



GROUNDTECH
CONSULTING

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Littleborough

Report type: Design Submission

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Plans		
Plan Reference	Revision	Title
GRO-23131-P01	-	Project Location Plan
GRO-23131-P03A-G (exc C)	-	Tensar Profile Plan
GRO-23131-P04	-	Slope Section Plan
GRO-23131-P05	-	Tensar Areas Plan
GRO-23131-P06	-	Manhole Detail – Section View
GRO-23131-P07	-	Manhole Detail – Plan View

1.0 INTRODUCTION

1.1 Background

Groundtech Consulting Ltd have been appointed to design the TensarTech Natural GreenSlope reinforced soil slope for the residential housing project at Hollingworth Gate, Littleborough.

The Design Submission is based solely on the information provided by the client Countryside Partnerships Yorkshire.

The reinforced soil design is strictly in accordance with the information contained within the Design Brief attached. Variations to the information contained within the Design Brief or the scope of the services detailed may affect the design of the reinforcement and should be notified to Groundtech prior to commencement of construction.

1.2 Sources of Information

In preparing this Design Submission the following documents and Plans were reviewed and should be read in conjunction with this report:

- *HOLL-WBA-XX-XX-DR-A-PL_501-P15_Proposed Masterplan*
- *10861-01 Topographical Survey*
- *45466_016E Canal Sections 1*
- *45466_016F Canal Sections 2*
- *45466_016C Canal Sections 3*
- *45466_040_C Swale Cross Section*
- *45466_004J - Levels Appraisal Sheet 1*
- *45466_005J - Levels Appraisal Sheet 2*
- *Ground Investigation Report (Factual) - Hollingworth Gate, Littleborough 21-763 by ARC Environmental, dated 20 December 2021*

2.0 DESIGN BRIEF

2.1 Summary

The purpose of this document is to set out the agreed design parameters and scope of the design services on which the design of the Tensar soil reinforcement has been based. The responsibility on providing representative strength parameters for the soil lies with the Client. Groundtech assumes no liability for interpretation or verification of subsurface conditions, for suitability of soil design parameters or for interpretation of subsurface groundwater conditions. The Client is responsible to verify that actual site conditions, parameters, loadings and structure geometries are as described herein prior to construction commencement.

2.2 Slope Stability

A slope stability assessment for the existing slope along the sites northern boundary has been undertaken by Groundtech Consulting to assess the overall stability and the findings are discussed in Section 9.0.

2.3 Reinforced Slope details

1) Type of Structure

TensarTech NaturalGreen Slope with select areas of Tensar reinforcement in a single retaining structure along the sites northern boundary adjacent to the canal. The area to be reinforced is shown on Eastwood and Partners Drawings 45466_016E to C as sections:

- *Section A-A – Proposed 1:1 slope*
- *Section B-B – Proposed 1:1.2 slope*
- *Section C-C – Proposed 1:2 slope*
- *Section D-D – Proposed 1:1 slope*
- *Section E-E – Proposed 1:1 slope*
- *Section F-F – Proposed 1:1 slope*
- *Section G-G – Proposed 1:1.5 slope*

2) Facing

TensarTech erosion control mat on all the faces of the engineered slope.

3) Reinforcement

Tensar uniaxial geogrids with Tensar triaxial secondary geogrids.

4) Geometry

Max. Design Height: 6.0m

Slope Face Angle: 30° to 45°

(Stability of Toe slope is to be checked and confirmed by Client Geotechnical Engineer prior to commencement of Construction)

5) Method of Analysis

Internal Stability only - Limit equilibrium Bishop method of slices with minimum factor of safety of 1.3 or higher.

External stability – Slope stability was modelled by Groundtech Consulting utilising Oasys software using the Bishop (circular failures) method to determine a range of Over Design Factors (ODF).

Bearing capacity (including stability of toe slope if required) is by others and outside the scope of Groundtech. The stability of the unreinforced slope is the responsibility of the Client.

6) Reinforced Fill

Geotechnical parameters were derived from the Ground Investigation undertaken by Arc Environmental, additional trial pits have been undertaken by Groundtech Consulting and the selected parameters from this exercise will revise the design when available. The existing slope is predominantly constructed from Made Ground Clay and clayey sand/gravel. A bulk density of $\gamma_b - 20\text{kN/m}^3$ has been utilised for the Tensar design.

Earthworks testing of the site won material has been undertaken and the results are currently outstanding. A conservative friction angle of $\phi' - 24^\circ$ has been selected for the Tensar design. This may be revised on receipt of the geotechnical testing results.

7) Retained fill

Indicated to be soft to firm and firm Made Ground Clay or clayey gravel/sand as such the following bulk density and phi values have been utilised for the Tensar design. Design Properties: $\gamma_b - 20\text{kN/m}^3$ $\phi' - 24^\circ$.

8) Foundation Soil

Foundation soil is presented by the clients Geotechnical Engineer within the Arc Environmental Reports. Foundation soils generally comprise bedrock, however in the locations of Section B and Section F the bearing strata appears to be Made Ground and Stiff Clay respectively. Inspection of the foundation soils will be required prior to construction and suitable preparation implemented.

9) Water Conditions

Based on the Ground Investigation by others, no groundwater has been modelled, a slight seepage has been recorded at the base of the Made Ground locally – this should be further assessed during construction and addressed by the proposed drainage strategy. Canal is located immediately to the north of the reinforced slope, it has been assumed the watercourse does not encroach on the reinforced earth slope and does not affect the stability. The wall has been modelled in the overall stability, exact construction details of the canal are not known.

10) External Loading

10kPa temporary (live) surcharge considered to model traffic for private drives and carriageways.

75 to 100 kPa permanent surcharge for considered to model gabion wall for Section F.

No other loads (vertical/horizontal loads) are modelled for the proposed TensarTech NaturalGreen Slope System. It is assumed that plots adjacent to the crest of the slope will be piled and no loadings have been applied in the model.

2.4 Modelling

Introduction

The following selected relevant sections were modelled by Groundtech Consulting:

- Section A-A – Proposed 1:1 slope
- Section B-B – Proposed 1:1.2 slope
- Section C-C – Proposed 1:2 slope
- Section D-D – Proposed 1:1 slope
- Section E-E – Proposed 1:1 slope
- Section F-F – Proposed 1:1 slope
- Section G-G – Proposed 1:1.5 slope

Modelling Results

The sections listed above were modelled in TensarSoil to check the internal stability of the reinforced earth and the results are presented in the table below:

Section Modelled	Height (m)	Load 1 (kN/m ²)	Distance load applied from crest (m)	Load 2 (kN/m ²)	Distance load applied from crest (m)	Design Acceptable (Yes/No)	Strap Length Required (m)
A-A	5.1	10.0 variable	1.0 – 4.0	n/a	n/a	Yes	6.75
B-B	3.2	10.0 variable	1.0 – 4.0	n/a	n/a	Yes	5.1
C-C	3.5	10.0 variable	1.0 – 4.0	n/a	n/a	Yes	5.7
D-D	5.3	10.0 variable	1.0 – 4.0	n/a	n/a	Yes	7.0
E-E	6.0	10.0 variable	1.0 – 4.0	10.0 variable	5.0 – 9.45	Yes	9.5
F-F	3.5	10.0 variable	1.0 – 4.0	100 Permanent	7.4 – 9.6	Yes	11.1
G-G	4.0	10.0 variable	1.0 – 11.0	n/a	n/a	Yes	6.4

Variable loads have generally been modelled for the driveways and carriageways adjacent to the proposed slope crest. Permanent loads have not been modelled for the proposed plots as it is assumed these will be piled to bedrock.

A permanent load has been modelled for the proposed gabion adjacent to the crest of section F-F. Based on the angle of friction (ϕ') of 24° selected, the straps extend beneath the gabion structure, the material used in this area will require a higher angle of friction (ϕ'), modelling using 26° reduces the strap length to 5.6m and does therefore not extend beneath the gabion structure.

2.5 Project Specific Notes

- *The maximum height of the slope is 6.0m therefore the maximum exerted unfactored imposed bearing pressure at the base of the 6.0m (max. height) TensarTech NaturalGreen Slope itself is approximately 120kPa.*
- *Any proposed barriers or fences on top of TensarTech Natural Green Slope should be self-stable and should not impose any horizontal loads onto the face of TensarTech structure. Minimum distance to any barrier foundation should be 0.7m.*
- *Geogrid should be curtailed longitudinally around any tree root bulbs, drainage pipes or inverts to be installed. Ideally this should be done during construction of the slope and not retroactively to ensure the cuts are neat and accurate.*
- *No structures have been assumed to be supported by the slope and therefore no allowance has been made for loadings on the reinforced soil slope.*
- *Please also note that the reinforced soil slopes are flexible structures and may accommodate larger differential settlement compared to rigid form of structures. The building foundations must not rely on the surrounding soil as any movement within reinforced soil slope will have a direct impact on the serviceability of the house.*
- *Drainage requirements to be assessed by others. The reinforced soil has been assessed for dry conditions and should remain reasonably dry both during the construction phase and its design life. The customer's geotechnical engineer should assess the need for an appropriate drainage layer at the base and back of the reinforced soil block.*
- *The mine shaft on the site has not been included in the model, subject to suitable earthworks the slope in this area will not require reinforced earth.*
- *Piling of the plots at the crest of the slope should not be within 3m.*
- *The existing slope continues below the reinforced earth towards the canal and allowances should be made for working on existing slope and preparation at toe will be required. Required permissions will be required from the Rivers and Canal Trust.*
- *The angle of the toe slope should not exceed 20° .*
- *When cutting back the existing slope, to aid in construction the retained material face should be left stepped, with each step spacing being the associated geogrid spacing. During the upfill and*

geogrid placement exercise each layer horizon would then be easily identifiable as the next step up for the contractor onsite.

- *As base strata is assumed to be competent the lower proportion of existing slope should be assessed during the cutting back exercise to confirm this.*
- *From the recent trial pitting exercise the Made Ground is variable and will require processing if to be reused in the reinforced earth.*
- *Organic contamination was also encountered and will require consideration in the design and construction of the reinforced earth, specifically where remedial work is proposed.*
- *To facilitate the most viable design the material may need to be improved via treatment/drying or additional material would need to be imported to for use in the slope, particularly in the lower levels where the associated failure forces are the largest and the highest strength material would be required. Reuse of material is subject to processing and additional confirmatory testing.*
- *Groundwater level to be observed during construction and remodelled if required.*
- *Proposed roads will be underlain by geogrid such as at Section G, requires consideration for roads and sewers.*
- *Utilities including chambers are present along the crest of the existing slope and a pipe is present that exits from the existing slope and crosses the adjacent canal to the north. The position of these utilities and substructure to remain will require consideration prior to the construction of the reinforced earth.*
- *The ground conditions adjacent to the canal are not known and if they vary during construction to the models produced, the design should be reassessed.*

2.4 Exclusions

1. *Bearing Capacity of foundation soils to be assessed by the Client.*
2. *All other design methods, modes of failure, limit states etc. not specifically detailed above are outside the limits of the services offered and arrangements should be made for these to be covered by others.*
3. *Any proposed/existing manholes, lampposts, fence/sign posts, parapets etc should be notified to Groundtech so they can be incorporated in the reinforced earth design prior to detailed design. Foundation design of any such structures is beyond the scope of Groundtech's services and should be designed by the Client as stand-alone structures and without transferring any horizontal loading on the Tensar structure.*
4. *Appropriate surface water and erosion control systems should be designed by the Client to operate during construction and during the design life of the Tensar structure. The reinforced earth zone should remain free-drained and pore water pressures should be appropriately assessed by the Client to dissipate by capturing and disposing of groundwater that might build up behind the Tensar structure.*

5. *Utilities carrying water within the reinforced zone or on the face of the Tensar structure must be designed (by the Client) to prevent/contain leakage. The potential of differential soil movement within the reinforced zone and its effect on any utilities would also need to be considered by the Client.*
6. *Groundtech exercises the right to rely on geometries, strength parameters, groundwater and loading conditions stated by the Client for the purpose of determining the geogrid layout for the Project. In the absence of the above explicitly stated by the Client, Groundtech recommends that the Client retain the services of a Geotechnical Engineer to confirm the appropriateness of the assumptions above.*
7. *Unless specifically stated no allowance has been included for entering into any warranties or collateral warranties and the contract will be solely between Groundtech and the company placing the order.*
8. *Treatment of mine entries is not covered by the design.*
9. *Modelling of the mine shaft, substructure and unidentified structures requires consideration where appropriate.*

3.0 DESIGN CALCULATIONS

The following designs were produced using TensorSoils modelling software, with the design parameters and geometric provided by the clients plans.

Client: Vistry

Project: Hollingworth Gate, Littleborough

Tensar
Structural Systems

TensarTech
NaturalGreen System



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Method of analysis

The Tensar 2-part Wedge Slope Design Method is based on the 2-part wedge calculation procedure described in Advice Note HA68/94 "Design Methods for the Reinforcement of Highway Slopes by Reinforced Soil and Soil Nailing Techniques" (Design Manual for Roads and Bridges, Volume 4, Section 1, Part 4, now withdrawn). Partial material factors are applied to the soil strength and the resistance provided by the geogrid reinforcement.

Reference

GRO-23131

Date

2 Jun 2023

Page

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Design analysis
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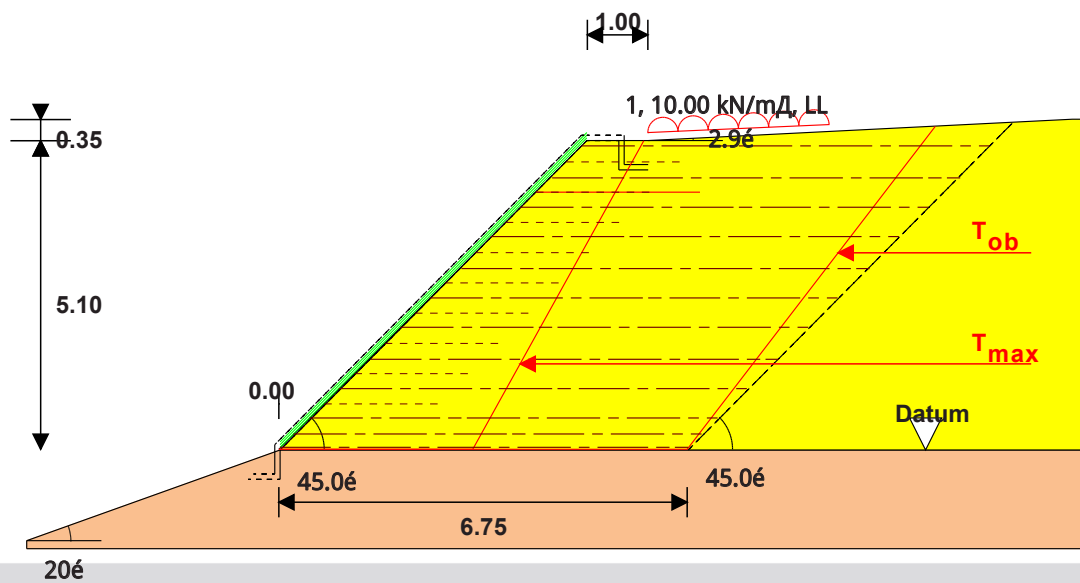
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Input data and Section

Project: Hollingworth Gate, Littleborough



Tensar Structural Systems **TensarTech** NaturalGreen System

Static loading case

All dimensions in metres

Scale 1:125

Fill/foundation properties

Design soil strength parameters are peak values

Soil zone	Drained/ undrained	c' (kN/m ²)	ϕ' (°)	γ_{bulk} (kN/m ³)
Reinforced fill	Drained	0.0	24.0	20.0
Retained fill	Drained	0.0	24.0	20.0
Foundation soil	Assumed to be competent			

Surcharges

No	Load acts from x (m)	To x (m)	Load (kN/m ²)	Temporary/Permanent
1	1.00	4.00	10	Temporary
2	11.00	20.00	75	Permanent

x coordinates are measured from the top of the reinforced fill block.

Water pressure data	Location	Height of water level above datum (m)	r_u
	In front of structure	No water pressures	
	Within fill	No water pressures	NA

Stability results	T_{ob} mechanism gives the minimum length of the base geogrid (m)		6.75
	T_{max} mechanism gives minimum length of theoretical top grid (m)		2.71
	Two-part wedge searches starting at various heights above the datum require percentage of available geogrid strength as shown	0.0 m	40.7%
		0.5 m	44.1%
		2.55 m	40.9%
		3.82 m	38.4%

Reinforcement layout Starting and finishing levels are related to datum	Tensar Geogrid	No of layers	Starting level (m)	Vertical spacing (m)	Finishing level (m)	Coverage (%)	f_b
	RE520	9	1.00	0.50	5.00	100	0.85
	RE520	2	0.25	0.25	0.50	100	0.85
	RE520	1	0.00	-	-	100	0.85

Secondary reinforcement layout	Tensar Geogrid	No of layers	Length (m)	Vertical spacing (m)
	TX150	9	2.00	0.250 m where primary spacing >0.250 m

Further information relevant to this Tensar Earth Retention System	Further information, specifications and bill of quantities descriptions for this TensarTechEarth Retaining Structure are given in the following documents which form part of this Design Analysis		System overview Installation guide Case histories Construction Animation Link
	The current versions of these documents may be found by following the website link to "Tensar Documentation" in the Help menu of the TensarSoil+ program		
	For program users who do not have a link to the internet contact your nearest Tensar representative or distributor	Tensar International Limited software@tensar.co.uk Web: www.tensar.co.uk	

Geogrid reinforcement design data

Geogrid design strength is calculated using the strengths and factors given below

Strength values quoted are per metre width of geogrid, and do not take into account percentage coverage

Design temperature (°C)		10	Design life (years)		60	Limit state		ULS
Maximum particle size of fill = 37.5mm								
Tensar geogrid	Creep rupture strength (kN/m)	Extrapolation of data	Installation damage	Weathering	Tensile resistance factor	Chemical and environmental effects	Design strength (kN/m)	Sliding coeff- icient
	T _{CR}	f _s	RF _{ID}	RF _W	f _m	RF _{CH}	T _{CR} /f _m f _n	f _{ds}
RE520	27.85	1.0	1.07	1.0	1.3	1.0	20.02	0.85

Grid coordinates

Levels are measured from the datum and horizontal location is measured from the toe of the wall

Tensar geogrid	Level	Left end	Right end	Length	Coverage	Pullout interaction factor f_b
	(m)	(m)	(m)	(m)	%	
RE520	5.000	5.000	11.750	6.750	100.0	0.850
RE520	4.500	4.500	11.250	6.750	100.0	0.850
RE520	4.000	4.000	10.750	6.750	100.0	0.850
RE520	3.500	3.500	10.250	6.750	100.0	0.850
RE520	3.000	3.000	9.750	6.750	100.0	0.850
RE520	2.500	2.500	9.250	6.750	100.0	0.850
RE520	2.000	2.000	8.750	6.750	100.0	0.850
RE520	1.500	1.500	8.250	6.750	100.0	0.850
RE520	1.000	1.000	7.750	6.750	100.0	0.850
RE520	0.500	0.500	7.250	6.750	100.0	0.850
RE520	0.250	0.250	7.000	6.750	100.0	0.850
RE520	0.000	0.000	6.750	6.750	100.0	0.850

T_{ob} and T_{max} Mechanisms

Check of two-part wedges in accordance with Section 3 of HA 68/94.

Minimum base width is determined by analysis of the T_{ob} mechanism.

Length of the upper geogrid determined from anchorage length behind T_{max} mechanism.

For T_{max} the critical case without reinforcement is unlikely to be the same as the critical case with reinforcement.

Co-ordinates are measured from the toe, x horizontal and y vertical

Inter-wedge friction in relation to design soil strength –'			0.5
Data	Mechanism		
	T _{ob}	T _{max}	
x at base (m)	0.000	0.000	
y at base (m)	0.000	0.000	
x at wedge junction (m)	6.750	3.206	
y at wedge junction (m)	0.000	0.000	
x at top (m)	10.851	6.033	
y at top (m)	5.337	5.100	
Weight Wedge1 W ₁ (kN/m)	210.5	198.9	
Weight Wedge2 W ₂ (kN/m)	428.6	102.8	
Surcharge Wedge1 Q ₁ (kN/m)	23.5	0.0	
Surcharge Wedge2 Q ₂ (kN/m)	0.0	0.0	
Pore water forces			
Base of wedge 1 U ₁	0.0	0.0	
Base of wedge 2 U ₂	0.0	0.0	
Inter-wedge U ₁₂	0.0	0.0	
External water forces (kN/m)			
Wedge 1, vertical U _{1v}	0.0	0.0	
Wedge 2, vertical U _{2v}	0.0	0.0	
Wedge 1, horizontal U _{1h}	0.0	0.0	
Wedge 2, horizontal U _{2h}	0.0	0.0	
Cohesion forces (kN/m)			
Wedge 1 K ₁	0.0	0.0	
Wedge 2 K ₂	0.0	0.0	
Inter-wedge K ₁₂	0.0	0.0	
Out of balance force (kN/m)	0.0	115.9	

Internal stability check

Check of two-part wedges in accordance with document HA 68/94.

Results are listed below for worst wedge at each level checked

Co-ordinates are measured from the toe, x horizontal and y vertical

Inter-wedge friction in relation to design soil strength –'				0.5
Data	Wedge base level (m)			
	0.000	0.500	2.550	3.825
x at base (m)	0.000	0.500	2.550	3.825
y at base (m)	0.000	0.500	2.550	3.825
x at wedge junction (m)	3.952	6.026	6.093	4.922
y at wedge junction (m)	1.059	4.740	4.807	4.280
x at top (m)	7.871	6.368	6.349	5.415
y at top (m)	5.188	5.113	5.112	5.100
Weight Wedge1 W_1 (kN/m)	143.3	1.2	0.8	6.9
Weight Wedge2 W_2 (kN/m)	114.3	62.5	35.7	7.1
Surcharge Wedge1 Q_1 (kN/m)	17.7	2.7	2.5	0.0
Surcharge Wedge2 Q_2 (kN/m)	0.0	0.0	0.0	0.0
Pore water forces				
Base of wedge1 U_1	0.0	0.0	0.0	0.0
Base of wedge2 U_2	0.0	0.0	0.0	0.0
Inter-wedge U_{12}	0.0	0.0	0.0	0.0
External water forces (kN/m)				
Wedge 1, vertical U_{1v}	0.0	0.0	0.0	0.0
Wedge 2, vertical U_{2v}	0.0	0.0	0.0	0.0
Wedge 1, horizontal U_{1h}	0.0	0.0	0.0	0.0
Wedge 2, horizontal U_{2h}	0.0	0.0	0.0	0.0
Cohesion forces (kN/m)				
Wedge 1 K_1	0.0	0.0	0.0	0.0
Wedge 2 K_2	0.0	0.0	0.0	0.0
Inter-wedge K_{12}	0.0	0.0	0.0	0.0
Reinforcement forces (kN/m)				
Base of wedge 1 T_1	144.6	7.5	3.4	12.9
Base of wedge 2 T_2	37.3	46.2	23.0	3.1
Inter-wedge T_{12}	67.2	3.8	3.2	3.7
Grid layout adequate?	YES	YES	YES	YES

Client: Vistry

Project: Hollingworth Gate, Littleborough

Tensar
Structural Systems

TensarTech
NaturalGreen System



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**Method of
analysis**

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GRO-23131

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2 Jun 2023

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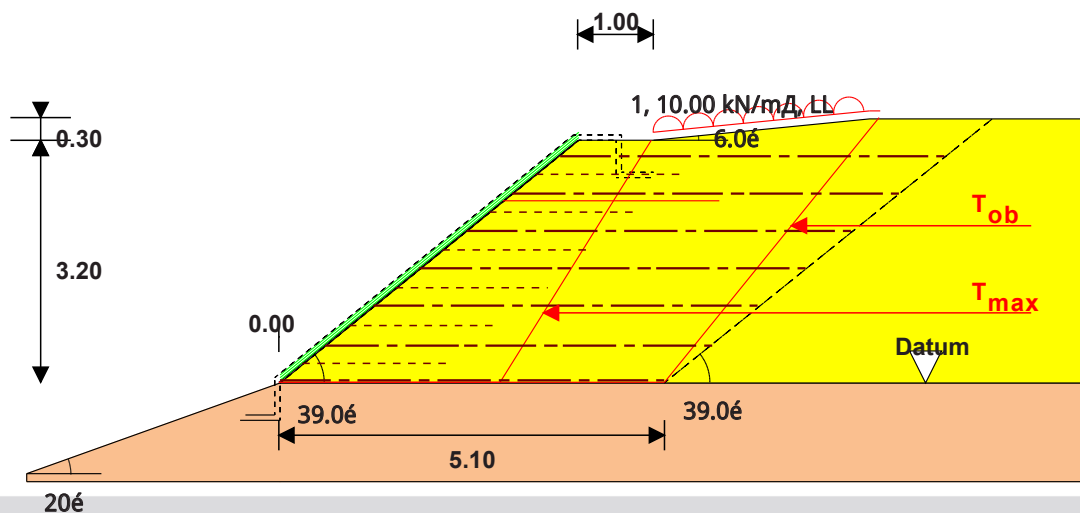
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Input data and Section

Project: Hollingworth Gate, Littleborough



Tensar Structural Systems **TensarTech** NaturalGreen System

Static loading case

All dimensions in metres

Scale 1:100

Fill/foundation properties

Design soil strength parameters are peak values

Soil zone	Drained/ undrained	c' (kN/m ²)	ϕ' (°)	γ_{bulk} (kN/m ³)
Reinforced fill	Drained	0.0	24.0	20.0
Retained fill	Drained	0.0	24.0	20.0
Foundation soil	Assumed to be competent			

Surcharges

No	Load acts from x (m)	To x (m)	Load (kN/m ²)	Temporary/Permanent
1	1.00	4.00	10	Temporary
2	11.80	21.00	75	Permanent

x coordinates are measured from the top of the reinforced fill block.

Water pressure data	Location	Height of water level above datum (m)	r_u
	In front of structure	No water pressures	
	Within fill	No water pressures	NA

Stability results	T_{ob} mechanism gives the minimum length of the base geogrid (m)		5.1
	T_{max} mechanism gives minimum length of theoretical top grid (m)		2.86
	Two-part wedge searches starting at various heights above the datum require percentage of available geogrid strength as shown	0.0 m	40.7%
		0.8 m	35.1%
		1.6 m	38.6%
		2.4 m	34.4%

Reinforcement layout Starting and finishing levels are related to datum	Tensar Geogrid	No of layers	Starting level (m)	Vertical spacing (m)	Finishing level (m)	Coverage (%)	f_b
	RE520	6	0.50	0.50	3.00	100	0.85
	RE520	1	0.00	-	-	100	0.85

Secondary reinforcement layout	Tensar Geogrid	No of layers	Length (m)	Vertical spacing (m)
	TX150	6	2.00	0.250 m where primary spacing >0.250 m

Further information relevant to this Tensar Earth Retention System	Further information, specifications and bill of quantities descriptions for this TensarTechEarth Retaining Structure are given in the following documents which form part of this Design Analysis		System overview Installation guide Case histories Construction Animation Link
	The current versions of these documents may be found by following the website link to "Tensar Documentation" in the Help menu of the TensarS oil+ program		
	For program users who do not have a link to the internet contact your nearest Tensar representative or distributor	Tensar International Limited software@tensar.co.uk Web: www.tensar.co.uk	

Geogrid reinforcement design data

Geogrid design strength is calculated using the strengths and factors given below

Strength values quoted are per metre width of geogrid, and do not take into account percentage coverage

Design temperature (°C)		10	Design life (years)		60	Limit state	ULS	
Maximum particle size of fill = 37.5mm								
Tensar geogrid	Creep rupture strength (kN/m)	Extrapolation of data	Installation damage	Weathering	Tensile resistance factor	Chemical and environmental effects	Design strength (kN/m)	Sliding coeff- icient
	T _{CR}	f _s	RF _{ID}	RF _W	f _m	RF _{CH}	T _{CR} /f _m f _n	f _{ds}
RE520	27.85	1.0	1.07	1.0	1.3	1.0	20.02	0.85

Grid coordinates

Levels are measured from the datum and horizontal location is measured from the toe of the wall

Tensar geogrid	Level	Left end	Right end	Length	Coverage	Pullout interaction factor f_b
	(m)	(m)	(m)	(m)	%	
RE520	3.000	3.705	8.805	5.100	100.0	0.850
RE520	2.500	3.087	8.187	5.100	100.0	0.850
RE520	2.000	2.470	7.570	5.100	100.0	0.850
RE520	1.500	1.852	6.952	5.100	100.0	0.850
RE520	1.000	1.235	6.335	5.100	100.0	0.850
RE520	0.500	0.617	5.717	5.100	100.0	0.850
RE520	0.000	0.000	5.100	5.100	100.0	0.850

T_{ob} and T_{max} Mechanisms

Check of two-part wedges in accordance with Section 3 of HA 68/94.

Minimum base width is determined by analysis of the T_{ob} mechanism.

Length of the upper geogrid determined from anchorage length behind T_{max} mechanism.

For T_{max} the critical case without reinforcement is unlikely to be the same as the critical case with reinforcement.

Co-ordinates are measured from the toe, x horizontal and y vertical

Inter-wedge friction in relation to design soil strength –'			0.5
Data	Mechanism		
	T _{ob}	T _{max}	
x at base (m)	0.000	0.000	
y at base (m)	0.000	0.000	
x at wedge junction (m)	5.100	2.926	
y at wedge junction (m)	0.000	0.000	
x at top (m)	7.938	4.925	
y at top (m)	3.500	3.200	
Weight Wedge1 W ₁ (kN/m)	91.6	102.8	
Weight Wedge2 W ₂ (kN/m)	200.0	69.3	
Surcharge Wedge1 Q ₁ (kN/m)	28.4	0.0	
Surcharge Wedge2 Q ₂ (kN/m)	0.0	0.0	
Pore water forces			
Base of wedge 1 U ₁	0.0	0.0	
Base of wedge 2 U ₂	0.0	0.0	
Inter-wedge U ₁₂	0.0	0.0	
External water forces (kN/m)			
Wedge 1, vertical U _{1v}	0.0	0.0	
Wedge 2, vertical U _{2v}	0.0	0.0	
Wedge 1, horizontal U _{1h}	0.0	0.0	
Wedge 2, horizontal U _{2h}	0.0	0.0	
Cohesion forces (kN/m)			
Wedge 1 K ₁	0.0	0.0	
Wedge 2 K ₂	0.0	0.0	
Inter-wedge K ₁₂	0.0	0.0	
Out of balance force (kN/m)	0.0	47.6	

Internal stability check

Check of two-part wedges in accordance with document HA 68/94.

Results are listed below for worst wedge at each level checked

Co-ordinates are measured from the toe, x horizontal and y vertical

Inter-wedge friction in relation to design soil strength –'				0.5
Data	Wedge base level (m)			
	0.000	0.800	1.600	2.400
x at base (m)	0.000	0.988	1.976	2.964
y at base (m)	0.000	0.800	1.600	2.400
x at wedge junction (m)	3.796	4.004	3.556	3.911
y at wedge junction (m)	2.288	2.652	2.290	2.774
x at top (m)	4.323	4.353	4.159	4.221
y at top (m)	3.200	3.200	3.200	3.200
Weight Wedge1 W_1 (kN/m)	8.8	3.8	7.8	2.5
Weight Wedge2 W_2 (kN/m)	29.9	17.8	9.3	3.7
Surcharge Wedge1 Q_1 (kN/m)	0.0	0.0	0.0	0.0
Surcharge Wedge2 Q_2 (kN/m)	0.0	0.0	0.0	0.0
Pore water forces				
Base of wedge1 U_1	0.0	0.0	0.0	0.0
Base of wedge2 U_2	0.0	0.0	0.0	0.0
Inter-wedge U_{12}	0.0	0.0	0.0	0.0
External water forces (kN/m)				
Wedge 1, vertical U_{1v}	0.0	0.0	0.0	0.0
Wedge 2, vertical U_{2v}	0.0	0.0	0.0	0.0
Wedge 1, horizontal U_{1h}	0.0	0.0	0.0	0.0
Wedge 2, horizontal U_{2h}	0.0	0.0	0.0	0.0
Cohesion forces (kN/m)				
Wedge 1 K_1	0.0	0.0	0.0	0.0
Wedge 2 K_2	0.0	0.0	0.0	0.0
Inter-wedge K_{12}	0.0	0.0	0.0	0.0
Reinforcement forces (kN/m)				
Base of wedge 1 T_1	16.8	6.5	13.0	2.6
Base of wedge 2 T_2	17.8	13.6	4.3	2.8
Inter-wedge T_{12}	7.1	3.1	3.7	2.2
Grid layout adequate?	YES	YES	YES	YES

Client: Vistry

Project: Hollingworth Gate, Littleborough

Tensar
Structural Systems

TensarTech
NaturalGreen System



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Tensar is a registered trademark.

**Method of
analysis**

The Tensar 2-part Wedge Slope Design Method is based on the 2-part wedge calculation procedure described in Advice Note HA68/94 "Design Methods for the Reinforcement of Highway Slopes by Reinforced Soil and Soil Nailing Techniques" (Design Manual for Roads and Bridges, Volume 4, Section 1, Part 4, now withdrawn). Partial material factors are applied to the soil strength and the resistance provided by the geogrid reinforcement.

Reference

GRO-23131

Date

2 Jun 2023

Page

1 of 6

Design analysis
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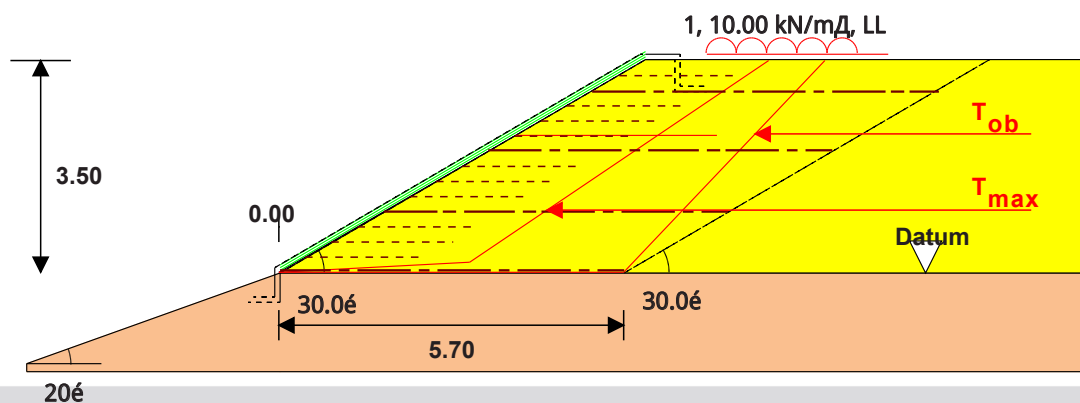
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Input data and Section

Project: Hollingworth Gate, Littleborough



Tensar Structural Systems **TensarTech** NaturalGreen System

Static loading case

All dimensions in metres

Scale 1:125

Fill/foundation properties

Design soil strength parameters are peak values

Soil zone	Drained/ undrained	c' (kN/m ²)	φ' (°)	γ _{bulk} (kN/m ³)
Reinforced fill	Drained	0.0	24.0	20.0
Retained fill	Drained	0.0	24.0	20.0
Foundation soil	Assumed to be competent			

Surcharges

No	Load acts from x (m)	To x (m)	Load (kN/m ²)	Temporary/Permanent
1	1.00	4.00	10	Temporary

x coordinates are measured from the top of the reinforced fill block.

Water pressure data

Location	Height of water level above datum (m)	r _u
In front of structure	No water pressures	
Within fill	No water pressures	NA

Reference

GRO-23131

Date

2 Jun 2023

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Stability results	T _{ob} mechanism gives the minimum length of the base geogrid (m)		5.7
	T _{max} mechanism gives minimum length of theoretical top grid (m)		3.32
	Two-part wedge searches starting at various heights above the datum require percentage of available geogrid strength as shown	0.0 m	40.2%
		0.88 m	31.6%
		1.75 m	23.4%
		2.63 m	18.6%

Reinforcement layout Starting and finishing levels are related to datum	Tensar Geogrid	No of layers	Starting level (m)	Vertical spacing (m)	Finishing level (m)	Coverage (%)	f _b
	RE520	3	1.00	1.00	3.00	100	0.85
	RE520	1	0.00	-	-	100	0.85

Secondary reinforcement layout	Tensar Geogrid	No of layers	Length (m)	Vertical spacing (m)
	TX150	10	2.00	0.250 m where primary spacing >0.250 m

Further information relevant to this Tensar Earth Retention System	Further information, specifications and bill of quantities descriptions for this TensarTechEarth Retaining Structure are given in the following documents which form part of this Design Analysis		System overview Installation guide Case histories Construction Animation Link
	The current versions of these documents may be found by following the website link to "Tensar Documentation" in the Help menu of the TensarSoil+ program		
	For program users who do not have a link to the internet contact your nearest Tensar representative or distributor	Tensar International Limited software@tensar.co.uk Web: www.tensar.co.uk	

Geogrid reinforcement design data

Geogrid design strength is calculated using the strengths and factors given below

Strength values quoted are per metre width of geogrid, and do not take into account percentage coverage

Design temperature (°C)		10	Design life (years)		60	Limit state		ULS
Maximum particle size of fill = 37.5mm								
Tensar geogrid	Creep rupture strength (kN/m)	Extrapolation of data	Installation damage	Weathering	Tensile resistance factor	Chemical and environmental effects	Design strength (kN/m)	Sliding coeff-icent
	T _{CR}	f _s	RF _{ID}	RF _W	f _m	RF _{CH}	T _{CR} /f _m f _n	f _{ds}
RE520	27.85	1.0	1.07	1.0	1.3	1.0	20.02	0.85

Grid coordinates

Levels are measured from the datum and horizontal location is measured from the toe of the wall

Tensar geogrid	Level	Left end	Right end	Length	Coverage	Pullout interaction factor f_b
	(m)	(m)	(m)	(m)	%	
RE520	3.000	5.196	10.896	5.700	100.0	0.850
RE520	2.000	3.464	9.164	5.700	100.0	0.850
RE520	1.000	1.732	7.432	5.700	100.0	0.850
RE520	0.000	0.000	5.700	5.700	100.0	0.850

T_{ob} and T_{max} Mechanisms

Check of two-part wedges in accordance with Section 3 of HA 68/94.

Minimum base width is determined by analysis of the T_{ob} mechanism.

Length of the upper geogrid determined from anchorage length behind T_{max} mechanism.

For T_{max} the critical case without reinforcement is unlikely to be the same as the critical case with reinforcement.

Co-ordinates are measured from the toe, x horizontal and y vertical

Inter-wedge friction in relation to design soil strength –'			0.5
Data	Mechanism		
	T _{ob}	T _{max}	
x at base (m)	0.000	0.000	
y at base (m)	0.000	0.000	
x at wedge junction (m)	5.700	3.155	
y at wedge junction (m)	0.000	0.167	
x at top (m)	9.026	8.097	
y at top (m)	3.500	3.500	
Weight Wedge1 W ₁ (kN/m)	115.6	115.9	
Weight Wedge2 W ₂ (kN/m)	187.6	52.2	
Surcharge Wedge1 Q ₁ (kN/m)	19.6	10.4	
Surcharge Wedge2 Q ₂ (kN/m)	0.0	0.0	
Pore water forces			
Base of wedge 1 U ₁	0.0	0.0	
Base of wedge 2 U ₂	0.0	0.0	
Inter-wedge U ₁₂	0.0	0.0	
External water forces (kN/m)			
Wedge 1, vertical U _{1v}	0.0	0.0	
Wedge 2, vertical U _{2v}	0.0	0.0	
Wedge 1, horizontal U _{1h}	0.0	0.0	
Wedge 2, horizontal U _{2h}	0.0	0.0	
Cohesion forces (kN/m)			
Wedge 1 K ₁	0.0	0.0	
Wedge 2 K ₂	0.0	0.0	
Inter-wedge K ₁₂	0.0	0.0	
Out of balance force (kN/m)	0.0	17.7	

Internal stability check

Check of two-part wedges in accordance with document HA 68/94.

Results are listed below for worst wedge at each level checked

Co-ordinates are measured from the toe, x horizontal and y vertical

Inter-wedge friction in relation to design soil strength –'				0.5
Data	Wedge base level (m)			
	0.000	0.875	1.750	2.625
x at base (m)	0.000	1.516	3.031	4.547
y at base (m)	0.000	0.875	1.750	2.625
x at wedge junction (m)	2.560	4.336	6.099	5.787
y at wedge junction (m)	0.224	1.250	3.051	3.028
x at top (m)	7.905	8.008	6.489	6.276
y at top (m)	3.500	3.500	3.500	3.500
Weight Wedge1 W_1 (kN/m)	104.3	65.4	1.7	1.9
Weight Wedge2 W_2 (kN/m)	32.1	35.4	14.4	3.9
Surcharge Wedge1 Q_1 (kN/m)	8.4	9.5	0.0	0.0
Surcharge Wedge2 Q_2 (kN/m)	0.0	0.0	0.0	0.0
Pore water forces				
Base of wedge1 U_1	0.0	0.0	0.0	0.0
Base of wedge2 U_2	0.0	0.0	0.0	0.0
Inter-wedge U_{12}	0.0	0.0	0.0	0.0
External water forces (kN/m)				
Wedge 1, vertical U_{1v}	0.0	0.0	0.0	0.0
Wedge 2, vertical U_{2v}	0.0	0.0	0.0	0.0
Wedge 1, horizontal U_{1h}	0.0	0.0	0.0	0.0
Wedge 2, horizontal U_{2h}	0.0	0.0	0.0	0.0
Cohesion forces (kN/m)				
Wedge 1 K_1	0.0	0.0	0.0	0.0
Wedge 2 K_2	0.0	0.0	0.0	0.0
Inter-wedge K_{12}	0.0	0.0	0.0	0.0
Reinforcement forces (kN/m)				
Base of wedge 1 T_1	43.8	27.4	0.7	0.7
Base of wedge 2 T_2	0.0	3.7	8.2	3.6
Inter-wedge T_{12}	6.4	7.4	0.7	0.7
Grid layout adequate?	YES	YES	YES	YES

Client: Vistry

Project: Hollingworth Gate, Littleborough

Tensar
Structural Systems

TensarTech
NaturalGreen System



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Method of analysis

The Tensar 2-part Wedge Slope Design Method is based on the 2-part wedge calculation procedure described in Advice Note HA68/94 "Design Methods for the Reinforcement of Highway Slopes by Reinforced Soil and Soil Nailing Techniques" (Design Manual for Roads and Bridges, Volume 4, Section 1, Part 4, now withdrawn). Partial material factors are applied to the soil strength and the resistance provided by the geogrid reinforcement.

Reference

GRO-23131

Date

2 Jun 2023

Page

1 of 6

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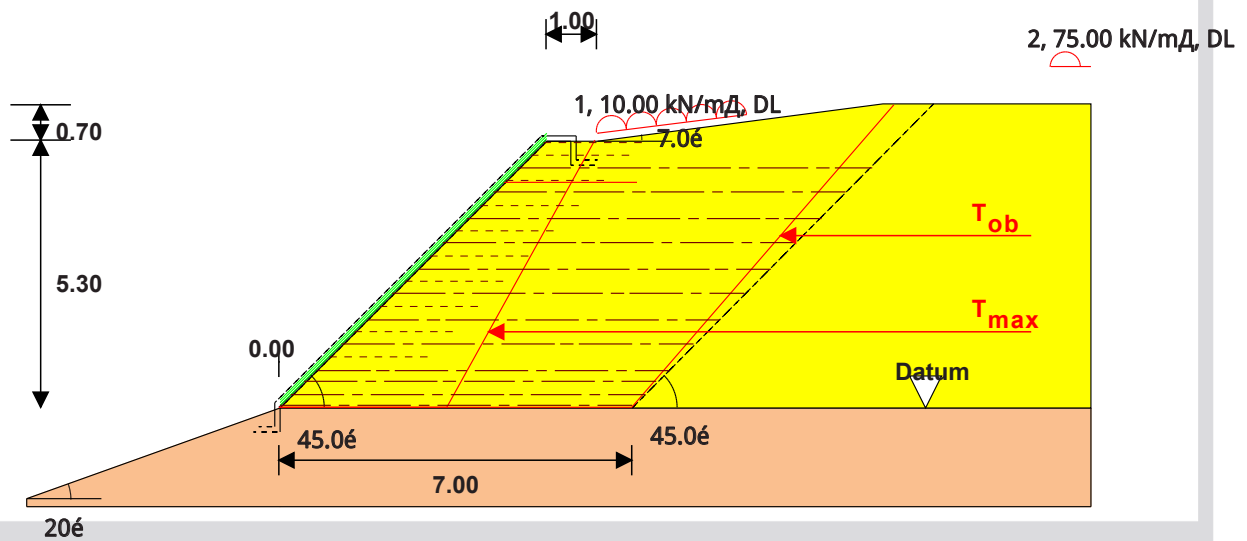
Orford Court, Greenfold Way

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Input data and Section

Project: Hollingworth Gate, Littleborough



Tensar Structural Systems **TensarTech** NaturalGreen System

Static loading case

All dimensions in metres

Scale 1:150

Fill/foundation properties

Design soil strength parameters are peak values

Soil zone	Drained/ undrained	c' (kN/m²)	φ' (°)	γ _{bulk} (kN/m³)
Reinforced fill	Drained	0.0	24.0	20.0
Retained fill	Drained	0.0	24.0	20.0
Foundation soil	Assumed to be competent			

Surcharges

No	Load acts from x (m)	To x (m)	Load (kN/m²)	Temporary/Permanent
1	1.00	4.00	10	Permanent
2	10.00	20.00	75	Permanent

x coordinates are measured from the top of the reinforced fill block.

Water pressure data	Location	Height of water level above datum (m)	r_u
	In front of structure	No water pressures	
	Within fill	No water pressures	NA

Stability results	T_{ob} mechanism gives the minimum length of the base geogrid (m)		7.0
	T_{max} mechanism gives minimum length of theoretical top grid (m)		2.64
	Two-part wedge searches starting at various heights above the datum require percentage of available geogrid strength as shown	0.0 m	42.3%
		0.75 m	49.3%
		2.65 m	43.5%
		3.98 m	38.3%

Reinforcement layout Starting and finishing levels are related to datum	Tensar Geogrid	No of layers	Starting level (m)	Vertical spacing (m)	Finishing level (m)	Coverage (%)	f_b
	RE520	8	1.25	0.50	4.75	100	0.85
	RE520	3	0.25	0.25	0.75	100	0.85
	RE520	1	0.00	-	-	100	0.85

Secondary reinforcement layout	Tensar Geogrid	No of layers	Length (m)	Vertical spacing (m)
	TX150	10	2.00	0.250 m where primary spacing >0.250 m

Further information relevant to this Tensar Earth Retention System	Further information, specifications and bill of quantities descriptions for this TensarTechEarth Retaining Structure are given in the following documents which form part of this Design Analysis		System overview Installation guide Case histories Construction Animation Link
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Geogrid reinforcement design data

Geogrid design strength is calculated using the strengths and factors given below

Strength values quoted are per metre width of geogrid, and do not take into account percentage coverage

Design temperature (°C)		10	Design life (years)		60	Limit state		ULS
Maximum particle size of fill = 37.5mm								
Tensar geogrid	Creep rupture strength (kN/m)	Extrapolation of data	Installation damage	Weathering	Tensile resistance factor	Chemical and environmental effects	Design strength (kN/m)	Sliding coeff-icient
	T _{CR}	f _s	RF _{ID}	RF _W	f _m	RF _{CH}	T _{CR} /f _m f _n	f _{ds}
RE520	27.85	1.0	1.07	1.0	1.3	1.0	20.02	0.85

Grid coordinates

Levels are measured from the datum and horizontal location is measured from the toe of the wall

Tensar geogrid	Level	Left end	Right end	Length	Coverage	Pullout interaction factor f_b
	(m)	(m)	(m)	(m)	%	
RE520	4.750	4.750	11.750	7.000	100.0	0.850
RE520	4.250	4.250	11.250	7.000	100.0	0.850
RE520	3.750	3.750	10.750	7.000	100.0	0.850
RE520	3.250	3.250	10.250	7.000	100.0	0.850
RE520	2.750	2.750	9.750	7.000	100.0	0.850
RE520	2.250	2.250	9.250	7.000	100.0	0.850
RE520	1.750	1.750	8.750	7.000	100.0	0.850
RE520	1.250	1.250	8.250	7.000	100.0	0.850
RE520	0.750	0.750	7.750	7.000	100.0	0.850
RE520	0.500	0.500	7.500	7.000	100.0	0.850
RE520	0.250	0.250	7.250	7.000	100.0	0.850
RE520	0.000	0.000	7.000	7.000	100.0	0.850

T_{ob} and T_{max} Mechanisms

Check of two-part wedges in accordance with Section 3 of HA 68/94.

Minimum base width is determined by analysis of the T_{ob} mechanism.

Length of the upper geogrid determined from anchorage length behind T_{max} mechanism.

For T_{max} the critical case without reinforcement is unlikely to be the same as the critical case with reinforcement.

Co-ordinates are measured from the toe, x horizontal and y vertical

Inter-wedge friction in relation to design soil strength –'			0.5
Data	Mechanism		
	T _{ob}	T _{max}	
x at base (m)	0.000	0.000	
y at base (m)	0.000	0.000	
x at wedge junction (m)	7.000	3.331	
y at wedge junction (m)	0.000	0.000	
x at top (m)	12.200	6.269	
y at top (m)	6.000	5.300	
Weight Wedge1 W ₁ (kN/m)	281.3	214.8	
Weight Wedge2 W ₂ (kN/m)	461.7	111.0	
Surcharge Wedge1 Q ₁ (kN/m)	23.0	0.0	
Surcharge Wedge2 Q ₂ (kN/m)	7.0	0.0	
Pore water forces			
Base of wedge 1 U ₁	0.0	0.0	
Base of wedge 2 U ₂	0.0	0.0	
Inter-wedge U ₁₂	0.0	0.0	
External water forces (kN/m)			
Wedge 1, vertical U _{1v}	0.0	0.0	
Wedge 2, vertical U _{2v}	0.0	0.0	
Wedge 1, horizontal U _{1h}	0.0	0.0	
Wedge 2, horizontal U _{2h}	0.0	0.0	
Cohesion forces (kN/m)			
Wedge 1 K ₁	0.0	0.0	
Wedge 2 K ₂	0.0	0.0	
Inter-wedge K ₁₂	0.0	0.0	
Out of balance force (kN/m)	0.0	125.2	

Internal stability check

Check of two-part wedges in accordance with document HA 68/94.

Results are listed below for worst wedge at each level checked

Co-ordinates are measured from the toe, x horizontal and y vertical

Inter-wedge friction in relation to design soil strength –'				0.5
Data	Wedge base level (m)			
	0.000	0.750	2.650	3.975
x at base (m)	0.000	0.750	2.650	3.975
y at base (m)	0.000	0.750	2.650	3.975
x at wedge junction (m)	4.381	6.481	5.515	5.552
y at wedge junction (m)	1.381	5.147	4.849	4.886
x at top (m)	9.215	6.680	5.894	5.900
y at top (m)	5.658	5.347	5.300	5.300
Weight Wedge1 W_1 (kN/m)	174.1	0.3	3.4	2.9
Weight Wedge2 W_2 (kN/m)	131.4	62.5	18.6	9.9
Surcharge Wedge1 Q_1 (kN/m)	29.2	2.0	0.0	0.0
Surcharge Wedge2 Q_2 (kN/m)	0.0	1.8	0.0	0.0
Pore water forces				
Base of wedge1 U_1	0.0	0.0	0.0	0.0
Base of wedge2 U_2	0.0	0.0	0.0	0.0
Inter-wedge U_{12}	0.0	0.0	0.0	0.0
External water forces (kN/m)				
Wedge 1, vertical U_{1v}	0.0	0.0	0.0	0.0
Wedge 2, vertical U_{2v}	0.0	0.0	0.0	0.0
Wedge 1, horizontal U_{1h}	0.0	0.0	0.0	0.0
Wedge 2, horizontal U_{2h}	0.0	0.0	0.0	0.0
Cohesion forces (kN/m)				
Wedge 1 K_1	0.0	0.0	0.0	0.0
Wedge 2 K_2	0.0	0.0	0.0	0.0
Inter-wedge K_{12}	0.0	0.0	0.0	0.0
Reinforcement forces (kN/m)				
Base of wedge 1 T_1	140.1	0.7	2.2	2.2
Base of wedge 2 T_2	49.4	46.6	17.3	7.5
Inter-wedge T_{12}	75.7	0.7	1.4	1.4
Grid layout adequate?	YES	YES	YES	YES

Client: Vistry

Project: Hollingsworth Gate, Littleborough

Tensar
Structural Systems

TensarTech
NaturalGreen System



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**Method of
analysis**

The Tensar 2-part Wedge Slope Design Method is based on the 2-part wedge calculation procedure described in Advice Note HA68/94 "Design Methods for the Reinforcement of Highway Slopes by Reinforced Soil and Soil Nailing Techniques" (Design Manual for Roads and Bridges, Volume 4, Section 1, Part 4, now withdrawn). Partial material factors are applied to the soil strength and the resistance provided by the geogrid reinforcement.

Reference

GRO-23131

Date

2 Jun 2023

Page

1 of 6

Design analysis
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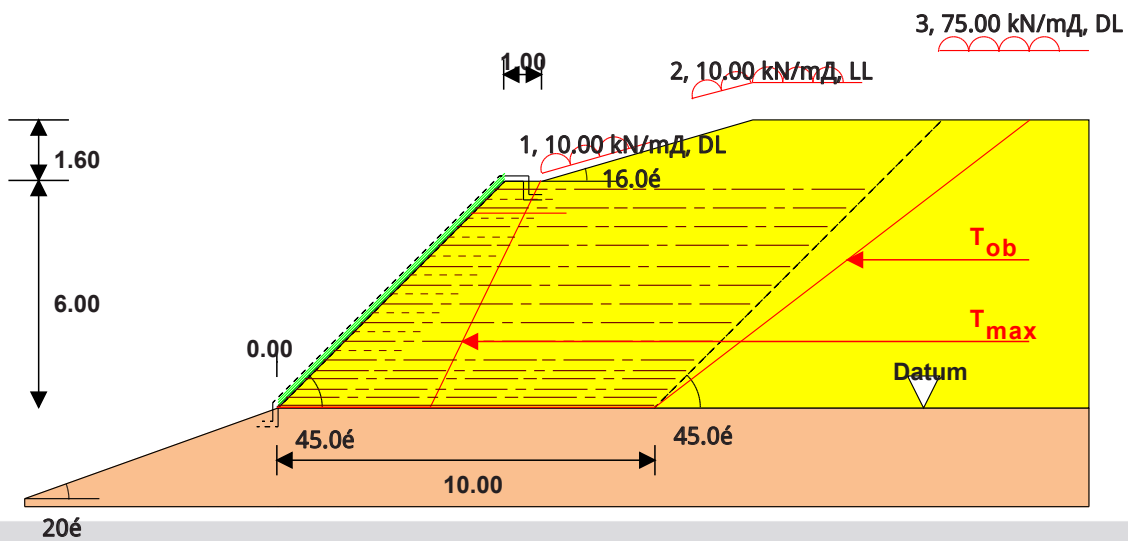
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Input data and Section

Project: Hollingsworth Gate, Littleborough



Tensar Structural Systems **TensarTech** NaturalGreen System

Static loading case

All dimensions in metres

Scale 1:200

Fill/foundation properties

Design soil strength parameters are peak values

Soil zone	Drained/ undrained	c' (kN/m ²)	φ' (°)	γ _{bulk} (kN/m ³)
Reinforced fill	Drained	0.0	24.0	20.0
Retained fill	Drained	0.0	24.0	20.0
Foundation soil	Assumed to be competent			

Surcharges

x coordinates are measured from the top of the reinforced fill block.

No	Load acts from x (m)	To x (m)	Load (kN/m ²)	Temporary/Permanent
1	1.00	4.00	10	Permanent
2	5.00	9.45	10	Temporary
3	11.50	21.50	75	Permanent

Water pressure data	Location	Height of water level above datum (m)	r_u
	In front of structure	No water pressures	
	Within fill	No water pressures	NA

Stability results	T_{ob} mechanism gives the minimum length of the base geogrid (m)		10.0
	T_{max} mechanism gives minimum length of theoretical top grid (m)		2.53
	Two-part wedge searches starting at various heights above the datum require percentage of available geogrid strength as shown	0.0 m	47.8%
		1.25 m	48.8%
		3.0 m	41.9%
		4.5 m	38.1%

Reinforcement layout Starting and finishing levels are related to datum	Tensar Geogrid	No of layers	Starting level (m)	Vertical spacing (m)	Finishing level (m)	Coverage (%)	f_b
	RE520	9	1.75	0.50	5.75	100	0.85
	RE520	5	0.25	0.25	1.25	100	0.85
	RE580	1	0.00	-	-	100	0.85

Secondary reinforcement layout	Tensar Geogrid	No of layers	Length (m)	Vertical spacing (m)
	TX150	9	2.00	0.250 m where primary spacing >0.250 m

Further information relevant to this Tensar Earth Retention System	Further information, specifications and bill of quantities descriptions for this TensarTechEarth Retaining Structure are given in the following documents which form part of this Design Analysis		System overview Installation guide Case histories Construction Animation Link
	The current versions of these documents may be found by following the website link to "Tensar Documentation" in the Help menu of the TensarS oil+ program		
	For program users who do not have a link to the internet contact your nearest Tensar representative or distributor	Tensar International Limited software@tensar.co.uk Web: www.tensar.co.uk	

Geogrid reinforcement design data

Geogrid design strength is calculated using the strengths and factors given below

Strength values quoted are per metre width of geogrid, and do not take into account percentage coverage

Design temperature (°C)		10	Design life (years)		60	Limit state		ULS
Maximum particle size of fill = 37.5mm								
Tensar geogrid	Creep rupture strength (kN/m)	Extrapolation of data	Installation damage	Weathering	Tensile resistance factor	Chemical and environmental effects	Design strength (kN/m)	Sliding coefficient
	T _{CR}	f _s	R _F _{ID}	R _F _W	f _m	R _F _{CH}	T _{CR} /f _m f _n	f _{ds}
RE520	27.85	1.0	1.07	1.0	1.3	1.0	20.02	0.85
RE580	72.41	1.0	1.0	1.0	1.3	1.0	55.70	0.85

Grid coordinates

Levels are measured from the datum and horizontal location is measured from the toe of the wall

Tensar geogrid	Level	Left end	Right end	Length	Coverage	Pullout interaction factor f_b
	(m)	(m)	(m)	(m)	%	
RE520	5.750	5.750	15.750	10.000	100.0	0.850
RE520	5.250	5.250	15.250	10.000	100.0	0.850
RE520	4.750	4.750	14.750	10.000	100.0	0.850
RE520	4.250	4.250	14.250	10.000	100.0	0.850
RE520	3.750	3.750	13.750	10.000	100.0	0.850
RE520	3.250	3.250	13.250	10.000	100.0	0.850
RE520	2.750	2.750	12.750	10.000	100.0	0.850
RE520	2.250	2.250	12.250	10.000	100.0	0.850
RE520	1.750	1.750	11.750	10.000	100.0	0.850
RE520	1.250	1.250	11.250	10.000	100.0	0.850
RE520	1.000	1.000	11.000	10.000	100.0	0.850
RE520	0.750	0.750	10.750	10.000	100.0	0.850
RE520	0.500	0.500	10.500	10.000	100.0	0.850
RE520	0.250	0.250	10.250	10.000	100.0	0.850
RE580	0.000	0.000	10.000	10.000	100.0	0.850

T_{ob} and T_{max} Mechanisms

Check of two-part wedges in accordance with Section 3 of HA 68/94.

Minimum base width is determined by analysis of the T_{ob} mechanism.

Length of the upper geogrid determined from anchorage length behind T_{max} mechanism.

For T_{max} the critical case without reinforcement is unlikely to be the same as the critical case with reinforcement.

Co-ordinates are measured from the toe, x horizontal and y vertical

Inter-wedge friction in relation to design soil strength –'			0.5
Data	Mechanism		
	T _{ob}	T _{max}	
x at base (m)	0.000	0.000	
y at base (m)	0.000	0.000	
x at wedge junction (m)	10.000	4.057	
y at wedge junction (m)	0.000	0.000	
x at top (m)	19.918	6.984	
y at top (m)	7.600	6.000	
Weight Wedge1 W ₁ (kN/m)	734.7	256.6	
Weight Wedge2 W ₂ (kN/m)	865.8	164.6	
Surcharge Wedge1 Q ₁ (kN/m)	225.9	0.0	
Surcharge Wedge2 Q ₂ (kN/m)	30.0	0.0	
Pore water forces			
Base of wedge 1 U ₁	0.0	0.0	
Base of wedge 2 U ₂	0.0	0.0	
Inter-wedge U ₁₂	0.0	0.0	
External water forces (kN/m)			
Wedge 1, vertical U _{1v}	0.0	0.0	
Wedge 2, vertical U _{2v}	0.0	0.0	
Wedge 1, horizontal U _{1h}	0.0	0.0	
Wedge 2, horizontal U _{2h}	0.0	0.0	
Cohesion forces (kN/m)			
Wedge 1 K ₁	0.0	0.0	
Wedge 2 K ₂	0.0	0.0	
Inter-wedge K ₁₂	0.0	0.0	
Out of balance force (kN/m)	0.0	157.2	

Internal stability check

Check of two-part wedges in accordance with document HA 68/94.

Results are listed below for worst wedge at each level checked

Co-ordinates are measured from the toe, x horizontal and y vertical

Inter-wedge friction in relation to design soil strength –'				0.5
Data	Wedge base level (m)			
	0.000	1.250	3.000	4.500
x at base (m)	0.000	1.250	3.000	4.500
y at base (m)	0.000	1.250	3.000	4.500
x at wedge junction (m)	3.810	4.107	6.936	5.997
y at wedge junction (m)	0.000	1.250	5.508	5.045
x at top (m)	14.080	12.689	7.525	6.571
y at top (m)	7.600	7.600	6.151	6.000
Weight Wedge1 W_1 (kN/m)	541.2	327.2	2.8	10.9
Weight Wedge2 W_2 (kN/m)	145.1	81.6	47.5	14.3
Surcharge Wedge1 Q_1 (kN/m)	60.8	46.9	5.3	0.0
Surcharge Wedge2 Q_2 (kN/m)	0.0	0.0	0.0	0.0
Pore water forces				
Base of wedge1 U_1	0.0	0.0	0.0	0.0
Base of wedge2 U_2	0.0	0.0	0.0	0.0
Inter-wedge U_{12}	0.0	0.0	0.0	0.0
External water forces (kN/m)				
Wedge 1, vertical U_{1v}	0.0	0.0	0.0	0.0
Wedge 2, vertical U_{2v}	0.0	0.0	0.0	0.0
Wedge 1, horizontal U_{1h}	0.0	0.0	0.0	0.0
Wedge 2, horizontal U_{2h}	0.0	0.0	0.0	0.0
Cohesion forces (kN/m)				
Wedge 1 K_1	0.0	0.0	0.0	0.0
Wedge 2 K_2	0.0	0.0	0.0	0.0
Inter-wedge K_{12}	0.0	0.0	0.0	0.0
Reinforcement forces (kN/m)				
Base of wedge 1 T_1	280.3	180.2	7.7	20.3
Base of wedge 2 T_2	0.0	0.0	31.0	3.8
Inter-wedge T_{12}	153.0	64.3	5.0	8.2
Grid layout adequate?	YES	YES	YES	YES

Client: Vistry

Project: Hollingsworth Gate, Littleborough

Tensar
Structural Systems

TensarTech
NaturalGreen System



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**Method of
analysis**

The Tensar 2-part Wedge Slope Design Method is based on the 2-part wedge calculation procedure described in Advice Note HA68/94 "Design Methods for the Reinforcement of Highway Slopes by Reinforced Soil and Soil Nailing Techniques" (Design Manual for Roads and Bridges, Volume 4, Section 1, Part 4, now withdrawn). Partial material factors are applied to the soil strength and the resistance provided by the geogrid reinforcement.

Reference

GRO-23131

Date

2 Jun 2023

Page

1 of 6

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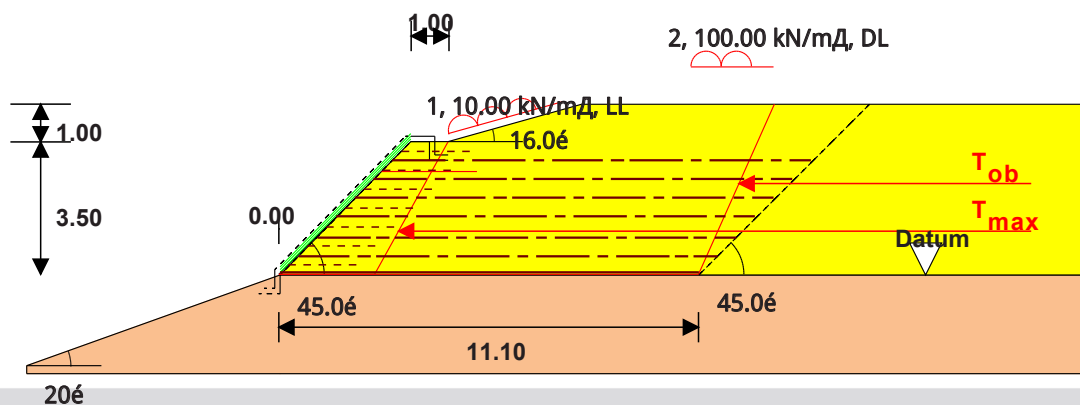
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Input data and Section

Project: Hollingsworth Gate, Littleborough



Tensar Structural Systems **TensarTech** NaturalGreen System

Static loading case

All dimensions in metres

Scale 1:200

Fill/foundation properties

Design soil strength parameters are peak values

Soil zone	Drained/ undrained	c' (kN/m²)	φ' (°)	γ _{bulk} (kN/m³)
Reinforced fill	Drained	0.0	24.0	20.0
Retained fill	Drained	0.0	24.0	20.0
Foundation soil	Assumed to be competent			

Surcharges

No	Load acts from x (m)	To x (m)	Load (kN/m²)	Temporary/Permanent
1	1.00	4.00	10	Temporary
2	7.40	9.60	100	Permanent

x coordinates are measured from the top of the reinforced fill block.

Water pressure data	Location	Height of water level above datum (m)	r_u
	In front of structure	No water pressures	
	Within fill	No water pressures	NA

Stability results	T_{ob} mechanism gives the minimum length of the base geogrid (m)		11.1
	T_{max} mechanism gives minimum length of theoretical top grid (m)		2.52
	Two-part wedge searches starting at various heights above the datum require percentage of available geogrid strength as shown	0.0 m	57.7%
		0.88 m	45.6%
		1.75 m	47.7%
		2.63 m	99.1%

Reinforcement layout Starting and finishing levels are related to datum	Tensar Geogrid	No of layers	Starting level (m)	Vertical spacing (m)	Finishing level (m)	Coverage (%)	f_b
	RE520	6	0.50	0.50	3.00	100	0.85
	RE580	1	0.00	-	-	100	0.85

Secondary reinforcement layout	Tensar Geogrid	No of layers	Length (m)	Vertical spacing (m)
	TX150	7	2.00	0.250 m where primary spacing >0.250 m

Further information relevant to this Tensar Earth Retention System	Further information, specifications and bill of quantities descriptions for this TensarTechEarth Retaining Structure are given in the following documents which form part of this Design Analysis		System overview Installation guide Case histories Construction Animation Link
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	For program users who do not have a link to the internet contact your nearest Tensar representative or distributor	Tensar International Limited software@tensar.co.uk Web: www.tensar.co.uk	

Geogrid reinforcement design data

Geogrid design strength is calculated using the strengths and factors given below

Strength values quoted are per metre width of geogrid, and do not take into account percentage coverage

Design temperature (°C)		10	Design life (years)		60	Limit state		ULS
Maximum particle size of fill = 37.5mm								
Tensar geogrid	Creep rupture strength (kN/m)	Extrapolation of data	Installation damage	Weathering	Tensile resistance factor	Chemical and environmental effects	Design strength (kN/m)	Sliding coeff-icent
	T _{CR}	f _s	RF _{ID}	RF _W	f _m	RF _{CH}	T _{CR} /f _m f _n	f _{ds}
RE520	27.85	1.0	1.07	1.0	1.3	1.0	20.02	0.85
RE580	72.41	1.0	1.0	1.0	1.3	1.0	55.70	0.85

Grid coordinates

Levels are measured from the datum and horizontal location is measured from the toe of the wall

Tensar geogrid	Level	Left end	Right end	Length	Coverage	Pullout interaction factor f_b
	(m)	(m)	(m)	(m)	%	
RE520	3.000	3.000	14.100	11.100	100.0	0.850
RE520	2.500	2.500	13.600	11.100	100.0	0.850
RE520	2.000	2.000	13.100	11.100	100.0	0.850
RE520	1.500	1.500	12.600	11.100	100.0	0.850
RE520	1.000	1.000	12.100	11.100	100.0	0.850
RE520	0.500	0.500	11.600	11.100	100.0	0.850
RE580	0.000	0.000	11.100	11.100	100.0	0.850

T_{ob} and T_{max} Mechanisms

Check of two-part wedges in accordance with Section 3 of HA 68/94.

Minimum base width is determined by analysis of the T_{ob} mechanism.

Length of the upper geogrid determined from anchorage length behind T_{max} mechanism.

For T_{max} the critical case without reinforcement is unlikely to be the same as the critical case with reinforcement.

Co-ordinates are measured from the toe, x horizontal and y vertical

Inter-wedge friction in relation to design soil strength –'			0.5
Data	Mechanism		
	T _{ob}	T _{max}	
x at base (m)	0.000	0.000	
y at base (m)	0.000	0.000	
x at wedge junction (m)	11.100	2.533	
y at wedge junction (m)	0.000	0.000	
x at top (m)	13.107	4.473	
y at top (m)	4.500	3.500	
Weight Wedge1 W ₁ (kN/m)	90.3	107.7	
Weight Wedge2 W ₂ (kN/m)	751.6	64.2	
Surcharge Wedge1 Q ₁ (kN/m)	200.0	0.0	
Surcharge Wedge2 Q ₂ (kN/m)	20.0	0.0	
Pore water forces			
Base of wedge 1 U ₁	0.0	0.0	
Base of wedge 2 U ₂	0.0	0.0	
Inter-wedge U ₁₂	0.0	0.0	
External water forces (kN/m)			
Wedge 1, vertical U _{1v}	0.0	0.0	
Wedge 2, vertical U _{2v}	0.0	0.0	
Wedge 1, horizontal U _{1h}	0.0	0.0	
Wedge 2, horizontal U _{2h}	0.0	0.0	
Cohesion forces (kN/m)			
Wedge 1 K ₁	0.0	0.0	
Wedge 2 K ₂	0.0	0.0	
Inter-wedge K ₁₂	0.0	0.0	
Out of balance force (kN/m)	0.0	59.9	

Internal stability check

Check of two-part wedges in accordance with document HA 68/94.

Results are listed below for worst wedge at each level checked

Co-ordinates are measured from the toe, x horizontal and y vertical

Inter-wedge friction in relation to design soil strength –'				0.5
Data	Wedge base level (m)			
	0.000	0.875	1.750	2.625
x at base (m)	0.000	0.875	1.750	2.625
y at base (m)	0.000	0.875	1.750	2.625
x at wedge junction (m)	10.909	4.995	10.881	10.916
y at wedge junction (m)	1.924	3.400	2.952	2.987
x at top (m)	12.959	5.686	12.226	12.231
y at top (m)	4.500	3.840	4.500	4.500
Weight Wedge1 W_1 (kN/m)	52.8	1.7	20.8	19.9
Weight Wedge2 W_2 (kN/m)	524.6	44.1	271.9	200.9
Surcharge Wedge1 Q_1 (kN/m)	204.9	6.9	132.6	131.5
Surcharge Wedge2 Q_2 (kN/m)	0.9	5.0	0.0	1.6
Pore water forces				
Base of wedge1 U_1	0.0	0.0	0.0	0.0
Base of wedge2 U_2	0.0	0.0	0.0	0.0
Inter-wedge U_{12}	0.0	0.0	0.0	0.0
External water forces (kN/m)				
Wedge 1, vertical U_{1v}	0.0	0.0	0.0	0.0
Wedge 2, vertical U_{2v}	0.0	0.0	0.0	0.0
Wedge 1, horizontal U_{1h}	0.0	0.0	0.0	0.0
Wedge 2, horizontal U_{2h}	0.0	0.0	0.0	0.0
Cohesion forces (kN/m)				
Wedge 1 K_1	0.0	0.0	0.0	0.0
Wedge 2 K_2	0.0	0.0	0.0	0.0
Inter-wedge K_{12}	0.0	0.0	0.0	0.0
Reinforcement forces (kN/m)				
Base of wedge 1 T_1	60.1	0.0	20.0	20.0
Base of wedge 2 T_2	60.8	29.6	37.3	0.0
Inter-wedge T_{12}	60.1	0.0	20.0	20.0
Grid layout adequate?	YES	YES	YES	YES

Client: Vistry

Project: Hollingsworth Gate, Littleborough

Tensar
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**Method of
analysis**

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Reference

GRO-23131

Date

8 Jun 2023

Page

1 of 6

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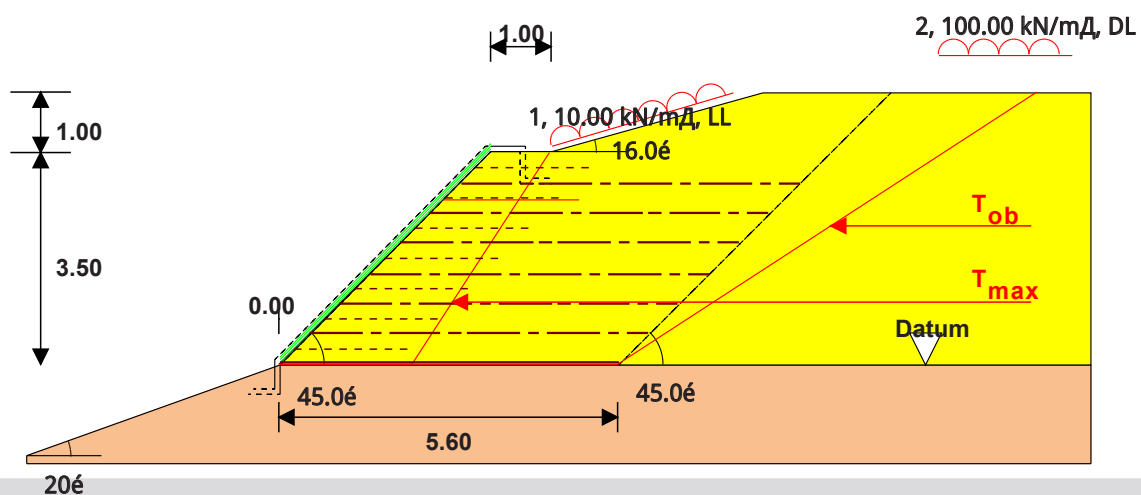
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Input data and Section

Project: Hollingsworth Gate, Littleborough



Tensar Structural Systems **TensarTech** NaturalGreen System

Static loading case

All dimensions in metres

Scale 1:125

Fill/foundation properties

Design soil strength parameters are peak values

Soil zone	Drained/ undrained	c' (kN/m²)	φ' (°)	γ _{bulk} (kN/m³)
Reinforced fill	Drained	0.0	26.0	20.0
Retained fill	Drained	0.0	26.0	20.0
Foundation soil	Assumed to be competent			

Surcharges

No	Load acts from x (m)	To x (m)	Load (kN/m²)	Temporary/Permanent
1	1.00	4.00	10	Temporary
2	7.40	9.60	100	Permanent

x coordinates are measured from the top of the reinforced fill block.

Water pressure data	Location	Height of water level above datum (m)	r_u
	In front of structure	No water pressures	
	Within fill	No water pressures	NA

Stability results	T_{ob} mechanism gives the minimum length of the base geogrid (m)		5.6
	T_{max} mechanism gives minimum length of theoretical top grid (m)		2.25
	Two-part wedge searches starting at various heights above the datum require percentage of available geogrid strength as shown	0.0 m	42.7%
		0.88 m	39.1%
		1.75 m	37.0%
		2.63 m	46.6%

Reinforcement layout Starting and finishing levels are related to datum	Tensar Geogrid	No of layers	Starting level (m)	Vertical spacing (m)	Finishing level (m)	Coverage (%)	f_b
	RE520	6	0.50	0.50	3.00	100	0.85
	RE580	1	0.00	-	-	100	0.85

Secondary reinforcement layout	Tensar Geogrid	No of layers	Length (m)	Vertical spacing (m)
	TX150	7	2.00	0.250 m where primary spacing >0.250 m

Further information relevant to this Tensar Earth Retention System	Further information, specifications and bill of quantities descriptions for this TensarTechEarth Retaining Structure are given in the following documents which form part of this Design Analysis		System overview Installation guide Case histories Construction Animation Link
	The current versions of these documents may be found by following the website link to "Tensar Documentation" in the Help menu of the TensarS oil+ program		
	For program users who do not have a link to the internet contact your nearest Tensar representative or distributor	Tensar International Limited software@tensar.co.uk Web: www.tensar.co.uk	

Geogrid reinforcement design data

Geogrid design strength is calculated using the strengths and factors given below

Strength values quoted are per metre width of geogrid, and do not take into account percentage coverage

Design temperature (°C)		10	Design life (years)		60	Limit state		ULS
Maximum particle size of fill = 75mm								
Tensar geogrid	Creep rupture strength (kN/m)	Extrapolation of data	Installation damage	Weathering	Tensile resistance factor	Chemical and environmental effects	Design strength (kN/m)	Sliding coefficient
	T _{CR}	f _s	R _{F ID}	R _{F W}	f _m	R _{F CH}	T _{CR} /f _m f _n	f _{ds}
RE520	27.85	1.0	1.25	1.0	1.3	1.0	17.14	0.85
RE580	72.41	1.0	1.06	1.0	1.3	1.0	52.55	0.85

Grid coordinates

Levels are measured from the datum and horizontal location is measured from the toe of the wall

Tensar geogrid	Level	Left end	Right end	Length	Coverage	Pullout interaction factor f_b
	(m)	(m)	(m)	(m)	%	
RE520	3.000	3.000	8.600	5.600	100.0	0.850
RE520	2.500	2.500	8.100	5.600	100.0	0.850
RE520	2.000	2.000	7.600	5.600	100.0	0.850
RE520	1.500	1.500	7.100	5.600	100.0	0.850
RE520	1.000	1.000	6.600	5.600	100.0	0.850
RE520	0.500	0.500	6.100	5.600	100.0	0.850
RE580	0.000	0.000	5.600	5.600	100.0	0.850

T_{ob} and T_{max} Mechanisms

Check of two-part wedges in accordance with Section 3 of HA 68/94.

Minimum base width is determined by analysis of the T_{ob} mechanism.

Length of the upper geogrid determined from anchorage length behind T_{max} mechanism.

For T_{max} the critical case without reinforcement is unlikely to be the same as the critical case with reinforcement.

Co-ordinates are measured from the toe, x horizontal and y vertical

Inter-wedge friction in relation to design soil strength –'			0.5
Data	Mechanism		
	T _{ob}	T _{max}	
x at base (m)	0.000	0.000	
y at base (m)	0.000	0.000	
x at wedge junction (m)	5.600	2.200	
y at wedge junction (m)	0.000	0.000	
x at top (m)	12.529	4.473	
y at top (m)	4.500	3.500	
Weight Wedge1 W ₁ (kN/m)	295.5	112.7	
Weight Wedge2 W ₂ (kN/m)	273.0	48.4	
Surcharge Wedge1 Q ₁ (kN/m)	181.9	0.0	
Surcharge Wedge2 Q ₂ (kN/m)	0.0	0.0	
Pore water forces			
Base of wedge 1 U ₁	0.0	0.0	
Base of wedge 2 U ₂	0.0	0.0	
Inter-wedge U ₁₂	0.0	0.0	
External water forces (kN/m)			
Wedge 1, vertical U _{1v}	0.0	0.0	
Wedge 2, vertical U _{2v}	0.0	0.0	
Wedge 1, horizontal U _{1h}	0.0	0.0	
Wedge 2, horizontal U _{2h}	0.0	0.0	
Cohesion forces (kN/m)			
Wedge 1 K ₁	0.0	0.0	
Wedge 2 K ₂	0.0	0.0	
Inter-wedge K ₁₂	0.0	0.0	
Out of balance force (kN/m)	0.0	52.5	

Internal stability check

Check of two-part wedges in accordance with document HA 68/94.

Results are listed below for worst wedge at each level checked

Co-ordinates are measured from the toe, x horizontal and y vertical

Inter-wedge friction in relation to design soil strength –'				0.5
Data	Wedge base level (m)			
	0.000	0.875	1.750	2.625
x at base (m)	0.000	0.875	1.750	2.625
y at base (m)	0.000	0.875	1.750	2.625
x at wedge junction (m)	4.561	4.549	3.954	3.535
y at wedge junction (m)	3.400	3.215	3.154	3.002
x at top (m)	4.806	5.170	4.244	3.939
y at top (m)	3.588	3.692	3.500	3.500
Weight Wedge1 W_1 (kN/m)	0.3	1.9	2.0	4.0
Weight Wedge2 W_2 (kN/m)	41.7	38.0	15.6	4.8
Surcharge Wedge1 Q_1 (kN/m)	2.4	6.2	0.0	0.0
Surcharge Wedge2 Q_2 (kN/m)	0.6	0.5	0.0	0.0
Pore water forces				
Base of wedge1 U_1	0.0	0.0	0.0	0.0
Base of wedge2 U_2	0.0	0.0	0.0	0.0
Inter-wedge U_{12}	0.0	0.0	0.0	0.0
External water forces (kN/m)				
Wedge 1, vertical U_{1v}	0.0	0.0	0.0	0.0
Wedge 2, vertical U_{2v}	0.0	0.0	0.0	0.0
Wedge 1, horizontal U_{1h}	0.0	0.0	0.0	0.0
Wedge 2, horizontal U_{2h}	0.0	0.0	0.0	0.0
Cohesion forces (kN/m)				
Wedge 1 K_1	0.0	0.0	0.0	0.0
Wedge 2 K_2	0.0	0.0	0.0	0.0
Inter-wedge K_{12}	0.0	0.0	0.0	0.0
Reinforcement forces (kN/m)				
Base of wedge 1 T_1	0.0	0.7	0.7	0.7
Base of wedge 2 T_2	31.8	27.5	11.6	4.5
Inter-wedge T_{12}	0.0	0.7	0.7	0.7
Grid layout adequate?	YES	YES	YES	YES

Client: Vistry

Project: Hollingworth Gate, Littleborough

Tensar
Structural Systems

TensarTech
NaturalGreen System



This document contains Tensar Software Output which has been prepared by Groundtech Consulting Limited on a confidential basis, to enable the application of **Tensar** geogrids to be evaluated. The Tensar Software Output is merely illustrative and is not a detailed design. It is specific to the unique characteristics of the **Tensar** geogrids which are referenced within the calculations.

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Method of analysis

The Tensar 2-part Wedge Slope Design Method is based on the 2-part wedge calculation procedure described in Advice Note HA68/94 "Design Methods for the Reinforcement of Highway Slopes by Reinforced Soil and Soil Nailing Techniques" (Design Manual for Roads and Bridges, Volume 4, Section 1, Part 4, now withdrawn). Partial material factors are applied to the soil strength and the resistance provided by the geogrid reinforcement.

Reference

GRO-23131

Date

2 Jun 2023

Page

1 of 6

Design analysis
prepared by

Groundtech Consulting Limited

Telephone: **0161 8201368**

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Leigh

First Floor Lloyd House

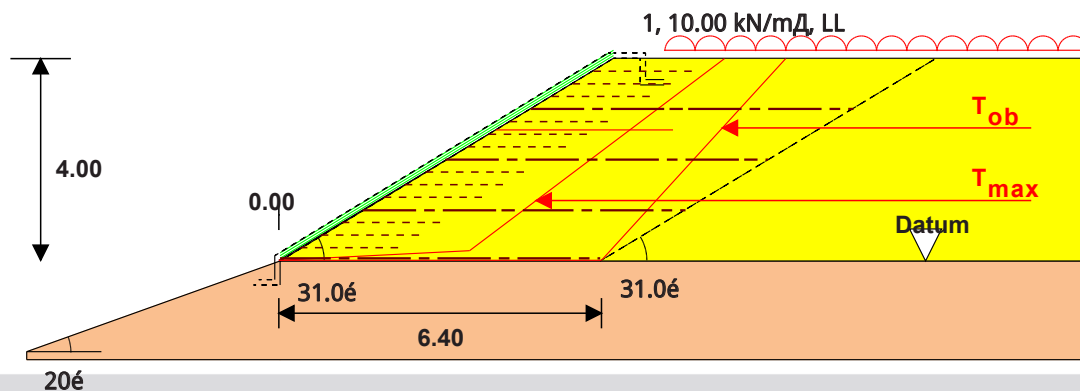
Orford Court, Greenfold Way

Leigh

WN7 3XJ

Input data and Section

Project: Hollingworth Gate, Littleborough



Tensar Structural Systems **TensarTech** NaturalGreen System

Static loading case

All dimensions in metres

Scale 1:150

Fill/foundation properties

Design soil strength parameters are peak values

Soil zone	Drained/ undrained	c' (kN/m ²)	φ' (°)	γ _{bulk} (kN/m ³)
Reinforced fill	Drained	0.0	24.0	20.0
Retained fill	Drained	0.0	24.0	20.0
Foundation soil	Assumed to be competent			

Surcharges

No	Load acts from x (m)	To x (m)	Load (kN/m ²)	Temporary/Permanent
1	1.00	11.00	10	Temporary

x coordinates are measured from the top of the reinforced fill block.

Water pressure data

Location	Height of water level above datum (m)	r _u
In front of structure	No water pressures	
Within fill	No water pressures	NA

Reference

GRO-23131

Date

2 Jun 2023

Page

2 of 6

Stability results	T _{ob} mechanism gives the minimum length of the base geogrid (m)		6.4
	T _{max} mechanism gives minimum length of theoretical top grid (m)		3.52
	Two-part wedge searches starting at various heights above the datum require percentage of available geogrid strength as shown	0.0 m	48.7%
		1.0 m	44.6%
		2.0 m	39.8%

Reinforcement layout Starting and finishing levels are related to datum	Tensar Geogrid	No of layers	Starting level (m)	Vertical spacing (m)	Finishing level (m)	Coverage (%)	f _b
	RE520	3	1.00	1.00	3.00	100	0.85
	RE520	1	0.00	-	-	100	0.85

Secondary reinforcement layout	Tensar Geogrid	No of layers	Length (m)	Vertical spacing (m)
	TX150	12	2.00	0.250 m where primary spacing >0.250 m

Further information relevant to this Tensar Earth Retention System	Further information, specifications and bill of quantities descriptions for this TensarTechEarth Retaining Structure are given in the following documents which form part of this Design Analysis		System overview Installation guide Case histories Construction Animation Link
	The current versions of these documents may be found by following the website link to "Tensar Documentation" in the Help menu of the TensarSoil+ program		
	For program users who do not have a link to the internet contact your nearest Tensar representative or distributor	Tensar International Limited software@tensar.co.uk Web: www.tensar.co.uk	

Geogrid reinforcement design data

Geogrid design strength is calculated using the strengths and factors given below

Strength values quoted are per metre width of geogrid, and do not take into account percentage coverage

Design temperature (°C)		10	Design life (years)		60	Limit state		ULS
Maximum particle size of fill = 37.5mm								
Tensar geogrid	Creep rupture strength (kN/m)	Extrapolation of data	Installation damage	Weathering	Tensile resistance factor	Chemical and environmental effects	Design strength (kN/m)	Sliding coeff-icient
	T _{CR}	f _s	RF _{ID}	RF _W	f _m	RF _{CH}	T _{CR} /f _m f _n	f _{ds}
RE520	27.85	1.0	1.07	1.0	1.3	1.0	20.02	0.85

Grid coordinates

Levels are measured from the datum and horizontal location is measured from the toe of the wall

Tensar geogrid	Level	Left end	Right end	Length	Coverage	Pullout interaction factor f_b
	(m)	(m)	(m)	(m)	%	
RE520	3.000	4.993	11.393	6.400	100.0	0.850
RE520	2.000	3.329	9.729	6.400	100.0	0.850
RE520	1.000	1.664	8.064	6.400	100.0	0.850
RE520	0.000	0.000	6.400	6.400	100.0	0.850

T_{ob} and T_{max} Mechanisms

Check of two-part wedges in accordance with Section 3 of HA 68/94.

Minimum base width is determined by analysis of the T_{ob} mechanism.

Length of the upper geogrid determined from anchorage length behind T_{max} mechanism.

For T_{max} the critical case without reinforcement is unlikely to be the same as the critical case with reinforcement.

Co-ordinates are measured from the toe, x horizontal and y vertical

Inter-wedge friction in relation to design soil strength -'		d	0.5
Data	Mechanism		
	T _{ob}	T _{max}	
x at base (m)	0.000	0.000	
y at base (m)	0.000	0.000	
x at wedge junction (m)	6.400	3.784	
y at wedge junction (m)	0.000	0.190	
x at top (m)	10.054	8.839	
y at top (m)	4.000	4.000	
Weight Wedge1 W ₁ (kN/m)	145.8	143.0	
Weight Wedge2 W ₂ (kN/m)	246.1	78.8	
Surcharge Wedge1 Q ₁ (kN/m)	24.0	11.8	
Surcharge Wedge2 Q ₂ (kN/m)	0.0	0.0	
Pore water forces			
Base of wedge 1 U ₁	0.0	0.0	
Base of wedge 2 U ₂	0.0	0.0	
Inter-wedge U ₁₂	0.0	0.0	
External water forces (kN/m)			
Wedge 1, vertical U _{1v}	0.0	0.0	
Wedge 2, vertical U _{2v}	0.0	0.0	
Wedge 1, horizontal U _{1h}	0.0	0.0	
Wedge 2, horizontal U _{2h}	0.0	0.0	
Cohesion forces (kN/m)			
Wedge 1 K ₁	0.0	0.0	
Wedge 2 K ₂	0.0	0.0	
Inter-wedge K ₁₂	0.0	0.0	
Out of balance force (kN/m)	0.0	25.0	

Internal stability check

Check of two-part wedges in accordance with document HA 68/94.

Results are listed below for worst wedge at each level checked

Co-ordinates are measured from the toe, x horizontal and y vertical

Inter-wedge friction in relation to design soil strength –'			0.5
Data	Wedge base level (m)		
	0.000	1.000	2.000
x at base (m)	0.000	1.664	3.329
y at base (m)	0.000	1.000	2.000
x at wedge junction (m)	2.133	3.798	6.347
y at wedge junction (m)	0.000	1.000	3.264
x at top (m)	8.661	8.693	7.045
y at top (m)	4.000	4.000	4.000
Weight Wedge1 W_1 (kN/m)	138.1	97.7	4.6
Weight Wedge2 W_2 (kN/m)	27.3	27.3	16.6
Surcharge Wedge1 Q_1 (kN/m)	10.0	10.4	0.0
Surcharge Wedge2 Q_2 (kN/m)	0.0	0.0	0.0
Pore water forces			
Base of wedge1 U_1	0.0	0.0	0.0
Base of wedge2 U_2	0.0	0.0	0.0
Inter-wedge U_{12}	0.0	0.0	0.0
External water forces (kN/m)			
Wedge 1, vertical U_{1v}	0.0	0.0	0.0
Wedge 2, vertical U_{2v}	0.0	0.0	0.0
Wedge 1, horizontal U_{1h}	0.0	0.0	0.0
Wedge 2, horizontal U_{2h}	0.0	0.0	0.0
Cohesion forces (kN/m)			
Wedge 1 K_1	0.0	0.0	0.0
Wedge 2 K_2	0.0	0.0	0.0
Inter-wedge K_{12}	0.0	0.0	0.0
Reinforcement forces (kN/m)			
Base of wedge 1 T_1	49.3	33.1	2.2
Base of wedge 2 T_2	0.0	0.0	6.7
Inter-wedge T_{12}	5.6	5.6	1.4
Grid layout adequate?	YES	YES	YES

4.0 CONSTRUCTION SEQUENCE

The following construction sequence has been provided by Tensar for the TensarTech NaturalGreen Earth Retaining Systems.

Installation Guideline for TensarTech® NaturalGreen™ Reinforced Embankment System



Introduction

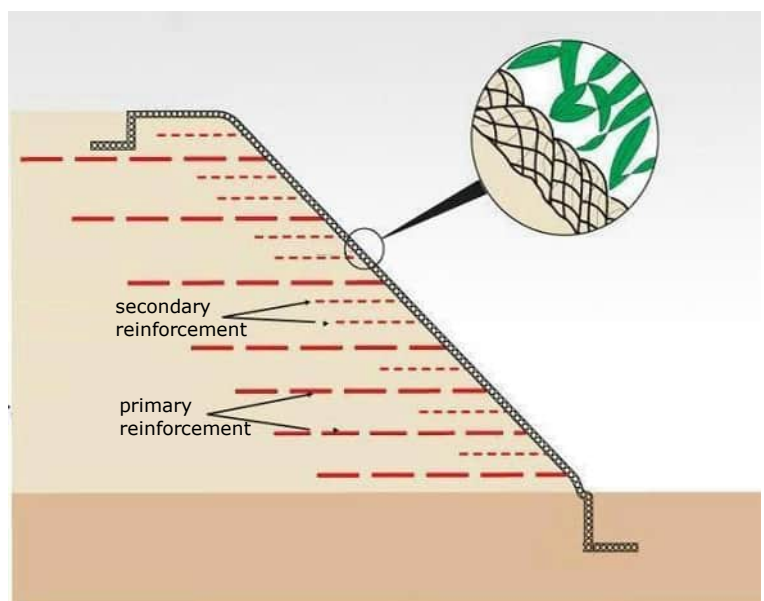
This Installation Guideline provides a step-by-step guide intended for use by contractors planning to construct a reinforced soil slope using TensarTech® NaturalGreen™ system.

TensarTech NaturalGreen System has been developed to provide engineers, architects and builders with an attractive and economical solution for the construction of embankments with a face slope angle up to 45° to the horizontal.

TensarTech NaturalGreen is one of a range of earth retaining systems available from Tensar International Limited, comprising proprietary Tensar uniaxial geogrid as primary reinforcement, TriAx® geogrid as secondary reinforcement and a rolled erosion control product secured with Tensar pegs.

Where applicable, the Contractor shall ensure that the installation fully complies with CDM Regulations 2015 and should refer to the Designer's Risk Assessment and COSHH statements.

The Tensar uniaxial geogrid for primary reinforcement are available in different strength grades identified by coloured banding. All supplied in 1.3m wide rolls either 50m or 75m long. TriAx geogrid for secondary reinforcement is supplied in 4m wide rolls 75m long. Both materials are supplied unwrapped and bound using coloured identifying tape. Both materials are UV protected and may be stored outside until use.



Typical section - TensarTech® NaturalGreen™ Slope

Rolled erosion control product can be supplied by Tensar depending on the project. A suitable erosion product is P300, supplied in rolls 35.0m long by 2.4m wide and comprising 100% UV stable polypropylene fibres incorporated between two layers of UV stable polypropylene netting. Erosion control materials are normally wrapped in polythene but should be stored in a cool dry place avoiding exposure to naked flame or spark, as they may be readily flammable, particularly bio-degradable erosion products comprising natural materials. They are vulnerable until installed and have had the opportunity to absorb moisture.

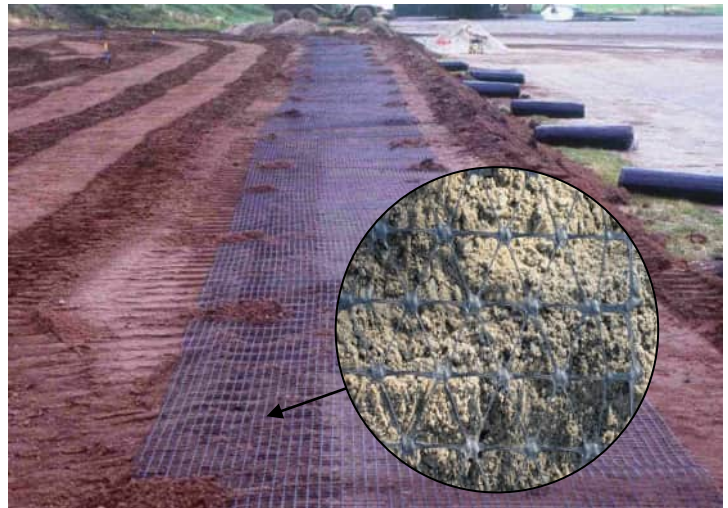
Tensar pegs to secure the rolled erosion control product are supplied in bags of 25 and may be stored outside if necessary.

Installation

1. The Contractor shall excavate to the lines and grades shown on the construction drawings and should take precautions to minimize over-excavation. Over-excavation should be filled with compacted approved infill material, or as directed by the Engineer.
2. Following the excavation, the foundation soil should be examined by the Engineer to assure actual foundation soil strength meets or exceeds the design bearing strength. Soils not meeting the required strength should be removed and replaced with infill soils, as directed.
3. Foundation soil shall be proof rolled and compacted then inspected by the Engineer prior to commencement of construction of the reinforced soil slopes.
4. Cut and position the base layer of Tensar uniaxial geogrid primary reinforcement at the formation level shown on the contract drawings. The uniaxial geogrid grades are identified by the letters RE and a number which will correspond with the geogrid layout shown on the construction drawing(s). The principle strength direction of the uniaxial geogrid is along the roll length and as such primary geogrid should be laid perpendicular to the slope face alignment.
5. Each geogrid reinforcement length shall be positioned to intercept the line of the final slope face at that elevation (after slope trim). Adjacent lengths of geogrid are butt jointed side-to-side at the slope face.
6. All geogrid should be installed to the levels, lengths and orientations as shown on the construction drawings.
7. Selected suitable fill material should be in full compliance with the needs of the design and have the approval of the engineer.
8. Place and compact the fill in layers as specified in the Contract Documents, incorporating primary reinforcement and secondary reinforcement as shown on the construction drawings.
9. The TriAx geogrid secondary reinforcement must be laid in the correct direction rolled out parallel to the slope face. The 4m wide rolls may be cut whilst still on the roll to widths corresponding with the construction drawing; normally 2m, but this must be checked.
10. Fill should be placed by plant such as an excavator with an opening bucket, which causes the fill to cascade onto the geogrid. A 150mm thick cover of fill must be maintained between the tracks of any plant and the geogrid to avoid damage to the geogrid.



11. The embankment may be overfilled, compacted and then trimmed to the final face slope profile in the conventional manner.
12. Use of a toothless excavator bucket is recommended for face trimming to prevent snagging on the edge of the buried geogrid. Although care should be taken not to over cut, the machine performing the face trim will not cause structural damage whilst performing this task.
13. On completion of the filling operation the slope surface should be covered with a minimum 100mm layer of suitable topsoil in accordance with BS3882, or as specified in the Contract Documents. Over-compaction of the topsoil should be avoided.
14. Where a grass cover is specified, scatter the chosen seed mix on to the slope at the specified rate per square metre.



TriAx geogrid secondary reinforcement cut from the roll 2m wide and rolled-out parallel to the slope face.

15. The rolled erosion control product should then be installed.

16. The rolled erosion control product is rolled down the slope face lapping adjacent rolls by a minimum of 100mm. Tensar pegs should be used to fix the rolled erosion control product at 1.0m centres along the laps by driving them into the soil using an appropriate rubber hammer. Rolled erosion control product must follow the slope profile and remain in contact with the underlying topsoil layer. Additional pinning and/or pinning of the centre of roll may be required.



17. Roll ends shall be buried at the shoulder and toe respectively in shallow trenches approximately 450mm wide by 250mm deep.

18. If specified, the slope may be planted with a suitable ground cover plant species as per the Contract Documents. The rolled erosion control product should be slit to allow the chosen plants pushed through the product into the topsoil below.

19. Care should be taken at this stage when using biodegradable rolled erosion control products to avoid exposure to naked flame or spark, as the product may be flammable until it has had the opportunity to absorb moisture.

20. The Contractor must fully assess the safety risk associated with working on the slope and at height and where appropriate install any necessary temporary edge protection and provide operatives with the appropriate safety equipment.

Notes

The contractor is responsible for checking slope geometry during construction and taking necessary action to ensure that tolerance are met in accordance with Tensar recommendations.

For cellular confinement erosion control products this construction sequence should be read in conjunction with IG_NaturalGreen_Cellular.

Please refer to Tensar International Limited if more specific advice is required.

This document was formerly published with the reference:CS/NaturalGreen

The information in this document supersedes any and all prior Construction Sequences for the products/system designated above and is supplied by Tensar International Limited without charge. Tensar International Limited excludes to the fullest extent lawfully permitted any and all liability whatsoever for any loss or damage howsoever arising out of the use of and reliance upon this information. It is your sole responsibility and you must assume all risk and liability for the final determination as to the suitability of any Tensar International Limited product and/or design for the use and in the manner contemplated by you in connection with a particular project.

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Applicable to Tensar International
and Tensar Manufacturing Ltd



Cert – EMS06463
Applicable to Tensar Manufacturing Ltd

5.0 PRODUCT SPECIFICATION

The following product specification has been provided by Tensar for the RE520 GeoGrid and TX150 Grid which is being utilised for the retaining slope design.

TensarTech® NaturalGreen™ Earth Retaining Structures: Model Specification

This document is intended to form a basis for Tender documents where the TensarTech® NaturalGreen™ reinforced soil system is required.

1. GENERAL

This work shall consist of constructing reinforced soil steep slopes (often referred to as strengthened embankments) typically using a proprietary system, constructed in accordance with the suppliers drawings and specifications and in conformity with the alignment, grades and dimensions shown on the contract documents or as established by the Engineer. Where necessary the Contractor shall provide complete set of drawings issued for construction, design calculations and complete specifications of the proposed system for the approval of the Engineer 90 days prior construction. Any particular requirements of approved detailed specifications for the approved proprietary system shall override any conflicting or incompatible requirement contained within this section.

The proposed solution must demonstrate previous use for reinforced soil steep slopes with a minimum height of 20.0m and a minimum in service life of 20 years.

The soil reinforcement must have a current British Board of Agrément (BBA) HAPAS certificate, demonstrating suitability for use in highways structures with a minimum 60-year design life.

2. DESIGN

The design shall address the climatic and soil conditions existing in UK and the specifically the site in question and provide a minimum design life of 60 years. The specifications as presented to the Engineer shall state any requirements for or limitations on the backfill used in the structure to ensure the design life. The tender submission shall be accompanied by:

- A. A copy of the current BBA certificate
- B. Sample design calculations for the proposed slopes in compliance with HA68/94 or BS8006 as appropriate
- C. Soils test information of the proposed reinforced soil fill
- D. Method statement for construction
- E. Confirmation of the Professional Indemnity and Product Liability insurance cover provided by the Slope System Supplier

3. STANDARDS

The following standards and codes in their latest edition shall be particularly applied to work covered by this specification where applicable; together with any further standards or codes as described within the approved Specification for the approved reinforced soil slope system.

3.01 Geogrid Reinforcement

- | | | |
|---|------------------------------|--|
| A | ISO 2602: 1980 | Statistical Interpretation of Test Results |
| B | BS EN ISO 9001: 2000 | Quality Systems – Model for Quality Assurance in Production, design and development Installation & Servicing |
| C | BS 2782: Part 4 | Methods of Testing Plastics. Part 4: Chemical Properties |
| D | GRI GG2 - 87 | Geogrid Junction Strength |
| E | BS EN ISO 10321: 1996 | Geotextiles – Tensile Test for Joints-Seams by Wide-Width Method |
| F | BS EN ISO 10319: 1996 | Wide-Width Tensile Test |
| G | BS EN ISO 13431: 1999 | Geotextiles and geotextiles related products. Determination of tensile creep and creep rupture behaviour |

3.02 Soils

- | | | |
|---|---------------------|--|
| A | BS1377: 1990 | Moisture Density Relationship for Soils, Standard Method |
| B | BS1377: 1990 | Gradation of Soils |
| C | BS1377: 1990 | Atterberg Limits of Soil |
| D | BS1377: 1990 | Shear Box Test |
| E | BS3882: 1994 | Specification for topsoil |

4. MATERIALS

The slope system will comprise primary horizontal layers of uniaxially orientated high density polyethylene (HDPE) geogrids and secondary polypropylene geogrids with a rolled erosion control product for erosion protection to the slope face helping establish and reinforce the root system of the vegetation in the long-term.

4.01 Geogrid Reinforcement

4.01.1 Primary Geogrid reinforcement

- A. The primary reinforcing element shall be a geogrid manufactured in accordance with a Quality Management System which complies with the requirements of BS EN ISO 9001:2000. If required by the Engineer, the Contractor shall provide evidence that the manufacturer's Quality Assurance System has been certified to conform with BS EN ISO 9001:2000 by an external authenticating authority approved by the Department of Trade and Industry.
- B. The reinforcing element shall be a geogrid manufactured from high density polyethylene sheet, oriented in one direction so that the resulting ribs shall have a high degree of molecular orientation, which is continued through the integral transverse bar.
- C. The long term creep rupture strength P_C (Ultimate Limit State), for a design life of 60 or 120 years, shall be in accordance with the following table at a mean temperature for design country (10°C, 20°C or 30°C). This shall be determined by application of standard extrapolation techniques to creep data obtained in accordance with BS EN ISO 13431:1999 and shall be a lower bound value. Values shall be based on a minimum 100,000 hour of continuous creep testing.

		Geogrid Type - design life of 60 years					
	Units	RE510	RE520	RE540	RE560	RE570	RE580
$P_{C10^\circ C}$	kN/m	21.10	27.85	34.02	46.78	62.44	72.41
$P_{C20^\circ C}$	kN/m	19.37	25.56	31.23	42.95	57.33	66.48
$P_{C30^\circ C}$	kN/m	17.56	23.18	28.32	38.94	51.98	60.27

		Geogrid Type - design life of 120 years					
	Units	RE510	RE520	RE540	RE560	RE570	RE580
$P_{C10^\circ C}$	kN/m	20.71	27.34	33.40	45.93	61.31	71.09
$P_{C20^\circ C}$	kN/m	19.01	25.10	30.66	42.16	56.28	65.27
$P_{C30^\circ C}$	kN/m	17.24	22.76	27.80	38.23	51.03	59.17

- D. The geogrid shall have an appropriate partial factor for site installation and construction damage, determined by the particle size distribution of the reinforced fill and in accordance with the values used in the design. This factor shall be based on full-scale tests carried out in accordance with BS8006 Annex D and witnessed by an independent Approval Authority. If required by the Engineer, the Contractor shall provide supporting documented evidence of testing for this and any other partial factors assumed in the design. Partial factors for site installation and construction damage based on limited laboratory based testing are not acceptable.
- E. The strength of the junctions between the longitudinal ribs and transverse bars, as determined by the Geosynthetics Research Institute, Drexel University, USA, Test Method GG2-87, shall be not less than 95% of the Quality Control Strength.
- F. Any site joints in the reinforcement roll length shall be capable of carrying 100% of the geogrid long term creep rupture strength. If required by the Engineer, the Contractor shall provide evidence of this.
- G. The geogrid shall be inert to all chemicals naturally found in soils and shall have no solvents at ambient temperature. It shall not be susceptible to hydrolysis, shall be resistant to aqueous solutions of salts, acids and alkalis, shall be non-biodegradable and shall have a minimum of 2% finely divided carbon black, as determined by BS 2782 Part 4, Method 452B 1993, to inhibit attack by ultraviolet light.
- H. The primary geogrid shall have an independent test certificate proving resistance and durability in a pH range of 2.0 to 12.5. Specifically, 'The sample of the primary geogrid chosen shall have a test certificate from a recognised independent test authority, showing that when tested to ENV ISO 12960, March 1998, they can withstand immersion in a saturated solution of calcium hydroxide with a pH of 12.5, at 60 deg C for 3 days with no loss of tensile strength'.
- I. The geogrid shall be CE Marked by an independent, authorised Certification Body to demonstrate that the product has been tested in accordance with the relevant European Standard relating to its specific use in construction, in accordance with the EU Construction Products Directive.
- J. The product labelling must show the CE Mark, together with the Certification Body Number and the FPC (factory production control) number. 'Accompanying Documentation' indicating the relevant testing 'declared values', should be available on request.

4.01.2 Erosion Control Product

To establish a grass cover to the finished structure by dry seeding, the face should be covered with one of the following as determined by the engineer:

- A. rolled erosion control product comprising of biodegradable coconut fibres incorporated into a permanent three-dimensional polypropylene mesh.
- B. Non-biodegradable rolled erosion control product comprising of four layers of polyethylene mesh which are heat bonded together to form a three-dimensional mat.

- C. Where a depth of topsoil greater than 150mm is required, a cellular confinement erosion control product should be used.

4.02 Erosion control to slope face

- A. Horticultural topsoil should be applied to the face of the slope to a thickness determined for the contract, but typically not greater than 100mm. The rolled erosion control product should be fixed to the slope face, in accordance with specification clause 5.03.

4.03 Reinforced (Infill) Soil

The reinforced soil material proposed should conform to the following:

- A. Minimum angle of friction (ϕ_{cv}) of 30 degrees unless agreed with the Engineer.
- B. The Contractor should provide the Slope System supplier and the Engineer/Client with Effective Stress Parameters soil test information including soil density to allow completion and checking of the final design.

4.04 Horticultural Topsoil Layer

- A. The horticultural soil layer shall be a medium loam with a workable 'crumb-like' consistency placed and lightly compacted immediately onto the trimmed fully compacted reinforced soil for the purpose of supporting vegetation and in accordance with BS3882:2007 'Specification for Topsoil'.
- B. It shall have moisture content in the range 20 to 25% when placed.

4.05 Vegetation

4.05.01 Primary vegetation

- A. Grass cover will be established by applying the specified seed mix at the specified rate (typically 60g/m²)
- B. One suggested specification of seed mix is as follows or as proposed by the engineer.

75%	Creeping Red Fescue
25%	Smooth Stalked Meadow Grass

4.05.02 Secondary vegetation (where detailed on the construction drawings)

- A. Ground cover vegetation will be established by planting healthy plants from an approved supplier at the base and on the face of the structure.
- B. Plants on the face should be planted on a 2m square grid pattern. This is may be carried out either during or post construction but with the approval and agreement of the engineer.
- C. All plants should be well established in 75mm pots prior to planting and should be seen to have a good quality rootball.
- D. All plants should be correctly irrigated when necessary during the first 3 months after completion of the structure.
- E. One suggested specification for ground cover planting is: Vinca Major Variegata or as specified elsewhere by the Engineer.

5. Construction

5.01 Excavation

- A. Contractor shall excavate to the lines and grades shown on the Contract Drawings. Contractor shall take precautions to minimize over-excavation. Over-excavation shall be filled with compacted approved infill material, or as directed by the client's Engineer.
- B. Contractor shall verify the location of existing structures and utilities prior to excavation. Contractor shall ensure all surrounding structures are protected from the effects of any excavation. Excavation support, if required, is the responsibility of the Contractor.

5.02 Foundation Preparation

- A. Following the excavation, the foundation soil shall be examined by the Engineer to assure actual foundation soil strength meets or exceeds the design bearing strength. Soils not meeting the required strength shall be removed and replaced with infill soils, as directed by the Engineer.
- B. Foundation soil shall be proof rolled and compacted to 95% standard Proctor density and inspected by the Engineer prior to commencement of construction of the reinforced soil slopes.

5.03 Construction of Steep Slope

- A. Cut and position the base layer of primary uniaxial geogrid reinforcement at the formation level shown on the contract drawings. The principle strength direction of the uniaxial geogrids is along the roll length and as such should be laid perpendicular to the longitudinal alignment of the slope structure. Adjacent lengths of geogrid are butt jointed at the slope face.
- B. The geogrid reinforcement need not be folded up the face on NaturalGreen slopes which have a maximum face angle of 45° to the horizontal.
- C. All of the geogrids should be installed to the levels, lengths and orientations as shown on the construction drawings.

- D. Selected suitable fill material should be in full compliance with the needs of the design and have the approval of the engineer. Place and compact the fill in layers to the Contract's specification incorporating primary reinforcement and secondary reinforcement as shown on the construction drawings.
- E. The secondary reinforcement geogrid must be laid in the correct direction. As such the material must be rolled out parallel to the face. The 4m wide material may be cut whilst still on the roll, into the widths which correspond with the construction drawing; normally 2m, but this must be checked. The newly cut narrower roll may now be laid out easily and parallel with the slope face.
- F. Fill should be placed by plant such as an excavator with an opening bucket, which causes the fill to cascade onto the geogrids. A 150mm thick cover of fill must be maintained between the tracks of any plant and the geogrid to avoid damage.
- G. The embankment may be overfilled, compacted and face trimmed in a conventional manner to the design angle.
- H. Use of a toothless excavator bucket is recommended for face trimming to prevent snagging on the edge of the buried geogrids. Although care should be taken not to over cut, the machine performing the face trim will not cause structural damage whilst performing this task.
- I. On completion of the structural filling operation the slope surface should be covered with a layer of suitable topsoil in accordance with BS3882 and the landscaping requirements. The thickness of the topsoil layer is typically 100mm thick or as indicated on the construction drawing. Over compaction of the topsoil should be avoided.
- J. Where a grass cover is detailed, scatter the chosen seed mix on to the slope at the specified rate per square metre.
- K. The rolled erosion control product should then be carefully installed.
- L. The rolled erosion control product is rolled down the slope face lapping adjacent rolls by a minimum of 100mm. The barbed polymer pegs supplied should be used to fix the mat at 1.0m centres along the laps by driving them into the soil using an appropriate hammer, preferably rubber to prevent damage. Rolled erosion control product must follow exact slope profile and remain in contact with the underlying topsoil layer. Additional pinning and/or pinning of the centre of roll may be required.
- M. Roll ends shall be buried at the shoulder and toe respectively in shallow trenches approximately 450mm wide by 250mm deep.
- N. Where the rolled erosion control used is a non-biodegradable product the finished slope surface should be filled with a friable topsoil brushed into the mat and sown with selected grass seed mix.
- O. If demanded by the Client, the slope may be planted with a suitable ground cover plant species as per the Client's requirements. The rolled erosion control product should be carefully cut and the chosen plants pushed into the topsoil below.
- P. Care should be taken at this stage when using biodegradable rolled erosion control products to avoid exposing it to naked flame or spark, as it may be flammable until it has had the opportunity to absorb moisture.
- Q. The Contractor must fully assess the safety risk associated with working on the slope and at height and where appropriate install any necessary temporary edge protection and provide operatives with the appropriate safety equipment.

6. Submission of Alternatives

6.01 Any alternative to the specified system for Reinforced Steep Slopes proposed by the Tenderer shall be submitted with the tender and shall include:

- the names of the supplier and designer
- a full set of calculations
- outline drawings
- product samples and specifications
- test certificates for the reinforcing elements

The outline drawings must be sufficient to indicate the details of the construction of the Reinforced Steep Slopes including:

- typical plans
- elevations and section drawings
- foundations
- facing details (including vegetation if appropriate)
- anchoring reinforcing elements at the face
- reinforcing element joints and overlaps
- The width and length of the soil reinforcing elements should be clearly shown along with details of their orientation in the works.

This document is drafted on an entirely generic basis and its use in any tender documentation in any way must be reviewed by the user and made specific to their project

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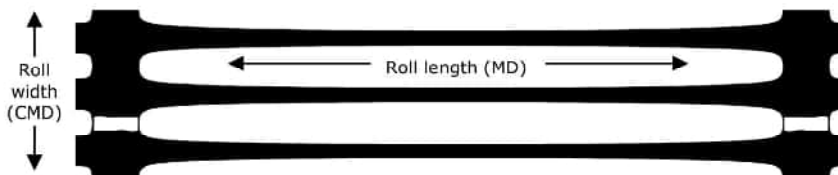
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Tensar RE500 series geogrids

Product specifications design temperature 10°C

Tensar RE500 geogrids are used for the reinforcement of soils in the construction of structures such as retaining walls, load bearing bridge abutments, steep slopes, slip repairs and TensarTech®Stratum® mattresses.



Properties	Units	Tensar RE500 geogrids (1), (2), (3)					
		RE510	RE520	RE540	RE560	RE570	RE580
Polymer		High density polyethylene					
Minimum carbon black (4)	%	2	2	2	2	2	2
Roll width	m	1.3	1.3	1.3	1.3	1.3	1.3
Roll length	m	75	75	50	50	50	50
Unit weight	kg/m ²	0.29	0.36	0.45	0.63	0.87	0.98
Roll weight	kg	30.0	37.0	31.0	45.0	59.0	67.0
Junction strength (5)	%	95	95	95	95	95	95
Long term strength at 10°C (6)							
ULS T _{CR} for 120 yrs (7)	kN/m	20.71	27.34	33.40	45.93	61.31	71.09
SLS T _{CS} for 1 month to 120 yrs (8)	kN/m	8.99	11.87	14.50	19.94	26.61	30.86
Partial factors of safety to calculate safe ultimate limit state (ULS) design strength (T_D) (9)							
Extrapolation of chemical and creep rupture data		$f_s = 1 + \sqrt{((1-R_1)^2 + (1-R_2)^2)} = 1.0$					
Installation damage D ₁₀₀ < 2mm, D ₈₅ < 0.65mm		RF _{ID} = 1.01	RF _{ID} = 1.00	RF _{ID} = 1.00	RF _{ID} = 1.00	RF _{ID} = 1.00	RF _{ID} = 1.00
Installation damage D ₁₀₀ < 37.5mm, D ₈₅ < 28mm		RF _{ID} = 1.18	RF _{ID} = 1.07	RF _{ID} = 1.07	RF _{ID} = 1.07	RF _{ID} = 1.07	RF _{ID} = 1.00
Installation damage D ₁₀₀ < 75mm, D ₈₅ < 69mm		RF _{ID} = 1.30	RF _{ID} = 1.25	RF _{ID} = 1.20	RF _{ID} = 1.15	RF _{ID} = 1.12	RF _{ID} = 1.06
Installation damage D ₁₀₀ < 125mm, D ₈₅ < 110mm		RF _{ID} = 1.60	RF _{ID} = 1.48	RF _{ID} = 1.36	RF _{ID} = 1.25	RF _{ID} = 1.19	RF _{ID} = 1.12
Weathering (including exposure to UV light)		RF _W = 1.00					
Chemical/environmental effects (10)		RF _{CH} = 1.05 for pH = 2 to 4, RF _{CH} = 1.00 for pH = 4 to 12.5					

- Tensar RE500 geogrids** are stiff monolithic geogrids with integral junctions and are manufactured in accordance with Quality and Environmental Management Systems which comply with the requirements of BS EN ISO 9001:2015 and BS EN ISO 14001:2015 respectively.
- All quoted dimensions and values are typical unless stated otherwise.
- Tensar RE500 geogrids** accreditation includes:
 - The British Board of Agrément (BBA) has awarded HAPAS Certificates: No 13/H201 and No 13/H202
 - The Geotechnical Engineering Office of the Civil Engineering & Development Department of the Government of Hong Kong SAR has awarded Certificate RF 2/2017
- Carbon black inhibits attack by UV light. Determined in accordance with ASTM D1603-14. Any section of grid fully exposed to sunlight can be expected to retain 90% of its quality control strength for periods in excess of 40 years in temperature climates and 20 years in tropical climates.
- Determined in accordance with GRI Test Method GG2-87, and expressed as a % of the quality control strength.
- In-soil temperature.
- ULS determined as a lower bound using standard extrapolation techniques to creep rupture data (real time test duration > 100,000 hours) obtained following the test procedure in BS EN ISO 13431:1999 for 120 year design life.
- SLS determined as the lower bound load which limits post-construction strain to 1% over the period from 1 month until design life, based on isochronous curves derived from creep tests carried out to BS EN ISO 13431:1999.
- Partial factors are determined following the requirements of BS EN 13251:2016 and guidelines given in PD ISO/TR 20432:2007, and are used to derive the ULS design strength which is given as: $T_D = T_{CR} / (f_s \times RF_{ID} \times RF_W \times RF_{CH})$
- Tensar RE500 geogrids** are inert to all chemicals naturally found in soils and have no solvents at ambient temperature. They are not susceptible to hydrolysis and are resistant to aqueous solutions of salts, acids and alkalis (pH 2.0 to 12.5) and are non-biodegradable.



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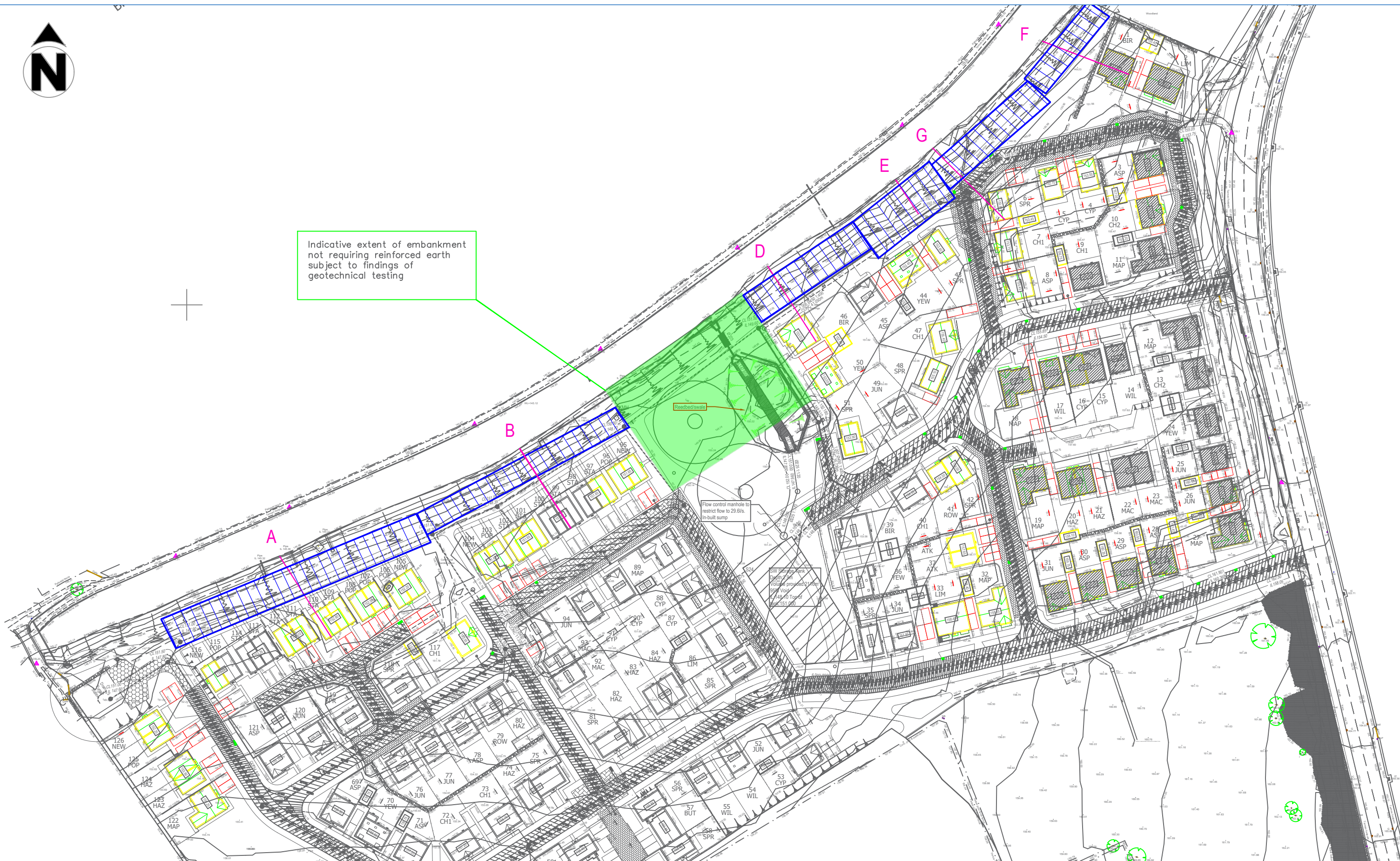


6.0 PLANS

The following designs were produced using CAD software, based off the TensarSoils modelling software with the design parameters and geometric provided by the clients plans.



Indicative extent of embankment
not requiring reinforced earth
subject to findings of
geotechnical testing



GROUNDTECH
CONSULTING



CLIENT
COUNTRYSIDE PARTNERSHIPS - WAKEFIELD

PROJECT TITLE
HOLLINGSWORTH GATE, LITTLEBOROUGH

PLAN TITLE
TENSAR AREAS PLAN

DATE
JUNE 2023

SCALE
NTS

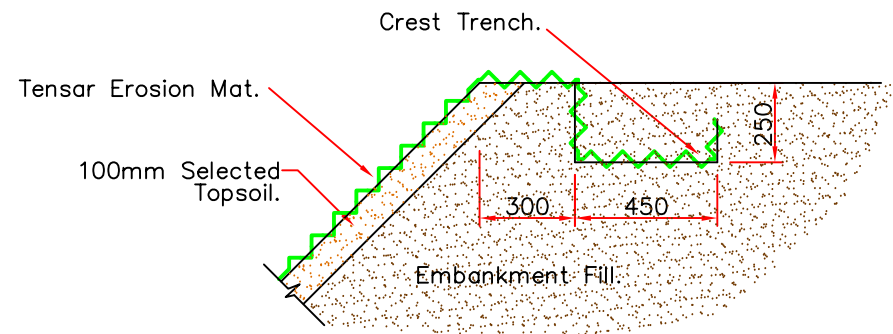
PLAN NUMBER
GRO-23131-P05

Rev.	Details	Date

Status	
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Draft	
Issued	●
For Comment	
Approved	

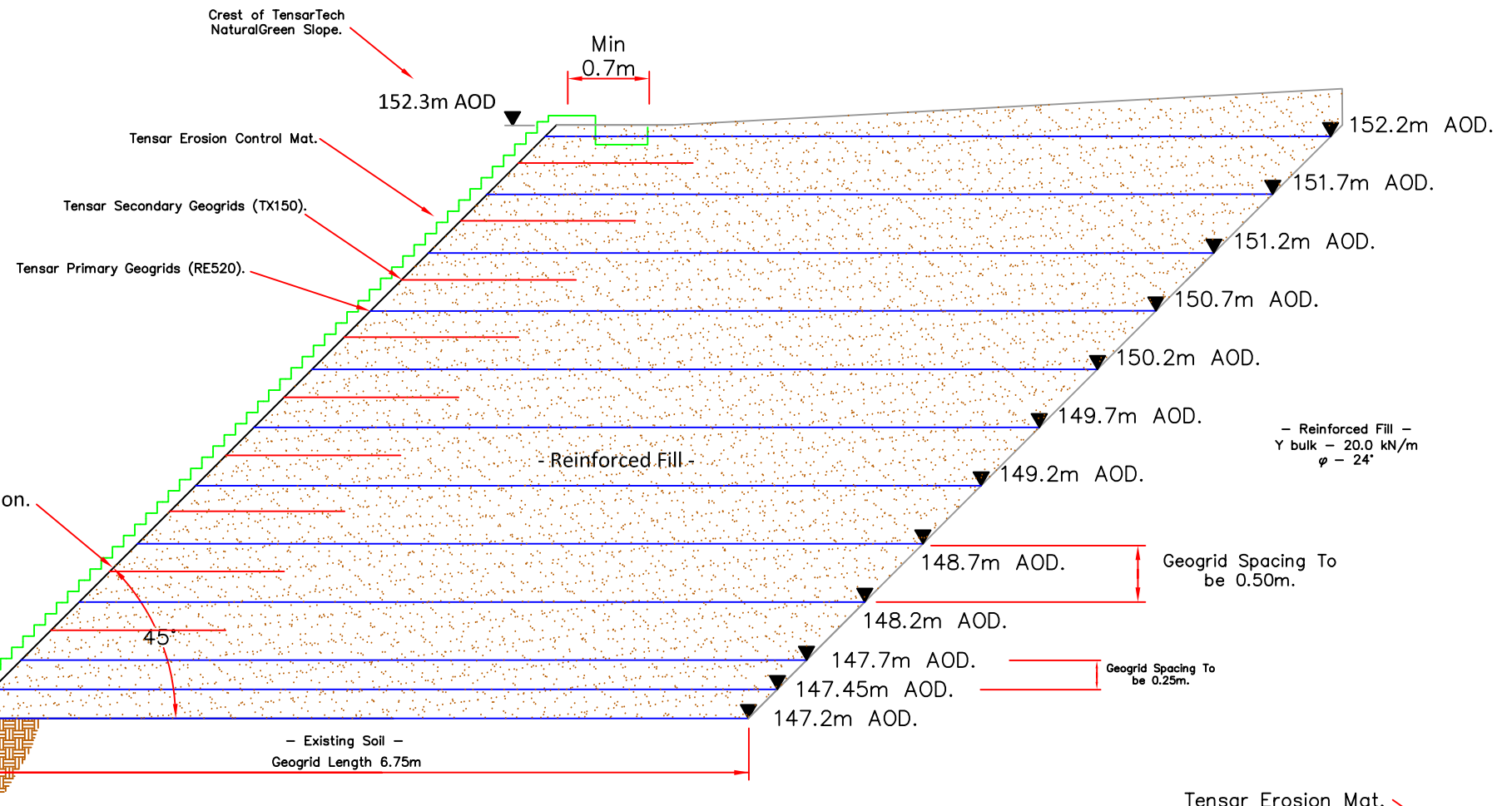
Notes
 - Extent of Tensar Geogrids for each Section



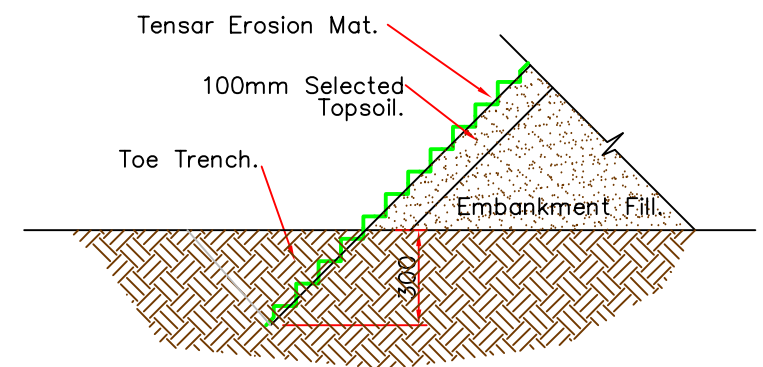


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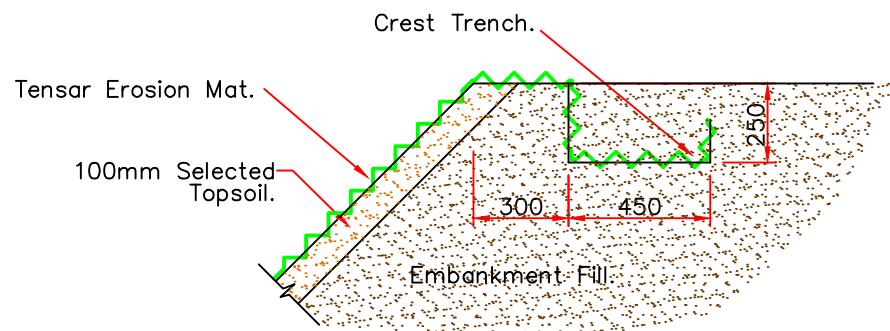


TensarTech NaturalGreen System Through Section A-A



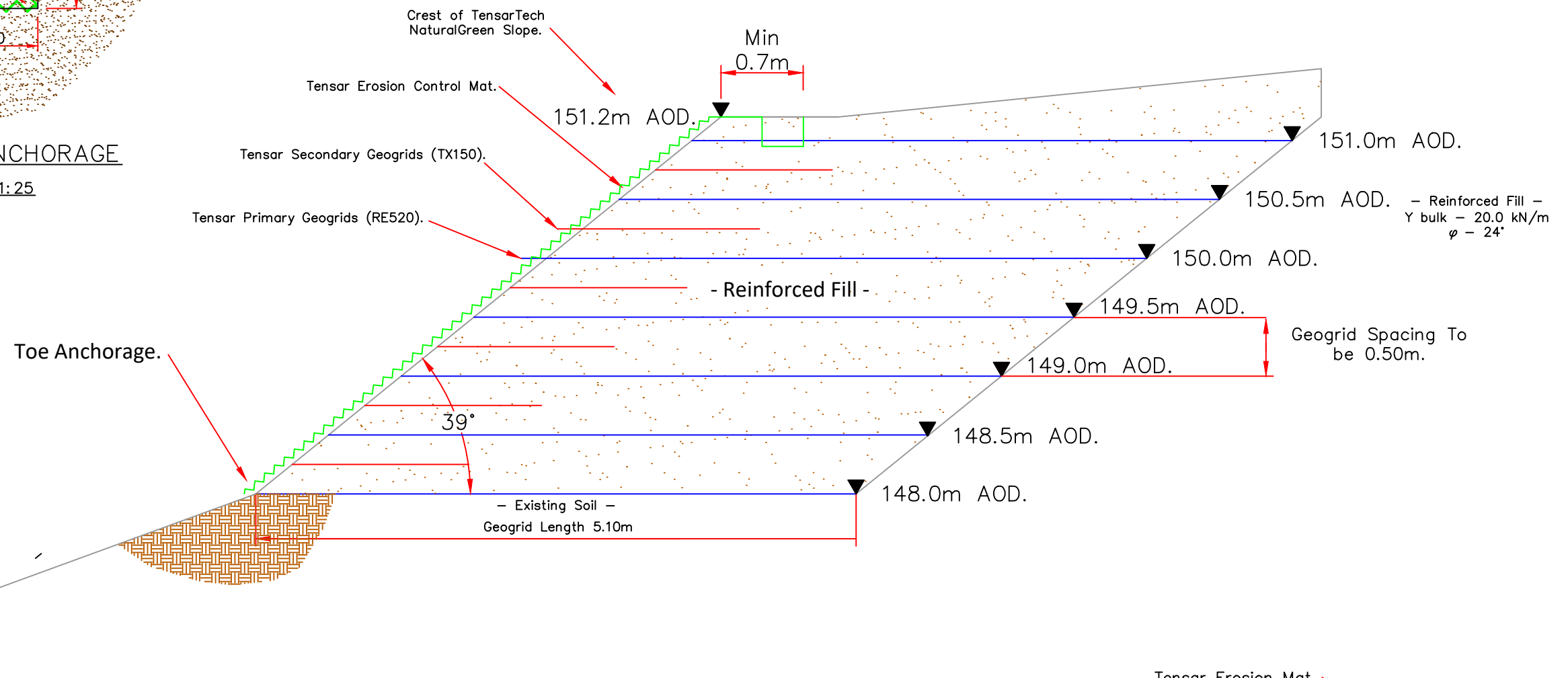
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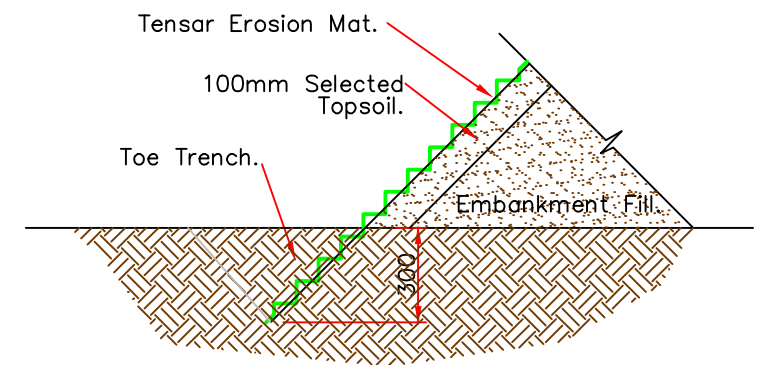


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TensarTech NaturalGreen System Through Section B-B



TENSAR MAT TOE ANCHORAGE

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PLAN TITLE	TENSARTECH NATURAL GREEN PROFILE PLAN - SECTION B

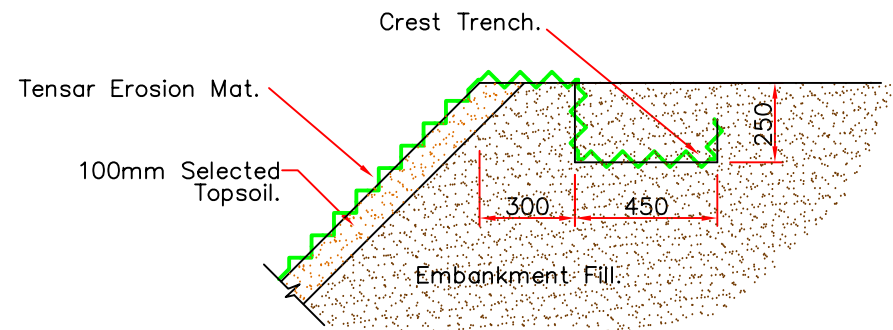
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SCALE	NTS
PLAN NUMBER	GRO-23131-P03B

Rev.	Details	Date
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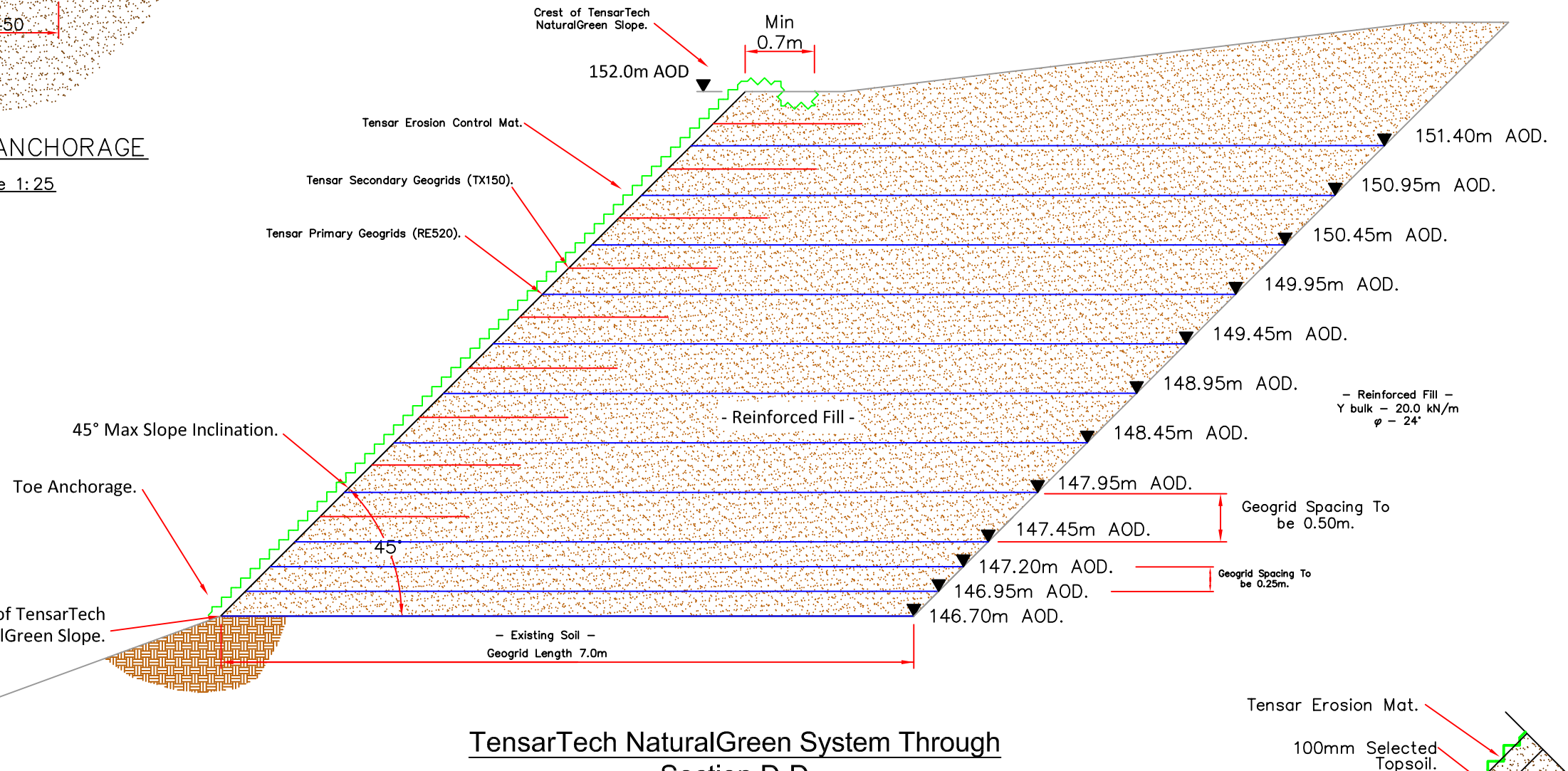
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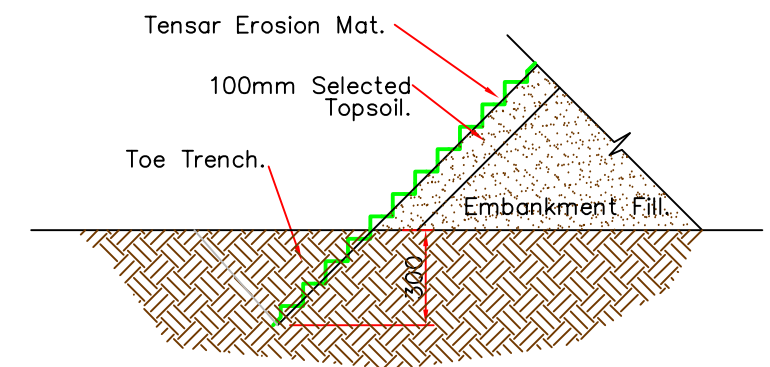


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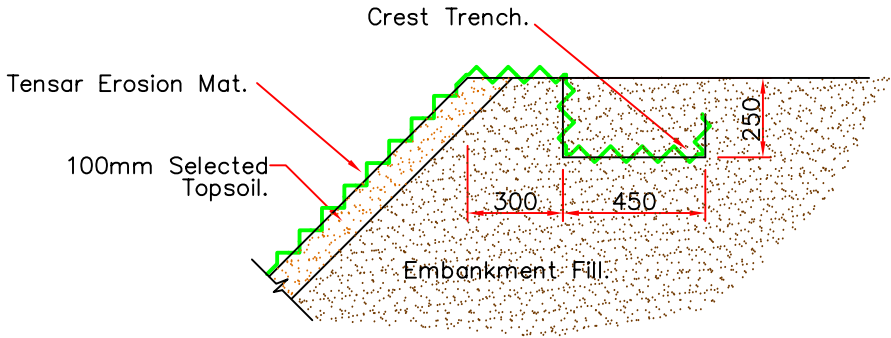


TensarTech NaturalGreen System Through
Section D-D

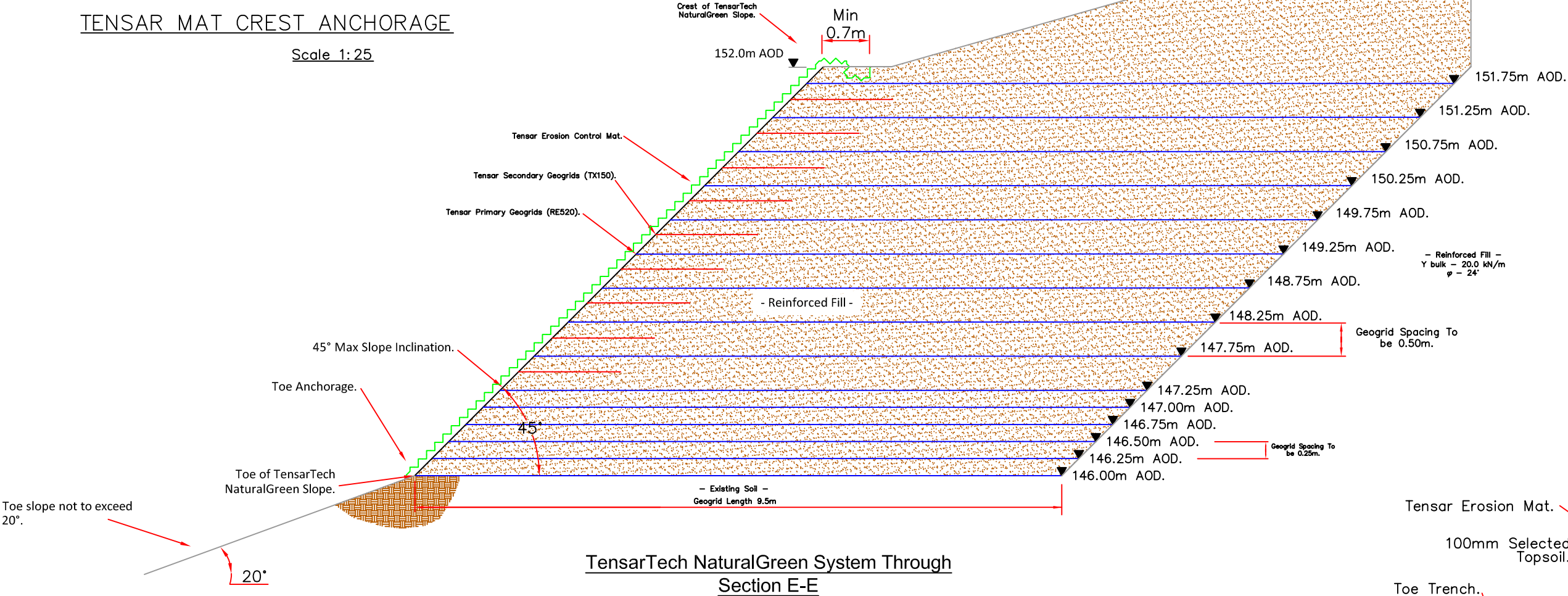


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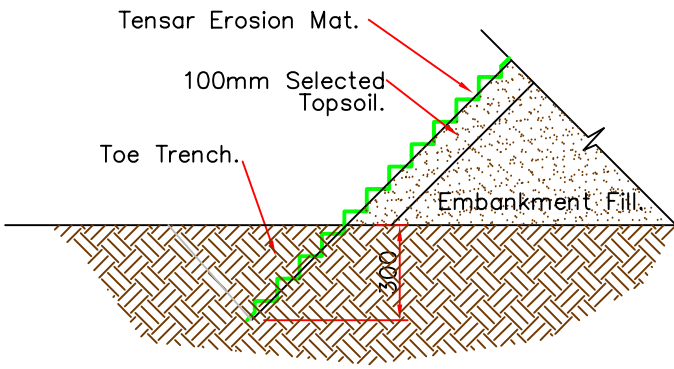
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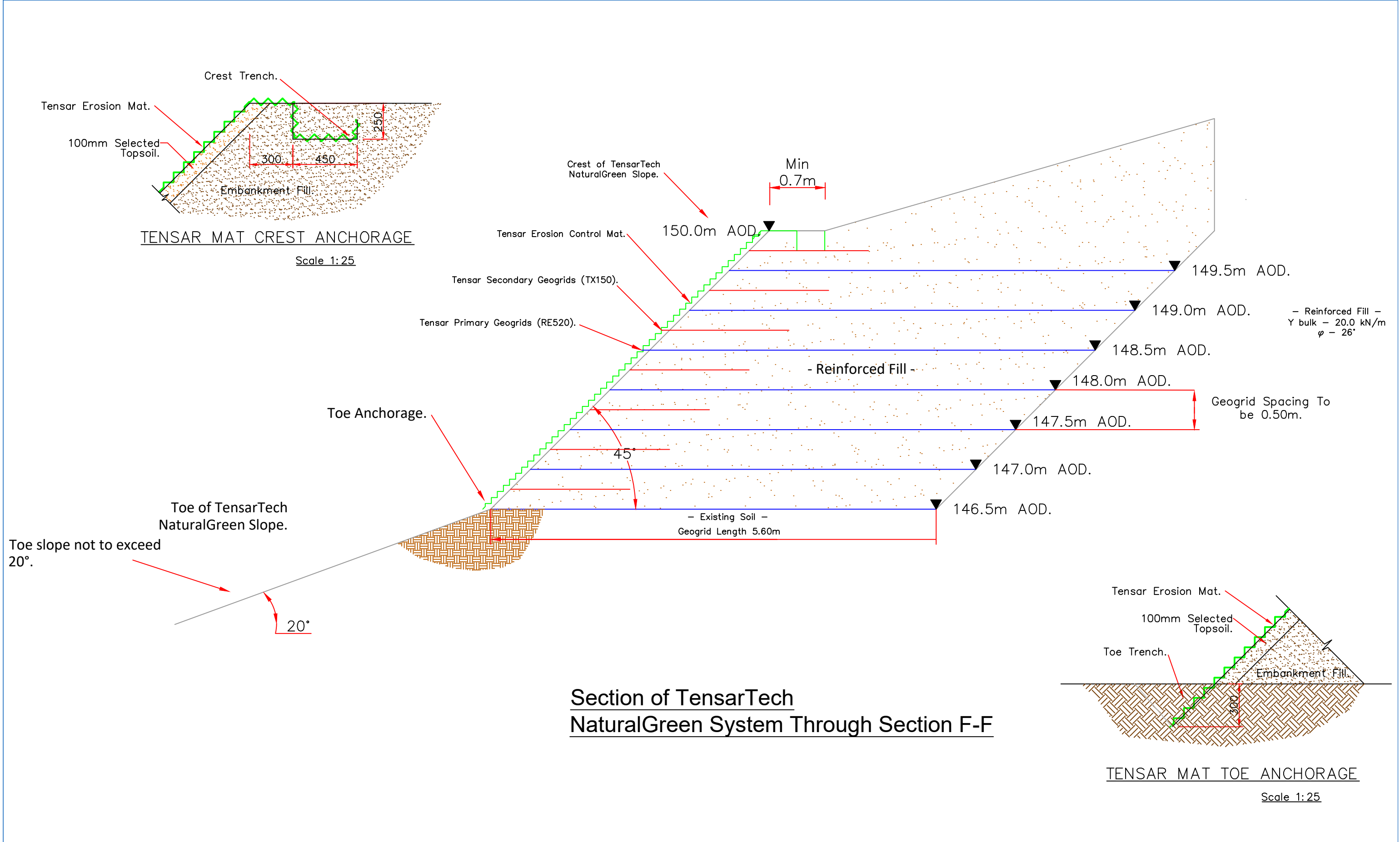
TensarTech NaturalGreen System Through
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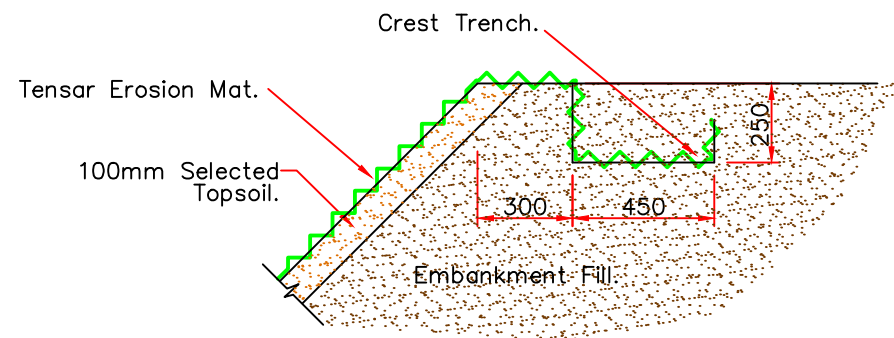
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	PROJECT TITLE	SCALE			Draft	
	HOLLINGWORTH GATE, LITTLEBOROUGH	NTS			Issued	
	PLAN TITLE	PLAN NUMBER			For Comment	
	TENSARTECH NATURAL GREEN PROFILE PLAN - SECTION E	GRO-23131-P03E	Rev.	Details	Date	Approved





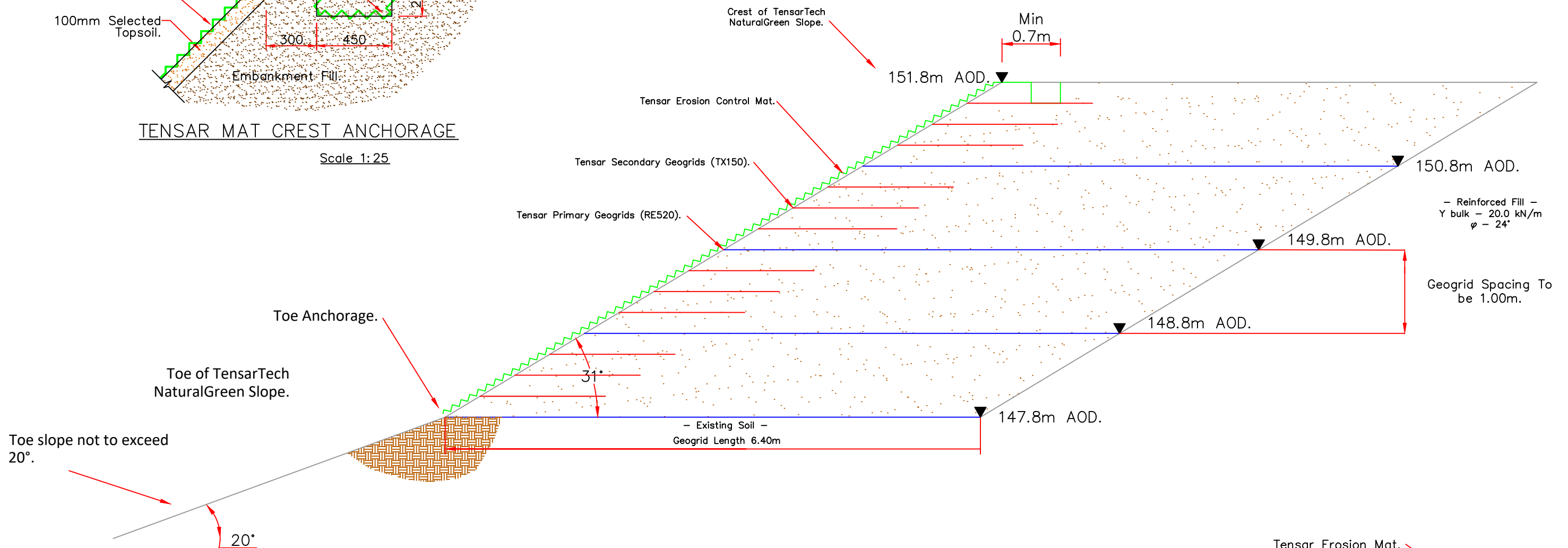
Section of TensarTech NaturalGreen System Through Section F-F

GROUNDTECH CONSULTING	CLIENT COUNTRYSIDE HOMES	DATE JUNE 2023				Status		Notes
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	PLAN TITLE TENSARTECH NATURAL GREEN PROFILE PLAN - SECTION F	PLAN NUMBER GRO-23131-P03F				Draft		
						Issued		
						For Comment		
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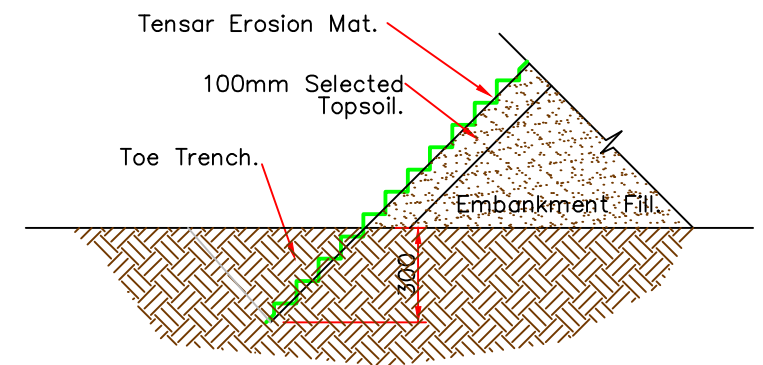


TENSAR MAT CREST ANCHORAGE

Scale 1:25



Section of TensarTech
NaturalGreen System Through Section G-G



TENSAR MAT TOE ANCHORAGE

Scale 1:25

GROUNDTECH
CONSULTING



CLIENT	COUNTRYSIDE HOMES
PROJECT TITLE	HOLLINGWORTH GATE, LITTLEBOROUGH
PLAN TITLE	TENSARTECH NATURAL GREEN PROFILE PLAN - SECTION G

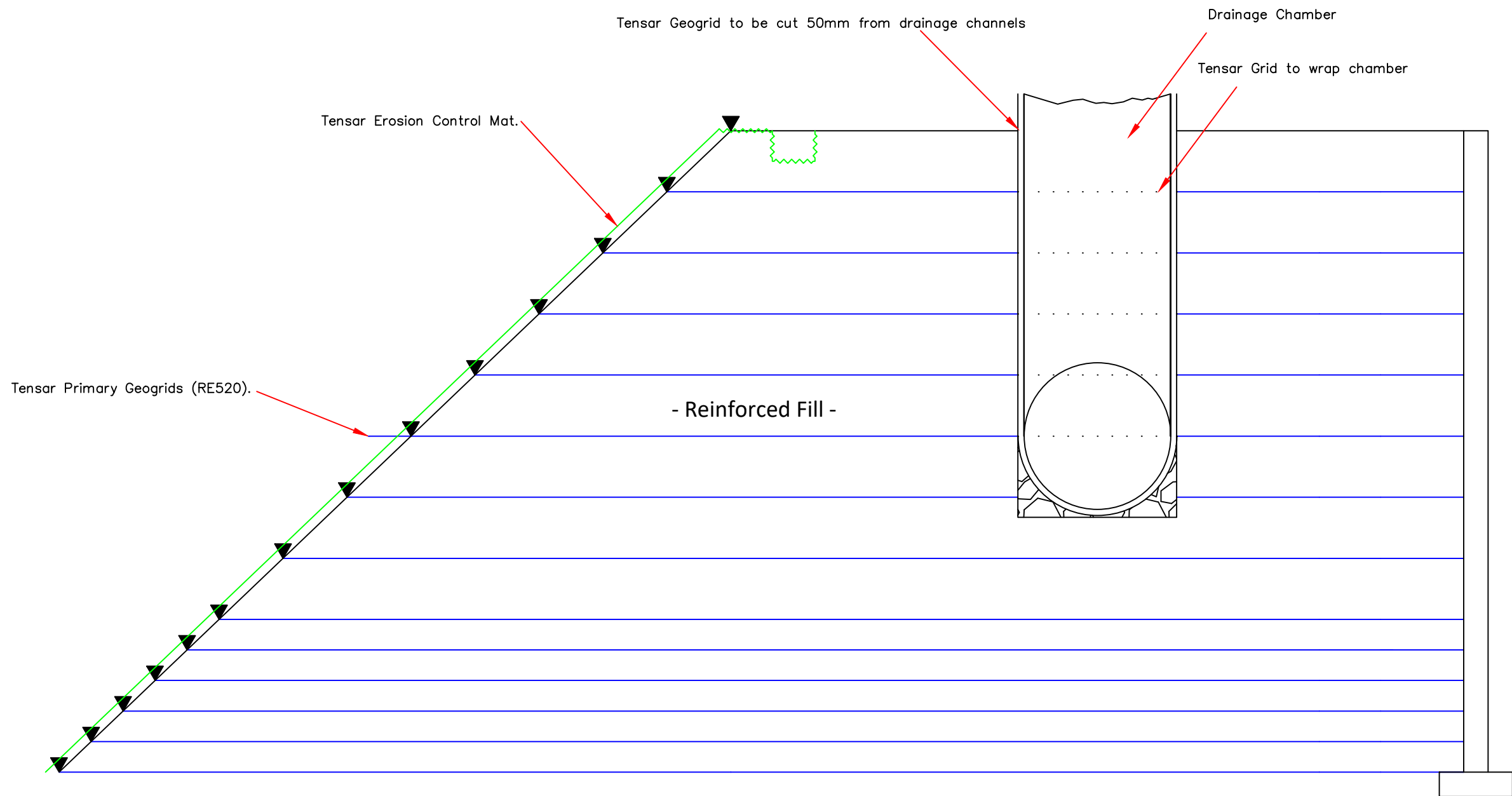
DATE	JUNE 2023
SCALE	NTS
PLAN NUMBER	GRO-23131-P03G

Rev.	Details	Date
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Status	
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Draft	
Issued	●
For Comment	
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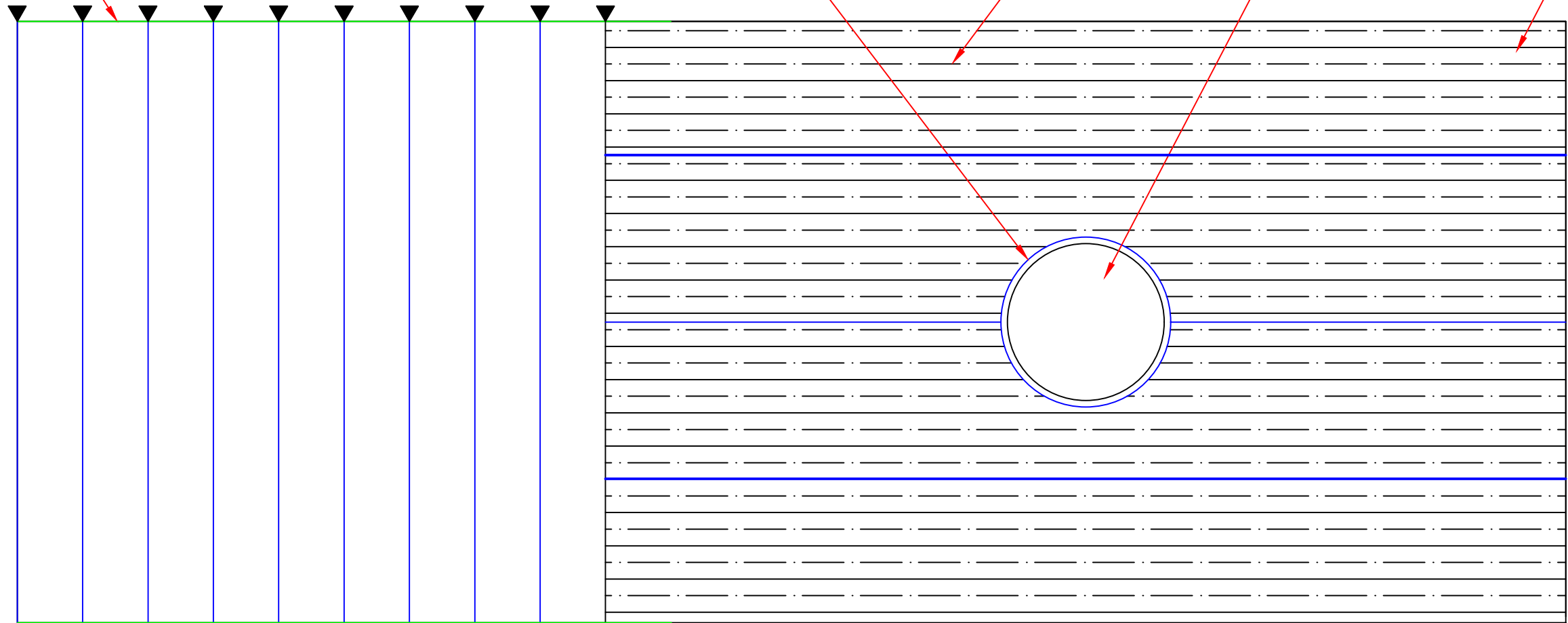
Tensar Erosion Control Mat.

Tensar Geogrid to be cut 50mm from drainage channels

Tensar Grid to wrap chamber

Drainage Chamber

Tensar Uniaxal Grid





7.0 DESIGN BRIEF CONFIRMATION FORM

Please complete, sign and return to:

*Groundtech Consulting Ltd
1st Floor Lloyd House
Orford Court
Greenfold Way
Leigh
WN7 3XJ*

We hereby confirm that the contents of the Design Brief as stated in Section 2 of this document are representative of the actual site conditions and are hereby agreed to be used for the detailed design of the reinforced soil structure for the above project.

Company:.....

Signed:

Name:

Title:.....

Date:.....

Notes

As Groundtech carries no liability for the accuracy of the assumed geotechnical components of this project, it is strongly recommended that the client assigns a suitably qualified Geotechnical engineer to carry out a review and confirmation of the Design Brief prepared by Groundtech.

8.0 SETTLEMENT ASSESSMENT

Settlement assessment has been undertaken for the proposed embankment.

The proposed embankment will have a slope angle of 30 to 45°. The largest change in loading will be applied where the reinforced earth is circa 6m in height.

Settlement calculations have been undertaken and where bedrock forms the foundation, settlement will be negligible. Where the stiff Clay is anticipated to be present, settlement will be less than 25mm.

The Made Ground is variable and also requires excavation and processing due to cobbles and boulders. Further assessment is required where Made Ground is encountered at formation level. The risk from total and differential settlement may be able to be designed out by preparing the foundation soils during construction. The settlement calculations are based on the available ground conditions information.

9.0 SLOPE STABILITY ASSESSMENT

The objective of the Slope Stability Appraisal is to demonstrate that the proposed reprofiling of the embankment using reinforced earth is stable. The appraisal has been undertaken in accordance with EC7-1 and BS 8006.

9.1 History

The site comprises a former chemical works, the site is currently disused comprising different levels generally sloping down to the canal to the north/north east.

9.2 Geology

Glacial Till and Head Deposits are indicated to underlie the site, the solid geology is the Pennine Lower Coal Measures including the Milnrow Sandstone Formation and Undifferentiated Mudstone.

9.3 Hydrology

A canal abuts the site to the north. A small pond is located to the south of the site and Hollingworth Lake is located further to the south.

9.4 Ground Investigation Information

The depth of Made Ground was highly variable, generally the Made Ground was deeper along the northern boundary. Clay was encountered on the eastern and western areas of the site and was variable in consistency.

The bedrock varied between Mudstone, Sandstone and Siltstone.

9.5 Assessment

A Slope Stability Appraisal has been undertaken using Oasys modelling software, both the graphical and tabular outputs are appended.

9.6 Parameters

Parameters were obtained from a range of sources and are summarised in the table below:

Parameter	Value	Source
Angle of proposed slope	30 to 45°	Tensar Green Slope
Groundwater level	NGW	-
Strata	Section A	Ground model in CP05
	Section B	Ground Model in CP05, TP21
	Section D	Ground Model in MW03, MW05, TP19, TP20
	Section E	Ground Model in TP07
	Section F	Ground Model in MW01, TP01, TP02

The stability assessment has been undertaken using the above parameters.

Geotechnical Parameters

The parameters for the strata on the subject site have been obtained from the Arc Environmental Ground Investigation and Slope Stability Assessment. The parameters will; be refined on receipt of the geotechnical testing recently undertaken.

The following geotechnical parameters and properties were considered to be representative of the soils: by Arc Environmental.

Strata	Friction angle ϕ' (°)	Unit weight γ (kNm ³)
<i>Reinforced Earth</i>	24	20
<i>Backfill Made Ground</i>	24	20
<i>Soft Clay</i>	24	20
<i>Stiff Clay</i>	24	20
<i>Sand</i>	34	20
<i>Mudstone</i>	30	21
<i>Siltstone</i>	34	21

Drained analysis has been carried out for long term stability, the model was run using a c' of 0 kPa for cohesive strata.

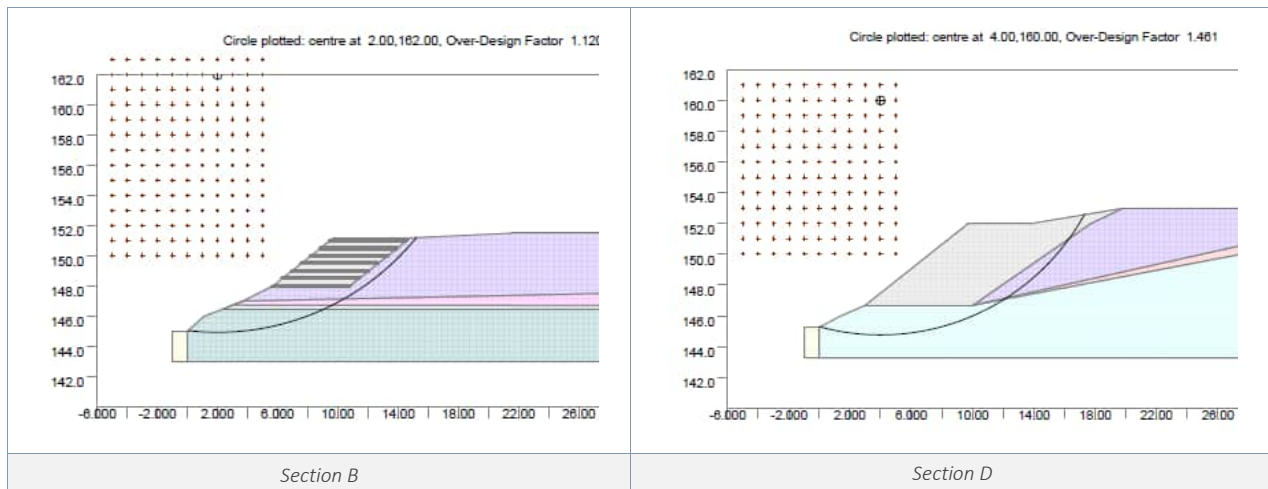
9.7 Slope Model Results (Rotational Failure)

The software model was run using the Bishop (circular failures) method to determine a range of Over Design Factors (ODF) which is the reciprocal of the Degree of Utilization for rotational failure. The results for Bishop Method are presented in the table below as they were lower than the Janbu Method and this method was driving the stability.

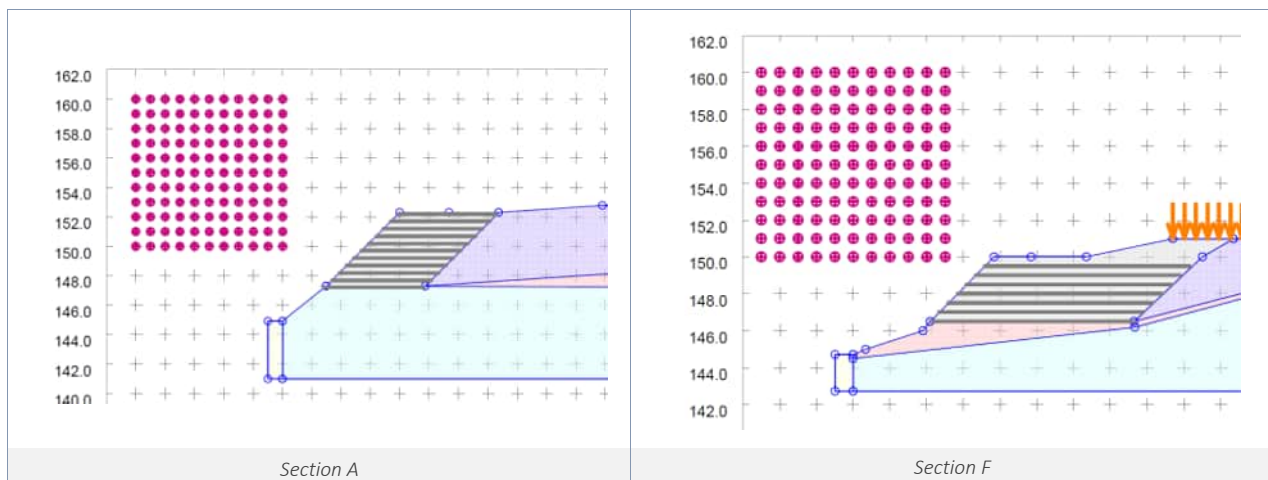
Design Situation	Computation Method	ODF
<i>Section A</i>	<i>Bishop</i>	-
<i>Section B</i>	<i>Bishop</i>	1.12
<i>Section D</i>	<i>Bishop</i>	1.461
<i>Section E</i>	<i>Bishop</i>	1.359
<i>Section F</i>	<i>Bishop</i>	-

The results presented in the table above confirm the overall stability is acceptable as an ODF of greater than 1 has been generated using partial factor analysis in accordance with EC7 Design Approach 1 Combination 2 (BS EN 1997-1:2011 DA1-2). Where no ODF is provided in the table above, the value is high demonstrating stability.

Below are the graphical outputs for Section B and Section D showing the circular failure behind the reinforced block with ODFs greater than 1.



Below is the graphical output for Sections A and F - no circular failure was generated when the slope stability was modelled with a common point behind the reinforced earth wedge primarily due to the shallow bedrock. When slope is modelled with a defined radii – failures with an ODF of less than 1 are shown through the reinforced earth wedge.



The length of the straps in Section F is 11.1m which extend beneath the proposed gabion structure. No permanent structures should be constructed over the reinforced earth, the ϕ' of the reinforced earth material has been increased to 26° which reduced the strap lengths to 5.6m. If the Made Ground cannot achieve a minimum ϕ' of 26° , an alternative source of material should be used.

Depending on the angle of friction of the Made Ground/material used in the reinforced earth, the Public Open Space area in the vicinity of Section C may not require reinforced earth as shown on GRO-23131-P04. This will also be dependent on the treatment of the mine shaft in this area.

9.8 Limitations

The following assumptions and exclusions have been made in the modelling of the slope stability, if the assumptions are varied in the design or construction the modelling results are not applicable and the slope should be remodelled:

- *Ground models are generated from available Ground Investigation information by others, assessment applicable to geometrics and ground conditions in modelling sections.*
- *Based on levels provided on dwg plans and canal sections.*
- *Treatment of the mine entry may have an effect on the proposed design, further details should be provided when available.*
- *No groundwater modelled based on Ground Investigation information provided, if this differs in construction or drainage strategy changes groundwater regime – design should be revisited.*
- *Design does not account for contamination or remedial activities.*
- *Based on the levels provided, some excavation into bedrock may be required and the contractor should allow for this.*
- *Processing of Made Ground will be required if proposed to be used in the reinforced earth construction, subject to testing results.*
- *An earthworks specification is required to inform installation of material in reinforced earth.*
- *Foundations are assumed to be piles and no additional loads are being applied to the reinforced earth or backfill material.*

9.9 Summary

The slope stability results demonstrate the embankment is stable. Peak ϕ' values have been used in the assessment as there is no evidence of ancient slippages, if observed during the earthworks, the modelling should be revised using residual values.



APPENDIX 1 - Plans

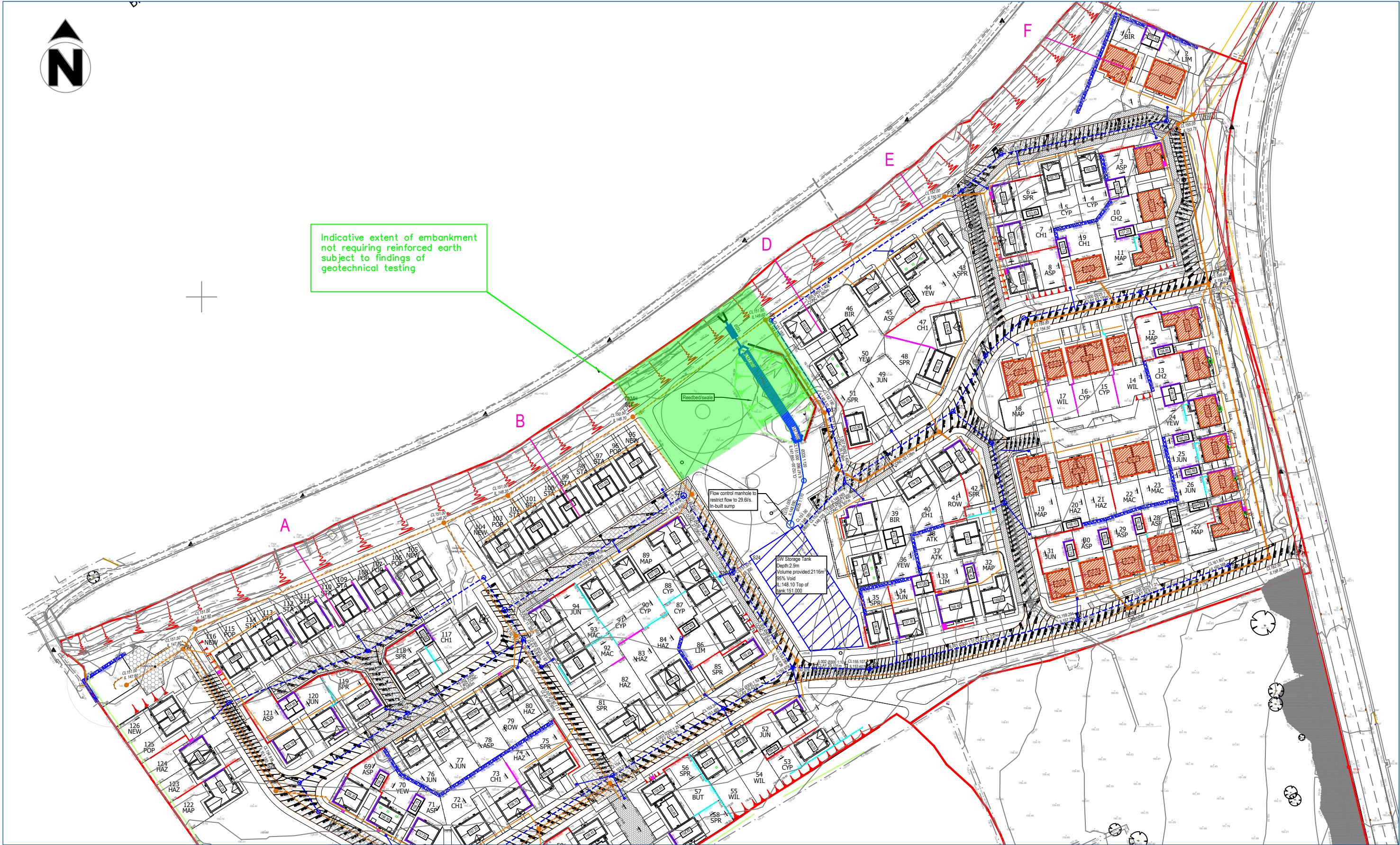


GROUNDTECH
CONSULTING



CLIENT	DATE			Status		Notes Site Location
COUNTRYSIDE PARTNERSHIPS	JUNE 2023			Preliminary		
PROJECT TITLE	SCALE			Draft		
HOLLINGWORTH GATE, LITTLEBOROUGH	NTS			Issued		
PLAN TITLE	PLAN NUMBER			For Comment		
PROJECT LOCATION PLAN	GRO-23131-P01	Rev.	Details	Date	Approved	



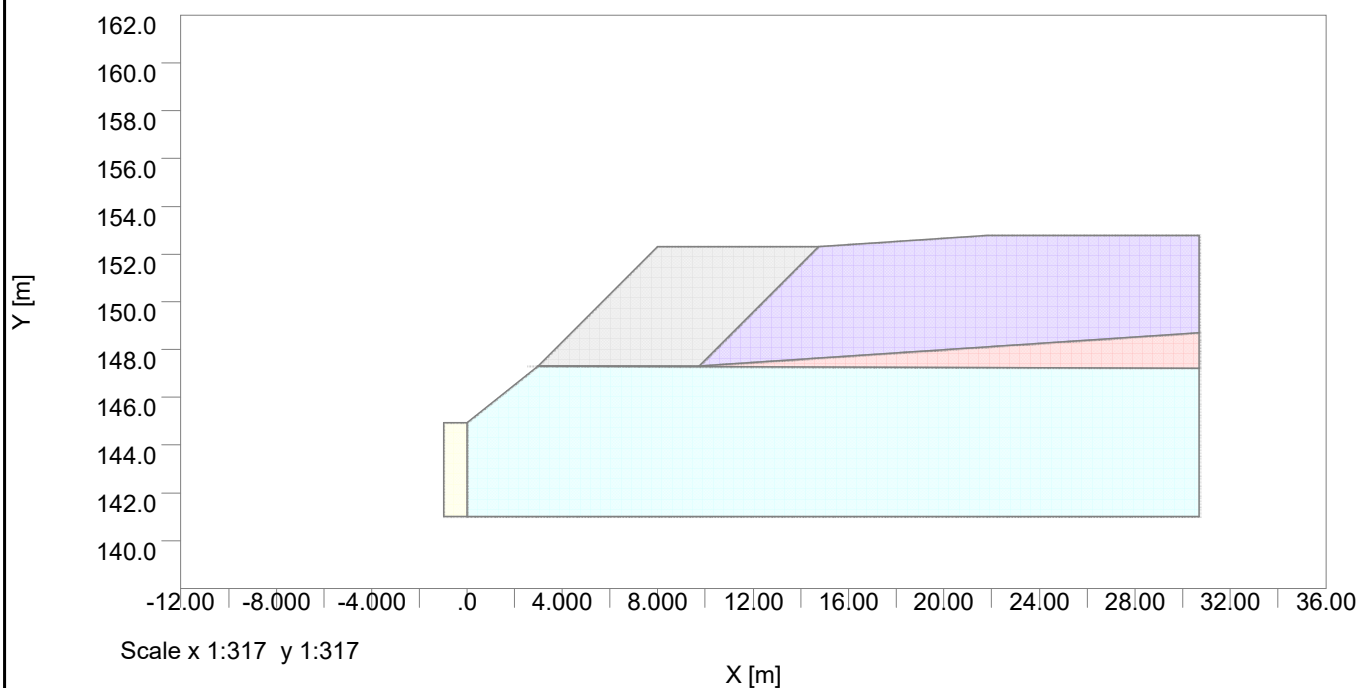


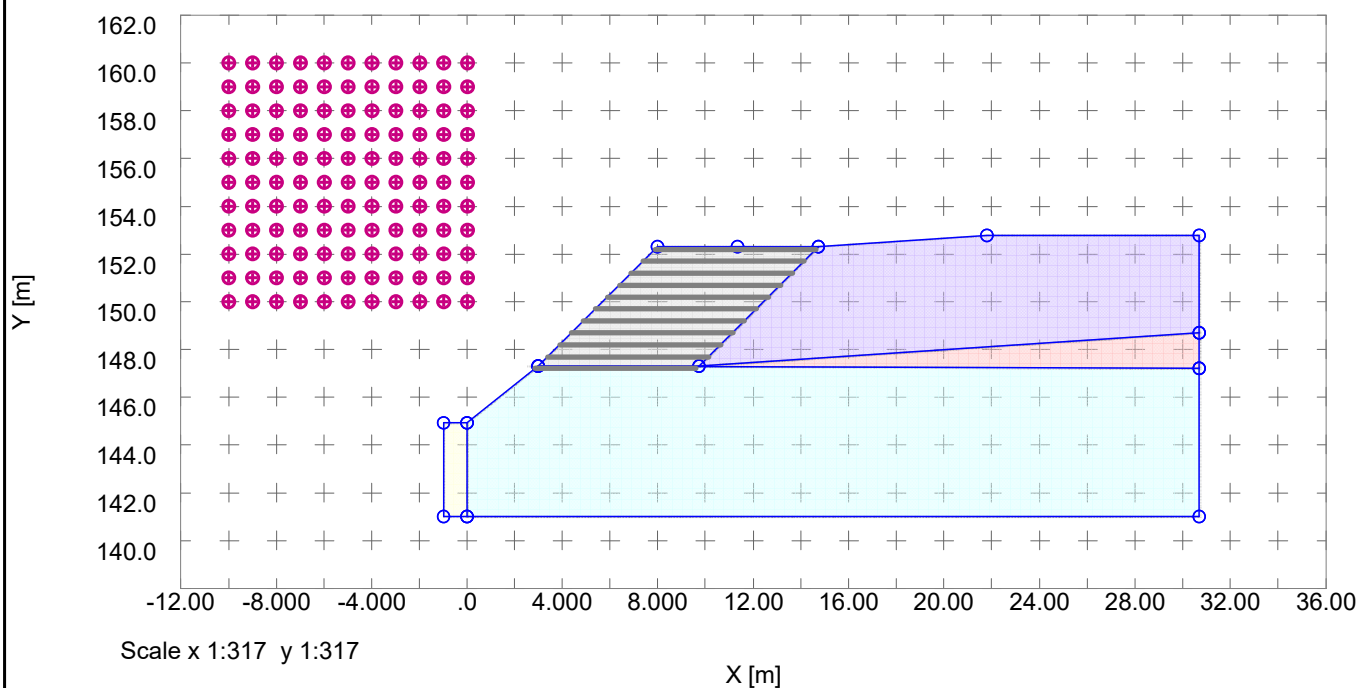
GROUNDTECH CONSULTING 	CLIENT	DATE				Status		Notes
	COUNTRYSIDE PARTNERSHIPS - WAKEFIELD	JUNE 2023				Preliminary		
	PROJECT TITLE	SCALE				Draft		
	HOLLINGSWORTH GATE, LITTLEBOROUGH	NTS				Issued		
	PLAN TITLE	PLAN NUMBER				For Comment		
	SLOPE SECTION PLAN	GRO-23131-P04	Rev.	Details	Date	Approved		



APPENDIX 2 - Section A Modelling Outputs

Job No.	Sheet No.	Rev.
GRO-23131		
Drg. Ref.		
Made by JD	Date	Checked CH
		Date 08 Jun 2023





Specification

```
Slip Type: CIRCULAR
Direction of slip: Downhill
Minimum slip weight [kN/m] :80.00000
Type of analysis: STATIC
Partial factor analysis
Minimum number of slices 25
Method: Bishop (Variably inclined interslice forces)
Maximum number of iterations: 300
Reinforcement: NOT ACTIVE
```

Material Properties

No	Description	Unit Weight		Shear Strength Parameters	Phi or c
		Above GWL	Below GWL		
or c0'					
		[kN/m3]	[kN/m3]		Phi0 [°]
0.0	1 Canal Wall	25.000	25.000	Drained	40.000
0.0	2 Reinforced Earth	20.000	22.000	Drained	24.000
0.0	3 Backfill made Ground	20.000	22.000	Drained	24.000
0.0	4 SAND	20.000	22.000	Drained	34.000
0.0	5 MUDSTONE	21.000	23.000	Drained	30.000

Reinforcement

NB: REINFORCEMENT IS DEFINED BUT NOT ACTIVE
Geotextile Reinforcement 1

Layers	Level of top layer [m]	Vertical Spacing [m]	Length Top [m]	Length Btm [m]	Offset from surface [m]	Angle from horizon [°]
11	152.20	0.50000	6.7500	6.7500	0.0	0

Bond Length	Bond Strength [kN/m]	Prestress [kN]	Grout Diameter [mm]
0.0%	0.0	0.0	0.0

Out of plane spacing	Tensile Capacity	Plate Capacity	Material Partial Factor
[m]	[kN]	[kN]	
0.0	1.3000	0.0	

Slip Surface Specification

Circle centre specification:
Bottom left of grid: x = -10.00000 m y = 150.00000 m
Inclination of grid: 0.00000 deg
(positive anticlockwise direction about bottom left of grid)
Centres on grid: 11 in x direction at 1.00000m spacing
 11 in y direction at 1.00000m spacing
Grid extended to find minimum FoS
All circles pass through common point at x = 9.75000 m, y = 147.30000 m

RESULTS OF ANALYSIS

In the following tables, values in italics are factored values using the currently selected Method Partial Factors.

Slip Centre	Radius	Slip Weight	Comment/Over-Design Factor	Disturbing Moment	Soil Restoring Moment	Strength Restoring Moment	Reinforcement Restoring Moment
x [m]	y [m]	[m]	[kN/m]	[kNm/m]	[kNm/m]	[kNm/m]	[kNm/m]
-10.000	150.00	19.934	Only 1 intersection with ground level				
-10.000	151.00	20.094	Only 1 intersection with ground level				
-10.000	152.00	20.302	Only 1 intersection with ground level				



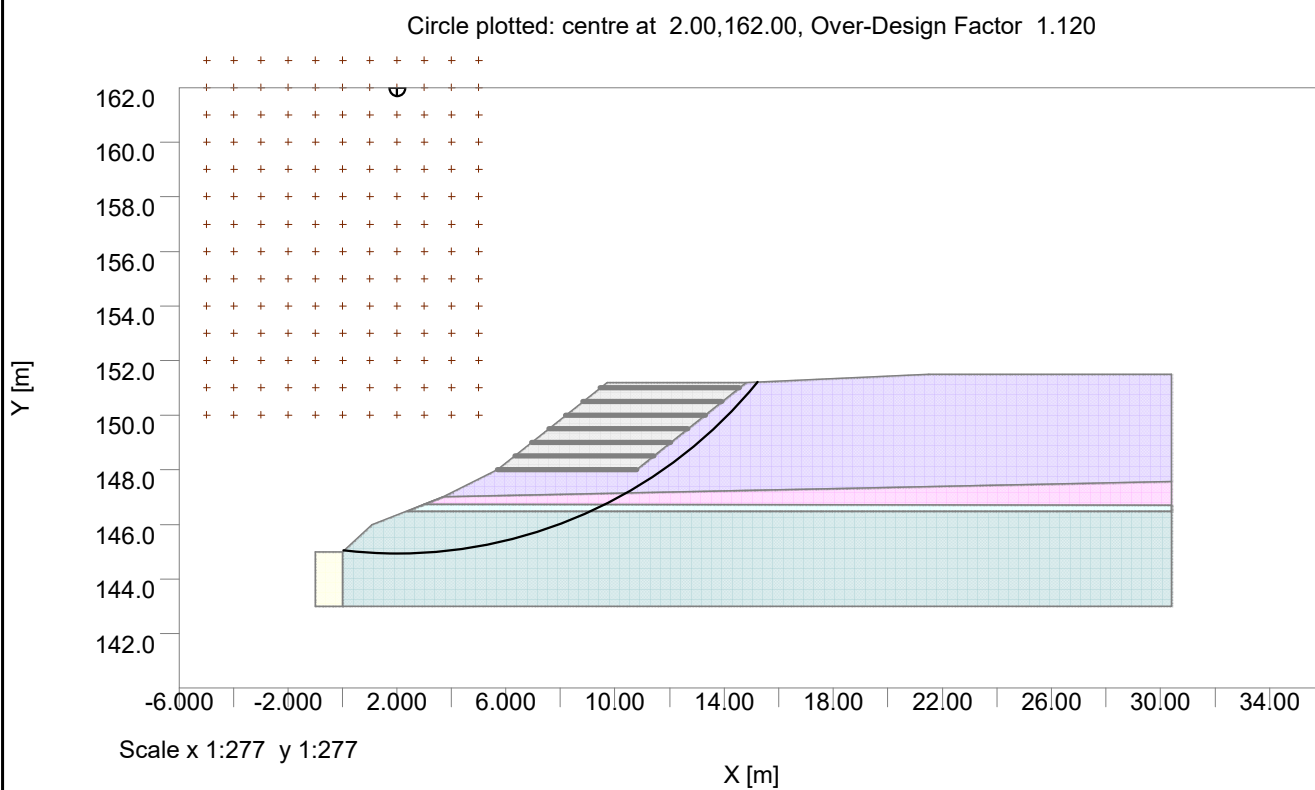
Hollingsworth Gate, Littleborough
Section A

Job No.	Sheet No.	Rev.
GRO-23131		
Drg. Ref.		
Made by JD	Date	Checked CH Date 08 Jun 2023

Slip Centre		Radius	Slip Weight	Comment/ Over-Design Factor	Disturbing Moment	Soil Strength Restoring Moment	Reinforcement Restoring Moment
x [m]	y [m]	[m]	[kN/m]		[kNm/m]	[kNm/m]	[kNm/m]
-10.000	153.00	20.556		Only 1 intersection with ground level			
-10.000	154.00	20.856		Only 1 intersection with ground level			
-10.000	155.00	21.198		Only 1 intersection with ground level			
-10.000	156.00	21.581		Only 1 intersection with ground level			
-10.000	157.00	22.003		Only 1 intersection with ground level			
-10.000	158.00	22.462		Only 1 intersection with ground level			
-10.000	159.00	22.955		Only 1 intersection with ground level			
-10.000	160.00	23.481		Only 1 intersection with ground level			
-9.0000	150.00	18.943		Only 1 intersection with ground level			
-9.0000	151.00	19.112		Only 1 intersection with ground level			
-9.0000	152.00	19.330		Only 1 intersection with ground level			
-9.0000	153.00	19.597		Only 1 intersection with ground level			
-9.0000	154.00	19.911		Only 1 intersection with ground level			
-9.0000	155.00	20.269		Only 1 intersection with ground level			
-9.0000	156.00	20.670		Only 1 intersection with ground level			
-9.0000	157.00	21.110		Only 1 intersection with ground level			
-9.0000	158.00	21.588		Only 1 intersection with ground level			
-9.0000	159.00	22.101		Only 1 intersection with ground level			
-9.0000	160.00	22.646		Only 1 intersection with ground level			
-8.0000	150.00	17.954		Only 1 intersection with ground level			
-8.0000	151.00	18.132		Only 1 intersection with ground level			
-8.0000	152.00	18.362		Only 1 intersection with ground level			
-8.0000	153.00	18.643		Only 1 intersection with ground level			
-8.0000	154.00	18.972		Only 1 intersection with ground level			
-8.0000	155.00	19.348		Only 1 intersection with ground level			
-8.0000	156.00	19.767		Only 1 intersection with ground level			
-8.0000	157.00	20.228		Only 1 intersection with ground level			
-8.0000	158.00	20.726		Only 1 intersection with ground level			
-8.0000	159.00	21.259		Only 1 intersection with ground level			
-8.0000	160.00	21.826		Only 1 intersection with ground level			
-7.0000	150.00	16.966		Only 1 intersection with ground level			
-7.0000	151.00	17.154		Only 1 intersection with ground level			
-7.0000	152.00	17.397		Only 1 intersection with ground level			
-7.0000	153.00	17.693		Only 1 intersection with ground level			
-7.0000	154.00	18.040		Only 1 intersection with ground level			
-7.0000	155.00	18.435		Only 1 intersection with ground level			
-7.0000	156.00	18.875		Only 1 intersection with ground level			
-7.0000	157.00	19.356		Only 1 intersection with ground level			
-7.0000	158.00	19.876		Only 1 intersection with ground level			
-7.0000	159.00	20.432		Only 1 intersection with ground level			
-7.0000	160.00	21.020		Only 1 intersection with ground level			
-6.0000	150.00	15.980		Only 1 intersection with ground level			
-6.0000	151.00	16.179		Only 1 intersection with ground level			
-6.0000	152.00	16.436		Only 1 intersection with ground level			
-6.0000	153.00	16.750		Only 1 intersection with ground level			
-6.0000	154.00	17.116		Only 1 intersection with ground level			
-6.0000	155.00	17.531		Only 1 intersection with ground level			
-6.0000	156.00	17.993		Only 1 intersection with ground level			
-6.0000	157.00	18.497		Only 1 intersection with ground level			
-6.0000	158.00	19.041		Only 1 intersection with ground level			
-6.0000	159.00	19.620		Only 1 intersection with ground level			
-6.0000	160.00	20.232		Only 1 intersection with ground level			
-5.0000	150.00	14.995		Only 1 intersection with ground level			
-5.0000	151.00	15.207		Only 1 intersection with ground level			
-5.0000	152.00	15.481		Only 1 intersection with ground level			
-5.0000	153.00	15.813		Only 1 intersection with ground level			
-5.0000	154.00	16.200		Only 1 intersection with ground level			
-5.0000	155.00	16.639		Only 1 intersection with ground level			
-5.0000	156.00	17.125		Only 1 intersection with ground level			
-5.0000	157.00	17.654		Only 1 intersection with ground level			
-5.0000	158.00	18.222		Only 1 intersection with ground level			
-5.0000	159.00	18.827		Only 1 intersection with ground level			
-5.0000	160.00	19.464		Only 1 intersection with ground level			
-4.0000	150.00	14.013		Only 1 intersection with ground level			
-4.0000	151.00	14.239		Only 1 intersection with ground level			
-4.0000	152.00	14.531		Only 1 intersection with ground level			
-4.0000	153.00	14.885		Only 1 intersection with ground level			
-4.0000	154.00	15.296		Only 1 intersection with ground level			
-4.0000	155.00	15.759		Only 1 intersection with ground level			
-4.0000	156.00	16.271		Only 1 intersection with ground level			
-4.0000	157.00	16.827		Only 1 intersection with ground level			
-4.0000	158.00	17.423		Only 1 intersection with ground level			
-4.0000	159.00	18.054		Only 1 intersection with ground level			
-4.0000	160.00	18.718		Only 1 intersection with ground level			
-3.0000	150.00	13.033		Only 1 intersection with ground level			
-3.0000	151.00	13.276		Only 1 intersection with ground level			
-3.0000	152.00	13.589		Only 1 intersection with ground level			

 Hollingsworth Gate, Littleborough Section A					Job No.	Sheet No.	Rev.
					GRO-23131		
					Drg. Ref.		
					Made by JD	Date	Checked CH Date 08 Jun 2023
Slip Centre	Radius	Slip Weight	Comment/ Over-Design Factor	Disturbing Moment	Soil Strength Restoring Moment	Reinforcement Restoring Moment	
x [m]	y [m]	[m]	[kN/m]	[kNm/m]	[kNm/m]	[kNm/m]	
-3.0000	153.00	13.966	Only 1	intersection	with ground level		
-3.0000	154.00	14.403	Only 1	intersection	with ground level		
-3.0000	155.00	14.895	Only 1	intersection	with ground level		
-3.0000	156.00	15.435	Only 1	intersection	with ground level		
-3.0000	157.00	16.020	Only 1	intersection	with ground level		
-3.0000	158.00	16.645	Only 1	intersection	with ground level		
-3.0000	159.00	17.305	Only 1	intersection	with ground level		
-3.0000	160.00	17.996	Only 1	intersection	with ground level		
-2.0000	150.00	12.056	Only 1	intersection	with ground level		
-2.0000	151.00	12.319	Only 1	intersection	with ground level		
-2.0000	152.00	12.655	Only 1	intersection	with ground level		
-2.0000	153.00	13.060	Only 1	intersection	with ground level		
-2.0000	154.00	13.526	Only 1	intersection	with ground level		
-2.0000	155.00	14.048	Only 1	intersection	with ground level		
-2.0000	156.00	14.620	Only 1	intersection	with ground level		
-2.0000	157.00	15.237	Only 1	intersection	with ground level		
-2.0000	158.00	15.892	Only 1	intersection	with ground level		
-2.0000	159.00	16.582	Only 1	intersection	with ground level		
-2.0000	160.00	17.302	Only 1	intersection	with ground level		
-1.0000	150.00	11.084	Only 1	intersection	with ground level		
-1.0000	151.00	11.369	Only 1	intersection	with ground level		
-1.0000	152.00	11.733	Only 1	intersection	with ground level		
-1.0000	153.00	12.168	Only 1	intersection	with ground level		
-1.0000	154.00	12.667	Only 1	intersection	with ground level		
-1.0000	155.00	13.223	Only 1	intersection	with ground level		
-1.0000	156.00	13.829	Only 1	intersection	with ground level		
-1.0000	157.00	14.479	Only 1	intersection	with ground level		
-1.0000	158.00	15.167	Only 1	intersection	with ground level		
-1.0000	159.00	15.889	Only 1	intersection	with ground level		
-1.0000	160.00	16.639	Only 1	intersection	with ground level		
0.0	150.00	10.117	Only 1	intersection	with ground level		
0.0	151.00	10.428	Only 1	intersection	with ground level		
0.0	152.00	10.824	Only 1	intersection	with ground level		
0.0	153.00	11.294	Only 1	intersection	with ground level		
0.0	154.00	11.830	Only 1	intersection	with ground level		
0.0	155.00	12.424	Only 1	intersection	with ground level		
0.0	156.00	13.067	Only 1	intersection	with ground level		
0.0	157.00	13.753	Only 1	intersection	with ground level		
0.0	158.00	14.476	Only 1	intersection	with ground level		
0.0	159.00	15.230	Only 1	intersection	with ground level		
0.0	160.00	16.011	Only 1	intersection	with ground level		

APPENDIX 3 - Section B Modelling Outputs



Specification

```
Slip Type: CIRCULAR
Direction of slip: Downhill
Minimum slip weight [kN/m] :80.00000
Type of analysis: STATIC
Partial factor analysis
Minimum number of slices 25
Method: Bishop (Variably inclined interslice forces)
Maximum number of iterations: 300
Reinforcement: ACTIVE
```

Method Partial Factors

```

BS EN 1997-1:2011 DA1-2
Factor on FAVOURABLE PERMANENT LOAD: 1.00000
Factor on UNFAVOURABLE PERMANENT LOAD: 1.00000
Factor on FAVOURABLE VARIABLE LOAD: 0.00000
Factor on UNFAVOURABLE VARIABLE LOAD: 1.30000
Factor on UNIT WEIGHT: 1.00000
Factor on DRAINED COHESION: 1.25000
Factor on UNDRAINED COHESION: 1.40000
Factor on TAN PHI': 1.25000
Factor on REINFORCEMENT PULLOUT: 1.50000
Factor on ECONOMIC FAILURE: 1.00000
Factor on SLIDING ALONG REINFORCEMENT: 1.50000

```

Material Partial Factors

[illegible]

Material Properties

Material Properties		Unit Weight		Shear Strength Parameters	
No	Description	Above GWL	Below GWL	Condition	Phi or c
or c0'					
		[kN/m3]	[kN/m3]		Phi0 [°]
0.0	1 Canal Wall	25.000	25.000	Drained	40.000
0.0	2 Reinforced Earth	20.000	22.000	Drained	24.000
0.0	3 Backfilled Made Ground	20.000	22.000	Drained	24.000
0.0	4 SAND	20.000	22.000	Drained	34.000
0.0	5 Firm CLAY	20.000	22.000	Drained	24.000
0.0	6 Soft CLAY	20.000	22.000	Drained	24.000
0.0	7 MUDSTONE	21.000	23.000	Drained	30.000

Reinforcement

Geotextile Reinforcement 1						
Layers	Level of top layer	Vertical Spacing	Length	Offset from surface	Angle from horizon	
	[m]	[m]	Top [m]	Btm [m]	[m]	[°]
7	151.00	0.50000	5.1000	5.1000	0.0	0

Bond Length	Bond Strength	Prestress	Grout Diameter
	[kN/m]	[kN]	[mm]
0.0%	0.0	0.0	0.0

Out of plane spacing	Tensile Capacity	Plate Capacity	Material Partial Factor
[m]	[kN]	[kN]	
0.0	1.3000	0.0	

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Made by JD	Date	Checked Date

Out of Tensile Plate Material
plane Capacity Capacity Partial
spacing [m] [kN] [kN] Factor

Slip Surface Specification

Circle centre specification:
Bottom left of grid: x = -5.00000 m y = 150.00000 m
Inclination of grid: 0.00000 deg
(positive anticlockwise direction about bottom left of grid)
Centres on grid: 11 in x direction at 1.00000m spacing
11 in y direction at 1.00000m spacing
Grid extended to find minimum FoS
All circles pass through common point at x = 11.00000 m, y = 147.50000 m

RESULTS OF ANALYSIS

In the following tables, values in italics are factored values
using the currently selected Method Partial Factors.

Slip Centre	Radius	Slip Weight	Comment/ Over-Design Factor	Disturbing Moment	Soil Strength Restoring Moment	Reinforcement Restoring Moment
x [m]	y [m]	[m]	[kN/m]	[kNm/m]	[kNm/m]	[kNm/m]
-5.0000	150.00	16.194	Only 1	intersection with ground level		
-5.0000	151.00	16.378	Only 1	intersection with ground level		
-5.0000	152.00	16.621	Only 1	intersection with ground level		
-5.0000	153.00	16.919	Only 1	intersection with ground level		
-5.0000	154.00	17.270	Only 1	intersection with ground level		
-5.0000	155.00	17.671	Only 1	intersection with ground level		
-5.0000	156.00	18.118	Only 1	intersection with ground level		
-5.0000	157.00	18.608	Only 1	intersection with ground level		
-5.0000	158.00	19.138	Only 1	intersection with ground level		
-5.0000	159.00	19.704	Only 1	intersection with ground level		
-5.0000	160.00	20.304	Only 1	intersection with ground level		
-4.0000	150.00	15.207	Only 1	intersection with ground level		
-4.0000	151.00	15.403	Only 1	intersection with ground level		
-4.0000	152.00	15.660	Only 1	intersection with ground level		
-4.0000	153.00	15.977	Only 1	intersection with ground level		
-4.0000	154.00	16.348	Only 1	intersection with ground level		
-4.0000	155.00	16.771	Only 1	intersection with ground level		
-4.0000	156.00	17.241	Only 1	intersection with ground level		
-4.0000	157.00	17.755	Only 1	intersection with ground level		
-4.0000	158.00	18.310	Only 1	intersection with ground level		
-4.0000	159.00	18.901	Only 1	intersection with ground level		
-4.0000	160.00	19.526	Only 1	intersection with ground level		
-3.0000	150.00	14.221	Only 1	intersection with ground level		
-3.0000	151.00	14.431	Only 1	intersection with ground level		
-3.0000	152.00	14.705	Only 1	intersection with ground level		
-3.0000	153.00	15.042	Only 1	intersection with ground level		
-3.0000	154.00	15.435	Only 1	intersection with ground level		
-3.0000	155.00	15.882	Only 1	intersection with ground level		
-3.0000	156.00	16.378	Only 1	intersection with ground level		
-3.0000	157.00	16.919	Only 1	intersection with ground level		
-3.0000	158.00	17.500	Only 1	intersection with ground level		
-3.0000	159.00	18.118	Only 1	intersection with ground level		
-3.0000	160.00	18.768	Only 1	intersection with ground level		
-2.0000	150.00	13.238	Only 1	intersection with ground level		
-2.0000	151.00	13.463	Only 1	intersection with ground level		
-2.0000	152.00	13.757	Only 1	intersection with ground level		
-2.0000	153.00	14.116	Only 1	intersection with ground level		
-2.0000	154.00	14.534	Only 1	intersection with ground level		
-2.0000	155.00	15.008	Only 1	intersection with ground level		
-2.0000	156.00	15.532	Only 1	intersection with ground level		
-2.0000	157.00	16.101	Only 1	intersection with ground level		
-2.0000	158.00	16.711	Only 1	intersection with ground level		
-2.0000	159.00	17.357	Only 1	intersection with ground level		
-2.0000	160.00	18.035	Only 1	intersection with ground level		
-1.0000	150.00	12.258	Only 1	intersection with ground level		
-1.0000	151.00	12.500	Only 1	intersection with ground level		
-1.0000	152.00	12.816	Only 1	intersection with ground level		
-1.0000	153.00	13.200	Only 1	intersection with ground level		
-1.0000	154.00	13.647	Only 1	intersection with ground level		
-1.0000	155.00	14.151	Only 1	intersection with ground level		
-1.0000	156.00	14.705	Only 1	intersection with ground level		
-1.0000	157.00	15.305	Only 1	intersection with ground level		
-1.0000	158.00	15.945	Only 1	intersection with ground level		
-1.0000	159.00	16.621	Only 1	intersection with ground level		
-1.0000	160.00	17.328	Only 1	intersection with ground level		
0.0	150.00	11.281	Only 1	intersection with ground level		
0.0	151.00	11.543	Only 1	intersection with ground level		
0.0	152.00	11.885	Only 1	intersection with ground level		

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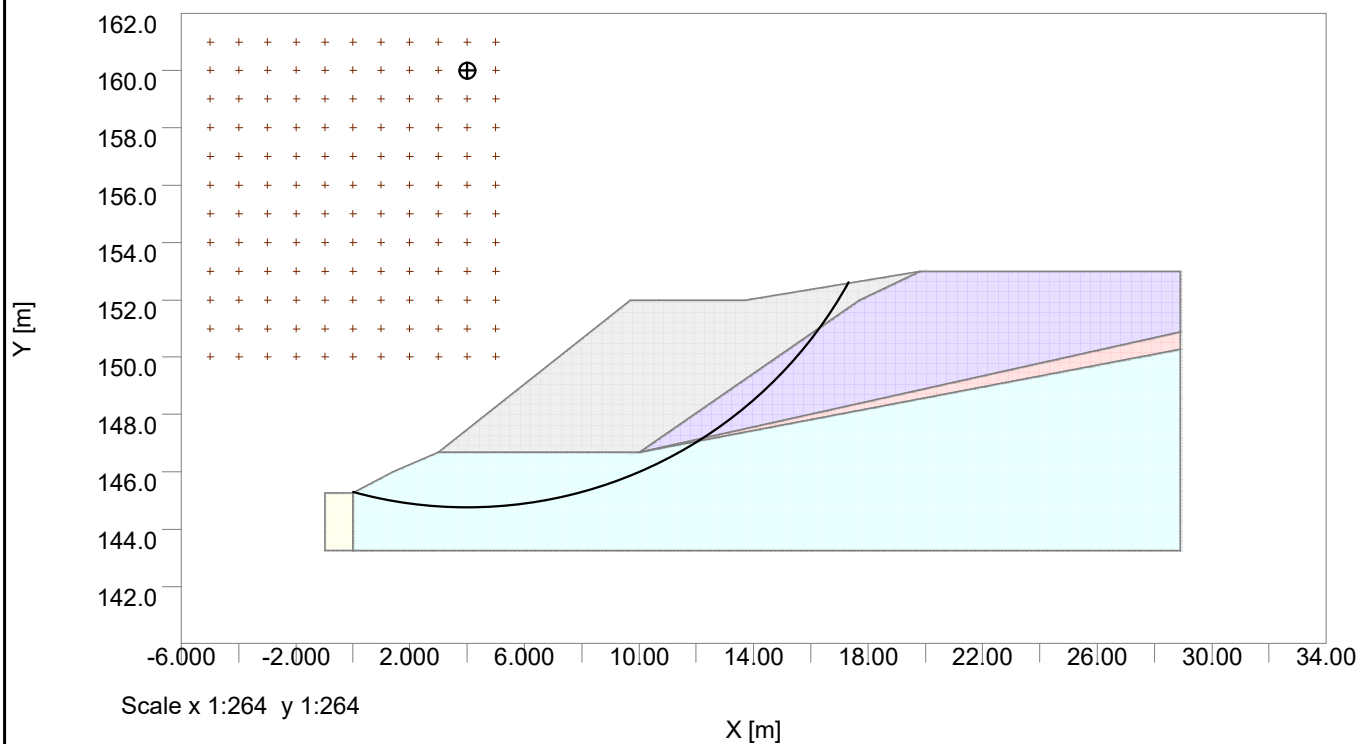
Slip Centre	Radius	Slip Weight	Comment/ Over-Design Factor	Disturbing Moment	Soil Strength Restoring Moment	Reinforcement Restoring Moment
x [m]	y [m]	[m]	[kN/m]	[kNm/m]	[kNm/m]	[kNm/m]
0.0	153.00	12.298	Only 1	intersection with ground level		
0.0	154.00	12.777	Only 1	intersection with ground level		
0.0	155.00	13.314	Only 1	intersection with ground level		
0.0	156.00	13.901	Only 1	intersection with ground level		
0.0	157.00	14.534	Only 1	intersection with ground level		
0.0	158.00	15.207	Only 1	intersection with ground level		
0.0	159.00	15.914	Only 1	intersection with ground level		
0.0	160.00	16.651	Only 1	intersection with ground level		
1.0000	150.00	10.308	Only 1	intersection with ground level		
1.0000	151.00	10.595	Only 1	intersection with ground level		
1.0000	152.00	10.966	Only 1	intersection with ground level		
1.0000	153.00	11.413	Only 1	intersection with ground level		
1.0000	154.00	11.927	Only 1	intersection with ground level		
1.0000	155.00	12.500	Only 1	intersection with ground level		
1.0000	156.00	13.124	Only 1	intersection with ground level		
1.0000	156.00	13.124	Only 1	intersection with ground level		
1.0000	157.00	13.793	Only 1	intersection with ground level		
1.0000	158.00	14.500	Only 1	intersection with ground level		
1.0000	159.00	15.240	Only 1	intersection with ground level		
1.0000	160.00	16.008	Only 1	intersection with ground level		
2.0000	150.00	9.3408	Only 1	intersection with ground level		
2.0000	151.00	9.6566	Only 1	intersection with ground level		
2.0000	152.00	10.062	Only 1	intersection with ground level		
2.0000	153.00	10.548	Only 1	intersection with ground level		
2.0000	154.00	11.102	Only 1	intersection with ground level		
2.0000	154.00	11.102	Only 1	intersection with ground level		
2.0000	155.00	11.715	Only 1	intersection with ground level		
2.0000	156.00	12.379	Only 1	intersection with ground level		
2.0000	157.00	13.086	Only 1	intersection with ground level		
2.0000	158.00	13.829	Only 1	intersection with ground level		
2.0000	159.00	14.603	Only 1	intersection with ground level		
2.0000	160.00	15.403	Only 1	intersection with ground level		
3.0000	150.00	8.3815	Only 1	intersection with ground level		
3.0000	151.00	8.7321	Only 1	intersection with ground level		
3.0000	151.00	8.7321	Only 1	intersection with ground level		
3.0000	152.00	9.1788	Only 1	intersection with ground level		
3.0000	152.00	9.1788	Only 1	intersection with ground level		
3.0000	153.00	9.7082	Only 1	intersection with ground level		
3.0000	154.00	10.308	Only 1	intersection with ground level		
3.0000	155.00	10.966	Only 1	intersection with ground level		
3.0000	156.00	11.673	1.2065	3540.4	4250.2	21.450
3.0000	157.00	12.420	1.1704	3614.9	4211.1	19.684
3.0000	158.00	13.200	1.1543	3689.0	4250.2	8.2297
3.0000	159.00	14.009	1.1471	3770.8	4324.6	0.77729
3.0000	160.00	14.841	1.1453	3858.3	4418.9	0.0
4.0000	150.00	7.4330	Only 1	intersection with ground level		
4.0000	150.00	7.4330	Only 1	intersection with ground level		
4.0000	151.00	7.8262	Only 1	intersection with ground level		
4.0000	152.00	8.3217	1.4245	2514.8	3569.5	13.000
4.0000	153.00	8.9022	1.3290	2591.0	3423.9	19.500
4.0000	154.00	9.5525	1.2731	2671.0	3381.0	19.500
4.0000	155.00	10.259	1.2338	2759.2	3385.3	18.978
4.0000	156.00	11.011	1.2069	2853.9	3425.9	18.496
4.0000	157.00	11.800	1.1861	2953.1	3494.6	8.0993
4.0000	158.00	12.619	1.1732	3058.0	3587.0	0.67432
4.0000	159.00	13.463	1.1680	3166.4	3698.4	0.0
4.0000	160.00	14.327	1.1668	3279.1	3826.2	0.0
5.0000	150.00	6.5000	Centre embedded/below end of slip			
5.0000	151.00	6.9462	Centre embedded/below end of slip			
5.0000	152.00	7.5000	1.4246	1854.1	2628.4	13.000
5.0000	153.00	8.1394	1.3346	1965.1	2608.4	14.300
5.0000	154.00	8.8459	1.2753	2079.9	2634.2	18.351
5.0000	155.00	9.6047	1.2347	2197.0	2695.5	17.029
5.0000	156.00	10.404	1.2063	2314.6	2784.3	7.8157
5.0000	157.00	11.236	1.1895	2435.8	2896.7	0.58261
5.0000	158.00	12.093	1.1832	2557.5	3026.1	0.0
5.0000	159.00	12.971	1.1822	2682.4	3171.1	0.0
5.0000	160.00	13.865	1.1847	2809.4	3328.3	0.0
-5.0000	161.00	20.934	Only 1	intersection with ground level		
-4.0000	161.00	20.180	Only 1	intersection with ground level		
-3.0000	161.00	19.449	Only 1	intersection with ground level		
-2.0000	161.00	18.742	Only 1	intersection with ground level		
-1.0000	161.00	18.062	Only 1	intersection with ground level		
0.0	161.00	17.414	Only 1	intersection with ground level		
1.0000	161.00	16.800	Only 1	intersection with ground level		
2.0000	161.00	16.225	1.1244	4634.7	5211.3	0.0

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Slip Centre	Radius	Slip Weight	Comment/ Over-Design Factor	Disturbing Moment	Soil Strength Restoring Moment	Reinforcement Restoring Moment
x [m]	y [m]	[m]	[kN/m]	[kNm/m]	[kNm/m]	[kNm/m]
3.0000	161.00	15.692	717.55	1.1466	3952.4	4532.0
4.0000	161.00	15.207	664.74	1.1684	3395.6	3967.6
5.0000	161.00	14.773	626.18	1.1896	2939.0	3496.4
-5.0000	162.00	21.593	Only 1 intersection with ground level			
-4.0000	162.00	20.863	Only 1 intersection with ground level			
-3.0000	162.00	20.156	Only 1 intersection with ground level			
-2.0000	162.00	19.474	Only 1 intersection with ground level			
-1.0000	162.00	18.822	Only 1 intersection with ground level			
0.0	162.00	18.200	Only 1 intersection with ground level			
1.0000	162.00	17.614	Only 1 intersection with ground level			
2.0000	162.00	17.066	764.04	1.1202	4708.5	5274.6
3.0000	162.00	16.560	708.36	1.1502	4052.7	4661.4
4.0000	162.00	16.101	661.97	1.1728	3515.5	4123.0
5.0000	162.00	15.692	629.64	1.1957	3070.5	3671.4
-5.0000	163.00	22.277	Only 1 intersection with ground level			
-4.0000	163.00	21.570	Only 1 intersection with ground level			
-3.0000	163.00	20.887	Only 1 intersection with ground level			
-2.0000	163.00	20.230	Only 1 intersection with ground level			
-1.0000	163.00	19.602	Only 1 intersection with ground level			
0.0	163.00	19.007	Only 1 intersection with ground level			
1.0000	163.00	18.446	Only 1 intersection with ground level			
2.0000	163.00	17.923	751.37	1.1255	4788.6	5389.4
3.0000	163.00	17.443	701.57	1.1557	4157.0	4804.1
4.0000	163.00	17.007	661.13	1.1794	3638.3	4291.0
5.0000	163.00	16.621	634.48	1.2018	3204.6	3851.1

APPENDIX 4 - Section D Modelling Outputs

Circle plotted: centre at 4.00,160.00, Over-Design Factor 1.461



Specification

```
Slip Type: CIRCULAR
Direction of slip: Downhill
Minimum slip weight [kN/m] :80.00000
Type of analysis: STATIC
Partial factor analysis
Minimum number of slices 25
Method: Bishop (Variably inclined interslice forces)
Maximum number of iterations: 300
Reinforcement: NOT ACTIVE
```

Method Partial Factors

```

BS EN 1997-1:2011 DA1-2
Factor on FAVOURABLE PERMANENT LOAD: 1.00000
Factor on UNFAVOURABLE PERMANENT LOAD: 1.00000
Factor on FAVOURABLE VARIABLE LOAD: 0.00000
Factor on UNFAVOURABLE VARIABLE LOAD: 1.30000
Factor on UNIT WEIGHT: 1.00000
Factor on DRAINED COHESION: 1.25000
Factor on UNDRAINED COHESION: 1.40000
Factor on TAN PHI': 1.25000
Factor on REINFORCEMENT PULLOUT: 1.50000
Factor on ECONOMIC FAILURE: 1.00000
Factor on SLIDING ALONG REINFORCEMENT: 1.50000

```

Material Properties

No	Description	Unit Weight		Shear Strength Parameters	Phi or c
		Above GWL	Below GWL		
or c0'					
		[kN/m3]	[kN/m3]		Phi0 [°]
0.0	1 Canal Wall	35.000	35.000	Drained	40.000
0.0	2 Reinforced Earth	20.000	22.000	Drained	24.000
0.0	3 Made Ground Backfill	20.000	22.000	Drained	24.000
0.0	4 Made Ground Gravel	20.000	22.000	Drained	24.000
0.0	5 SANDSTONE	22.000	24.000	Drained	34.000

Reinforcement

NB: REINFORCEMENT IS DEFINED BUT NOT ACTIVE
Geotextile Reinforcement 1

Layers	Level of top layer	Vertical Spacing [m]	Length Top [m]	Length Btm [m]	Offset from surface [m]	Angle from horizon [°]
11	151.80	0.50000	7.0000	7.0000	0.0	0

Bond Length	Bond Strength	Prestress	Grout Diameter
	[kN/m]	[kN]	[mm]
0.0%	0.0	0.0	0.0

Out of plane spacing	Tensile Capacity	Plate Capacity	Material Partial Factor
[m]	[kN]	[kN]	
0.0	1.3000	0.0	

Slip Surface Specification

Circle centre specification:
 Bottom left of grid: x = -5.00000 m y = 150.00000 m
 Inclination of grid: 0.00000 deg
 (positive anticlockwise direction about bottom left of grid)
 Centres on grid: 11 in x direction at 1.00000m spacing
 11 in y direction at 1.00000m spacing

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Out of Tensile Plate Material
plane Capacity Capacity Partial
spacing [m] [kN] Factor

Grid extended to find minimum FoS

All circles pass through common point at x = 11.50000 m, y = 146.70000 m

RESULTS OF ANALYSIS

In the following tables, values in italics are factored values using the currently selected Method Partial Factors.

Slip Centre	Radius	Slip	Comment/ Weight	Over-Design Factor	Disturbing Moment	Soil Strength Restoring Moment	Reinforcement Restoring Moment
x [m]	y [m]	[m]	[kN/m]		[kNm/m]	[kNm/m]	[kNm/m]
-5.0000	150.00	16.827	Only 1	intersection	with	ground level	
-5.0000	151.00	17.051	Only 1	intersection	with	ground level	
-5.0000	152.00	17.330	Only 1	intersection	with	ground level	
-5.0000	153.00	17.662	Only 1	intersection	with	ground level	
-5.0000	154.00	18.043	Only 1	intersection	with	ground level	
-5.0000	155.00	18.470	Only 1	intersection	with	ground level	
-5.0000	156.00	18.940	Only 1	intersection	with	ground level	
-5.0000	157.00	19.451	Only 1	intersection	with	ground level	
-5.0000	158.00	19.999	Only 1	intersection	with	ground level	
-5.0000	159.00	20.580	Only 1	intersection	with	ground level	
-5.0000	160.00	21.193	Only 1	intersection	with	ground level	
-4.0000	150.00	15.847	Only 1	intersection	with	ground level	
-4.0000	151.00	16.085	Only 1	intersection	with	ground level	
-4.0000	152.00	16.381	Only 1	intersection	with	ground level	
-4.0000	153.00	16.731	Only 1	intersection	with	ground level	
-4.0000	154.00	17.133	Only 1	intersection	with	ground level	
-4.0000	155.00	17.582	Only 1	intersection	with	ground level	
-4.0000	156.00	18.076	Only 1	intersection	with	ground level	
-4.0000	157.00	18.610	Only 1	intersection	with	ground level	
-4.0000	158.00	19.182	Only 1	intersection	with	ground level	
-4.0000	159.00	19.787	Only 1	intersection	with	ground level	
-4.0000	160.00	20.424	Only 1	intersection	with	ground level	
-3.0000	150.00	14.871	Only 1	intersection	with	ground level	
-3.0000	151.00	15.124	Only 1	intersection	with	ground level	
-3.0000	152.00	15.438	Only 1	intersection	with	ground level	
-3.0000	153.00	15.809	Only 1	intersection	with	ground level	
-3.0000	154.00	16.234	Only 1	intersection	with	ground level	
-3.0000	155.00	16.707	Only 1	intersection	with	ground level	
-3.0000	156.00	17.226	Only 1	intersection	with	ground level	
-3.0000	157.00	17.786	Only 1	intersection	with	ground level	
-3.0000	158.00	18.383	Only 1	intersection	with	ground level	
-3.0000	159.00	19.014	Only 1	intersection	with	ground level	
-3.0000	160.00	19.676	Only 1	intersection	with	ground level	
-2.0000	150.00	13.897	Only 1	intersection	with	ground level	
-2.0000	151.00	14.168	Only 1	intersection	with	ground level	
-2.0000	152.00	14.503	Only 1	intersection	with	ground level	
-2.0000	153.00	14.898	Only 1	intersection	with	ground level	
-2.0000	154.00	15.347	Only 1	intersection	with	ground level	
-2.0000	155.00	15.847	Only 1	intersection	with	ground level	
-2.0000	156.00	16.393	Only 1	intersection	with	ground level	
-2.0000	157.00	16.981	Only 1	intersection	with	ground level	
-2.0000	158.00	17.605	Only 1	intersection	with	ground level	
-2.0000	159.00	18.263	Only 1	intersection	with	ground level	
-2.0000	160.00	18.951	Only 1	intersection	with	ground level	
-1.0000	150.00	12.928	Only 1	intersection	with	ground level	
-1.0000	151.00	13.219	Only 1	intersection	with	ground level	
-1.0000	152.00	13.577	Only 1	intersection	with	ground level	
-1.0000	153.00	13.998	Only 1	intersection	with	ground level	
-1.0000	154.00	14.475	Only 1	intersection	with	ground level	
-1.0000	155.00	15.005	Only 1	intersection	with	ground level	
-1.0000	156.00	15.580	Only 1	intersection	with	ground level	
-1.0000	157.00	16.197	Only 1	intersection	with	ground level	
-1.0000	158.00	16.851	Only 1	intersection	with	ground level	
-1.0000	159.00	17.537	Only 1	intersection	with	ground level	
-1.0000	160.00	18.252	Only 1	intersection	with	ground level	
0.0	150.00	11.964	Only 1	intersection	with	ground level	
0.0	151.00	12.278	Only 1	intersection	with	ground level	
0.0	152.00	12.663	Only 1	intersection	with	ground level	
0.0	153.00	13.113	Only 1	intersection	with	ground level	
0.0	154.00	13.621	Only 1	intersection	with	ground level	
0.0	155.00	14.182	Only 1	intersection	with	ground level	
0.0	156.00	14.790	Only 1	intersection	with	ground level	
0.0	157.00	15.438	Only 1	intersection	with	ground level	
0.0	158.00	16.123	Only 1	intersection	with	ground level	
0.0	159.00	16.839	Only 1	intersection	with	ground level	
0.0	160.00	17.582	Only 1	intersection	with	ground level	

Oasys Hollingsworth Gate, Littleborough Section D					Job No.		Sheet No.	Rev.
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Slip Centre	Radius	Slip Weight	Comment/ Over-Design Factor	Disturbing Moment	Soil Strength Restoring Moment	Reinforcement Restoring Moment		
x [m]	y [m]	[m]	[kN/m]	[kNm/m]	[kNm/m]	[kNm/m]		
1.0000	150.00	11.006	Only 1	intersection with ground level				
1.0000	151.00	11.346	Only 1	intersection with ground level				
1.0000	152.00	11.762	Only 1	intersection with ground level				
1.0000	153.00	12.245	Only 1	intersection with ground level				
1.0000	154.00	12.788	Only 1	intersection with ground level				
1.0000	155.00	13.384	Only 1	intersection with ground level				
1.0000	156.00	14.026	Only 1	intersection with ground level				
1.0000	157.00	14.709	Only 1	intersection with ground level				
1.0000	158.00	15.425	Only 1	intersection with ground level				
1.0000	159.00	16.172	Only 1	intersection with ground level				
1.0000	160.00	16.945	Only 1	intersection with ground level				
2.0000	150.00	10.057	Only 1	intersection with ground level				
2.0000	151.00	10.428	Only 1	intersection with ground level				
2.0000	152.00	10.878	Only 1	intersection with ground level				
2.0000	153.00	11.399	Only 1	intersection with ground level				
2.0000	154.00	11.981	Only 1	intersection with ground level				
2.0000	155.00	12.615	Only 1	intersection with ground level				
2.0000	156.00	13.294	Only 1	intersection with ground level				
2.0000	157.00	14.012	Only 1	intersection with ground level				
2.0000	157.00	14.012	Only 1	intersection with ground level				
2.0000	158.00	14.763	Only 1	intersection with ground level				
2.0000	158.00	14.763	Only 1	intersection with ground level				
2.0000	159.00	15.542	Only 1	intersection with ground level				
2.0000	160.00	16.344	Only 1	intersection with ground level				
3.0000	150.00	9.1181	Only 1	intersection with ground level				
3.0000	151.00	9.5258	Only 1	intersection with ground level				
3.0000	152.00	10.017	Only 1	intersection with ground level				
3.0000	153.00	10.580	Only 1	intersection with ground level				
3.0000	154.00	11.204	Only 1	intersection with ground level				
3.0000	154.00	11.204	Only 1	intersection with ground level				
3.0000	155.00	11.880	Only 1	intersection with ground level				
3.0000	155.00	11.880	Only 1	intersection with ground level				
3.0000	156.00	12.599	Only 1	intersection with ground level				
3.0000	157.00	13.354	Only 1	intersection with ground level				
3.0000	158.00	14.140	Only 1	intersection with ground level				
3.0000	159.00	14.951	Only 1	intersection with ground level				
3.0000	160.00	15.784	Only 1	intersection with ground level				
4.0000	150.00	8.1939	Only 1	intersection with ground level				
4.0000	150.00	8.1939	Only 1	intersection with ground level				
4.0000	151.00	8.6452	Only 1	intersection with ground level				
4.0000	151.00	8.6452	Only 1	intersection with ground level				
4.0000	152.00	9.1837	Only 1	intersection with ground level				
4.0000	152.00	9.1837	Only 1	intersection with ground level				
4.0000	153.00	9.7949	Only 1	intersection with ground level				
4.0000	153.00	9.7949	Only 1	intersection with ground level				
4.0000	154.00	10.466	Only 1	intersection with ground level				
4.0000	155.00	11.187	Only 1	intersection with ground level				
4.0000	156.00	11.947	Only 1	intersection with ground level				
4.0000	157.00	12.741	1248.2	1.4994	5478.8	8215.1	0.0	
4.0000	158.00	13.562	1239.2	1.4767	5788.6	8547.8	0.0	
4.0000	159.00	14.406	1236.4	1.4648	6103.2	8940.0	0.0	
4.0000	160.00	15.269	1238.6	1.4606	6426.1	9385.7	0.0	
5.0000	150.00	7.2897	Only 1	intersection with ground level				
5.0000	150.00	7.2897	Only 1	intersection with ground level				
5.0000	151.00	7.7936	Only 1	intersection with ground level				
5.0000	151.00	7.7936	Only 1	intersection with ground level				
5.0000	152.00	8.3869	Centre embedded/below end of slip					
5.0000	153.00	9.0521	1191.3	1.6687	3513.8	5863.4	0.0	
5.0000	154.00	9.7745	1170.4	1.6117	3785.8	6101.7	0.0	
5.0000	155.00	10.542	1159.6	1.5731	4074.2	6409.0	0.0	
5.0000	156.00	11.346	1156.0	1.5487	4373.0	6772.3	0.0	
5.0000	157.00	12.179	1157.6	1.5350	4680.4	7184.1	0.0	
5.0000	158.00	13.036	1164.2	1.5276	5002.6	7642.1	0.0	
5.0000	159.00	13.912	1174.2	1.5257	5335.4	8140.5	0.0	
5.0000	160.00	14.803	1186.7	1.5284	5676.0	8674.9	0.0	
-5.0000	161.00	21.834	Only 1	intersection with ground level				
-4.0000	161.00	21.089	Only 1	intersection with ground level				
-3.0000	161.00	20.365	Only 1	intersection with ground level				
-2.0000	161.00	19.666	Only 1	intersection with ground level				
-1.0000	161.00	18.993	Only 1	intersection with ground level				
0.0	161.00	18.350	Only 1	intersection with ground level				
1.0000	161.00	17.741	Only 1	intersection with ground level				
1.0000	161.00	17.741	Only 1	intersection with ground level				
2.0000	161.00	17.168	Only 1	intersection with ground level				
3.0000	161.00	16.636	Only 1	intersection with ground level				
4.0000	161.00	16.147	1244.4	1.4635	6755.9	9887.5	0.0	



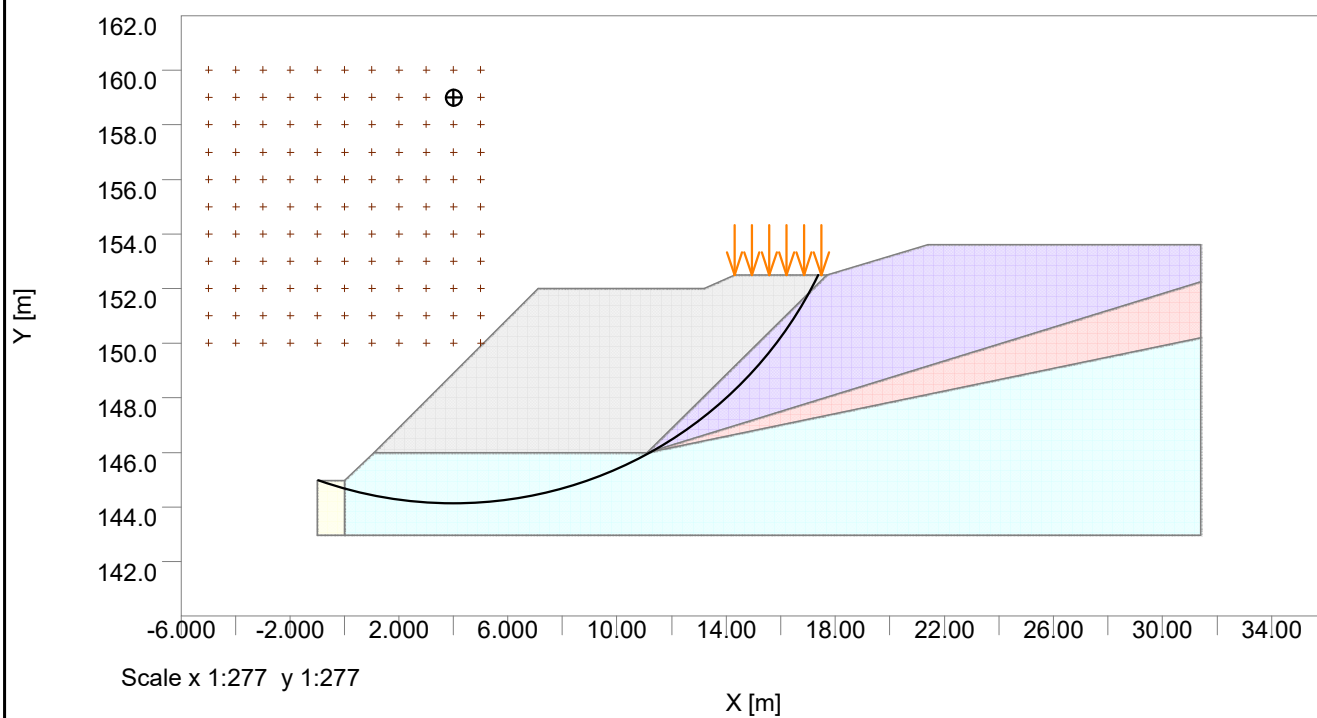
Hollingsworth Gate, Littleborough
Section D

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Drg. Ref.		
Made by JD	Date 07 Jun 2023	Checked Date

Slip Centre		Radius	Slip Weight	Comment/ Over-Design Factor	Disturbing Moment	Soil Strength Restoring Moment	Reinforcement Restoring Moment
x [m]	y [m]	[m]	[kN/m]		[kNm/m]	[kNm/m]	[kNm/m]
5.0000	161.00	15.708	1202.0	1.5332	6030.9	9246.9	0.0

APPENDIX 5 - Section E Modelling Outputs

Circle plotted: centre at 4.00,159.00, Over-Design Factor 1.359



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	Made by JD		Date		Checked Date	

Specification

Slip Type: CIRCULAR
Direction of slip: Downhill
Minimum slip weight [kN/m] :100.00000
Type of analysis: STATIC
Partial factor analysis
Minimum number of slices 25
Method: Bishop(Variably inclined interslice forces)
Maximum number of iterations: 300
Reinforcement: NOT ACTIVE

Material Properties

No	Description	Unit Weight		Shear Strength Parameters Condition	Phi or c
		Above GWL	Below GWL		
or c0'					
		[kN/m3]	[kN/m3]		Phi0 [°]
	[kN/m²]				
0.0	1 Canal Wall	25.000	25.000	Drained	40.000
0.0	2 Reinforced Earth	20.000	22.000	Drained	24.000
0.0	3 Clay Made Ground	20.000	22.000	Drained	24.000
0.0	4 Stiff CLAY	21.000	23.000	Drained	24.000
0.0	5 MUDTSTONE	21.000	23.000	Drained	30.000

Surface loads

No.	Limits of loaded area		Distributed load	Permanent / Variable load	Favourable / Unfavourable load	Use in pull-out calc
	X1	X2	Vert	Horiz		
	[m]	[m]	[kN/m²]	[kN/m²]		
1	14.300	17.500	10.000	0.0	Variable	Unfavourable No

Reinforcement

NB: REINFORCEMENT IS DEFINED BUT NOT ACTIVE

Geotextile Reinforcement 1

Layers	Level of top layer	Vertical Spacing	Length	Offset from surface	Angle from horiz
	[m]	[m]	Top [m]	Btm [m]	[°]
12	151.50	0.50000	10.000	10.000	0.0 0

Bond Length	Bond Strength	Prestress	Grout Diameter
	[kN/m]	[kN]	[mm]
0.0%	0.0	0.0	0.0

Out of plane spacing	Tensile Capacity	Plate Capacity	Material Partial Factor
[m]	[kN]	[kN]	
0.0	1.3000	0.0	

Slip Surface Specification

Circle centre specification:
Bottom left of grid: x = -5.00000 m y = 150.00000 m
Inclination of grid: 0.00000 deg
(positive anticlockwise direction about bottom left of grid)
Centres on grid: 11 in x direction at 1.00000m spacing
11 in y direction at 1.00000m spacing
Grid extended to find minimum FoS
All circles pass through common point at x = 11.60000 m, y = 146.20000 m

RESULTS OF ANALYSIS

In the following tables, values in italics are factored values

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Out of Tensile Plate Material
plane Capacity Capacity Partial
spacing Factor

[m] [kN] [kN]

using the currently selected Method Partial Factors.

Slip Centre Radius Slip Comment/ Disturbing Soil Strength Reinforcement
Weight Over-Design Moment Restoring Restoring
Factor Moment Moment Moment

x [m] y [m] [m] [kN/m] [kNm/m] [kNm/m] [kNm/m]

-5.0000	150.00	17.029	Only 1 intersection with ground level
-5.0000	151.00	17.280	Only 1 intersection with ground level
-5.0000	152.00	17.584	Only 1 intersection with ground level
-5.0000	153.00	17.939	Only 1 intersection with ground level
-5.0000	154.00	18.341	Only 1 intersection with ground level
-5.0000	155.00	18.788	Only 1 intersection with ground level
-5.0000	156.00	19.277	Only 1 intersection with ground level
-5.0000	157.00	19.804	Only 1 intersection with ground level
-5.0000	158.00	20.367	Only 1 intersection with ground level
-5.0000	159.00	20.962	Only 1 intersection with ground level
-5.0000	160.00	21.587	Only 1 intersection with ground level
-4.0000	150.00	16.056	Only 1 intersection with ground level
-4.0000	151.00	16.322	Only 1 intersection with ground level
-4.0000	152.00	16.643	Only 1 intersection with ground level
-4.0000	153.00	17.018	Only 1 intersection with ground level
-4.0000	154.00	17.441	Only 1 intersection with ground level
-4.0000	155.00	17.911	Only 1 intersection with ground level
-4.0000	156.00	18.423	Only 1 intersection with ground level
-4.0000	157.00	18.974	Only 1 intersection with ground level
-4.0000	158.00	19.560	Only 1 intersection with ground level
-4.0000	159.00	20.179	Only 1 intersection with ground level
-4.0000	160.00	20.828	Only 1 intersection with ground level
-3.0000	150.00	15.086	Only 1 intersection with ground level
-3.0000	151.00	15.369	Only 1 intersection with ground level
-3.0000	152.00	15.710	Only 1 intersection with ground level
-3.0000	153.00	16.106	Only 1 intersection with ground level
-3.0000	154.00	16.553	Only 1 intersection with ground level
-3.0000	155.00	17.047	Only 1 intersection with ground level
-3.0000	156.00	17.584	Only 1 intersection with ground level
-3.0000	157.00	18.160	Only 1 intersection with ground level
-3.0000	158.00	18.772	Only 1 intersection with ground level
-3.0000	159.00	19.416	Only 1 intersection with ground level
-3.0000	160.00	20.090	Only 1 intersection with ground level
-2.0000	150.00	14.121	Only 1 intersection with ground level
-2.0000	151.00	14.422	Only 1 intersection with ground level
-2.0000	152.00	14.785	Only 1 intersection with ground level
-2.0000	153.00	15.205	Only 1 intersection with ground level
-2.0000	154.00	15.678	Only 1 intersection with ground level
-2.0000	155.00	16.199	Only 1 intersection with ground level
-2.0000	156.00	16.763	Only 1 intersection with ground level
-2.0000	157.00	17.367	Only 1 intersection with ground level
-2.0000	158.00	18.006	Only 1 intersection with ground level
-2.0000	159.00	18.676	Only 1 intersection with ground level
-2.0000	160.00	19.375	Only 1 intersection with ground level
-1.0000	150.00	13.161	Only 1 intersection with ground level
-1.0000	151.00	13.483	Only 1 intersection with ground level
-1.0000	152.00	13.871	Only 1 intersection with ground level
-1.0000	153.00	14.318	Only 1 intersection with ground level
-1.0000	154.00	14.819	Only 1 intersection with ground level
-1.0000	155.00	15.369	Only 1 intersection with ground level
-1.0000	156.00	15.962	Only 1 intersection with ground level
-1.0000	157.00	16.595	Only 1 intersection with ground level
-1.0000	158.00	17.263	Only 1 intersection with ground level
-1.0000	159.00	17.961	Only 1 intersection with ground level
-1.0000	160.00	18.687	Only 1 intersection with ground level
0.0	150.00	12.207	Only 1 intersection with ground level
0.0	151.00	12.554	Only 1 intersection with ground level
0.0	152.00	12.969	Only 1 intersection with ground level
0.0	153.00	13.446	Only 1 intersection with ground level
0.0	154.00	13.979	Only 1 intersection with ground level
0.0	155.00	14.560	Only 1 intersection with ground level
0.0	156.00	15.186	Only 1 intersection with ground level
0.0	157.00	15.849	Only 1 intersection with ground level
0.0	158.00	16.547	Only 1 intersection with ground level
0.0	159.00	17.274	Only 1 intersection with ground level
0.0	160.00	18.028	Only 1 intersection with ground level
1.0000	150.00	11.261	Only 1 intersection with ground level
1.0000	151.00	11.636	Only 1 intersection with ground level
1.0000	152.00	12.083	Only 1 intersection with ground level
1.0000	153.00	12.594	Only 1 intersection with ground level
1.0000	154.00	13.161	Only 1 intersection with ground level
1.0000	155.00	13.777	Only 1 intersection with ground level

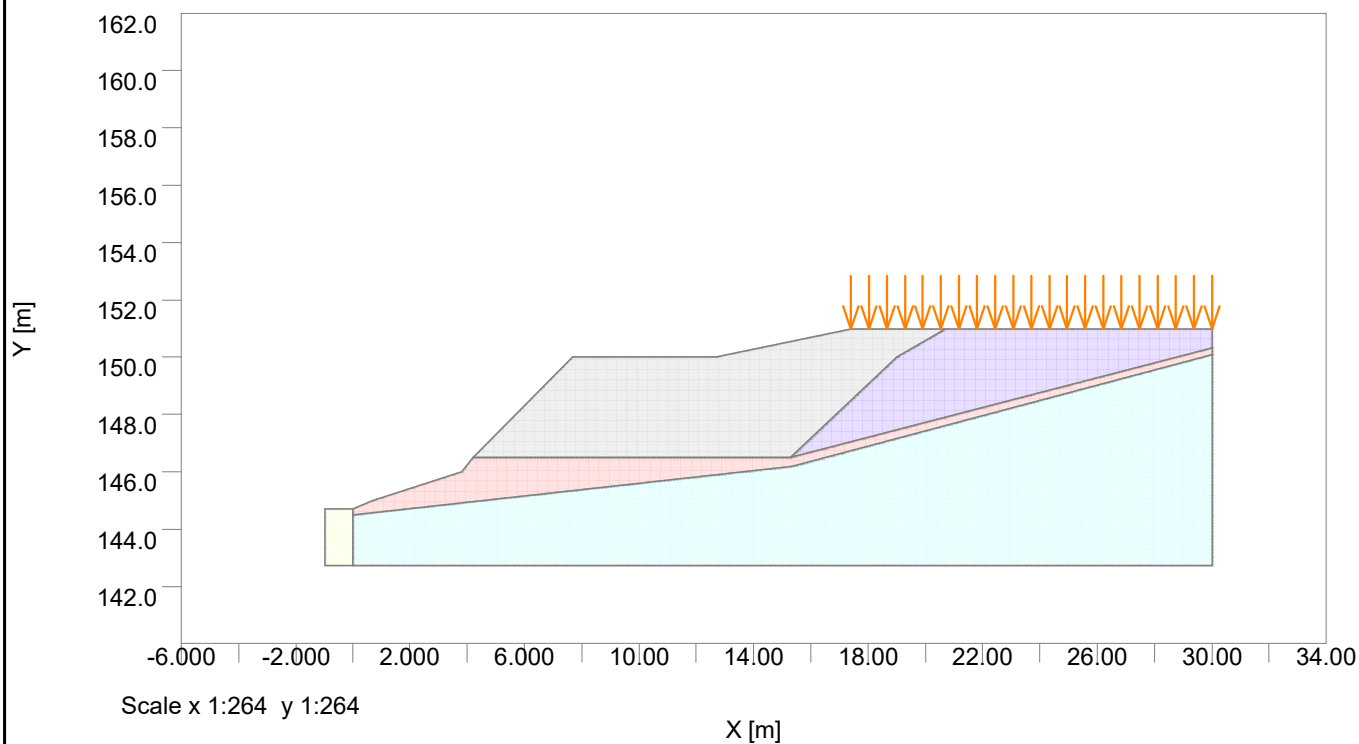


Hollingsworth Gate, Littleborough
Section E

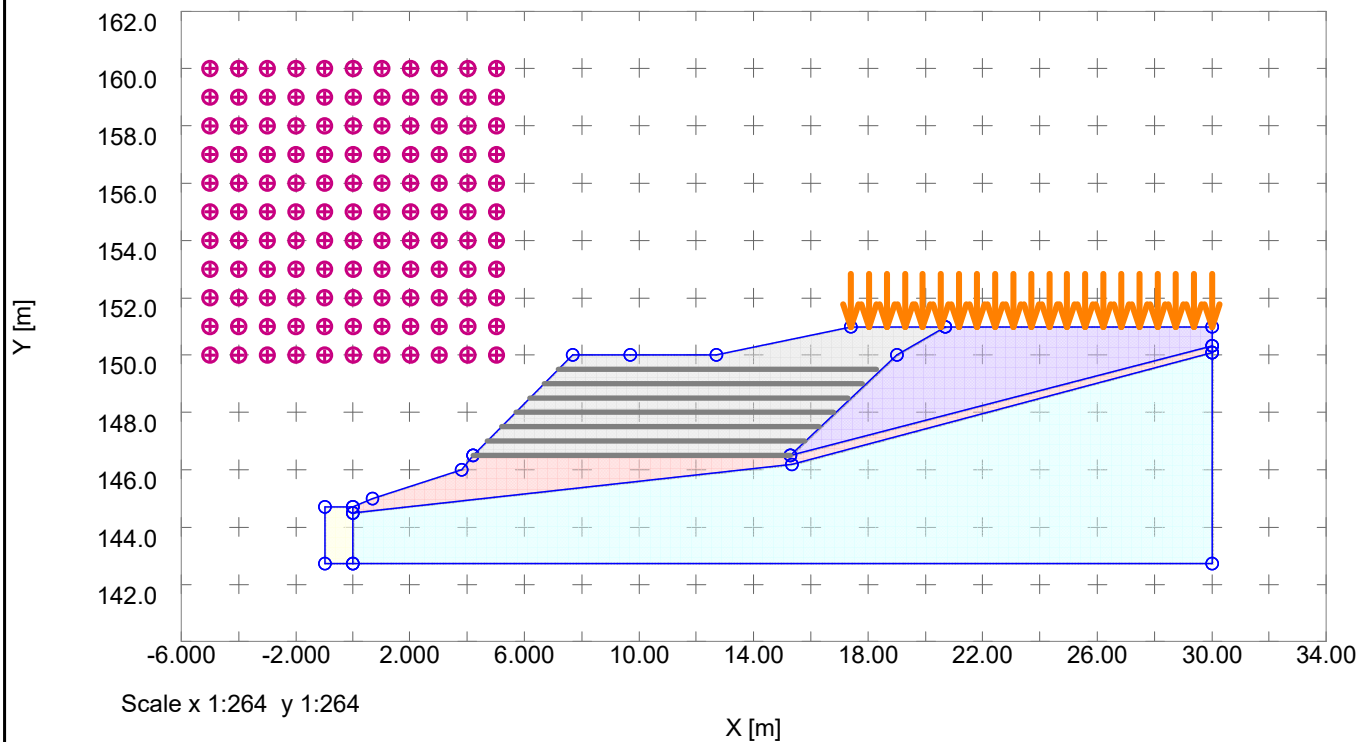
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Made by JD	Date	Checked Date

Slip Centre		Radius	Slip Weight	Comment/ Over-Design Factor	Disturbing Moment	Soil Strength Restoring Moment	Reinforcement Restoring Moment
x [m]	y [m]	[m]	[kN/m]		[kNm/m]	[kNm/m]	[kNm/m]
1.0000	156.00	14.436		Only 1 intersection with ground level			
1.0000	157.00	15.133		Only 1 intersection with ground level			
1.0000	158.00	15.862		Only 1 intersection with ground level			
1.0000	159.00	16.619		Only 1 intersection with ground level			
1.0000	160.00	17.401		Only 1 intersection with ground level			
2.0000	150.00	10.325		Only 1 intersection with ground level			
2.0000	151.00	10.733		Only 1 intersection with ground level			
2.0000	152.00	11.216		Only 1 intersection with ground level			
2.0000	153.00	11.764		Only 1 intersection with ground level			
2.0000	154.00	12.369		Only 1 intersection with ground level			
2.0000	155.00	13.023		Only 1 intersection with ground level			
2.0000	156.00	13.719		Only 1 intersection with ground level			
2.0000	157.00	14.450		Only 1 intersection with ground level			
2.0000	158.00	15.212		Only 1 intersection with ground level			
2.0000	158.00	15.212		Only 1 intersection with ground level			
2.0000	159.00	16.000		Only 1 intersection with ground level			
2.0000	160.00	16.811		Only 1 intersection with ground level			
3.0000	150.00	9.4021		Only 1 intersection with ground level			
3.0000	151.00	9.8489		Only 1 intersection with ground level			
3.0000	152.00	10.373		Only 1 intersection with ground level			
3.0000	153.00	10.964		Only 1 intersection with ground level			
3.0000	154.00	11.610		Only 1 intersection with ground level			
3.0000	154.00	11.610		Only 1 intersection with ground level			
3.0000	155.00	12.304		Only 1 intersection with ground level			
3.0000	155.00	12.304		Only 1 intersection with ground level			
3.0000	156.00	13.038		Only 1 intersection with ground level			
3.0000	156.00	13.038		Only 1 intersection with ground level			
3.0000	157.00	13.806		Only 1 intersection with ground level			
3.0000	158.00	14.601		Only 1 intersection with ground level			
3.0000	159.00	15.421		Only 1 intersection with ground level			
3.0000	160.00	16.260		Only 1 intersection with ground level			
4.0000	150.00	8.4971		Only 1 intersection with ground level			
4.0000	150.00	8.4971		Only 1 intersection with ground level			
4.0000	151.00	8.9889		Only 1 intersection with ground level			
4.0000	151.00	8.9889		Only 1 intersection with ground level			
4.0000	152.00	9.5603		Only 1 intersection with ground level			
4.0000	152.00	9.5603		Only 1 intersection with ground level			
4.0000	153.00	10.198		Only 1 intersection with ground level			
4.0000	153.00	10.198		Only 1 intersection with ground level			
4.0000	154.00	10.890		Only 1 intersection with ground level			
4.0000	155.00	11.628		Only 1 intersection with ground level			
4.0000	156.00	12.402		Only 1 intersection with ground level			
4.0000	157.00	13.206		Only 1 intersection with ground level			
4.0000	158.00	14.036		Only 1 intersection with ground level			
4.0000	159.00	14.886	1642.6	1.3593	8095.0	11004.	0.0
4.0000	160.00	15.754	1648.8	1.3615	8497.7	11570.	0.0
5.0000	150.00	7.6158		Only 1 intersection with ground level			
5.0000	150.00	7.6158		Only 1 intersection with ground level			
5.0000	151.00	8.1609		Only 1 intersection with ground level			
5.0000	151.00	8.1609		Only 1 intersection with ground level			
5.0000	152.00	8.7864		Centre embedded/below end of slip			
5.0000	153.00	9.4763	1544.1	1.6288	4229.0	6888.2	0.0
5.0000	154.00	10.218	1539.0	1.5591	4697.2	7323.4	0.0
5.0000	155.00	11.000	1540.0	1.5134	5165.0	7816.7	0.0
5.0000	156.00	11.815	1545.9	1.4833	5633.7	8356.4	0.0
5.0000	157.00	12.657	1555.7	1.4645	6104.6	8940.2	0.0
5.0000	158.00	13.520	1568.0	1.4540	6574.1	9558.9	0.0
5.0000	159.00	14.401	1583.0	1.4577	6989.5	10188.	0.0
5.0000	160.00	15.297	1600.5	1.4660	7396.2	10843.	0.0

APPENDIX 6 - Section F Modelling Outputs



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Drg. Ref.		
Made by JD	Date	Checked Date





Hollingsworth Gate, Littleborough
Section F

Job No.	Sheet No.	Rev.
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Made by JD	Date	Checked Date

Specification
Slip Type: CIRCULAR
Direction of slip: Downhill
Minimum slip weight [kN/m] :80.00000
Type of analysis: STATIC
Partial factor analysis
Minimum number of slices 25
Method: Bishop(Variably inclined interslice forces)
Maximum number of iterations: 300
Reinforcement: NOT ACTIVE

Method Partial Factors
BS EN 1997-1:2011 DA1-2
Factor on FAVOURABLE PERMANENT LOAD: 1.00000
Factor on UNFAVOURABLE PERMANENT LOAD: 1.00000
Factor on FAVOURABLE VARIABLE LOAD: 0.00000
Factor on UNFAVOURABLE VARIABLE LOAD: 1.30000
Factor on UNIT WEIGHT: 1.00000
Factor on DRAINED COHESION: 1.25000
Factor on UNDRAINED COHESION: 1.40000
Factor on TAN PHI': 1.25000
Factor on REINFORCEMENT PULLOUT: 1.50000
Factor on ECONOMIC FAILURE: 1.00000
Factor on SLIDING ALONG REINFORCEMENT: 1.50000

Material Properties

No	Description	Unit Weight		Shear Strength Parameters		Phi or c
		Above GWL	Below GWL	Condition		
		[kN/m3]	[kN/m3]			Phi0 [°]
1	Canal Wall	25.000	25.000	Drained		40.000
2	Reinforced Earth	20.000	22.000	Drained		24.000
3	Backfill Made Ground	20.000	22.000	Drained		24.000
4	Stiff CLAY	20.000	22.000	Drained		24.000
5	SILTSTONE	21.000	23.000	Drained		34.000

Surface loads

No.	Limits of loaded area		Distributed load	Permanent / Variable load	Favourable / Unfavourable load	Use in pull-out calc
	X1 [m]	X2 [m]	Vert [kN/m²]	Horiz [kN/m²]		
1	17.400	30.000	100.00	0.0	Permanent	Unfavourable No

Reinforcement
NB: REINFORCEMENT IS DEFINED BUT NOT ACTIVE
Geotextile Reinforcement 1

Layers	Level of top layer	Vertical Spacing	Length	Offset from surface	Angle from horiz
	[m]	[m]	Top [m] Btm [m]	[m]	[°]
7	149.50	0.50000	11.100 11.100	0.0	0

Bond Length	Bond Strength	Prestress	Grout Diameter
	[kN/m]	[kN]	[mm]
0.0%	0.0	0.0	0.0

Out of plane spacing	Tensile Capacity	Plate Capacity	Material Partial Factor
[m]	[kN]	[kN]	
0.0	1.3000	0.0	

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Out of plane spacing

Tensile Capacity

Plate Capacity

Material Partial Factor

[m]

[kN]

[kN]

Slip Surface Specification

Circle centre specification:

Bottom left of grid: x = -5.00000 m y = 150.00000 m

Inclination of grid: 0.00000 deg

(positive anticlockwise direction about bottom left of grid)

Centres on grid: 11 in x direction at 1.00000m spacing

11 in y direction at 1.00000m spacing

Grid extended to find minimum FoS

All circles pass through common point at x = 15.50000 m, y = 146.50000 m

APPENDIX 7 - Limitations

Limitations

This report (Report) forms part of the Services and if applicable Additional Services undertaken by Groundtech Consulting Ltd pursuant to a written contract (Agreement) which contains detailed provisions including express limitations of the liability of Groundtech Consulting Ltd.

This Report was prepared using reasonable skill and care as stated in the Agreement for the purpose including intended end use stated by the Client (Purpose) and the liability of Groundtech Consulting Ltd in respect of the form and content of this Report is no greater than its liability under the Agreement. All records, measurements notes, or any other data (Data) obtained by or for the benefit of the Consultant were obtained at a specific point in time and it may not be assumed by the Client or any person relying on this Report that the Data will remain unaffected by the passage of time, the seasons, weather conditions, changes in the water table or the carrying out and completion of works at the Site.

Unless otherwise agreed this Report has been prepared exclusively for the use and reliance of the Client and may not be relied upon, by any other party except as provided for in the Agreement. A third party who relies on this Report, does so at their own and sole risk and Groundtech Consulting Ltd has no liability to such parties.

Groundtech Consulting Ltd that this Report is to be used for the Purpose. The Purpose was instrumental in determining the scope and of the Services provided. If the Purpose should change, the Client may not be able to rely on the Report without the separate agreement of Groundtech Consulting Ltd.

Since the Report was written, later changes in legislation, statutory requirements and industry best practices have not been considered and this should be allowed for. Ground conditions can also change (see below) and should be investigated if there is any significant delay in acting on the findings of this Report. The period of time may result in changes in site conditions, regulatory or other legal provisions, technology or economic conditions which could render the Report inaccurate or unreliable. The information and conclusions in this Report should not be relied upon in the future without written confirmation from Groundtech Consulting Ltd that it is safe to do so.

The observations and conclusions outlined in this Report are based exclusively on the services that were provided as set out in the agreement between the client and Groundtech Consulting Ltd.

Groundtech Consulting Ltd is not liable for the existence of any condition, the discovery of which would require additional investigation outside the agreed scope of works or core competency. The Report is based upon Groundtech Consulting Ltd's observations of existing physical conditions at the Site gained from site reconnaissance together with interpretation of information including documentation, obtained from third parties and from the Client on the history and usage of the Site. The findings and recommendations contained in this Report are based in part upon information provided by third parties, and Groundtech Consulting Ltd have relied upon such information assuming it to be correct.

Groundtech Consulting Ltd accepts no responsibility for errors or inaccuracies in third party information presented in this Report. Groundtech Consulting Ltd was not authorised to independently verify the accuracy or completeness of information, documentation or materials received from the client or third parties, including laboratories and information services, during the performance of the Services or Additional Services. Groundtech Consulting Ltd is not liable for any inaccurate information, misrepresentation of data or conclusions, which may inform the scope of investigation undertaken by Groundtech Consulting Ltd and forms the contract with the client.



Where field investigations have been carried out these have been restricted to a level of detail required to achieve the stated objectives of the work. Ground conditions may also vary due to the ground's heterogeneous properties and because investigation exploratory locations only allow examination of the ground at discrete locations. The potential exists for ground conditions to be encountered which are different to those considered in this Report, particularly between exploratory holes. The extent of the limited area depends on the soil and groundwater conditions, together with other constraints such as the position of any existing structures and underground utilities. If so stipulated in the Agreement, geo-environmental testing was carried out for a limited number of parameters based on an understanding of the available operational and historical information, and it should not be inferred that other chemical species are not present.

Any groundwater conditions entered on the exploratory hole records are those observed at the time of investigation. The groundwater level often has not had time to reach equilibrium and a monitoring period is required. Furthermore, groundwater levels are subject to seasonal variation or changes in local drainage conditions and groundwater levels may occur at other times of the year which are higher than were recorded during this investigation.

Any site drawings provided in this Report are preliminary and used to present the general relative locations of features on, and surrounding, the Site.

