Istituto per le Tecnologie della Costruzione Consiglio Nazionale delle Ricerche Via Lombardia 49 - 20098 San Giuliano Milanese – Italia tel: +39-02-9806.1 – Telefax: +39-02-98280088 e-mail: info@itc.cnr.it UEAtc member	CE marked construction product for soil reinforcement and stabilisation. Geogrids TENAX **“TT SAMP 045, 060, 090, 120, 160”**	DVT **Technical Application Document No. DVT-0001 of 2011-03-14**
Manufacturer: TENAX S.p.A. Via dell’Industria, 3 – 23897 Viganò (LC) – Italy www.tenax.net	**Manufactured at:** VIGANÒ (LC)	**Expiring date:** 2016-03-13

The Technical Application Document (DVT) is a voluntary national integration for construction products that are under the compulsory CE Marking in accordance with the CPD. Its aim is to help designers and contractors properly use the product, on the basis of the technical data contained in the Document, as well as to steer optimal design, installation, application and maintenance processes. While the CE Marking relates to the “conformity” to a European technical specification, the DVT expresses a pre-emptive quality technical assessment based on aspects that are not ruled by the compulsory system.
This DVT does not bind or imply any juridical liability of ITC, whether of civil or penal nature, with respect to events or consequences deriving from the total or partial application of materials, structures, mechanisms or systems being the subject of the certificate, neither is it an authorization for use or a guarantee.
This DVT evaluates voluntary aspects not covered by the CE Marking. It refers to the general principles expressed within the Union Européenne pour l’Agrément technique dans la construction (UEAtc) (cfr. “Application document”) and may apply to construction products as provided for by Directive 89/106/EEC “Construction Products”, with reference to EN harmonised technical standards or to a European Technical Approval (ETA).
Any modification of the material, component or system considered under this DVT or any incompliance with the envisaged conditions/limitations of use, invalidate this technical evaluation. The current original of this packing with coloured adhesive tapes and identification of each roll by coloured paint (cfr. Tab.1) and labelling with roll serial number and product type according to standard method ISO 10320 is on ITC website. An original English version of this DVT is available. The lists of valid DVTs are periodically updated by ITC on its website: www.itc.cnr.it This DVT is made of 15 pages.

ITC Resolution No. 058/11
The Director of ITC, having seen:
- Decree-Law D.L. n. 19 del 30.1.1999 concerning the reorganization of the National Research Council;
- the Decree of the National Research Council n. 015789 of 12.2.2001 concerning the organization of ITC;
- the application submitted by Tenax S.p.A. having seat in Viganò (LC) via dell’Industria 3, for the granting of a DVT for five different versions of CE marked geogrids for soil reinforcement and stabilisation, under the series trade name: ”TT SAMP”;
- the declaration of conformity to the applicable harmonised European technical specifications issued by the manufacturer and the documents produced to illustrate the product, manufacturing systems, results of performed tests and reports concerning the investigations carried out at the factory and in the construction yards;
- the surveillance reports of the factory production control performed by the beneficiary and the results of the conformity verification tests;

agrees to grant DVT-0001

to CE marked geogrids intended for the reinforcement and separation of soils, under the trade name ”**TT SAMP 045, 060, 090, 120, 160**”, manufactured by Tenax S.p.A. at the factory located in Viganò (LC), as defined in this certificate with respect both to composition and characteristics and to proper design, installation and maintenance, under the following conditions:

MANUFACTURING AND ACCEPTANCE CONDITIONS

- The beneficiary is bound to perform acceptance controls on raw materials both during the manufacturing phase and on the final product, according to what specified at § 4.2 of the Technical Description and foreseen by the Control Plan approved by ITC.
- According to the technical instructions supplied by the beneficiary, the designer and/or the works director must extend the control also to the elements composing the system incorporating the certified product not produced directly by the beneficiary.

INSTALLATION CONDITIONS

- Taking into account the installation techniques and the different slopes, the fitness for use declared by this certificate is specifically and exclusively related to the installation conditions described in detail at § 5 of the Technical Description.
- The soil reinforcement made by geogrids must be designed in conformity with the current regulations in the territory where the product is to be used.
- Although installation is quite simple, it is recommended that, due to the care that is required for the operative sequence and for each operation, installation is carried out by experienced civil engineering contractors.
- It is particularly recommended to pay attention to the realization of the joints (overlaps), where foreseen, and to verify the subgrade conditions are acceptable before starting the work.
- Should it be necessary to realize butt joints at small portions of the system, the design must guarantee the continuity of the strength performances of the geogrid.
- Geogrids are made through a process of extrusion and mono-directional stretching and are capable to transmit a main tensile strength action in the stretching (longitudinal) direction. They must therefore be unrolled and fixed perpendicularly to the slope face of the reinforced soil work to be done.
- Care must be given during backfilling and compaction operation, in order to avoid any possible perforating damage to the geogrid that may be caused by improper execution of the work.

CONDITIONS FOR USAGE

- After installation, the geogrids are not directly exposed to solar radiation and to UV rays, since they are covered by layers of soil and/or by the vegetation/blocks of the face.
- A storing period not exceeding 30 days in the job site under exposure conditions that may be even critical (temperature, irradiation) is considered acceptable. In case the duration of storing in the job site should exceed this period, it is suggestible to adopt any precaution so to avoid the direct sunlight irradiation, such as temporary protection shelters (cf. § 5.3).
- In addition to the Technical Description regarding the constituents of the soils to be used and, with particular reference to § 5, it is important to keep in mind that weather conditions may remarkably affect the moisture content in the soil, which would compromise its optimal compaction. Should a too high or too low moisture content be measured with respect to the optimum values determined through a Proctor compaction test, it might be necessary to sample some soil and to experimentally test the water content.
- It is suggestible to avoid installation at temperatures below -5 °C (cf. § 5.4.1).

LABELLING AND STOCKING CONDITIONS

- Apart from the compulsory CE Marking and avoiding any confusion, adhesive labels to be applied on the package (pallet) must bear reference to this certificate in the following form, without any prejudicial bond to the colour reproduction:

DVT-0001 of 2011-03-14

Validity of DVT: five years - intended use: soil reinforcement and stabilisation

MAINTENANCE AND VALIDITY CONDITIONS

- This Technical Evaluation Document is valid for five years, that is, until March 13th 2016 and is subject to the maintenance conditions pointed out by ITC.
- The beneficiary is bound to forward electronically to ITC, every six months, the results of all the internal control tests performed by the manufacturer on the basis of what prescribed by the Control Plan (§ 4.2), using the format agreed upon and, once a year, the updated list of references. He shall also send a copy of the report of the FPC surveillance visit, prepared by NB 0799 as soon as available.

S. Giuliano M.se, 2011-03-14

SIGNED IN ORIGINAL
The Director
Mr. Roberto Vinci

SECTION A – *DECLARATIONS BY THE MANUFACTURER*

0 – Conformity with Directive 89/106/EEC “Construction Products”

In accordance with Annex ZA of harmonized standards EN13249/A1, 13250, 13251, 13253, 13254, 13255, 13257 and 13265, the company Tenax SpA has prepared its own Declarations of conformity under the CPD regime for the construction product versions object of this DVT, having executed, in pursuance of the Conformity Attestation System 2+ (reinforcement) and 4 (stabilisation), the requested initial type testing and having obtained the FPC certificate of conformity No. 0799-CPD-25 from the Notified Certification Body (AoC 2+), identification number 0799 (first issuing 15-09-2002), that also certifies the implementation of the FPC continuous surveillance. On the basis of what declared above, the company affixes on its construction products the following compulsory Marking.

0799-CPD-25

1 – Intended use

In compliance with the above mentioned EN standards, the intended use concerns the reinforcement (R) and the stabilisation (S) of soils for the construction of: roads and other areas subject to trafic (EN 13249/A1); railways (EN 13250); earthworks, foundations and retaining structures (EN 13251); erosion control works to avoid migration of fine granulometry materials to layers of alternate hydraulic gradients materials (EN 13253); reservoirs and dams (EN 13254); canals (EN 13255); solid waste disposals (EN 13257); liquid waste containment projects (EN 13265).

2 – Description

2.1 – Trade name

Geogriglie TENAX ***“TT SAMP 045, 060, 090, 120, 160”***

2.2 – Definition of constituent materials

2.2.1 – Compulsorily declared characteristics (R+S)

EN	*“TT SAMP”*	*Characteristic*	*Test method*	*Declared value/Unit*		*Tolerance*
13249/A1, 13250, 13251, 13253, 13254, 13255, 13257, 13265	***045***	*Tensile strength*	*EN ISO 10319*	*45. 0*	*kN/m*	*-0*
	060			*60.0*		
	090			*90.0*		
	120			*120.0*		
	160			*160.0*		
	045	*Elongation at maximum load*	*EN ISO 10319*	*11.5*	*%*	*±3,0*
	060			***13.0***		
	090					
	120					
	160					
	045	*Durability*	*EN 12224*	*120 years minimum expectation for soils with 1.6 < pH < 13; with soil temperature up to 40 °C*		*///*
	060					
	090					
	120					
	160					

Table 1 – Declared characteristics

2.2.2 – Additional information by the manufacturer

“TT SAMP”	*Characteristic*	*Test method*	*Minimum value/Unit*		*Tolerance*
045	*Tensile strength at 2 % deformation*	*EN ISO 10319*	*11.0*	*kN/m*	*-0*
060			*17.0*		
090			*26.0*		
120			*36.0*		
160			*45.0*		
045	*Tensile strength at 5 % deformation*	*EN ISO 10319*	*25.0*	*kN/m*	*-0*
060			*32.0*		
090			*50.0*		
120			*72.0*		
160			*90.0*		
045	*Tensile strength of the joints*	*Internal method GRI-GG2*	*36.0*	*kN/m*	*-0*
060			*50.0*		
090			*80.0*		
120			*110.0*		
160			*130.0*		

Table 2 – Additional information by the manufacturer

SECTION B - *DVT*

0 – Complementarity to the compulsory regime as foreseen by the CPD

Under the voluntary regime, the Tenax Quality Management System is certified in conformity with standard EN ISO 9001:2000 by the independent body SGS Italia and SGS UK.
The certificates issued by SGS have the following reference numbers:

SGS Italia: IT93/0008.01
SGS UK: IT93/2568.01

Updated copies of Certificates ISO 9001:2000 and of CE Certificate of Conformity of FPC (Factory Production Control) issued by the Notified Body tBU *(Institute for Textile, Building and Environment Technology – Greven – Germany)*, are available on Tenax website www.tenax.net.

1 – Intended use

Consistently with what declared at §1 of Section A and with what resolved by ITC, mono-oriented geogrids "Tenax TT SAMP" are used for reinforcement and stabilisation of steep slopes for embankments and retaining structures of roads, highways, railways and similar structures, for the consolidation of landslides and for the protection against erosion.
For reinforced soil walls, usually made with concrete blocks, geogrids can be used up to 90° slope angles.

2 – Technical description

2.1 – Geogrid

Tenax TT SAMP geogrids are black-coloured prefabricated grids with meshes having oval openings, made of high density polyethylene (HDPE), obtained by extrusion and continuous mono-directional stretching that determines orientation of the HDPE molecular chains, increasing the mechanical performances of the product.
Tenax TT SAMP geogrids are available in the following versions, characterized by different values of mass per unit area and tensile strength: "045", "060", "090", "120", "160".
High-density polyethylene may be supplied by different suppliers (cf. FPC manual); the mix must have the following characteristics as declared by the beneficiary:

- HDPE content: 98.5 % +0/-0.5 (Type III, Class A, Category 5 - ASTM D1248);
- Colour and stabilizing masterbatch: 1.5 % +0.5/-0

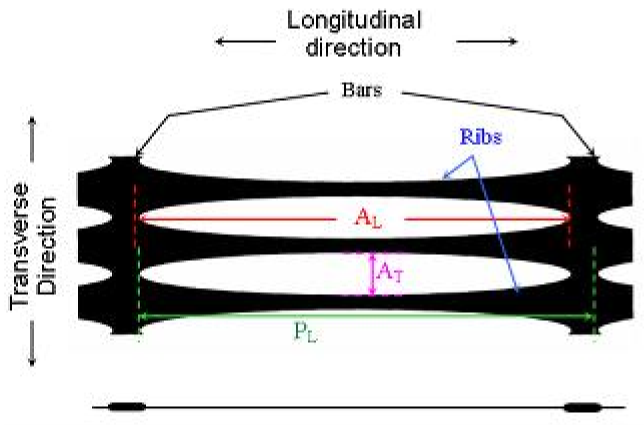
The beneficiary guarantees a minimum content of 0.5% carbon black in the mix (ASTM D 4218).
The obtained mix shows:

- melt index: 0.20 g/10min (± 0.10) (ISO 1133-condition 4)
- density: 0.950 to 0.960 g/cm³ (ISO 1183).

Geogrids are supplied in rolls with a label and a coloured tape which identify the type of product. Moreover, a film of paint of the same colour is sprayed on the last portion of each roll so as to identify the type of product also at the construction site, after unrolling. The beneficiary declares the general characteristics specified in Table 3.

Characteristic	TT SAMP								
	045		060		090		120		160
Width (m)	1 (± 3%)	2 (± 3%)	1 (± 3%)	2 (± 3%)	1 (± 3%)	2 (± 3%)	1 (± 3%)	2 (± 3%)	1 (± 3%)
Length (m)	≥ 100	≥ 50	≥ 75	≥ 40	≥ 50	≥ 30	≥ 30	≥ 30	≥ 30
Weight (kg)	≥ 30	≥ 30	≥ 30	≥ 32	≥ 30	≥ 36	≥ 24	≥ 48	≥ 30
Mass per unit area (g/m²)	≥ 300		≥ 400		≥ 600		≥ 800		≥ 1.000
Longitudinal opening (A_L) (mm)	220 (± 10 %)								
Transversal opening (A_T) (mm)	13÷20								
Longitudinal pitch (P_L) (mm)	240 (± 10 %)								
Tape colour Paint colour	Orange		Blue		Yellow		Red		Green

Table 3 – General characteristics



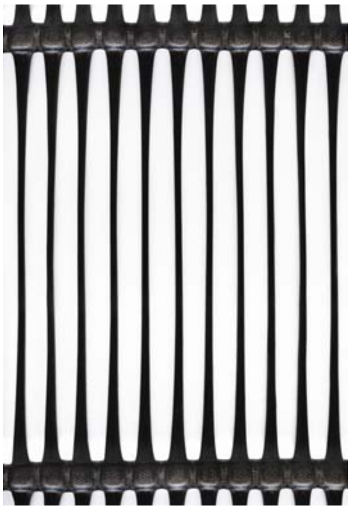


Figure 1: Elevation, plan and section of geogrids Tenax "TT SAMP",
A_L (Longitudinal opening), A_T (Transversal opening), P_L (Longitudinal pitch)

3 – Production process

The production phases are the following:

- melting of the polymer/masterbatch mix and extrusion of a tubular structure with holes consisting of longitudinal ribs and rings, by means of a series of extrusion heads allowing to diversify the different product versions;
- cooling and solidification of the tubular piece which is immersed in water at room temperature, after having calibrated the diameter to adjust the final height;
- cutting of the tubular piece along its longitudinal line;
- stretching in hot water, along the extrusion direction, on a drawing bench allowing to adjust velocity;
- cutting of the geogrid at the predefined lengths and wrapping it up into rolls;
- packing with coloured adhesive tapes and identification of each roll through coloured paint (cf. Table 3) and labelling in accordance with the requirements of applicable harmonized EN standards and with the specifications of ISO 10320 as well as with the requirements laid down by the resolution of this DVT.

4 – Manufacturing and controls

4.1 – Manufacturing

Extruded geogrids "TT SAMP" are manufactured at Tenax S.p.A. factory located in Viganò (LC), via dell'Industria 3, stretching over a surface are of 102000 m^2 of which 41500 m^2 are covered.

4.2 – Manufacturing controls

The controls executed at the internal laboratory are performed and stored in accordance with procedures PRQ05 and PRQ06 foreseen by the Tenax S.p.A. FPC Manual in force at the factory located in Viganò. In particular, for geogrids "TT SAMP" the controls executed are the following.

4.2.1 – Acceptance controls

The two constituents of the mix are supplied by Tenax S.p.A. on the basis of the technical specifications (together with the specified tolerances) and come from one or more suppliers (always the same) that ensure, as per contract, that the tender specifications are met on the basis of the outcomes of their factory production control systems, which the beneficiary declared to have acknowledged, assessed and accepted beforehand. Each supply is accompanied by its respective test report containing, among other information, the following:

- Polymers:
  - density (ISO 1183 or ASTM D 792)
  - Melt Flow Index (MFI) (ISO 1133 or ASTM D 1238)
- Colour and stabilizing masterbatch:
  - carbon black content (Supplier's method)

The test reports are kept by Tenax S.p.A. and duly recorded for 5 years.

The beneficiary can carry out his own indirect controls on the mix at the factory (melt flow in accordance with ISO 1133 - condition 4 and density in accordance with ISO 1183) without a scheduled frequency in case he has to evaluate new suppliers and/or in case he should observe repeated unconformities on the final product.

4.2.2 – Controls during production

The production cycle is quite simple and is controlled by the beneficiary through the verification of the process parameters reported in table 4 which are recorded by the staff in charge in compliance with the procedures contained in the FPC Manual.

PROCESS VARIABLE		FREQUENCY
Extrusion temperature	"Neck" Area	Every 8 hours
	"Head" Area	
	"Moulding" Area	
	"Stretching" Area	
Velocity	Screw engine	
	Pulling	
	Stretching	
Pressure	Before filter	
	After filter	

Table 4 – List of controls performed on the production plant

4.2.3 – Controls on final product

Controls on the final product are carried out and recorded partly by the staff in charge of production (Table 5) and partly by laboratory staff (Table 6) according to the stated frequencies in compliance with the procedures contained in the FPC Manual.

PRODUCTION CONTROLS	FREQUENCY
Height	Every 10 rolls
Longitudinal pitch	
Weight of the roll	
Roll circumference	

Table 5 – List of controls performed on final product at the plant

LABORATORY CONTROLS	FREQUENCY
Height	Every100 rolls
Mass per unit area	
Tensile strength at 2% deformation	
Tensile strength at 5% deformation	
Tensile strength	
Elongation at peak load	
Tensile strength of junctions	Every 150 rolls

Table 6 – List of controls performed on final product at the laboratory

5 – Design criteria and installation

5.1 – General

With reference to what is indicated in ITC resolution concerning installation and use assumptions and conditions, the beneficiary indicates the following.

5.2 – Design features

The geogrid reinforced structure can be designed according to calculation systems that are typically applied for the use of geosynthetics taking into account the structure's geometry, the geotechnical characteristics of the existing soil and of the fill soil to be used, of the morphological and geohydrological features of the slope face. Preliminary operations for the design of a reinforced soil structure are:

- accurate planimetric and altimetric survey of the area in order to obtain the layout plan and cross sections;
- acquisition of geotechnical and geohydrological data of the site; structure, layers' pattern, presence of water in the slope or in the foundation soil, seismicity, geomechanical properties (effective friction angle ϕ', cohesion c', soil specific weight γ) and soil granulometry. It is important to verify the presence of water to correctly design a structure that shall envisage, if necessary, suitable systems to collect and drain water;
- collection of "historical" information about events such as landslides and active and/or potential sliding surfaces;
- definition of the structure's geometry and overloads (permanent overloads, seismic accelerations, accidental loads).

Both the internal and global stability of the structure can only be ensured by carefully designing the soils reinforcement with geogrids. The choice of the products meeting the design dimensioning criteria and requirements related to their characteristics and intended use is coming from the executive design which should at least envisage the following:
- stability analysis, indicating the type and dimension of geogrid to be used;
- spacing, layout and length of the reinforcing layers, their characteristics/typology.

Under normal conditions spacing is about 0.6 m.
It is likewise important to underline the importance, mainly for the construction of vertical reinforced walls, of properly specifying the connection for the interposition and/or fixing of the geogrids between superimposed blocks in relation to the expected thrusts.

5.2.1 – *Design references*

The allowable long term design strength T_a for the geogrids is calculated with the following relation:

$$T_a = \frac{T_B}{(f_{m1} \cdot f_{m2})}$$

where:

T_B = long term design strength obtained from creep tests (cf. § 7);

f_{m1} = partial material factors related to the intrinsic characteristics of the geogrid;

f_{m2} = partial material factors related to any damage occurred during construction and to environmental factors.

Partial material factors are calculated with the following formulas:

$$f_{m1} = f_{m11} \cdot f_{m12}$$

$$f_{m2} = f_{m21} \cdot f_{m22}$$

where:
f_{m11} = partial material factor related to the consistency and quality of the geogrid;
f_{m12} = partial material factor related to the extrapolation of data;
f_{m21} = partial material factors related to any damage occurred during construction;
f_{m22} = partial material factors related to any damage due to exposure to chemically aggressive environments.

Partial material factor of geogrids		Backfill material	f_m
f_{m1}	f_{m11}: consistency and quality	---	1.00
	f_{m12}: data extrapolation		
f_{m2}	f_{m21}: damage during construction	Sand, Clay, Silt $\phi < 6$ mm	
		Medium crushed gravel $\phi < 40$ mm	
		Coarse crushed gravel $\phi < 75$ mm	1.03
		Gravel with stones and pebbles $\phi < 125$ mm	1.07
	f_{m22}: damage due to exposure to chemically aggressive environments	pH < 2.0	1.05

Table 7 – Partial material factors typical of geogrids Tenax TT SAMP

The shear resistance developed through friction along a reinforcing element in geogrid reinforced structure is the combination of the shear resistance at the interface between the soil and the solid part of the geogrid and the shear resistance at the soil-soil interface through the geogrid's openings.
The direct sliding resistance T_{ds} may be measured experimentally (EN ISO 12957-1) and it allows to calculate the direct shear resistance coefficient f_{ds} through the following formula:

$$f_{ds} = \frac{T_{ds}}{L \cdot B \cdot \sigma_n' \cdot tg\phi'}$$

where:
T_{ds} = direct sliding resistance;
L = reinforcing element length;
B = reinforcing element width;
σ_n' = actual normal stress on the reinforcing element;
ϕ' = soil internal friction angle.

Values of f_{ds} obtained for the different soil types for geogrids Tenax TT SAMP under this DVT are summed up in Table 8.

Pullout resistance measures the force that must be applied to a reinforcing element to pull it out from the soil. Pullout resistance T_b may be measured experimentally (EN 13738) and it allows to calculate the pullout resistance coefficient f_{po} through the following formula:

$$f_{po} = \frac{T_b}{2 \cdot L \cdot B \cdot \sigma_n' \cdot tg\phi'}$$

where:
T_b = pullout resistance;
L = reinforcing element length;
B = reinforcing element width;
σ_n' = actual normal stress on the reinforcing element;
ϕ' = soil internal friction angle.

Values of f_{po} obtained for the different soil types for geogrids Tenax TT SAMP under this DVT are summed up in Table 8.

Soil type	Direct shear resistance coefficient f_{ds}	Pullout resistance coefficient f_{po}
Sand, Clay, Silts ϕ < 6 mm	0.85 – 1.00	1.10 – 1.80
Medium Crushed Gravel ϕ < 40 mm	1.00	1.60 – 1.90

Table 8 – Direct shear resistance (f_{ds}) and pullout resistance (f_{po}) coefficients specific for geogrids Tenax "TT SAMP"

5.3 – Storage conditions

The beneficiary suggests that rolls be stored at the site in stacks not exceeding 2.5 m in height, in a place not exposed to heat sources or direct solar radiation. If geogrids have to be exposed to solar radiation for a long time, the rolls shall be covered with an opaque black fabric sheet.
Storing temperature shall not exceed 40 °C.

5.4 – Installation conditions

5.4.1 – Environmental conditions

Installation shall be avoided under circumstances that could prevent a proper soil compaction. It shall likewise be avoided to handle and install materials with temperatures below –5 °C.

5.4.2 – Installation tools

According to the envisaged design specifications, the reinforcement/stabilisation system can be done by means of the following installation tools:

- Welded wire steel mesh formwork or other types of sacrificial ("left in place") formworks to allow proper compaction at the face (cf. § 5.5.1).
- Hooks or other fixing systems.
- Synthetic or natural-fibre geomat and/or biomat for erosion control.
- U-shaped steel staples for geogrid lateral connections.
- Concrete or stone blocks.
- Geotextiles.

5.4.3 – Installation equipment

Further to the site earth-moving equipment, the installation of geogrids usually requires the following:

- tools for cutting, fixing and measuring geogrids;
- vibrating compactor.

5.4.4 – Organization of installation

Upon request, the beneficiary guarantees that he shall provide technical assistance to the installation companies concerned.

5.5 – Installation

Structures in soil reinforced with the geogrids under this DVT can be done with different construction technologies, depending on the conditions of the site and design requirements. In any case the subgrade of reinforced soil shall be stable and free of roots, stones or debris that may alter its flatness.

Installation may be carried out, as far as possible, under climatic and meteorological conditions allowing to work and compact the backfill soil at the densities indicated in the design by the Engineer.

Some of the most recurring and/or critical cases of correct installation/use of geogrids "TT SAMP" are extracted from the technical information documents of the beneficiary and hereafter reported.

5.5.1 – Construction of reinforced steep slopes with high facing angle

For reinforced steep slopes with facing angle greater or equal to 50°, the installation system foresees the use of a sacrificial formwork aimed at guiding and supporting the grid, obtained by folding a welded wire steel mesh panel (generally with mesh of 0.15x0.15 m or 0.20x0.20 m, and wire of Ø 8 mm).

Hooks are provided in order to ensure the geometrical stability of the formwork also during the soil compaction phase. The use of formworks allows to have high installation rates and a more accurately constructed structure. It is suggestible to superimpose the geogrids (lateral overlap) to facilitate the spreading of the soil and to prevent face erosion. Lateral overlaps are realized by superimposing the two lateral ribs of the geogrids and fixing them by means of the U-shaped staples approximately every 2 m. The reinforcing geogrids are folded into the steel formwork. The synthetic or natural-fibre mat is placed on the internal side of the geogrid at the face both to protect the face from erosion and to prepare a surface suitable for hydroseeding

The type of hydroseeding shall be chosen taking into account the existing environmental characteristics. As an alternative, the greenery covering of the outer facing may be obtained by planting out scions, rhizomes and shrubs between one reinforcing layer and the next or by using a pre-seeded biomat.

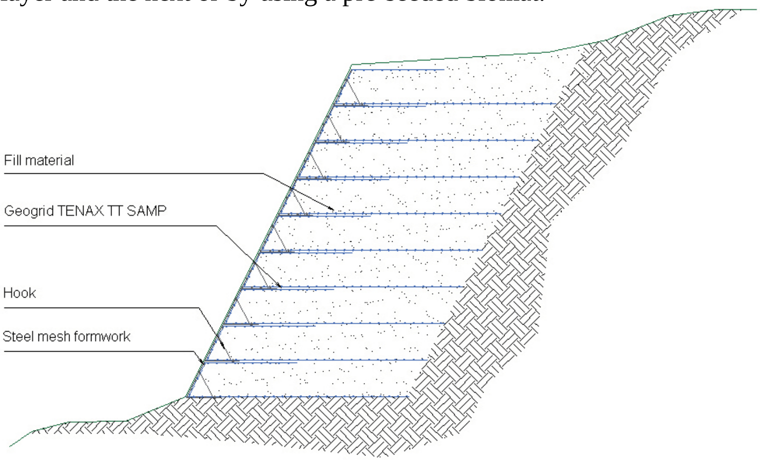


Figure 2 – Section of the steep slope with high facing angle

5.5.1.1 - Installation sequence

The installation operations sequence is the following:

1. The foundation soil is prepared, if necessary by excavating the existing soil; roots, stones or debris that may be found in the area of the foundation are removed; then the foundation soil is rolled and compacted. Whenever foreseen, a base drainage layer is created. The lining and positioning operations of the structure are executed.
2. The welded wire steel mesh formworks are placed and lined up along the facing section to be created; formworks are connected to each other by means of a steel wire or plastic ties (Figure 3a).

Figure 3a –Positioning of the formwork

3. The reinforcing geogrid rolls are unrolled and cut to the design lengths by means of proper tools: length is determined by the anchoring depth, by the face wrapping (about 0.70 m) and by the top wrapping (about 1.50 m).
4. The portion of geogrid previously cut to the requested length is placed inside the welded wire steel mesh formworks, then laid down on the foundation soil in horizontal layers perpendicular to the face and anchored to the soil by means of the U-shaped staples; the reinforcing geogrid shall adhere to the inner surface of the welded wire steel mesh formwork taking care that its last portion is temporarily left outside the formwork. The last portion of the geogrid shall correspond to the top wrapping length (about 1.50 m) (Fig. 3b).

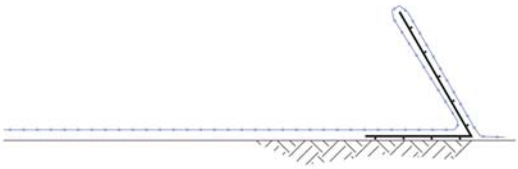



Figure 3b – Positioning of the reinforcing geogrid

5. The erosion protection mat or the pre-seeded biomat are placed inside the geogrid wrapped at the face; hooks are then positioned into the formwork (approx. 1 every 0.40 m) (Figure 3c).

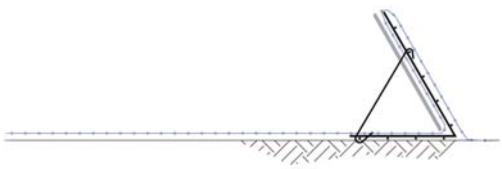



Figure 3c – Positioning of the pre-seeded biomat and of hooks

6. The fill soil is spread over the reinforcing geogrids in approximately 0.30 m lift; at the slope face it is suggested to use top soil over about 0.30 – 0.50 m. A layer of at least 0.10 m of soil shall be placed over the geogrids, before allowing the passage of site vehicles.
7. The soil is compacted until it reaches a compaction degree not less than 95 % of Standard Proctor and in any case equal to the value indicated by the designer. At the slope face (and for approximately 1.00 m) compaction shall be carried out by means of vibrating compactor; the area behind the reinforced block may be compacted with heavy roller compactors (Figure 3d).

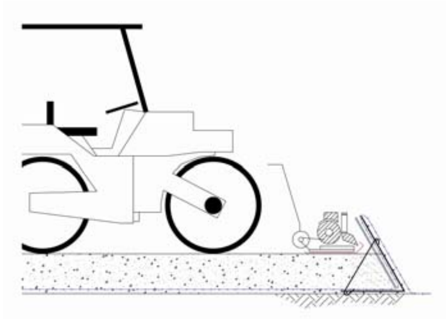


Figure 3d – Soil compaction

8. When compaction is completed, the final portion of the reinforcing geogrid, previously kept outside the formwork, is wrapped inside the formwork itself by slightly drawing it and anchoring it temporarily to the soil (Figure 3e).

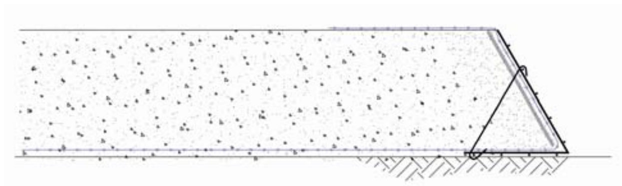


Figure 3e – Wrapping of the portion of geogrid, previously kept outside the formwork

9. Phase 1 to 8 shall be repeated until completion of the work.
10. If the pre-seeded biomat has not been used, then the face shall be hydroseeded or soil cover plants, shrubs or scions shall be planted out.

As an alternative, welded wire mesh formworks may be replaced with:

- removable formworks: in this case, after the soil has been compacted and the geogrid has been wrapped inside, the formworks are moved over the layers above until completion of the work;
- traditional formworks made of timber boards properly fixed or propped with props and/or tie bars in order to resist the thrusts.

5.5.2 – Construction of reinforced steep slopes with low facing angle

To construct steep slopes with facing angle less than 50°, geogrids shall be placed in horizontal layers without using temporary and/or sacrificial formworks. The facing shall be carefully protected from soil erosion by wrapping the reinforcing geogrid or by laying down an erosion protection biomat.

The soil shall be spread and compacted in accordance with the procedure described in the previous paragraph.

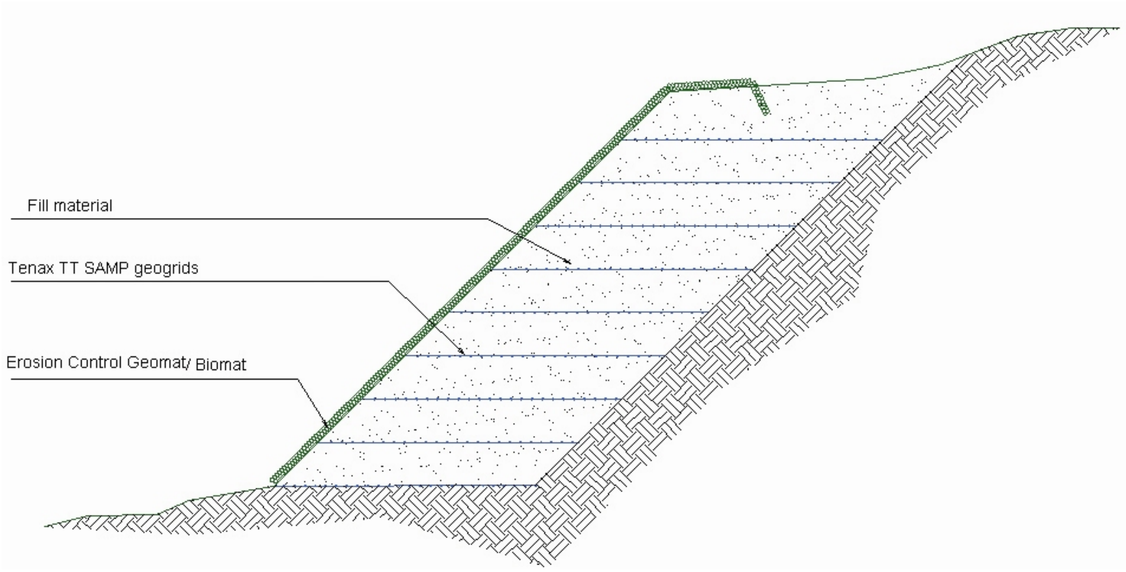


Figure 4 – Section of the steep slope with low facing angle

5.5.3 – Construction of vertical walls

To construct vertical walls, the geogrids shall be laid in horizontal layers connected to the facing concrete blocks. These blocks shall have a minimum thickness of 0.20 m and a flat supporting base allowing the positioning and/or fixing of the geogrid. The geogrid is connected to the face blocks by gravity and friction or through mechanical connections; blocks shape shall prevent sliding between blocks. Concrete panels connected to the reinforcing geogrids may be used instead of the blocks. Since the blocks shall be connected to the geogrids, no lateral overlaps shall be realized. To construct a vertical wall, a proper drainage system must be done at the toe of the wall in order to discharge water in an effective way.

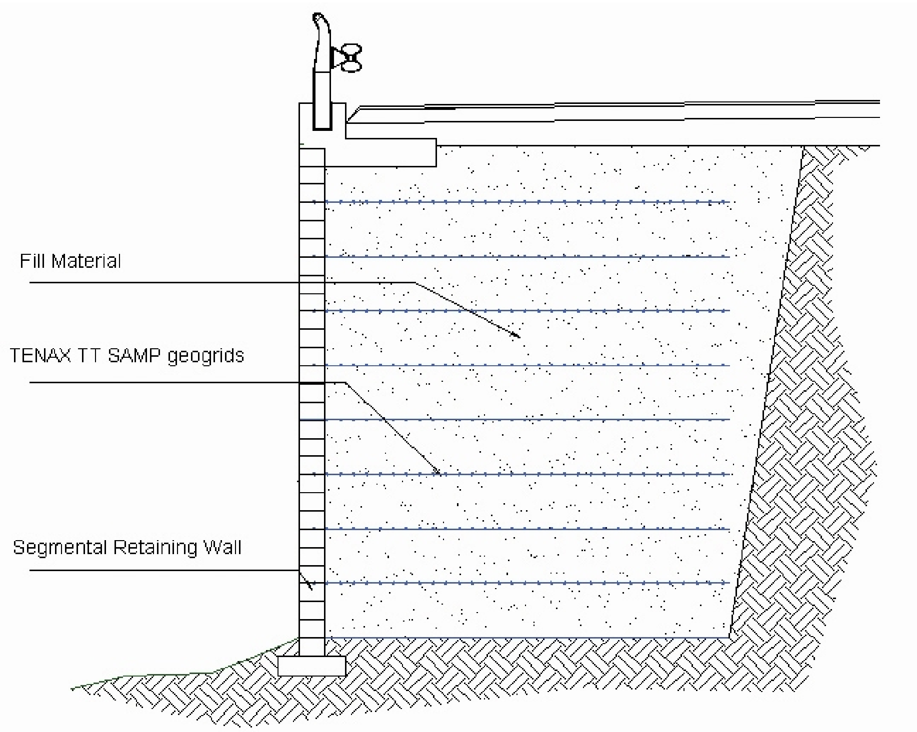


Figure 5 – Section of the vertical wall

5.6 – Maintenance

The maintenance of reinforcement soil structures may concern the structural part of the work, the external finishing and/or the final planted out area.

5.6.1 – Maintenance of the structural parts and of the external finishing

The structural maintenance of the work and/or the external finishing is solely envisaged under extraordinary circumstances and is normally carried out following accidental events such as: a fire breaking out on the slope, damages caused to the slope by impacts, excavations on the top.

- <u>Fire</u>: the work is not statically compromised since the reinforcing structural elements (geogrids placed horizontally on the soil) have not been damaged by the flames, there being no soil conditions that may lead to combustion. Following a fire, should there be superficial erosion phenomena at the face, it might be necessary to protect the slope with biomats or erosion protection geomats (if necessary, hydroseeded) able to prevent erosion phenomena. Should the welded wire mesh be considered unfit for the intended use, it might be necessary to replace it by fixing a new one to the soil by means of stakes at least 0.50 m long, whose function is to stiffen the elements placed on the face of the slope. According to the beneficiary's experience, when the face is covered with grass, the damages caused by fire are mitigated.
- <u>Impacts</u>: in the event of impacts caused by vehicles or machineries hitting the face elements, it would be appropriate to remove the damaged layers and to proceed with a new installation if these elements are placed at the top of the reinforced structure. If, on the contrary, the damaged parts are at the toe of the structure, it would still be necessary to remove any element of the sacrificial formwork that might have twisted out of shape. Any hollow that might appear on the face following an impact (causing voids in the soil or compressing it) should be filled and the slope should be protected with biomats or erosion protection geomats; it might be necessary to hydroseed prior to installing the geomat, in order to even the support or to install a new flat welded wire mesh, fixed to the soil by means of stakes at least 0.50 m long whose function is to stiffen the elements placed on the face of the slope.
- <u>Excavations on the top</u>: should it be necessary to make excavations on the top of the reinforced structure following the end of the works, they should preferably be performed, as far as possible, out of the reinforced area. If excavations are to be performed in the reinforced area, earth should be moved down to a maximum depth of 1 m and, as a general rule, no more than one reinforcing geogrid layer shall be interrupted by the excavation. Before starting the embankment operations it is necessary to check the face stability; compaction of the soil of the area concerned by the excavation shall be very carefully performed.

5.6.2 – Maintenance of the planted out area

The maintenance of the final planted out area should follow the rules usually applied for the maintenance of public parks and gardens. The planting of trees in the area on the top of the reinforced structure shall be properly designed to prevent the face of the structure from being harmfully affected (type of roots, type of foliage, local ventilation, etc.)

5.7 – Instruction manual for installation

The beneficiary has prepared an instruction document aimed at the proper installation of the reinforcing geogrids which he keeps regularly updated on his website and, on request, he guarantees technical assistance to design and installation.

6 – Test results

6.1 – Initial type tests (compulsory regime)

During the inspection visit, ITC verified the existence of Test Reports concerning the initial type tests of all versions of the geogrid "TT SAMP" this certificate refers to. Such tests were carried out in 2002.

6.2 – Additional tests

Surveillance tests have been executed on the occasion of this first issuing of the DVT. The results of such surveillance tests are contained in Assessment Report 935 and are reported below:

Characteristic	Test method	Declared value		Recorded value	
		TT SAMP 60	TT SAMP 160	TT SAMP 060	TT SAMP 160
Melt index (g/10 min)	ISO 1133	0.20 (± 0.10)		0.11	0.11
Density (kg/dm³)	ISO 1183 - Met. A	0.95 to 0.96		0.95	0.95
Ash content at 600 °C (%)	ASTM D 4218	≥ 0.5		0.51	0.83
Wide width tensile strength Peak load (kN/m)	EN ISO 10319	≥ 60	≥ 160	79.8	180.7

Table 9 – Tested characteristics not subject to the manufacturer's control on production

Characteristic	Method		045	060	090	120	160
Mass per unit area (g/m^2)	In-house	ITC	---	522	---	---	1108
		Mean (*)	324	458	662	908	1097
		No. of tests (*)	74	97	51	39	22
Single rib tensile strength Load at 2% strain (kN/m)	GRI-GG1 Modified	ITC	---	25.0	---	---	60.2
		Mean (*)	16.4	22.5	33.8	46.9	57.7
		No. of tests (*)	74	97	51	39	22
Single rib tensile strength Load at 5% strain (kN/m)	GRI-GG1 Modified	ITC	---	43.8	---	---	107.8
		Mean (*)	31.3	41.4	62.0	86.6	103.9
		No. of tests (*)	74	97	51	39	22
Single rib tensile strength Load at peak (kN/m)	GRI-GG1 Modified	ITC	---	76.6	---	---	181.4
		Mean (*)	52.6	72.5	109.3	147.6	175.2
		No. of tests (*)	74	97	51	39	22
Single rib tensile strength Strain at peak (%)	GRI-GG1 Modified	ITC	---	13.1	---	---	12.9
		Mean (*)	12.1	12.5	12.6	12.2	12.6
		No. of tests (*)	74	97	51	39	22
Junction tensile strength Load at peak (kN/m)	GRI-GG2	ITC	---	62.2	---	---	149.6
		Mean (*)	37.3	56.3	90.5	130.6	143.2
		No. of tests (*)	25	33	18	14	7

Table 10 – Dimensional/mechanical characteristics of geogrids Tenax "TT SAMP"
(*) Statistical reference concerning manufacturer's controls on production performed over the last six months

7 – Durability

The minimum expected service life of geogrids Tenax TT SAMP is 120 years in natural soils with 1.6 < pH < 13 and temperatures up to 40 °C, based on test reports concerning initial type tests.

Characteristic		Report number	Test method	Residual longitudinal tensile strength (%)	Residual longitudinal elongation (%)
Determination of resistance to weathering		1.1/29169/226-2002e	EN 12224	99.1	107.90
Determination of microbiological resistance		1.1/29169/226-2002e	EN 12225	103.6	102.10
Determination of resistance to acid and alkaline liquids	$Ca(OH)_2$ saturated	1.1/29169/226.2-2002e	EN 14030	97.9	119.40
	0.025 M H_2SO_4			103.2	119.30
Determination of resistance to oxidation		1.1/29169/226.2-2002e	ENV ISO 13438	100.50	173.50

Table 11 – Resistance to aggressive environments

Table 12 summarises the values of the long term design strengths for an estimated service life of the structure of 60 and 120 years according to the *creep strain* and *creep rupture* criteria.

Geogrid	Long Term Design Strength T_B			
	Design tensile creep strain strength T_{CS} (kN/m)		Design tensile creep rupture strength T_{CR} (kN/m)	
	Up to 60 years	Up to 120 years	Up to 60 years	Up to 120 years
045	19.8	18.5	21.6	21.2
060	26.4	24.6	28.7	28.3
090	39.6	36.9	43.1	42.4
120	52.8	49.2	57.5	56.5
160	70.4	65.6	76.6	75.4

Table 12 – Long term design strengths of geogrids Tenax "TT SAMP" according to *creep strain* (T_{CS}) and *creep rupture* (T_{CR}) criteria

8 – References

This geogrid was first used in 1995 and, among the works performed, the beneficiary lists the following:

Intended use	Place	Year	Surface area of the "face" (m^2)
Railway embankment	Porto S. Giorgio (AP)	1995	18300
Slope crest enlargement	Ancona	1996	10000
Slope reinforcement	Urbino (PS)	1996	3700
Reinforced embankment – Realization of the Storage Area of the Thermoelectric Power Plant	Altomonte (CZ)	2003	7250
Extraordinary maintenance intervention for the improvement of safety conditions involving the construction of the fourth motorway lane – Slope reinforcement	Bardonecchia (TO)	2004	18700
Rehabilitation project for the decayed area Grontone-Corpo Sud	Parma	2004	8000
Embankment for Urban Solid Waste Containment	Teglio (SO)	2004	2500
Embankment for Rock Fall Protection	Valle D'Aosta	2004	5500
Enlargement of Industrial Storage Area	Pomezia (Roma)	2004	4550
Sound Deadening Barrier	Pavia	2005	2500
Retaining Wall Reinforcement	Korea	2005	30000

Table 13 – List of references