

# GEOTEXTILES IN SPECIALIST MARINE APPLICATIONS: AN AUSTRALIA PERSPECTIVE OVER 32 YEARS

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## ABSTRACT

Geotextiles were first applied into civil construction projects in the 1960s in the USA and Europe in drainage and separation applications for road construction. The technology rapidly developed from that point onwards with the First International Conference on Geotextiles held in Paris in 1977. Due to the need for greater knowledge and understanding of the material, the International Geosynthetics Society (IGS) founded in 1982 has subsequently organized a worldwide conference every four years and its numerous chapters have additional conferences.

The use of geotextiles has now grown to such an extent that virtually every civil construction project undertaken includes a geosynthetic of some description. The marine and coastal environment is an extremely harsh environment to use what is a relatively thin light weight material, where the geotextile will be subjected to abrasion from armour rock and marine sediment, large dynamic flow conditions from both tidal action and wave impact. As such, geotextiles used in coastal and marine must be able to withstand conditions which are far more aggressive than the original road construction applications.

This paper highlights four significant coastal/marine projects which have contributed to development and understanding of use of geotextiles in the coastal and marine environment in Australia over the past 32 years.

## 1 INTRODUCTION

The use of geotextiles began in Australia in the early 1970s with existing weaving companies such as Amoco and Sarlon producing woven geotextiles for road construction applications with nonwoven geotextiles first imported around 1978. The first plant developed specifically for the manufacture (Soil Filters Australia) of geotextiles alone was opened in 1984 on the Gold Coast. A standardised approach to the selection of geotextiles for various applications in road construction was adopted by the New South Wales and Queensland road authorities in 1997, however, there is no such tool for coastal and marine structures. Designers must therefore rely on past experience or field trials to ascertain the suitable grade to be installed.

The primary use of geotextiles in coastal and marine applications is currently in filtration applications under rock armour where the geotextile is used to retain or contain fine material which would otherwise be eroded away due to wave and tidal action. A new trend has now emerged where geotextiles form the main component of the marine structure, i.e. sand filled geotextile tubes and containers. These structures are pushing the boundaries with regard to geotextile durability.

As with all new technology, the question of long term performance and durability of the material can be difficult to estimate when there are few or no real world applications to base any assumptions on. This paper will report on four projects which have each aided in enhancing our understanding of the durability and performance of geotextiles in coastal and marine environments. The choice of projects selected was based on what would be considered unique attributes for the time, details are as follows:

- 1979 Port Kembla Coal Loader Sea Wall
- 1999 Narrowneck Reef, Gold Coast
- 2003 Fishermans Island Sea Wall, Port of Brisbane
- 2004 Limeburners Breakwater, Port Phillip Bay

This paper describes the design, construction techniques and the performance of the structure to date for each project.

## 2 PORT KEMBLA (1979)

In 1979 the NSW Government constructed a new coal loader at Port Kembla near Wollongong. In order to provide additional land for coal stockpiles it was necessary to construct a 1200 m long by 13 m high seawall and reclaim the land behind the wall. The seawall would form an integral part of the new coal loader, containing a roadway and rail stackers servicing half of the total stockpile area. Failure of the seawall would not only lead to extensive damage to the facility, but more importantly, reduce the coal export capacity of the facility.

The seawall was constructed within the surf zone, which posed some construction and quality control problems particularly if the traditional graded filter option was used in the design. There were two key points which made this project unique: a) The replacement of the thick granular filter layer by a geotextile is such a critical application (Figure 1) and b) the placement technique which involved the attachment of concrete blocks to the geotextile (Figure 2) to ensure the geotextile stayed in position in the surf zone.

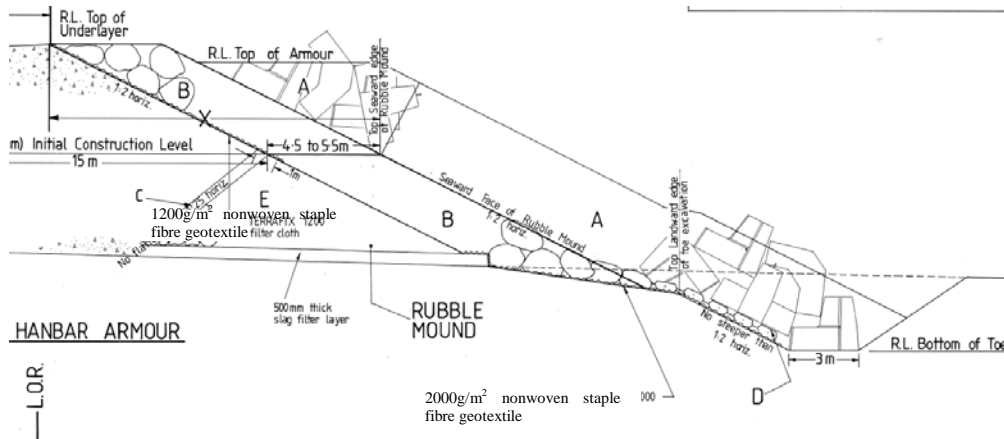


Figure 1: Sea wall x-section (Andrew Dunne)

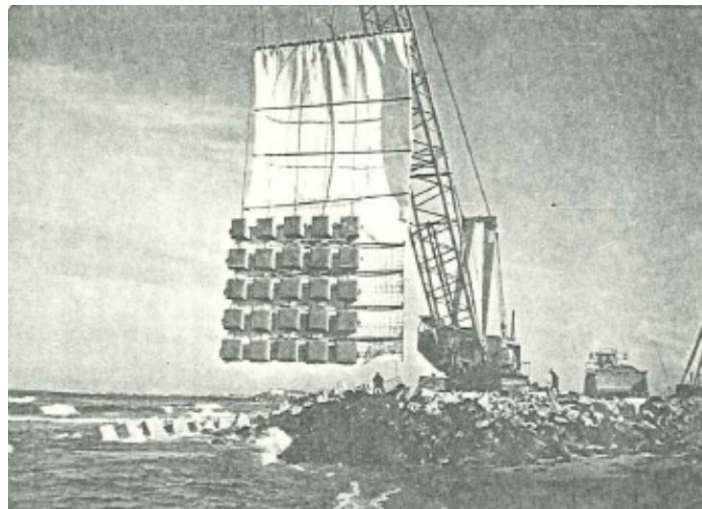


Figure 2: Placement of geotextile panels (Poulter, 1980)

Two nonwoven staple fibre geotextiles were incorporated into the design, with a heavy 2000 g/m<sup>2</sup> geotextile used under the 15 tonne Hanbar concrete armour units and a 1200 g/m<sup>2</sup> geotextile used below the 1.5 to 3 tonne rock armour. The geotextiles were supplied to site in pre-sewn panel sizes of 16 m x 11 m (1200g/m<sup>2</sup>) and 8 m x 14 m (2000 g/m<sup>2</sup>). The panels became too heavy to manoeuvre by hand when wet and every effort was made to keep them dry until they were in the desired position. The 8 m x 14 m panels of 2000 g/m<sup>2</sup> geotextile with concrete block mat (Figure 3) were placed using a crane fitted with special spreader bars (scrap tram line) to ensure the geotextile panel retained its shape despite wave action. A total of 196 concrete block mats were placed as part of the construction. A 1.5 m wide x 11.9 m long x 50 mm thick flexible protector plate was placed over the side overlap section of the geotextile panel immediately after placement of the mat. This protector plate served three purposes

1. to keep the lap edge in place until the next mat was placed on it
2. to protect the lap edge during excavation of the next section of toe trench
3. to remove any accumulation of sand on the lap edge (the sand was lifted off as the plate was lifted off).

Considering the uniqueness of the mats, the whole operation was surprisingly quick and easy from the first attempt. The record placement of the mats was seven in one day.

The robustness of the block mats was demonstrated on several occasions during construction, when two were dropped while hanging from the crane and three were dragged out of the trench and onto the construction platform by the dragline bucket with little or no damage occurring. All five were subsequently re-used in the construction.

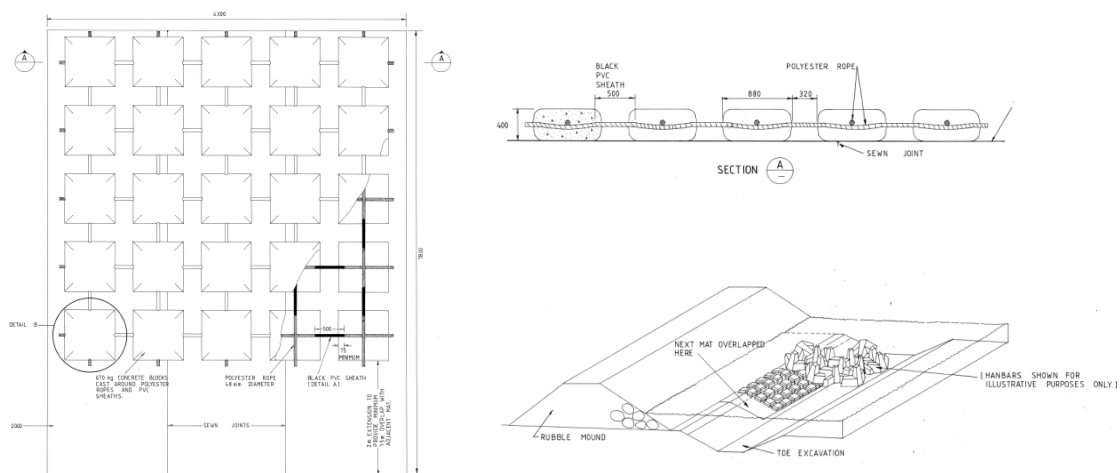


Figure 3: Arrangement of geotextile concrete block mats (*Andrew Dunne*)

The  $1200 \text{ g/m}^2$  geotextile suffered some damage due to the dropping of the sharp 3 tonne rocks directly onto it, and when it was left exposed to wave action for a few days. The  $2000 \text{ g/m}^2$  geotextile, however, performed well, and with the benefit of experience, only the  $2000 \text{ g/m}^2$  geotextile should have been specified, mainly because of its ability to withstand the construction operations and exposure.

The construction method incorporating geotextiles translated into considerable savings in material and construction time, over traditional graded filter methodology. The performance of the geotextiles in this critical and aggressive application has been impressive and was used as a benchmark for subsequent seawall contracts.

Annual inspections have shown that the structure is still performing well with no maintenance required since construction.

### 3 NARROWNECK REEF (1999)

The artificial reef is located at Narrowneck at the northern end of Surfers Paradise, on Australia's Gold Coast. The Gold Coast is the major coastal holiday destination in Australia and the economy of the Gold Coast region is dependent on the tourism industry. In order to continue to attract tourist, it was important to maintain and protect the wide sandy beaches. The Gold Coast is in the cyclone belt and the wave buoy nearby has recorded waves of over 13 m. The worst storm erosion occurred in 1967 when seven cyclones affected this section of the east Australian coastline causing extensive damage to the Gold Coast beaches and beachfront developments and resulted in substantial loss in revenue to the tourist industry. Ongoing beach nourishment was implemented and has been effective, but there were inadequate long-term sources of suitable sand to maintain the beaches even without the added effects of projected sea level rise.

The concept of constructing a reef using large sand filled geotextile containers was accepted to protect the beach against storm erosion and recession due to sea level rise while improving the surfing amenity. However, it was recognised that the state of the art with respect to submerged breakwater design and the use of sand filled geotextile containers would need to be developed.

The manufacture and filling of the large containers is one of the aspects that make this project unique. Previously large containers were manufactured by placing a sheet of geotextile into a hopper barge, filling the barge with material using an excavator, then folding the edges of the container inwards and sewing them together on site. Obviously this was not a simple task when the barge is moving due to the swell conditions, and quality control is somewhat limited. This technique also allowed the containers to be filled to capacity resulting in a greater filled height than site sewn containers.

The large containers used were constructed from  $2100 \text{ g/m}^2$  heavy-duty polyester/polypropylene nonwoven staple fibre geotextile. Quality assurance was identified as the key to the successful deployment and durability of the sand containers. The manufacture of the containers was carried out under strict supervision and complied with ISO 9001 standards. Specialist sewing techniques were developed specifically for this project and have proven themselves in extreme conditions. The containers were pre-manufactured, with inlet valves and exhaust vents the only items that required closure on board the hopper dredge. Developments in the closure methods, such as the double seal closure, ensured improved long-term durability and integrity of the closure system.

Nearly 400, 20 m long mega sand containers varying from 3.0 m to 4.6 m in diameter, were placed using the split hulled, trailing suction hopper dredge, *Faucon*, fitted with computer interfaced DGPS. This purpose fitted out vessel, was again unique, in that a single vessel was used to carry out all the functions required to construct the reef from filling the container to accurate location and placement. The containers were accurately filled utilising a calibrated flow density meter, ensuring repeatability and consistency of the construction. The marine contractor was required to work in very difficult conditions. These became progressively worse as the height of the structure was raised, resulting in shallower water and increased wave heights above the structure due to shoaling. Notwithstanding these difficult conditions, the contractor was still able to manoeuvre his ship in such a way that containers were generally placed to a horizontal accuracy of  $\pm 0.5$  m (Figure 4).



Figure 4: Placement of containers using a split hulled barge

The design team together with the geotextile container supplier carry out regular dives on the reef in order to assess the durability and stability of the containers. This monitoring confirms that the containers did not deform beyond what was allowed for in the design of the structure. Back analysis of the geocontainers using the GeoCops program produced an expected shape of the container filled on dry land. These predicted dimensions compared well with field data obtained from the monitoring dives.

The reef provided a full scale model to measure and observe the performance of exposed geosynthetics in the marine environment and valuable data has been collected on the suitability of geotextiles as marine structures. In 2004 the National Marine Science Centre, carried out a detailed analysis of two facets of the structure: a) the ability of the geotextile to support marine life (four different geotextiles were trialled) and b) to compare the fish and benthic communities found on geotextile reef with natural rock reefs in the area Edwards *et al.* (2005). The results of which showed that geotextile choice will have an influence on the marine growth (Figure 5) and that while fish abundance was comparable with the other reefs, the structure lacked complexity (e.g. sufficient voids) to make it an ideal habitat.

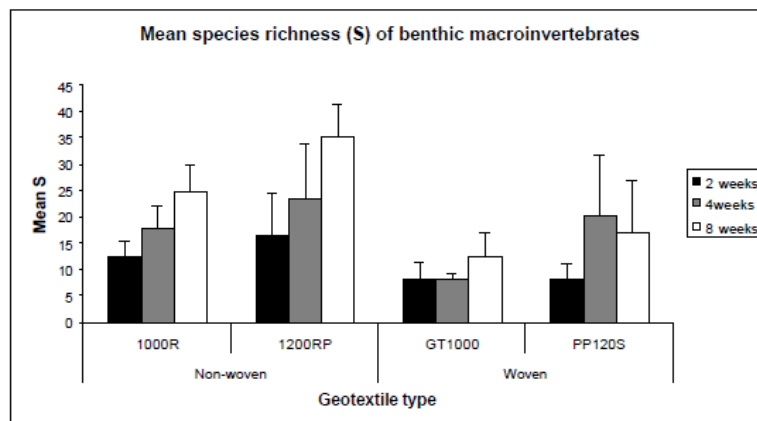


Figure 5: Ability of Geotextile to support and encourage marine life

While there is still conjecture on the success of the project in terms of the beach protection and surf amenity, a great deal has been learnt about the use of geotextiles and geocontainers in artificial reefs. This project pushed

the boundaries of geotextile container use to new levels. As with most ground breaking projects of this nature, the success of this project was possible due to the close working relationship involving ongoing Research and Development between Client, Engineer, Geosynthetic Supplier and Contactor.

#### 4 FISHERMANS ISLAND, PORT OF BRISBANE (2003/2004)

The Port of Brisbane is located at the mouth of the Brisbane River at Fishermans Island in Brisbane. The objective of the project was to allow the Port to reclaim and develop an additional 230 ha of port land including extending the current quay line by a further 1800 m. The first stage of this process was the construction of a 4.6 km long and up to 8 m high seawall to encompass the area so that reclamation could be carried out in an environmentally friendly and controlled manner (Ameratunga *et al.*, 2006). What makes this project unique is the damage trials carried out in order to assess the suitability of the various geotextiles offered and the method of installation (Figure 12).

The seawall consisting of a rock embankment placed on a high strength geotextile laid on the seabed was the design adopted where the seabed is shallow (1 m below low water). A wide sand pancake was included in the design because of weaker subsoil condition (see design section for East Bund in Figure 6). The rock bund forming the upper part of the seawall was then placed on this sand pancake. During construction an appropriate filtration geotextile was selected to cover and contain the sand to prevent losses from the effects of tides and waves. Damage trials were conducted on the selected geotextiles to assess whether significant damage would occur during the placement of the rock and construction trafficking above, and what allowance should be made for these effects.

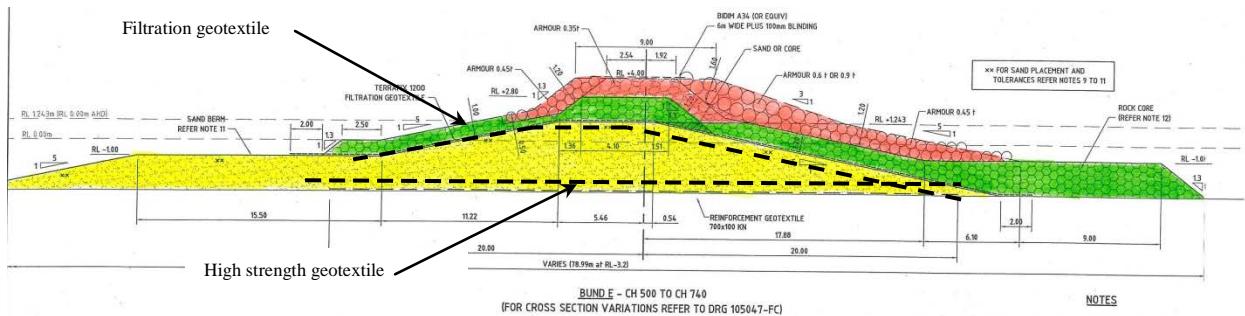


Figure 6: East bund x-section

#### 4.1 GEOTEXTILE DAMAGE TRIALS

At the initial stages of the design, risk assessments were carried out. Damage to high strength geotextiles during rock placement and trafficking was identified as a significant hazard. However, it was recognised that down rating the basal geotextile strength was an acceptable way to treat such issues in the design. Theoretical formulae were available to assess the requirements of a geotextile but not to assess the damage factors. There were also no documented experiences on damage due to trafficking on rock placed on a geotextile. Also of great concern was the potential for damage of the filtration fabric, because of the potential consequences if sand was sucked out by the tides, leading to collapse of the rock wall above and consequent major failures.

From the outset it was decided to carry out a set of field trials to assess these effects using typical rock core and armour materials to be used on the project. The trials were conducted in one of the reclamation paddocks filled with dredged mud capped off with a 2 m thick sand base. Dynamic Cone Penetrometer testing conducted to assess the strength variation of the base generally indicated medium to dense conditions.

The individual rolls of geotextile were stitched together to form a panel of approximately 12 m x 12 m. Two types of seams (J – Seam and a Butterfly Seam) were used to make an additional check on the effects on seams. To hold the geotextile in place, smaller rock was placed as a weight along the edges and down the centre of the test panel.



Figure 7: Trial panel set up with 3 m drop in progress.

The panel was divided into 4 equal cells so that the seams were running along the centreline of the cells. The trials were conducted using maximum 300 mm rock core with varying the number of drops and/or drop height of 1.5 m and 3.0 m (Figure 7). On completion, rock core was carefully removed from the geotextile to assess, measure and photograph the damage prior to quantifying the damage.

To assess the effect of construction vehicle movement, the removed rock core was placed over the geotextile to form an access track wide enough for a large excavator to travel. The length of the access track was about 5 m and the height was 1.0 m (Figure 8). This track was then subjected to 16 passes of the excavator moving parallel to the weft direction. The number of passes used was excessive compared to actual conditions during construction.



Figure 8: Trafficking with excavator.

#### 4.1.1 BASAL HIGH STRENGTH GEOTEXTILE

Although trials were conducted on several products only the trials conducted on the materials of the successful tenderer are discussed in this paper. The geotextile tested were 200 kN/m and 800 kN/m (AS3706.2) knitted polyester geotextiles (WX200 and WX800).

For the basal geotextile, the damage was calculated as a ratio of the width of damaged section over the total width of the panel or cell. Random parallel lines were drawn and the assessment for each line assessed and only the worst case is summarized in Table 1.

The results indicated that:

- Except for an outlier, the damage factor varied between 1.2 and 1.8 (Figure 9).
- WX800 showed better resistance than WX200.
- Tracking damage is more significant than damage created by rock core drops.
- WX200 was significantly damaged by the tracking trial.



Figure 9: Typical high strength geotextile damage.

Table 1: Drop height damage (High strength geotextile)

Test Location.	Drop Height (mm)	Factor Worst Case	Remarks
M200/1	2 x 1500	1.7	J Seam
M200/2	1500	2.4	J Seam
M200/3	1500	1.4	Test over ballast
M200/4	1500	1.6	B Seam
M200/5	3000	1.8	B Seam
M200	Tracking	60-70% of testing section damaged	
M800/1	1500	1.3	
M800/2	1500	1.2	Test over Ballast
M800/3	1500	1.2	B Seam
M800/4	1500	1.4	B Seam
M800/5	3000	1.5	J Seam
M800	Tracking	1.8	

Based on the test results it was decided as a minimum to use geotextiles whose strength is at least double the 200 kN/m strength. A constant damage factor of 1.7 was used for all grades of geotextile between 400 kN/m and 850 kN/m used on the project.

#### 4.1.2 FILTRATION GEOTEXTILE

The client was very concerned about the effects of rock placement and trafficking on the filtration geotextile covering the cohesionless white sand. Therefore, the damage trials carried out on the filtration geotextile were more extensive. The geotextile trialled was a 1200 g/m<sup>2</sup> nonwoven staple fibre geotextile (Table 2).

Drop trials were carried out as per the method described in Section 4.1.1 above, while the trafficking trials were conducted in an area of moist, loose to medium dense white sand. 0.3 t armour rock was placed carefully by excavator on the geotextile to varying heights. The rock surface was divided into 4 sections, each approximately 4 m by 4 m, so that several trials could be conducted. The results for the series of trials conducted with large excavators are summarized in Tables 3 and 4.

Table 2: Drop height damage (filtration geotextile).

No.	Drop Height (mm)	No. of fabric punctures
1200/1	1500	Nil
1200/2	1500	Nil
1200/3	3000	1 x 1mm diameter puncture
1200/4	3000	Nil

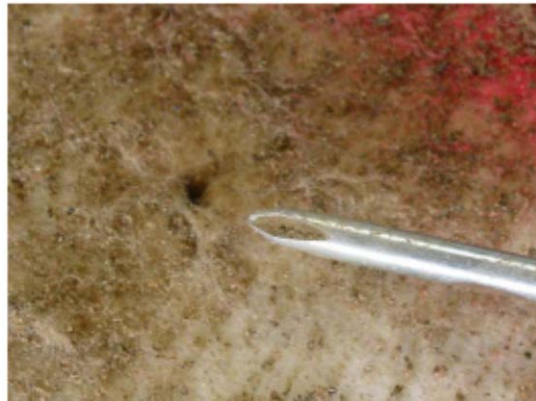


Figure 10: 3 m drop height damage to nonwoven geotextile.

Table 3: Trafficking damage by 30 tonne excavator (filtration geotextile)

No.	Materials cover and no. of passes	No. of fabric punctures
T1	0.3 m of fine sand – 6 passes	Nil
T2	No cover – 6 plus 1 slight screw on tracks	Nil
T3	1.0 m of fine core – 12 passes	1 x 100 mm tear <sup>#</sup>
T4	0.35 m of 60/40 mm crushed aggregate – 6 passers	Nil
T5	1.2 m of 0.35 t armour rock over 0.3 m of fine sand – 12 passes	Nil
T6	0.9/1.0 m of 0.35 t armour rock – 12 passes	1 x 75 mm tear <sup>#</sup> and 6 tears (20-30 mm)
T7	0.3 m crushed concrete 75 mm – passes	Nil

(# Damage assessed to be by bucket on uncovering test panel)

There were numerous indentations which were also recorded but not included in the above tables. The presence of indentations indicated the significantly high strain the geotextile could withstand without rupture.

Further trials T8 to T10 were conducted with a 45 tonne excavator using previously tracked panels (T8 and T10) and a new panel (T9). The results summarised in Table 4 indicate that the damage from the 45 tonne excavator was greater than that from the 30 tonne excavator and the damage on re-used geotextile was greater.

Table 4: Trafficking damage by 45 tonne excavator (filtration geotextile).

Trial No.	Materials description	No. of passes	No. of fabric punctures (tear width)
T8*	1.1 m of armour rock	12 plus 3 track screws	3 (50 – 75 mm)
T9	1.0 m of core rock	12 plus 3 track screws	6 (10 – 50 mm)
T10*	1.1 m of armour rock	12 plus 3 track screws	12 (10 – 150 mm)

\* previously tracked panels

For trials T11 to T13, 1.0 m of core rock (T11) and 1.0 m of armour rock (T2 and T13) were placed over new fabric and subjected to 12 passes of a 30 t excavator plus 4 track screws on T11 and 6 on T12 and T13. No punctures were observed in T11 and only two tears, minimum 25 and 75 mm, were observed on each T12 and T13 panels respectively.

Subsequent to Trial T11, approximately 0.3 m thick layer of core rock was placed on the previously trafficked geotextile and was subjected to the following at the same location:

- Full downward pressure of excavator bucket
- Four free thumps of the bucket
- Bucket screwing causing all rocks to move.

The above actions produced only two (2) small (30 mm) punctures indicating the robust nature of the geotextile used.

#### 4.2 GEOTEXTILE PLACEMENT

A 'multipurpose' barge was used for laying both geotextiles and for placing the sand through a spreader system. A flat-top barge, 53 m x 17 m, with an unloaded draft of 0.6 m was modified for the Project (Figure 11).

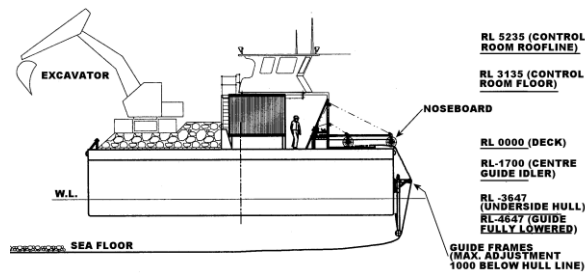


Figure 11: Deployment barge

In general the barge consisted of three zones:

- The high strength geotextile deployment zone on the port side of the barge.
- The ballast storage and loading zone on the starboard side of the barge later used for the deployment of the filtration geotextiles.
- The barge controls, facilities, power and hydraulic systems running along the centre of the barge.

The barge positioned and moved itself once set with the hydraulic winches. At the completion of an anchor set, the tug would assist in retrieving the anchors and returning the barge to the load out facility.

Geotextiles were stitched off site using a J seam into panels up to 42 m wide and 100 m long. The basal geotextile was rolled over in front of the barge and under as shown in Figure 2 with the initial panel done by divers. To avoid the geotextile folding transversely, 12 mm steel reinforcement bars were attached to the geotextile with cable ties at 10 m spacing to hold the geotextile tight. Ballast was placed from the barge to hold the geotextile in place on the seabed.

The filtration geotextile was required to cover the sand and separate it from rock above to minimize sand losses due to wave action. The filtration geotextiles were stitched together using a prayer seam stitch to panels of size 32 m x 40 m and transported to the site. The filtration geotextile panels were placed on top of the sand straight off the starboard side of the barge (the area previously used as ballast storage during the placement of the high strength geotextile) as the sand was placed from the sand spreader (attached to the starboard side of the barge). To minimize the risk of the geotextile moving, rock was placed to cover fabrics at the crest (using land-based methods) as soon as practical.



Figure 12: Completed Seawall

## 5 LIMEBURNERS BREAKWATER (2004)

Limeburners breakwater was constructed in September 2004 and is located in Geelong, Victoria. The structure is an 80 m long x 5.5 m high emergent breakwater designed to reduce wave transmission into the 20 m wide mouth of Limeburners Point boat harbour. The harbour was subjected to excessive wind waves, which entered the harbour and caused considerable damage to the floating pontoons, and made launching and retrieving recreational vessels both difficult and dangerous at times. The structure is founded on the existing rock sea bed located at -4.0 m LAT and is located 40 m off the end of the harbour entrance.

In order to achieve the desired crest height, a 3-2-1 stack of geotextile tubes was constructed as shown in Figure 14. The base layer consisted of three 14 m circumference containers with a theoretical height of 2.3 m, and 40 m each in length. The middle and top layers made use of 12 m circumference containers with a theoretical height of 2.1 m and a length of 35 m and 30 m respectively. The overall dimensions of the island breakwater are 80 m long and 16 m wide at the base, with a crest length of 60 m and width of 5 m.

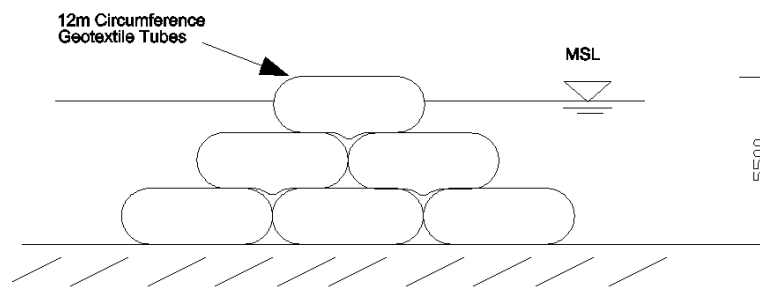


Figure 13: Section through breakwater

Accurate placement of the containers was of the utmost importance to ensure the final height achieved the specified design height. In order to achieve this, anchor blocks were placed at the end of the structure and along the length to hold the containers in position while they were being filled. Deployment of the mega containers was carried out off a 3 m x 3 m floating pontoon which also acted as the support platform for the dredge pipe (Figure 14). The containers were filled using a 10 inch (250 mm) suction cutter dredge. Due to the very fine nature of the dredge material the containers took 5-8 hours to fill, compared with the normal 2-3 hours which can be achieved when using good quality sand.



Figure 14: Geotextile tube filling

The 40 m long by 12 m circumference geotextile containers were manufactured from a combination of a standard heavy duty staple fibre geotextile on the base and sides, and the composite staple fibre geotextile on the exposed surface where significant exposure to UV radiation was expected. High tenacity polyester thread was used on all seams.

Using a floating pontoon as a platform to deliver the dredge material to the containers limited the time available to fill the containers, as work had to be aborted when winds exceeded 15 knots and/or wave heights exceeded 0.5 m. A jack up pontoon may have overcome this problem and allowed faster construction times.

Lower construction costs combined with the flexibility and safety of the containers ensured the project received the necessary approvals and funding to proceed. In addition, a significantly reduced construction timeframe when compared to traditional methods meant minimal inconvenience to harbour users. Evaluation of the fill material available prior to starting the project would allow better estimation of construction times. Despite the poor quality fill material, there has been minimal settlement of the structure (<300 mm) and the crest height is within the design limits.

The project has resulted in a greater understanding of the final dimensions of containers filled *in situ* and how they can be combined to form larger integrated structures. It has also showcased the flexibility of design options available to the design engineer in terms of container shape (tapered ends) protection options (vandal deterrent geotextile) and maintenance (patches). The experience gained during the construction phase will be extremely valuable for future projects of this nature.

To date the project has provided the required protection to the harbour, with modelling showing reducing the maximum wave heights at the pontoons from Hs of 0.35 m to Hs of 0.12 m (Cardno, Lawson and Treloar, 2008). The structure poses limited threat to the small craft using the harbour and in the unlikely event that they should

collide with the breakwater the damage to the small craft is expected to be far less than if it were to impact with a rock/concrete structure.



Figure 15: Limeburner's Breakwater under wave attack

## **6 CONCLUSION**

The use of geotextiles in coastal and marine applications has grown significantly since the early applications. Their use in these applications has tested their performance capabilities to the limits and the geotextiles have proven to be a valuable and durable component of the structure.

Due to the unique nature of many of the marine structures, standard geosynthetic design procedures associated with general construction practices are of limited value. It is therefore useful to understand the performance of products used in similar applications in the past to assist in the development of robust specifications for current projects. This paper gives some guidance on the performance of geotextiles in extreme applications which can be used as a guide. However in projects of this nature actual field trials are recommended as the best method to determine the suitability of geotextile proposed.

## **7 ACKNOWLEDGEMENTS**

Andrew Dunne, General Manager Engineering & Environment, Port Kembla Port Corporation  
Simon Restall, GSR International.

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