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High performance of TRMs with wire mesh reinforcement – Case Studies

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ABSTRACT
Erosion control is one of the biggest challenges for soil conservation in rivers, channels, agriculture and infrastructure. Soil erosion is a natural process, however accelerated erosion can occur when human activities create disequilibrium in the environment. Soil erosion can cause several problems including decreases in agricultural productivity and eutrophication of waterways. Soil erosion often causes damage to civil infrastructure and accelerates desertification and sedimentation. Among the existing solutions for erosion control, geosynthetics serve as an effective and economical option. High performance Rolled Erosion Control Products (RECPs) are designed for critical erosion control applications in high flow velocity channels, stream banks, and on steep slopes. Double-twist steel wire mesh can be incorporated within the filaments of geomats during production, enhancing their performance against erosion and providing additional reinforcement. Incorporating double twisted wire mesh into the geomat increases resistance to shear forces and high velocity flow. This product is flexible and easy to install, and it gives a strong protection against erosion while promoting vegetation growth.

Keywords: turf reinforcement mat, erosion control, channel lining

1. INTRODUCTION

1.1 Definition, causes and types of soil erosion

Erosion occurs naturally at low rates in all types of soils by forces of water and wind. This process is considered a form of soil degradation and is characterized by detachment, transport, and deposition of soil particles. Environmental factors such as climate, vegetation cover, soil characteristics, and topography are major controlling conditions in natural erosion rates. Human activities, however, can dramatically increase the rates of soil loss by means of urbanization, industrial and mining activities, intensive agriculture, overgrazing, and deforestation.

Soil erosion has become a global issue because of negative impact on agricultural productivity, increased damage to civil infrastructure, siltation of water ways and reservoirs, and water and air pollution. Erosion also reduces soil potential to help mitigate and adapt to climate change, triggering a cycle in which extreme weather events and soil erosion reinforce each other, so warmer and wetter atmosphere expected in the future can cause larger and more frequent storms leading to higher amounts of runoff and erosion. These adverse economic and environmental impacts highlight the need for proper erosion control solutions.

1.2 Geosynthetics as soil erosion control solution

One of the most effective ways to control erosion is to maintain a cover of growing plants and minimize the disturbance of existing soils, especially near water bodies and on steep slopes. Geosynthetics accomplish this task by creating a physical barrier which can absorb the impact of water and wind on bare soils, resulting in the prevention of soil loss and enhances vegetation growth.

Erosion control products represent one of the fastest-growing application areas in the geosynthetics industry. They provide protection against erosion on soil slopes either until vegetation is established or for long-term applications. These products have been named as Rolled Erosion Control Products (RECPs) by the Erosion Control Technology Council (ECTC, 2017), while they are named as Geosynthetics (GSY) for erosion control by the International Geosynthetics Society (IGS, 2019) Examples of geosynthetics for erosion control are shown in Figure 1. These products are easy and fast to install and can be applied directly onto slopes and along river and canal banks, conforming to the shape of the slopes or banks due to their flexibility.
Geosynthetics for erosion control (IGS, 2019) are classified as:

- temporary erosion and revegetation materials (TERMs);
- permanent erosion and revegetation materials (PERMs).

TERMs consist of GSY that are wholly or partly degradable. TERMs provide temporary erosion control and are either degradable after a given period or they function only long enough to facilitate vegetative growth. After the growth is established the TERM becomes sacrificial. The natural products are completely biodegradable, while the polymeric products may be only partially so. Temporary degradable erosion control blankets (biomats) are used to enhance the establishment of vegetation. They can be made of natural fibers (e.g., straw, jute, coconut) which are kept together by natural or synthetic low weight nets. Biomats absorb large amounts of water and, during their natural degradation, they decompose and produce nutritious materials for the vegetation. These products are used where vegetation alone would provide enough protection after the erosion control product has degraded.

PERMs provide erosion control, aid in vegetative growth and eventually become entangled with the vegetation to provide reinforcement to the root system. As long as the material is shielded from sunlight, it should not degrade. PERMs can be divided in two different categories depending also on their installation technique, these categories are usually referred to as: erosion control revegetation mats (ECRMs) and turf reinforcement mats (TRMs). The basic difference is that ECRMs are placed on the ground surface, already seeded, without a topsoil infill; while TRMs are placed on the ground surface with topsoil and seeding filling. Vegetation roots grow below the ECRMs, while they grow through the TRMs. Thus, TRMs can be expected to provide better vegetative entanglement, improved shear resistance of the root system, and longer performance. Permanent nondegradable erosion control mats can be made of synthetic nets, fibers or filaments tangled together (geomats). They are generally used in critical erosion control applications by creating a high porosity deformable layer on soil slopes where immediate protection is required.

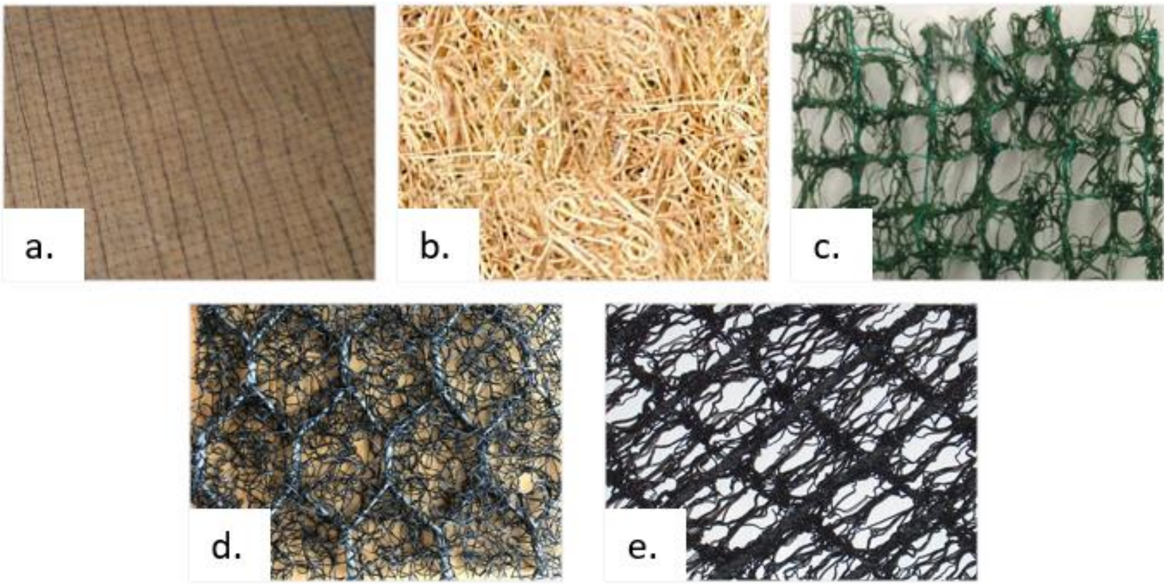

Figure 1. Examples of geosynthetics for erosion control: a. biomat with coconut fibers, b. biomat with wood fibers, c. PE geomat, d. TRM with metallic reinforcement, TRM with polymeric reinforcement.

In addition, there is a stronger version of permanent nondegradable erosion control mats: reinforced geomats. Reinforced Geomats are geocomposites produced by factory joining a Geomat and a metallic mesh or a Geogrid (Fig. 1, bottom row), having a tensile strength in the range 50 – 300 kN/m (IGS, 2019). Reinforced Geomats possess all the characteristics of Geomats, plus they provide high tensile strength. They can be used on long and steep slopes, along the banks of canals and river courses with relatively high water velocities, where high tensile strength is required.

The purpose of this paper is to present the characteristics and applications of a metallic mesh reinforced geomat through the description of the product and case studies.

1.3 TRM reinforced with steel wire mesh

Maccaferri MacMat R is a geomat with metallic mesh reinforcement, manufactured by extruding UV stabilized synthetic filaments onto a double-twist steel wire mesh (DTWM). The presence of the steel wire mesh significantly increases the tensile strength of the geomat so it can be used on long and steep slopes and along the banks of canals and river courses with high water velocities. Properties of this product are shown in Table 1.

Geomat with woven steel wire mesh reinforcement works as a shield on the slope protecting it from the effects of wind and rainfall and preventing the wash out of soil particles before vegetation is established (see Figure 2). At the same time, the double twist steel wire mesh provides higher tensile strength and shear resistance and protects the geomat from potential damage. Therefore, if a cut occurs in the geomat it will not propagate through the entire product, instead, it will be limited to just a single mesh opening (see Fig. 3). Also, the steel wire mesh can protect the slope from shallow superficial failures by reinforcing the slope surface.

Table 1. Physical and Mechanical Properties of the Geomat with DTWM reinforcement.

GEOMAT	Polymer	PP	
	Mass / Unit area ASTM D6566	450 g/m^2	
REINFORCEMENT	Double Twist Mesh Type	6 mm x 8 mm	8 mm x 10 mm
	Wire Coating	95 % Zn – 5 % Al alloy (+ polymeric coating if needed)	
REINFORCED GEOMAT	Tensile Strength ASTM D4595	37 kN/m	50 kN/m
	Nominal Thickness ASTM D6525	12 mm	

Additionally, double-twist steel wire mesh reinforcement helps establish TRM continuity during the installation, the edges of the adjacent steel meshes can be joined without any overlapping (see Figure 4). It also facilitates the connection of the product to other structures along or at the bottom of the slope, improving anchorage and protection where stresses are concentrated, and erosion is usually more critical.

Hence, geomats with double-twist steel wire mesh reinforcement have a wide spectrum of applications: from regular soil slopes (2:1 or less) to very steep ones (more than 1:1), from lining of irrigation channels to riverbanks protection. In addition, steel reinforced geomats can be used in rockfall mitigation systems and in combination with soil nails.

Three case studies are now presented, each one for a different application of double-twist steel wire mesh reinforced geomat.

Figure 2. Geomat with DTWM reinforcement on a steep soil slope before and after the establishment of vegetation

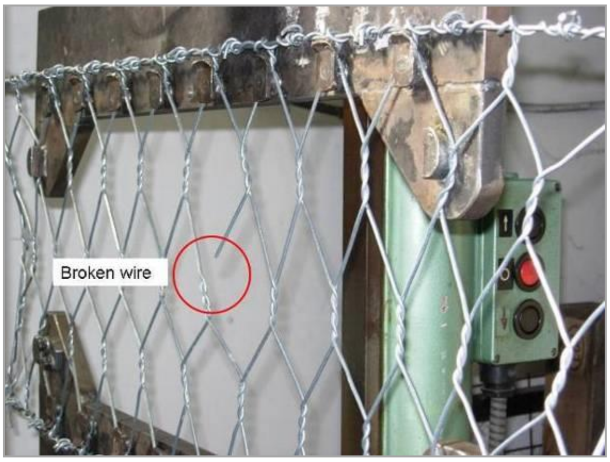

Figure 3. Unravelling effect of the woven mesh

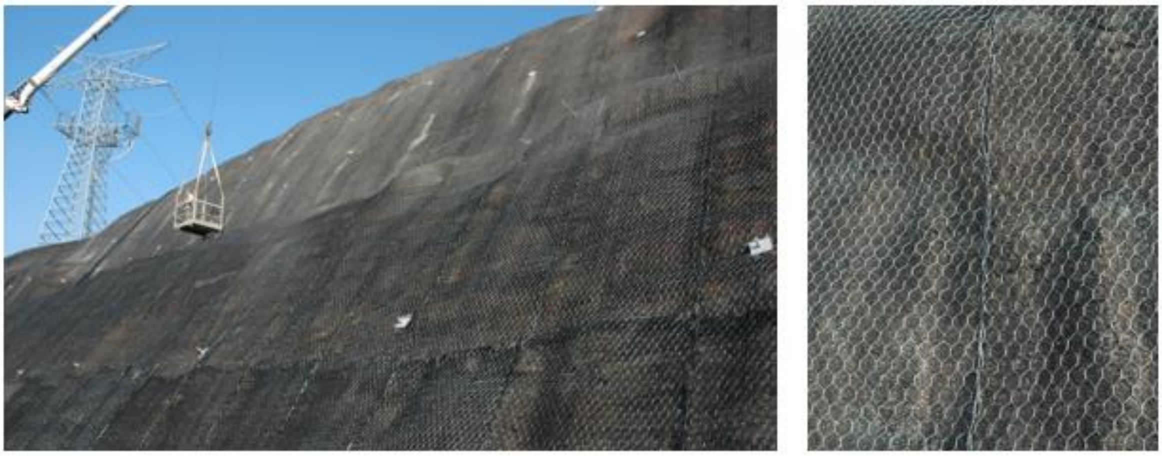

Figure 4. Installation of geomat with DTWM adjacent rolls and detail of connection without overlapping.

2. SLOPE STABILIZATION IN ANAHEIM, CALIFORNIA

Soil nailing is a widely used technique to reinforce and strengthen steep slopes and consists of inserting reinforcing bars directly into the ground at optimal inclinations. In soil nailing applications, the facing element is often required to provide both tensile strength and erosion control. Shotcrete is commonly used to accomplish these tasks. However, shotcrete stabilized slopes are rigid, and require the installation of a proper drainage system to prevent the build-up of pore water pressures behind the slope. Geomats with double-twist steel wire mesh reinforcement not only meet the erosion control and tensile strength requirements for slope stabilization, but are also flexible, permeable, and very easy to install. This system can be installed in just a one-time application, cutting down installation time and associated installation costs. This is very important because soil nailing for slope stabilization is often used to protect infrastructure like highways and roads. It is difficult and costly to temporarily close a single lane or an entire road, especially due to the high costs and economic impact associated with traffic control and road closures.

A double twist wire mesh geomat solution was installed adjacent to North Santiago Boulevard, in Anaheim, California. North Santiago Boulevard is a major expressway linking several residential and commercial developments. At the intersection with E. Nohl Ranch Rd, there was a steeply cut slope that was highly erodible and prone to frequent mud slides. Previously, the slope had been covered with different light weight erosion control blankets, yet erosion was still actively occurring. The designer selected a soil nailing application in combination with the geomat with woven steel wire mesh reinforcement to stabilize the face of the slope. A network of 3-meter-long soil nails was grouted into 80 mm diameter drill holes and organized into an array with 2 m vertical and horizontal spacing. It was possible to apply hydromulch and hydroseeding, as shown in Figure 5, on top of the geomat with DTWM, thanks to its permeable characteristics, to enhance and facilitate vegetation growth on the slope.

Figure 5. Soil Nailing system with DTWM reinforced geomat and hydromulch before growth of vegetation.

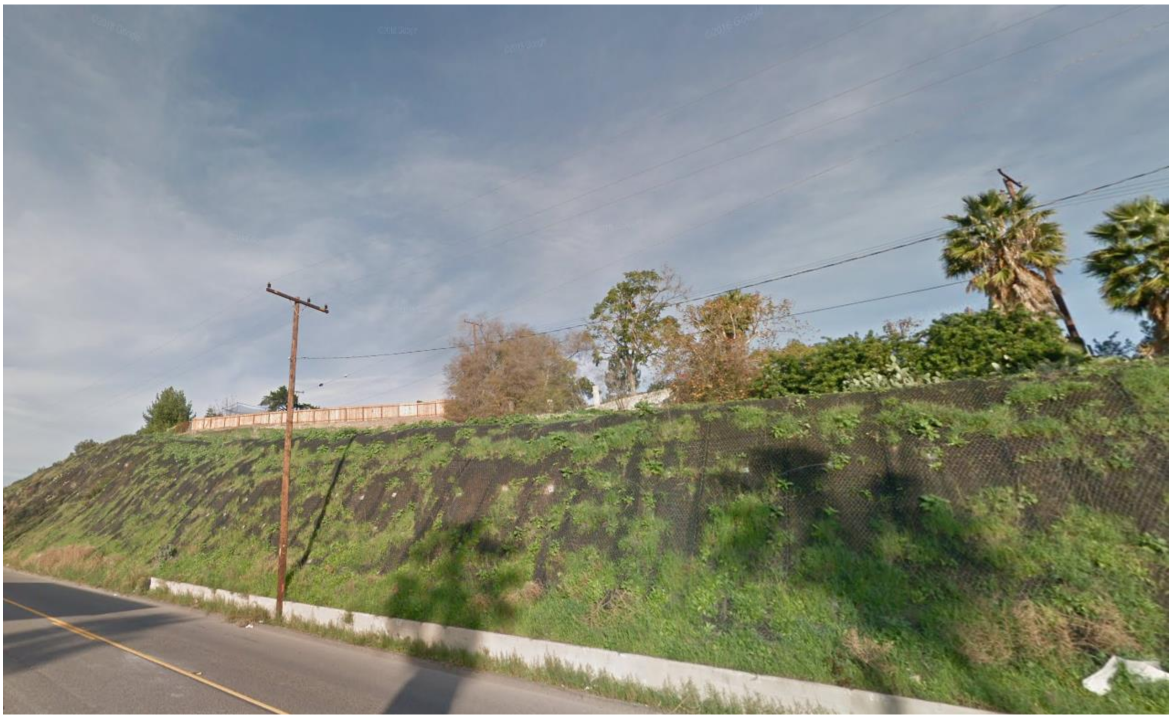

Figure 6. Soil Nailing system with DTWM reinforced geomat and hydromulch after growth of vegetation

3. CULVERT AND CHANNEL PROTECTION IN FORT WORTH, TEXAS

Geomats with woven steel wire mesh reinforcement are also used to line the banks of canals and rivers and protect them from erosion due to flowing water. The geomat with DTWM reinforcement creates a protective layer which increases the shear strength of the soil on the surface of banks while reducing the velocity of flow at the banks of the channel section. This type of geomat is a permanent solution that can resist up to 2.5 - 3 m/s flow velocities, depending on the geomat thickness and the flood duration. The strength of the woven steel wire mesh reduces the 'uplifting' of the geomat when exposed to aggressive hydraulic flows. Stresses generated at the geomat anchor points are dissipated by the reinforcing mesh.

Figure 7. Installation of DTWM reinforced geomat on steep creek banks and connected to gabions.

Figure 8. Vegetation growing on the DTWM reinforced geomat.

A geomat with DTWM reinforcement was installed on a creek bank in Fort Worth, Texas, to reduce erosion along the slopes (Figures 7 and 8). The development of a new residential neighborhood caused the waterproofing of a large area, and therefore caused the formation of significant storm water runoff during heavy rainfall events. The nearby creek was having severe erosion problems due to the excessive runoff. Steel wire mesh reinforced geomat was installed on the creek banks, in combination with gabions directly outside the newly constructed box culvert. The selected geomat had a double twist steel wire mesh with a combined metallic and polymeric coating to ensure long-term corrosion and abrasion resistance. A trench was prepared to provide anchoring at the top of the slope, and threaded steel bars with plates were used to fix the geomat to the slope. The geomat then was fixed to the gabions at the bottom of the creek for improved stability and anchoring, leading to optimal protection in the weakest part of the section, where scour was previously occurring.

4. ROCKFALL MITIGATION AND SLOPE STABILIZATION CLOSE TO QUITO, ECUADOR

Double-twist wire mesh is widely used for small rockfall events mitigation (rock diameter up to 0.6 m). When a slope is made of a mix of fine soil particles and small rocks, it is not only important to contain the rocks from falling, but it is also necessary to control the erosion process caused by rainfall and wind impacts. Generally, in these types of slopes, erosion is the real triggering factor for the rockfall event, so it is fundamental to mitigate the erosion process to prevent the risk of rocks falling. As already mentioned, the geomat with double twist steel wire mesh reinforcement combines both erosion protection and rockfall mitigation, so it can be applied on the slopes previously described.

An example of this application is in Ecuador. After a magnitude 5.1 earthquake struck the Ecuadorian province of Pichincha, between the capital, Quito and Guayllabamba, landslides made some roads unserviceable. With the epicenter in the immediate vicinity and the risk of further landslides, the Ministry of Transportation and Public Works closed the roads to allow slope stabilization work to be carried out. The cause of the landslides was attributed to the soils weakened by erosion from wind, water, and the earthquake. A geomat with double twist steel wire mesh reinforcement was selected to prevent soil loss and occasional larger rocks (up to 250 mm diameter) from falling from the slope (see Figure 9). The use of a flexible and permeable system also enabled the slope to revegetate, and additionally, provide root reinforcement to the vegetation.

Figure 9. Installation of a geomat with DTWM reinforcement on a rocky slope.

5. CONCLUSIONS

Geosynthetics for erosion control are very versatile products that can be easily installed on slopes, providing immediate protection to bare soils. Among the geosynthetics for erosion control, geomats with double-twist wire mesh reinforcement are one of the most resistant erosion protection products. These reinforced geomats have a higher tensile strength and shear resistance, compared to non-reinforced geomats, but they can still maintain their flexibility. In addition, the presence of the steel reinforcement guarantees long-term durability and performance even in critical conditions. These systems can perform on high and steep slopes, where vegetation doesn't have the possibility to establish uniformly, and on river or channel banks with high flow velocities and shear stresses. These steel wire mesh reinforced geomats can also perform on steep slopes made of a mix of fine soil particles and small to medium size rocks. The combination of a geomat and a woven steel wire mesh is also environmentally friendly, since vegetation can grow through the system either naturally or with the help of hydroseeding. When the vegetation is established, the roots anchor the geomat to the slope, and the steel mesh provides a stronger protection capable of handling steeper slopes and higher run-off flow velocities. Furthermore, the case studies presented in this paper show that the installation of the system is easy and fast, in just one-time the geomat and the double-twist wire mesh can be applied on the slope, thus cutting installation time and labor costs, while also improving the safety conditions of the workers.

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