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Slope Stabilization using a Green Terramesh System

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Abstract

In June 2016, after the excessive rainfall, a major slip of an embankment occurred resulting in a mass of soil to washing away, creating a large slip in the embankment. The major concern was the railway line situated next to the embankment and further erosion would be detrimental to its functioning. The failure occurred in Bluff, Durban, which is a residential area that overlooks the port of Durban.
The use of soil reinforcement, particularly geosynthetics, for slope rehabilitation has been well researched and documented, however, incorporating an environmentally friendly facing to build a structure that blends into the natural environment is a developing concept in South Africa. The intervention deemed necessary by the Municipality, had a requirement to be economical, functional and environmentally friendly. The most feasible solution accepted was the use of a Green Terramesh® System. This is a soil reinforced system with a green facing.
This paper aims to showcase the basic design principles applied to soil reinforcement, and the construction procedure for this solution.

Keywords: *Soil Reinforcement, Green Terramesh System, Paragrid.*

1 Introduction

Contemporary civil engineering technology includes the use of geosynthetics as soil reinforcement, and has been researched and applied for the last 50 years. There are, however, some question marks surrounding this, as there is a general lack of knowledge surrounding geosynthetics. – compared to traditional reinforced concrete solution. However, due to the sensitivity of the environment and the good collaboration between the client and product specialist, the ideal solution proposed was to stabilize the slope using geosynthetics.
The Coastal, Stormwater and Catchment Management department of eThekwini Municipality, together with Maccaferri Africa managed to assess the damage and together formulate a suitable solution. After some analysis and calculations, the best solution was deemed to be a combination of Maccaferri's Terramesh and Green Terramesh System.

The key concepts in developing a suitable solution included:

- Environmentally friendly (Solution that integrates into the natural environment)
- Economical
- Functionality
- Aesthetics

2. Proposed Solutions

2.1 Concrete Retaining Wall

While this concept is functional, and knowledge about this type of solution is well known, the costs of building such a structure is excessive. Accessibility to the site was another governing concern that made this solution unfeasible. The main concern of the municipality is the aesthetics of a concrete structure in this environment. Eventually, for these reasons, the solution was rejected.

2.2 Mass Gravity Wall (Gabion Wall)

Due to the height of the structure, building a mass gravity structure would be too costly. The duration of completion was foreseen to be too long, due to the labour intensive nature of the structure. Considering these factors, the solution was rejected

2.3 Soil Reinforcement

The slope stabilization was carried out using geosynthetic grids, incorporating a front face made from modular units of double twisted hexagonal mesh, manufactured with a biojute face to allow for a vegetated surface (Green Terramesh System). Maccaferri's Terramesh system was used at the toe to increase stability and create natural drainage due to the permeability of the system. The polymeric soil reinforcement used was Paragrid and MacGrid, which varied in strength and length, to optimize the solution. The concept is displayed in Figure 1 below.

2.3.1 Products used

2.3.1.1 Green Terramesh System - Green Terramesh® has an inclined vegetative facing made with a Type 80 double twist hexagonal woven wire mesh base reinforcement Type 80, provided with a welded mesh panel for facing and a Biomac for soil retention and metallic ties for installation procedures as per *EN 10233-3 Hexagonal steel wire mesh products for civil engineering purposes*. The dimensions are given in length of tail from the front face x width of the front face (3.0m) x height of the front face. The diameter of the wire is 2.7mm and complies with the relevant requirements of SANS 10244-2 Table 2 Class A (Zn95Al5, known as Galfan) coated with tensile strength between 350-550N/mm². The PVC is extruded over the wire to provide added protection for use in aggressive environments. The PVC coating is grey and has a nominal thickness of 0,5mm to SANS 1580 (Maccaferri Africa Technical data sheet, 2016)

2.3.1.2 Terramesh System - Terramesh® System is used in vertical facing structures for soil reinforcement applications such as mechanically stabilised earth walls as per EN 10233-3. The double twist Type 80 mesh providing soil reinforcement is continuous from the tail through to the front and bent up to form, together with back panel and a diaphram a gabion face. The dimensions are given in length of tail from the front face x width of the front face x height of the front face x depth The diameter of the wire is 2.7mm and complies with the relevant requirements of SANS 10244-2 Table 2 Class A (Zn95Al5, known as Galfan) coated with tensile strength between 350-550N/mm². The PVC is extruded over the wire to provide added protection for use in aggressive environments. The PVC coating is grey and has a nominal thickness of 0,5mm to SANS 1580. (Maccaferri Africa - Technical data sheet, 2016)

2.3.1.3 Paragrid - Paragrid® is a bonded geogrid with unidirectional strength made from straps of polyester fibres encased in a tough and durable polyethylene sheath. Elongation at break is not higher than 12% and at 40% of Ultimate tensile strength (UTS) less than 6%. Post construction creep elongation calculated on the 24h and 10.000h are not higher than 1% for loads from 40 to 60% of the UTS in accordance to SANS ISO 13431. (Maccaferri Africa Technical data sheet, 2016)

2.3.1.4 MacTex - MacTex H40.1 (Heat bonded) or MacTex N 20.2 is nonwoven continuous filament needlepunched polyester geotextile with a CBR of 2.6 kN (SANS 10221), puncture resistance of 21 mm (ISO 13433). Permeability of 4.3x10-3 m/s (SANS 10221) and apparent opening size of 138x10-12 m (ISO 12956). Thickness at 2 kPa of 2.0 mm (SANS 10221). (Maccaferri Africa Technical data sheet, 2016). The geotextile is primarily used for filtration purposes.

2.3.1.5 MacDrain W1051 - Macdrain W1051 is a geocomposite for drainage made by thermobonding a W shape draining core in extruded monofilaments with two filtering nonwoven geotextiles. The weight of the filter is 120gr/sqm;. The tensile strength of the geocomposite is 8kN/m in accordance of ISO 10319. Water flow in accordance to ISO 12958 with hydraulic gradient of 1 of 0.50 l/m sec at 200 kPa. Minimum thickness of the geocomposite according to EN 9863-1 not less than 5 mm. (Maccaferri Africa Technical data sheet, 2016).

This Solution was accepted and approved:

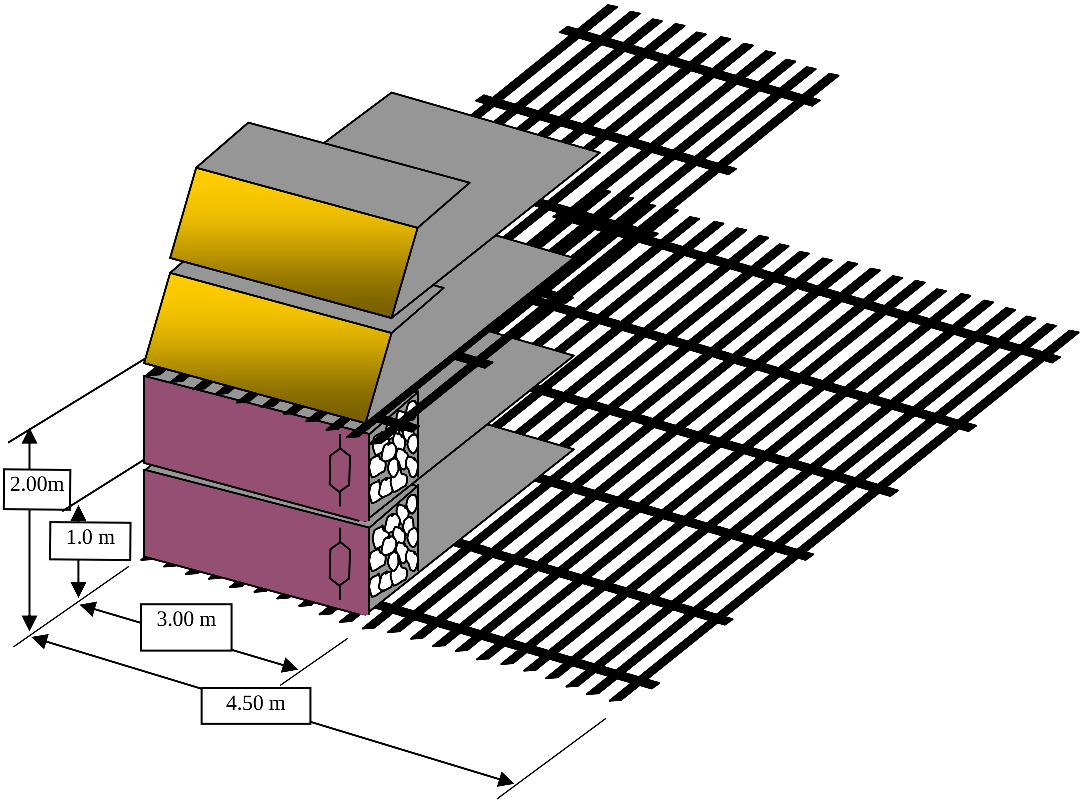

Figure 1: Concept of the combination of Terramesh, Green Terramesh and Geosynthetic grids

2 Design

2.1 Design Methods

The design analysis was carried out using MACSTARS W (Maccaferri Stability Analysis of Reinforced Soils and Walls). For this analysis, the design was compliant to the standards established in SANS 207 – “The Design and construction of reinforced soils and fills.”
SANS 207 adopts limit state principles; ultimate limit state, serviceability limit state, which is clearly defined.

MacStars makes use of the of calculation method defined by the Bishop and Janbu method. These two methods make reference to the Mohr-Coulomb failure criterion

$$\tau = c + (\partial - u)tan(\theta')$$

Where: τ = maximum tangential stress
c = cohesion
∂ = total normal pressure
u = pore water pressure
θ' = friction angle

2.2 Design Information

The structure was classified as a reinforced slope, category 3 with a design life at 120 years. The coating of the double twist products and the geosynthetic grids are compliant with BBA certificates issued upon testing of the products.

The surcharge loading considered was 10Kpa, as a maximum load at the serviceability limit state.

The soil characteristics were defined by the client.

Material Name	Unit Weight (kN/m^3)	Residual Friction Angle (Degree)	Cohesion (kPa)
Structural Fill	18	30	0
In-situ Soil	18	30	0

Table 1: Soil Parameters

2.3 Design Checks

The stability checks that were performed using MacStars include:

1. Global stability
2. Internal stability
3. Sliding stability

2.3.1 Safety factors achieved

Stabilty check	FOS achieved
Global Stability	1.114
Internal stability	1.528
Sliding stability	1.646

Illustrated in Figures 2,3 and 4

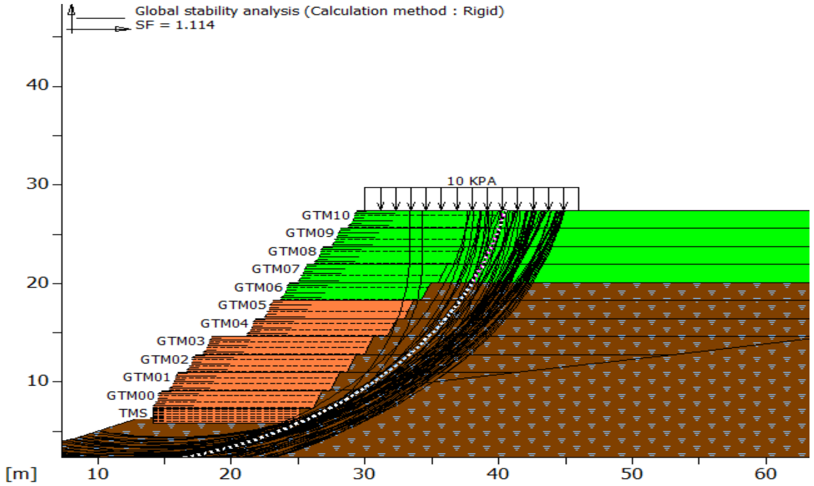

Figure 2: Global stability Analysis

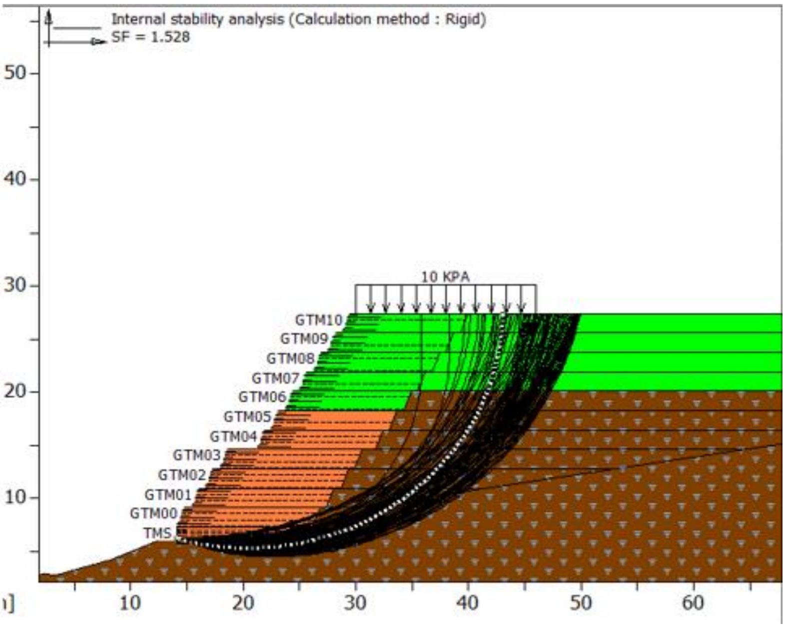

Figure 3: Internal stability Analysis

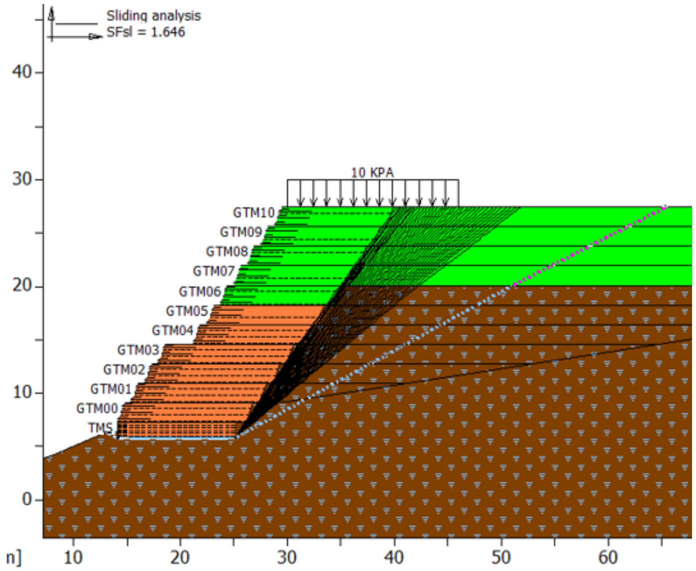

Figure 4: Sliding stability Analysis

2.4 Design of the Toe

The toe of the structure is designed with a Terramesh system for stability and natural drainage attributes. The geotextile used is for filtration purposes, to allow water to pass while retaining the fine material. A geocomposite drain (MaacDrain W1051) was used as a subsoil drain to keep water from disrupting the structural fill. (Figure 5).

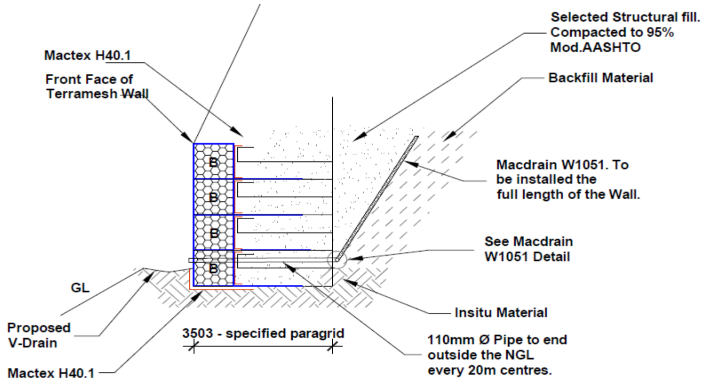

Figure 5: Toe protection detail

3. Construction

3.1 Installation

Installation was performed according to the installation manual from Macacferri Africa, with QA/QC documents being monitored by the responsible engineer.
The installation procedure maybe sub-divide into critical sections:

1. Foundation preparation and setting out (Figure 6)
2. Assembly and lacing of individual units
3. Placing the geogrids – tensioned and in the correct direction
4. Placing of the Green Terramesh units
5. Placing the vegetative soil - Placed on the back of the facing element, approximately 500mm. This soil must be lightly compacted
6. Inserting the structural fill
7. Compaction of the Structural fill – 95% MOD AASHTO
8. Hydroseeding/Planting – Vegetating the front face is a critical component to ensure the finished products.

3.2 Images

Figure 6 illustrates the setting out and positioning of the system. Surface preparation was concluded and the placement of the individual components were conducted as seen below. The geogrids placed were then tensioned before the structural fill was placed.

Figure 6: During construction

Figure 7: Structure before vegetation

Figure 8: Vegetated face

The contractor adopted the hydroseeding approach, to vegetate the surface of the structure. The hydroseeding is a key component and much care must be taken in ensuring that the final structure achieves an effective level of vegetation (Figure 8)

Conclusion:

The structure was officially completed in May 2017, and has achieved the desired requirements. The final structure unified the construction with the natural environment while stabilizing the embankment simultaneously (Figure 9).

The advantages of using geosynthetics for soil reinforcement include:
- Cost effectiveness
- Easy Installation
- Environmentally friendly
- Effective

The growing need for sustainable development, coupled with the favorability of 'green' engineering makes this sort of solution desirable and effective. The carbon footprint of using geosynthetics is much lower than that of traditional concrete solutions and as such, the future of geosynthetics look bright.

Figure 9: Final Solution

References

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