

Applications of Volumetric Erosion Control Geocomposites

O. Ansa & J. Castelo

Intermas Nets, Barcelona, Spain

ABSTRACT: Rain, snow, surface runoff and wind are the main causes for the erosion of soils. This erosive process is responsible in a first stage for aesthetical problems (streams and gullies) which may lead to slope stability issues and surface detachments. The most effective way that exists to avoid erosion is to ensure the presence of vegetation but, in numerous occasions, erosion removes the first vegetal shoots preventing the growth of their roots and impeding their fixation to the soil. The main function of erosion control geosynthetics is to avoid the early erosive stages allowing the adequate growth of the vegetation. This article will expose the main characteristics of volumetric erosion control geocomposites, explain the vital importance of a good design and execution of the substratum projection, overview the installation process and, finally, real applications of these products will be presented.

1 INTRODUCTION

For a long time erosion has been considered a secondary problem in civil works. It is in the recent years when, due to the increasing awareness and the respect to the environment, this matter is gaining protagonism. Erosion control is a tool to ensure the vegetation of areas affected by the anthropic action.

One of the most common mistakes in erosion control is to confuse the erosive process with a surface landslide. To clarify the difference between one and the other we shall begin defining each one of them as follows:

Erosion (Figure 1) is the degradation and transport of material or soil substrate through a dynamic agent such as water, wind, ice or temperature. It may affect either soils or rocks and it implies movement, that is to say, transport of grains or particles but not the disaggregation of rocks, phenomenon known as weathering (Tarbuck & Lutgens, 2005).

A landslide is a geological phenomenon which implies instability of a slope that causes ground movement (shallow or deep failures). This occurs when a large mass of soil becomes unstable and slides or overturns over a stable area.

This article aims to deal only with the erosive process. It is important to recall that erosion control products are not meant to avoid landslides.

Erosive processes are usually rapid and sometimes impede the development of vegetation because roots do not have time to grow enough to fix vegetation to the soil.

This causes not only aesthetical issues, but can also favor future problems such as deeper instabilities in slopes, problems in ditch maintenance by clogging superficial drainage systems, etc.

The most effective way that exists to avoid erosion is to ensure the presence of vegetation which, through its roots, stabilizes the surface of the soil. But in numerous occasions, erosion removes the first vegetal shoots preventing the growth of their roots and impeding their fixation to the soil which would allow the anti-erosive process to begin.

The role of erosion control products is, in fact, to extend the permanence of seeds on the slope until roots have deepened enough to be able to fully grow vegetation which will serve thereafter as the best stabilizer of the slope.



Figure 1 Erosive process in a slope

2 EROSION CONTROL PRODUCTS

There are currently numerous erosion control products available in the market. This diversity is the result of the development of products to accommodate different needs. Depending on the geometric and geotechnical characteristics of the slope, its location, etc. the requirements of the product can be very different. Sometimes we can even find a combination of several types of products in the same jobsite.

Broadly speaking, we may highlight the following erosion control products:

Biodegradable organic products (Figure 2a): depending on their structure they are referred as organic mats (grid structure) or organic blankets. They can be made out of different organic components, being the most common coconut fibers and jute.

Blankets are often used on slopes with low inclinations with lack of organic matter. Blankets retain moisture and serve as substrate that favor the growth of vegetation in the initial stages, as well as protect slopes from erosion.

Mats, on the other hand, due to their open structure, serve the role of retaining seeds and enabling their implantation directly on the natural substrate of the soil.

These are biodegradable products which makes them very interesting for those applications that are temporary or in which the product must “disappear” after a relatively short period of time.

However, there are occasions in which neither can be used due to their low tensile resistance. When large loads are imposed (steep and long slopes) organic products may break or slide leaving the slope exposed again without being able to accomplish their role. In such cases, as an alternative element, geosynthetic products with greater tensile resistance may be used.

Monofilaments (Figure 2b): usually formed through polypropylene filaments. Their tangled structure retains topsoil and seeds, avoiding erosion and allowing roots to grow through them until they reach the slope. They may be combined with geogrids to increase their tensile resistance.

Geocells (Figure 2c): this system differs from others due to its capacity of confinement. The cellular structure of geocells and the height of their walls allow confinements of over 10 cm of topsoil, gravel or sand on slopes steeper than the internal angle of friction of these materials. Some structures also allow water flow through their walls which increases their drainage capacity.

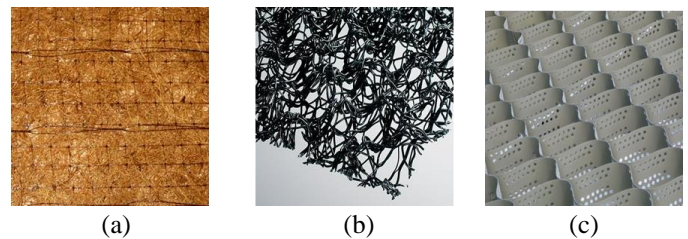


Figure 2 Erosion control products: (a) Organic biodegradable products; (b) Monofilaments; (c) Geocells

Last but not least, we may find volumetric erosion control geocomposites (Figure 3). This article, as previously indicated, will focus on these products in the upcoming sections.

3 VOLUMETRIC EROSION CONTROL GEOCOMPOSITES

The main characteristic of volumetric erosion control geocomposites is its unique configuration based in a geometry formed by continuous horizontal “waves”. These products morphology confers the property of being magnificent retainers of substratum projections and hydroseedings.

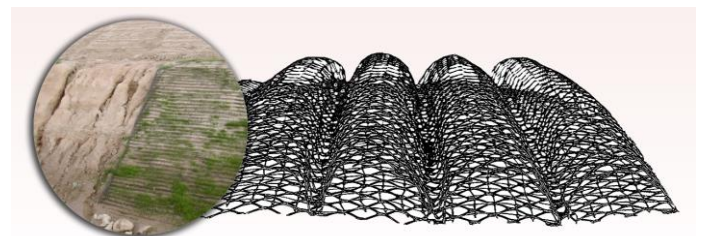


Figure 3 Volumetric erosion control geocomposite

Their structure is formed by three layers, two exterior rhombic grids and a central square grid. The upper external rhombic grid creates undulations, around 2,5 cm high, that will act as the particle retainer. The lower rhombic external grid allows the product to adapt to the varying geometry of the slope.

On the other hand, the central square grid is meant to provide an adequate tensile resistance to the geocomposite and it can be made out of polypropylene or high tenacity polyester up to very large tensile resistances.

It is very important to ensure the continuity of the horizontal undulations through the whole surface in order to avoid the appearance of vertical channels that serve as preferred flow zones that could cause the washing of the organic material that we intend to reduce with the installation of an erosion control product.

On the other hand, experience indicates that, the height of this “waves” is the adequate to favor the growth of the roots and their later fixation to the slope. However, besides experience, it is important to have a technical background in these applications that validates their use. The following section will deal with these calculations.

4 DESIGN AND CALCULATIONS FOR EROSION CONTROL PRODUCTS

There are two main types of calculations that must be addressed when a volumetric erosion control mat or any other erosion control product is prescribed: mechanical equilibrium and soil erosion.

4.1 Mechanical equilibrium

Mechanical equilibrium calculations deal with the stability of the product against sliding. The required tensile strength of the product and the dimensions of the anchor trench are defined with these calculations taking into account the geometry of the slope and the design loads.

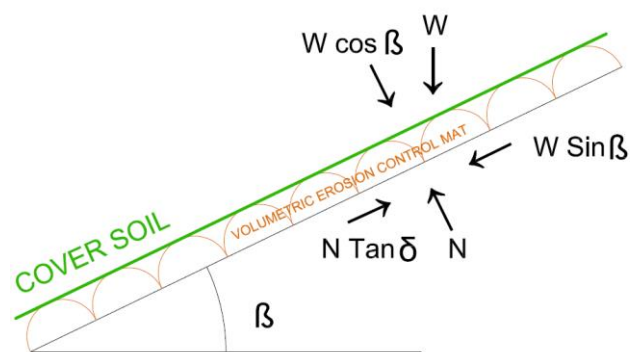


Figure 4 Limit equilibrium forces involved in an infinite slope analysis for a uniformly thick cohesionless cover soil

The potential failure surface for veneer cover soils is usually a linear cover soil sliding with respect to the lowest interface friction layer in the cross-section (Koerner & Soong, 2005). The calculation of the global factor of safety against sliding can be addressed with the classical limit equilibrium concepts,

considering the free body diagram of an infinitely long slope with a uniformly thick cover soil and comparing the resisting forces with the driving or mobilizing forces (Figure 4).

As an example, we may find the global factor of safety for sliding for an unreinforced erosion control mat (Equation 1), considering that δ is the worst interface friction angle between the erosion control mat and the cover soil or the existing soil in the slope and β is the angle of the slope.

$$FS = \frac{\sum \text{Resisting forces}}{\sum \text{Driving forces}} = \frac{\tan \delta}{\tan \beta} \quad (1)$$

The same approach can be easily developed for other loading and reinforcement requirements in order to be able to design volumetric erosion control mats.

4.2 Soil erosion

Soil erosion is, indeed, a key point to study for a volumetric erosion control mat as this is the main purpose for its installation. There are two different approaches for these calculations depending on the application: soil erosion in earthen channels and soil erosion in slopes.

When water flows in an earthen channel, water imposes shear stresses on the sides and bottom of the canal that cause soil loss, thus erosion. Volumetric erosion control mats allow higher shear stresses than natural soils and are installed to improve the growth of vegetation and avoid soil loss or reduce it to an acceptable limit (Figure 5).

Due to this fact, the first important thing to evaluate when we want to use an erosion control mat in a canal is the maximum shear stress (or tractive force) that the product can resist with an adequate loss of soil. This value is product dependent and is obtained according to standard ASTM D 6460 which considers a maximum allowable soil loss of 0,5 inches.

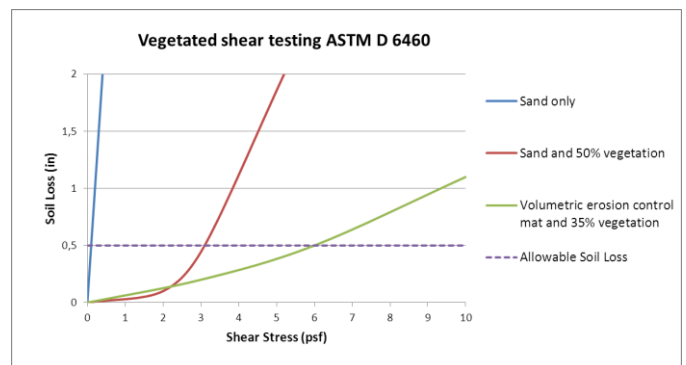


Figure 5 Conceptual comparison of soil loss according to ASTM D 6460

Once we know this value we can calculate the permissible velocity in our channel (Chen & Cotton, 1988) such that, if the real velocity in the channel is

equal or lower to this permissible velocity, soil loss will be equal or lower to 0,50 inches (Equation 2).

$$V_p = \frac{1}{n} \cdot \sqrt{\frac{R \tau_p}{\gamma \cdot d}} \quad (2)$$

Where, V_p is the permissible velocity, R is the hydraulic radius, τ_p is the permissible shear stress (obtained through ASTM D 6460), n is Manning's roughness coefficient, γ is the unit weight of water and d is the maximum depth of flow in the channel for the design discharge.

The real velocity and depth of flow in the channel can be calculated with the well-known Manning formula.

On the other hand, soil erosion calculations in slopes differ greatly from calculations in canals. In slopes, the erosion process is estimated through an empirical model called the Universal Soil Loss Equation (USLE) that was developed by the United States Department of Agriculture at the National Runoff and Soil Loss Data Center in Purdue University (Wischmeier & Smith, 1978).

The USLE (Equation 3) provides a quick approach to estimating the long-term average annual soil loss (A) with the use of six factors: the rainfall and runoff factor (R), the soil erodibility factor (K), the slope length factor (L), the slope steepness factor (S), the cover and management factor (C) and the support practice factor (P).

$$A = R \cdot K \cdot L \cdot S \cdot C \cdot P \quad (3)$$

All these factors are described in detail by Wischmeier and Smith for natural soils but when an erosion control mat is used the product must be tested according to ASTM D 6459 to find its unique C factor at different rain intensities.

Once this C factor is determined, the USLE can be used to compare the expected soil loss with and without the erosion control protection and decide whether the product is adequate or not.

5 INSTALLATION GUIDELINES

The installation process for these geocomposites is quite straightforward, but their success depends directly in its adequate performance.

The first step to follow is the preparation of the slope. All important bumps and cavities must be eliminated in order to achieve a homogeneous surface such that, when the volumetric erosion control geocomposite is laid, it is in contact with the ground throughout its whole surface

After the slope regularization, prior to the installation of the product, an anchor trench must be executed at the top of the slope according to the design's dimensions and geometry (Figure 6). Sometimes an anchor trench is also required in the bottom of the slope.



Figure 6 Excavation of the anchor trench

It is necessary to allow a 10 cm longitudinal overlap (Figure 7) to ensure that the whole surface of the slope is perfectly covered. The product may then be fixed to the slope with the aid of steel staples or stakes. The amount of staples to install per square meter and their depth varies depending on the application and the slope's characteristics.



Figure 7 Product deployment and longitudinal overlaps

Once the product is installed, proceed to backfill the anchor trench to ensure a proper anchorage (Figure 8).

Finally, it is advised to hydroseed (Figure 9). This procedure will help to create a first fast growing layer of vegetation which will permanently stabilize the system when grown.



Figure 8 Installation process: Ensuring a proper anchorage



Figure 9 Hydroseeding

6 VEGETATION. HYDROSEEDING

There are several procedures to vegetate a slope, although hydroseeding is the most widespread due to its speed, possibility to reach inaccessible areas for machinery and its magnificent results.

However, these results depend greatly in the correct choice of hydroseeding, that is to say, of the election of its components, at which period of the year it is performed and of a former humidity control of the slope to favor the germination of seeds.

In those cases in which the natural soil is not fertile enough for the vegetation to take roots, a substrate projection will be needed prior to hydroseeding.

As stated previously, volumetric erosion control geocomposites allow, due to their unique height of 2,5 cm, a better grip of the hydroseed to the slope and in many cases, if they were not present, hydroseeding would be washed out by the first rain (Figure 10). Added to this fact, they minimize the rebound of the projection, maintaining most of the hydroseeding retained in their structure.

Generally speaking, hydroseeding is composed by a mixture of seeds, mulch, additives, fertilizers, stabilizers, etc. and, of course, by water. Standard compositions for hydroseeding and substratum are:

Hydroseeding:

- 125 g/m² of wooden or short fiber mulch
- 15 g/m² of organic stabilizer
- 40 g/m² of slow release fertilizer
- 15 cm³/m² of humic acids
- 35 g/m² of vegetation seeds

Substratum:

- 25 l/m² of substratum
- 230 g/m² of wooden or short fiber mulch
- 125 g/m² of stabilizer
- 40 g/m² of mineral fertilizer
- Apply 2 to 4 times



Figure 10 Slope with and without volumetric erosion control geocomposite

The most adequate seasons to perform a hydroseeding are autumn and spring. Other seasons will reduce success possibilities.

Seeds must be selected according to the location and orientation of the slope being important to select native species which will be most likely to succeed than foreign species. The use of fast growing species that cover a large percentage of the area will ensure a better short-term erosion control that will allow the fixation of other slower growing species with deeper roots that will finally stabilize the whole system in the long-term.

7 REAL APPLICATIONS OF VOLUMETRIC EROSION CONTROL GEOCOMPOSITES

7.1 Papua New Guinea

Aiming to minimize the effects of mining on the environment, the owner of the mine is implementing a

comprehensive management plan in the Hidden Valley mine which is based on the best practices in the world.

Within the actions of this management plan, the vegetation of the environment plays a very important role. Due to the large, steep slopes and heavy rains present during the whole year it has been necessary to install a volumetric erosion control geocomposite to control soil loss and the correct establishment of vegetation. Over 40.000 m² of product were installed (Figure 11).



Figure 11 General view of the volumetric erosion control geocomposite installed in one of the covered areas

To ensure the success of full soil vegetation and due to the special value that the area of rehabilitation deserved, most of the species planted on the slope where native, limiting the use of a large variety of local varieties.

7.2 Belgium

In 2007, 18.000 m² of volumetric erosion control geocomposite were used to vegetate the slopes of several canals and a reservoir in Belgium (Figure 12).



Figure 12 Reservoir with volumetric erosion control product

The required slope inclinations and the possibility that the water level could reach the slopes in the usual operational levels, warned designers about the need of studying the erosion problem. It was decided

to ensure the correct vegetation of the slopes by using volumetric geocomposites.

Due to the easy access to the slopes with machinery, there was no need of substratum projection. Topsoil was directly installed over the product (Figure 13).



Figure 13 Laying of the topsoil on top of the geocomposites in one of the canals

7.3 Spain

A volumetric erosion control geocomposite was used in Alzira, (Valencia) to vegetate the slopes of several canals (Figure 14).



Figure 14. Slopes covered with the volumetric erosion control geocomposite

One of the key characteristics of this region of Spain is the rain regime, which is usually torrential. This means that these canals are almost empty during most part of the year but they may reach high water levels with high velocities during a rainstorm.

In this application the geocomposite was installed in the whole surface of the channel because it was needed to protect slopes against erosion after storms.

After the installation a correct hydroseeding allowed to achieve the expected results (Figure 15).



Figure 15 Fully vegetated channels

8 CONCLUSIONS

Erosion alters slopes depending on their orientation, location, geology and the environmental conditions they are subjected to. It is important to understand the erosive process and the jobsite requirements in order to be able to select the most adequate product for each application.

Volumetric erosion control geocomposites, due to their undulated configuration and their high tensile strength are specially indicated in steep and long slopes. Thorough calculations must be followed to design the required tensile resistance that ensures the short-term and long-term stability of the system. In those cases in which there is perpendicular water flow, such as is the case of channels, specific calculations and tests must be considered. All these technical calculations should be followed regardless of the type of product selected to ensure the quality and performance of the project.



Figura16 Fully vegetated soil with volumetric erosion control geocomposite

achieve the expected results with special regards to hydroseeding (Figure 16).

The unique geometry of volumetric erosion control geocomposites favors the retention of hydroseeding and seed germination inside the undulations, allowing roots to grow and reach the slope, stabilizing thereafter its surface.

REFERENCES

- ASTM D6459, 2011. Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Hillslopes from Rainfall-Induced Erosion
- ASTM D6460, 2007 Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Earthen Channels from Stormwater-Induced Erosion
- Chen, Y.H. and Cotton, G.K., 1988. Design of Roadside Channels with Flexible Linings. United States Department of Transport, Federal Highway Administration, Hydraulic Engineering Circular. Number 15.
- Koerner, R. M. and Soong, T. Y., 2005. Analysis and design of veneer cover soils. Geosynthetics International, Special Issue on the Giroud Lectures, 12, No. 1, 28-49.
- Tarbut, E. J. & Lutgens, F. K. 2005. Ciencias de la Tierra, 8ª edición. Pearson Educación S. A., Madrid.
- Wischmeier, W. H. and Smith, D. D., 1978. Predicting rainfall erosion losses. A guide to conservation planning. Agriculture handbook number 537. United States Department of Agriculture.

Besides the importance of a correct design, the installation procedure of the product is vital in order to