TensarTech® GreenSlope™ Earth Retaining Structures: Model Specification

This document is intended to form a basis for Tender documents where the TensarTech® GreenSlope™ 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 supplier's 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 provider of the proposed solution must demonstrate previous International experience for design and construction of reinforced soil steep slopes with a minimum height of 20.0m and a minimum in service life of 20 years.

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

2. DESIGN

The choice and specification of the system shall address the climatic and soil conditions existing specific to the site in question and provide a minimum design life of 60 years and up to 120 years if specifically required to do so. 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 walls 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 wall system.

3.01 Steel Mesh Facing Units

A. **BS4483:1998** - Steel fabric for the reinforcement of concrete
B. **BS EN ISO 1461-2009** - Hot dip galvanized coatings on fabricated iron and steel articles

3.02 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

3.03 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 proprietary structural steel mesh facing units, steel braces, approved face liner, uniaxially orientated high-density polyethylene (HDPE) geogrids and a high efficiency mechanical connection between facing and primary geogrid.

4.01 Steel Mesh Facing

A. Steel mesh should be welded high tensile steel mesh type structural fabric, manufactured in accordance with BS4483: 1998

B. Vertical bar diameter will be a minimum of 8mm at 100mm spacing and the horizontal bar diameter will be a minimum of 8mm at a 200mm spacing

C. Minimum weight shall be 5.93Kg/m^2

D. Where specified the steel mesh facing will be galvanised in accordance with BS EN ISO 1461 : 2009 with a minimum mean coating of 85 µm.

E. Mesh shall be supplied to site cut and bent to the required dimensions and angle.

4.02 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 (HDPE) 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.

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 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 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.

		Geogrid Type - design life of 60 years					
	Units	RE510	RE520	RE540	RE560	RE570	RE580
$P_{C\ 10°C}$	kN/m	21.10	27.85	34.02	46.78	62.44	72.41
$P_{C\ 20°C}$	kN/m	19.37	25.56	31.23	42.95	57.33	66.48
$P_{C\ 30°C}$	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
$P_{C\ 10°C}$	kN/m	20.71	27.34	33.40	45.93	61.31	71.09
$P_{C\ 20°C}$	kN/m	19.01	25.10	30.66	42.16	56.28	65.27
$P_{C\ 30°C}$	kN/m	17.24	22.76	27.80	38.23	51.03	59.17

4.03.1 Face to geogrid connection

A. The connection between the steel mesh facing units and the geogrid shall be a continuous mechanical connection. The full width of geogrid is connected to the horizontal portion of the facing unit using a HDPE bodkin. Friction only connection will not be allowed.

4.04 Face Liner

A. To establish a grass cover to the finished structure by dry seeding, the inside face of the steel mesh should be lined with either of the following as determined by the Engineer:

i. Rolled erosion protection product - The material shall be of consistent thickness with the coconut fibre evenly distributed over the entire area of the blanket. The blanket shall be covered on the top and bottom with heavyweight polypropylene netting having ultraviolet additives to delay the breakdown and approximate 1.59x1.59cm mesh size. The blanket shall be sewn together on 3.81cm centres with UV stable polypropylene thread. Nominal weight per m2 = 271 grams.

ii. Geomesh - The material shall be manufactured from Low density polyethylene (LDPE) with an aperture size of 8mmx6mm and thickness of 2.9mm. UV protection shall be provided by 2% minimum of well dispersed finely divided particles of carbon black. Nominal weight per m2 = 495 grams.

B. Where ground cover and/or climbing vegetation is the only vegetation, the face may be lined with a black needle punched geotextile manufactured from 100% virgin polypropylene in compliance with the following specification:

C. Any face liner shall be manufactured in accordance with a Quality Management System which complies with the requirements of BS EN ISO 9001:2000.

Polymer	100% virgin black polypropylene
Thickness (mm) under 2kPa according to BS4501:1987	3.50
Unit weight (gm^{-2})	400
Maximum Tensile Strength (kN/m) according to BS EN ISO 10319:1996	
MD	16
TD	32
Elongation at Maximum Tensile Strength(%) according to BS EN ISO 10319:1996	
MD	110
TD	75
Puncture Resistance (CBR) according to BS EN ISO 12236	
Maximum Force (kN) (5)	3.5
Maximum Displacement (mm) (6)	67
Metal Detector test for broken needles	YES
Roll size (m)	2.1 x 50

Roll weight (kg)	44

4.05 Infill Soil

The infill soil material proposed should comply with the specification for 6I/6J material as detailed in Tables 6/1 and 6/2 of the 'MANUAL OF CONTRACT DOCUMENTS FOR HIGHWAY WORKS (MCHW) VOLUME 1 SPECIFICATION FOR HIGHWAY WORKS (MCHW1) – Series 600 for Earthworks, Highways Agency document November 2009'
This preferred material should be well graded crushed and granular not sub-rounded, and should also comply with the following:

A. Minimum angle of friction ($ø_{cv}$') of 30 degrees

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.

C. The contractor may propose the use of an alternative fill material such as a consistent good quality cohesive or semi cohesive material as well as recycled materials. Proposals should also include provision for any additional drainage materials that may be necessary along with the design properties for use in the design.

4.06 Plantable Fill or Horticultural Topsoil Layer

A. The horticultural soil layer shall be a medium loam with a workable 'crumb-like' consistency placed immediately behind the face liner 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.

4.07 Vegetation

4.07.01 Grass Cover

A. Where indicated on the drawing grass cover will be established by introducing the specified grass seed mix at the specified rate(typically 60g/m^2) in to the horticultural topsoil layer during placement. In addition grass should be spread in to the biodegradable face liner upon completion of the structure.

B. A typical specification of the seed mix for sewing into the topsoil and biodegradable matting may be:

75%	Creeping Red Fescue
25%	Smooth Stalked Meadow Grass

Or as specified by the Engineer

4.07.02 Ground cover and/or climbing vegetation

A. Ground cover and/or climbing vegetation will be established by planting healthy plants from an approved supplier at the base and on the face of the structure.

B. Plants along the base will be planted into the approved horticultural topsoil and carefully tied in to the face at 1m centres.

C. Plants on the face should be planted on a minimum 2m square grid pattern. This may be carried out either during or post construction but with the approval and agreement of the engineer.

D. All plants should be well established in 75mm pots prior to planting and should be seen to have a good quality rootball.

E. All plants should be correctly irrigated when necessary up to the first 12 months after completion of the structure either by carefully monitored hand watering or by installation of an approved irrigation system using perforated polymer pipes and delivering water to the root system in a controlled manner.

F. A typical specification for the ground cover plant specification is: Hedera Colchica (Persian Ivy) or similar approved

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 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 Clients Engineer prior to placement of the steel facing units and reinforced fill.

5.03 Steel facing units and geogrid installation

A. The Steel Facing Units are delivered to site bundled together and tied using steel tying wire, together with brace bars (3 per unit) and anchor pins. They may be stored outside.

B. The primary geogrid reinforcement is delivered in either 75m or 50m long x 1.3m wide rolls and may be stored outside.

C. HDPE bodkins are delivered in cardboard boxes of 40No. These may be stored outside but may benefit from being stored undercover to prevent water damage to the cardboard box.

D. Prepare the formation to line and level in accordance with the contract documents.

E. Cut the lengths of the required grade of geogrid from the roll as indicated by the design drawings. Place on to the formation with the leading edge at the front edge of the structure. Ensure that the geogrid is orientated in the correct direction.

F. Position the facing units along the line of the structure, overlapping longitudinally by 100mm. Connect adjacent units using steel tying wire to locate.

G. The system must be constructed in accordance with the contract drawings using the required number of grid layers.

H. Lay the geogrid flat and pulling it by hand to ensure that no slack is left in the bodkin connection. Drive in to the ground two anchor pins behind the longitudinal bars on the base of the facing unit. This will ensure no movement of the steel facing unit when the geogrid is lightly tensioned using the beam supplied. Adjacent lengths of geogrid need only be butt-jointed, there is no necessity for overlap.

I. Using the polymer bodkin, connect the uniaxial geogrid reinforcement to the horizontal base of the steel facing unit, at the first aperture away from the face. The geogrid should be lightly tensioned using the tensioning beam supplied so that all slack is removed from the bodkin joint. Whilst maintaining tension, place a layer of fill on the grid which is sufficient to restrain it in position when the load is released or alternatively retain the tension by driving 2 steel pins through the last row of apertures at the rear end of the geogrid.

J. Cut and place the biodegradable mat or geotextile/net supplied inside the face, locating it temporarily with cable ties or tying wire if necessary. The face liner should lap back horizontally in to the structure by a minimum of 100mm. Care should be taken at this stage if using the biodegradable mat to avoid exposing it to naked flame or spark, as it may be readily flammable until it has had the opportunity to absorb moisture. It is recommended that positive measures are taken to ensure the establishment of vegetation within 4 months of installation if the biodegradable mat liner option is chosen.

K. Fix the brace bars in to position at a rate of 3 per facing unit. They should hook around a steel bar junction in the uppermost horizontal bar of the face and a junction point at the rear-most horizontal bar of the base.

L. Where a vegetated face is specified, place horticultural topsoil in accordance with BS3882, behind the face lining at lift heights compatible with the structural fill compaction. This is continued up to the level of the next layer of reinforcement in tandem with the structural fill material, to a typical width in cross section not exceeding 150mm. If the Landscape Architects require a greater topsoil thickness than 150mm then they should consult Tensar International Ltd in advance who can then advise on an appropriate construction approach and facing detail.

M. The topsoil should be consolidated by hand tamping or 'heeling–in' so as to avoid over compaction.

N. 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 accordance with Contract specification, up to the level of the next geogrid layer. Fill should be placed by plant such as an excavator bucket or a dozer with an opening bucket, which causes the fill to cascade onto the grids. A minimum of 150mm thick cover of fill must be maintained between the tracks of any plant and the geogrid to avoid damage. Care should be taken during this operation to maintain the alignment of the facing units.

O. Care should be taken to avoid compaction of the topsoil layer and contact with the facing units by any of the compaction plant.

P. All construction plant, including compaction equipment with a mass exceeding 1000kg should be kept at least 2m from the face of the wall. Compaction plant within 2m of the wall should be restricted to vibrating rollers having a mass per metre width not exceeding 1300kg or plate compactors with a mass less than 1000kg.

Q. Compaction should always commence nearest the facing units, working away towards the free end of the grid.

R. If secondary reinforcement is specified, this should be cut from the roll and laid in to the face area as required. The geogrid should be butted-up to the face of the steel facing unit but no connection is necessary.

S. Placement of the topsoil layer and fill material should be continued as described in steps L-R up to the level of the next layer of primary reinforcement. At this point the next course of steel facing units may be installed to stretcher bond and construction of the reinforced slope continues to the required height.

T. Upon completion further grass seed may be scattered on to the finished face of the structure.

U. Where there is step back or terrace to the next facing unit, it is recommended that the protruding vertical bars are bent down to the horizontal. This is to prevent the possibility snagging when operatives are climbing on or abseiling down the face for planting or maintenance purposes. A short piece of scaffold tube may be improvised to bend the bars in question.

V. The Contractor must fully assess the safety risk associated with working at height and where appropriate install any necessary temporary edge protection.

W. As well as following procedures for health and safety, it is essential when handling wire products that suitable protective glasses and gloves are worn.

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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