

AUSTRALIAN & GERMAN EXPERIENCES WITH GEOTEXTILE CONTAINERS FOR COASTAL PROTECTION

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ABSTRACT: Encapsulating or wrapping soil materials into geotextiles provides a variety of flexible, economical and ecological applications in the field of hydraulic engineering. Geotextile containers and tubes are used for dam and dike flood emergency protection and also as construction elements for erosion control, scour fill, reefs, groynes, dams, breakwaters and dune revetments. New shore protection structures, especially at sandy coasts, are increasingly required which have less ecological and visual impacts than conventional structures. However, due to the increasing storminess associated with climate changes some of the existing dunes must be protected/reinforced. Furthermore, these reinforcement/protection solutions are more cost effective, which implies the use of local material without any heavy equipment, especially when the required infrastructure is not available. Hydraulic model investigations were carried out at Leichtweiss-Institute for Hydrodynamics and Coastal Engineering (LWI) of Technical University of Braunschweig to establish reliable stability formulae for sand containers applied as dune protection/reinforcement subject to storm waves. The German recommendations on geotextile containers, bags and tubes "EAG-CON" will be released soon and will present detailed information about the geotextile container technology.

1 INTRODUCTION

Coastal and hydraulic engineering problems were the starting point of the technical development of geotextiles. Various other geosynthetic disciplines of civil engineering were opened up later on. 50 years ago first trials with sandbags made of synthetic textiles were realised in the USA, the Netherlands and in Germany. In recent years, geotextile container technology has experienced growth success and highly visible projects. Nowadays geotextile sand containers find their application as construction elements for erosion control, scour fill, reefs, groynes, dams, breakwaters and dune revetments.

Encapsulating or wrapping sand into geotextile units provides a variety of flexible, economical and ecological coastal applications. Especially at indifferent dynamic sandy beaches, where the use of rocks, steel and concrete as "hard coastal structures" is contrary to the soft coastal protection philosophy, geotextile sand filled containers made of needle-punched nonwovens offer more advantages as "soft rock structures". As flexible construction elements geotextile containers behave advantageously relating cyclical hydrodynamic loads and morphological sea bed changes.

This paper shows Australian projects and examples of technologies where the encapsulation of sediments in geotextile sand containers dominates but other functions, e.g. reinforcement and filtration cannot be neglected. Additionally results from German large scale model tests are presented and the content of German recommendations dealing with geotextile containers is described.

2 AUSTRALIAN EXPERIENCES

Sand filled geotextile containers have been used in Australia for over 20 years. The first applications were simple hydraulically filled tubes used in relatively sheltered environments where temporary or short term solutions (<1 year) were required. However the technology has now advanced to a stage where the containers are now being

used to construct complex structures, which are subjected to extreme physical and climatic conditions with a life expectancy of as much as 20 years.

Understanding the conditions, in which the geotextile will be subjected to during the structure life time, the development of hybrid geotextiles has prompted to suite this extreme exposure. Developments in container technology to suite the application have been developed so that the client can choose the best container type for a range of applications. Initially the main emphasis was on hydraulically filled geotextile tubes (typically 1.2mØ) used mainly as groynes to protect beaches. With time this focus has changed to individual containers used in coastline protection and marine structures (reefs). Experience has shown that although large tube structures are cost effective in the short term they do not provide a long term engineering solution as localised damage or vandalism can cause large sections of the structure to fail.

Considerations in terms of geotextile requirements are discussed in Section 2.1 while landmark projects are described in Section 2.2.

2.1 Geotextile requirements & considerations

Geotextiles used for sand filled containers are subjected to significantly different forces than geotextiles used in the conventional drainage and separation applications. These differences must be taken into account when designing these structures, the Sections below describe the issues, which should be considered when designing a sand filled geotextile container.

2.1.1 UV-Resistance

In regions such as Australia and the Middle East where UV radiation is in the order of 180 Kilo Langleys, UV degradation is the most significant factor in terms of long term survivability of the container. Container structures used on coastal foreshore areas are exposed to UV for long periods of time and it is essential that the geotextile used to manufacture the containers has the highest possible UV resistance.

Australian Standard AS3706.11 Determination of Durability – Resistance to degradation by light and heat – utilises exposure to an MBTF lamp. For conventional geotextiles, a strength retention of 50% after 672 hours may be acceptable.

For geotextiles utilised in containers, a minimum of 80% strength retention is recommended. This translates to a minimum life of 10 years.

2.1.2 Abrasion Resistance

The containers will be exposed to constant abrasion due to water born sands and gravel carried by currents and waves, this abrasion can be extreme in areas where sand, coral and shell fragments are present. The geotextile must therefore have the highest possible abrasion resistance.

The German rotating drum test method best replicates the abrasive near shore surf environment, which these structures will be exposed to. This test subjects the geotextile to 80,000 rotations of a water/gravel mixture, a minimum of 75% strength retention is recommended for coastal applications.

2.1.3 Damage Resistance

Vandalism and incidental damage from driftwood etc. to sand filled geotextile is unavoidable. The geotextile must therefore have high elongation and puncture resistance to limit damage from impact by driftwood and boats. The geotextile should also allow the ingress of sand into the structure of the geotextile to limit damage by knife cuts.

A composite vandal deterrent geotextile has been developed which traps 3 kg/m² of sand within the geotextile. This product has significantly improved the resilience and durability of the individual containers.

It should be noticed that ice and frost load cases play no important role in Australia.

At present there are no indicator tests available, that model puncturing of the containers using a sharp instrument, hence there is very little information available to the engineer on which to base the vandal resistance of the various geotextile. One solution may be to modify the current ASTM D4833-00 puncture resistance test to from a knife-edge thereby mimicking a knife cut by a vandal.

2.1.4 Fines Retention

The containers will be exposed to wave action and dynamic flow conditions and it is critical the geotextile selected retain sufficient fill material to ensure the container does not deflate and remains stable.

The NF.G 38.C17 Hydrodynamic test should be used to assess the fines retention capability of the geotextile. In Germany the BAW turbulence test is used.

2.1.5 Permeability

The containers are likely to be exposed to cyclic wetting and drying due to tidal variation, the geotextile through flow will control the period for which the sand fill remains saturated after being submerged, stability of the structure is dependant of the water release capacity of the geotextile i.e. the faster the water is drained from the container the more stable the structure.

The geotextiles should be dimensioned as filter or alternatively have a minimum permeability of 10 higher comparing the fill material.

2.1.6 Interface Friction

This angle is of importance when assessing the stability of the structure, particularly when containers are placed on top of each other. Again the greatest friction angle is desirable.

A large 300mm x 300mm shear box should be used for this test to limit edge effects.

2.1.7 Elongation

A high elongation geotextile allows the containers to mould itself in with the existing features and also allows a certain degree of self healing of the structure (see Figure 1.)

An ultimate elongation (wide strip) of greater than 50% is recommended, to limit installation damage and allow flexibility of the structure.



Figure 1 Self-healing characteristic of high elongation containers

2.2 Projects

The following projects highlight some of the more important projects carried out by Soil Filters Australia over the past 20 years.

2.2.1 Russell Heads Groyne

Constructed in 1993 the Russell Heads groyne is significant because it provided a cost effective and socially acceptable solution to small isolated community. The comparatively remote location limited resources and lack of government funding presented a serious dilemma for the small Russell Heads community. What was needed was a solution which would allow the community themselves to construct the protection works and with very little expensive/specialist plant requirements.

By combining their resources, the community constructed a small dredge enabling them to install hydraulically filled 1.2 m dia. geotextile tubes and nourish the beach in a series of progressive "working bees". Although the wave climate was such that some displacement of the tubes occurred, the inherent flexibility of the nonwoven needle punched material utilised enabled re-alignment and settlement to follow scour contours and continue to provide stabilising protection.

Ultimately a 250 m long sand filled geotextile groyne was constructed, which has withstood extreme UV and abrasion for over 10 years.



Figure 2 Russell Heads Groyne (2000)

2.2.2 Stockton Beach Revetment

Constructed in 1996 the Stockton Beach revetment has shown that although designed as a short term solution, geotextile sand containers can provide longer term protection to important structures.

Severe erosion to the beachfront at Stockton beach had placed the Stockton Beach Surf Lifesaving Club in danger of collapse. Due to state government regulatory requirements an interim measure was the only rapid solution whilst a coastal management plan was finalised. The geotextile sand container option was chosen because the structure provided an economical and user friendly solution. The structure consists of in total 480 of staple fibre nonwoven geotextile containers each with a fill volume of 0.75m^3 . The structure design includes an encapsulated self-healing toe.

Despite the “temporary” nature of the structure, the non-woven geotextile containers have withstood a number of storm cycles. This installation has outlived the original design requirements and met the objectives of protecting the surf club whilst complying with providing a ‘soft’ interim solution to the total coastal management problem at this site. The “soft solution has also proven popular with beach goers who find the structure a user friendly option when compared with conventional rock and concrete structures. Until now no “permanent” works have been carried out and further extensive works, using sand containers, have been proposed for the properties adjacent to the site with construction due to begin in late 2004 (Restall et al., 2002).



Figure 3 Stockton Beach Revetment (2000)

2.2.3 Narrowneck Reef

Constructed in 1999/2000 the Narrowneck Reef rates as one of the most innovative and complex geotextile sand container structures ever built.

The 200m x 400m submerged reef is an integral part of the Northern Gold Coast Beach Protection Strategy whose aim was to widen and protect the northern beaches as well as enhancing the surfing amenity. The reef provides a low profile, near shore control point to retain approximately $80,000\text{m}^3$ of the $500,000\text{m}^3$ of sand transported each year to the north along this shoreline.

Nearly 400 mega containers manufactured from heavy-duty polyester non-woven geotextile containers varying from 3.0 metres to 4.6 metres in diameter, were placed using a split hulled, trailing suction hopper dredge fitted with computer interfaced DGPS. The containers were accurately filled utilising a calibrated flow density metre, ensuring repeatability and consistency of the construction. Containers were dropped in depths of water ranging from 3m to 10m, onto a sandy seabed.

The structure has proven to most successful in maintaining the widened beach profile (Turner, 2003). Based on the success of this first project the Gold Coast City council will construct similar reefs at another erosion prone area in 2004.

A feature not anticipated when originally considering the original design was the growth of algae and soft coral's on the containers and how this food source has attracted marine life to the structure. The Australian National Marine Science centre is currently carrying out detailed research into the suitability of various geotextiles to promote growth of algae and provide habitat to small crustations Edwards (2003). Figures 5 & 6 show some examples of the growth and marine life found on the containers.

During the first design phases the main supplier Soil Filters Australia Ltd. has engaged BBG Bauberatung Geokunststoffe GmbH & Co. KG for providing additional advise relating technical geosynthetic questions.



Figure 4 Narrowneck Reef (2000)



Figure 5 Crinoid & Soft Coral (2003)

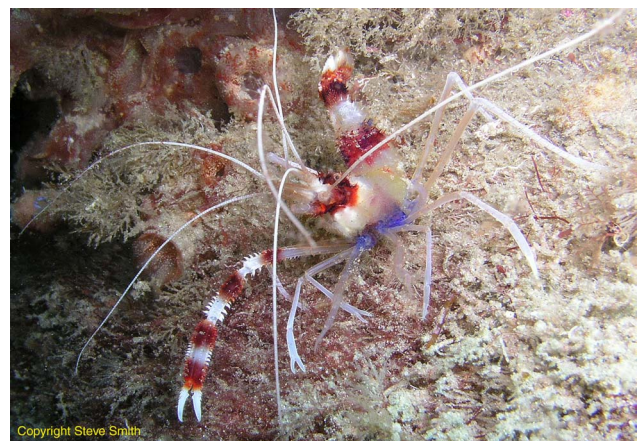


Figure 6 Banded Coral Shrimp (2003)

2.2.4 Maroochydore Groynes

Maroochy groyne No. 1 was constructed in November 2001 in order to prevent ongoing erosion of Maroochydore beach. Due to the success of the Maroochydore geotextile container sea wall constructed as emergency protection to the Cotton Tree caravan park, the council called for the design and construction of a groyne constructed from Geosynthetic sand containers. The tender called for a groyne 2.5m high by 100m long which could withstand 3m high waves. Another important criteria was that the geotextile should provide some form of vandal resistance.

The first groyne was constructed using 2.5m³ containers (see Figure 7) proved to be a success. The structure was stable under severe wave attack, was user friendly, aesthetically pleasing and the vandal deterrent geotextile had performed beyond expectations.



Figure 7 Maroochy Groyne No1 (2002)

This allowed the council to approve the second phase of project which consisted of a further 3 groynes, constructed in April 2003, to protect the exposed headland. The groynes were as follows:

- Groyne 2 – 92m long & up to 3.90 m high
- Groyne 3 – 47m long & up to 3.25 m high
- Groyne 4 – 71m long & up to 3.90 m high

The areas between the groynes were nourished with 30,000 m³ of sand from a sand source north of the Maroochy River.



Figure 8 Maroochy Groynes 1-4 (2003)

2.2.5 Jumaira Beach Revetment (UAE)

Constructed in February 2003 the structure was built to protect an amenities block, which extends out beyond the

seawall and is regularly subjected to wave attack during the Shamal (storm) season. These storms threatened to undermine the foundations of the structure, which could have resulted in significant damage or loss of the structure.

To protect the structure the municipality initially placed 1m³ woven bulker bags around its perimeter to provide cheap and flexible protection. However the durability, stability and aesthetics of the structure proved undesirable and another solution was required. A revetment structure, which combined the 0.75m³ and 2.5m³ Terrafix® Soft Rock® containers, was recommended.

As the structure was likely to be subjected to a large volume of pedestrian traffic and possible vandalism, a 2000g/m² composite geotextile was used on the top of the containers.



Figure 9 Jumaira Beach Revetment (2003)

The structure has weathered a number of storms since completion of the project and provides a user friendly, aesthetically pleasing and stable structure to an important tourist area.

3 LARGE-SCALE MODEL STUDY - GERMANY

In the framework of an applied research programme at the Leichtweiss-Institute for Hydrodynamics and Coastal Engineering of the Technical University Braunschweig, the large scale model tests were recently conducted, particularly focussing on the hydraulic stability of nonwoven geotextile containers used as dune protection. The results are described as follows.

3.1 Objectives

The main purpose of this study was the detailed testing of the stability of sand containers under wave load. Within three test phases a 1:1 sloping barrier composed of sand container of different sizes (150 l and 25 l) with and without fixation belts were investigated.

3.2 Results of Large-Scale Model Tests

The sand containers at the crest of the structure started to move earlier than the elements on the slope due to the different load conditions on the crest and on the slope. For the geometry investigated, design formulae have been developed which can distinguish between crest and slope elements. The main loading of the crest elements is induced by wave run-up and overtopping whereas the load of the slope elements is principally induced by the uplift during the wave run-down. The results of the *three test phases* are summarised below:

3.2.1 Test Phase I with Sand Containers (150 litres)

The analysis of the data from test phase I using 150 l geotextile containers (1.50 m x 0.75 m unfilled) showed a

large scatter of the stability number N_s from which a clear threshold between movement and no movement can hardly be identified.

Relating the initiation of movement to the number of container layers it was however possible to obtain a distinction with respect to the stability behaviour of crest and slope elements. Therefore, two stability formulae were developed to distinguish between the stability of crest and slope elements. For the slope elements the following formula was obtained (Figure 10):

$$N_s = \frac{H_s}{(\rho_E / \rho_W - 1) \cdot D} = \frac{2.75}{\sqrt{\xi_0}} \quad (1)$$

- D = characteristic diameter of sand container defined as $D = l \cdot \sin \alpha$
- l = length of sand container (container dimensions in wave direction) [m]
- H_s = significant wave height in front of the structure [m]
- ρ_W, ρ_E = density of water and sand container, respectively [kg/m^3] with
 - $\rho_E = \rho_s(1-n) + \rho_W$,
 - n = porosity of sand,
 - ρ_s = density of sandgrain (2650 kg/m^3),
- ξ_0 = surf similarity parameter.

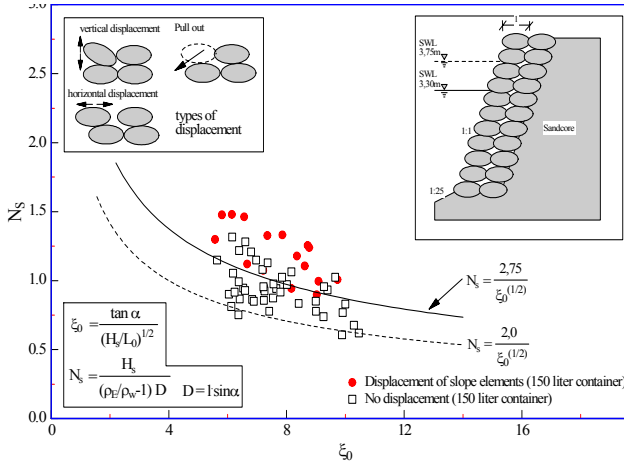


Figure 10 Stability of containers on the structure slope in test phase I (Oumeraci et al., 2002b)

As already mentioned, the crest elements start to move earlier than the elements on the slope (Figure 11). It was observed that the stability behaviour of the crest elements was clearly dependent on the relative freeboard R_c/H_s .

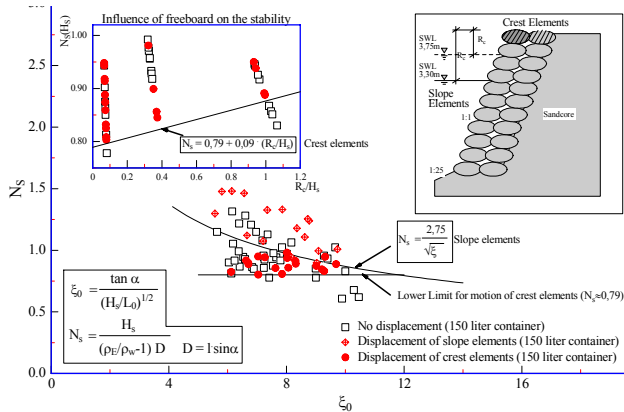


Figure 11 Stability of sand containers at the crest of the structure in test phase I (Oumeraci et al., 2002b)

From these observations a linear relation of the stability number N_s from the relative freeboard R_c/H_s was obtained:

$$N_s = \frac{H_s}{(\rho_E / \rho_W - 1) \cdot D} < 0.79 + 0.09 \cdot \frac{R_c}{H_s} \quad (2)$$

where R_c = freeboard [m].

3.2.2 Test Phase II with sand containers (25 litres)

In general, a similar behaviour of the small sand containers as compared to the 150 l sand containers was observed, i.e. the crest elements started to move earlier than the slope elements (Figure 12).

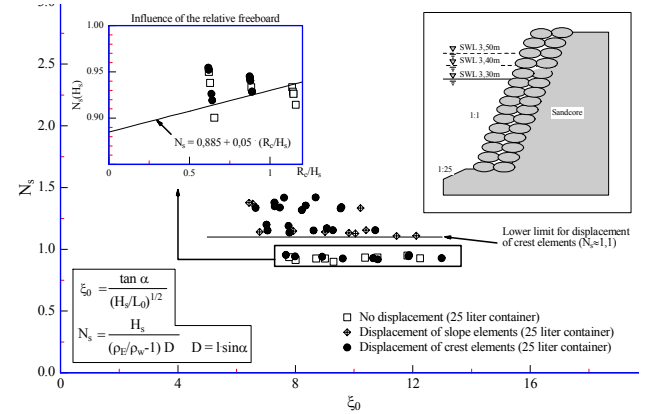


Figure 12 Stability of sand containers in test phase II (Oumeraci et al., 2002b)

No wave period effect on the stability could be observed for the stability number N_s for the slope elements.

$$N_s = \frac{H_s}{(\rho_E / \rho_W - 1) \cdot D} < 1.1 \quad (3)$$

A more detailed analysis of the movement of the crest elements has shown that a similar relationship between stability number N_s and relative freeboard R_c/H_s exists:

$$N_s = \frac{H_s}{(\rho_E / \rho_W - 1) \cdot D} < 0.885 + 0.05 \cdot \frac{R_c}{H_s} \quad (4)$$

Comparing these results with the results found with 150 l sand containers the smaller containers are relatively more stable.

3.2.3 Test Phase III with Velcro Tapes

In test phase III, each layer of sand containers was connected to the neighbouring layer by means of a self-adhesive velcro tapes which were fixed approximately at the front one third of the higher layer.

Generally, it was found that the velcro tapes increase the stability of the sand containers considerably (Oumeraci et al., 2002b).

Moreover it was observed that the filling material is removed from the front part of the containers to the back part. Consequently, the front parts of the containers were folded backwards up to the position of the velcro tapes, but still kept in position.

The effect of velcro tapes should however not be overestimated since the percentage of fastened container length was rather high due to the width of the fixation belts used. Furthermore, there is a strong need to carefully fix the belts. When re-using the velcro tapes the fastening characteristics significantly decrease. Generally, new velcro belts should be used.



Figure 13 Large-scale morel tests with geotextile containers

3.3 Concluding Remarks

The analysis of the large-scale model tests in the Large Wave Flume of Hannover (GWK) has allowed to identify the most heavily loaded parts of the sand container barrier. It could be shown that the stability of the crest elements is generally dependent on the relative freeboard whereas the stability of the slope elements is mainly governed by the wave height, the wave period and the slope of the structure. The latter has a major influence since it directly affects the degree of overlapping of the slope elements. Subsequently, the length of the sand containers should be large enough to ensure a proper overlapping.

The "fixation" of the sand container by self-adhesive belts resulted in a substantial stability increase. Due to the type of belt fixation used in the tests which is associated with a large "fixation area", caution is recommended when trying to transfer these results to other conditions in prototype.

3.4 Acknowledgements

The large-scale model tests were conducted at the Large Wave Flume of the German Coastal Research Centre (FZK). The funding by and the cooperation with the "Staatliches Amt für Umwelt und Natur Rostock (STAUN Rostock)" are gratefully acknowledged. The support of the permanent staff of the FZK during the experiments and the cooperation with Naue Fasertechnik GmbH & Co. KG are also gratefully acknowledged.

4 GERMAN RECOMMENDATIONS "EAG-CON"

In 1994 the above mentioned technical requirements for the geotextile container technology have led to the formation of the working group 'geotextile containers in hydraulic engineering', named UG 5. This working group is placed below the working group Ak 5.1 for "Geosynthetics for Geotechnics and Hydraulic Engineering" and within the German Geotechnical Society (DGGT).

The main objectives of UG 5 'geotextile container' are directed to practical planners and users in the field of hydraulic and coastal engineering applications. The aim is to provide technical information and recommendations for geotextile container solutions (geotextile hand bags, large bags, containers, tubes, mattresses and double layered distance elements) as well as giving details relating tendering, contracting and quality assurance. One main focus is set knowingly on presentation of case studies relating experienced geotextile container applications. A

significant part of German geotextile container projects is shown in Saathoff (2002).

The technical recommendations include following main topics relating principles in geotextile container technology:

- Principles in geotextile container applications,
- Principles in material parameters and system requirements,
- Principles in the design,
- Principles in quality assurance,
- Principles in construction methods and installation possibilities
- Execution with fill methods relating a final geotextile container position (fill materials, filling with suction excavator, filling with mobile excavator pump or solid and thick-matter pumps, filling with dredge or a simple hopper fill and pneumatical filling)
- Execution with pre-filled geotextile containers (fill methods for small handbags, large geotextile containers up to 1m³ fill volume, loading and transportation facilities, installation methods for previous filled and for very large geotextile containers)
- References and Appendix

The German recommendations on geotextile containers, bags and tubes "EAG-CON" will be released soon and will present detailed information about the geotextile container technology.

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