Integration of geosynthetics into civil engineering

From products to functions

a case study: Hazyview slip repair

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INTRODUCTION

The shortage of borrow sources for granular material, combined with the limited availability of funds for rehabilitation projects, is generating more opportunities for innovative engineering in order to achieve cost-effective solutions. Since the introduction of geosynthetics, governments, consultants and contractors have been assisted to deliver projects to stakeholders. Geosynthetics are now considered necessary and indispensable for a cost-effective solution in multiple functions, such as reinforcement, separation, filtration, drainage, barriers, erosion control, containment and protection (ISO 10318:2006: Geosynthetics: Terms and Definitions).

The use of geosynthetics in South Africa is still novel to engineers, but its use is nevertheless increasing every year in sectors such as reinforcement of fill, management of pore water pressure, foundations and pavements.

An example of this was a project to stabilise a slip failure on a 25 m high embankment undertaken in 2010 on the road between Hazyview and Graskop, near the Kruger National Park. The stability of the road embankment was enhanced exponentially through the use of geosynthetics in five of its eight functions: reinforcement, separation, filtration, erosion control and drainage.

BACKGROUND

In October 2010, after attending a Continuing Professional Development (CPD) lecture on geosynthetics, Masetlaoka Scott Wilson approached Maccaferri to visit a site on the D1043 between Hazyview and Graskop where it was feared a slip failure may occur, thus compromising the stability of the embankment. Further research revealed that the slip was caused by a lack of maintenance of the stormwater drainage system, which was not sufficient to handle the heavy rains characteristic of this region. The situation was aggravated by the presence of a clay silty sand soil, resulting in a massive erosion donga of about 25 m high and 80 m wide.

The geotechnical investigation revealed very poor in-situ soil with a high level of silt and clay (55% passing the 0.075 sieve) classifiable as a G9. A friction angle of 22° with cohesion of 32 kPa was determined, using a shear box test.

Primary reinforcement using 80 kN/m bonded geogrids

Basal reinforcement platform using 300 kN/m geogrids in both directions

A global stability analysis revealed a deep-seated global instability at the bottom of the embankment (about 25 m from the road) due to the uncontrolled erosion which had removed most of the soil at the toe of the embankment. In addition to this, water was seeping under the embankment from a pond which holds stormwater received from the catchment area on the opposite side of the embankment.

As the site was enclosed by private land, the idea of importing fill to re-establish the natural slope was not possible. With the steeper angle that was required it became apparent that soil reinforcement was the only possible solution, as this would reduce the footprint and also the volume of fill which would have to be imported.

The final solutions comprised the use of geosynthetics as follows:

- Soil reinforcement structure
- Basal reinforcement to support the soil reinforcement structure
- Separation between the in-situ soil and the imported soil to avoid mixing and reducing mechanical performance
- Filtration behind all hydraulic structures
- Drainage control at the top 8 m to collect any seepage water coming from the other side of the embankment to avoid contamination on the structural fill
- Erosion control blanket to protect the slope at the top and avoid erosion.

SOIL REINFORCEMENT

The traditional methods to counteract a deep-seated global instability are piles, sheet piling or soil nailing. These methods are often used in high-skilled engineering where time is at a premium, and where most of the work is done by machines. At Hazyview, however, the contractor was limited to only one excavator, two impact rollers and inexperienced labour from the local community.

The technology of soil reinforcement, using geosynthetics, allowed the contractor to use a large local labour force to cut the geogrid to the required length, place it on site and transport the structural fill to the areas that were inaccessible to the excavator. This solution also allowed the steepening of the slope to 70° (50° more than its angle of repose), enabling them to maintain the construction within the property boundaries, as well as saving on earthmoving and importing of soil.

The geogrids used were high-tensile polyester, encased in a LLDPE coating to prevent installation damage, with a strength of 200 kN/m at the bottom and 80 kN/m at the top, all at 2 m spacing, acting as primary reinforcement. A secondary reinforcement in-between was given by a double-twisted mesh of 50 kN/m linked to the facing. For most of the structure a 70° angle was maintained, with surface erosion control. Where hydraulic structures were required, a gabion face was used.

The final solution comprised three berms – the first one (to prevent global stability failure) of 11 m high with a foundation of 4 m in order to intercept the deep-seated instability; the second one closer to the road (in order to save on the volume of imported material) of 8 m high; and the third one a natural slope of 2 m high which restored the previous distance of about 11 m between the road and the edge of the cliff, thereby improving the safety of the road.

BASAL REINFORCEMENT

Once the contractor reached the foundation level for the reinforced structure, a standard penetration test revealed the soil's low bearing capacity (between 10 and 60 kPa), which would have caused a failure due to the un-drained shear stress of the foundation. Basal reinforcement was suggested to avoid interruption by construction (standing time would have compromised the entire programme) and to maintain the costs within budget.

Based on the analysis done with Mac.St.A.R.S in-house software, 300 kN/m mono-directional geogrid reinforcement was placed at the foundation in both directions. A mono-directional geogrid, with a creep deformation of less than 1% in 120 years, was selected in accordance with the SANS 207:2006 for embankments on highways. (The use of bi-directional geogrid would have required a 4 m overlap to obtain the same result, and this would not have been cost-effective.)

SEPARATION

To counter the very real possibility of the imported material mixing with the in-situ soil (G9 of which more than 50% passed the

Separation using nonwoven geotextile between in-situ soil and imported material

0.075 sieve) and thereby drastically reducing the mechanical properties of the imported soil, nonwoven geotextile was placed at every interface between the imported material and the in-situ soil. Benching was adopted to prevent a weak interface, and hence a failure zone, behind the reinforced structure and the in-situ soil.

FILTRATION

One of the main causes of failure in a reinforced soil structure is the mismanagement of water. The project at Hazyview included the rehabilitation of the stormwater drainage system, comprising two 8 m high weirs in the top part and one 11 m high weir at the bottom, connected with reno mattresses, plus a concrete pipe culvert collecting the water from the opposite side of the embankment, as well as a stilling basin at the toe of the embankment to dissipate the energy and reduce the tractive forces of the water, which over the years, along with the silty soil and lack of maintenance, had created the 25 m high donga.

It was suggested that a geocomposite clay liner (GCL) be placed underneath all the hydraulic structures, but this proved too costly. To remain within budget, a 21 mm thick nonwoven geotextile was used instead.


Nonwoven geotextile placed under reno mattress for filtration purposes


Geocomposite for drainage placed just at the back of the reinforced structure with a perforated pipe at the bottom to collect water

DRAINAGE

Water that had not been properly contained on the other side of the embankment created a water table in the top 8 m of the reinforced structure. To avoid any pore water pressure in the embankment, which would have increased the reinforcement requirement by about 50%, a geocomposite liner was installed at the back of the reinforced structure with a perforated pipe at the bottom to collect water. The pipe was then connected to the hydraulic structures.

EROSION CONTROL

A full-height gabion-faced soil-reinforced structure to counter erosion and instability (caused by high rainfall in the area) would not be cost-effective in terms of the available budget.

It was therefore decided to use a more economical pre-formed unit made of double-twisted mesh to provide primary reinforcement. A synthetic biodegradable erosion control blanket was installed on the 70° front face of the slope, and was held in place by the wraparound double-twisted mesh. The erosion control blanket was then hydro-seeded to stimulate appropriate plant growth on the slope.

SUCCESSFUL COMPLETION

The use of a geosynthetic solution at Hazyview enabled the contractor to complete the project within time and within budget, while also empowering a local labour force in the construction of a 25 m high soil reinforcement structure, complete with hydraulic structures for water management.

More than 13 000 m^2 of geosynthetics were used on this project. Although the geosynthetics made up 22% of the total cost of the project, their use generated a saving in earthmoving, trench drains and erosion control measurements estimated at between 25% and 30% of the total cost of the project.

CLOSURE

Geosynthetics are related to civil engineering through eight functions: reinforcement, separation, filtration, drainage, barriers, erosion control, containment and protection. Engineers have in the past few years indeed moved towards the concept of using geosynthetics. This move has been shifting the focus from the product (geotextiles, geogrids, etc) to its function (filtration, reinforcement, etc). Although this approach leads to simpler solutions, the choice of the right product has become more complicated.

Solutions have become simpler because a 'function approach' clearly identifies what a particular geosynthetic needs to be able to do and what its key parameters should therefore be – e.g. a geotextile with a separation function needs to have mechanical properties (tensile strength, CBR), whereas in a geotextile with a filtration function hydraulic properties become more important (apparent opening size, permeability).


Close-up of biodegradable erosion control blanket to enhance vegetation on a 70° face

The choice of the right product has become more complicated because geosynthetics are evolving all the time, requiring increased knowledge of the intrinsic properties of geosynthetics.

Engineers and manufacturers, together with academics, have since the 1970s when the first geosynthetic was used in civil engineering, striven to demonstrate the trustworthiness of geosynthetics. More than 50 million m^2 of geosynthetics were used worldwide in thousands of projects in 2011 (the quantity of geosynthetics sold by the Maccaferri Group in that year), acting as primary structural products, with a very high level of reliability. As far as the author is aware, not a single failure was due to the geosynthetics themselves. Failures occurred because of poor or incorrect construction and/or the incorrect assumption of parameters at the design stage.

One of the main challenges when using geosynthetics is proper quality control. A lack of quality control is one of the most common reasons for failure. Geosynthetics are becoming fundamental structural elements in projects, almost like steel is for concrete. If the necessary quality control is not performed, the integrity of the project could be severely compromised. ◻


Completed structure (just before hydro-seeding)

Source:
http://www.saice.org.za/downloads/monthly_publications/2013/2013-Civil-Engineering-April/#/0