A review of the use of geotextile erosion protection structures in the coastal zone

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ABSTRACT

In the last decade, there has been an increasing use of sand-filled geotextile units to build erosion protection structures in the coastal zone, as an alternative to traditional construction methods. Typical structures include seawalls and groynes subjected to both tidal currents in estuaries and waves on the open coast. Early structures using geotextile material often suffered from degradation due to exposure to sunlight and vandalism but the availability of UV and vandal resistant materials has made the use of this material more attractive.

This paper will review the development in the use of geotextile materials in the coastal zone, examining their inherent advantages and disadvantages. Recent examples from Maroochydore in Queensland and Busselton in Western Australia will be used to illustrate the design, construction, and maintenance features of this type of structure.

INTRODUCTION

There has been an increasing use of geotextile sand containers (GSC) as a building element for coastal structures in Australia and around the world in the last 20 years. The GSCs used in revetments and groynes typically vary from containers in three standard sizes: 0.35m^3 (0.5 tonne), 0.75m^3 (1.5 tonne), 2.5m^3 (5 tonne), to long tubes or mega containers starting at 1.2m diameter and 20m long. In addition, the material used in the GSCs has evolved and improved in response to the demands of the applications.

The locations in Australia where GSCs have been used has been reported in the literature (Restall *et al*, 2003) and demonstrate the use of the full range of container sizes for revetments and groynes over a wide geographical area. Some more recent projects involving GSCs have been completed in the Swan River, Perth, and at Busselton, Western Australia, and are proposed for Cocos (Keeling) Island in 2009.

MATERIALS

The basic material used to construct the GSC is a heavy duty UV stabilised non-woven staple fibre needle punched geotextile with a high tenacity thread in all seams (Restall etal, 2003). For additional resistance to vandalism and abrasion, a composite material is used, the outer layer of which can trap 3kg/m^2 of sand. The use of this composite material significantly improves the resilience and durability of the individual containers.

As well as the requirements for the material as an effective building element (retention of fill material, high permeability, and high seam strength), GSC structures are designed to maximise stability through:

1. the provision of adequate toe protection; and
2. adopting a layout such that the containers are tightly packed and can mould themselves with their neighbours to maximise stability against sliding.

The main challenges to ensuring the longevity of GSC materials are related to the ability of the material to withstand:

1. Ultraviolet light and therefore be UV resistant;
2. Abrasion from sand and gravel contained in currents and waves;

3. Damage from incidental impact damage (driftwood, surfboards); and
4. Wilful damage (vandalism).

The materials used in projects to date have a minimum life of 10 years for UV resistance. Monitoring of existing structures into the future will provide valuable data with respect to UV resistance and abrasion resistance.

ADVANTAGES OF GSCs

The most significant advantage of GSCs is that they can often be filled on site using local materials. This provides a significant cost saving as the only materials that need to be transported to the site are the containers themselves. Apart from the cost, the use of GSCs is a much safer option from a community point of view as the the structure is 'soft' instead of 'hard'

Other advantages of GSC structures are:

- They provide a people friendly structure in high amenity areas;
- Can be constructed with basic machinery and simple techniques which ensure that the containers are filled properly, sealed, and placed into position without being damaged
- Maintenance is simple, usually involving the replacement of containers that have been displaced or placing additional containers to bring the structure back to the design level
- They are, to a large extent, self-healing, in that, if a container is split or damaged, the surrounding containers will mould to fill the gap. These structures have inherent flexibility which is particularly useful in the coastal environment
- In the unlikely event that the structure needs to be removed in the future, the containers can be simply split and the geotextile material removed leaving the sand on the beach.
- Have visually low impact, tending to blend in with the natural coastal surroundings and where these structures are designed with a low profile in relation to the beach levels, they have good public acceptance as they can be easily traversed with relative safety.

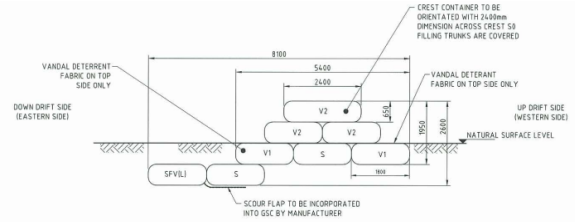
LIMITATIONS

The issues regarding vandalism and wear on the containers due to UV exposure and abrasion are current limitations, and will remain so until further research has been carried out and/or existing GSC structures exceed the design life assumptions. Manufacturers of non-woven geotextiles have been diligent in continually developing better materials to address these issues and currently the geotextile material used to make the GSCs is available in vandal deterrent, UV stabilised and abrasion resistant fabrics which, in combination, will maximise the life of the structure.

The second limitation issue is the lack of definitive design criteria to be able to relate wave conditions with stability criteria. To date, the manufacturer has provided recommendations of design wave height for different size containers, that together with the performance of existing structures, has proven to be reasonably realistic. Nevertheless, further design information is needed to provide more certainty in the design process and allow more widespread acceptance of these types of structures in the coastal zone.

TYPICAL DESIGN LAYOUTS

For groynes, GSC's are typically orientated with the shorter side facing the wave and the longer side aligned to the longitudinal axis of the groyne, refer Figure 1. This is to minimize movement of the containers due to wave action, through suction and uplift. The optimum orientation has been developed through extensive discussions with the manufacturer, and observations from existing similar structures. The manufacturers have also recently commissioned physical model testing of GSC structures, and the results of this



testing should be available in the near future.

The orientation of the crest containers is an exception to the typical arrangement. Crest containers are placed with the short side parallel to the longitudinal axis of the structure to ensure that the filling ports on the long side can be covered by the adjoining GSC, thus providing protection of this weak point from the incoming wave action.

CASE STUDY 1 – MAROOCHYDORE

Figure 2: Maroochydore, QLD

The Maroochy River flows through Maroochydore on the Sunshine Coast in Queensland approximately 100km north of Brisbane, refer Figure 2. The river mouth is untrained and its location over the last 60 years has varied over a wide area under the influence of semi-diurnal tides (spring tide range 1.6m), flood flows, and ocean waves. Located in the middle of this area is a small rocky outcrop called Pincushion Island. The river mouth had been moving south over a long period and after the river broke through south of Pincushion Island, the northern end of Maroochy Beach underwent significant erosion, as the beach alignment adjusted to the new conditions.

The serious and ongoing erosion threatened the viability of the caravan park and the adjacent permanent development on the southern shoreline. In addition, the popularity of the area as a tourist destination was under threat because of the state of the eroded beach. The local government commissioned a number of reports to determine the best way to combat the erosion and restore the viability of the local economy. These investigations culminated in the project described here.

Figure 3: Maroochydore Groyne Layout

The proposed works were focussed on containing any further movement of the river mouth to the south and retaining the northern end of Maroochy Beach in as natural a state as possible. Interference with the remainder of the river mouth area was to be kept to a minimum.

The project consisted of four groynes, perpendicular to the coastline and spaced about 90m apart, located where the southern bank of the river intersects with the beach, refer Figure 3. The length, location, and orientation of the groynes was model tested at the Queensland Government Hydraulics Laboratory by WBM Pty Ltd. The Council decided that the groynes would be constructed with GSCs for a number of reasons and the GSC groyne structure was subsequently designed by International Coastal Management.

Design Condition

Given the location of the groynes inside the river bar which extends in a wide arc from the southern shoreline to the northern shoreline, and analysis of the model testing results, the design wave was determined as H_{max} = 3.0m spilling or 2.5m plunging.

Other factors which formed part of the decision process that resulted in the use of GSCs were:

1. Alternative materials could be obtained locally but would need to be carted through relatively dense residential and holiday areas;
2. State government approving agencies (including the Beach Protection Authority) expressed a clear preference for a construction type that could be easily removed in the event that the groynes proved to be detrimental to the adjacent coastline;
3. The Council was familiar with GSCs for coastal protection works, having had a GSC revetment wall constructed along the beach as emergency protection works prior to the groynes being put in place; and

4. GSCs would offer a much safer and publically acceptable form of construction on a very popular beach.

Structure Type/s

Four groynes comprising 2.5m^3 (5t) geotextile sand containers in a pyramid shape were constructed. The geotextile containers were manufactured from a composite UV stabilised non-woven staple fibre needle punched geotextile. Filling for the containers was to be sourced from the beach. The design included an additional lower layer of containers to provide scour protection for the end of the groynes.

Beach Nourishment

Approximately 100,000m^3 of sand was provided as beach nourishment for the beach south of the most southern groyne to provide immediate improvements to the eroded beach. This sand was sourced from the landward side of the large sand spit on the northern side of the river entrance.

During the second stage of the project which saw the construction of the remaining 3 groynes, a further 30,000m^3 of sand was sourced from the same area to fill the areas between the groynes.

Performance

The most southern groyne of the four GSC groynes constructed at the mouth of the Maroochy River has been in place for 7 years. Despite being in need of some maintenance to replace a small number of displaced containers, the groyne continues to function successfully today.

An assessment of the condition of the GSC that comprise the upper layers of the groynes reveals very little damage from incidental impact or vandalism, and what damage that has occurred has been patched successfully. By comparison the nearby revetment wall has suffered considerable damage with a number of containers split probably as a result of knife cuts. The main factor that explains the difference is that the groynes are constructed of GSC made from the composite material that is much thicker than the base material and traps sand within the material fibres. The revetment wall containers are made from the base material only.

In relation to public perceptions, the experience at Maroochydore shows that the groynes are popular fishing platforms and provide a comfortable elevated area for observing and enjoying the beach environment.

CASE STUDY 2 – BUSSELTON

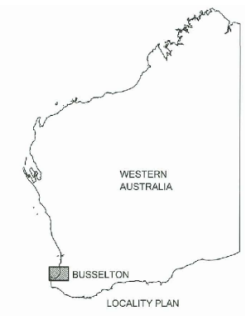


Figure 4: Busselton, WA

Town Beach at Busselton, approximately 200km south of Perth in Western Australia, refer Figure 4, is a popular tourist and local beach, protected with timber groyne structures and concrete slab seawalls until recent times. The existing timber coastal protection structures had significantly deteriorated during the last few years and were no longer performing a significant sand trapping function, culminating in the erosion of the beach prior to winter 2007. A condition assessment of the timber groynes revealed that they had degraded to an extent that refurbishment was not feasible. A range of options to replace these timber groynes and stabilise the beach was considered. GSCs were the preferred option based on consideration of cost, design life, effectiveness and amenity.

Figure 5: Busselton Groyne Layout

To protect the Busselton beachfront from further erosion the construction of three new GSC groynes took place in 2008, refer

Figure 5, with the option of an additional two groynes to be constructed in future if required.

Based on analysis of the nearshore wave climate, one groyne was placed on the eastern side of the historic Busselton jetty, close to the existing boat ramp. Two groynes were placed on the western side of the jetty, in front of the restaurants and car park area. The works started in late July 2008 and were completed in 3 months. The project has assisted in reinstating a wide sandy beach for all users.

Design Condition

Busselton Town Beach is on an exposed coastline, protected to an extent from the southerly swells by Cape Naturaliste to the south. Western Australia has a dominant seasonal summer / winter weather pattern, with storms mainly occurring during winter. During summer, the dominant winds are from south-east, while during winter they are more from the west, directly impacting on the coastline. The primary function of the groyne field is to assist in the buildup of an adequate beach buffer to provide protection from the winter storms.

The design conditions adopted were as follows:

- Design water level = +2.14m CD (MHHW + Surge + Sea Level Rise); and
- Design wave (depth limited): H_{sig} = 1.7m, T_p = 9sec

Structure Type/s

Three (3) groynes comprising 2.5m^3 (5t) GSCs were constructed, with an option for 2 additional groynes in the future. Scour flap containers were incorporated into the design on the downdrift side of the groyne. Scour flap containers are a new addition to the range of containers available and consist of an additional geotextile flap being sewn into the GSC during manufacture on either the short or the long side of the GSC.

Beach Nourishment

Beach nourishment was undertaken in conjunction with the groyne construction on the downdrift side of the groynes. A total of 7,500m^3 was placed on the beach. Some of the beach nourishment sand was used during construction to form temporary bunds.

Performance

To date, the groynes have succeeded in rebuilding a wide, useable, sandy beach which has been widely accepted by the users, and are functioning well. As well as providing the beach amenity, the groynes are assisting in providing erosion protection for local government foreshore assets. The winter storms of 2009 will provide the first test as to their effectiveness.

TAKE HOME MESSAGES

The case studies illustrate the growing acceptance of this type of construction in the coastal zone.

Geotextile sand containers are:

- Suitable and recommended for high use public areas;
- Compatible with the beach environment;
- Capable of withstanding in excess of design conditions with minimal damage (displacement of individual containers, collapse of small number of containers);
- Easily maintained;
- Easy to use in remote areas or areas where rock / other traditional materials may not be available or difficult to transport to site, for example, through populated areas; and
- Flexible structures.

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