TENAX RIVEL

THE SOLUTION FOR GEOGRID REINFORCED SLOPES

Slope Stabilisation of the historical village of Genzano di Lucania, Italy, in order to preserve the main church and an ancient monastery.

Mankind has often chosen to settle in locations with a good geographical position and favourable environmental conditions, even though in some cases the land is not well suited to the construction of residential, industrial and commercial buildings.

Slopes, mountainsides and inhospitable sites have been modified over time with continually developing technologies and methods.

Hillside control works, the consolidation of road embankments, slopes subject to landslides, rockfall barriers, canals, dams and landfill sites are just a few of the many applications for geogrid reinforced slopes using geosynthetic elements – a structural technique used throughout the world in advanced civil engineering, environmental and geotechnical projects which fully respect the environment.

INTRODUCTION TO GEOGRID REINFORCED SLOPES

The term "geogrid reinforced slope" refers to a composite material which combines the strength of two different materials – fill soil and reinforcing geosynthetic – a combination which is synergistically improved.

The geotechnical properties of the fill soil (compressive strength and shear strength) are improved by being combined with geosynthetics – polymer structures with a very high tensile strength – making it possible to construct and stabilise slopes and embankments with very steep inclines and small sections, thereby saving space and excavation material.

A reinforced slope with a grassed face is a valid alternative to reinforced concrete, especially where the works are of a large scale that have a real environmental impact.

The system comprises of three elements:

- The HDPE (high-density polyethylene) mono-oriented reinforcing geogrid from the **TENAX TT** range;
- The fill material;
- The facing elements.

On the TENAX industrial site, located in the heart of the green hills of Brianza (Italy), it has been necessary to increase the size of the storage facilities.

Embankments were constructed using the **TENAX RIVEL** system, which has enabled the space right up to the edge of the site to be fully utilised by the erection of 10-metre high walls, with an inclination of 75°.

The face of the structure was completely grassed in a matter of weeks from the completion of construction and then planted with shrubs and tall trees.

TENAX RIVEL SYTEM – A PROVEN TECHNOLOGY

Geogrid reinforced slope technology is generally used for large-scale environmental engineering projects and in landscape planning as it is a valuable working tool for the construction of slopes. The flexibility of the **TENAX RIVEL** system and the simplicity of its installation means that it can also be employed in small scale construction projects.

For example, in the private sector, it can be used for the construction or profiling of inclines, steep slopes and banks, or to reduce the environmental impact of buildings and structures.

35m high reinforced soil embankment constructed to retain future waste fill in Nent landfill, Hong Kong.

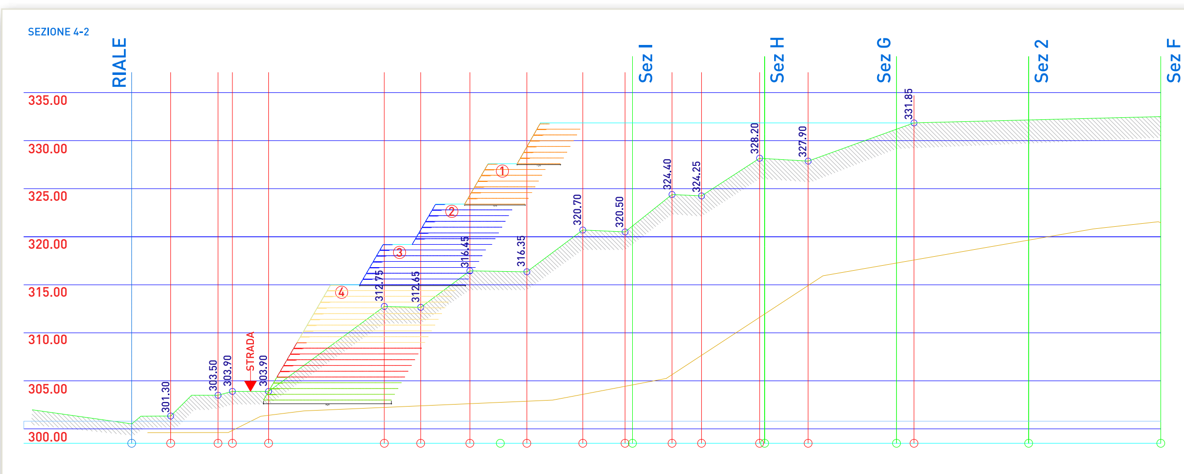
Immediately, after construction

Slope after vegetation establishment.

Railway embankment connecting Newton Cap viaduct on River Wear, England.

Terraced gardens using TENAX reinforced slopes at Merano Botanical Garden, Italy.

As part of the re-development of the " Castello di Cantone" estate, Switzerland, the inert landfill has been transformed into a terraced hill to create a riding school.



Series of four reinforced embankments protecting a 15 kV electric line and a local road in Rhemes-Notre-Dame nr. Aosta, Italy

Construction and re-profiling of a 12.5m high slope close to a small residential area close to Lecco , Italy.

A geogrid reinforced noise barrier built on Milan East Ring Road, Italy.

Construction of four soil reinforced trapezoidal perimeter dikes to retain waste within Genna Luas landfill, nr.Cagliari, Italy.

INSTALLATION PROCEDURE

The **TENAX RIVEL** system is easy to install and does not require the use of specialised labour. For best results, however, it is essential to follow the specific design instructions and installation procedures.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1. Preparation of the foundations:

avoid excessive settlement of the structure and possible deformation of the geometry, it is important that the foundations are suitably prepared to take the design load. It is also advisable to put in place a basic drainage layer. Mark out the line of the embankment (Photograph 1).

2. Installation of the system:

2.1 Position and align the metal formwork components, attaching them to each other with wire;

2.2 Unwind the rolls of geogrid and cut them to the lengths stated in the design (it is advisable to allocate an area for carrying out this operation). The length is determined by the anchoring depth, the return on the face (approx. 700mm) and the length of the return at the top (1500mm minimum);

2.3 Position the cut lengths of geogrid carefully on the foundation level inside the formwork, in layers perpendicular to the face; the geogrid must run along the internal face ofthe formwork and extend approx.1500mm outside (to form the return) (Photograph 2);

2.4 The ends of the cut lengths of geogrid are to be fixed to the ground with U-shaped steel pins to hold the geogrid taut and in position.

2.5 If required install the erosion control matting ensuring adequate coverage (Photograph 3);

2.6 Position the retaining bars that are used to brace the formwork at approx. 450mm intervals (Photograph 4).

3. Spreading and compacting the fill material:

3.1 Spread the fill material over the geogrid in layers approx. 300mm thick; near the face, it is advisable to use a depth of 250-300mm of topsoil to allow for the rapid establishment of grass growth (Photograph 5);

3.2 Use a light vibrating roller and compact to not less than 95% of the Proctor Standard up to 1m from the face. For the area closest to the face, compact using a hand vibrating compactor or vibrating plates (Photograph 6 and 7);

3.3 Once the filling operation is completed, turn back the section of geogrid, previously left outside the metal formwork, onto the compacted embankment, tension it slightly and secure with U-shaped steel pins.

4. Repeat the installation operations from step 2.1 to step 3.3 until the design level has been reached.

5. Where a pre-seeded erosion cintrol mat is not being used, hydro-seed the face or plant ground-cover plants, shrubs, or cuttings.


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Positioning of a parapet or guard rail.

A typical example of a soil reinforced slope adjacent to a concrete structure (e.g. adjoining wing walls or bridge abutments)

Tenax Rivel structure installed using a weed control fabric and awaiting ornamental planting.

The geogrids are placed at the front or back depending on whether the section is convex or concave.

Parapet in accordance with site safety standards.

Placement of metallic tiles for drainage of surface waters.

Before filling the last course of the embankment, it is possible to create recesses to take street lighting.

THE SYSTEM **COMPONENTS**

The reinforcement

TENAX TT geogrids are two-dimensional structures manufactured from HDPE by a process of extrusion and mono-directional drawing and are certified for the construction of steep reinforced slopes with inclines of up to 85° by the ITC-CNR (Institute for Construction Technology-National Research Council).

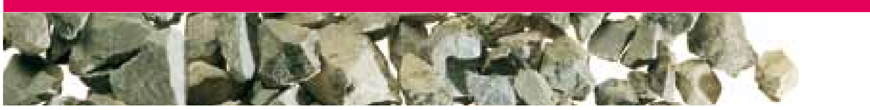
Long-Term Design Strength (LTDS)

TENAX TT geogrids have undergone tensile creep tests for over 10 years at various temperatures. From the results of these tests, extrapolated to 1,000,000 hours (120 years), a long term strength greater than 40% of the peak strength is obtained.

The long-term strength of various geogrids on the market must be compared on the basis of the same test method, showing the performance of the geogrid and not of its components.

NOTE: Creep tests on the fibres of woven geogrids are misleading. The LTDS figure of 60% for tensile strength relates to the fibre of which the woven geogrid is made, whereas the effective figure is actually 40% of the peak.

Table A		TENSIL
Characteristics	U.M.	TT045
Junction Strength	kN/m	36
Long-term strength (LTDS) at 120 years	kN/m	18.5
Strength at 2% elongation	kN/m	11.0



Resistance to construction damage

When the fill material, especially if it is sharp gravel, is placed on the geogrid and compacted, the geogrid can be damaged by the puncturing and abrasion effects of the aggregate. Extensive test programmes, carried out to assess the residual tensile strength of various geosynthetics subjected to damage procedures in the laboratory and in situ, show that the performance of extruded geogrids compared to woven geogrids is completely different.

The production process for TENAX extruded geogrids means that a product is obtained with (longitudinal and transversal) elements guaranteeing the continuity of the molecular chains over the entire monolithic structure of the geogrid.
This structure is less sensitive to cutting, abrasion, perforation and damage from compaction, even where the impact force is high when the aggregate is unloaded directly onto the geogrid. The Safety Factor for damage during construction is shown in Table B1.

Information about the parameters of reduction due to mechanical damage for some types of reinforcement geosynthetics on the market has been provided by the Federal Highway Administration of the USA (Elias, 1996), as illustrated in Table B2.

NOTE: The individual fibres making up the longitudinal and transversal elements of woven geogrid are easily cut by pieces of aggregate and the thin covering of PVC or similar material is not sufficient to protect it.

Table B1	SAFETY FACTOR FOR DAMAGE (I.T.C.)	
Type of ground	D_{max} of particles (mm)	Factor f_{m21}
Aggregate with stones	< 125	1.07
Large-grade aggregate	< 75	1.03
Medium-grade aggregate	< 40	1.00
Sand, clay and silt	< 6	1.00

Table B2	SAFETY FACTOR FOR DAMAGE (FHWA)	
Reinforcement typology / Soil typology	D_{max} 100 mm, D_{50} 30 mm	D_{max} 20 mm, D_{50} 0.7 mm
PVC-covered PET woven	1.30 – 1.85	1.10 – 1.30
Woven geotextiles (PP and PET)	1.40 – 2.20	1.10 – 1.40
Nonwoven geotextiles (PP and PET)	1.40 – 2.50	1.10 – 1.40
Geotextiles strips (PP)	1.60 – 3.00	1.10 – 2.00

Bodkin: longitudinal connection of two pieces of **TENAX TT** geogrid.

E STRENGTH OF TT GEOGRIDS (ITC DVT-0001 2011.03.14)				
5	TT060	TT090	TT120	TT160
	50	80	110	130
	24.6	36.9	49.2	65.6
	17.0	26.0	36.0	45.0

Junction Strength

The strength of joints is a fundamental parameter for assessing the lateral confinement provided by the geogrid in the ground and the integrity of the transversal and longitudinal ribs of the geogrid itself. In addition, whenever a longitudinal connection has to be made between two pieces of geogrid using bodkin connections, the strength of the joints is structurally important, as it must allow the transmission of forces from adjacent lengths of geogrid.

As geogrids are designed on the basis of their Long-Term Design Strength (LTDS), they are never subjected to greater tensile stresses than the LTDS. Therefore, a rational approach to a specification is that the strength of a geogrid must be equal to at least 1.50 x LTDS, as is the case with **TENAX TT** geogrids.

If this ratio is met, then no further safety coefficient needs to be applied for the connection strength.

NOTE: There is a clear difference between the junction strength of extruded geogrids and those of woven and welded geogrids, for which the junction strength is equal to a maximum of 20% of the peak value.

Chemical Resistance

Chemically aggressive environments can affect the long-term performance of geogrids depending on their polymer composition.

HDPE is universally considered the most inert polymer and therefore, the most resistant to chemical attack.

Tests carried out in the USA on **TENAX TT** geogrids in accordance with standard E.P.A. 9090, certify that there is no danger of chemical attack from substances naturally occurring in the soil, or even in particularly aggressive environments (for example controlled household refuse landfill). No safety coefficient for chemicalresistance needs to be applied for **TENAX TT HDPE** geogrids.

NOTE: After 20 months' exposure to an environment with a pH of 9, PET can undergo a loss of strength of 9% (even in dirty water, over a similar period, hydrolysis causes a 3% loss of strength).

For PET materials (geotextiles or woven geogrids) without suitable certificates guaranteeing resistance, the American FHWA suggests adopting very conservative partial safety factors (see Table C).

Fill material

Geogrid Reinforced Slope technology allows the use of many types of fill. However, it is preferable to use a free-draining granular material with a high angle of internal friction, if possible without large stones as they would make compaction difficult.

If using on site material with poor mechanical properties, it is advisable to mix it with sand and aggregate.

It is also possible to use poor soil using the lime stabilised technique.

Near the face, it is recommended filling with topsoil in order to create optimum conditions for plants to become established and to ensure the durability of the vegetation.
The fill material should be placed and compacted in layers, with a recommended thickness of 0.30 - 0.35m, to reach a compaction of not less than 95% of the Proctor Standard.

NOTE: The use of lime stabilised techniques is effective with extruded HDPE geogrids but cannot be used with PET reinforcement as it is subject to chemical degradation in alkaline environments.

TENAX RIVEL system: detailed cross sections

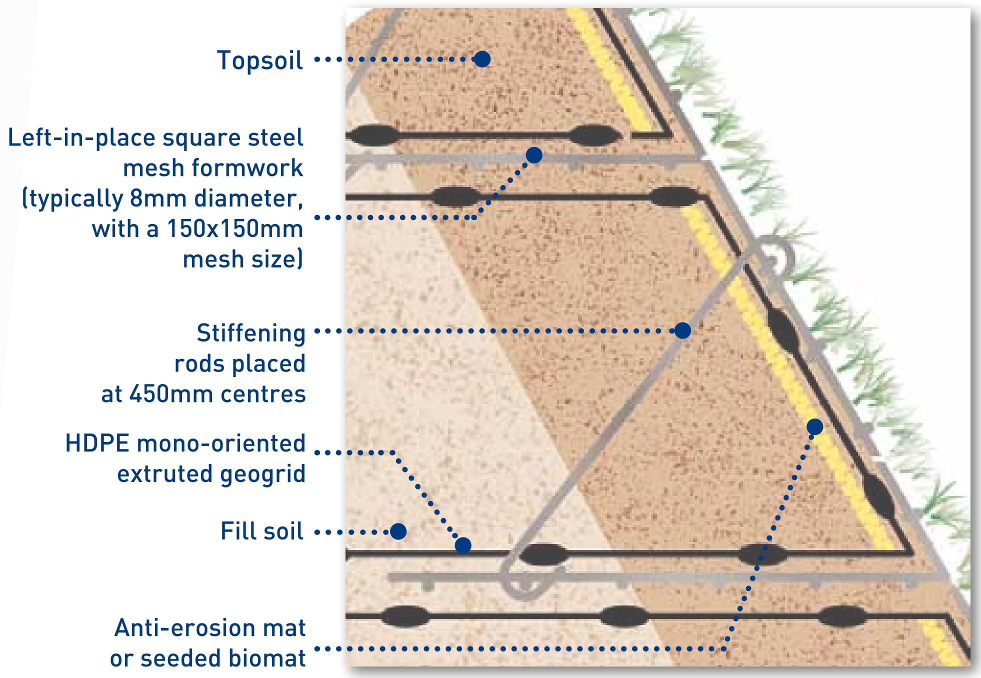


Table C	REDUCTION FACTORS FOR CHEMICAL ATTACK FOR DIFFERENT DEGREES OF ACIDITY OF THE GROUND (FHWA)		
Characteristics	TT060	TT120	TT160
PET geotextiles	2.00	1.60	2.00
Woven PET PVC-coated geogrids	1.30	1.15	1.30

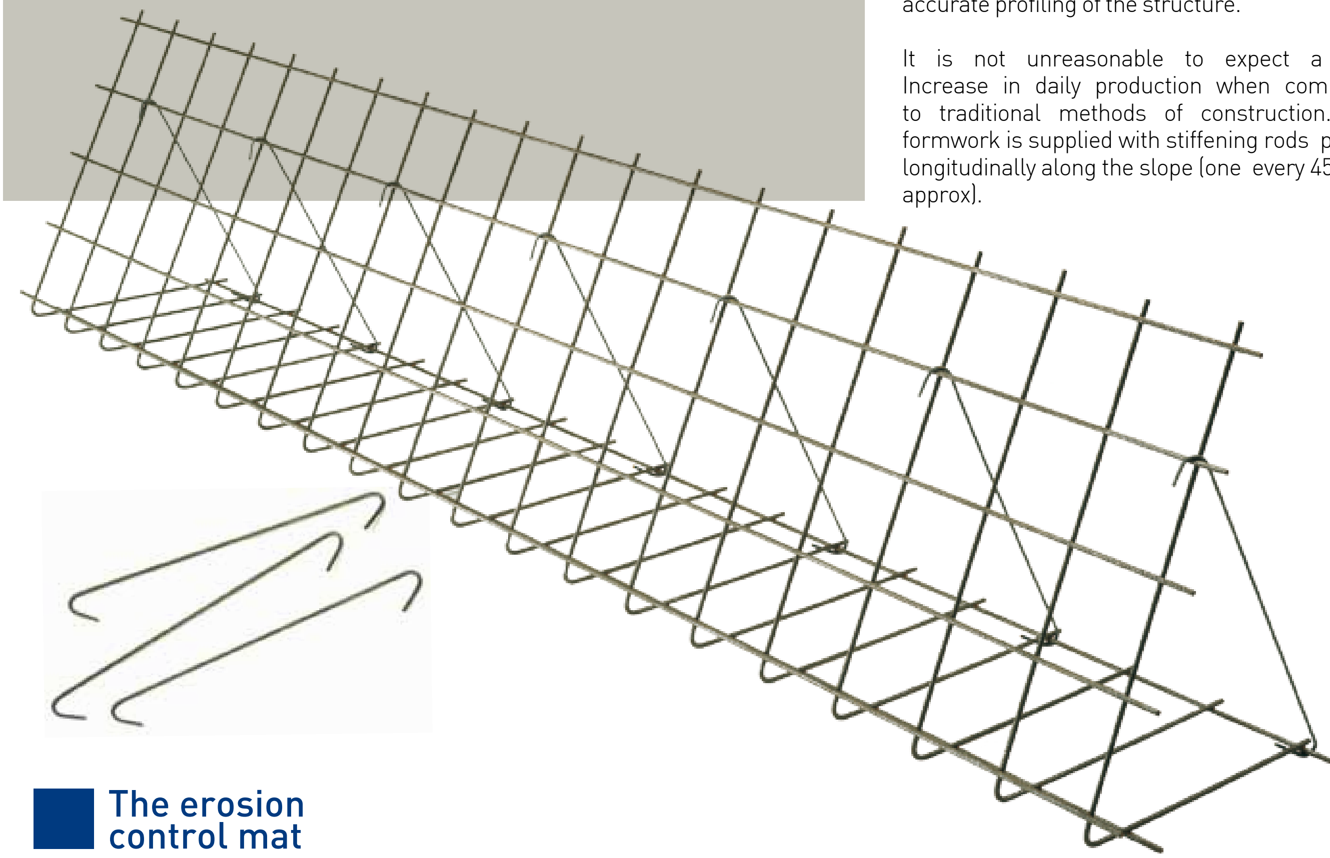
TENAX TT geogrids are stabilised using a black colour master batch containing carbon black which protects the polymer from degradation caused by UV rays.

The facing

The Steel Mesh Formwork

The **TENAX RIVEL** system uses, on the face of the structure, formwork made of electro-welded mesh (8mm rebar with a 150x150mm mesh size) acting as a guide support and which is left in place. It does not have a structural function but speeds up the installation process and allows accurate profiling of the structure.

It is not unreasonable to expect a 30% Increase in daily production when compared to traditional methods of construction. The formwork is supplied with stiffening rods placed longitudinally along the slope (one every 450mm approx).



The erosion control mat

Planting plays an active role in the protection of the slope in all landscaping projects. Without it, the work would be incomplete and would be less effective. The grassing of the face by hydro-seeding disguises the artificial elements of the system and drastically reduces the environmental impact of the slope.

The time for germination and greening of the structure can range from four to eight weeks, depending on the seasonal weather conditions. It is advisable to carry out hydro-seeding in the wetter months of the year. In order to protect reinforced slopes from erosion and to provide a suitable surface for hydro-seeding a biomat made of jute, straw, or coconut fibre can be used on the face of structures incorporating the **TENAX RIVEL** system.

To avoid carrying out hydro-seeding, a pre-seeded biomat can also be used. This material comprises of a fibre filling made of biodegradable viscose containing seeds of various grass species and a fertiliser to aid rapid grass growth.

The pre-seeded biomat allows rapid and uniform growth of vegetation and guarantees total coverage of the face, reducing the loss of seeds and topsoil.

Germination is facilitated by the slow biodegradation of the woven textile which, being eco friendly, does not upset the equilibrium of the surrounding area. The choice of mix and quantity of seed per square metre can be calculated as appropriate for the particular project requirements and the pedological and climatic conditions.

The face of the slope can be planted with cuttings, shrubs, bulbs and other plants that are installed between one reinforcement layer and the other. In this way, a uniform cover effect is guaranteed.

THEORETICAL INFORMATION

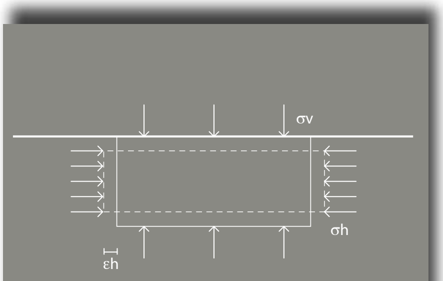


Fig. 1a

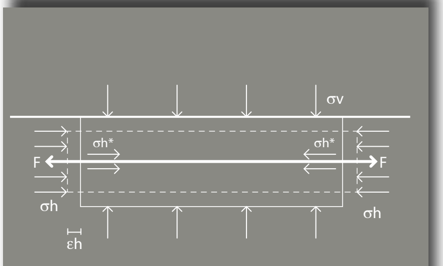


Fig. 1b

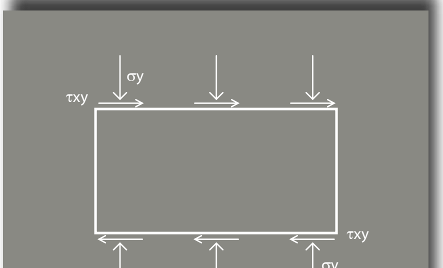


Fig. 2

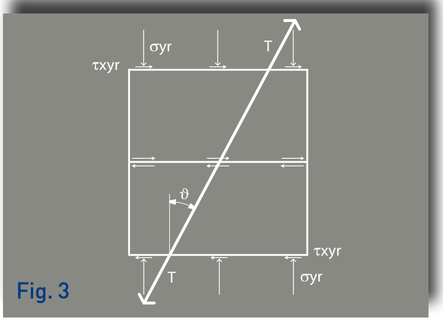


Fig. 3

A simple model helps explain the principle on which reinforced slope technology is based.

A ground element **(Fig.1a)**, part of an undefined mass, following application of a vertical
stress σ_v undergoes a horizontal deformation ε_h. The adjacent soil opposes this deformation with a horizontal confinement action σ_h.

Where a reinforcement element is inserted into the soil **(Fig.1b)**, the horizontal deformation ε_h, to which the soil is subject, causes a deformation of the reinforcement itself, to which the said reinforcement opposes a reaction F translating to a subsequent compressive stress σ_h*. A reinforcement element can therefore be inserted to increase the compressive resistance of the soil.

Considering the shear stresses **(Fig. 2)**, in one element of loose soil we have:

$$(\tau_{xy})_{max} = \sigma_y \cdot \tan \phi_{max}$$

where:

ϕ_{max} = maximum angle of shear strenght of the soil;
$(\tau_{xy})_{max}$ = maximum force of shear strength provided by the soil.

Where the element of soil is crossed by a reinforcement element with an angle of inclination θ in relation to the vertical (Fig. 3), the state of tension is modified because the stress T generates a shear force produced by the tangential component T . sinθ, whereas the normal component T . cosθ generates another τ_{xy} due to the friction angle ϕ_{max} of the soil.

$$(\tau_{xyr})_{max} = \sigma_{yr} \cdot \tan\phi_{max} + (T/A_s) \cdot \cos\theta \cdot \tan\phi_{max} + (T/A_s) \,.\, \sin\theta$$

Total shear resistance	Shear resistance of soil only	Shear stress generated by the normal T component	Shear stress generated by the tangential T component

where:

A_s = area of the reinforcement element.
$(\tau_{xyr})_{max}$ = maximum shear resistance value of the reinforced slope.

In this way, the normal stress on the soil element is increased by:

σ_y^ = (T/A) · cosθ

whereas the maximum shear stress which the soil can bear is increased by:

τ_{xyr}^ = $(T/A_s) \cdot \cos\theta \cdot \tan\phi_{max} + (T/A_s) \cdot \sin\theta$

Shear test carried out in the laboratory of **TENAX** SpA.

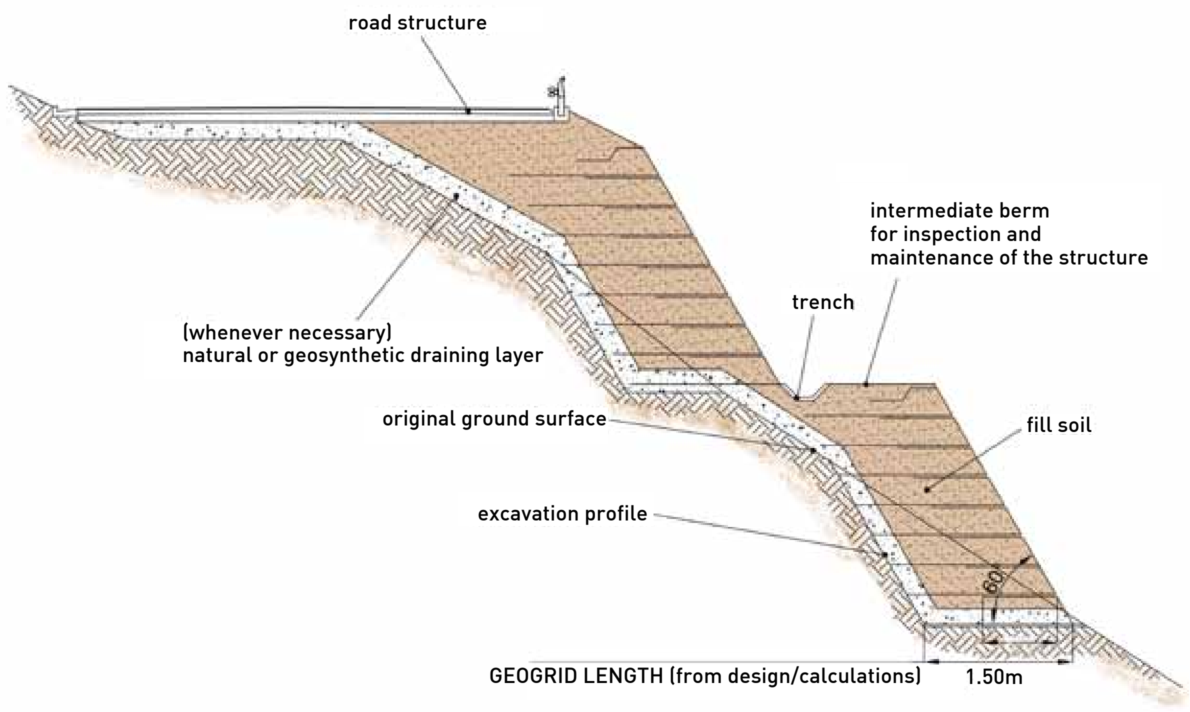
The factors influencing the shear resistance of reinforced soil are:

- The strength and rigidity of the reinforcement relative to the surrounding soil;
- The position of the reinforcement;
- The shape of the reinforcement which must be able to develop a high apparent angle of friction at the interface with the soil;
- The creep characteristics (elongation under constant tensile load) of the reinforcement during the design life;
- Durability of the reinforcement.

In particular, the geometric structure of the reinforcement must guarantee high friction, so as to avoid the reinforcement itself unwinding due to the tensile stress T to which it is subjected.

NOTE: An excessively rigid reinforcement, for example a metallic element, can break when subjected to minor deformations without mobilising high strength values; excessively extensible materials (such as non-woven geotextiles) cannot provide sufficient reinforcement if large deformations have already occurred, which are usually incompatible with the lifetime of a structure.

DESIGNING A GEOGRID **REINFORCED SLOPE**



Checking the stability of a reinforced slope is generally not a very complex operation, but it is, nonetheless, a necessary one. Underestimating the importance of checks and not carrying out the necessary investigations mentioned below, could cause design or construction errors which in turn can result in structural stability problems in the medium term.

The following procedure is recommended before commencing the design work:

- Carry out an elevation survey of the site to obtain a layout and cross-sections;
- Acquire geotechnical and hydro-geological data of the site: structure, routes of strata, presence of water in the slope or subsoil, seismic data, mechanical properties (effective angle of friction ϕ', cohesion c' and specific weight of the soil γ) and grain distribution analyses of the soil. The assessment on the presence of water is essential for the correct design of a structure and provide adequate systems for water collection and drainage;
- Collect "historical" information about events such as active and potential landslides and run-off areas affecting the site;
- Define the geometry of the structure and calculate loadings.

The TENAX Geosynthetics Division work with the latest commercially available slope design software using either seismic or static conditions with layered or homogenous soils and any type of geometry of reinforced slopes using mono-oriented HDPE geogrids.

Normally, an internal stability analysis is carried out which determines the type of reinforcement geogrid necessary for the given geometry, the depth, the quantity and the spacing of the reinforcement layers.

If the structure is to be built in an earthquake zone, the stability analysis must to take account, the design seismic acceleration for the area in accordance with either national or international standards. If internal stability is assured, then sliding at the base, the only significant external stability check, is also guaranteed.

For reinforced soils, stability against overturning is always ensured as a result of the extreme flexibility of the structure which cannot pivot rigidly, the position of its centre of gravity and its geometry.

Finally, as regards the bearing capacity check, it is important to underline that a reinforced slope structure is much "lighter" than traditional reinforced concrete structure or gabions and it is therefore possible to construct on soils with a poor bearing capacity by using "lighter" fill material.

If the structure is built on a slope and if the soil behind the structure is of a different type from that used for the fill, global stability checks are then necessary to investigate deep failure surfaces, and if necessary, to modify the reinforced slope structure to obtain an appropriate Factor of Safety. The same check must be carried out for seismic conditions.

SPECIAL APPLICATIONS: **ROCKFALL BARRIER SYSTEMS**

To guarantee the protection of residential buildings or roads located close to hills and mountains where there is a risk of rockfall, technological solutions of an active type (able to prevent rocks breaking away), or of a passive type (able to intercept or divert moving rocks), can be used.

These structures can be designed and planned to reduce the risk or vulnerability associated with rockfalls. In particular, passive defence works are normally located so as to intercept the trajectory of a falling mass.

Boulder blocked by a Tenax soil reinforced Rockfall Barrier Embankment built near Aosta, Italy.

The definition of the motion of the block and the kinetic energy to be absorbed is a very important factor for a correct design.

The rockfall barrier embankments constructed using the **TENAX RIVEL** system are protective works of a passive type with high energy absorption which are more effective than metal barriers:

- they provide effective protection even in the event of "showers" of rocks or repeated falls along the same line;
- they require much less maintenance even following intensive periods of rockfalls and are not subject to corrosion;
- they are durable and not subject to damage or disintegration;
- the environmental impact is negligible especially if the structure is concealed by suitable landscaping works;
- the environmental impact is negligible especially if the structure is concealed by suitable landscaping works;
- they can be made by re-using material from previous rock falls.

A **TENAX RIVEL** reinforced slope has many advantages over a traditional embankment:

- smaller footprint with a consequent reduction of the soil to be moved;
- fewer difficulties in identifying suitable areas from a topographical point of view;
- lower risk of rocks tipping over the structure because of the greater inclination of the face.

In reinforced slopes, the soil is "bound" by the geogrid. The tensile strength provided by the geogrid and its rigid structure prevents the rocks breaking through the embankment, notwithstanding the reduced area compared with a traditional embankment. If the width of the crest of the structure is less than 2.00m (particularly narrow structures), to increase the binding effect, it is advisable to position a second reinforcement structure perpendicular to the main one (i.e. longitudinally to the embankment).

TENAX TT geogrids have an elastic, plastic-viscous type behaviour depending on the load factors and the conditions of application. The analysis of the stress situation induced by an impact, (which can be modelled as an instantaneous loading of a high intensity), has meant that it is possible to identify a stiffening of the geogrid-soil system or an increase in the modulus of elasticity.

Following these stresses, the force-deformation curve has a greater incline and the geogrid reacts to the stresses by minor deformations. Given the almost instantaneous duration of the phenomenon, viscous-type deformations (creep) have no way of manifesting themselves. The reinforcement is, therefore, able to mobilise a tensile strength close to the peak value and no longer the long-term strength to which reference is made by the application of static loads.

The greater "binding" of the soil involves a dynamic load distribution on a cone with a larger base and, therefore, a greater mass of soil is involved in the resistance to the impact and in the dissipation of energy.

Numerous tests and consequent scientific publications illustrate the model of interaction, validated by various series of laboratory tests between **TENAX TT** geogrids and the soil in the event of the application of dynamic loads.

Comparison between TENAX RIVEL rockfall barriers and embankments using metal gabions filled with rubble

The impact of a mass on the face of an embankment constructed using metal gabions prodces chips of stone which could travel beyond the embankment itself, without the knowledge of their trajectory in advance. In contrast, the **TENAX RIVEL** embankment is able to absorb the impacting mass without crumpling.

Following impact, the mesh of the gabions can be torn, causing the partial or total emptying of the gabion and compromising the stability of those above with the real risk of triggering an uncontrollable and thus dangerous domino effect.

The function of the metal mesh is only to contain the backfill material. In contrast, a geogrid and the ground interact permanently with a consequent improvement in the strength of the structure. Each gabion in a rockfall barrier system transmits almost elastically the impact to the adjacent gabion and from the last one to the ground which can be projected outwards.

With the **TENAX RIVEL** system, the ground is spread and compacted considerably reducing the deformability of the material, thereby guaranteeing the continuing integrity of the individual elements of which the structure is composed, even following a violent impact on its face.

The better "binding" of the ground enables the load to be distributed over a larger volume; the area of influence, usually conical in shape, therefore, has a wider base and thus a larger mass of ground is involved in the resistance to shock and dissipation of energy.

Video recordings of life sized tests carried out on reinforced rockfall barriers using TENAX geogrids have revealed that the downhill face moves back again once the displacement peak has been reached. This effect is certainly due to the presence and action of the geogrid. This rebound effect, together with observation of the formation of tension cracks on the crest of the embankment, allows us to conclude that in the absence of a connection between the uphill and downhill faces, a barrier can be broken through, or at least, the volume of ground isolated by tension cracks can collapse on the downhill side.

The downhill side of the reinforced rockfall barrier following impact is damaged but remains intact

Minimum extrusion of the downhill face of the embankment

Certification of Tenax Rockfall Barriers

Reinforced slope barriers using **TENAX TT** geogrids have undergone repeated trials in the test field of Vigo di Meano (TN), accredited by the Polytechnic of Turin. Following these tests, the TENAX system was certified by the Polytechnic of Turin, which had demonstrated the effectiveness of barriers 4.20m high, with a minimum crest width of 0.90m reinforced with **TENAX TT** extruded geogrids.

The certificates issued for reinforced barriers using **TENAX TT** geogrids state that they can be created using earth with frictional-type behaviour (good quality material) or with plastic-type cohesive material. In both cases, the barriers have demonstrated that they can withstand repeated shocks by a mass with energy of approximately 4,500kJ. The results can be extended to any structures with a minimum geometry guaranteeing compliance with the proportions of certified structures.


PROVE IN SITU IN SCALA REALE DEL COMPORTAMENTO DI RILEVATI PARAMASSI IN TERRA RINFORZATA

Construction of three Rockfall Barrier Embankments on Como Lake, protecting the picturesque village of Verenna, Italy. The total vertical embankment surface area is 8,000m², with a height ranging between 4.2m and 7.2m.

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TENAX is an international group that manufactures and sells a wide range of geosynthetics, all certified by the most important technical and international organisations, and used in many construction projects of different sizes, importance and complexity all over the world.
For more than thirty years, **TENAX** has been a company at the forefront of constant process - product research in order to guarantee the highest quality standards anytime.

Some examples of the fields of application of geosynthetics :

- **stabilisation and reinforcement** of loose foundations and improvement of their bearing capacity (TENAX LBO, GT, 3D GRID);
- **horizontal and vertical drainage** through the removal of fluids and gas (TENAX CE, GNT, TENDRAIN, TN, TNT, HF, HD);
- **soil rinforcement** in embankments with vegetative geomat cladding or reinforced block walls (TENAX TT, RIVEL, T-BLOCK);
- **erosion control** applications and vegetation protection on slopes during germination, even on waterproofing (TENAX TENWEB, MULTIMAT).

Technical experts will assist you with precision and without delay from the first moment of design and development to the construction of your project, assisting you with expert advice to find appropriate solutions to any occuring civil engineering and environmental problem.

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