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Use of HDPE geocells to replace rip rap and reinforced concrete in superficial drainage structures in Photovoltaic Power Stations.

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ABSTRACT
Currently, our society is showing a strong preference for the use of renewable energy sources due to its benefits in terms of contamination and generation of toxic gases or waste emitted to the environment, when compared to conventional sources of electricity generation. In Brazil and in the world, one of the most common is solar energy, converted into electricity on farms that group a large number of photovoltaic panels. The choice of the appropriate place for the implantation of these farms considers, among the requirements, places with high index of insolation, low humidity and long periods of drought, characteristic of regions located in the states of Bahia, Piaui or Minas Gerais. Unfortunately, these regions also have concentrated months of heavy rains, which generate great erosion problems due to the flow that forms on the large solar panels, which descends and "washes" the foundations soil, putting at risk the cementation of the solar capture structures. This problem needs to be treated with an appropriate piping and surface drainage system, but the ideal regions for the implantation of photovoltaic plants are also located away from cities or reservoirs able to provide resources for the deployment works, therefore, the construction of reinforced concrete channels, gabions or rockfills is extremely expensive, as well as complex in terms of construction and transportation.

The present work will demonstrate how the use of high-density polyethylene (HDPE) geocells allowed the construction of low cost and very fast channels to be installed, in several of the largest photovoltaic works in the country, using cement-sand mixtures or cement with soil. It will be presented extraction tests that show how the geocell interaction with filling material allows a shear failure of the inserted block in the geocell and not by flexion, as in the conventional concrete slabs, which allows the geocell system to dispense the use of steel of reinforcement, as well as construction joints and expansion / contraction, even with the use of depreciating materials for structural applications such as cement sand. Finally, we present the economic comparative between geocells and reinforced concrete that led the builders to prefer the system with geocells filled with mortar before conventional systems of low cost-benefit.

1. INTRODUCTION

In their entirety, whether in mining, landfills, photovoltaic plants, wind farms, urban drainage, canals are usually lined with reinforced concrete or stone materials. Therefore, the construction costs of these structures consume high percentages of the total investments for new infrastructure and water maintenance. These costs also include the scarcity of stone material that can make stone or concrete works unfeasible, little flexibility to adapt to possible soil deformation, constructive and / or maintenance deficiencies due to poorly trained workforce in the region etc., which may cause leaks. structures, geotechnical and erosion damage, as well as reduced carrying capacity due to reduced transport flow, which can become major repair or recovery costs, which greatly compromises viability. of hydraulic projects.

The role of today's engineering is to look for alternatives that can safely and responsibly combine or even replace conventional reinforced concrete or rockfill structures with structures that represent real economic advantages in order to reduce costs and make projects feasible.

It is in this scenario that geosynthetics become a highly interesting alternative to irrigation, conduction and / or drainage projects. Specifically, materials such as high density polyethylene (HDPE) geocells are available, which allow to eliminate the use of steel in reinforced concrete structures and also to reduce the thickness of the concrete or aggregate layer, such as gabion boxes or rockfill, forming structures with “relative” flexibility to adapt to complex shapes and slightly uneven surfaces.

2. HDPE GEOCELLS

HDPE geocells are geosynthetic materials developed by the US Corps of Engineers and consist of a set of HDPE strips connected by a series of ultrasonic weld beads, distributed across the width of the strip, aligned perpendicular to the longitudinal axis of the strips. Extending, the interconnected strips form walls of a hive-like "cell confinement" structure that can be filled with materials such as vegetation substrates, cement soil, gravel, mortar or concrete, depending on the requirements of each control. its slip caused by hydrodynamics. and gravitational forces. Each “cell” acts as a small vessel that holds concrete and eliminates the need for steel reinforcement. Compared to the textures and perforations on all walls, these features allow the final structure to function as a set of interconnected blocks, providing better performance than conventional structures when installed on uncontrolled floors.

The use of HDPE geocells in channel designs and surface drainage has grown at a rapid pace, largely due to the great advantages that geocells offer over conventional structures such as rockfill, reinforced concrete or stone-filled metal mattresses. To cite just one example, coatings made with HDPE geocells eliminate the use of reinforcing steel, placement and removal of molds, building-joints and expansion, and even allow the use of easily obtainable local materials such as for example the use of cement soil in regions where no aggregate availability.

3. GEOCELL COATING

When filled with concrete, HDPE geocells form a coating that is heavy enough to withstand the tensile forces generated by the conveyed flow, sufficiently abrasion resistant (directly related to the compressive strength of the concrete used) and, due to the presence of geocells, highly flexible. , able to adapt to different channel geometries as well as possible deformations in the foundation. Of the latter, there are excellent references in Chile for functioning geocell channels, including after the 2010 and 2015 earthquakes. In the hypothesis of filling with aggregate (gravel 1, 2, 3 or hand stone), due to the confinement generated by the walls with geocells, it becomes possible to reduce the diameters of the stone material, when compared to the structures solely formed by this type of material.

Figure 1. Using HDPE geocells for channels.

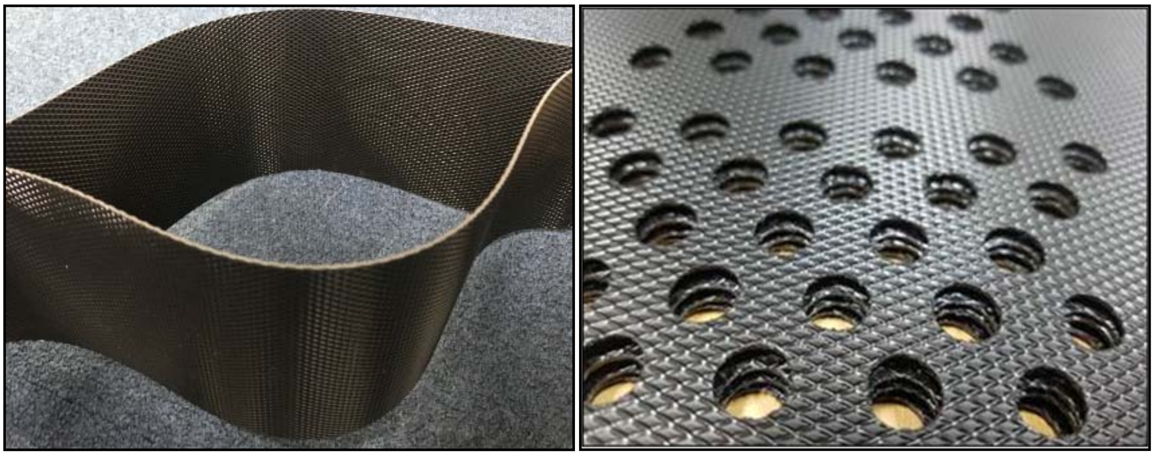
The success of channel coatings using mainly concrete filled geocells has led this alternative to increasingly ambitious applications such as building structures to withstand high speed flows. Regrettably, these applications have in some cases been accompanied by poor quality materials, out-of-specification (e.g. GRI GS15) or lacking the correct characteristics to properly interact with the filler material, producing both satisfactory and disastrous adverse results. In most cases of failure, the main problem was the loss (or expulsion) of concrete blocks from inside geocells, due to lack of mechanical locking and the consequent problems of soil disintegration under the coating.

4. GEOCELL SELECTION CRITERIA

The use of coatings as use of HDPE geocells is not new, whether for channels, hydraulic descents, surface drainage subjected to major repression, such as the closure of landfills and mines. However, it is important, to avoid failures, to know the critical properties when calculating and specifying geocells.

4.1 Perforations and wall texture

Because they are polymeric materials, geocells do not adhere to concrete, so they need features to be able to work together with it, especially to prevent block loss during the life of the structure, a feature directly related to the interaction of fill with geocell walls. In figures 2 and 3 below, we can see some types of geocells that can be found on the market.



a) Textured Geocells b) Textured and Perforated Geocells

Figure 2. Types of geocells.

To ensure this iteration between the filler material and the geocell walls, they must have both perforations and a texture to ensure this locking and that it is not removed with simple efforts, either extraction or pressure. Extraction tests performed with concrete filled geocells have shown that rigid HDPE walls, evenly drilled with 10mm diameter holes and textured with 22 to 31 diamonds per square centimeter, allow mechanical locking of the thick and thin aggregate of concrete, respectively, with the geocell walls, so that in order to be able to extract the block, the applied force must be large enough to break the aggregate and the concrete / mortar first.

a) Fill extraction test b) Extraction Test Result

Figure 3. Fill Extraction Test.

4.2 Geocell opening

To ensure this mechanical clamping between the concrete and the HDPE geocell walls, the contraction of the concrete installed within it must also be controlled. The contraction of the concrete block is directly related to the geocell opening, since the larger the opening and size of the concrete block, the greater the contraction of the same. The important thing is to calculate the opening so that the contraction of the concrete is less in the depth of the texture, in the form of a rhombus, stamped on the walls of the HDPE geocell. If the soil where the structure is implanted has the potential for erosion, the analysis of the use of a non-woven geotextile can be an excellent option to control the loss of fines and the disintegration of the soil under the cover. Although they appear to be irrelevant items, they are critical to the long-term performance of the solution.

In figure 06 below, we can find some of the commercial openings commonly found in the market.

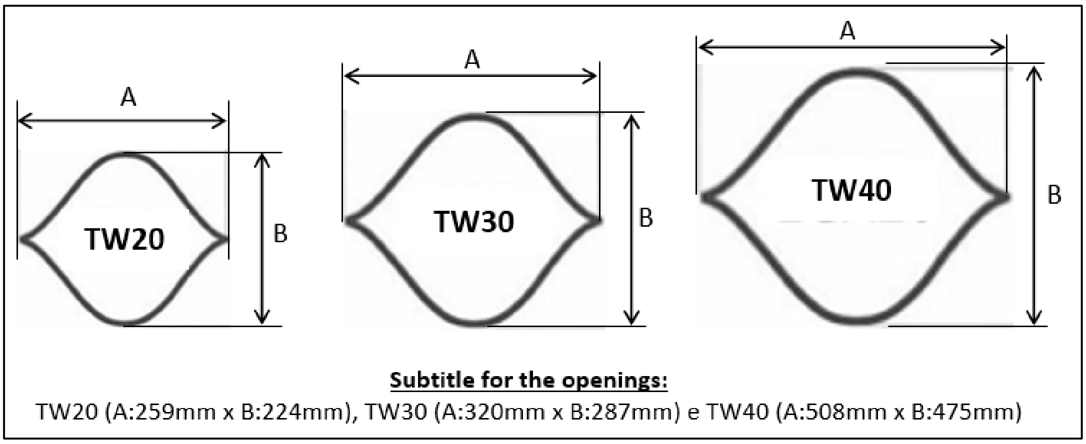


Figure 4. Commercials apertures of geocells.

With the constant advance of technology, followed by new tests, geocells are constantly evolving and, today, we can already find a wide range of openings, developed according to the specific requirements of each project, which will be submitted. As an example, we have the following models:

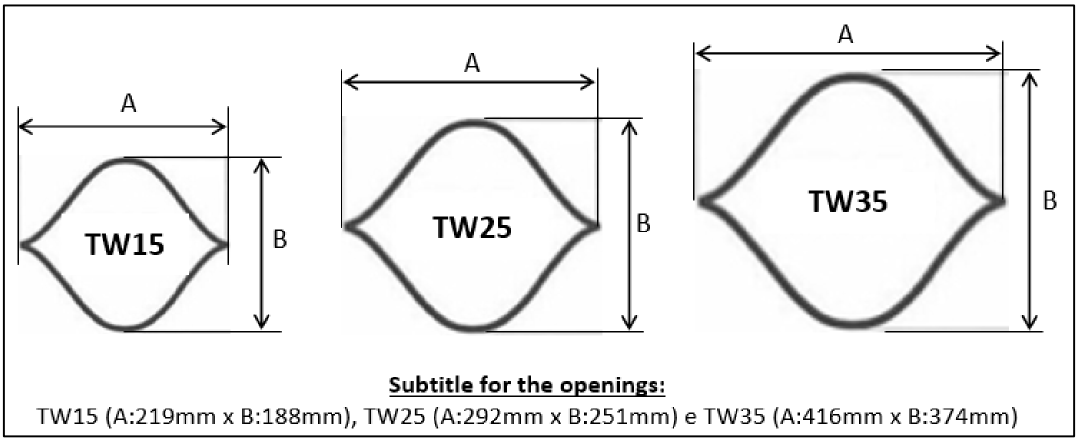


Figure 5. Special apertures of geocells.

4.3 Geocell heights

For application in channels, the CIRIA “Design of reinforced grass waterways (1987)” report is widely used, which suggests the use of a certain filling height as a function of the flow speed, based on the results of hydraulic tests performed on articulated and semi-articulated block coverings. This study recommends the use of coatings up to 200mm in height, when subjected to speeds equal to or greater than 7.0 m/s. For scenarios of filling with stone material the concept is similar. To guarantee the stability / permanence of the aggregate inside the alveoli, it is recommended that the D50 of this material is at most equal to half the height of the geocell wall, thus ensuring the conformation of two layers of material.

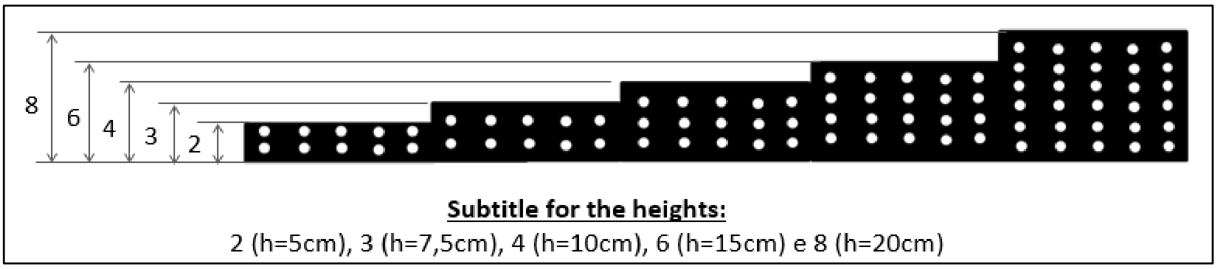


Figure 6. Commercial Heights of geocells.

5. GEOCELL COATING DESIGN

For the dimensioning of the coating structures, it is extremely important to determine the dimensions of the geocell to be used, which are the active forces generated by the fluid to be transported by the hydraulic structures.

According to PORTO (2006), these forces are generated due to the head losses generated by the speeds or flows in certain stretches and the roughness of the structure. In figure 11 below, we can find the components to be considered for the calculation.

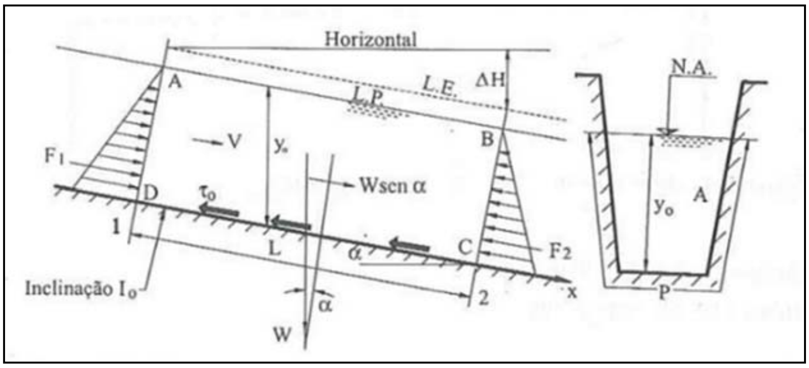


Figure 7. Forces acting in the section. (PORTO, 2006).

For the determination of the shear stress of the structures, formula 1 can be used, which is presented below.

$$\sum Fx = F_1 + \gamma\, A\, L\, \text{sen}\,\alpha - F_2 - \tau_0\, P\, L = 0 \quad [1]$$

Onde:

γ : Volumetric weight of the fluid. (kN/m³);
A : Wet area. (m²).
L : Length (m).
τ_0 : Shear stress. (kN/m²).
P : Wet perimeter. (m).

There are numerous formulas for determining shear stress values. For small slopes, with small angles (α <6 °), as in the case of channels, to obtain the average shear stress value can be found through formula 2, shown below. PORTO (2006).

$$\tau_0 = \gamma\, R_h\, I_0 \quad [2]$$

Onde:

R_h : Hydraulic radius (m);
I_0 : Slope (m/m).

On the other hand, for steeper slopes, attention should be paid to the speeds generated along the structure, so that the average speed of the system is less than the maximum speed supported for each type of material, thus avoiding erosions in the bottom and in the cladding walls. PORTO (2006)

Determined by forces acting on the coating, using the principle of the free-body diagram, illustrated in figure 8, the resistance efforts required for the stability of the structure are determined, as well as the determination of the safety factors for each type of structure.

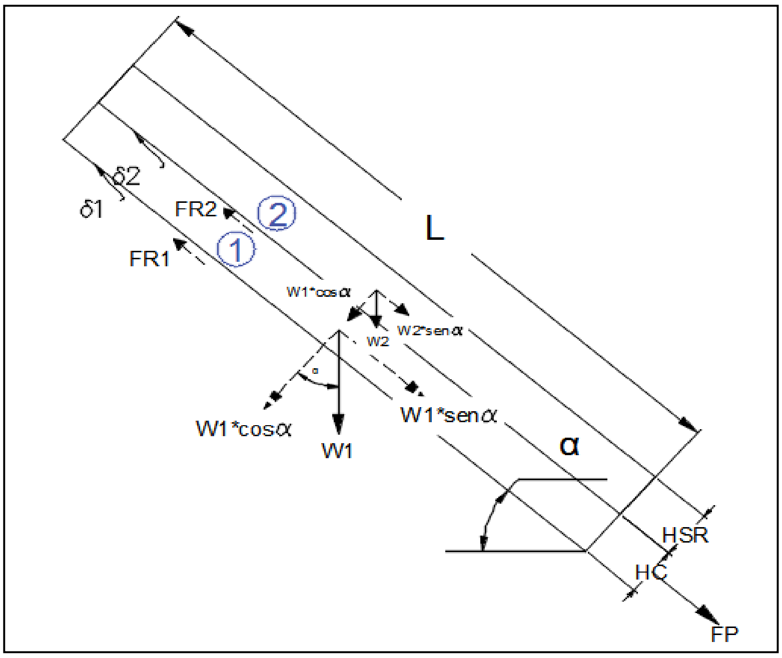


Figure 8. Free body diagram.

Due to these setbacks, there are methodologies and solutions to reduce the kinetic energy generated throughout the structure, which can be reduced by increasing basins or dissipation blocks, up to macro roughness.

6. COMPARISON BETWEEN CHANNEL COATING STRUCTURES

To reduce the execution time and due to the lack of materials in the arid regions of the country, a comparison was made between conventional solutions, where we can list the channels in reinforced concrete, gabion-type mattress, rockfill etc., used for drainage systems. versus HDPE geocell coatings, both filled with concrete / mortar and gravel. For this analysis, two types of structures were considered, impermeable and permeable. In figures 9 and 10, respectively, the results can be found.

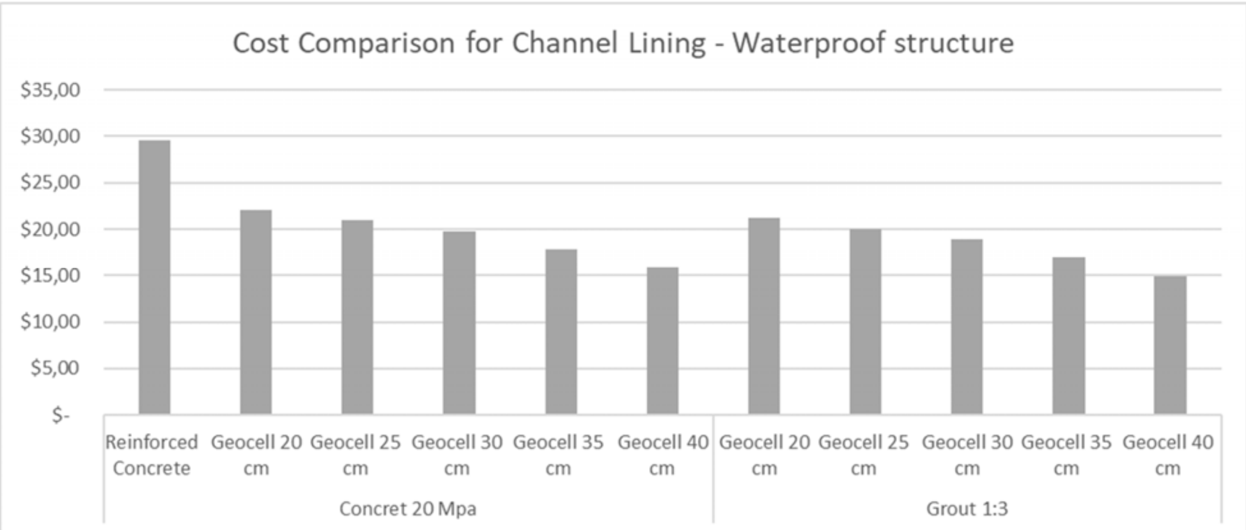


Figure 9. Cost comparation for waterproof channels.

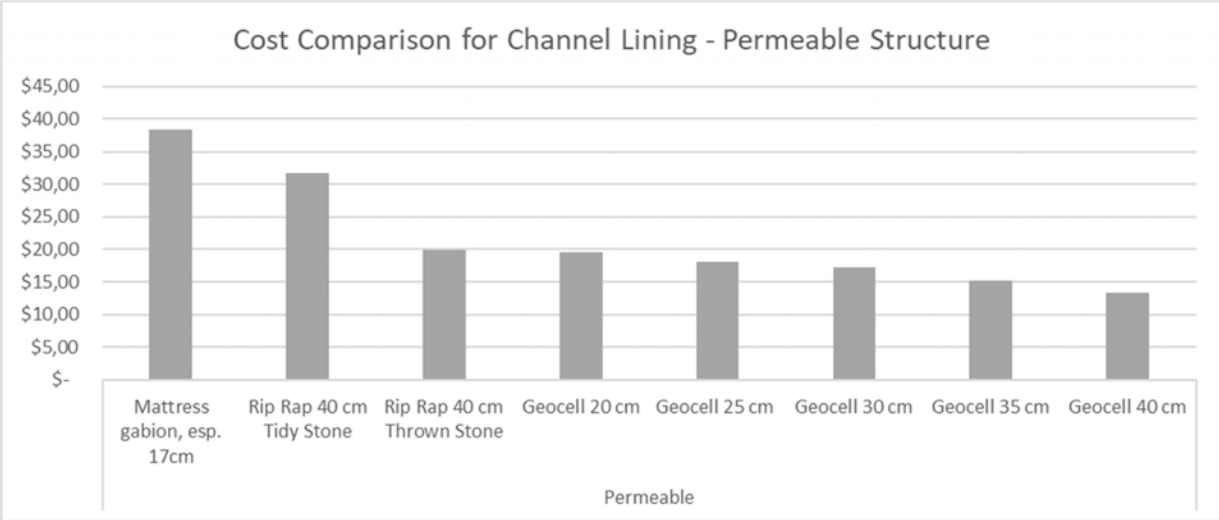


Figure 10. Cost comparation for permeable channels.

7. CONCLUSION

There are a wide variety of geocells on the market, It is up to the designer to select the most suitable material, given the adversities of each project, to determine which is the best type to be considered.

Among the main advantages of using HDPE geocells, we can mention the installation speed and the absence of specialized labor for the execution, which, even generating a higher initial value in the purchase of materials, when compared to conventional structures, the final return on this investment can reach up to 50% savings for the customer.

Currently, several researchers have actively supported the execution of works in this area, in order to provide customers with technical information and detailed calculation processes, in addition to materials manufactured with the best resins available, ensuring good performance and long-term durability. A long list of successful works provides the confidence to calculate and build hydraulic descents safely and with the certainty that the great advantages of HDPE geocells, in this type of application, will remain over time.

8. SUCCESSFUL WORK CASES

Following, some work cases carried out in Brazil where HDPE Geocells were used to replace reinforced concrete structures.

Figure 11. Photovoltaic plant in Ribeira do Piauí, PI. The biggest plant in operation of South America.


Figure 12. Photovoltaic plant in São Gonçalo do Gurguéia, PI


Figure 13. Photovoltaic plant in Bom Jesus da Lapa, BA.

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