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Terramesh: Solutions for great heights. Design and durability

Terramesh: Solutions pour de grandes hauteurs. Conception et durabilité

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ABSTRACT: A wide variety of construction systems to execute reinforced ground structures exist. Reinforced soil structures consist of improving the properties of the soil by installing reinforcement with metal strips or synthetic mesh, with the aim of providing tensile strength. The implementation of geogrids in the market is a competitive alternative with the added value of environmental sustainability. The geogrids work as a reinforcement element for each layer, distributing the efforts and generating friction due to the soil-reinforcement interaction, in such a way that the friction angle of the ground increases. Consequently, it is possible to use as structural material, tolerable soils with low mechanical properties, thus avoiding the transport of material and making its use viable. In 1979, the first officially executed structure with the combination of gabions and mechanically reinforced soil was built. At the time, a 14-meter structure was verticalized and as these results were extremely satisfactory, the solution was used again in other applications. From this work, the evaluation studies of the use of the double torsion hexagonal mesh as a reinforcement element in private and international laboratories resulted in the creation of the Terramesh System. This type of structure replaces the classic concrete structures which reduces the environmental impact. The mechanical and environmental characteristics are certified in accordance with international institutions and standards that include the CE mark. In this presentation, we want to demonstrate the main criteria, advantages, and durability of the Terramesh systems that have been studied in recent years.

RÉSUMÉ: Il existe une grande variété de systèmes de construction pour réaliser des structures de sol renforcé. Les structures de sol renforcé consistent à améliorer les propriétés du sol en installant un renforcement avec des bandes métalliques ou un treillis synthétique dans le but de fournir une résistance à la traction. L'introduction de géogrilles sur le marché constitue une alternative compétitive avec une valeur ajoutée en termes de durabilité environnementale. Les géogrilles agissent comme un élément de renforcement pour chaque couche, répartissant les efforts et générant des frottements dus à l'interaction entre le sol et le renforcement, de telle sorte que l'angle de frottement du sol augmente. Par conséquent, il est possible d'utiliser des sols tolérables ayant de faibles propriétés mécaniques en tant que matériau structural, ce qui évite le transport de matériau et rend son utilisation viable. En 1979, la première structure officiellement réalisée avec la combinaison de gabions et de sol mécaniquement renforcé a été construite. À l'époque, une structure de 14 mètres a été verticalisée, et comme ces résultats étaient extrêmement satisfaisants, la solution a été réutilisée dans d'autres applications. A partir de ce travail, les études d'évaluation de l'utilisation du treillis hexagonal double torsion comme élément de renforcement dans des laboratoires privés et internationaux ont abouti à la création du Système Terramesh. Ce type de structure remplace les structures classiques en béton ce qui réduit l'impact environnemental. Les caractéristiques mécaniques et environnementales sont certifiées conformément aux institutions internationales et aux normes qui incluent la marque CE. Dans cette présentation, nous souhaitons démontrer les principaux critères, avantages et durabilité des systèmes Terramesh qui ont été étudiés au cours des dernières années.

Keywords: Soil reinforced; durability; ecological; CE mark; software design.

1 INTRODUCTION

There are several established construction systems to execute reinforced soil slope (RSS) due to the economic advantages over conventional retaining walls (Hatami, et al., 2001). The range of products offered as reinforcing material has expanded over the years. There are materials for soil reinforcement: steel and geosynthetics as geogrids. The suitable design RSS involves understanding the different responses of the reinforcement under load. The geosynthetics are characterized by having a time-load sensitive response because of the creep effect, and instead, the steel has a constant rigid elastoplastic response.

The hybrid reinforcement consists of a combination of steel wire mesh and geogrids, where the steel component provides a function as secondary reinforcement (modular ready-to-use facing units) and the geogrids provide the primary reinforcement functions. After making a preliminary numerical approach applying mixed reinforcement configurations, the results indicate a response under

load resembling a theoretical uniform reinforcement pattern (Vicari, 2009). Additionally, significant progress has been achieved with the development of the numerical simulations which showed that a hybrid reinforcement scheme appears to be a more effective reinforcement arrangement (Vicari, 2009). These outcomes indicated that a smaller gap between the reinforcement layers is a suitable setting to minimize facing deformation (Vicari, 2009). Thus, the same results are not achieved using stiffer reinforcement layers at greater distances.

1.1 Background

The Terramesh System was designed based on the principle of reinforced soil system developed in the early 1960s, where steel ties were used as reinforcement. The first officially executed structure was built in Sabah (Malaysia) in 1979 which was a design ahead of its time (Egoavil, 2011). This consisted of building a gabion-facing anchored to the embankment by inserting stainless-steel strips. Over the years there has been an evolution in the structural design replacing the stainless-steel strips by double-twist woven steel wire mesh panels. In this way, continuous and longitudinal reinforcement is achieved with high interlocking forces involved.

The experience acquired since this first construction promoted broader studies in this area, encouraging the simplification of placement phases on site. The findings have led to the design of the hybrid RSS from the combination of steel wire mesh and geogrids.

1.2 Description of Terramesh Solutions

The hybrid RSS is composed of a front facing element of the Terramesh family, geogrids, the drainage system, and the material fill. The Terramesh family involves three options of front facings: Terramesh, Green, and Mineral Terramesh. The first type can provide a mechanically stabilized earth wall with a gabion lining finish. Another option for a stone finish is the Mineral Terramesh, which are factory-pre-assembled units with inclined surfaces filled with stone. In contrast, the Terramesh Green is an environmentally friendly modular system with a surface vegetation finish (green). Perspective views of each type of modular system is shown in Figure 1. However, this paper focuses only on structures with gabion facings, whose units are formed by creating the rectangular-shaped cells used to contain the stones.

Figure 1. Elements of Terramesh Solutions.

The Terramesh units are 3.0 (W) x 3.0m (L) x 1.0m (H) as indicated in Figure 2. The cladding section is formed by connecting a back panel and diaphragms to the main front panel, thus creating the rectangular-shaped cell used to contain the stones. It is worth highlighting that these units are filled with rock varying in size between 15cm and 20cm properly graded to provide a high packing density. The gabion front facing does not comply with a structural function within the RSS because its main function is cladding and erosion control of the facing. To stabilize the facing, a wire mesh tail with a length of 3m is required, and the geogrids spacing should not exceed 2m.

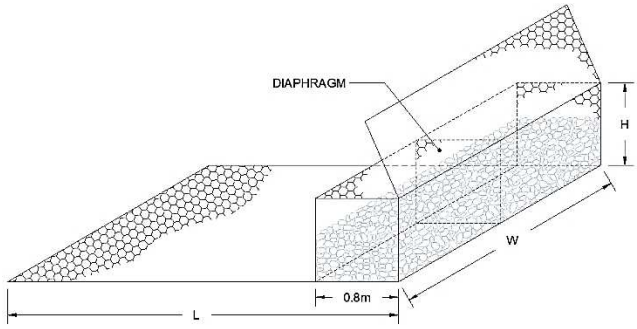

Figure 2. Typical Terramesh Dimensions.

In general terms, the main advantage of the RSS is the economic affordability compared to most of the classic concrete wall solutions. In addition, using gabion lining has the benefit of ensuring soil drainage on the front face. For this reason, the cladding is not subject to the actions of hydrostatic forces. Reducing emissions derived from the transportation of materials represents a distinctive characteristic of being environmentally friendly.

2 CERTIFIED QUALITY

The design process of the Terramesh solution is based on test campaigns and investment in performance evaluation. Different trials were carried out to define the strength and anchoring features of the double twisted hexagonal steel mesh and the structural behavior of the Terramesh System. Mesh testing took place at Universidad New South Wales (1990), STS Consultant Lab. (1989), and Bathurst Clarabut

Geotechnical Testing Inc. (2001) (Egoavil, 2011). The assessment of the mesh consists of its deformation modulus behavior that varies if the mesh is in the air or confined. According to the results, the mesh in air stretches to close transversally and elongates longitudinally resulting in high deformation (or low deformation modulus); while the mesh in contact with soil prevents the starching (Zannoni, et al., 2011).

Besides, trials developed in real structures were carried out in cooperation with laboratories and universities (Ghionna, et al., 2002), where two aspects were examined: the pull-out and the strength of the mesh. The structural analysis needs an overall evaluation of the reinforcement system. Considering that the double-twisted hexagonal wire mesh behaves elastically instead, the geogrid reinforcement is influenced by viscous deformation.

The efforts in the field of research have resulted in an assembly of quality certifications such as BBA, and the CE mark. Those certifications with international institutions and standards evidence the quality management checks and production inspections. It is also committed to following the International EPD System to communicate environmental characteristics transparently and comparably.

2.1 Durability

Durability depends not only on the manufacturing process but also on the technical characteristics of the materials used. The wire complies with the strictest international standards (EN 10218-2, ASTM A 641), moreover, the protection revetments selected to provide optimum durability for up to 120 years. The steel wire is coated with an alloy of Zn95-Al5 to protect against corrosion and it in addition to the galvanization, it is coated with an innovative polymer. It is therefore a highly abrasion and UV-resistant coating, which protects the steel wire mesh underneath against ever more severe environmental and mechanical effects.

The aggressiveness of the environment depends on the location construction site because the degree of corrosion is associated with the exposure time to humidity combined with other factors such as temperature, atmosphere chemical composition, and the nature of the material. The effect of atmospheric corrosion and abrasion are assessed as the major risks that affect the service life of metal structures. Currently, the standard establishes a relation between the type of galvanization, the coating, and the estimated service life, based on the accelerated artificial aging test of the official regulations.

3 DESIGN TOOLS

In the field of geotechnical engineering, the analysis of stability and safety is essential for the design of reinforced soil for different applications. For the design of slopes and retaining structures, computational tools are used to evaluate the behavior of different types of soil reinforcement and the evaluation of their performance in terms of stability.

The software for the RSS with Terramesh is based on the Limit Equilibrium Method with the possibility to introduce the mechanical characteristics of synthetic or metallic reinforcements and define the regulations. Stability checks are carried out with references to the geometry, soil typologies, and the hydraulic characteristics of the site. Therefore, the initial phase of the design aims to achieve the RSS sketch and then it could be analyzed with FEM to interpret deformations.

The accurate choice of reinforcement material from a deformation point of view is essential to not compromise the serviceability limit of the structure (Zannoni, et al., 2011). Therefore, the evaluation of performances in the short- and long-term including safety factors, can provide the difference between an effective design and an overdesign. The reinforced soil deformations can be vertical or horizontal, where the vertical movements are attributed to soil behavior and the horizontal ones occur due to the facing or the reinforcement (Zannoni, et al., 2011). The design parameters to characterize the reinforcement material are configured for the end of the service life of the structure. In the short term, deformations develop during the construction phase, where the soil deforms until the equilibrium between soil and reinforcement is achieved (Zannoni, et al., 2011). The steel reinforcement of the Terramesh is only evaluated in the short-term deformations because steel does not present creep phenomena as does geosynthetics. After the soil consolidation process, the deformations are associated with viscous behavior which is partially offset by the effective performance of geosynthetic.

Regarding the introduction of Building Information Modeling, all the objects and libraries were created. In the case of complex projects, the project management will improve by integrating all the construction processes, thus avoiding interferences and errors on site. Inside each object, there is a large amount of information available such as quality certifications and technical data sheets.

4 CONCLUSIONS

The Terramesh System is a technically and cost-effective solution for the construction of reinforced

soil structures. The design of the pre-assembled units with gabion facing was focused on test campaigns and investments in performance evaluation of the solution. Additionally, research suggests that the best reinforcement assembly is the hybrid combining the geogrids as the primary reinforcement and steel wire mesh as the second one.

In addition, the technical design of RSS is supported by software with good modeling capabilities using limit equilibrium. The analysis considers the quality and technical characteristics of the materials to provide optimum durability for up to 120 years. To ensure the stability of the structure the software incorporates the majority of international regulations. Finally, it is encouraged in further research focused on the monitoring of strength and deformation reinforcements in the long-term using remote sensors.

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