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Geogrid Reinforced Crusher Wall, with Face in Stones and Galvanized Articulated Meshes Facing - Quadratum - Nova Lacerda, MT

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ABSTRACT
This paper presents the case study of a geogrid-reinforced containment wall with facing of stones and galvanized articulated wire mesh, located in the city of Nova Lacerda, state of Mato Grosso. The containment structure with U-shaped geometry, has a height of 6m and a length of 49 m, being 25 m faced in the front and 12 m in each side. The reinforcements used in the structure were polyester geogrids, with nominal tensile strength in the main direction of 110 kN / m and 80 kN / m, both with 10% maximum strain at the nominal strength. Due to the specific project needs such as the vertical slope of the face, high load and constant vibrations, the galvanized wire mesh face was specified mainly due to its following properties: durability, ease of installation due to the innovative articulation system, possibility of localized deformation and safety. The containment structure was finished in the last semester of 2017, ensuring the success of the project, the required performance and the desired execution productivity.

Key words: Containment, Geogrid, Reinforced Wall, Facing

1. INTRODUCTION

Containment structures are indispensable elements in engineering works and projects. In mining, the challenges of deploying the infrastructure necessary to meet the business demands are constant. The large loads and the dynamics to which these structures are subjected require greater attention, especially for design and execution of works.

The use of geogrid-reinforced soil for containment with stones and wire mesh facing has been growing in Brazil in the last few years due to the development of products and processes that allow a considerable improvement in the quality of the works and the execution time without the need for skilled labor and sophisticated equipment. The main innovation presented in the system used for this wall, an articulated, easy to assemble wire mesh was essential to meet the needs of the project.

The case presented here is located in a mine in the city of Nova Lacerda / MT. The reinforced wall project for the new gravel plant required a retaining wall very close to the receiving hopper and feeder.

The major concerns of the project were: the stresses that would be imposed by the loaded trucks (40.00 kN/m²) and the vibration generated by the crusher and other equipment in operation.

Due to the design considerations, the geogrid-reinforced containment system with galvanized mesh face was adopted because it showed a better technical-economical ratio than the other alternatives considered, using the soil and stones already present at the mine.

2. RETAINING STRUCTURES WITH GEOSYNTHETIC REINFORCED WALLS

For the execution of reinforced soil strictures, the inclusion of geogrids as a reinforcement element provides for a global redistribution of stresses and deformations, allowing for the adoption of vertical faced structures or steeper slopes (slopes).

The presence of the reinforcements in the containment structure generates a strong tensile force that acts to balance the landfill mass that tends to rupture. These reinforcements may consist of geogrids with mechanical properties suitable for this purpose and must be dimensioned to ensure the stability conditions of the wall immediately after its construction and throughout the lifetime of the project.

The stability of reinforced structures must also be ensured by the soil-reinforcement interaction mechanisms, which is the geogrid's anchoring capacity, as a function of its geometric characteristics and the confinement stress to which it is subjected.

The facing of the wall is also an important part of the conception, since it is subjected to solicitations and must be adequate for the specific characteristics of the project. Desirable features for the facing, in this case, are tolerance to deformations, since high loading and vibrations are expected to cause significant settlement during the time of the operation, easy and fast installation, and durability.

3. DESIGN

The design for the reinforced wall was carried out by determining the necessary tensile properties and length of the geogrids for a minimum factor of safety of 1.5 for the local and global stability, considering the foundation soil was verified.

Also, the recommendations of the British Standard BS 8006 (2010), were considered, and an initial design was based on reinforcements having a minimum length of 70% of the wall height, and never less than 3.0 meters. In the present case, this recommendation was adopted, in addition to the reinforcement elongation in the lower portion of the wall, ΔL, according to the criteria illustrated in Figure 1.

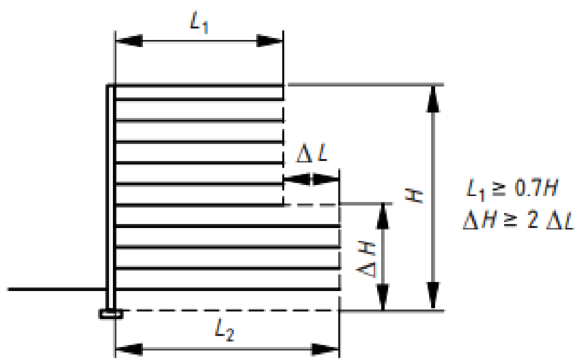

Figure 1. Geogrid-reinforced wall (from BS 8006, 2010).

There are a wide variety of stability analysis methods that can be used for the design of reinforced walls. The limit equilibrium method is widely applied to verify the safety of these structures due to its ease of use.

Stability analyzes by the limit equilibrium method were performed using the RocScience software Slide v. 6.0, in order to ensure Safety Factors for local and global stability of at least 1.50 for the end-of-life condition.

The simplified Bishop method (1955) was employed, assuming potential circular slip surfaces. The Safety Factor was therefore defined by the relationship between the soliciting forces and the geosynthetic available tensile strength, which must be mobilized to maintain the equilibrium condition
Among the specifics of the project, it is expected the installation of equipment for the crushing process, in addition to overloading the reinforced structure, as shown in Figure 2.
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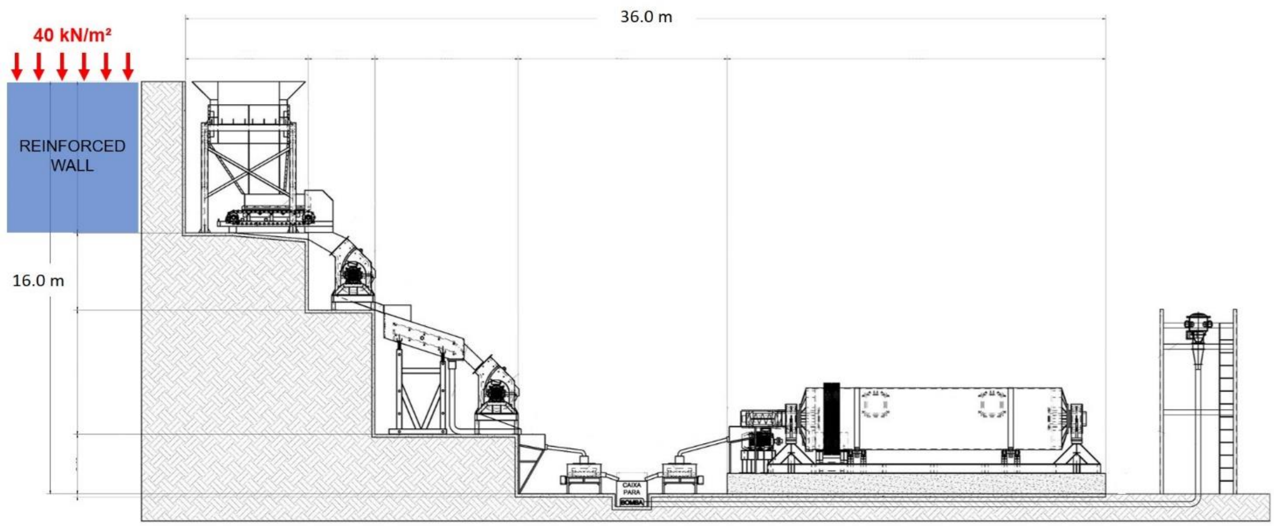

Figure 2. Schematic crusher installation.

Due to the vibrations that should occur in the structure during operation, a seismic load capable of representing such condition was considered for design. In addition, a distributed load of 40 kN/m² was added to the structure.

The structural configuration of the section has been optimized with varying strengths and reinforcement lengths for the lower and upper portions of the structure according to the BS 8006 standard.

In the upper portion of the wall, geogrids with a nominal tensile strength of 80 kN/m with a length of 5.5 meters were used, while in the lower part were considered geogrids with a tensile strength of 110 kN/m and 7.0 meters in length.

The available tensile strength of the reinforcement for 60-year design time was calculated by applying Reduction Factors to nominal strength, according to the equation:

$$T_{adm} = \frac{T_{\max}}{FR_f \times FR_{dm} \times FR_{amb} \times \gamma} \tag{1}$$

Where T_{max} [kN/m] is the nominal tensile strength, FR_f [-] is the reduction factor for creep, FR_{dm} [-] is the reduction factor for mechanical damage, FR_{amb} [-] is The reduction factor for chemical and environmental damage and γ [-] is the safety factor for data extrapolation.

Considering a Total Reduction Factor of 1.90 and a spacing of 0.6 meters between the reinforcements, it was possible to obtain the desired Safety Factor according to the section illustrated in Figure 3, which shows the result of the stability analysis performed.

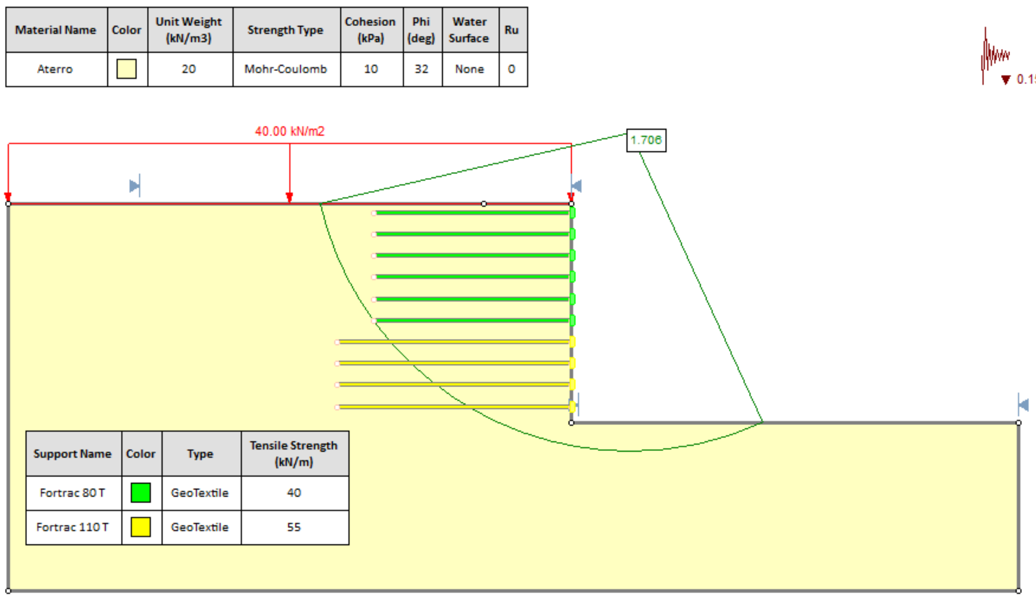

Figure 3. Stability analysis performed for dimensioning the reinforcements of the structure.

4. WALL FACING – ARTICULATED GALVANIZED METAL MESH

As stated previously, a system composed of welded wire mesh, articulated (with a kneecap) and protected by galvanization was specified for this project.

Each piece has dimensions of 0.7 m in height, 0.6 m in width and 2.5 m in length, as shown in Figure 4.

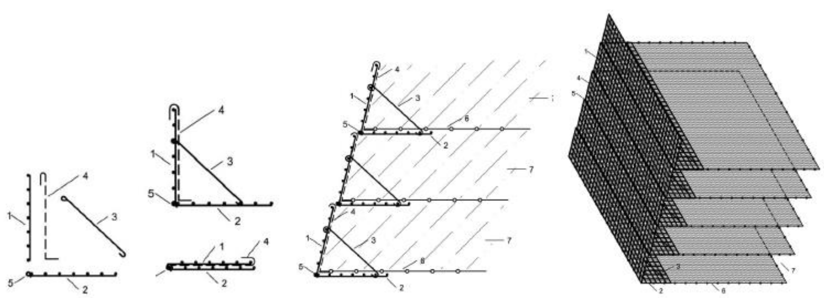

Figure 4. Wire mesh detail.

The height of 0.7 m at the front provides spacing of layers between the geogrids of 0.6 m, leaving 0.1 m of “clearance” so that the upper geogrid always fits behind the lower one, and enable each module to be an independent structure, absorbing any localized deformations.

The steel bars have a diameter of 6.0 mm in the horizontal part immersed in the soil filling, where the stiffness is not so important and 8.00 mm in the front face, both with 10 cm spacing in both directions. This difference in bar thickness and spacing in both directions allows the screens to have similar weights and the faces to be more rigid, since the stiffness is directly related to the moment of inertia of the bars, which vary with the diameter to fourth power.

For locking, 8.0 mm diameter galvanized bars were used, arranged to ensure the locking of the jigs and enable the positioning of the stones.

4.1 Galvanization the steel meshes

As the project envisioned the use of a stone-filled face and steel mesh as a permanent face, it was necessary to use hot-dip galvanized electrowelded mesh.

The use of unprotected steel mesh cannot be considered as a permanent facing system, especially when exposed to weathering, corrosive environments and other aspects that cause the loss of corrosion life.

Galvanization is nothing more than the process of creating a sacrificial layer to isolate steel from the corrosive agent. In the case of the system used, the galvanizing of the meshes was performed in the hot process to create a surface of protective layer of zinc with a minimum thickness of 74 microns, according to the Brazilian Standard NBR-6323 - “Hot Dip Galvanization of Steel and Cast Iron”.

Figure 5 presents the graph of life (years) per average zinc layer (µm).

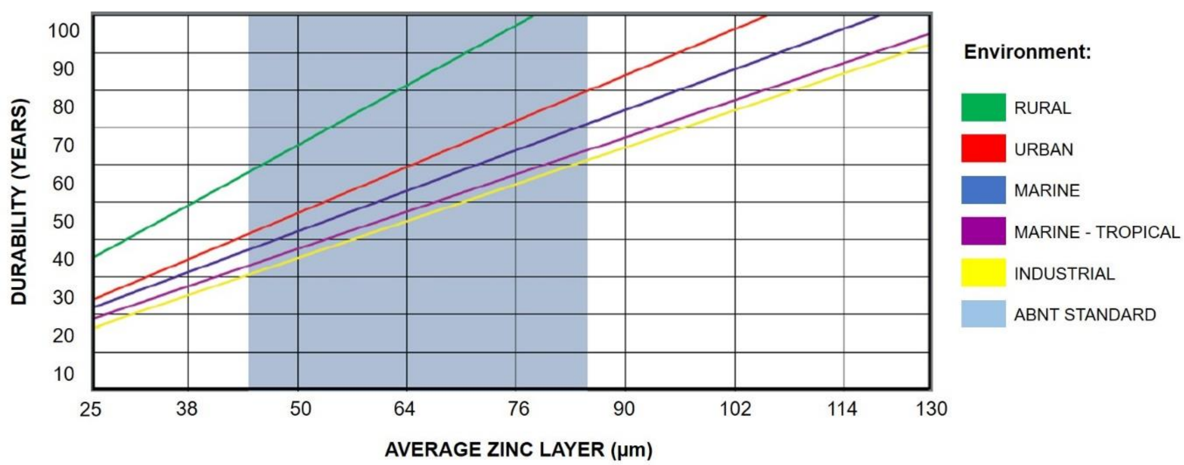

Figure 5. Shelf life x average zinc layer. (from Brazilian Standard ABNT NBR 6323).

The use of this technique guarantees the durability and aesthetics of the mesh, a quick and simple assembly and practicality, since the templates arrive ready for use on site.

5. EXECUTION

During the construction, the base area was highlighted topographically, for the positioning of the metal jigs. In parallel to the preparation of the base of the wall, the metal jigs were assembled by manually opening the meshes and fixing the lock bars according to Figures 6 (a) and (b).

(a) (b)

Figure 6. Mounting the Quadratum Template

Figure 7. Mounted metal templates for positioning.

The recommendation of compaction was to perform it with vibratory roller in initial layers with maximum thickness of 20 cm, respecting the distance of 1.5 m from the face. Face compaction was performed with hand-held frog-type equipment in maximum thickness of 15 cm. Optimum humidity +/- 2% and 100% degree of compaction of the normal proctor. Soil with a maximum of 50% by weight passing through sieve # 200 and free of organic matter, peat and / or soft clay.

The positioning process of the meshes and stones was carried out manually by the construction workers, using a polypropylene woven geotextile with tensile strength of 50 kN/m in both directions to separate the materials, as shown in Figure 8.

Figure 8. Positioning of the meshes and stones.

In each layer, the process is repeated, with the mounting of the steel meshes after the installation of the geogrids, as shown in Figure 9. Figure 10 shows the finished geogrid-reinforced, stone-faced wall.

Figure 9. Reinforced soil layers at crusher wall

Figure 10. Completed Containment - Quadrate Stone

6. CONCLUSION

The execution of the project had its success guaranteed by the quality of the construction phases, from the design to the final conclusion of the works. The geotechnical stability analysis and specification of materials and solutions adequate to the specific needs of the project provided greater security for its execution and use, considering the high loads and vibration imposed by the heavy equipment used for crushing.

The ease of assembly and installation of the galvanized articulated metal meshes ensured the expected construction productivity. Not to mention, the savings generated on the site, by using the available soil and stones mine.

Finally, the application of a geogrid-reinforced wall system with steel mesh and stones as permanent facing requires the galvanization process to ensure its durability, as well as rigidity to avoid large deformations or even rupture of the wall screens.

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