AMANZIMTOTI RAILWAY: EMBANKMENT RECONSTRUCTION AND REHABILITATION USING A SPECIALIST GEOSYNTHETIC SOLUTION

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SUMMARY

In early December 2012, torrential rainfall caused the Amanzimtoti River to flood. This, combined with sustained wave action due to rough seas, eroded approximately 350m of railway embankment carrying the south-bound rail line. The south-bound rail line collapsed into the river, resulting in the derailment of three electric units. A rapid and cost-effective solution was required to reconstruct the railway embankment, whilst still being robust enough to withstand future erosion from the river. Construction was to be undertaken adjacent to the remaining single railway line which was still in operation.

Contrary to conventional methods, a wrap-around retaining structure was designed using large, specialist, multi-laminate geotextile containers, filled with beach sand and wrapped with the reinforcing multi-laminate geotextile sand container fabric tied back into the backfilled slope to further stabilise the rehabilitated embankment. The comparison and reasoning behind the construction method and materials used, versus the conventional methods are described and illustrated. Construction proved cost-effective and expedited the rehabilitation of the embankment, which was paramount to the client's urgency in getting the strategic rail connection back into full commission.

1 INTRODUCTION

Madan Singh and Associates cc (MSA) were appointed on the 28th February 2013 to investigate the erosion and slope failure caused by wave and flood action at km 21.236 of the railway line from Durban to Port Shepstone.

The site is located in Amanzimtoti in Kwazulu–Natal adjacent to the Amanzimtoti River. A complete failure of approximately 350m of the railway embankment carrying the South Bound rail line occurred on Thursday 11th December 2012 after torrential rains and flooding of the Amanzimtoti River resulted in the derailment of three of Transnet's electric units and their collapse into the river at the foot of the embankment. This resulted in a change of the scope of the works from the original submission, which involved embankment protection. This project was at tender stage before the unforeseen collapse occurred.

A team comprising a Surveyor, Environmental Consultant and a Professional Geotechnical Specialist, was appointed as part of the team. The project was to be fast-tracked under an Emergency Status to provide remedial measures to reinstate the collapsed embankments using an environmentally friendly solution. Kaytech's technical specialists were consulted for the specifications of a robust, durable geotextile to not only withstand the harsh coastal conditions, but also be puncture resistant to branches, trees and other damaging debris in the estuary. The Specialist Geotechnical Engineer designed the embankment reinstatement and protection within these specifications.

Six specialist contractors were invited to tender for the project. Leomat Plant Hire and Construction (Pty) Ltd was awarded the contract in October 2013 out of only three tender submissions received, scoring the highest in both the Technical and Financial Criteria.

Figure 1: Derailment of three of the electric units [1]

Figure 2: Collapsed Rail, South Bound

2 ENVIRONMENTAL CONSIDERATIONS AND MANAGEMENT PROGRAMME

Initially a concrete retaining block wall (CRBW) with a gabion structure directly behind to allow for drainage followed by a geotextile filter layer and back fill from local quarries, was the preliminary solution proposed. The toe of the CRBW was to have Geotextile sand containers (GSCs) manufactured from a high strength (200 x 200 kN/m) multi-laminate reinforcement geotextile for additional protection and aesthetic purposes. The possibility of piling into bedrock was also discussed as an option.

The gabion wall was not practical due to the harsh coastal conditions (corrosion) therefore the design was revised using a CRBW with reinforced soil (use of anchor ties) and the use of GSCs. The anchor foundation was to be keyed into rock with dowels. Breaching of the river flowing parallel to the railway line with the use of a berm of GSCs was a temporary solution to redirect the river away from the site for ease of construction.

However, after meeting with various relevant departments (eThekwini Coastal, Ezemvelo Wildlife, Department of Environmental Affairs), the use of a CRBW was no longer considered a viable option as eThekwini Coastal preferred a softer, more aesthetically pleasing structure.

A specialist Environmental Consultant was appointed for the Environmental Management Programme (EMPr) and the Environmental Control Officer (ECO) monitoring. In December 2012, PRASA/Metrorail was issued with a letter after the embankment failure, allowing emergency construction under NEMA Section 30 [2]. However, due to the delay in procurement of the contractor, this was no longer an option and a NEMA Section 24G was required, including an Environmental Impact Assessment (EIA) [3]. Section 24G is the unauthorized commencement or continuation of activities identified in terms of the Environmental Impact Assessment regulations that can be rectified by means of an application to the relevant authority. The 24G application could have been avoided, but the EIA would only be completed in 6-8 months thereby delaying the construction.

The rehabilitation involved the breach of the estuary that flows parallel to the railway line. Working in the sensitive environment required input from an estuarine specialist. The estuarine specialist produced an Estuary and Sandy Beach Ecological Impact Assessment that was included in the EMPr.

The contractor was issued a copy of the EMPr, which was kept on site. The construction works were completed in accordance with the EMPr and audited monthly by an Environmental Control Officer.

During construction, Toti Conservancy raised several concerns about the estuary breach. The controlled breach on the northern, estuary side of the site was constructed using GSCs, which was originally intended to divert the river flow from the construction. The diverted water scoured through the sandbank, draining the estuary into the sea. In order to maintain the estuary water level, the contractor placed several GSCs as a berm across the scoured channel. These GSCs sank until they reached bedrock; thereafter several more GSCs were placed to retain the shape of the berm. Many of these GSCs re-surfaced after the contractor de-established from site.

3 DESIGN PROCESS

Meetings between the Department of Environmental Affairs, KZN Ezemvelo Wildlife, eThekwini Coastal, Madan Singh & Associates and the lead design engineer, the following options were proposed to the client:

Option 1: This comprised the use of a double row of 550 g/m^2 nonwoven continuous filament polyester GSCs (measuring 2.5 x 2m each), reinforced with a high strength (200 x 200 kN/m) multi-laminate reinforcement geotextile and filled with imported material. The specialist geotextile is then wrapped over two lifts of GSCs and tied back horizontally 4m into the fill, to ensure stability of the structure.

Each container has a vertical depth of approximately 500mm when filled.

Option 2: This involved the use of a single row of 550 g/m^2 nonwoven continuous filament polyester GSCs (measuring 2.5 x 2m each), reinforced with a high strength (200 x 200 kN/m) multi-laminate reinforcement geotextile. The fill in the outer GSC facing erosion and wave action is stabilised with cement, whilst the fill in the second, inner GSC is not stabilised. Two lifts of GSCs are then wrapped and tied back as per Option One. The reinforced fill, type of fill and the embankment behind the GSC structure is constructed as per Option 1. Option 2 provides additional puncture protection and protection from the elements. Loss of fill due to damage occurring to the reinforcement geotextile and the 550 g/m^2 geotextile GSC, is decreased

Option 3: This is similar to Option 1, except that it comprises a single row of 550 g/m^2 nonwoven continuous filament polyester GSCs and offers less protection from the elements compared to Option 1.

Option 4: This involves the use of a double row of high strength (200 x 200 kN/m) multi-laminate reinforcement geotextile GSCs (measuring 2.5 x 2m each), filled with imported fill. The construction process then follows that of the previous Options. This option offers the most strength and stability.

For all 4 options, the fill embankment is constructed simultaneously with the GSC structure to the required finished level. The backfill was specified as compacted G5 material.

All four options were reviewed by the client and the relevant authorities and the following was noted:

- Cement stabilization was not an option due to the sensitive nature of the environment
- The client requested the most cost effective solution be implemented

A final attempt to reduce cost produced two alternatives (revised from Option 4):

Option 4.1: A single row of high strength (200 x 200 kN/m) multi-laminate reinforced GSCs wrapped with a high strength (200 x 200 kN/m) multi-laminate reinforcement geotextile tied 4m into the embankment up to a height of 5m, thereafter sloped 6.25m back towards the top of the embankment. This option although cost effective showed a risk of losing back-fill material over the top of the GSCs.

Option 4.2: A single row of high strength (200 x 200 kN/m) multi-laminate reinforced GSCs reinforced with a high strength (200 x 200 kN/m) multi-laminate reinforcement geotextile tied 4m into the embankment up to a height of 8m. Sand was sourced on site and it was decided that this sand was to be used as backfill due to its free draining properties (initially G7).

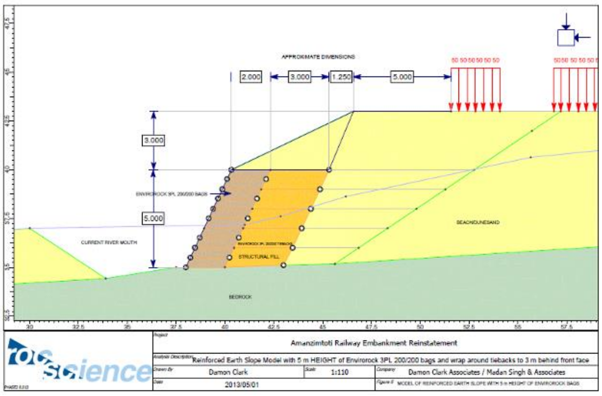

Figure 3: Option 4.1: 200 x 200kN GSC with reinforced tieback into embankment fill to 5m high

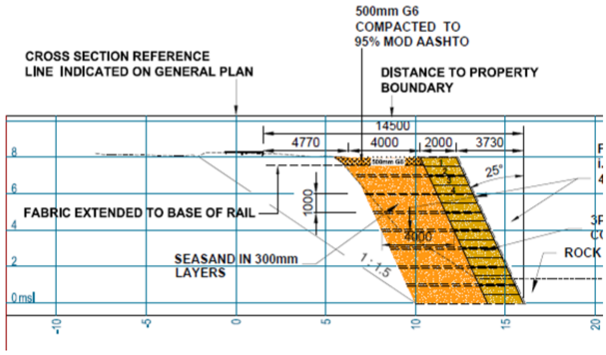

Figure 4: Option 4.2: 200 x 200kN GSC with reinforced tieback into embankment fill to 8m high

Ultimately Option 4.2 was approved as the most cost effective, environmentally friendly, aesthetically pleasing and structurally stable choice.

4 GSC PROPERTIES

The geotextile sand containers (GSCs) are made from a specifically designed and manufactured multi-layered nonwoven, needle-punched, coarse polypropylene staple fibre and continuous filament polyester outer and inner geotextiles reinforced with a high strength composite geotextile. The properties of the geotextile used in this project can be seen in Table 1. This multi-layered geotextile enhances filtration whilst providing puncture and abrasion resistance, as well as reduced elongation and UV degradation. These properties make the product ideal for coastal applications, providing maximum durability in harsh conditions. GSCs are specifically designed for the marine environment with durability, permeability, stability and flexibility providing an excellent solution for constructing sea walls, groynes and revetments [4].

Table 1: Specialist geotextile specification [5]

200kN/m Specialist Geotextile Properties				
Mass		g/m²	1950	SANS 9864:13 / ISO 9864:05
Thickness	Under 2kPa	mm	10	SANS 9863-1:13 / ISO 9863-1:05
Tensile Strength	Machine	kN/m	150	SANS 1525:13 / ISO 10319:08
	Elongation	%	10	
	Across	kN/m	150	
	Elongation	%	10	
Static Puncture	CBR	kN	20	SANS 12236:13 / ISO 12236:06
Peel	Average	N/m	N/A*	ASTM 6496-04a
Through-flow	@100mm head	ℓ/m^2/s	45	SANS 11058:13 / ISO 11058:10
Drop Cone	500mm H	mm	1	SANS 13433:13 / ISO 13433:06
Abrasion Resistance	Strength Retained	%	> 85	BAW Method
UV Resistance	Strength Retained @ 2000hrs	%	> 90	ASTM D 4355
Pore Size		µm	< 75	SANS 12956:13 / ISO 12956:10

5 CONSTRUCTION METHOD

The following methodology was proposed:

5.1. The existing sand bank was breached at the end of the Amanzimtoti River to divert the river access direct to the sea during the construction phase on the north end and south end of the site.
5.2. Berms/groynes for river training were constructed near the shoreline to protect the construction area from sea water flooding during high tide.
5.3. The berm was reconstructed on the solid rock outcrop to divert the river via the most direct route to the sea.
5.4. Existing river access to the stream bed parallel to the rail line was blocked.
5.5. A wall, using GSCs was constructed along the embankment, at the edge of the existing stream position.
5.6. The embankment was a double GSC layer wide and approximately 8 m high from bedrock (at least 1.5 m above the normal high tide level). See Options 1 – 4.
5.7. Backfilling was carried out simultaneously during the GSC construction. The backfill was a G5 material compacted in layers not exceeding 300mm for optimal density purposes.
5.8. GSCs were filled with beach sand by means of a hopper system and hydraulically compacted.
5.9. A wrap-around structure to contain the fill of the embankment was constructed using a high strength (200 x 200 kN/m) multi-laminate reinforcement geotextile in strips wrapped around the GSCs with a 2.0m tie back into the fill area at every second lift, i.e. for every 1m height.
5.10. This method of construction was continued to the underside of the railway layer works.
5.11. The railway layer works was constructed as follows: 300 mm thick G7 compacted material; 200 mm G2 graded stone compacted to 98% Mod AASHTO density; 500 mm railway ballast; sleepers and the rail line to link with the existing lines was completed by the approved service providers from Metrorail.

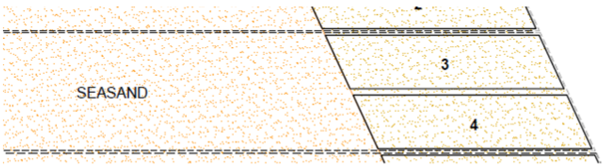

Figure 5: Geotextile Wrapped around two GSCs and tied back into backfill on the upper layer

Figure 6: Completed embankment protection - South Bound

Figure 7 : Completed embankment protection - North Bound

6 CHALLENGES

6.1 Environmental

An Environmental Management Plan was required for the sensitive working environment on the coast and the estuary surrounds. An Environmental Specialist and an Estuarine Specialist were appointed to undertake the task.

Construction in a coastal region near a sensitive environment is very challenging. There are many organizations and various entities that have different objectives and expectations. It proved difficult to satisfy all the parties. The site was under constant surveillance by both the Toti Conservancy and the local Community. The design and construction methods for rehabilitation were carried out according to the Environmental Management Programme to mitigate any negative impact on the Environment.

6.2 Estuary maintenance

Fluctuating levels in the estuary coupled with high tides requiring the North and South bound breach to be constantly maintained throughout the project. In many instances the North bound breach was especially challenging and had to be closed so as to maintain an acceptable water level. The North Bound Breach had to be modified so as to relieve the construction area of excess water.

6.3 Construction with Dune Sand

Sheet piling was initially required to be constructed and used in sections, however due to the dune sand behaviour and the depth that was excavated; sheet piling was constructed throughout most of the length of the slope failure and in certain sections constructed in two rows (upper and lower levels).

Dune sand at the toe of the embankment was excavated to bedrock to accommodate the first row of GSCs and reinforcement geotextile tie backs. This proved to be difficult due to the water levels near the seaside.

7 CONCLUSION

This construction method proved rapid and cost-effective, whilst still being robust enough to withstand future erosion from the river and wave action. Construction of the embankment was completed within the planned time-frame. Filling the GSCs with in-situ beach sand decreased the need for imported materials, thus decreasing beach contamination, transport expenses and carbon emissions. The GSCs and geotextile blend in with the surrounding beach environment and the softer finish is aesthetically pleasing. The resulting embankment solution is environmentally friendly.

The South Bound line returned to service in September 2014, some 11months after construction commenced. In the period since then the reinforced embankment structure has been monitored and little or no settlement or movement is evident.

8 ACKNOWLEDGEMENTS

- Kaytech Engineered Fabrics
- Madan Singh and Associates cc
- Damon Clark Associates

9 REFERENCES

[1] Figure 1 News 24, picture by Netcare911: http://www.news24.com/SouthAfrica/News/Train-plunges-into-river-in-KZN-20121211

[2] National Environmental Management Act 107 of 1998, Section 30 pp.44.

[3] National Environmental Management Act 2010 EIA Regulations GN R543 of 18 June 2010, Listing Notice 1: GN R544, 2: GN R545, 3: GN R546 of same date, pp. 34-38.

[4] Kaytech, Enviro Rock Brochure BR ERSN 0308-03/2011

[5] Kaytech, Enviro Rock 3PL Technical Data Sheet, Ref No. DS COST 0548-07/2014, July 2014.