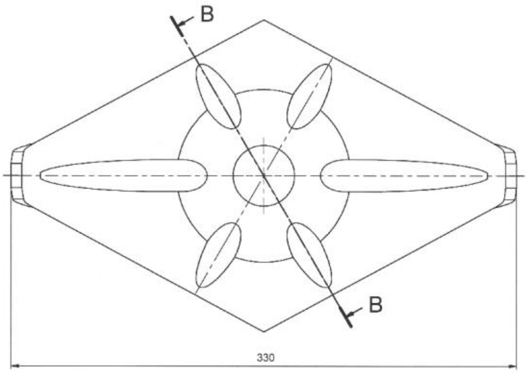
Spike plate P33/40 N and P33/50 N
for high-tensile steel wire mesh TECCO® / SPIDER®

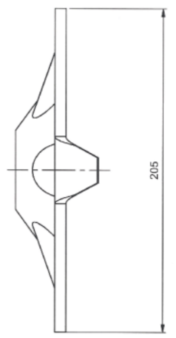
Spike plate P33	
Length:	330 mm
Width:	205 mm
Thickness:	7 mm
Hole diameter:	40 mm / 50 mm
Length of the spikes:	min. 20 mm
Weight:	2.2 kg
Geometry:	diamond
Longitudinal bending resistance:	≥ 2.5 kNm

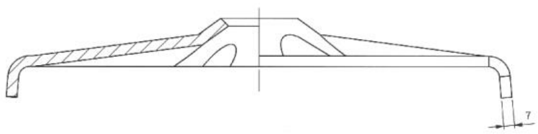
Spike plate P33 Steel	
Steel quality:	S355J according to EN 10025-2

Spike plate P33 corrosion protection	
Corrosion protection:	hot-dip galvanized based on EN ISO 1461
Layer thickness in average:	55 µm

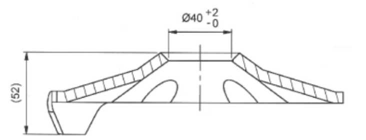
Spike plate P33/40N, P33/50N

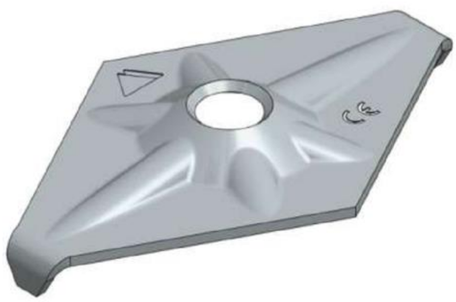




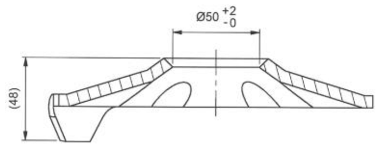


Section B-B





Section B-B



TECHNICAL DATA SHEET
Erosion control mat TECMAT®

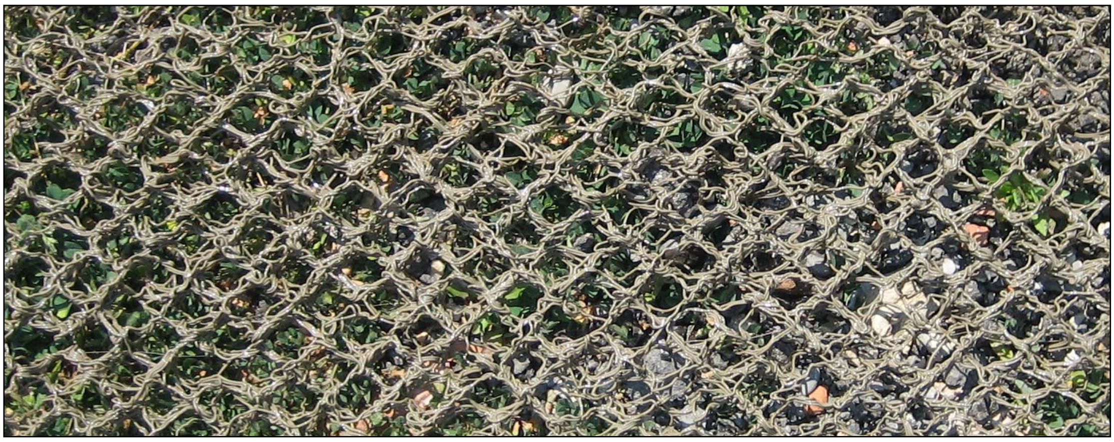
The Geobrugg erosion control mat TECMAT® is a three dimensional structural mat of PP monofilaments and is typically used in combination with a TECCO® mesh cover and an appropriate nailing. The erosion control mat needs to be installed underneath the steel wire mesh, in general, and it features no static function.

Physical properties		Test method
Fibers:	extruded monofilaments	
Material:	Polypropylene (PP)	
Structure:	irregular loopy structure	
Thickness:	h_m = 18 mm	
Specific mass:	g_m = 600 g/m^2	
Void ratio:	> 95%	
Colour:	Curry green *	

Mechanical properties			
Tensile strength:	MD: $z_m \geq$ 1.8 kN/m	CMD: $z_m \geq$ 0.6 kN/m	EN ISO 10319
Tensile strain:	MD: ε = 20%	CMD: ε = 20%	EN ISO 10319

TECMAT® standard roll	
Roll width:	b_{Roll} = 2.00 m
Roll length:	l_{Roll} = 40 m
Total surface per roll:	A_{Roll} = 80 m^2
Weight per roll:	G_{Roll} = 48 kg

TECMAT®



* Slight color changes are normal and cannot be seen as product fault.

Although not guaranteed, these results do to the best of our knowledge, offer a true and accurate record of the production performance. Any kind of responsibility for the performance of these products cannot be accepted. The right of alter product specifications without prior notice is reserved.

Rockfall, slides, mudflows and avalanches are natural events and therefore cannot be calculated. This is why it is impossible to determine or guarantee absolute safety for persons and property with scientific methods. This means that to provide the protection we strive for, it is imperative to maintain and service protective systems regularly and appropriately. Moreover, the degree of protection can be diminished by events that exceed the absorption capacity of the system as calculated to good engineering practice, failure to use original parts or corrosion (i.e., from environmental pollution or other outside influences).

Appendix D: Calculation Sheets

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RUVOLUM® ONLINE TOOL

RUVOLUM® - The Program to dimension the slope stabilization system TECCO®/SPIDER®

Project No.	21287
Project Name	Ponsharden (unfactored)
Date, Author	2021-12-06_MT

Input quantities			
Slope inclination	α=	70.0	degrees
Layer thickness	t=	0.75	m
Friction angle ground (characteristic value)	Φ_k=	26.0	degrees
Volume weight ground (characteristic value)	γ_k=	19.0	kN/m^3
Nail inclination	ψ=	30.0	degrees
Nail distance horizontal	a=	2.00	m
Nail distance in line of slope	b=	1.00	m

Load cases			
Streaming pressure		No	
Earthquake		No	
Coefficient of horizontal acceleration due to earthquake	ε_h=	0.000	[-]
Coefficient of vertical acceleration due to earthquake	ε_v=	0.000	[-]

Defaults and Safety Factors			
Cohesion ground (characteristic value)	c_k=	0.0	kN/m^2
Radius of pressure cone, top	ζ=	0.15	m
Inclination of pressure cone to horizontal	δ=	45.0	degrees
Slope-parallel force	Z_d=	15.0	kN
Pretensioning force of the system	V=	30.0	kN
Partial safety correction value for friction angle	γ_Φ	1.00	[-]
Partial safety correction value for cohesion	γ_c	1.00	[-]
Partial safety correction value for volume weight	γ_γ	1.00	[-]
Model uncertainty correction value	γ_{mod}	1.10	[-]

Dimensioning quantities	Φ_d=	26.0	degrees
	c_d=	0.0	kN/m^2
	γ_d=	19.0	kN/m^3

Elements of the system

Applied mesh type		TECCO G65/3	
Applied spike plate		system spike plate P33	
Bearing resistance of mesh to selective, slope parallel tensile stress	Z_R=	30	kN
Bearing resistance of mesh to pressure stress in nail direction	D_R=	180	kN
Bearing resistance of mesh against shearing-off in nail direction	P_R=	90	kN
Elongation in longitudinal tensile strength test	δ<	6	%

Applied nail type		DYWI DRILL R38-420	
Taking into account rusting away		Yes	
Bearing resistance of nail to tensile stress	T_{Rred}=	237	kN
Bearing resistance of nail to shear stress	S_{Rred}=	137	kN
Cross-section surface of the applied nail with / without rusting away	A_{red}=	446	mm^2

Proofs

Proof of the mesh against shearing-off at the upslope edge of the spike plate	Fulfilled
Proof of the mesh to selective transmission of the force Z onto the nail	Fulfilled
Proof of the nail against sliding-off of a superficial layer parallel to the slope	Fulfilled
Proof of the mesh against puncturing	Fulfilled
Proof of the nail to combined stress	Fulfilled

The given proofs concern the investigation of superficial instabilities. Additional investigations are required if there is a risk regarding global stability of the slope. If necessary the nail type and nail pattern have to be adapted.

Investigation of local instabilities between single nails

Proof of the mesh against shearing-off at the upslope edge of the spike plate

Maximum stress on the mesh for shearing-off in nail direction at the upslope edge of the spike plate (dimensioning level).	P_d=	0.0	kN
Thickness of decisive sliding mechanism	t_{rel}=		m
Bearing resistance of the mesh against shearing-off in nail direction at the upslope edge of the spike plate (characteristic value).	P_R=	90.0	kN
Resistance correction value for shearing-off of the mesh	γ_{PR}=	1.0	[-]
Dimensioning value of the bearing resistance of the mesh against shearing-off	P_R/γ_{PR}=	90.0	kN
Proof of bearing safety	$P_d<=P_R/\gamma_{PR}$	Fulfilled	

Proof of the mesh to selective transmission of the force Z onto the nail

Slope parallel force taken into account in the equilibrium considerations	Z_d=	15.0	kN
Bearing resistance of the mesh to selective, slope-parallel tensile stress	Z_R=	30.0	kN
Resistance correction value for selective, slope-parallel transmission of the force Z	γ_{ZR}=	1.0	[-]
Dimensioning value of the bearing resistance of the mesh to tensile stress	Z_R/γ_{ZR}=	30.0	kN
Proof of bearing safety	$Z_d<=Z_R/\gamma_{ZR}$	Fulfilled	

Investigation of slop-parallel instabilities

Proof of the nail against sliding-off of a superficial layer parallel to the slope

Pretensioning force effectively applied on nail	$V=$	30.0	kN
Load factor for positive influence of pretension V	$\gamma_{VI}=$	1.0	[-]
Dimensioning value of the applied pretensioning force by positive influence of V	$V_{dI}=$	30.0	kN
Calculatorily required shear force at dimensioning level in function of V_{dI}	$S_d=$	14.6	kN
Bearing resistance of the nail to shear stress	$S_{Rred}=$	137.0	kN
Resistance correction value for shearing-off of the nail	$\gamma_{SR}=$	1.0	[-]
Dimensioning value of the bearing resistance of the nail to shear stress	$S_{Rred}/\gamma_{SR}=$	137.0	kN
Proof of bearing safety	$S_d<=S_{Rred}/\gamma_{SR}$	Fulfilled	

Proof of the mesh against puncturing

Pretensioning force effectively applied on nail	$V=$	30.0	kN
Load factor for positive influence of pretension V	$Y_{VII}=$	1.0	[-]
Dimensioning value of the applied pretensioning force by positive influence of V	$V_{dII}=$	30.0	kN
Bearing resistance of the mesh to pressure stress in nail direction	$D_R=$	180.0	kN
Resistance correction value for puncturing	$Y_{DR}=$	1.0	[-]
Dimensioning value of the bearing resistance of the mesh to pressure stress	$D_R/Y_{DR}=$	180.0	kN
Proof of bearing safety	$V_{dII} <= D_R/Y_{DR}$	Fulfilled	

Proof of the nail to combined stress

Pretensioning force effectively applied on nail	$V=$	30.0	kN
Load factor for positive influence of pretension V	$\gamma_{VI}=$	1.0	[-]
Dimensioning value of the applied pretensioning force by positive influence of V	$V_{dI}=$	30.0	kN
Load factor for negative influence of pretension V	$\gamma_{VII}=$	1.0	[-]
Dimensioning value of the applied pretensioning force by negative influence of V	$V_{dII}=$	30.0	kN
Calculatorily required shear force at dimensioning level in function of V_{dII}	$S_d=$	14.6	kN
Maximum stress on the mesh for shearing-off	$P_d=$	0.0	kN
Bearing resistance of the nail to tensile stress	$T_{Rred}=$	237.0	kN
Bearing resistance of the nail to shear stress	$S_{Rred}=$	137.0	kN
Resistance correction value for tensile stress	$\gamma_{TR}=$	1.0	[-]
Resistance correction value for shear stress	$\gamma_{SR}=$	1.0	[-]
Proof of bearing safety $\{[V_{dII}/(T_{Rred}/\gamma_{TR})]^2 + [S_d/(S_{Rred}/\gamma_{SR})]^2\}^{0.5} <= 1.0$	0.17	Fulfilled	
Proof of bearing safety $\{[P_d/(T_{Rred}/\gamma_{TR})]^2 + [S_d/(S_{Rred}/\gamma_{SR})]^2\}^{0.5} <= 1.0$	0.11	Fulfilled	

Minimal tensile strength in the nail for superficial instabilities

Dimensioning value of the static equivalent tensile force in the nail for determination of the nail length	$T_d=$	30.0	kN

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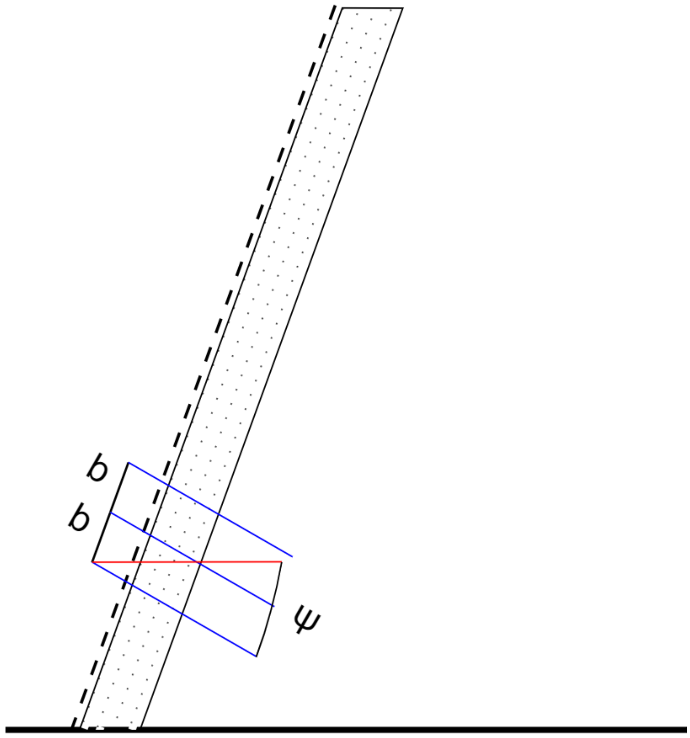
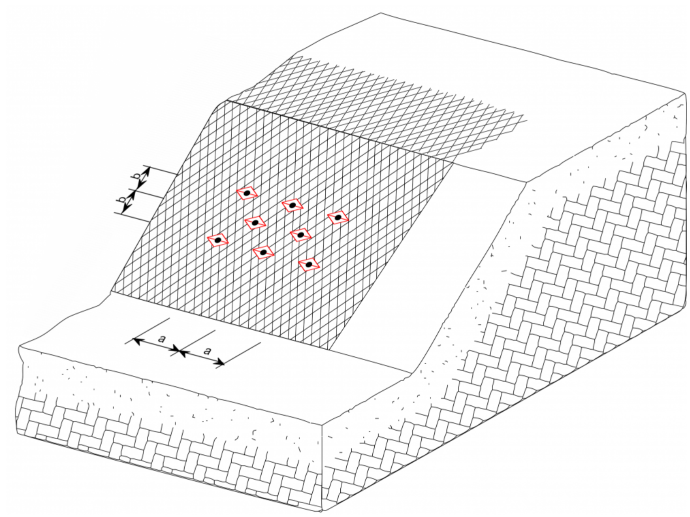
Cross-section:

Layer thickness	t=	0.75	m
Nail inclination	ψ=	30.0	degrees
Slope inclination	α=	70.0	degrees



View nail arrangement:



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RUVOLUM® ONLINE TOOL

RUVOLUM® - The Program to dimension the slope stabilization system TECCO®/SPIDER®

Project No.	21287
Project Name	Ponsharden (Factored)
Date, Author	2021-12-06_MT

Input quantities			
Slope inclination	α=	70.0	degrees
Layer thickness	t=	0.75	m
Friction angle ground (characteristic value)	Φ_k=	26.0	degrees
Volume weight ground (characteristic value)	γ_k=	19.0	kN/m³
Nail inclination	ψ=	30.0	degrees
Nail distance horizontal	a=	2.00	m
Nail distance in line of slope	b=	1.00	m

Load cases			
Streaming pressure		No	
Earthquake		No	
Coefficient of horizontal acceleration due to earthquake	ε_h=	0.000	[-]
Coefficient of vertical acceleration due to earthquake	ε_v=	0.000	[-]

Defaults and Safety Factors			
Cohesion ground (characteristic value)	c_k=	0.0	kN/m²
Radius of pressure cone, top	ζ=	0.15	m
Inclination of pressure cone to horizontal	δ=	45.0	degrees
Slope-parallel force	Z_d=	15.0	kN
Pretensioning force of the system	V=	30.0	kN
Partial safety correction value for friction angle	γ_Φ	1.25	[-]
Partial safety correction value for cohesion	γ_c	1.25	[-]
Partial safety correction value for volume weight	γ_γ	1.00	[-]
Model uncertainty correction value	γ_{mod}	1.10	[-]

Dimensioning quantities	Φ_d=	21.3	degrees
	c_d=	0.0	kN/m²
	γ_d=	19.0	kN/m³

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Elements of the system

Applied mesh type		TECCO G65/3	
Applied spike plate		system spike plate P33	
Bearing resistance of mesh to selective, slope parallel tensile stress	Z_R=	30	kN
Bearing resistance of mesh to pressure stress in nail direction	D_R=	180	kN
Bearing resistance of mesh against shearing-off in nail direction	P_R=	90	kN
Elongation in longitudinal tensile strength test	δ<	6	%

Applied nail type		DYWI DRILL R38-420	
Taking into account rusting away		Yes	
Bearing resistance of nail to tensile stress	T_{Rred}=	237	kN
Bearing resistance of nail to shear stress	S_{Rred}=	137	kN
Cross-section surface of the applied nail with / without rusting away	A_{red}=	446	mm^2

Proofs

Proof of the mesh against shearing-off at the upslope edge of the spike plate	Fulfilled
Proof of the mesh to selective transmission of the force Z onto the nail	Fulfilled
Proof of the nail against sliding-off of a superficial layer parallel to the slope	Fulfilled
Proof of the mesh against puncturing	Fulfilled
Proof of the nail to combined stress	Fulfilled

The given proofs concern the investigation of superficial instabilities. Additional investigations are required if there is a risk regarding global stability of the slope. If necessary the nail type and nail pattern have to be adapted.

Investigation of local instabilities between single nails

Proof of the mesh against shearing-off at the upslope edge of the spike plate

Maximum stress on the mesh for shearing-off in nail direction at the upslope edge of the spike plate (dimensioning level).	P_d=	0.0	kN
Thickness of decisive sliding mechanism	t_{rel}=		m
Bearing resistance of the mesh against shearing-off in nail direction at the upslope edge of the spike plate (characteristic value).	P_R=	90.0	kN
Resistance correction value for shearing-off of the mesh	γ_{PR}=	1.5	[-]
Dimensioning value of the bearing resistance of the mesh against shearing-off	P_R/γ_{PR}=	60.0	kN
Proof of bearing safety	$P_d<=P_R/\gamma_{PR}$	Fulfilled	

Proof of the mesh to selective transmission of the force Z onto the nail

Slope parallel force taken into account in the equilibrium considerations	Z_d=	15.0	kN
Bearing resistance of the mesh to selective, slope-parallel tensile stress	Z_R=	30.0	kN
Resistance correction value for selective, slope-parallel transmission of the force Z	γ_{ZR}=	1.5	[-]
Dimensioning value of the bearing resistance of the mesh to tensile stress	Z_R/γ_{ZR}=	20.0	kN
Proof of bearing safety	$Z_d<=Z_R/\gamma_{ZR}$	Fulfilled	

Investigation of slop-parallel instabilities

Proof of the nail against sliding-off of a superficial layer parallel to the slope

Pretensioning force effectively applied on nail	$V=$	30.0	kN
Load factor for positive influence of pretension V	$\gamma_{VI}=$	0.8	[-]
Dimensioning value of the applied pretensioning force by positive influence of V	$V_{dI}=$	24.0	kN
Calculatorily required shear force at dimensioning level in function of V_{dI}	$S_d=$	19.1	kN
Bearing resistance of the nail to shear stress	$S_{Rred}=$	137.0	kN
Resistance correction value for shearing-off of the nail	$\gamma_{SR}=$	1.5	[-]
Dimensioning value of the bearing resistance of the nail to shear stress	$S_{Rred}/\gamma_{SR}=$	91.3	kN
Proof of bearing safety	$S_d<=S_{Rred}/\gamma_{SR}$	Fulfilled	

Proof of the mesh against puncturing

Pretensioning force effectively applied on nail	$V=$	30.0	kN
Load factor for positive influence of pretension V	$Y_{VII}=$	1.5	[-]
Dimensioning value of the applied pretensioning force by positive influence of V	$V_{dII}=$	45.0	kN
Bearing resistance of the mesh to pressure stress in nail direction	$D_R=$	180.0	kN
Resistance correction value for puncturing	$Y_{DR}=$	1.5	[-]
Dimensioning value of the bearing resistance of the mesh to pressure stress	$D_R/Y_{DR}=$	120.0	kN
Proof of bearing safety	$V_{dII} <= D_R/Y_{DR}$	Fulfilled	

Proof of the nail to combined stress

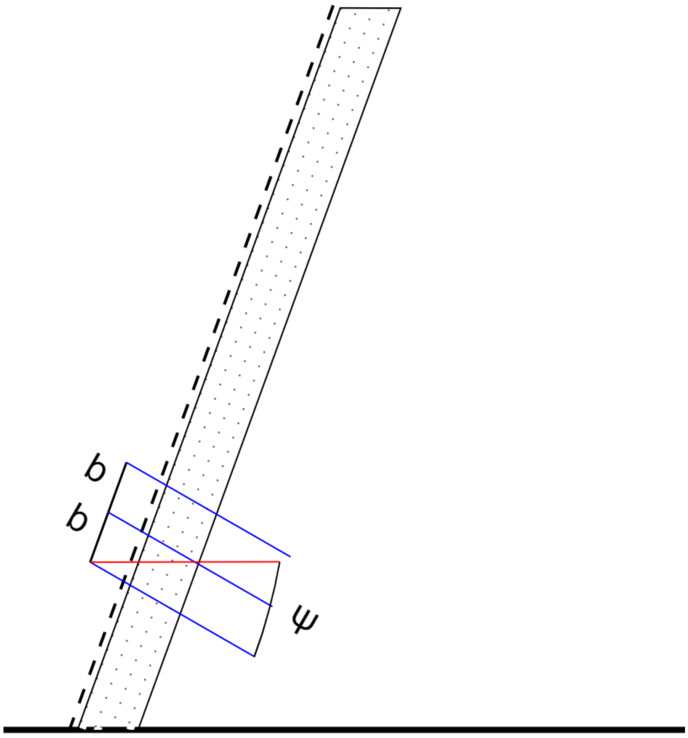
Pretensioning force effectively applied on nail	$V=$	30.0	kN
Load factor for positive influence of pretension V	$\gamma_{VI}=$	0.8	[-]
Dimensioning value of the applied pretensioning force by positive influence of V	$V_{dI}=$	24.0	kN
Load factor for negative influence of pretension V	$\gamma_{VII}=$	1.5	[-]
Dimensioning value of the applied pretensioning force by negative influence of V	$V_{dII}=$	45.0	kN
Calculatorily required shear force at dimensioning level in function of V_{dII}	$S_d=$	19.1	kN
Maximum stress on the mesh for shearing-off	$P_d=$	0.0	kN
Bearing resistance of the nail to tensile stress	$T_{Rred}=$	237.0	kN
Bearing resistance of the nail to shear stress	$S_{Rred}=$	137.0	kN
Resistance correction value for tensile stress	$\gamma_{TR}=$	1.5	[-]
Resistance correction value for shear stress	$\gamma_{SR}=$	1.5	[-]
Proof of bearing safety $\{[V_{dII}/(T_{Rred}/\gamma_{TR})]^2 + [S_d/(S_{Rred}/\gamma_{SR})]^2\}^{0.5} <= 1.0$	0.35	Fulfilled	
Proof of bearing safety $\{[P_d/(T_{Rred}/\gamma_{TR})]^2 + [S_d/(S_{Rred}/\gamma_{SR})]^2\}^{0.5} <= 1.0$	0.21	Fulfilled	

Minimal tensile strength in the nail for superficial instabilities

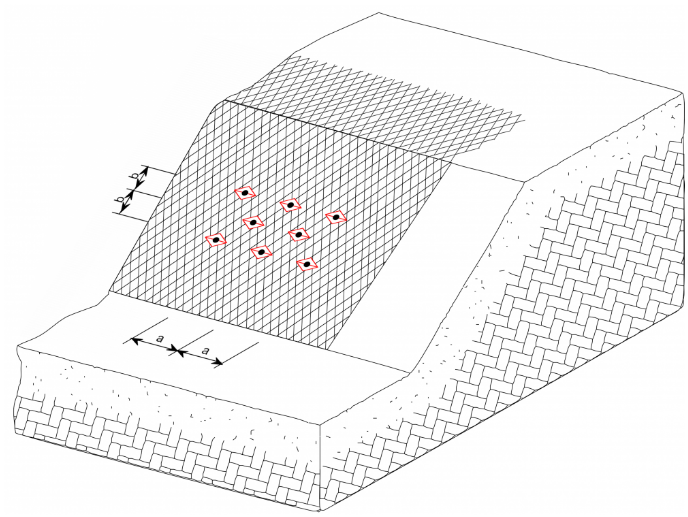
Dimensioning value of the static equivalent tensile force in the nail for determination of the nail length	$T_d=$	49.0	kN

Cross-section:

Layer thickness	t=	0.75	m
Nail inclination	ψ=	30.0	degrees
Slope inclination	α=	70.0	degrees



View nail arrangement:



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RUVOLUM® ONLINE TOOL

RUVOLUM® - The Program to dimension the slope stabilization system TECCO®/SPIDER®

Project No.	21287 - Stairway
Project Name	Ponsharden
Date, Author	2021-12-07_MT

Input quantities			
Slope inclination	α=	70.0	degrees
Layer thickness	t=	0.50	m
Friction angle ground (characteristic value)	Φ_k=	26.0	degrees
Volume weight ground (characteristic value)	γ_k=	19.0	kN/m³
Nail inclination	ψ=	30.0	degrees
Nail distance horizontal	a=	1.00	m
Nail distance in line of slope	b=	1.00	m

Load cases			
Streaming pressure		No	
Earthquake		No	
Coefficient of horizontal acceleration due to earthquake	ε_h=	0.000	[-]
Coefficient of vertical acceleration due to earthquake	ε_v=	0.000	[-]

Defaults and Safety Factors			
Cohesion ground (characteristic value)	c_k=	0.0	kN/m²
Radius of pressure cone, top	ζ=	0.15	m
Inclination of pressure cone to horizontal	δ=	45.0	degrees
Slope-parallel force	Z_d=	5.0	kN
Pretensioning force of the system	V=	20.0	kN
Partial safety correction value for friction angle	γ_Φ	1.25	[-]
Partial safety correction value for cohesion	γ_c	1.25	[-]
Partial safety correction value for volume weight	γ_γ	1.00	[-]
Model uncertainty correction value	γ_{mod}	1.10	[-]

Dimensioning quantities	Φ_d=	21.3	degrees
	c_d=	0.0	kN/m²
	γ_d=	19.0	kN/m³

Elements of the system

Applied mesh type		TECCO G45/2	
Applied spike plate		system spike plate P33	
Bearing resistance of mesh to selective, slope parallel tensile stress	Z_R=	10	kN
Bearing resistance of mesh to pressure stress in nail direction	D_R=	110	kN
Bearing resistance of mesh against shearing-off in nail direction	P_R=	55	kN
Elongation in longitudinal tensile strength test	δ<	6	%

Applied nail type		Dywidag R25-200	
Taking into account rusting away		Yes	
Bearing resistance of nail to tensile stress	T_{Rred}=	66	kN
Bearing resistance of nail to shear stress	S_{Rred}=	38	kN
Cross-section surface of the applied nail with / without rusting away	A_{red}=	127	mm^2

Proofs

Proof of the mesh against shearing-off at the upslope edge of the spike plate	Fulfilled
Proof of the mesh to selective transmission of the force Z onto the nail	Fulfilled
Proof of the nail against sliding-off of a superficial layer parallel to the slope	Fulfilled
Proof of the mesh against puncturing	Fulfilled
Proof of the nail to combined stress	Fulfilled

The given proofs concern the investigation of superficial instabilities. Additional investigations are required if there is a risk regarding global stability of the slope. If necessary the nail type and nail pattern have to be adapted.

Investigation of local instabilities between single nails

Proof of the mesh against shearing-off at the upslope edge of the spike plate

Maximum stress on the mesh for shearing-off in nail direction at the upslope edge of the spike plate (dimensioning level).	P_d=	0.0	kN
Thickness of decisive sliding mechanism	t_{rel}=		m
Bearing resistance of the mesh against shearing-off in nail direction at the upslope edge of the spike plate (characteristic value).	P_R=	55.0	kN
Resistance correction value for shearing-off of the mesh	γ_{PR}=	1.5	[-]
Dimensioning value of the bearing resistance of the mesh against shearing-off	P_R/γ_{PR}=	36.7	kN
Proof of bearing safety	$P_d<=P_R/\gamma_{PR}$	Fulfilled	

Proof of the mesh to selective transmission of the force Z onto the nail

Slope parallel force taken into account in the equilibrium considerations	Z_d=	5.0	kN
Bearing resistance of the mesh to selective, slope-parallel tensile stress	Z_R=	10.0	kN
Resistance correction value for selective, slope-parallel transmission of the force Z	γ_{ZR}=	1.5	[-]
Dimensioning value of the bearing resistance of the mesh to tensile stress	Z_R/γ_{ZR}=	6.7	kN
Proof of bearing safety	$Z_d<=Z_R/\gamma_{ZR}$	Fulfilled	

Investigation of slop-parallel instabilities

Proof of the nail against sliding-off of a superficial layer parallel to the slope

Pretensioning force effectively applied on nail	$V=$	20.0	kN
Load factor for positive influence of pretension V	$\gamma_{VI}=$	0.8	[-]
Dimensioning value of the applied pretensioning force by positive influence of V	$V_{dI}=$	16.0	kN
Calculatorily required shear force at dimensioning level in function of V_{dI}	$S_d=$	5.0	kN
Bearing resistance of the nail to shear stress	$S_{Rred}=$	38.0	kN
Resistance correction value for shearing-off of the nail	$\gamma_{SR}=$	1.5	[-]
Dimensioning value of the bearing resistance of the nail to shear stress	$S_{Rred}/\gamma_{SR}=$	25.3	kN
Proof of bearing safety	$S_d<=S_{Rred}/\gamma_{SR}$	Fulfilled	

Proof of the mesh against puncturing

Pretensioning force effectively applied on nail	$V=$	20.0	kN
Load factor for positive influence of pretension V	$Y_{VII}=$	1.5	[-]
Dimensioning value of the applied pretensioning force by positive influence of V	$V_{dII}=$	30.0	kN
Bearing resistance of the mesh to pressure stress in nail direction	$D_R=$	110.0	kN
Resistance correction value for puncturing	$Y_{DR}=$	1.5	[-]
Dimensioning value of the bearing resistance of the mesh to pressure stress	$D_R/Y_{DR}=$	73.3	kN
Proof of bearing safety	$V_{dII} <= D_R/Y_{DR}$	Fulfilled	

Proof of the nail to combined stress

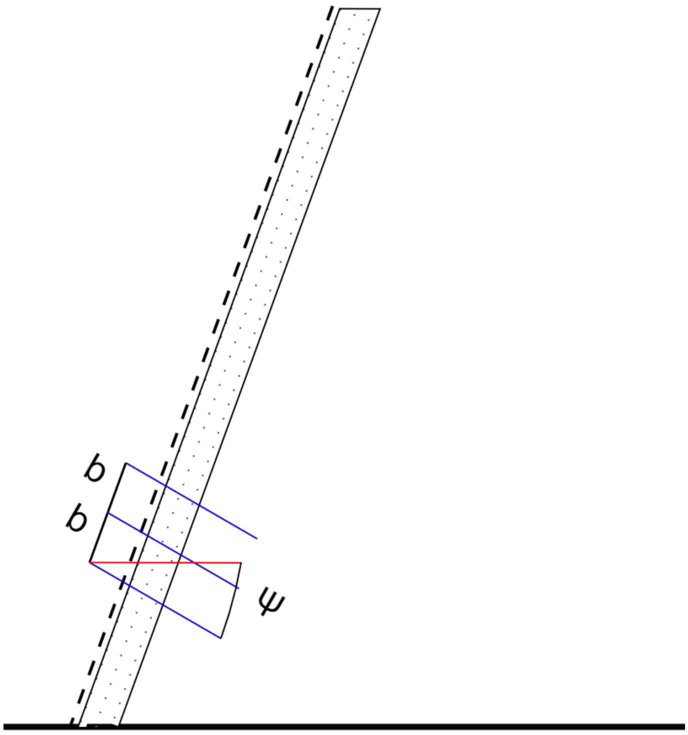
Pretensioning force effectively applied on nail	$V=$	20.0	kN
Load factor for positive influence of pretension V	$\gamma_{VI}=$	0.8	[-]
Dimensioning value of the applied pretensioning force by positive influence of V	$V_{dI}=$	16.0	kN
Load factor for negative influence of pretension V	$\gamma_{VII}=$	1.5	[-]
Dimensioning value of the applied pretensioning force by negative influence of V	$V_{dII}=$	30.0	kN
Calculatorily required shear force at dimensioning level in function of V_{dII}	$S_d=$	5.0	kN
Maximum stress on the mesh for shearing-off	$P_d=$	0.0	kN
Bearing resistance of the nail to tensile stress	$T_{Rred}=$	66.0	kN
Bearing resistance of the nail to shear stress	$S_{Rred}=$	38.0	kN
Resistance correction value for tensile stress	$\gamma_{TR}=$	1.5	[-]
Resistance correction value for shear stress	$\gamma_{SR}=$	1.5	[-]
Proof of bearing safety $\{[V_{dII}/(T_{Rred}/\gamma_{TR})]^2 + [S_d/(S_{Rred}/\gamma_{SR})]^2\}^{0.5} <= 1.0$	0.71	Fulfilled	
Proof of bearing safety $\{[P_d/(T_{Rred}/\gamma_{TR})]^2 + [S_d/(S_{Rred}/\gamma_{SR})]^2\}^{0.5} <= 1.0$	0.20	Fulfilled	

Minimal tensile strength in the nail for superficial instabilities

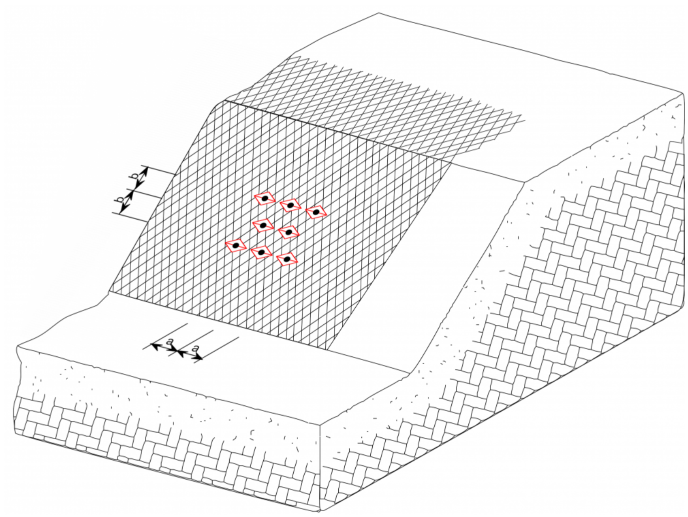
Dimensioning value of the static equivalent tensile force in the nail for determination of the nail length	$T_d=$	30.0	kN

Cross-section:

Layer thickness	t=	0.50 m
Nail inclination	ψ=	30.0 degrees
Slope inclination	α=	70.0 degrees



View nail arrangement:



Soil Nailing Calculation Sheet - Unfactored					
Project Name	Ponsharden Cemeteries	Author	MJT	Date	06/12/2021
Project No.	21287	Checked	MEC	Date	06/12/2021

BS8006-2 Soil Nails 2011 A1 2017 Partial Factors

			Set 1		Set 2	
Actions	Self-weight of soil, W	Disturbing	ɣg	1.35	ɣg	1.00
		Stabilising	ɣg	1.00	ɣg	1.00
	Permenent Surcharge, Qp	Disturbing	ɣqp	1.35	ɣqp	1.00
		Stabilising	ɣqp	1.00	ɣqp	1.00
	Variable Surcharge, Qv	Disturbing	ɣqv	1.50	ɣqv	1.30
		Stabilising	ɣqv	0.00	ɣqv	0.00
	Groundwater Pressure, u	Disturbing	ɣg	1.00	ɣg	1.00
		Stabilising	ɣg	1.00	ɣg	1.00
Material Properties	tanΦ'k		ɣ	1.00	ɣ	1.30
	c'k		ɣc'	1.00	ɣc'	1.30
	cuk		ɣcu	1.00	ɣcu	1.40
	ɣk		ɣɣ	1.00	ɣɣ	1.00
Soil Nail Resistances	Bond Stress, τbk	Empirical	ɣτb	1.00	ɣτb	1.50
		Effective Stress	ɣτb	1.00	ɣτb	1.50
		Total Stress	ɣτb	1.00	ɣτb	1.50
		Pull-out tests	ɣτb	1.10 - 1.70	ɣτb	1.50 - 2.25
	Tendon Strength, τk		ɣg	1.00	ɣg	1.15
Model Factor	Applied to the effect of unfavourable actions (e.g. to Mdriving in the case of Bishop's slip circles)		ɣsd	-	ɣsd	-

Soil Parameters								
Strata	**Unit Weight**		**Cohesion**		**Friction Angle**		**Shear Strength**	
	kN/m3		kN/m2		Degrees		kN/m2	
Glacial Till Deposits	19		0		34		100	
	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2
	19	19	0	0	34	29.73	100	71.4

Bar Properties			
Item	**Notation**	**Units**	**Value**
Bar Diameter	Dbar	mm	38.00
		m	0.04
Borehole Diameter	Dhole	mm	115.00
		m	0.12
Reduced Cross Sectional Area		mm2	560.00
Less Internal Area (18.5mm)		mm2	269.00
Nominal cross-sectional area of the tendon at the end of its design life	As nom	mm2	291.00
		m	0.29
Steel Grade		N/mm2	610.00
Characteristic yield strength	Fyk	kN	510.00
Partial Material Factor	ɣs		1.00
Characteristic yield strength of tendon	Rtk	kN	148.41
Design Tensile Resistance	Rtd	kN	**148.41**

Slope Properties			
Item	**Notation**	**Units**	**Value**
Slope Height	H	m	5.1
Slope Angle	β	Degrees	70

Soil Nailing Calculation Sheet - Unfactored					
Project Name	Ponsharden Cemeteries	Author	MJT	Date	06/12/2021
Project No.	21287	Checked	MEC	Date	06/12/2021

Pull Out Resistance

Effective Stress Method			
Item	**Notation**	**Units**	**Value**
Horizontal Pressure Co-efficient	Ka	-	0.28
	Kl	-	0.64
Factor	λpf		1.00

Row	Entry	Angle	Length	Free	Embed	Level	σ'v	σ'r	b	Tw		Nail force (kN/m)
1	**0**	30	3	0.75	1.875	0.9375	17.813	14.618	9.8602	8.0152	OK	2.422
2	**1**	30	4.5	0.75	2.625	2.3125	43.938	36.059	24.322	32.951	OK	7.156
3	**2**	30	3.5	0.75	2.125	3.0625	58.188	47.753	32.21	32.002	OK	8.929
4	**3**	30	3	0.75	1.875	3.9375	74.813	61.397	41.413	33.664	OK	10.971
5	**4**	30	3	0.75	1.875	4.9375	93.813	76.99	51.93	42.214	OK	14.071
					0	0	0	0	0	0	OK	#DIV/0!

Total Stress Method			
Item	**Notation**	**Units**	**Value**
Bond co-efficient	α		0.5
Ultimate Pullout Resistance of nail	Pult	kN/m	**343.2189974**

Nail Head Plate										
Row	**Entry**	**Angle**	**Length**	**Free**	**Embed**	**Level**	**σ'v**	**σ'r**	**b**	**Tfd**
1	**0**	30	3	0.75	1.875	0.9375	17.813	14.618	9.8602	40.14
2	**1**	30	4.5	0.75	2.625	2.3125	43.938	36.059	24.322	25.678
3	**2**	30	3.5	0.75	2.125	3.0625	58.188	47.753	32.21	17.79
4	**3**	30	3	0.75	1.875	3.9375	74.813	61.397	41.413	8.5872
5	**4**	30	3	0.75	1.875	4.9375	93.813	76.99	51.93	-1.93
					0	0	0	0	0	50

Soil Nailing Calculation Sheet - Set 1					Jubb
Project Name	Ponsharden Cemeteries	Author	MJT	Date	06/12/2021
Project No.	21287	Checked	MEC	Date	06/12/2021

BS8006-2 Soil Nails 2011 A1 2017 Partial Factors

			Set 1		Set 2	
Actions	Self-weight of soil, W	Disturbing	ɣg	1.35	ɣg	1.00
		Stabilising	ɣg	1.00	ɣg	1.00
	Permenent Surcharge, Qp	Disturbing	ɣqp	1.35	ɣqp	1.00
		Stabilising	ɣqp	1.00	ɣqp	1.00
	Variable Surcharge, Qv	Disturbing	ɣqv	1.50	ɣqv	1.30
		Stabilising	ɣqv	0.00	ɣqv	0.00
	Groundwater Pressure, u	Disturbing	ɣg	1.00	ɣg	1.00
		Stabilising	ɣg	1.00	ɣg	1.00
Material Properties	tanΦ'k		ɣ	1.00	ɣ	1.30
	c'k		ɣc'	1.00	ɣc'	1.30
	cuk		ɣcu	1.00	ɣcu	1.40
	ɣk		ɣɣ	1.00	ɣɣ	1.00
Soil Nail Resistances	Bond Stress, τbk	Empirical	ɣτb	1.10	ɣτb	1.50
		Effective Stress	ɣτb	1.10	ɣτb	1.50
		Total Stress	ɣτb	1.10	ɣτb	1.50
		Pull-out tests	ɣτb	1.10 - 1.70	ɣτb	1.50 - 2.25
	Tendon Strength, τk		ɣg	1.00	ɣg	1.15
Model Factor	Applied to the effect of unfavourable actions (e.g. to Mdriving in the case of Bishop's slip circles)		ɣsd	-	ɣsd	-

Soil Parameters								
Strata	**Unit Weight**		**Cohesion**		**Friction Angle**		**Shear Strength**	
	kN/m3		kN/m2		Degrees		kN/m2	
Mercia Mudstone	19		0		34		100	
	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2
	19	19	0	0	34	29.73	100	71.4

Bar Properties			
Item	**Notation**	**Units**	**Value**
Bar Diameter	Dbar	mm	38.00
		m	0.04
Borehole Diameter	Dhole	mm	115.00
		m	0.12
Reduced Cross Sectional Area		mm2	560.00
Less Internal Area (18.5mm)		mm2	269.00
Nominal cross-sectional area of the tendon at the end of its design life	As nom	mm2	291.00
		m	0.29
Steel Grade		N/mm2	610.00
Characteristic yield strength	Fyk	kN	510.00
Partial Material Factor	ɣs		1.00
Characteristic yield strength of tendon	Rtk	kN	148.41
Design Tensile Resistance	Rtd	kN	**148.41**

Slope Properties			
Item	**Notation**	**Units**	**Value**
Slope Height	H	m	5.1
Slope Angle	β	Degrees	70

Soil Nailing Calculation Sheet - Set 1					Jubb
Project Name	Ponsharden Cemeteries	Author	MJT	Date	06/12/2021
Project No.	21287	Checked	MEC	Date	06/12/2021

Pull Out Resistance

Effective Stress Method			
Item	**Notation**	**Units**	**Value**
Horizontal Pressure Co-efficient	Ka	-	0.28
	Kl	-	0.64
Factor	λpf		1.00

Row	Entry	Angle	Length	Free	Embed	Level	σ'v	σ'r	b	Tw		Nail force (kN/m)
1	**0**	30	3	0.75	1.875	0.9375	17.813	14.618	8.9638	7.2866	OK	2.179
2	**1**	30	4.5	0.75	2.625	2.3125	43.938	36.059	22.111	29.956	OK	6.490
3	**2**	30	3.5	0.75	2.125	3.0625	58.188	47.753	29.282	29.092	OK	8.098
4	**3**	30	3	0.75	1.875	3.9375	74.813	61.397	37.648	30.604	OK	9.951
5	**4**	30	3	0.75	1.875	4.9375	93.813	76.99	47.209	38.376	OK	12.792
					0	0	0	0	0	0	OK	#DIV/0!

Total Stress Method			
Item	**Notation**	**Units**	**Value**
Bond co-efficient	α		0.5
Ultimate Pullout Resistance of nail	Pult	kN/m	**343.2189974**

Nail Head Plate										
Row	**Entry**	**Angle**	**Length**	**Free**	**Embed**	**Level**	**σ'v**	**σ'r**	**b**	**Tfd**
1	**0**	30	3	0.75	1.875	0.9375	17.813	14.618	7.5888	42.411
2	**1**	30	4.5	0.75	2.625	2.3125	43.938	36.059	18.719	31.281
3	**2**	30	3.5	0.75	2.125	3.0625	58.188	47.753	24.79	25.21
4	**3**	30	3	0.75	1.875	3.9375	74.813	61.397	31.873	18.127
5	**4**	30	3	0.75	1.875	4.9375	93.813	76.99	39.968	10.032
					0	0	0	0	0	50

Soil Nailing Calculation Sheet - Set 2					Jubb
Project Name	Ponsharden Cemeteries	Author	MJT	Date	06/12/2021
Project No.	21287	Checked	MEC	Date	06/12/2021

BS8006-2 Soil Nails 2011 A1 2017 Partial Factors

			Set 1		Set 2	
Actions	Self-weight of soil, W	Disturbing	γg	1.35	γg	1.00
		Stabilising	γg	1.00	γg	1.00
	Permenent Surcharge, Qp	Disturbing	γqp	1.35	γqp	1.00
		Stabilising	γqp	1.00	γqp	1.00
	Variable Surcharge, Qv	Disturbing	γqv	1.50	γqv	1.30
		Stabilising	γqv	0.00	γqv	0.00
	Groundwater Pressure, u	Disturbing	γg	1.00	γg	1.00
		Stabilising	γg	1.00	γg	1.00
Material Properties	tanΦ'k		γ	1.00	γ	1.30
	c'k		γc'	1.00	γc'	1.30
	cuk		γcu	1.00	γcu	1.40
	γk		γγ	1.00	γγ	1.00
Soil Nail Resistances	Bond Stress, τbk	Empirical	γτb	1.10	γτb	1.50
		Effective Stress	γτb	1.10	γτb	1.50
		Total Stress	γτb	1.10	γτb	1.50
		Pull-out tests	γτb	1.10 - 1.70	γτb	1.50 - 2.25
	Tendon Strength, τk		γg	1.00	γg	1.15
Model Factor	Applied to the effect of unfavourable actions (e.g. to Mdriving in the case of Bishop's slip circles)		γsd	-	γsd	-

Soil Parameters								
Strata	**Unit Weight**		**Cohesion**		**Friction Angle**		**Shear Strength**	
	kN/m3		kN/m2		Degrees		kN/m2	
Glacial Deposits	19		0		34		100	
	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2
	19	19	0	0	34	29.73	100	71.4

Bar Properties			
Item	**Notation**	**Units**	**Value**
Bar Diameter	Dbar	mm	38.00
		m	0.04
Borehole Diameter	Dhole	mm	115.00
		m	0.115
Nominal cross-sectional area of the tendon at the end of its design life	As nom	mm2	226.00
		m2	0.23
Steel Grade		N/mm2	610.00
Characteristic yield strength	Fyk	kN	510.00
Partial Material Factor	γs		1.15
Characteristic yield strength of tendon	Rtk	kN	115.26
Design Tensile Resistance	Rtd	kN	**100.23**

Slope Properties			
Item	**Notation**	**Units**	**Value**
Slope Height	H	m	5.1
Slope Angle	β	Degrees	70

Soil Nailing Calculation Sheet - Set 2

Project Name	Ponsharden Cemeteries	Author	MJT	Date	06/12/2021
Project No.	21287	Checked	MEC	Date	06/12/2021

Pull Out Resistance

Effective Stress Method

Item	Notation	Units	Value
Horizontal Pressure Co-efficient	Ka	-	0.27
	Kl	-	0.64
Factor	λpf		1.00

Row	Entry	Angle	Length	Free	Embed	Level	σ'v	σ'r	b	Tw		Nail force (kN/m)
1	**0**	30	3	0.75	1.875	0.9375	17.813	14.575	5.5487	4.5105	OK	1.253
2	**1**	30	4.5	0.75	2.625	2.3125	43.938	35.952	13.687	18.543	OK	3.954
3	**2**	30	3.5	0.75	2.125	3.0625	58.188	47.613	18.126	18.008	OK	4.931
4	**3**	30	3	0.75	1.875	3.9375	74.813	61.216	23.305	18.944	OK	6.065
5	**4**	30	3	0.75	1.875	4.9375	93.813	76.763	29.223	23.755	OK	7.918
					0	0	0	0	0	0	OK	#DIV/0!

Total Stress Method

Item	Notation	Units	Value
Bond co-efficient	α		0.5
Ultimate Pullout Resistance of nail	Pult	kN/m	**245.1564267**

Nail Head Plate

Row	Entry	Angle	Length	Free	Embed	Level	σ'v	σ'r	b	Tfd
1	**0**	30	3	0.75	1.875	0.9375	17.813	14.575	5.5487	44.451
2	**1**	30	4.5	0.75	2.625	2.3125	43.938	35.952	13.687	36.313
3	**2**	30	3.5	0.75	2.125	3.0625	58.188	47.613	18.126	31.874
4	**3**	30	3	0.75	1.875	3.9375	74.813	61.216	23.305	26.695
5	**4**	30	3	0.75	1.875	4.9375	93.813	76.763	29.223	20.777
					0	0	0	0	0	50

Soil Nailing Calculation Sheet - Unfactored					
Project Name	Ponsharden Cemeteries	Author	MJT	Date	06/12/2021
Project No.	21287	Checked	MEC	Date	06/12/2021

BS8006-2 Soil Nails 2011 A1 2017 Partial Factors

			Set 1		Set 2	
Actions	Self-weight of soil, W	Disturbing	ɣg	1.35	ɣg	1.00
		Stabilising	ɣg	1.00	ɣg	1.00
	Permenent Surcharge, Qp	Disturbing	ɣqp	1.35	ɣqp	1.00
		Stabilising	ɣqp	1.00	ɣqp	1.00
	Variable Surcharge, Qv	Disturbing	ɣqv	1.50	ɣqv	1.30
		Stabilising	ɣqv	0.00	ɣqv	0.00
	Groundwater Pressure, u	Disturbing	ɣg	1.00	ɣg	1.00
		Stabilising	ɣg	1.00	ɣg	1.00
Material Properties	tanΦ'k		ɣ	1.00	ɣ	1.30
	c'k		ɣc'	1.00	ɣc'	1.30
	cuk		ɣcu	1.00	ɣcu	1.40
	ɣk		ɣɣ	1.00	ɣɣ	1.00
Soil Nail Resistances	Bond Stress, τbk	Empirical	ɣτb	1.00	ɣτb	1.50
		Effective Stress	ɣτb	1.00	ɣτb	1.50
		Total Stress	ɣτb	1.00	ɣτb	1.50
		Pull-out tests	ɣτb	1.10 - 1.70	ɣτb	1.50 - 2.25
	Tendon Strength, τk		ɣg	1.00	ɣg	1.15
Model Factor	Applied to the effect of unfavourable actions (e.g. to Mdriving in the case of Bishop's slip circles)		ɣsd	-	ɣsd	-

Soil Parameters

Strata	Unit Weight		Cohesion		Friction Angle		Shear Strength	
	kN/m3		kN/m2		Degrees		kN/m2	
Glacial Till Deposits	19		0		34		100	
	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2
	19	19	0	0	34	29.73	100	71.4

Bar Properties

Item	Notation	Units	Value
Bar Diameter	Dbar	mm	25.00
		m	0.03
Borehole Diameter	Dhole	mm	50.00
		m	0.05
Reduced Cross Sectional Area		mm2	560.00
Less Internal Area (18.5mm)		mm2	269.00
Nominal cross-sectional area of the tendon at the end of its design life	As nom	mm2	291.00
		m	0.29
Steel Grade		N/mm2	690.00
Characteristic yield strength	Fyk	kN	520.00
Partial Material Factor	ɣs		1.00
Characteristic yield strength of tendon	Rtk	kN	151.32
Design Tensile Resistance	Rtd	kN	**151.32**

Slope Properties

Item	Notation	Units	Value
Slope Height	H	m	5.1
Slope Angle	β	Degrees	70

Soil Nailing Calculation Sheet - Unfactored

Project Name	Ponsharden Cemeteries	Author	MJT	Date	06/12/2021
Project No.	21287	Checked	MEC	Date	06/12/2021

Pull Out Resistance

Effective Stress Method			
Item	**Notation**	**Units**	**Value**
Horizontal Pressure Co-efficient	Ka	-	0.28
	Kl	-	0.64
Factor	λpf		1.00

Row	**Entry**	**Angle**	**Length**	**Free**	**Embed**	**Level**	**σ'v**	**σ'r**	**b**	**Tw**		**Nail force (kN/m)**
1	**0**	40	3	0.75	1.875	1.2052	22.899	18.793	12.676	4.4801	OK	1.243
2	**1**	30	3.5	0.75	2.125	2.0625	39.188	32.16	21.692	9.3705	OK	2.463
3	**2**	30	3	0.75	1.875	2.9375	55.813	45.804	30.895	10.919	OK	3.390
4	**3**	30	3	0.75	1.875	3.9375	74.813	61.397	41.413	14.636	OK	4.629
					0	0	0	0	0	0	OK	#DIV/0!
					0	0	0	0	0	0	OK	#DIV/0!

Total Stress Method			
Item	**Notation**	**Units**	**Value**
Bond co-efficient	α		0.5
Ultimate Pullout Resistance of nail	Pult	kN/m	**149.225651**

Nail Head Plate										
Row	**Entry**	**Angle**	**Length**	**Free**	**Embed**	**Level**	**σ'v**	**σ'r**	**b**	**Tfd**
1	**0**	40	3	0.75	1.875	1.2052	22.899	18.793	12.676	37.324
2	**1**	30	3.5	0.75	2.125	2.0625	39.188	32.16	21.692	28.308
3	**2**	30	3	0.75	1.875	2.9375	55.813	45.804	30.895	19.105
4	**3**	30	3	0.75	1.875	3.9375	74.813	61.397	41.413	8.5872
					0	0	0	0	0	50
					0	0	0	0	0	50

Soil Nailing Calculation Sheet - Set 1					Jubb
Project Name	Ponsharden Cemeteries	Author	MJT	Date	06/12/2021
Project No.	21287	Checked	MEC	Date	06/12/2021

BS8006-2 Soil Nails 2011 A1 2017 Partial Factors

			Set 1		Set 2	
Actions	Self-weight of soil, W	Disturbing	ɣg	1.35	ɣg	1.00
		Stabilising	ɣg	1.00	ɣg	1.00
	Permenent Surcharge, Qp	Disturbing	ɣqp	1.35	ɣqp	1.00
		Stabilising	ɣqp	1.00	ɣqp	1.00
	Variable Surcharge, Qv	Disturbing	ɣqv	1.50	ɣqv	1.30
		Stabilising	ɣqv	0.00	ɣqv	0.00
	Groundwater Pressure, u	Disturbing	ɣg	1.00	ɣg	1.00
		Stabilising	ɣg	1.00	ɣg	1.00
Material Properties	tanΦ'k		ɣ	1.00	ɣ	1.30
	c'k		ɣc'	1.00	ɣc'	1.30
	cuk		ɣcu	1.00	ɣcu	1.40
	ɣk		ɣɣ	1.00	ɣɣ	1.00
Soil Nail Resistances	Bond Stress, тbk	Empirical	ɣтb	1.10	ɣтb	1.50
		Effective Stress	ɣтb	1.10	ɣтb	1.50
		Total Stress	ɣтb	1.10	ɣтb	1.50
		Pull-out tests	ɣтb	1.10 - 1.70	ɣтb	1.50 - 2.25
	Tendon Strength, тk		ɣg	1.00	ɣg	1.15
Model Factor	Applied to the effect of unfavourable actions (e.g. to Mdriving in the case of Bishop's slip circles)		ɣsd	-	ɣsd	-

Soil Parameters

Strata	**Unit Weight**		**Cohesion**		**Friction Angle**		**Shear Strength**	
	kN/m3		kN/m2		Degrees		kN/m2	
Mercia Mudstone	19		0		34		100	
	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2
	19	19	0	0	34	29.73	100	71.4

Bar Properties

Item	**Notation**	**Units**	**Value**
Bar Diameter	Dbar	mm	25.00
		m	0.03
Borehole Diameter	Dhole	mm	50.00
		m	0.05
Reduced Cross Sectional Area		mm2	560.00
Less Internal Area (18.5mm)		mm2	269.00
Nominal cross-sectional area of the tendon at the end of its design life	As nom	mm2	291.00
		m	0.29
Steel Grade		N/mm2	690.00
Characteristic yield strength	Fyk	kN	520.00
Partial Material Factor	ɣs		1.00
Characteristic yield strength of tendon	Rtk	kN	151.32
Design Tensile Resistance	Rtd	kN	**151.32**

Slope Properties

Item	**Notation**	**Units**	**Value**
Slope Height	H	m	5.1
Slope Angle	β	Degrees	70

Soil Nailing Calculation Sheet - Set 1					Jubb
Project Name	Ponsharden Cemeteries	Author	MJT	Date	06/12/2021
Project No.	21287	Checked	MEC	Date	06/12/2021

Pull Out Resistance

Effective Stress Method			
Item	**Notation**	**Units**	**Value**
Horizontal Pressure Co-efficient	Ka	-	0.28
	Kl	-	0.64
Factor	λpf		1.00

Row	Entry	Angle	Length	Free	Embed	Level	σ'v	σ'r	b	Tw		Nail force (kN/m)
1	**0**	40	3	0.75	1.875	1.2052	22.899	18.793	11.524	4.0728	OK	1.108
2	**1**	30	3.5	0.75	2.125	2.0625	39.188	32.16	19.72	8.5186	OK	2.220
3	**2**	30	3	0.75	1.875	2.9375	55.813	45.804	28.087	9.9266	OK	3.059
4	**3**	30	3	0.75	1.875	3.9375	74.813	61.397	37.648	13.306	OK	4.185
					0	0	0	0	0	0	OK	#DIV/0!
					0	0	0	0	0	0	OK	#DIV/0!

Total Stress Method			
Item	**Notation**	**Units**	**Value**
Bond co-efficient	α		0.5
Ultimate Pullout Resistance of nail	Pult	kN/m	**149.225651**

Nail Head Plate										
Row	**Entry**	**Angle**	**Length**	**Free**	**Embed**	**Level**	**σ'v**	**σ'r**	**b**	**Tfd**
1	**0**	40	3	0.75	1.875	1.2052	22.899	18.793	9.7559	40.244
2	**1**	30	3.5	0.75	2.125	2.0625	39.188	32.16	16.695	33.305
3	**2**	30	3	0.75	1.875	2.9375	55.813	45.804	23.778	26.222
4	**3**	30	3	0.75	1.875	3.9375	74.813	61.397	31.873	18.127
					0	0	0	0	0	50
					0	0	0	0	0	50

Soil Nailing Calculation Sheet - Set 2					Jubb
Project Name	Ponsharden Cemeteries	Author	MJT	Date	06/12/2021
Project No.	21287	Checked	MEC	Date	06/12/2021

BS8006-2 Soil Nails 2011 A1 2017 Partial Factors

			Set 1		Set 2	
Actions	Self-weight of soil, W	Disturbing	ɣg	1.35	ɣg	1.00
		Stabilising	ɣg	1.00	ɣg	1.00
	Permenent Surcharge, Qp	Disturbing	ɣqp	1.35	ɣqp	1.00
		Stabilising	ɣqp	1.00	ɣqp	1.00
	Variable Surcharge, Qv	Disturbing	ɣqv	1.50	ɣqv	1.30
		Stabilising	ɣqv	0.00	ɣqv	0.00
	Groundwater Pressure, u	Disturbing	ɣg	1.00	ɣg	1.00
		Stabilising	ɣg	1.00	ɣg	1.00
Material Properties	tanΦ'k		ɣ	1.00	ɣ	1.30
	c'k		ɣc'	1.00	ɣc'	1.30
	cuk		ɣcu	1.00	ɣcu	1.40
	ɣk		ɣɣ	1.00	ɣɣ	1.00
Soil Nail Resistances	Bond Stress, τbk	Empirical	ɣτb	1.10	ɣτb	1.50
		Effective Stress	ɣτb	1.10	ɣτb	1.50
		Total Stress	ɣτb	1.10	ɣτb	1.50
		Pull-out tests	ɣτb	1.10 - 1.70	ɣτb	1.50 - 2.25
	Tendon Strength, τk		ɣg	1.00	ɣg	1.15
Model Factor	Applied to the effect of unfavourable actions (e.g. to Mdriving in the case of Bishop's slip circles)		ɣsd	-	ɣsd	-

Soil Parameters

Strata	**Unit Weight**		**Cohesion**		**Friction Angle**		**Shear Strength**	
	kN/m3		kN/m2		Degrees		kN/m2	
Glacial Deposits	19		0		34		100	
	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2
	19	19	0	0	34	29.73	100	71.4

Bar Properties

Item	Notation	Units	Value
Bar Diameter	Dbar	mm	25.00
		m	0.03
Borehole Diameter	Dhole	mm	50.00
		m	0.050
Nominal cross-sectional area of the tendon at the end of its design life	As nom	mm2	226.00
		m2	0.23
Steel Grade		N/mm2	690.00
Characteristic yield strength	Fyk	kN	520.00
Partial Material Factor	ɣs		1.15
Characteristic yield strength of tendon	Rtk	kN	117.52
Design Tensile Resistance	Rtd	kN	**102.19**

Slope Properties

Item	Notation	Units	Value
Slope Height	H	m	5.1
Slope Angle	β	Degrees	70

Soil Nailing Calculation Sheet - Set 2					Jubb
Project Name	Ponsharden Cemeteries	Author	MJT	Date	06/12/2021
Project No.	21287	Checked	MEC	Date	06/12/2021

Pull Out Resistance

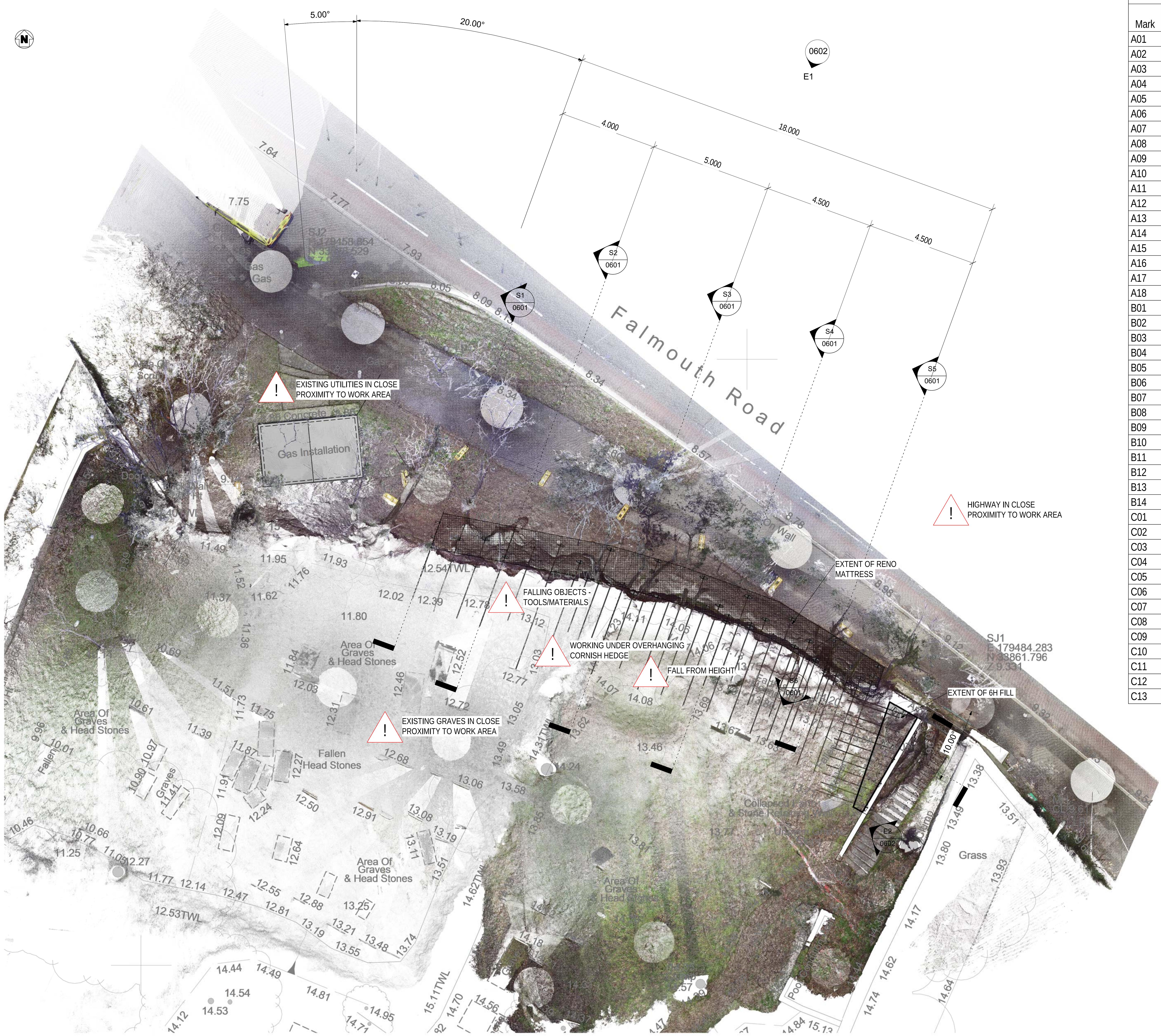
Effective Stress Method			
Item	**Notation**	**Units**	**Value**
Horizontal Pressure Co-efficient	Ka	-	0.27
	Kl	-	0.64
Factor	λpf		1.00

Row	Entry	Angle	Length	Free	Embed	Level	σ'v	σ'r	b	Tw		Nail force (kN/m)
1	**0**	40	3	0.75	1.875	1.2052	22.899	18.738	7.1333	2.5211	OK	0.590
2	**1**	30	3.5	0.75	2.125	2.0625	39.188	32.066	12.207	5.2731	OK	1.292
3	**2**	30	3	0.75	1.875	2.9375	55.813	45.669	17.386	6.1447	OK	1.798
4	**3**	30	3	0.75	1.875	3.9375	74.813	61.216	23.305	8.2365	OK	2.496
					0	0	0	0	0	0	OK	#DIV/0!
					0	0	0	0	0	0	OK	#DIV/0!

Total Stress Method			
Item	**Notation**	**Units**	**Value**
Bond co-efficient	α		0.5
Ultimate Pullout Resistance of nail	Pult	kN/m	**106.5897507**

Nail Head Plate										
Row	**Entry**	**Angle**	**Length**	**Free**	**Embed**	**Level**	**σ'v**	**σ'r**	**b**	**Tfd**
1	**0**	40	3	0.75	1.875	1.2052	22.899	18.738	7.1333	42.867
2	**1**	30	3.5	0.75	2.125	2.0625	39.188	32.066	12.207	37.793
3	**2**	30	3	0.75	1.875	2.9375	55.813	45.669	17.386	32.614
4	**3**	30	3	0.75	1.875	3.9375	74.813	61.216	23.305	26.695
					0	0	0	0	0	50
					0	0	0	0	0	50

Appendix E: Design Drawings



GENERAL ARRANGEMENT

SCALE 1 : 100

BANK SOIL NAIL SCHEDULE						
Mark	Type	Soil Nail Drill Length (m)	Easting (m)	Northing (m)	Soil Nail Head Elevation (m)	Bearing
A01	SOIL NAIL 3m	3.000	179479.849	33860.837	13.400	20°
A02	SOIL NAIL 3m	3.000	179479.424	33861.130	13.400	20°
A03	SOIL NAIL 3m	3.000	179478.590	33861.763	13.400	20°
A04	SOIL NAIL 3m	3.000	179477.827	33862.590	13.400	20°
A05	SOIL NAIL 3m	3.000	179476.955	33863.120	13.400	20°
A06	SOIL NAIL 3m	3.000	179476.009	33863.443	13.200	20°
A07	SOIL NAIL 3m	3.000	179475.117	33863.917	13.200	20°
A08	SOIL NAIL 3m	3.000	179474.130	33864.127	13.200	20°
A09	SOIL NAIL 3m	3.000	179473.245	33864.620	13.200	20°
A10	SOIL NAIL 3m	3.000	179472.332	33865.037	13.200	20°
A11	SOIL NAIL 3m	3.000	179471.317	33865.172	13.500	20°
A12	SOIL NAIL 3m	3.000	179470.309	33865.326	13.500	20°
A13	SOIL NAIL 3m	3.000	179469.370	33865.668	13.500	20°
A14	SOIL NAIL 3m	3.000	179468.389	33865.897	13.500	20°
A15	SOIL NAIL 3m	3.000	179465.904	33866.380	11.900	20°
A16	SOIL NAIL 3m	3.000	179463.809	33866.471	11.900	20°
A17	SOIL NAIL 3m	3.000	179462.845	33866.748	11.700	20°
A18	SOIL NAIL 3m	3.000	179461.979	33867.292	11.700	20°
B01	SOIL NAIL 4.5m	4.500	179479.962	33861.147	12.800	20°
B02	SOIL NAIL 4.5m	4.500	179479.055	33861.578	12.800	20°
B03	SOIL NAIL 4.5m	4.500	179478.382	33861.924	12.800	20°
B04	SOIL NAIL 4.5m	4.500	179477.573	33862.623	12.800	20°
B05	SOIL NAIL 4.5m	4.500	179477.144	33862.907	12.800	20°
B06	SOIL NAIL 4.5m	4.500	179476.460	33863.219	12.800	20°
B07	SOIL NAIL 4.5m	4.500	179475.563	33863.680	12.400	20°
B08	SOIL NAIL 4.5m	4.500	179474.658	33864.116	12.400	20°
B09	SOIL NAIL 4.5m	4.500	179473.684	33864.364	12.400	20°
B10	SOIL NAIL 4.5m	4.500	179472.783	33864.812	12.400	20°
B11	SOIL NAIL 4.5m	4.500	179471.804	33865.048	12.400	20°
B12	SOIL NAIL 4.5m	4.500	179469.908	33865.685	12.800	20°
B13	SOIL NAIL 4.5m	4.500	179467.864	33865.918	12.800	20°
B14	SOIL NAIL 4.5m	4.500	179466.788	33865.884	12.800	20°
C01	SOIL NAIL 3.5m	3.500	179480.134	33861.619	12.000	20°
C02	SOIL NAIL 3.5m	3.500	179479.673	33861.814	12.000	20°
C03	SOIL NAIL 3.5m	3.500	179478.745	33862.189	12.000	20°
C04	SOIL NAIL 3.5m	3.500	179477.805	33862.531	12.000	20°
C05	SOIL NAIL 3.5m	3.500	179476.948	33863.098	12.000	20°
C06	SOIL NAIL 3.5m	3.500	179476.060	33863.583	11.500	20°
C07	SOIL NAIL 3.5m	3.500	179475.161	33864.038	11.500	20°
C08	SOIL NAIL 3.5m	3.500	179474.221	33864.380	11.500	20°
C09	SOIL NAIL 3.5m	3.500	179473.295	33864.759	11.500	20°
C10	SOIL NAIL 3.5m	3.500	179472.356	33865.101	11.500	20°
C11	SOIL NAIL 3.5m	3.500	179470.757	33865.094	11.900	20°
C12	SOIL NAIL 3.5m	3.500	179468.872	33865.764	11.900	20°
C13	SOIL NAIL 3.5m	3.500	179466.890	33866.166	11.900	20°

BANK SOIL NAIL SCHEDULE						
Mark	Type	Soil Nail Drill Length (m)	Easting (m)	Northing (m)	Soil Nail Head Elevation (m)	Bearing
C14	SOIL NAIL 3.5m	3.500	179465.005	33866.833	11.400	20°
D01	SOIL NAIL 3m	3.500	179480.231	33861.885	11.200	20°
D02	SOIL NAIL 3m	3.000	179480.383	33862.304	10.000	20°
D03	SOIL NAIL 3m	3.500	179479.313	33862.288	11.200	20°
D04	SOIL NAIL 3m	3.000	179478.623	33863.317	10.000	20°
D05	SOIL NAIL 3m	3.500	179477.566	33863.334	11.200	20°
D06	SOIL NAIL 3m	3.000	179476.832	33864.244	10.000	20°
D07	SOIL NAIL 3m	3.000	179475.765	33864.234	10.800	20°
D08	SOIL NAIL 3m	3.000	179475.046	33865.183	10.000	20°
D09	SOIL NAIL 3m	3.000	179473.847	33864.813	10.800	20°
D10	SOIL NAIL 3m	3.000	179473.200	33865.960	10.000	20°
D11	SOIL NAIL 3m	3.000	179471.814	33865.075	10.900	20°
D12	SOIL NAIL 3m	3.000	179471.326	33866.659	9.800	20°
D13	SOIL NAIL 3m	3.000	179469.860	33865.553	10.900	20°
D14	SOIL NAIL 3m	3.000	179469.365	33867.117	9.800	20°
D15	SOIL NAIL 3m	3.000	179468.112	33866.599	10.900	20°
D16	SOIL NAIL 3m	3.000	179467.305	33867.306	9.800	20°
D17	SOIL NAIL 3m	3.000	179466.190	33867.165	10.400	20°
D18	SOIL NAIL 3m	3.000	179465.399	33867.918	9.400	20°
D19	SOIL NAIL 3m	3.000	179464.201	33867.549	10.400	20°
D20	SOIL NAIL 3m	3.000	179463.138	33867.552	10.700	20°
D21	SOIL NAIL 3m	3.000	179463.410	33868.300	9.800	20°
D22	SOIL NAIL 3m	3.000	179462.096	33867.613	10.700	20°
D23	SOIL NAIL 3m	3.000	179462.313	33868.210	9.800	20°
E01	SOIL NAIL 2.5m	2.500	179479.718	33856.574	13.200	289°
E02	SOIL NAIL 2.5m	2.500	179479.840	33856.929	13.200	289°
E03	SOIL NAIL 2.5m	2.500	179480.085	33857.638	13.200	289°
E04	SOIL NAIL 2.5m	2.500	179480.330	33858.347	13.200	289°
E05	SOIL NAIL 2.5m	2.500	179480.574	33859.056	13.200	289°
E06	SOIL NAIL 2.5m	2.500	179480.819	33859.765	13.200	289°
E07	SOIL NAIL 2.5m	2.500	179481.064	33860.474	13.200	289°
F01	SOIL NAIL 2.5m	2.500	179479.902	33856.511	12.475	289°
F02	SOIL NAIL 2.5m	2.500	179480.146	33857.220	12.475	289°
F03	SOIL NAIL 2.5m	2.500	179480.391	33857.929	12.475	289°
F04	SOIL NAIL 2.5m	2.500	179480.636	33858.638	12.475	289°
F05	SOIL NAIL 2.5m	2.500	179480.880	33859.347	12.475	289°
F06	SOIL NAIL 2.5m	2.500	179481.186	33860.233	12.475	289°
F07	SOIL NAIL 2.5m	2.500	179480.452	33857.511	11.750	289°
F08	SOIL NAIL 2.5m	2.500	179480.697	33858.220	11.750	289°
F09	SOIL NAIL 2.5m	2.500	179480.941	33858.929	11.750	289°
F10	SOIL NAIL 2.5m	2.500	179481.186	33859.638	11.750	289°
F11	SOIL NAIL 2.5m	2.500	179481.431	33860.347	11.750	289°
F12	SOIL NAIL 2.5m	2.500	179481.003	33858.511	11.025	289°
F13	SOIL NAIL 2.5m	2.500	179481.247	33859.220	11.025	289°
F14	SOIL NAIL 2.5m	2.500	179481.614	33860.284	11.025	289°
Grand total: 90		289.000				

NOTES

Soil nails located at the steps (with the prefix E & F) have predicted locations based on point cloud data. Positions could vary as only removal of soft and slumped material required and to be replaced with class 6H fill determined by the contractor.

Approx. 180 no. of spikes plates

Total drilling length of 289 m, contractor to allow for additional soil nail length to extend through Reno interface.

APPROX. AREA OF TECCO MESH AT BANK = 115 m^2
APPROX. AREA OF TECCO MESH AT STEPS = 11 m^2
APPROX. AREA OF RENO MATTRESS = 115 m^2

GENERAL NOTES

1. All proprietary products to be installed strictly in accordance with manufacturers instructions.

2. This drawing is to be read in conjunction with all other relevant Jubb drawings, specifications 21287-SPEC-01 and Geotechnical Design Report 21287-GDR-01.

3. All drawings and survey information are to AOD. Survey sections are based on survey information provided by the client.

4. Refer to drawings 21287-JCE-XX-ZZ-DR-Y-0601 to 0602 for detail locations

Rev	Date	Description	By	Apvd
P01	07/01/22	REVISED SOIL NAIL SCHEDULE	MD	MT
WIP	15/12/21	WORK IN PROGRESS INITIAL ISSUE	MD	MT

PROJECT:
PENRYN SLOPE STABILISATION

TITLE:
GENERAL ARRANGEMENT

CLIENT:
FALMOUTH TOWN COUNCIL

SCALE@A1:
1 : 100

PROJECT REF: 21287 **STATUS:** S0 **REV:** P01

DRAWING No.:
21287- JCE -XX-ZZ-DR-Y-0600

Revision Referencing
P = Preliminary A = Approval T = Tender C = Construction

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jubb.uk.com
+44(0)292 052 4444

GENERAL NOTES

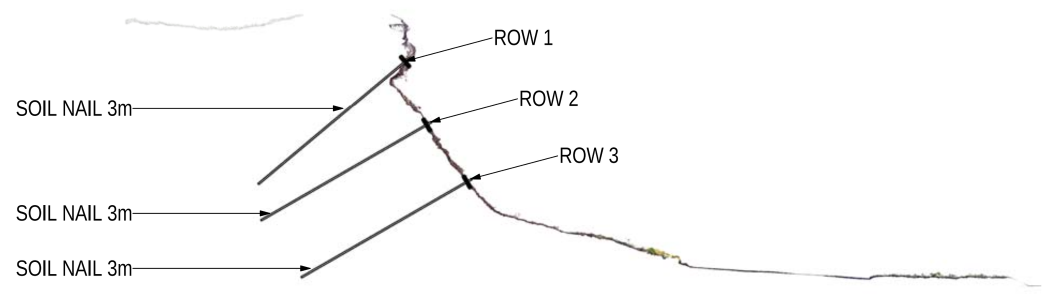
1. All proprietary products to be installed strictly in accordance with manufacturers instructions.

2. This drawing is to be read in conjunction with all other relevant Jubb drawings, specifications 21287-SPEC-01 and Geotechnical Design Report 21287-GDR-01.

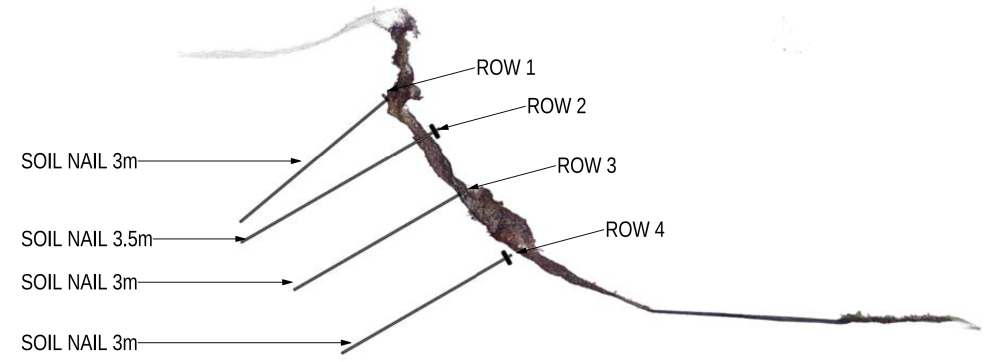
3. All drawings and survey information are to chart datum. Survey sections are based on survey information provided by the client.

4. Refer to drawings 21287-JCE-XX-ZZ-DR-Y-0601 to 0602 for detail locations

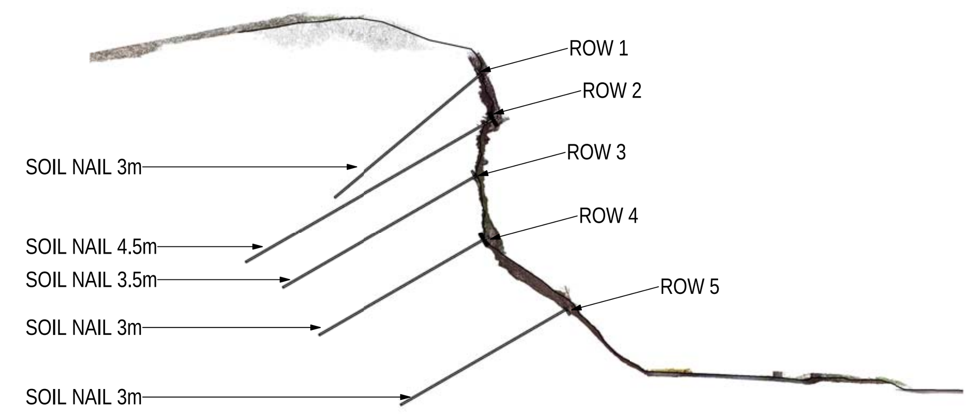
5. Refer to drawing 21287-JCE-XX-ZZ-DR-Y-0600 for general arrangement.



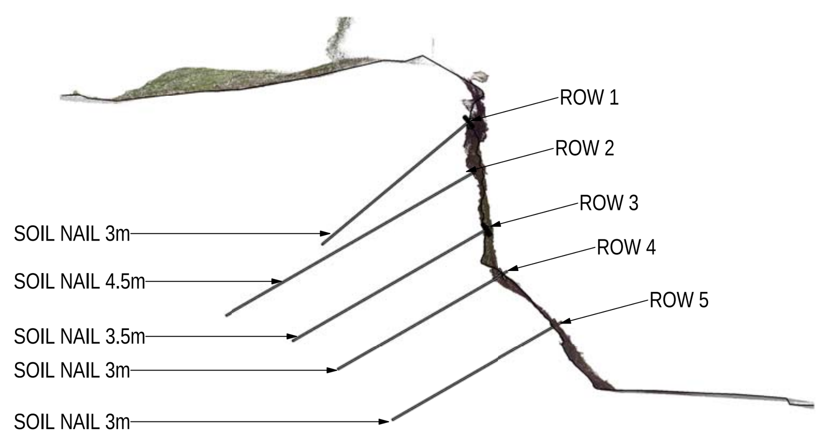
S1 0600 **BANK SECTION 1**
SCALE 1 : 100



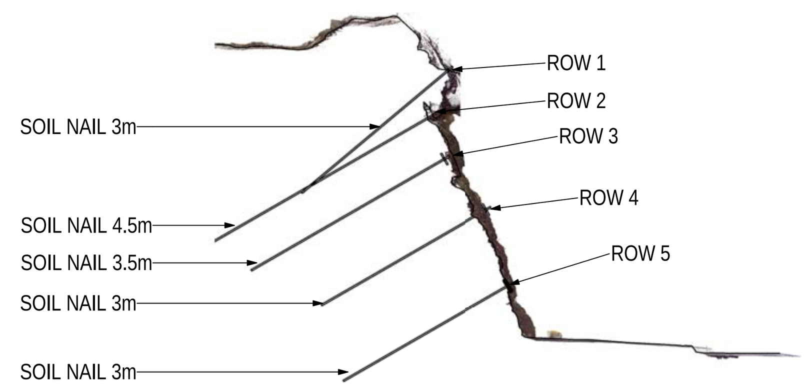
S2 0600 **BANK SECTION 2**
SCALE 1 : 100



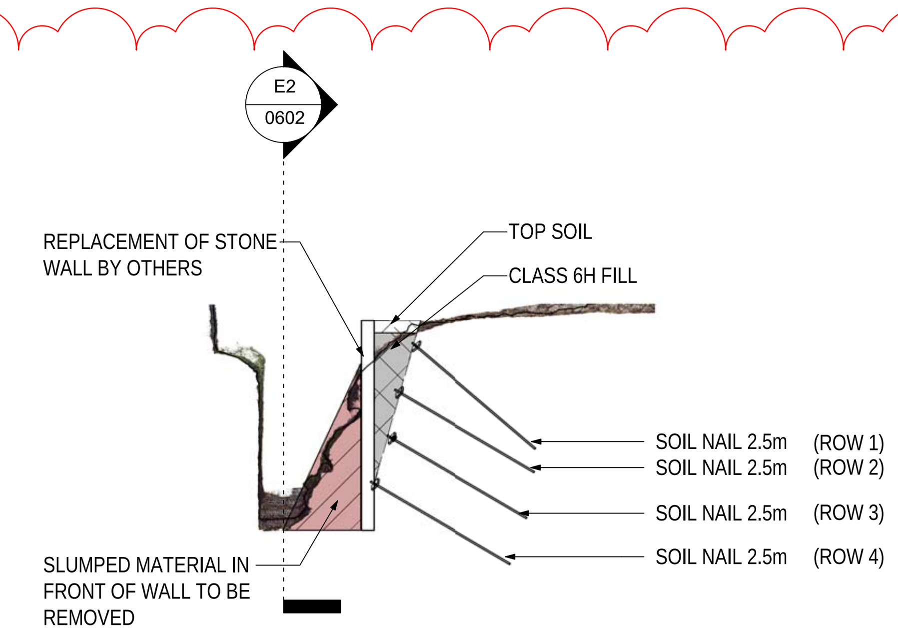
S3 0600 **BANK SECTION 3**
SCALE 1 : 100



S4 0600 **BANK SECTION 4**
SCALE 1 : 100



S5 0600 **BANK SECTION 5**
SCALE 1 : 100



S6 0600 **BANK SECTION 6 - STEPS**
SCALE 1 : 100

Rev	Date	Description	By	Apvd
P01	07/01/22	REVISED STEPS SECTION	MD	MT
WIP	15/12/21	WORK IN PROGRESS INITIAL ISSUE	MD	MT

PROJECT:
PENRYN SLOPE STABILISATION

TITLE:
SITE SECTIONS

CLIENT:
FALMOUTH TOWN COUNCIL

SCALE@A1:
1 : 100

PROJECT REF: 21287
STATUS:
REV: P01

DRAWING No.:
21287- JCE -XX-ZZ-DR-Y-0601

Revision Referencing
P = Preliminary A = Approval T = Tender C = Construction

Jubb

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GENERAL NOTES

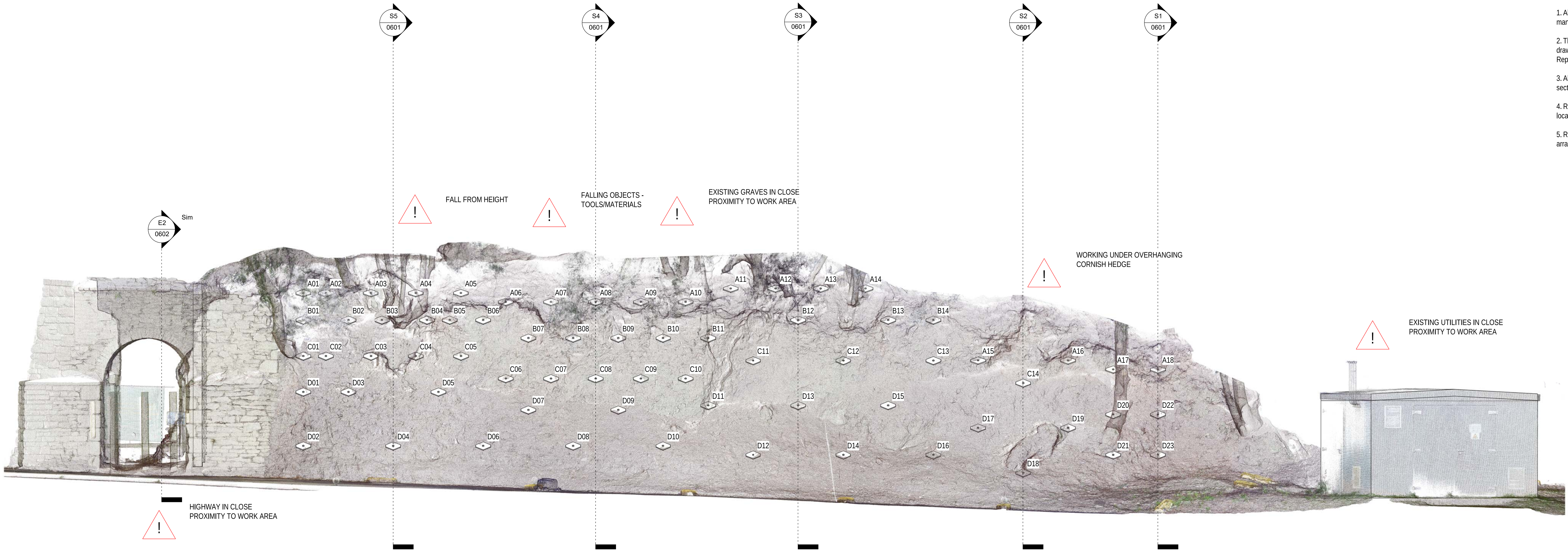
1. All proprietary products to be installed strictly in accordance with manufacturers instructions.

2. This drawing is to be read in conjunction with all other relevant Jubb drawings, specifications 21287-SPEC-01 and Geotechnical Design Report 21287-GDR-01.

3. All drawings and survey information are to chart datum. Survey sections are based on survey information provided by the client.

4. Refer to drawings 21287-JCE-XX-ZZ-DR-Y-0601 to 0602 for detail locations

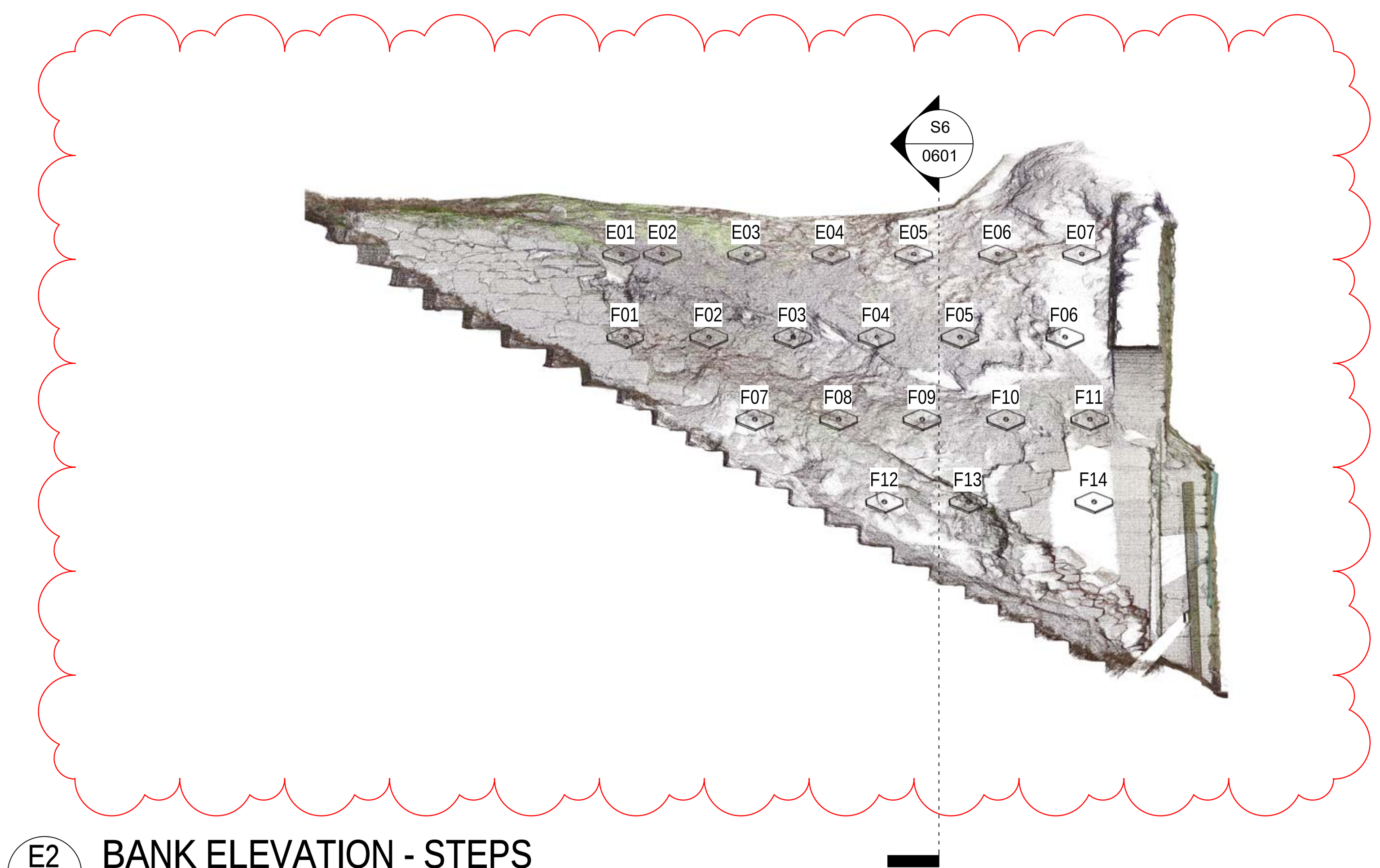
5. Refer to drawing 21287-JCE-XX-ZZ-DR-Y-0600 for general arrangement.



NOTE

REFER TO DRAWING 0600 FOR ROCK BOLT LOCATION COORDINATES

E1 0600 **BANK ELEVATION**
SCALE 1 : 50



E2 0600 **BANK ELEVATION - STEPS**
SCALE 1 : 50

Rev	Date	Description	By	Apvd
P01	07/01/22	SPIKE PLATES AND STEPS BANK ELEVATION ADDED	MD	MT
WIP	15/12/21	WORK IN PROGRESS INITIAL ISSUE	MD	MT

PROJECT:
PENRYN SLOPE STABILISATION

TITLE:
BANK ELEVATION

CLIENT:
FALMOUTH TOWN COUNCIL

SCALE@A1:
1 : 50

PROJECT REF: 21287
STATUS:
REV: P01

DRAWING No.:
21287- JCE -XX-ZZ-DR-Y-0602

Revision Referencing
P = Preliminary A = Approval T = Tender C = Construction

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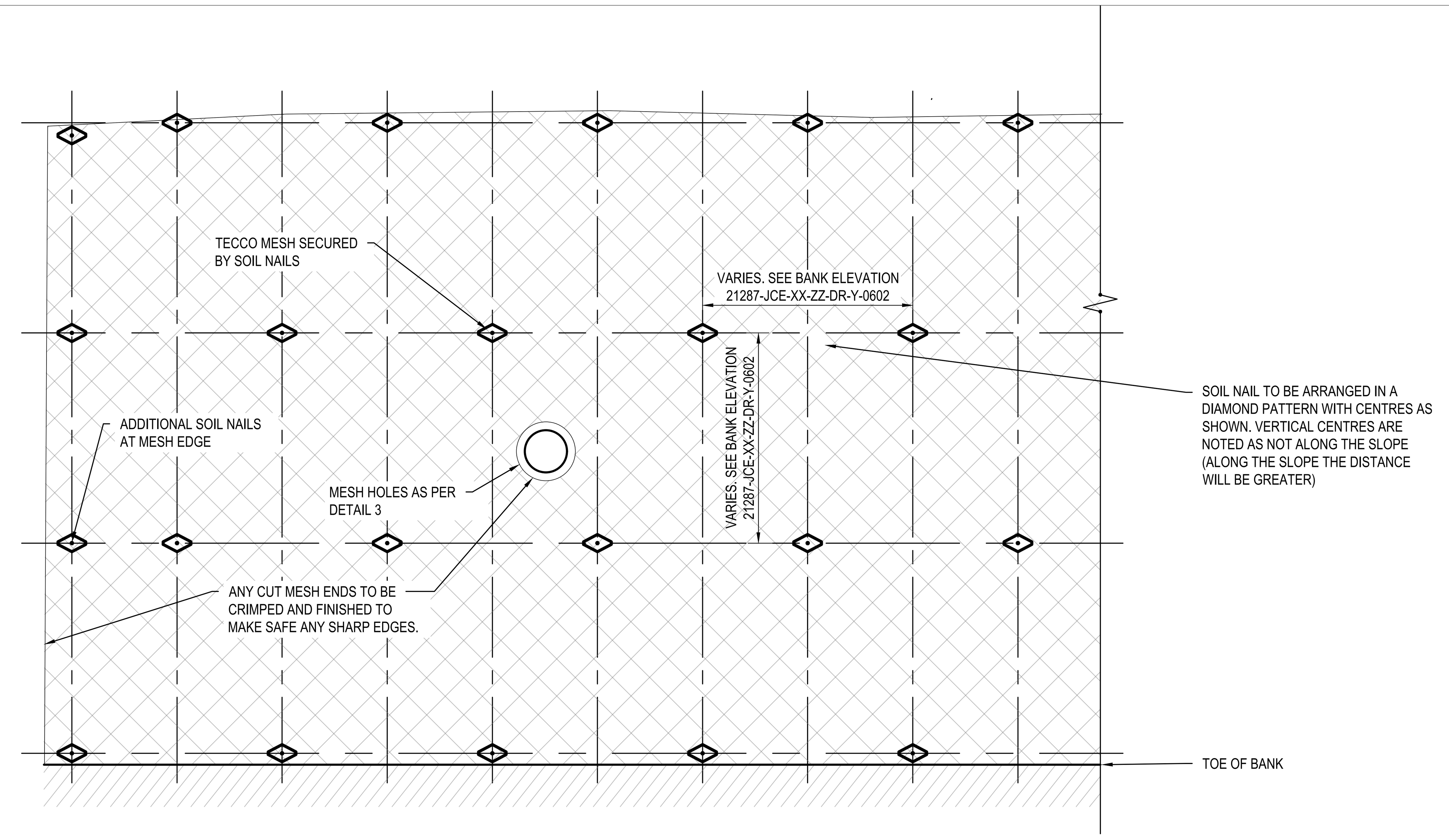
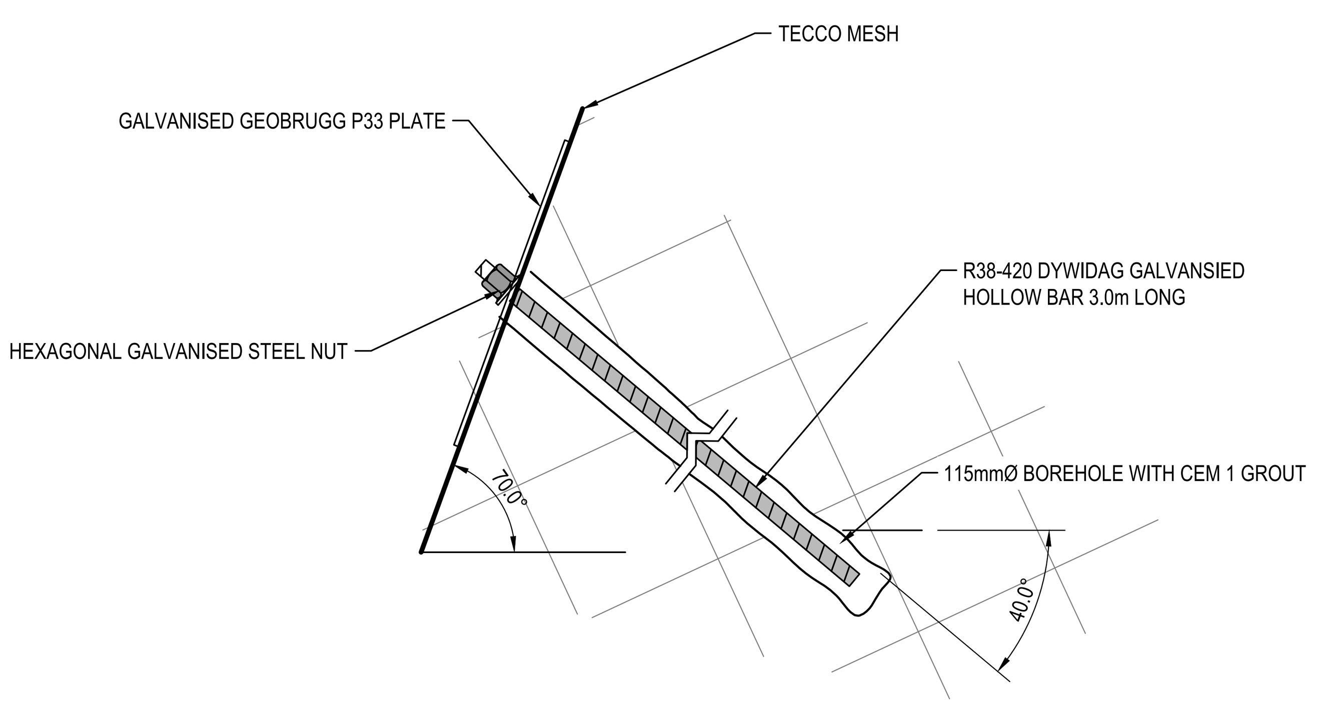
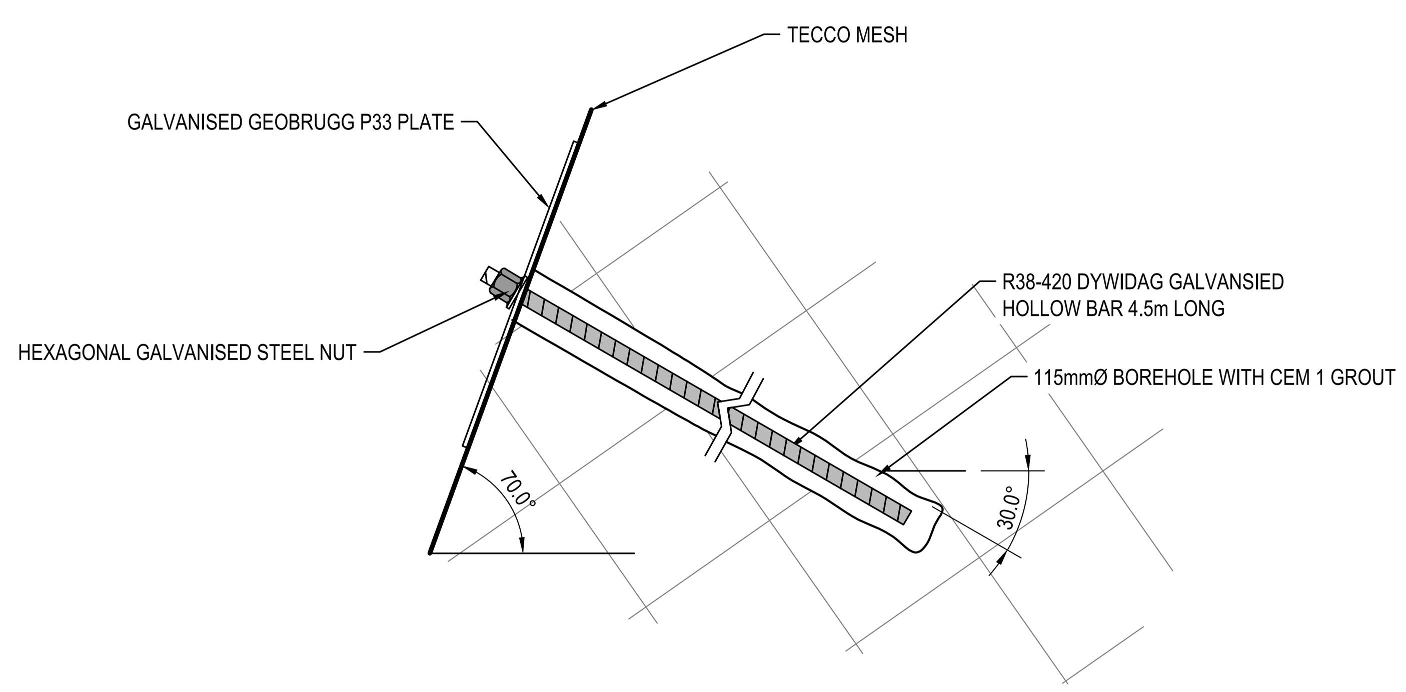


TYPICAL SOIL NAIL ARRANGEMENT ELEV.
(N.T.S.)



SOIL NAIL DETAIL - TYPE A



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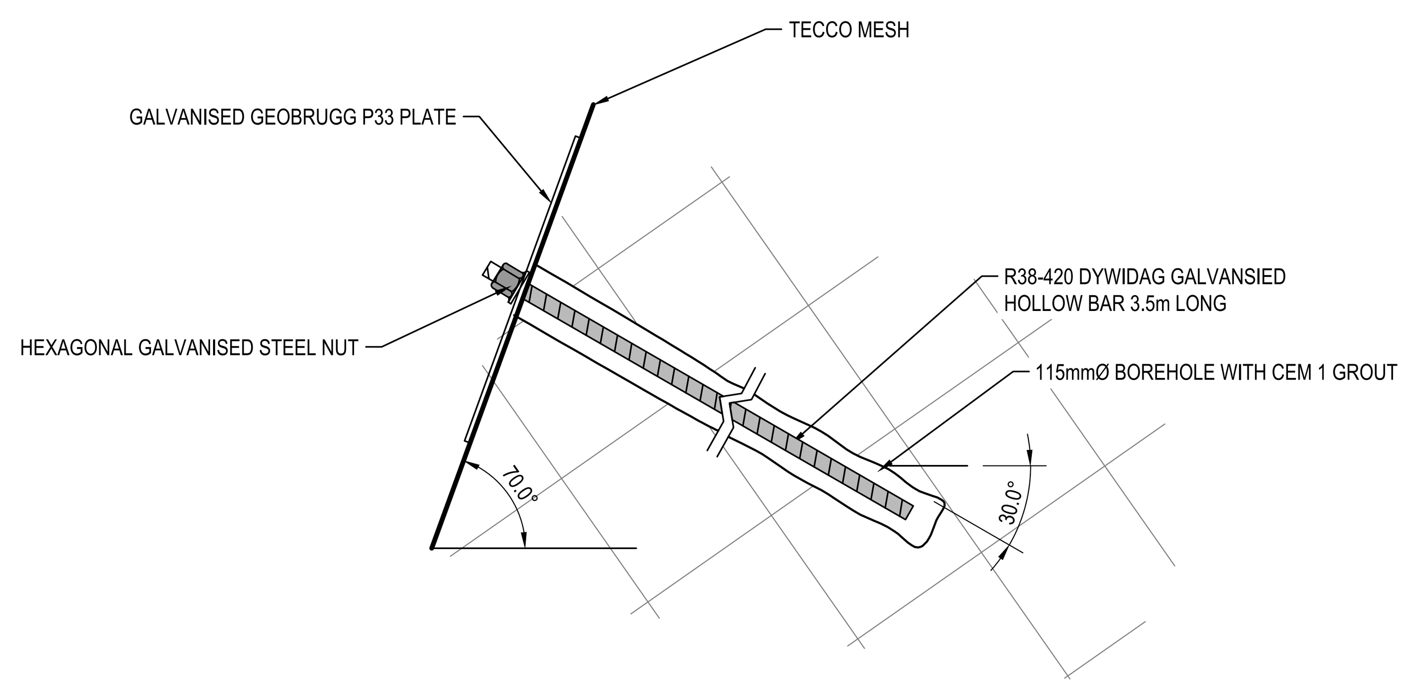
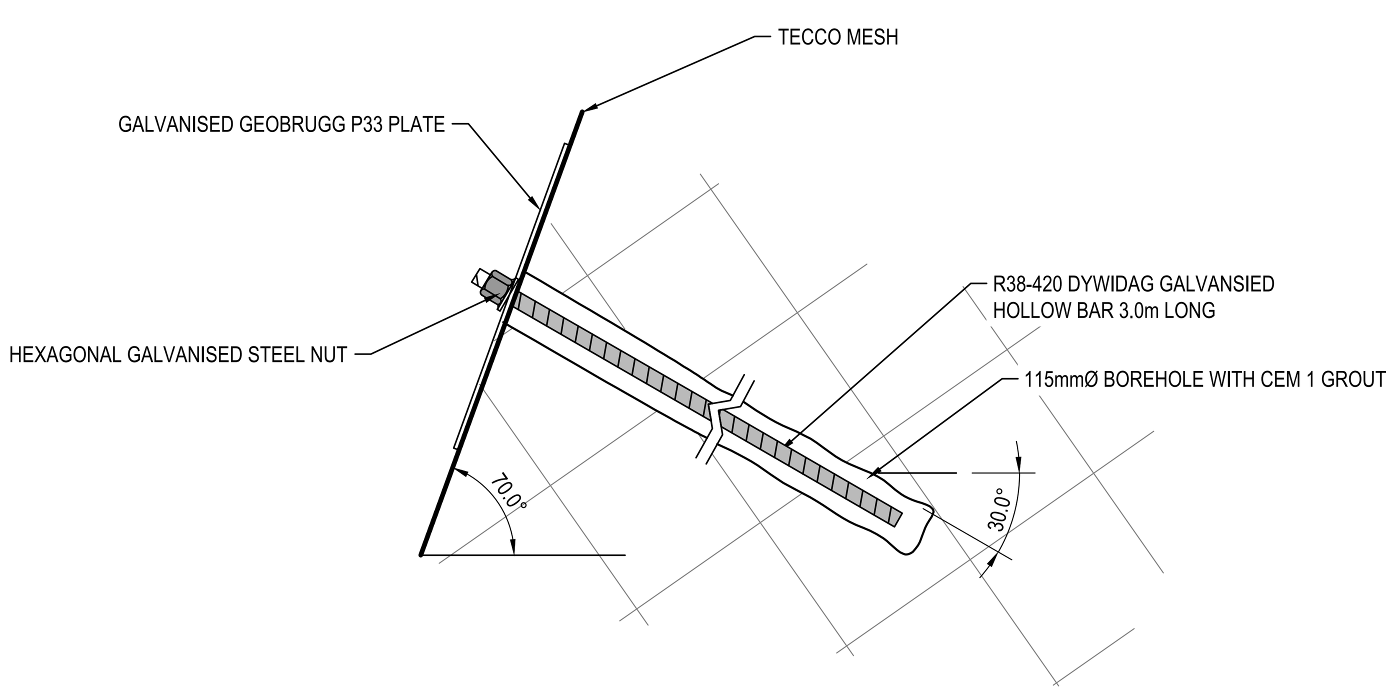
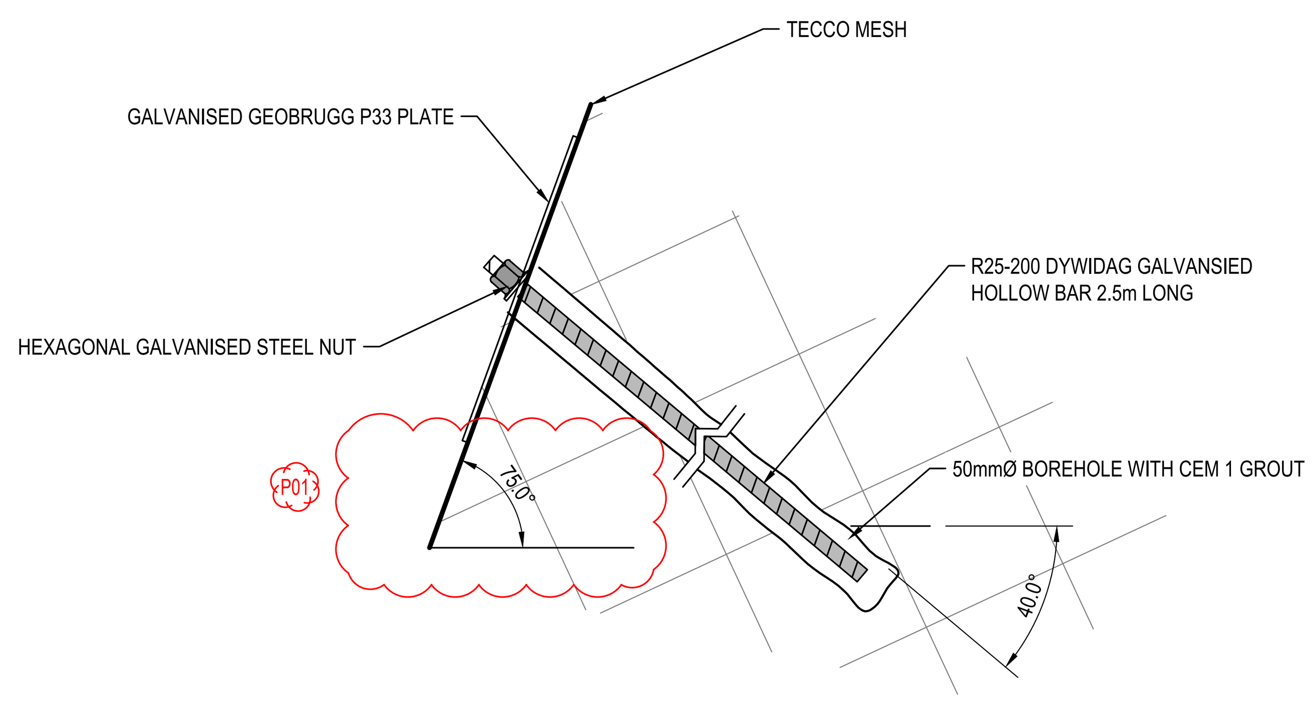


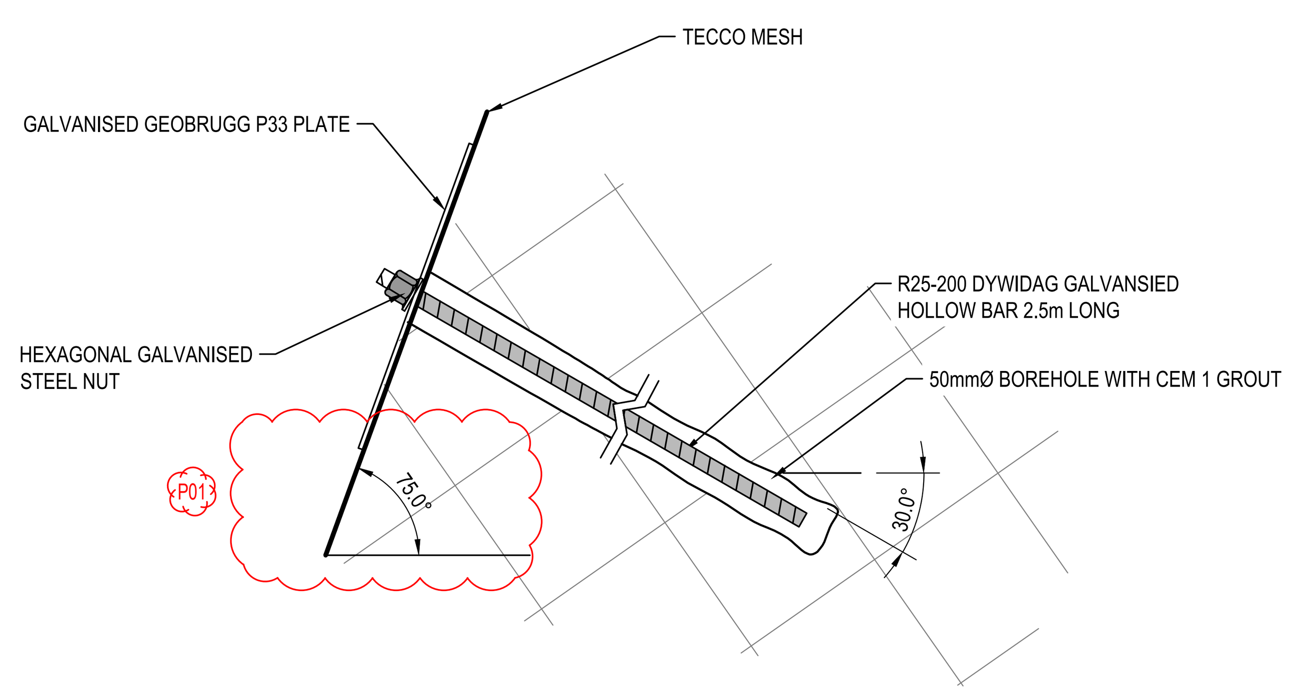
SOIL NAIL DETAIL - TYPE C



SOIL NAIL DETAIL - TYPE D



SOIL NAIL DETAIL - TYPE E



SOIL NAIL DETAIL - TYPE F

GENERAL NOTES

1. All proprietary products to be installed strictly in accordance with manufacturers instructions.
2. This drawing is to be read in conjunction with all other relevant Jubb drawings, specifications 21287-SPEC-01 and Geotechnical Design Report 21287-GDR-01.
3. All drawings and survey information are to AOD. Survey sections are based on survey information provided by the client.
4. Refer to drawings 21287-JCE-XX-ZZ-DR-Y-0601 to 0604 for detail locations
5. Refer to drawing 21287-JCE-XX-ZZ-DR-Y-0600 for general arrangement.
6. Sequence of works outline in Sections 3.6.1 of the Specification, 21287-SPEC-01.

Rev	Date	Description	By	Apvd
P01	07/01/2022	PRELIMINARY ISSUE FOR INFORMATION/COMMENT	MD	MT
WIP	15/12/2021	WORK IN PROGRESS INITIAL ISSUE	MD	MT

PROJECT:
PENRYN SLOPE STABILISATION

TITLE:
TYPICAL DETAILS
SHEET 1

CLIENT:
FALMOUTH TOWN COUNCIL

SCALE@A1:
AS STATED

PROJECT REF: 21287
STATUS: S0
REV: P01

DRAWING No:
21287-JCE-XX-ZZ-DR-Y-0650

Revision Referencing
P = Preliminary A = Approval T = Tender C = Construction

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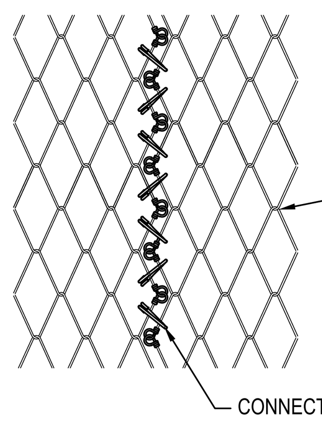
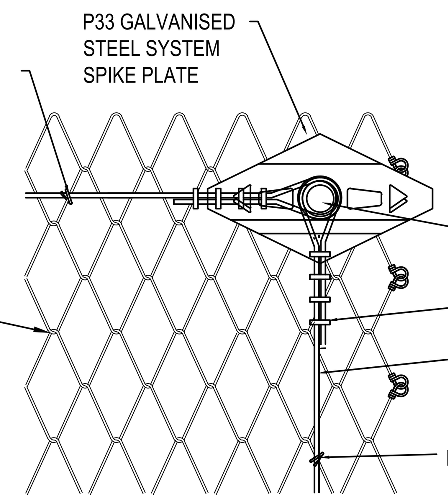
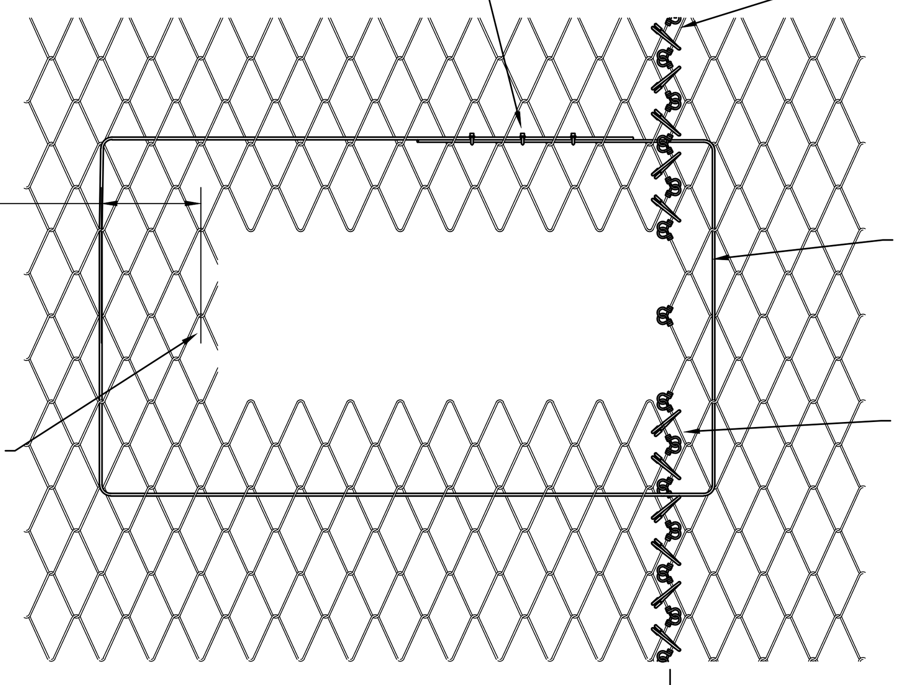


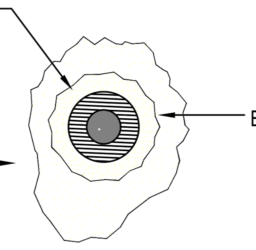
SOIL NAIL MESH DETAIL 1 - TECCO MESH PANEL CONNECTION



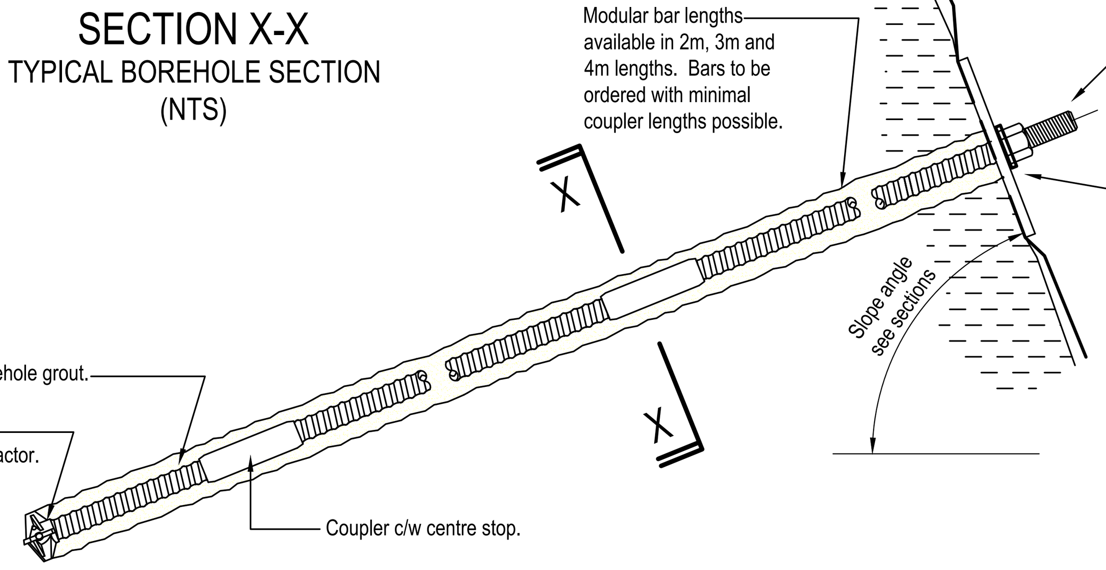
SOIL NAIL MESH DETAIL 2 - TECCO MESH AND BOUNDARY ROPE



SOIL NAIL MESH DETAIL 3 - TECCO MESH HOLES



SECTION X-X
TYPICAL BOREHOLE SECTION
(NTS)



DETAIL 1
SOIL NAIL TENDON
TYPICAL SECTION
(1:10)

Soil Nail Elements:
Galvanized hollow bar System assumes the following criteria:

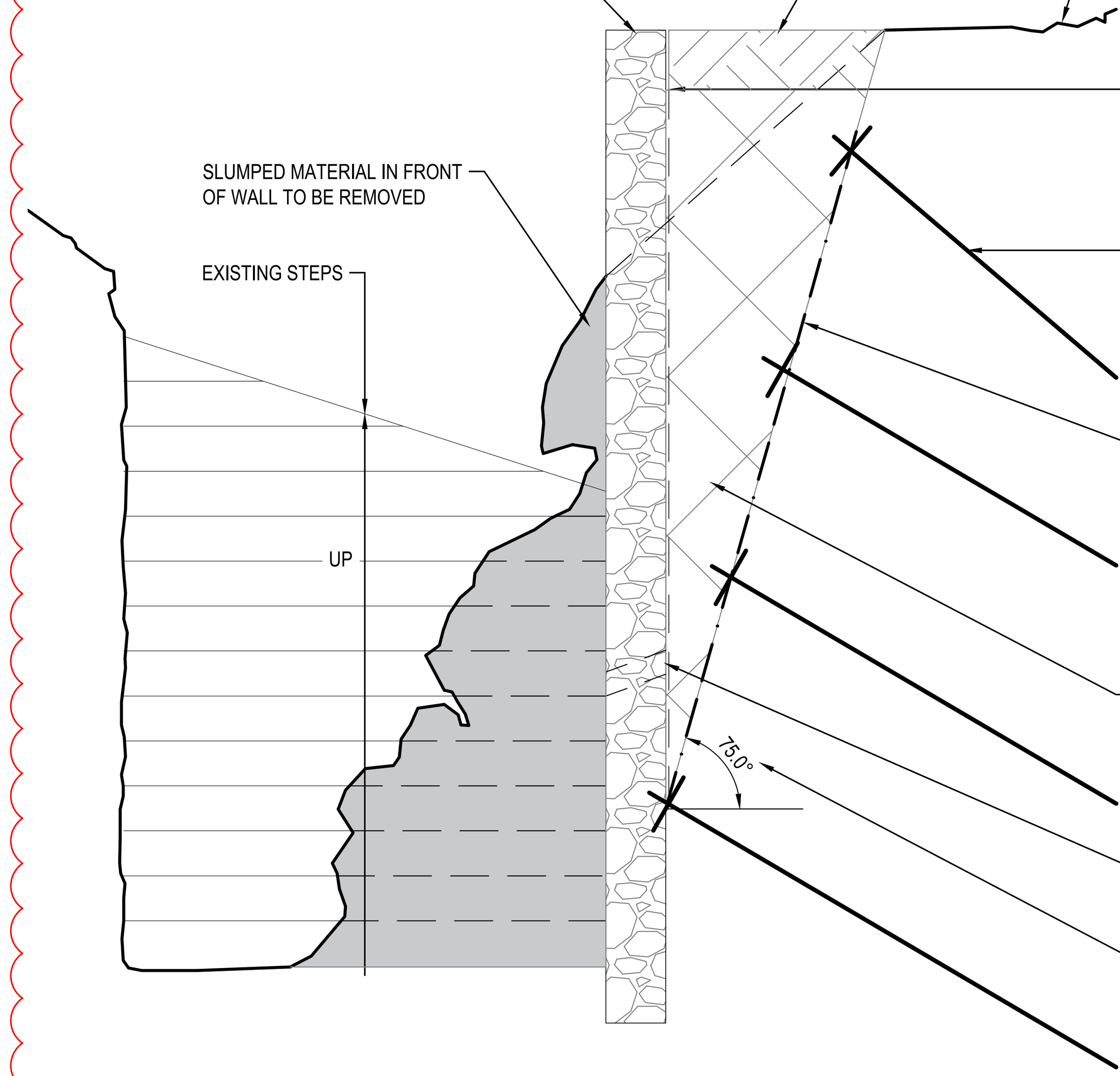
TABLE 1 - SOIL NAIL PARAMETERS

	UNITS	MAIN CUTTING - FALMOUTH ROAD	STAIRWAY CUTTING
BAR TYPE		DYWIDAG R38-420	DYWIDAG R25-200
Nominal thread diameter	mm	38	25
Effective external diameter	mm	36.4	23.8
Internal diameter	mm	21	14
Cross-section area	mm^2	660	290
Ultimate strength	kN	420	200
Yield strength	kN	350	150
Steel grade (yield/ultimate)	N/mm^2	510/610	520/690

Given the design life of 60 years is assumed, the rural location of the proposed works and in accordance with BS 8006-2:2011+A1:2017: Code of practice for strengthened/reinforced soils Part 2 : Soil Anchor Design, a corrosivity category of C3 (medium) has been considered appropriate based on the DYWIDAG technical data indicates in 'low' soil aggressivity condition, the following has corrosion parameters been assumed within the design:

TABLE 2 - TENDON PROPERTIES AND STRENGTH PARAMETERS

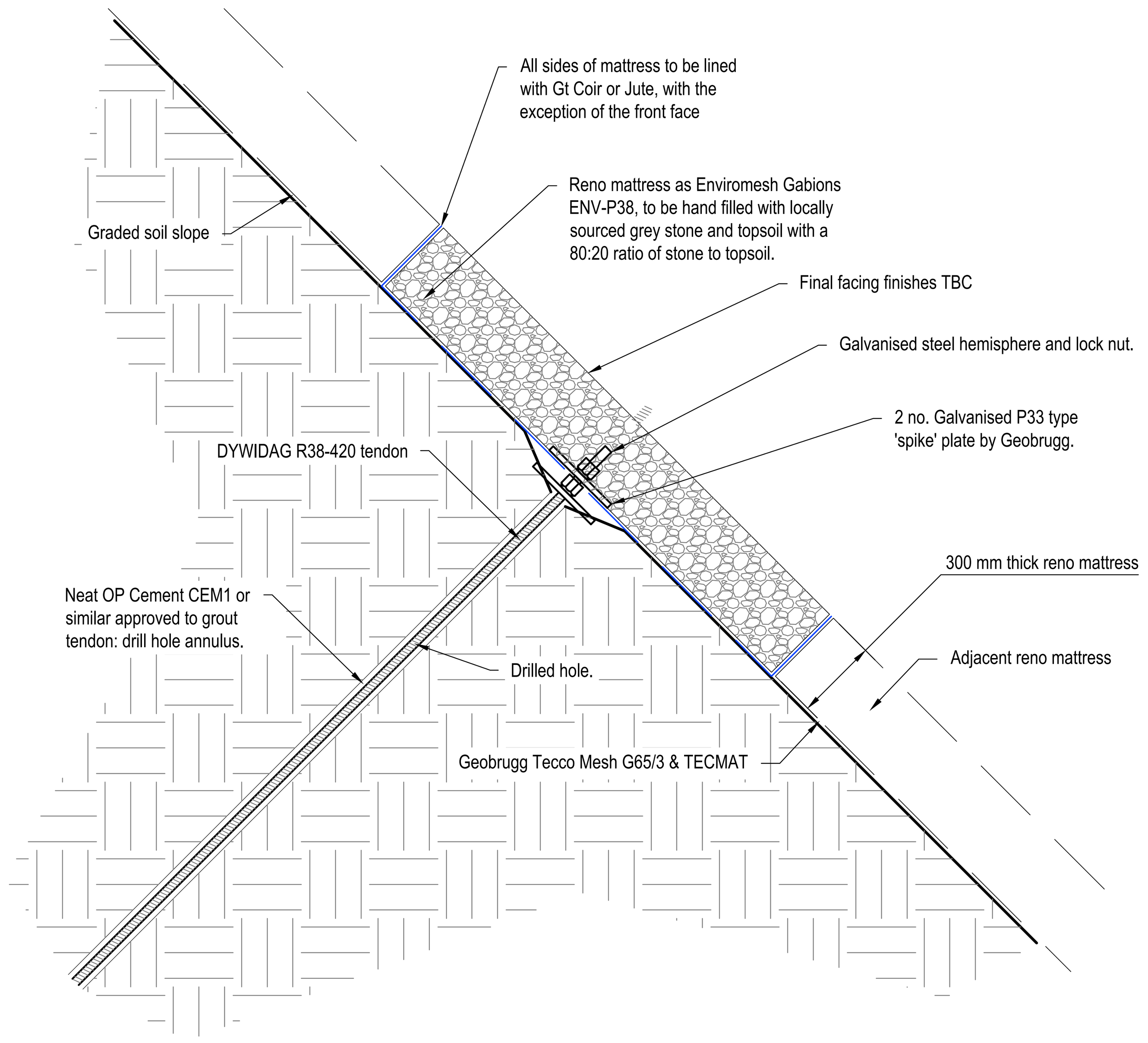
	UNITS	MAIN CUTTING - FALMOUTH ROAD	STAIRWAY CUTTING
BAR TYPE		DYWIDAG R38-420	DYWIDAG R25-200
Sacrificial thickness	mm	4.9	4.9
Cross-sectional area (with rusting away)	mm^2	406	129
Ultimate strength	kN	256	86
0.2% yield strength	kN	214	65



STEPS
BANK REPAIR DETAILS - SCALE (1:50)

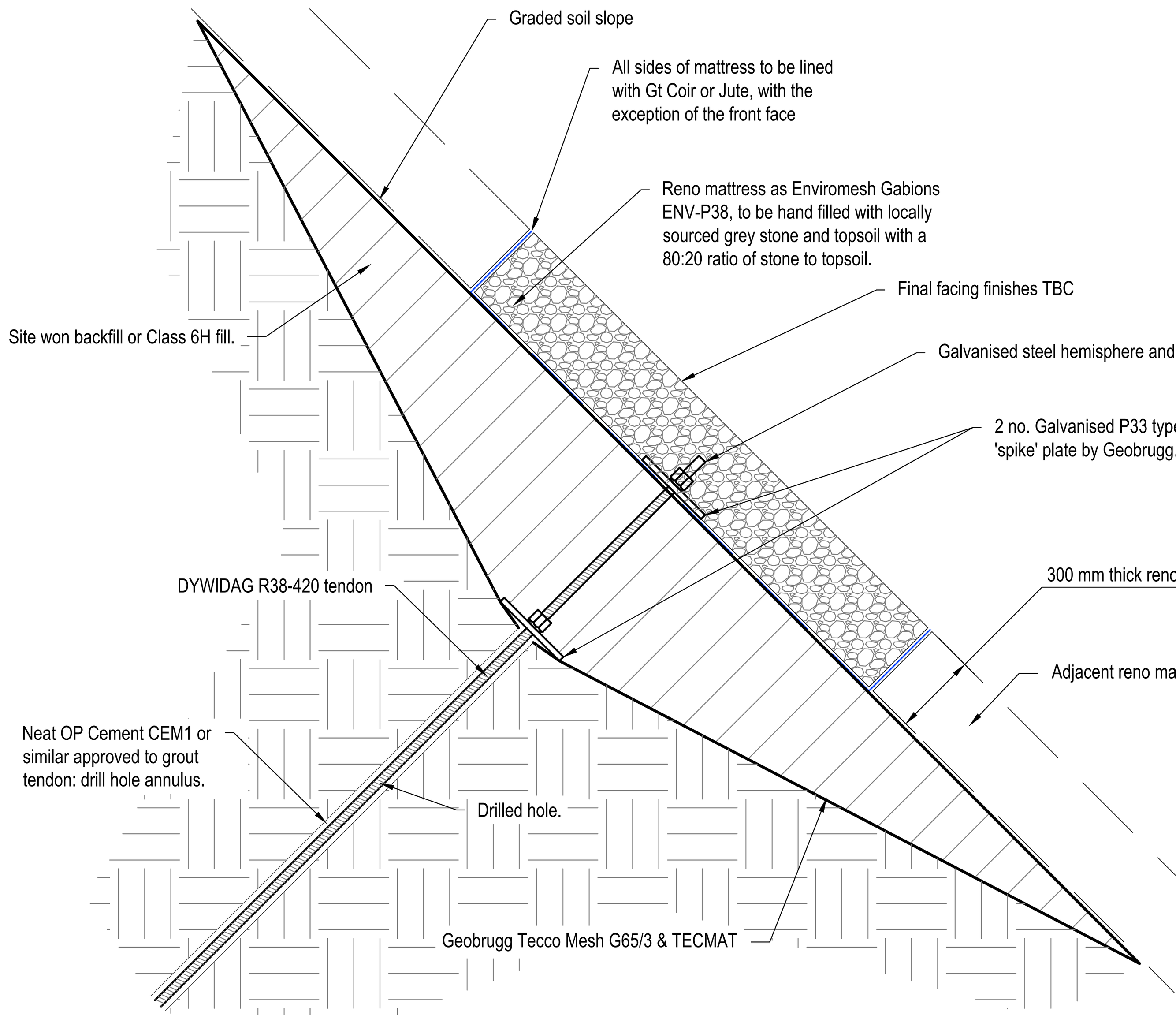
GENERAL NOTES

1. All proprietary products to be installed strictly in accordance with manufacturers instructions.
2. This drawing is to be read in conjunction with all other relevant Jubb drawings, specifications 21287-SPEC-01 and Geotechnical Design Report 21287-GDR-01.
3. All drawings and survey information are to AOD. Survey sections are based on survey information provided by the client.
4. Refer to drawings 21287-JCE-XX-ZZ-DR-Y-0601 to 0604 for detail locations
5. Refer to drawing 21287-JCE-XX-ZZ-DR-Y-0600 for general arrangement.
6. Sequence of works outline in Sections 3.6.1 of the Specification, 21287-SPEC-01.

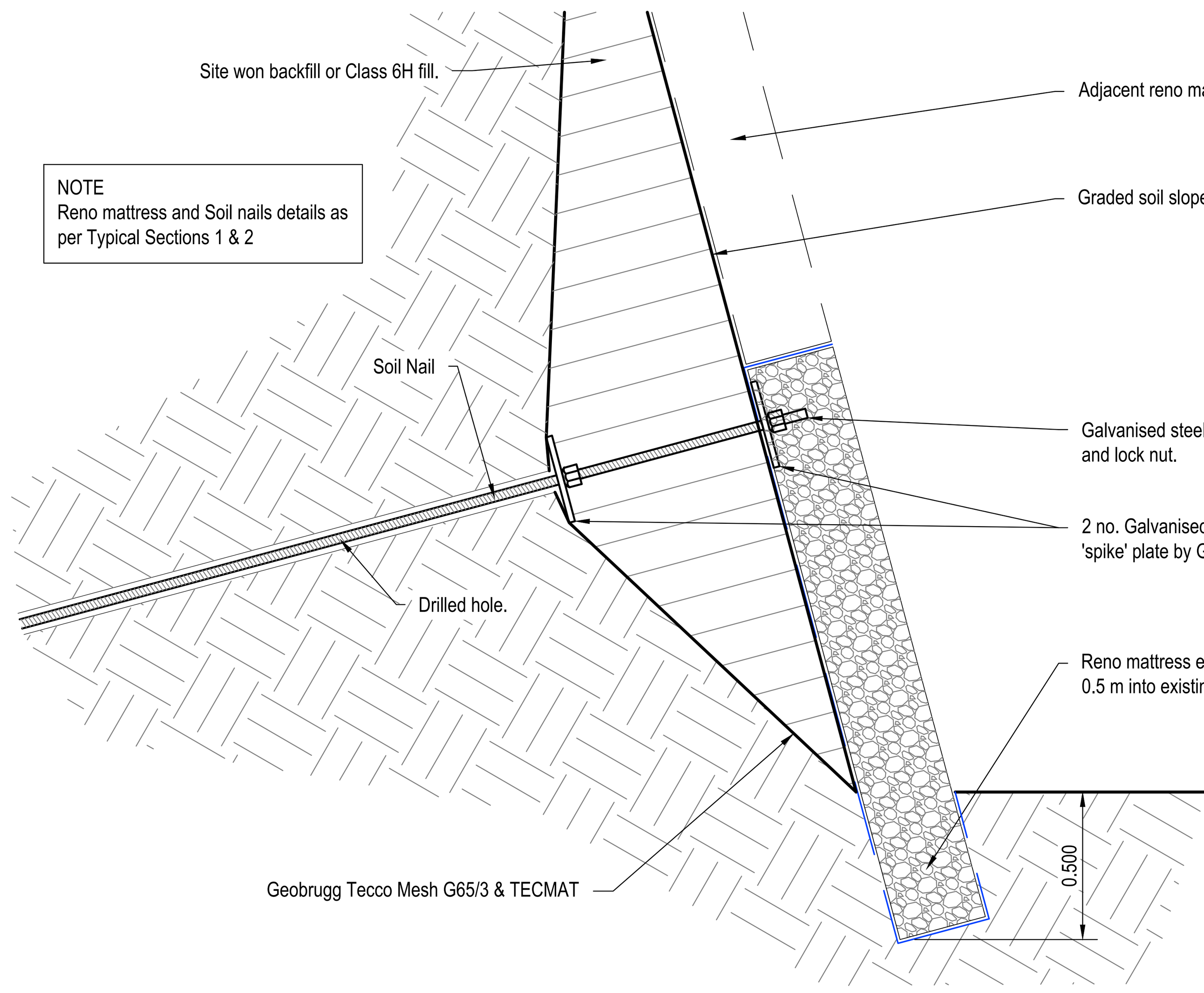


TYPICAL SECTION 1
RENO MATTRESS TYPICAL ARRANGEMENT - SCALE (1:20)

P01



TYPICAL SECTION 2
RENO MATTRESS WITH FILL TYPICAL ARRANGEMENT - SCALE (1:20)



TYPICAL SECTION 3
BASE OF RENO MATTRESS TYPICAL ARRANGEMENT - SCALE (1:20)

Rev	Date	Description	By	Apvd
P01	07/01/2022	ADDITIONAL DETAILS ADDED AS CLOUDED	MD	MT
WIP	15/12/2021	WORK IN PROGRESS INITIAL ISSUE	MD	MT

PROJECT:
PENRYN SLOPE STABILISATION

TITLE:
TYPICAL DETAILS
SHEET 2

CLIENT:
FALMOUTH TOWN COUNCIL

SCALE@A1:
AS STATED

PROJECT REF: 21287
STATUS: S0
REV: P01

DRAWING No:
21287-JCE-XX-ZZ-DR-Y-0651

Revision Referencing
P = Preliminary A = Approval T = Tender C = Construction

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Appendix F: Integrated Project Risk Register

INTEGRATED PROJECT RISK REGISTER
CLOCK CAFÉ SCARBOROUGH

Client: Falmouth Town Council
Principal Designer: Cadastria
Principal Contractor: TBC

CATEGORY			RISK ASSESSMENT							CONTROL MEASURES				
			HAZARD	CAUSE	CONSEQUENCE	PROJECT STAGE				CONTROL MEASURES	RISK RATING			METHOD OF COMMUNICATION
REFERENCE No.	CDM	PROJECT	*Record the nature of the hazard.*	*Note the conditions that may lead to a hazard causing harm or disruption.*	*List the consequences, should the hazard come into effect*	PRE-CONSTRUCTION	CONSTRUCTION	OPERATION & MAINTENANCE	DECOMMISSIONING	*List those measures that you consider may be put in place to mitigate (reduce) both the likelihood and effect of the risk identified.*	LIKELIHOOD	EFFECT	RISK RATING	*List risk communication media additional to this document e.g. drawings.*
1	x		Tendon Failure	Overstressing of tendon on installation. Damage of tendon during storage.	Global and localised slope instability. Loss of infrastructure or life.		x			Installation to be carefully monitored by contractor and designer. Appropriate storage of tendons including transport to tendon location. Inspection of tendon before installation. Testing of tendon.	M	L	L	Geotechnical Design Report
2	x		Permanent Nail Clashing	Poor setting out of soil nails	Damage to nail Delay of programme		x			Soil nails to be set out to 75mm accuracy vertically and horizontally. Layout design to be checked for clashes	L	M	L	Design drawings with nail setting out position.
3		x	Inadequate penetration of soil nail due to in-ground obstructions.	Boulders and cobbles within fill embankment	Shallow/inadequate penetration of soil nail, slope failure		x			Onsite quality control. Ensure all nails are installed to the proposed depths (at least 3 m into rock). Where depths are not achieved on refusal on a boulder/cobble, nail position should be revised.	L	M	L	
4		x	Aggressive Chemicals (Sulphates)	Sulphate Levels	Degradation of grout and steel tendon, headworks and mesh.			x		Steel products to be galvanised and protected.	L	L	L	Sulphate section of Geotechnical Design Report
5	x		Ultimate limit state failure	Insufficient anchor design	Slope instability during construction.			x		Determine sufficient bond strength within at least 2.25 m fixed length. ULS stability checks carried out to ensure local and global stability is satisfied.	L	M	L	Geotechnical Design Report
6	x		Serviceability limit state failure	Variable ground conditions to poorer than expected	Slope deformation.			x		Inspection of cutting to confirm similar ground conditions to expected.	L	M	L	Construction Inspection.
7	x		Buried Services – underground water main	Soil nails to be installed to incorrect depth and inclination	Soil Nail strikes and damages underground services.		x			Soil Nail Installation contractor to fully understand proposed design and depth to existing services. Gas main to be accurately surveyed. Works proximal; to gas terminal building to be checked prior to commencing works.	M	M	M	Service drawings. Constraints plan.
8	x	x	Re-activation of existing landslide or new instability triggered	Groundwater flow / seepage encountered in cutting or a confined head of groundwater increases, resulting in a	Instability which may cause injury, delay and disruption to the works	x	x	x		Site investigation, including monitoring wells; Geotechnical Design Repost recommending design values for pore water pressure ratio (Ru) in permanent condition;	L	L	L	Drawings and specification; Method statement

CATEGORY			RISK ASSESSMENT							CONTROL MEASURES				
REFERENCE No.	CDM	PROJECT	HAZARD *Record the nature of the hazard.*	CAUSE *Note the conditions that may lead to a hazard causing harm or disruption.*	CONSEQUENCE *List the consequences, should the hazard come into effect*	PROJECT STAGE: PRE-CONSTRUCTION	CONSTRUCTION	OPERATION & MAINTENANCE	DECOMMISSIONING	CONTROL MEASURES *List those measures that you consider may be put in place to mitigate (reduce) both the likelihood and effect of the risk identified.*	RISK RATING: LIKELIHOOD	EFFECT	RISK RATING	METHOD OF COMMUNICATION *List risk communication media additional to this document e.g. drawings.*
				corresponding increase in pore water pressure; Surcharging of crest area; Excavation of the instability toe 'runout' debris ahead of specified construction stage;						Slope stability analysis if construction stages undertaken to ULS following EC7 procedures; Specification of pressure relief face drain holes; Specification of construction stages Design of toe drainage system; Specification of drainage blankets within structural fill; Monitoring during construction; Maintenance of drains post-construction.				
9	x	x	Necking of soil nail grout collar	Sub-surface groundwater flow or confined sub-artesian head.	Insufficient grout : ground bond achieved resulting in failure of soil nail/s,		x	x		Drillers to record groundwater during drilling and report any adverse conditions; Simultaneous drill and grout flushing techniques to be adopted	M	L	L	Specification
10	x		Groundwater seepage	Shallow groundwater and perched groundwater encountered as seepage flow.	Require the use of de-watering techniques if encountered within foundation excavations. Discharge consents. Additional retaining wall drainage considerations required during construction. Potential to trigger landslide reactivation.		x			Monitoring of ground conditions during construction. Drainage allowances made within the stairway as weepholes. Main face is free draining.	M	L	L	Geotechnical Design Report
11		x	Falling from height	Lack of edge protection	Injury/death of member of public		x	x		Permanent edge protection to be installed along the crest of the retaining wall. Construction phase edge protection required.	L	M	L	Edge protection to be agreed by Falmouth town Council.
12		x	Slope Instability	Shallow instability within made ground and surficial deposits due to poorer than expected ground conditions.	Slope collapse Damage/death to plant and personnel		x			Top down construction, with mesh and headworks to be installed progressively prior to cutting lower benches. Regular monitoring of cutting face required to assess stability.	M	M	M	Geotechnical Design Report Soils to be assessed and confirmed with ground model during site inspection.

Client: Falmouth Town Council
Principal Designer: Cadastria
Principal Contractor: TBC

CATEGORY			RISK ASSESSMENT							CONTROL MEASURES				
			HAZARD	CAUSE	CONSEQUENCE	PROJECT STAGE				CONTROL MEASURES	RISK RATING			METHOD OF COMMUNICATION
REFERENCE No.	CDM	PROJECT	*Record the nature of the hazard.*	*Note the conditions that may lead to a hazard causing harm or disruption.*	*List the consequences, should the hazard come into effect*	PRE-CONSTRUCTION	CONSTRUCTION	OPERATION & MAINTENANCE	DECOMMISSIONING	*List those measures that you consider may be put in place to mitigate (reduce) both the likelihood and effect of the risk identified.*	LIKELIHOOD	EFFECT	RISK RATING	*List risk communication media additional to this document e.g. drawings.*
										Limit cut bench height, work sequentially and allow time for soil nail grout to cure; Design revision requirement - If instability occurs, regrade slope to form at 45° batter.				Method statement.
13		x	Intersection and damage of grave sites.	Incorrect angle and position of soil nail.	Damage to grave and cemetery site.		x			Installation to be carefully monitored by contractor and designer. Soil nails to be installed within accuracy requirements	M	M	M	Geotechnical Design Report
14		x	Fill settlement and damage to retaining wall during compaction.	Incorrect placement and compaction of structural fill.	Wall damage		x	x		Compaction and placement of fill to be carried out in accordance with specification criteria and in accordance with Specification for Highway Works – Series 600.	L	M	L	Soil Nail Specification. Geotechnical Design Report
15	x	x	Fire	Accident or vandalism	Damage to plastic geo-grid or other components of the system that are vulnerable to heat damage leading to failure of reinforced earth retaining structure		x	x		Site security measures; Site controls to mitigate the risk of fire during construction e.g. hot works permit system; O&M manual to include details of reinforced earth system and the risk that a fire could reduce the strength of the reinforced earth system	L	L	L	Method statements; O&M manual
16	x	x	Entrapment in drilling equipment	Rotating drill string	Severe injury or death		x			Guarding and automatic rotation kill devices fitted to drill rigs; Instruction, information, training and supervision of drilling team/s.	L	L	L	Method statements and risk assessment
17		x	Settlement or displacement (e.g. over-turning) of retaining wall face	Imported fill soils outside of specification tolerances, poorly or over compacted	Serviceability tolerances of retaining structure exceeded e.g. over-steepened or over-hanging retaining wall face angle		x	x		Specification to limit fill material types to granular fill (SHW class 6I/H), grading, geotechnical & chemical properties and compaction limits;	L	L	L	Specification; Drawings; Method statement; Quality management procedures and records;

CATEGORY			RISK ASSESSMENT							CONTROL MEASURES				
REFERENCE No.	CDM	PROJECT	HAZARD *Record the nature of the hazard.*	CAUSE *Note the conditions that may lead to a hazard causing harm or disruption.*	CONSEQUENCE *List the consequences, should the hazard come into effect*	PROJECT STAGE: PRE-CONSTRUCTION	CONSTRUCTION	OPERATION & MAINTENANCE	DECOMMISSIONING	CONTROL MEASURES *List those measures that you consider may be put in place to mitigate (reduce) both the likelihood and effect of the risk identified.*	RISK RATING: LIKELIHOOD	EFFECT	RISK RATING	METHOD OF COMMUNICATION *List risk communication media additional to this document e.g. drawings.*
										Staged construction sequence; Drainage blanket and mattress to ensure pore pressure dissipates; Ensure appropriate compaction equipment is used; Maintain records of compaction plant, passes and layer thickness; Source testing of imported fill materials; In-situ testing of 'as placed' materials; Survey monitoring, setting out and tolerance checks during construction; Controls to ensure fill materials are placed at optimum moisture content, are not over- or under- compacted;				Monitoring records; Completion report.
18		x	Injury to a member of the public accessing the work site	Poor site security or intentional act to breach site fencing	Accident or injury Litigation		x							
19	x	x	Plant overturning / accident	Poor planning, temporary works design or execution of construction	Serious injury to site personnel or the public; Commercial loss and delay; Litigation		x			Detailed design to consider construction and post-construction phase surcharge loads; Construction phase plant equipment selected within design surcharge load limits; Temporary works design of construction access and operating platforms; Access from the base of the landslide with limited or no crest surcharge loads applied; Lift plans for any items of lifting equipment; Inspection, testing and certification of plant equipment including bespoke drilling rigs e.g. excavator mounts to be within safe operating limits of machinery, including any attachment points.	L	L	L	Temporary works design checks

Client: Falmouth Town Council
Principal Designer: Cadastria
Principal Contractor: TBC

CATEGORY			RISK ASSESSMENT							CONTROL MEASURES				
			HAZARD	CAUSE	CONSEQUENCE	PROJECT STAGE				CONTROL MEASURES	RISK RATING			METHOD OF COMMUNICATION
REFERENCE No.	CDM	PROJECT	*Record the nature of the hazard.*	*Note the conditions that may lead to a hazard causing harm or disruption.*	*List the consequences, should the hazard come into effect*	PRE-CONSTRUCTION	CONSTRUCTION	OPERATION & MAINTENANCE	DECOMMISSIONING	*List those measures that you consider may be put in place to mitigate (reduce) both the likelihood and effect of the risk identified.*	LIKELIHOOD	EFFECT	RISK RATING	*List risk communication media additional to this document e.g. drawings.*
20		x	Dust emission, noise nuisance	Rock drilling	Silicosis (long term health risk), eye injury, hearing damage or public nuisance		x			Noise assessment for proposed plant equipment; Hearing, eye and dust protection for plant operators;	L	L	L	Risk assessment and method statement
21		x	Cement burn	Improper grouting method or poor control measures causes exposure to liquid cement-based grout	Hospitalisation, personal injury		x			Information, instruction, training, supervision and PPE for construction personnel	L	L	L	COSHH assessment
22		x	Failure of soil nails to reach service life	Degradation of materials and performance of components over time or improper / missing maintenance	Financial cost of maintenance or remedial works			x		Client specifies service life required; Detailed design considers durability of components; Contractor procures suitable components; Construction phase controls to protect components and inspect immediately prior to utilisation; Batch testing certificates to be provided by suppliers; Post-construction operation, maintenance and repairs to ensure longevity of accessible components e.g. drainage, wall face.	L	L	L	Project scope / brief; Geotechnical Design Report; Construction phase Q&A records; O&M manual.
23		x	Uncontrolled failure of retaining wall structure or soil nailed cutting slope (during de-commissioning)	De-tensioning of soil nails	Uncontrolled failure could cause serious injury or landslide activation				x	As built drawings, specification, construction records and this Design Risk Assessment to be retained by Client	L	L	L	O&M manual
24	x		Environmental pollution of controlled water or designated area	Silt laden surface water runoff from the work site	Prosecution under environmental law		x			Construction phase control measures to be developed to ensure surface water is not contaminated by silt arising from the works (e.g. cutting face excavations) and allowed to flow from the site area into a water body or designated area e.g. the sea.	L	L	L	Method statement

Client: Falmouth Town Council
Principal Designer: Cadastria
Principal Contractor: TBC

CATEGORY			RISK ASSESSMENT							CONTROL MEASURES				
			HAZARD	CAUSE	CONSEQUENCE	PROJECT STAGE				CONTROL MEASURES	RISK RATING			METHOD OF COMMUNICATION
REFERENCE No.	CDM	PROJECT	*Record the nature of the hazard.*	*Note the conditions that may lead to a hazard causing harm or disruption.*	*List the consequences, should the hazard come into effect*	PRE-CONSTRUCTION	CONSTRUCTION	OPERATION & MAINTENANCE	DECOMMISSIONING	*List those measures that you consider may be put in place to mitigate (reduce) both the likelihood and effect of the risk identified.*	LIKELIHOOD	EFFECT	RISK RATING	*List risk communication media additional to this document e.g. drawings.*
25	x	x	Unstable crest of slope (Cornish hedge) during drilling works.	The crest of the slope has a Cornish hedge. It is a client requirement for the hedge to remain untouched for the duration of the works.	Existing crest of slope and hedge is undercut – becomes unstable during drilling works.		x			Monitoring of the crest to be carried out during the works.	M	M	M	Geotechnical Design Report;