Geotextile Sand Containers- Erosion Protection in Marine Applications

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Abstract

This paper explores the use of geotextile sand containers (GSCs) as an erosion protection and rehabilitation measure along the coastline of South Africa. GSCs can be manufactured from a multi-layered geosynthetic material, comprising of a nonwoven, needle punched, staple fibre and continuous filament geotextiles with a high strength composite fabric. The GSCs are considered to be a soft solution utilizing in-situ material and eliminating the need for imported material thereby reducing beach contamination. Over the last decade, these GSCs have been installed on different beaches along the KwaZulu-Natal Shoreline from Durban to Richards Bay. In this paper, we look at the performance of these GSCs and assess its durability, through case histories, especially after the recent high spring tides experienced.

Keywords: *Geotextile, Geocontainers, erosion protection, rehabilitation, durability*

1 Introduction

Durban is one of South Africa's prime Coastal Cities located on the east coast of the country. The city experiences warm subtropical weather conditions making it an ideal tourist destination. This coastline has experienced severe weather patterns over the last decade or two which have affected both the environment and the man-made structures.

Over time various studies have shown that autumn is when our coastline experiences the most frequent and amplified wave events. Furthermore, we can attribute storm damage to high waves, long duration storms, elevated sea levels and various other factors. The case histories which we have focused on have occurred during the autumn months (Corbella et al, 2012).

We will look at two case histories which were affected by spring and king tides, when water levels and wave action is higher than the norm. The first case history was impacted by a king tide a phenomenon whereby the gravitational pull on the Earth is at its greatest due to the Moon and Sun being at its closest position to the Earth in a yearly cycle. The second case history involved the spring tide which is a phenomenon that occurs 14 days into the lunar cycle. This is when there is a new or full moon and the gravitational pull of the moon and sun are aligned. Both events are naturally occurring and predictable and can be compounded by poor weather conditions at the time of these events.

2 Erosion protection Solutions

There are two types of solutions offered in marine erosion protection applications. These are known as the “hard” and “soft” solutions. The hard solution is generally rock-filled gabion baskets, whilst the soft solution involves the use of Geosynthetics such as Geotextile Sand Containers (GSCs).

These GSCs are generally made from bi-component nonwoven, needlepunched, staple fibre geotextiles but more recently a specifically designed multi-layered needle punched, nonwoven, staple-fibre and continuous filament geotextiles with a high strength composite fabric core are manufactured, making it a favorable choice in harsh conditions due to its high strength at low strain, durability and robustness. The GSC’s are environmentally friendly providing a soft, aesthetically pleasing finish, having the ability to blend with the existing environment. The use of these GSC’s eliminates the use of hard or sharp materials that may endanger bathers and walkers. In-situ material is used to fill the bags, thus minimizing imported materials and beach contamination. One of the key properties of the GSC’s is that they are easily covered by sand & indigenous vegetation. They are flexible and nest into each other and can be removed if not effective.

3 Geosynthetic Sand Container Characteristics and Method of Installation

3.1 Characteristics

A typical GSC should have the following characteristics; high tensile strength and moderate elongation, resistance to abrasion and UV degradation, high permeability, adequate pore opening sizes and a high interface friction. Other important attributes include; a strong seam stitch and a material which fosters biological marine growth. In order for us to understand how these characteristics function effectively in marine applications, we must understand how the GSC behaves when put to the test.

A good GSC should exhibit good tensile characteristics providing structural stability to the rehabilitation structure. The GSC must comprise of materials that allow for elongation without compromising its strength. A moderate elongation should allow the material to conform under loading thereby limiting installation damage. High elongation GSCs tend to continue to strain under load over time leading to settlement and deformation of the structure. The GSCs are subjected to continuous wave action when placed in the surf zone and intermittent wave action during high tides when placed at the shoreline. If the material does not have sufficient abrasion resistance the design life of the structure will be severely compromised, thereby making the structure ineffective as a long-term solution. The ability of the GSC to allow growth of biological marine substances increases its UV stability and abrasion resistance leading to a longer lifespan of the GSC. Interface friction is important when looking at the stability of the structure; the outer geotextile of the GSC should comprise a coarse fabric that entraps more sand which provides enhanced interface friction. Multi-directional wave action requires the GSC to comprise of a permeable material with adequate pore sizing which retains the fill material whilst facilitating the flow of water through the container. The heavy-duty joint stitching at the seam ensures the GSC’s survivability in aggressive marine applications. Seam strength is substantially enhanced when the multi-layer composite geotextile is first stitched and subsequently overlocked covering both edges in one seam and drizzled with a penetrating glue to add dimensional stability.

3.2 Method of installation

The filling of these GSC's is a crucial part of the installation; the following requirements will facilitate acceptable filling and placement of Geotextile Sand Containers:

- The filling equipment - which is the filling formwork and hopper
- 5-ton lifting slings each 6.0m in length, with a loop on each end large enough to fit over the teeth on the bucket of an excavator. Three slings are required to lift and move a GSC; therefore, a minimum of six lifting slings are required.
- An excavator of appropriate size to load sand and lift sand filled GSC's
- Two 1.0 – 1.5 m lengths of rope or straps to tie the GSC filling spouts around the hopper filling nozzles
- 3 – 4 labourers excluding excavator drivers (with suitable PFE).

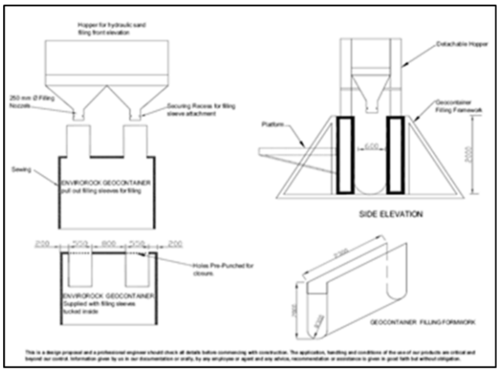

Figure 1: Filling Hopper detail

Method:

Filling of GSC's is carried out using an excavator. The bucket should be large enough to allow for rapid filling of the GSC's but not wider than the filling hopper. The formwork should be suitably positioned where the excavator can easily access sand and water.

The detachable hopper is placed on its side in a clear area next to the filling formwork and the GSC filling spouts are drawn over the hopper nozzles. The GSC filling spouts are then fastened to the hopper nozzles with rope or suitable straps.

The hopper with the GSC attached is then placed on top of the filling formwork so the GSC extends down into it. Prior to this, each of the three lifting slings is draped from the top edge on one side down to the bottom and up the other side, at an even spacing. The position of the lifting straps must be such that they are evenly spaced around the suspended GSC.

A sand and water mix is loading into the hopper at a rate of approximately 2 excavator buckets of sand to 1 excavator bucket of water. In this way the sand is hydraulically compacted into the GSC. All the water drains immediately through and out of the GSC. The alternative method is to use the excavator to load the sand into the hopper while water is continuously pumped into the hopper by pipe.

The ropes tying the GSC filling spouts to the hopper nozzle are then loosened. The hopper is then lifted off the filling formwork and placed in a clear area for the next GSC to be attached.

Each pair of loops on the ends of the 3 lifting slings is then placed around the teeth of the excavator bucket and the GSC is lifted out of the filling formwork. It is important for the lifting straps to be evenly positioned across the GSC when lifting and moving.

The GSC is placed in a holding area where the filling spouts are rolled up, pushed into the GSC and the opening then sewn closed by hand using the polyester rope supplied with the bag. Pre-manufactured holes in the container make the hand sewing an easy operation.

GSCs that are filled according to these guidelines will provide structurally sound solutions for shoreline erosion protection in marine applications.

4 Case histories

In 2005 the Langebaan groyne saw the incorporation of these types of GSCs, for the first time in South Africa; they were installed in a groyne application as an erosion protection measure to help reinstate the eroding beach.

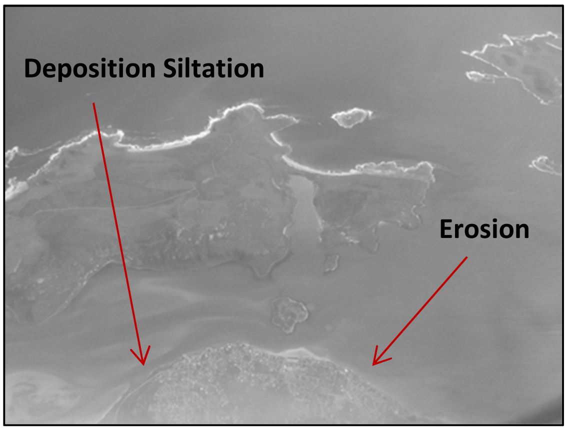

Figure 2: Indication of the erosion and deposition of material


Figure 3: the GSC groyne extending out

Figure 4: 10 months after the construction of the groyne

GSCs have locally become a preferred soft solution since then. In this paper we look at two of the most recent applications in which the GSCs have been installed:

4.1 Case history 1 – Bay of Plenty, Durban Central

The pier at the Bay of Plenty was originally constructed in 1982. In the year 1990 the pier had to be repaired due to excessive scour. The load of the rock fill between the stanchions resulted in some of the piles kicking. The pier was then repaired and had remained stable. However due to heavy storms over the years, more especially the heavy storms in March 2007 and June 2011, the sea bed became severely eroded which resulted in the pier moving by as much as 577mm horizontally (Figure 5). Some of the piles have reached their ultimate state and have failed under compression (Figure 6). Over time the sand and rock levels around the pier had increased resulting in the rip currents changing in direction and surging through the pier (CSCM, 2015).

There were two problems identified at the Bay of Plenty:

1. The moving of the pier and subsequent failure of the piles due to significant erosion of the sea bed at the seaward face. The extent of the scour was measured at up to 8m deep.

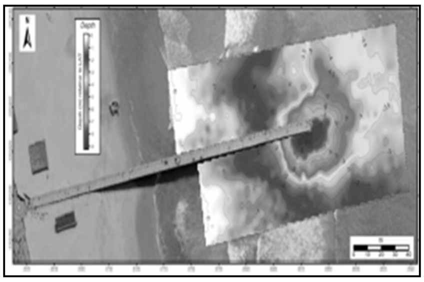

Figure 5: Indicates the severe storms eroding the sea bed resulting in the pier moving (CSCM)

Figure 6: Failure of the piles (CSCM)

2. The second problem was the existing internal rock groyne causing the rip current to pass through the pier, depositing sand within and around the groyne, resulting in an uneven distribution of sand on the beach.

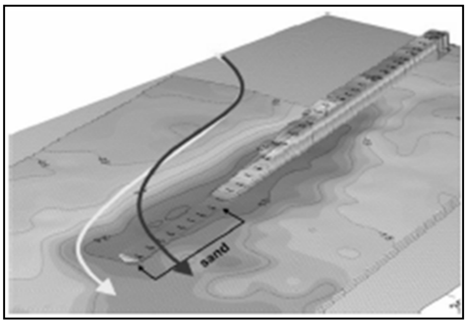

Figure 7: Indicates the current rock and sand levels in and around the pier due to scour. As a result, rip currents have moved from the normal position (lighter arrow) to going through the piers (darker arrow). Maintenance of the pier rock levels will return the rip current to its designed position (lighter arrow). (CSCM)

To alleviate the issue discussed in the first problem the municipality designed a wider concrete deck with deeper piles replacing the old structure thus stabilizing the pier (figure 8). The GSC's where installed within the pier to reinstate the rock groyne to the original design level thus correcting the behavior of the rip current. This was quiet an intricate installation. The GSC's were hydraulically filled as discussed under 'method of installation'. Tidal behavior determined when installation would occur, at low tide the GSC was lowered into the water where a diver would then direct the GSC into position before releasing it.

The engineering approach to reduce and limit further scouring at the seaward face of the pier involved the installation of GSC's. The GSC's where stitched together in a 'mat formation' with 3 bags laid adjacent to one another and placed in front of and along the sides of the newly constructed piles on the sea bed. The purpose of the bags was to provide protection during large storms and alleviated the force of the wave action against the pier, thereby reducing the original 8m scour depth.

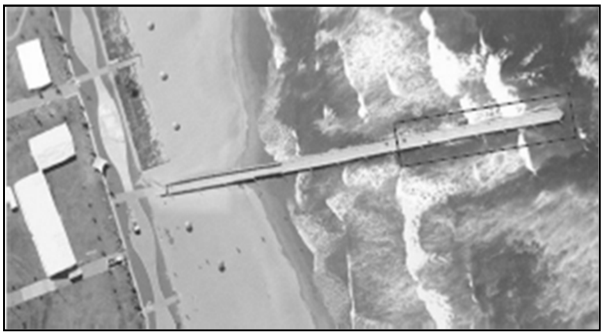

Figure 8: 80m of the seaward deck was removed and replaced by a wider concrete deck (CSCM)

Figure 9: GSC's used to restore the design rip current. (CSCM)

At the Bay of Plenty the GSC's were installed in different applications and resolved two significant problems allowing the rip current to behave as it would normally whilst alleviating the scour in front of the pier.

4.2 Case Study 2 – Dairy Beach, Durban Central

The sand replenishment of the city's central beaches north of uShaka Marine World was anticipated to only take place in the second half of 2015. This was a result of construction delays at the Port's new sand pumping facility. The delay posed a serious problem as the city is reliant on the supply of dredged sand from the Transnet hopper station to the beaches. This lack of sand replenishment, coupled with recent storm surges and heavy wave action resulted in the loss of considerable sand buffer from the beaches. The infrastructure at Durban central beachfront was thus subjected to damage from normal tidal wave run-up and the Municipality was concerned with predictions of a reoccurrence of storm surges and heavy wave action in the autumn season, which could lead to greater damage (Urban Renewal and Engineering Units, 2016).

The Municipality proposed that the GSC's be used to protect the infrastructure and assist in reinstating the sand buffer. The geobags were installed along the promenade protecting it from damage due to heavy wave action and storm surges. GSC's were the only form of barrage defence that was the most viable solution adopted in the wave run-up zones. Environmentally the GSC's behaved in the same manner as previously described under 'erosion protection solutions'. The procedure remains the same for installation, referred to in 'method of installation'.

Figure 10: GSC's during installation

Figure 11: Initial installation of GSC's

In order to prevent undermining scour of the GSC structure, the design engineers implemented a Dutch toe, which is an additional geobag at the toe (Figure 12), this is a common practice used in GSC structures, which ensures its survivability. The GSC must be sized adequately if they are undersized failure would occur at the toe under extreme weather conditions. (Hornsey et al, 2010).

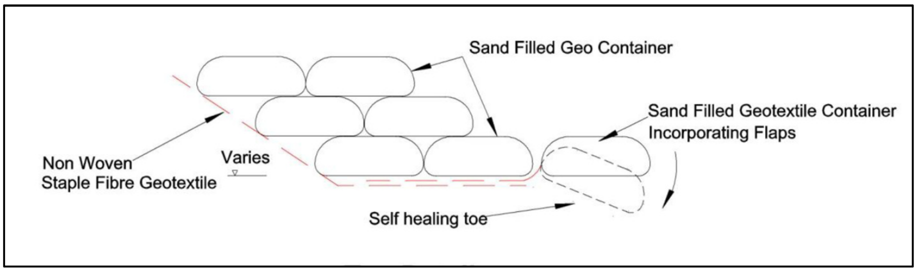

Figure 12: detail of a flexible toe GSC (Hornsey, 2010)

As predicted the erosion protection measure was tested shortly after being installed as the Durban Central Beach Front was subjected to spring tides coupled with a storm surge, which resulted in very high sea swells and harsh wave action crashing against the promenade (figure 13). The section in which the GSCs were installed experienced the least amount of damage. The geobags protected the Promenade and also acted as an energy dissipation breaker to the heavy wave action. This incident clearly highlighted the importance of the properties discussed that enable the GSC to perform well under severe storm conditions. In retrospect the measures that had been used previously, in the form of rip-rap, did not perform as well as the GSCs. The old rip-rap is evident in Figure 10.

Figure 13: High Sea swells up against the recently installed GSCs

5 Conclusion

GSCs have become an environmentally preferred 'soft' solution in shoreline erosion rehabilitation and control. In order to understand the success of these GSCs in these applications, it is need to compare them to the alternative that would have been implemented or the damage that could have occurred had the problem not been remediated properly.

In case history 1, there were two issues highlighted; the rock groyne which needed to be reinstated and the scour depth at the seaward face. Reinstatement of the rock groyne would call for large quantities of rock fill material to be hauled to the beach front in major construction vehicles, this would then need to be placed by large machinery within the void between the piles, making it nearly impossible to construct and thus proving to be uneconomical. However, if one could install the rock fill, there would still be other issues to consider. The initial rock groyne was designed to be a low level groyne and became ineffective due to settlement. This was attributed to the density of the rock being greater than the density of the in-situ beach sand in a totally saturated environment, coupled with the angular shape of the rock causing the material to settle within itself between the voids, which may have been accelerated by continuous wave action. Installing GSCs with the in-situ fill material having the same density as the sea bed material meant the settlement due to dead weight loading would be far less than the rock structure. Hydraulic compaction of the GSC infill leads to a more stable structure.

In case history 2, without the GSCs providing protection to the promenade the concrete coping structures and paving would have been severely damaged. Due to the same reasons given in case history 1, the use of inadequately sized rip-rap may have still lead to placement of material and ultimate damage to the Promenade. Besides the large sized rip-rap 'hard' solution is unsightly and a safety hazard. Once again the use of GSCs provided an environmentally friendly 'soft' solution eradicating the need for haulage of large rock fill quantities which over time settle into the saturated sand bed and lose their integrity as a defense wall.

As a workable, practical solution that provides effective erosion control with little to no impact on the environment or safety of beachgoers, the GSCs have proven to be most suitable. The ability of the GSC to adapt to the environment makes for a seamless integration between the beach rehabilitation structure and the natural environment.

6 Acknowledgements

We would like to extend our thanks to Mr. Godfrey Vella from the Coastal, Stormwater and Catchment Management Department at eThekwini Municipality, for his contribution on both case histories. Mr. Sugan Venketraju of the Urban Renewal and Engineering Unit at eThekwini Municipality for his contribution to the Dairy Beach Case History and not forgetting Mr. Garth James ,the Technical Director at Kaytech for his invaluable input.

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