The Growth And Development Of Geosynthetic Solutions For Coastal Erosion Repairs In South Africa.

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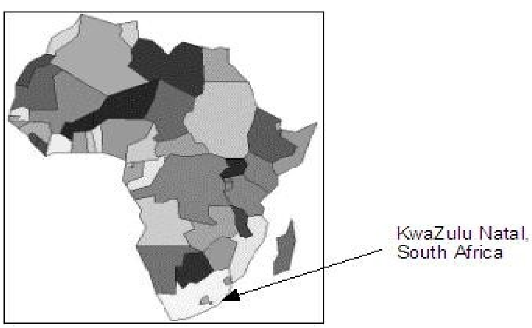
ABSTRACT

The South African coast experiences harsh marine conditions, providing an ideal opportunity to evaluate the performance of geosynthetic “soft engineering” solutions. Recent exceptional storms, increased development along the coastal buffer zone and the implementation of the new Integrated Coastal Management Bill (DEAT 2006), resulted in a conflict of interests between affected parties and authorities as to acceptable methods of repair. Lessons learned from previous failures of low cost emergency repair systems, from accelerated adjacent downstream erosion caused by the installation of hard structures and from the importance of retaining the natural vegetation cover, provided the opportunity for the growth and development of geosynthetic solutions for coastal erosion repairs. This paper records a recent major storm, highlights public uncertainties, explains why only certain types of structure were permitted, details various methods of repair that were installed and evaluates their performance. Each repair technique is affirmed with a case history.

1.0 INTRODUCTION

In March 2007 adverse sea conditions along the coast of KZN resulted in extensive beach erosion and damage to property. Economics, speed of installation and environmental legislation constraints resulted in the development of innovative geosynthetic methods of repair. The damage occurring between 19 and 22 March 2007 required immediate action. At this time geosynthetics were available ex stock and bags could be manufactured at short notice. The benefits of various forms of sand-filled geocontainers were immediately realised and implemented. Large geocontainers had been previously used by a local authority and were specified at a number of municipal locations. In domestic applications, site access, limited experience of contractors and economics lead to the development of smaller systems. Where failure had occurred to concrete block retaining structures, the design was revisited and improved to prevent future failures.



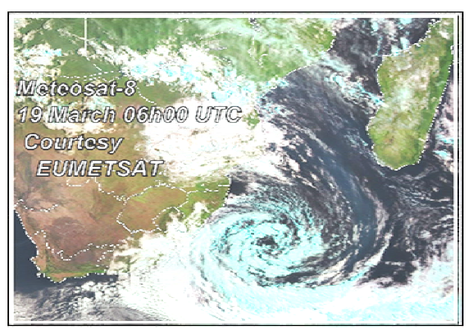


Figure 1 - Locality map of KwaZulu Natal. Figure 2 - A satellite image of the storm on 19 March 2007

1.1 Meteorological and Oceanographical Background

Erosion to the KZN coastline during March 2007 was compounded by a number of factors. In early March Cyclone Gamede, situated South of Madagascar, resulted in a prolonged period of 2 to 4m swells from an easterly direction. This caused some flooding to Durban’s lower beachfront when these swells coincided with spring high tides on 3 to 4 March 2007. Beachfront shop owners had to install small temporary sandbags to protect their properties. A fortnight later, on 18 to 20 March, a semi-stationary, cut-off low formed some 700km to the southeast of Durban (figure 2). This cut-off low, with a central pressure that dropped below 996 hPa, produced very high coastal SW wind, with speeds in excess of 40 knots recorded along the coast. This, in combination with a 450km fetch distance, caused the alongshore wind to produce a significant onshore swell, direction of SSE-SE. Wave heights of 8.5 m and a peak wave height of 14 m were recorded at the Richards Bay wave rider buoy (CSIR), 150 km north of Durban. Storm surge was the main contributing factor to the extent of coastal erosion damage. The storm inflated the highest tide to 2.84m Tidal Chart Datum (CD), the lowest predicted tide within a 19 year cycle, but it was the wind set-up, wave set-up and wave run-up effects that were measured to a height of approximately 8.0m CD. The peak vernal (March 21) equinoctial new moon spring high tide of the saros (18.6 year) tidal cycle also provided a minor contribution of a 2.24 m CD, as opposed to the average 1.8m CD.

Figure 3 - Map of KwaZulu Natal shoreline.

1.2 Extent of Damage

An estimated 4 million cubic metres of sand was lost off the visible beach and damage of approximately R400 million was incurred. Areas damaged can be divided into municipal infrastructure, provincial government infrastructure and private property. Immediate clean up and repair to critical services was undertaken by authorities, this included roads, car parks, sewer pipelines etc. Some municipalities were not able to rearrange their own budgets to fund repairs and appealed to National Government to declare a disaster area with the hope of receiving national funding. Three months later still no disaster had been declared and with no monies forthcoming, the affected areas lay in a state of disrepair.

Figure 4 - Rough seas at Ballito on 20-03-2007. Figure 5 - Some damage that occurred

Although this storm was unusual it was not unique. A number of similar storms that produced significant swells have been recorded. The devastation caused has been attributed to the current coastal building boom, where construction has been permitted too close to the High Water Mark (HWM).

1.3 The South African Coastal Management Legislation

On 15 December 2006 the new Integrated Coastal Management Bill (DEAT 2006) was gazetted for comment. The proposed Bill replaces the former Sea-Shore Act of 1935. It declares all seashore, territorial seas and tidal estuaries as coastal public property. Section 14 of the new Bill states that if the high-water mark moves inland due to sea-level rise or coastal erosion, the landowner loses ownership of the land below the new high-water mark and is not entitled to any compensation for this loss. Section 65 of the Bill also states that any construction activity within the coastal public zone cannot commence without a coastal use permit. Failure to comply could result in a fine of up to R 5 Million or ten years imprisonment. The National Environmental Management Act of 1998 (NEMA) Section 30 application, for permission for temporary construction work, was adopted in emergency situations to speed up the application process for a coastal use permit. Geosynthetic temporary erosion defence structures were accepted under the NEMA Section 30 permit as they can be easily removed.

2.0 GEOSYNTHETIC SOLUTIONS

Both "soft" and "hard" finish geosynthetic solutions were offered. Two applications were identified: short-term temporary/emergency repairs comprising of "soft finish" solutions only; and long-term final solutions that comprised both "soft" and "hard" finishes. The preferred short-term temporary/emergency "soft" finish solutions, included PVC coated 1.0 m by 1.0 m by "length" gabion baskets lined with a geotextile bag filled with compacted beach sand. The principal benefits of this solution are the low cost, the speed of installation and the "soft" aesthetically pleasing finish achieved. Gabions filled with 70kg sand bags were used in areas where a more permanent structure was required. Large sand filled bags, weighing 3.5 to 4.0 tonnes, were placed in beach areas where a longer-term solution was required. Because of cost constraints, hard structures such as Waterloffel® wave action erosion control concrete block dry-stack sea walls were only installed where these walls had previously existed.

2.1 Geotextile Properties

Exposed geotextiles used in direct contact with marine wave action are subjected to aggressive conditions. Tables 1 and 2 present specifications for geotextiles that have been successfully used in marine applications.

2.1.1 Abrasion Resistance

Geotextiles placed within the surf zone are subjected to harsh abrasive conditions with constant wave action. Constant movement of sand particles and the drawdown effects of receding waves are particularly aggressive. 75 % strength retention after 80,000 rotations of the German BAW rotating drum abrasion resistance test is recommended. (Saathoff, et al. 2003).

Table 1, Exposed geotextiles properties for marine conditions

Property		Unit	Test Method	Grade 1	Grade 2	Grade 3
Dense, staple-fibre, nonwoven, polypropylene						
Mass		g/m2	EN ISO 9864	500	1200	2000
Thickness at 2 kPa		mm	EN ISO 9863-01	3.2	8	12
Tensile	Strength	kN/m	EN ISO 10319-1996	30	75	35
	Elongation	%		65	65	70
UV resistance		%	AS3706.11			
Abrasion resistance		%	BAW P200 6091	77.5		97
Pore size		mm	EN ISO 12956	70	60	<75
Flow rate		l/s/m2	EN ISO 11058-1999	45	15	30
Penetration load (CBR)		kN	EN ISO 12236-1996	5.2	14	
Puncture resistance		mm	EN ISO 918-1996	9		2.5

Table 2, Non-exposed geotextiles

Property		Units	Test Method	Grade 4	Grade 5	Grade 6
Continuous-filament, nonwoven needle-punched polyester						
Thickness	Thickness under 2 kPa	mm	EN ISO 9864	2.6	2.7	6.1
Tensile Strength	Machine	kN/m		16.5	29.1	63.1
	Across	kN/m	EN ISO 10319	14.3	23.6	60.8
	Elongation	%		40 - 60		
Penetration Load	CBR	kN	EN ISO 12236	3.6	4.7	12.5
Puncture Resistance	Dia. of hole	mm	EN ISO 918-1996	18	16	7
Throughflow	@ 100 mm head	l/s/m2	EN ISO 11058	103	73	28
Pore Size	O95 H	µm	NF.G 38017	125	100	35

2.1.2 Geotextile Strength

The geotextile must have sufficient strength to survive installation, storm conditions and have a degree of resistance to vandalism. The recommended index tests include EN ISO 10319-1996 (tensile strength); EN ISO 12236-1996 (CBR penetration) and EN ISO 918-1996 (puncture resistance) as these best represent the minimum survivability strength requirements. The bi-component geotextile used for geocontainer manufacture captures a percentage of sand within the coarse outer layer. This provides added resistance against degradation and damage.

2.1.3 Geotextile Elongation

A geotextile with a wide strip elongation of greater than 50% (EN ISO 10319-1996) limits installation damage and provides flexibility to the structure. High elongation, flexible structures are self-healing, preventing loss of sand between units (Saathoff et al. 2003).

2.1.4 Geotextile Pore Opening Size

It is critical that the geotextile retain sufficient fill material to ensure the stability of the structure under regular multi-directional flow conditions. The NF.G 38.C17 German BAW turbulence hydrodynamic test is conducted to assess the fines retention capability of the geotextile under dynamic flow conditions. (Saathoff et al. 2003).

2.1.5 Ultra Violet Resistance

It is essential that the geotextile have appropriate resistance to UV degradation, as it may remain exposed for considerable periods. The test method used is the Australian Standard AS3706.11 Xenon Arc Weatherometer. 80 % strength retention is recommended for a minimum lifetime of 10 years.

2.1.6 Geotextile Permeability

The stability of the structure is dependant on the speed at which the geotextile is able to absorb and release water. The containment geotextile must have a permeability of 10 to 100 times the retained fill material to provide a factor of safety. The EN ISO 11058-1999 permeability test, measured in litres per second per square metres under 100mm head is recommended.

3.0 APPLICATIONS

3.1 Sand-filled Geotextile Bags in Gabions

Two types of sand bag were used. The first solution consisted of PVC coated 1.0 m by 1.0 m by “length” gabion baskets lined with a 1.0 m by 1.0 m by 1.0 m combination geotextile bags in each diaphragm compartment and filled with compacted beach sand (figure 6). The geotextile bags were manufactured using two different types of geotextile. The exposed faces (lid and front, or lid, front and sides for corner units) were made from a grade 1 (ref Table 1) UV and abrasion-resistant staple fibre geotextile (Table 1). The non-exposed areas were made with a grade 5 geotextile (Table 2). Bags were supplied with the seam facing into the bag to protect the sewing thread from abrasion and UV attack. A 500mm

Figure 6 – 1.0 m by 1.0 m by 1.0 m gabion bag sample. Figure 7 - Gabion bags protecting slipway.

flap was extended to the back and sides to ensure closure to the lid. The grade 1 UV and abrasion resistant staple fibre geotextile of the exposed surfaces was supplied in beige to blend with the natural colour of the dunes. The bags were made from a combination of these two different geotextiles to cut costs. Formwork was applied to the baskets prior to filling to ensure closure of the gabion lid and a neat final appearance. Formwork is essential, as wire tie bracing within the baskets should only be installed between side diaphragms. Wire bracing ties should not be installed from front to back, as this would require holes to be made through the exposed geotextile. Wave action may lead to sand loss at such locations. Omitting the formwork would result in the baskets becoming oval in shape during compaction of the sand making it extremely difficult to close the gabion lid. Compaction of the sand fill was achieved using water. This system using 1.0 m by 1.0 m by 1.0 m gabion bags was only promoted for emergency/temporary repairs. It was limited to areas that, under normal conditions, were not exposed to constant wave action during high spring tides. The areas where this system was used were generally covered with sand and well above the high tide level. The reason for this was to prevent any washout of sand, as the bags are not sewn closed along the lid. Any damage to this lighter geotextile or sand washout from the lid closure flaps would lead to collapse and failure of the system.

Figures 8 and 9 – 1.0 m by 1.0 m by 1.0 m gabion bag underpinning to seawall at Ansteys Beach , Bluff.

3.1.1 Case History 1:

Protection to the promenade and surf lifesavers clubhouse at Ansteys Beach was undertaken as a pilot project. A double row height of 1.0 m by 1.0 m by 1.0 m sandbag gabion baskets was installed directly in front of a concrete seawall to prevent loss of sand from under the promenade (figure 8 and 9). The system was adopted elsewhere, such as this slipway damage repair shown in Figure 7.

3.1.2 Case History 2:

At Santorini, a private development in Ballito, a 2.0 m high vertical sand-filled gabion basket wall was constructed directly under the exposed building foundations. A single line of gabion baskets was placed in the high tide zone as temporary protection for construction repairs (figure 10 and 11). As vertical gabions in the tidal zone produce rebounded waves, which result in further erosion and are a danger to beach users, these baskets were set back at an angle. Wave run-up energy was dissipated upwards while transported sediment was deposited directly in front of the line of gabions. The wave sediment deposition process quickly buried the structure. Due to its proven effectiveness, this system was continued in front of the remaining eroded beach at Santorini.

Figures 10 and 11: 1.0 m by 1.0 m by 1.0 m gabion bag temporary defence barrier at Santorini, Ballito.

3.2 Small 70kg Geocontainer Sand Bags (800 mm by 500 mm)

Small 70 kg sand bags installed within 0.5 m high gabion boxes were used where the gabion systems were installed in the intertidal zone. The geotextile bags were made entirely from 500 g/m2 UV and abrasion resistant staple fibre geotextile. Bags are 0.8 m by 0.5 m and measure 0.5 m by 0.5 m by 0.2 m when filled. Closure is effected using a large cable tie. 12 bags were installed per 1.0 m by 1.0 m by 0.5 m PVC gabion basket. All bags were placed with the bag closure facing away from the exposed face. The bags weigh approximately 70kg each when full, making manageable handling. Bags were supplied with the seam facing into the bag to protect the sewing thread from abrasion and UV. The face of the bags and the 0.5 m stepped gabions provide a broken face that absorbs energy and limits wave rebound. Dynamic forces from impacting waves would cause the rocks in typical gabions to move and damage the coated wires. Sand-filled geocontainer bags eliminate this problem. Where high steep structures were required, a tieback geogrid was installed between gabion baskets for global stability. The 70 kg bags were also used for all PVC Reno mattress foundations in combination with the gabion basket system. Grade 4 geotextile was installed behind all gabions and under all Reno mattresses to prevent wash out of sand.

Case History: Ballito Manor, Ballito.

Occupation of the newly constructed Ballito Manor was halted after erosion along the side exposed to the sea (figure 12). Installation: Shallow bedrock was exposed and a doweled concrete foundation cast directly in front of a replaced municipal sewer line. Specially manufactured 0,5 m high uPVC coated Class A galvanised mild steel wire reinforced gabion units, called Green Terramesh® were placed to

Figures 12 to 15 – 70 kg gabion bag defence wall at Ballito Manor.

3.5 m height from bedrock level. Wire reinforced units consist of an integral tieback, which strengthens the backfill material, simultaneously keeping the unit in place and providing a face to resist wave attack. The wire reinforced units were offset 0,5 m, with every 0,5 m lift to provide greater stability and dampen the effect of wave run up. 0.8 m by 0.5 m geocontainer sand bags were used inside the wire reinforced units in place of traditional rock fill. The use of 0.8 m by 0.8 m geocontainer sand bags offered a "soft finish" in line with environmental constraints and provide greater protection to the uPVC coated wires (figures 13 and 14). The final structure was 56 m long by 3.5 m height, consisting of 5 500 by 0.8 m by 0.8 m geocontainer sand bags in 230 wire reinforced units of 3.0 m by 0.5 m by 1.0 m. 1 000 m2 of a 60/30 kN geogrid was also installed under every second wire reinforced unit with a 4.0 m tieback length. The contract took 13 weeks to complete (figure 15).

3.3 Geocontainers

Grade 3 geotextile geocontainers are manufactured from a bi-component geotextile consisting of an inner layer that provides high tensile strength, filtration and good containment of the sand inside the bag and a beige outer layer that provides robustness, durability, abrasion resistance and UV resistance. The mass of the geocontainer geotextile is approximately 2.0 kg/m2. The bags are sewn with a specialized heavy-duty double stitching, leaving two openings for filling spigots. The bag size laid flat is 2.5 m x 2.0 m. The bags are hydraulically filled with beach sand and weigh 3.5 to 4.0 tonnes when filled and 0.5 m to 0.6 m thick. The first large scale usage of grade 3 geotextile geocontainers in South Africa was at Langebaan Lagoon in the Cape Province in 2004 when a 250 m groin was built perpendicular to the shore to limit erosion caused by strong alongshore currents.

Engineers from Ethekwini Municipality (Durban) visited the site in 2005 and noted the benefits of the system. The Ethekwini Municipality as shore protection to a yacht basin first used grade 3 geotextile geocontainers during a dredging contract. The geocontainers were filled off site, loaded onto a flatbed truck and transported to site because of the limited working area at the site. The geocontainers were placed by crane directly off the truck (figure 16).

Figure 16 – Transporting of 4 ton geocontainers. Figure 17 - Geocontainers in a stretcher bond pattern.

In 2006, coastal erosion occurred at Eastmoor Crescent, La Lucia, a suburb of Ethekwini Municipality. The Municipality installed geocontainers to protect an outfall pipeline. Residents were informed that coastal erosion repair to private properties was the responsibility of the owners, and that authorities would only accept a soft solution repair technique. One property owner opted to install grade 3 geotextile

Figure 18 – Commercial formwork filling rig. Figure 19 - Hand-filling in a wood formwork rig.

geocontainers, five bags high across the full width of his property, which were effective against the storm in March 2007. Ethekwini Municipality decided to install the system along South Beach Road, Umdloti. Experience gained while transporting the geocontainers by truck proved useful, as it was more efficient to fill the geocontainers at one location and transport them by road to the furthest position on site. Geocontainers were placed in a stretcher bond technique, averaging 3 rows high and along 1.4 km of unprotected beach (figure 17). The natural beige colour and soft finish blended into the sandy shoreline. The geocontainers have protected the road from subsequent rough seas and high tides. The system of filling the geocontainers at another location and transporting by road has proved very useful for a number of small emergency repairs, where establishment of a filling station was not a viable option. Geocontainers were filled at Umdloti and transported to La Mercy, Umhlanga and Amanzimtoti, (70 km away). The conventional method of filling geocontainers is to use steel formwork as shown figure 18. Some contractors simplified the filling formwork technique by utilizing standard wooded boards and gum poles and filling the geocontainers by hand (figure 19). To speed up the filling process geocontainers were removed from the formwork and stockpiled before sewing the gussets closed (figure 20). This enabled the contractors to effectively fill a maximum number of geocontainers with one filling rig. Once standard geocontainers have been placed the usual method of relocation is achieved by lifting the end of the geocontainer with excavator bucket. To prevent damage to the geocontainer the operator will scoop sand under the geocontainer so that a layer of sand is trapped between the geocontainer and the excavator bucket. Lifting straps are then slipped under the geocontainer and the process is repeated on the opposite end of the geocontainer. Proposals from a local authority led to the development of looped strapping handles sewn into the four corners of the geocontainer (figure 21). The advantage of the handles is that geocontainers placed on top of each other can be lifted using the handles, strapping placed underneath and relocated. Prefilled bags with loop straps can be stockpiled for use in emergency situations. The geocontainers can also be tied together to prevent slippage between geocontainers.

Figure 20 – Stockpiling geocontainers for closure to filling spouts. Figure 21 - Loop handles on geocontainer corners

3.3.1 Case history: Happy Wanderers Resort, Kelso, KZN South Coast

Happy Wanderers resort, near Kelso on the KZN south coast was largely unaffected by the March storm. However, it appeared to have removed sand reserves from underwater, which resulted in the erosion of the beach during winter storms in July 2007. Large woven bulk bags were placed as emergency protection in an attempt to prevent further erosion and damage to the resort buildings. The bulk bags had little effect and the owner had to obtain another option quickly. By coincidence a contractor experienced in installing geocontainers was busy with an earthworks contract on the adjacent property. 3 geotextile geocontainers were proposed as a quick, effective solution. Grade 3 geotextile geocontainers were filled at a river mouth located on the northern boundary and immediately installed. Speed of installation was critical and despite some manufacturing and installation delays, 7 rows of geocontainers by 300m were installed in one month, thereby protecting the existing accommodation apartments. In September the contractor returned to site for a week to add a further 4 rows of geocontainers onto a 100m section where further erosion had caused some subsidence. The approximate total cost of the project was \$ 390 000. (figures 22 to 25)

3.4 Geocontainer Sausage Bags

The first local installation was on Bazaruto Island off Mozambique after extensive coastal damage caused by Cyclone Japhet in 2003. The technique used was labour-intensive. The system was founded at low spring tide level and constructed in 0.5 m lifts, 5 rows high to a total height of 2.5 m. Vertical formwork was placed along the front face and the geotextile placed overlapping the formwork. 0.5 m of beach sand was placed and compacted. The sand fill was then cut back by hand to a 30° front slope and completely enclosed by the geotextile. The next layer was continued. A similar process was

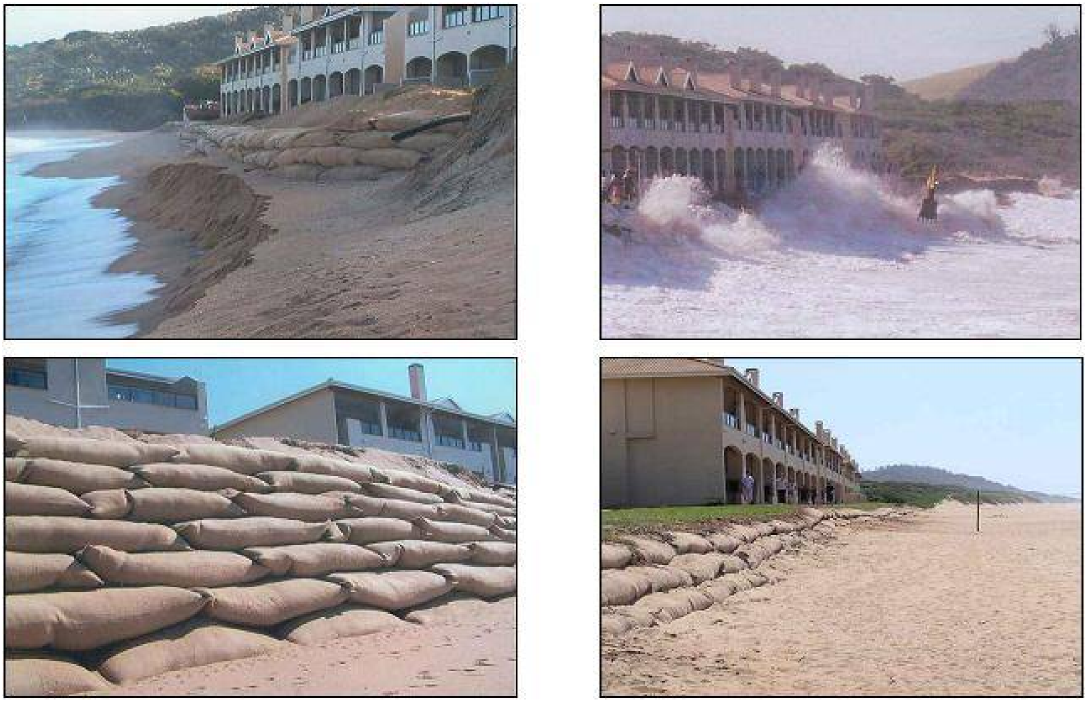


Figure 22 to 25 – Geocontainers placed in front of Happy Wanderers beach resort

followed at St Michaels-on-Sea based on the experienced gained on Bazaruto Island. The geotextile specified was a low-cost, 210 g/m2 nonwoven continuous filament spunbond polyester geotextile based on the assumption that an event of this magnitude is unlikely in the near future and that an immediate economical solution was required.

3.4.1 Case history: 33 Little Maritzburg Road, Ballito.

This geocontainer sausage bag technique was used for a domestic application in Ballito, where access to the beach was limited (figure 26). The design consisted of a sand bag filled gabion and Reno mattress foundation with 12 wrapped geosynthetic layers above. 70 kg sand bags were filled and stockpiled above the high water level. 1.0 m by 1.0 m PVC coated gabion baskets and 0.3 m deep by 6.0 m wide Reno mattresses were assembled ready for use on an adjacent property. The foundation was excavated using a backactor and limited to low tide and calm sea conditions. A single row of Gabions filled with approximately twenty, 70 kg bags per m3 was installed along the front toe of the Reno mattress. Rapid construction was required as the excavation readily collapsed and each day's completed work was buried by sand during the next high tide. Once the gabion toe structure was in place, the 6.0 m wide Reno foundation was installed and filled with 70 kg bags. Once the gabion/Reno mattress foundation/scour protection toe was in place construction of the 2.5 m wide by 0.5 m high grade 3 geotextile panels commenced. The bi-component grade 3 geotextile is supplied in a maximum of 4.0 m width, so panels had to be manufactured (sewn) to 6.5 m wide. Manufacturing limitations and difficulty of handling resulted in the supply of a maximum of 10m long panels. 10 m long panels were then joined using two 40 mm by 5 mm PVC strips, bolted to the inside of a volcano type joint using 8 mm class 316 stainless steel bolts at 100 mm centres. A 350 mm by 100 mm deep anchor/key trench was excavated in the middle of the placed compacted sand infill parallel to the front face of the wall. The key limits lateral sliding of geotextile upon geotextile and maximises tension in the front exposed face. Five rows 0.5 m high were installed, including two rows of Manta Ray ground anchors at 2.0 m centres. The remaining wrap systems were completed in a similar fashion with a 1 200 g/m^2 UV resistant high quality staple fibre geotextile (figures 27 and 28). The final layer was stabilised with cement. A reinforced concrete foundation was installed above, followed by a 1.2 m high dry stack retaining wall on the boundary. By the time construction had reached the top of the upper wrap system level a considerable quantity of sand had returned, burying the bulk of the work. The project took four months to complete at a cost of approximately $ 140 000 (figure 29).

Figure 26 to 29 – Installation of geocontainer fabric sausage bags at 33 Little Maritzburg Road, Ballito.

3.5 Concrete Block Dry-Stack Seawalls

The reconstruction of dry-stack interlocking concrete block seawalls was only permitted where such walls had previously existed. Concrete block walls were damaged or destroyed where storm surge wave run-up had either over-topped or eroded around the ends of walls. This resulted in the wash out of sand from behind the wall and subsequent collapse. These specialised concrete blocks have a divided compartment system to prevent washout of19 mm stone and maximise stability during periods of rapid drawdown of water. 19 mm stone is placed in the back compartment and to 0.3 m deep behind the blocks. A 60 kN by 10% elongation geogrid reinforcement was placed every fourth row with a tie back length of 0.7 by the vertical height of the wall. To prevent similar washout damage from re-occurring grade 5 geotextile (ref Table 2) was installed in a 0.45 m high by 2.4 m wide wrapped technique. The concrete blocks were founded on a concrete foundation on bedrock. 0.15 m diameter weep holes were installed at 1.5 m centres in the concrete foundation (figures 31 and 32).

3.5.1 Case history: Bronze Beach sewer pump station, Umhlanga.

The Umhlanga promenade and pump station protection seawall was destroyed during the March 2007 storm when waves overtopped the wall and eroded the sand backfill. Immediate remedial action was required. The wall was reconstructed with the technique described above. Where the wall terminated, large 2.5 m by 2.0 m geocontainers were installed behind the concrete block to prevent any future

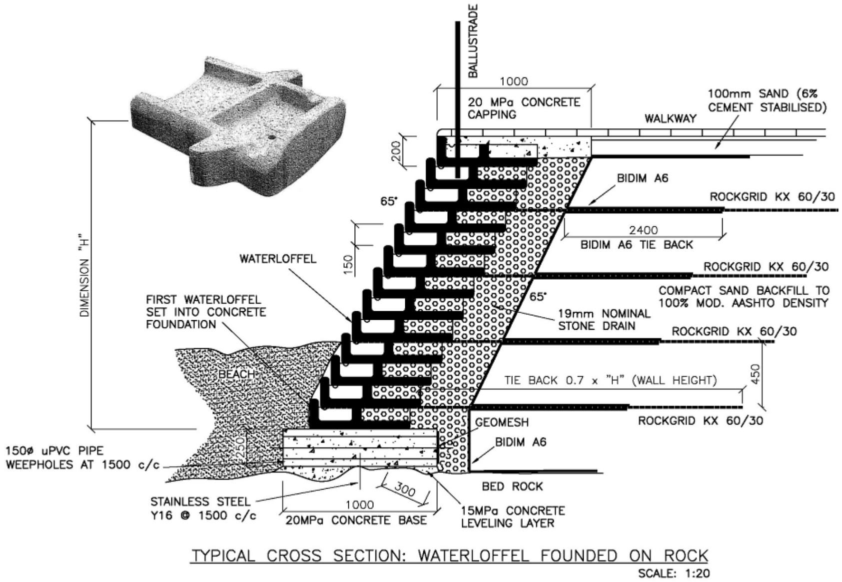


Figure 30 – Typical section of a concrete block dry-stack seawall.

erosion at the ends. The geocontainers were manufactured with grade 6 geotextile (ref Table 2) as is not exposed. Phase 1 and 2 cost approximately $ 4.3 million, for 520 m by 5.63 m high on concrete block wall

Figure 31 – A concrete block dry-stack seawall under construction. Figure 32 - Completed sea wall.

and included geocontainers for 300 m by 11 rows high and other infrastructure.

4. Conclusions

Most geosynthetic methods of repair were installed as an emergency, with little time to investigate designs in depth. Neighbouring private land owners were often reluctant to implement protection methods as permitted by authorities, which resulted in increased costs for willing land owners and lead to delays in construction and further damage. The gabion bag technique is ideal for emergency short-term applications where site access is restricted. The 1.0 m by 1.0 m by 1.0 m tilted gabion basket technique worked well as a temporary protective structure and was successfully adopted at a few sites. Lessons learned with geocontainers included modification to include corner lifting loops, hand-filling using simplified formwork techniques and filling off site. It is now possible for authorities to fill and stockpile geocontainers for future emergency applications. Geocontainers have proved particularly useful where homeowners have required immediate action and had geocontainers installed, followed by section 30 applications. As soft solutions are classed as a preferred finish there is no objection to accepting geocontainers as the permanent solution at a later date. This works favourably for the homeowner as insurance companies have made it clear that they will not pay a second time should the homeowner be instructed to remove the intervention. It was recommended that all soft engineering geosynthetic structures were covered and vegetated to provide maximum protection from ultra-violet light and vandalism (figure 33 and 34).

Figure 33 – Buried gabion bag structure at Brighton Beach. Figure 34 - Buried geocontainer wall with jute erosion control matting and vegetation cover.

The improved reinforced concrete block system as per Figure 30 was adopted to increase the factor of safety to this expensive walling system.

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