ICOPMAS

Applications of Geosynthetics Sand Filled Containers for Coastal Protection

Abdolhosein Haddad, Ph.D.
Civil Eng. Dept, Semnan University, Iran
Email: ahadad@semnan.ac.ir
Jalil Jalali, Ph.D.
Munich Technical University (TUM), Germany

Abstract:

Geosynthetic products such as geotextiles and geomemberanes are used in containers and tubes for dam and dike flood emergency protection and also as construction elements for coastal erosion control, groynes, scour fill, reefs, breakwaters and dune revetments. On the other hand due to the increasing storminess associated with climate changes and tsunami's waves phenomena some of the existing dunes must be protected or reinforced. Traditional construction techniques utilizing rock, concrete and steel are being increasingly challenged by alternatives offered in geosynthetic forms for revetments, scour protection, groynes, berms, and dunal stabilization. Nowadays geotextile sand containers find their application as construction elements for erosion control, scour fill and dune revetments. Wrapping or encapsulating sand into geotextile units provides a variety of flexible, economical and ecological coastal applications. The use of such containers for this type project also appears to have the potential to reduce settlements in poor sub-grade conditions, however it is recognized that this is a relatively new system and the knowledge base required to carry out a design with a high degree of confidence is limited.
This paper shows some experiments 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 some recommendations dealing with geotextile containers are described.
Keywords: Geosynthetics, Coastal protection, Sand filled containers, Stability

1- INTRODUCTION

However 50 years ago first trials with sandbags made of synthetic textiles were realized in the USA, the Netherlands and in Germany, the geosynthetic sand filled containers have been developed for coastal applications during the last 20 years. Hydraulic engineering and Coastal problems were the starting point of the technical development of geotextiles. Various other geosynthetic disciplines of civil engineering were opened up later on. 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. These systems use specialized fabrics sewn into tubes hydraulically filled with sand or large bags mechanically filled and placed.
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 some Australian projects and examples where the encapsulation of sediments in geotextile sand containers dominates but other functions, e.g. reinforcement and filtration cannot be

neglected. Additionally the results of German large scale model tests are presented and the content of German recommendations dealing with geotextile containers is described.

2- 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.

- *UV-Resistance*

In regions such as Middle East and Australia the 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 – utilizes exposure to an MBTF lamp. For conventional geotextiles, a strength retention of 50% after 672 hours may be acceptable. For geotextiles utilized in containers, a minimum of 80% strength retention is recommended.

- *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. 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.

- *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 NFG 38.C17 Hydrodynamic test should be used to assess the fines retention capability of the geotextile.

- *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. 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.

- *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.

- *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.

- *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.

Figure 1: Self-healing characteristic of high elongation containers

3- Maroochydore Groynes (Australia)

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 criterion was that the geotextile should provide some form of vandal resistance. The first groyne was constructed using 2.5m3 containers (see Figure 2) 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 2: Maroochy Groyne No1 [1]

4- 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 of the top of the containers, (See Figure 3).

Figure 3: Jumaira Beach Revetment [2]

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 [2] .

5- LARGE-SCALE MODEL STUDY

In the framework of an applied research programme at the Leichtweiss-Institute for Hydrodynamics and Coastal Engineering of the Technical University Braunschweig in Germany, the large scale model tests were recently conducted, particularly focussing on the hydraulic stability of nonwoven geotextile containers used as dune protection.
The main purpose of this study was the detailed testing of the stability of sand containers under wave load. Within two 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, Figure 4. The results are described as follows.

5.1 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 [3].The results of the two test phases are summarised below:

Figure 4: Large-scale model tests with geotextile containers [3]

5.2 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 Ns 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[4], (see Figure 5).

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

Where D = characteristic diameter of sand container defined as D = l.sinα ,l = length of sand container (container dimensions in wave direction) [m], Hs =significant wave height in front of the structure [m], ρw, ρE = density of water and sand container, respectively [kg/m3] with ρE=ρs(1-n)+ ρw , n= porosity of sand, ρs= density of sand grain (2650 kg/m3) and ξ0 = surf similarity parameter.

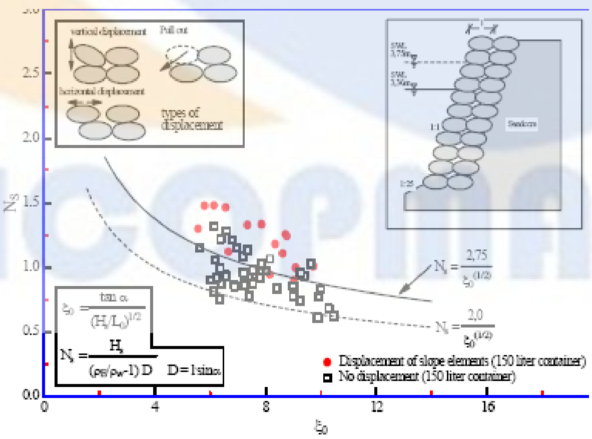

Figure 5: Stability of containers on the structure slope in test phase I[5]

As already mentioned, the crest elements start to move earlier than the elements on the slope (Figure 6). It was observed that the stability behavior of the crest elements was clearly dependent on the relative freeboard Rc/Hs.

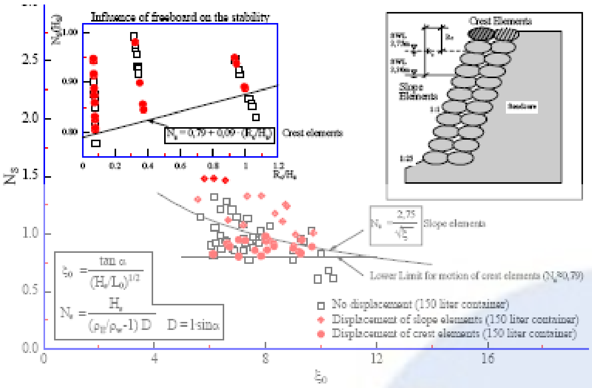

Figure 6: Stability of sand containers at the crest of the structure in test phase I [5]

From these observations a linear relation of the stability number Ns from the relative freeboard Rc/Hs was obtained:

$$N_s = \frac{H_s}{(\rho_E/\rho_W - 1)\times D} \leq 0.79 + 0.09\frac{R_C}{H_s} \quad (2)$$

Where Rc = freeboard [m].

5.3 Test Phase II with sand containers (25 litres)

In general, a similar behavior 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 7).

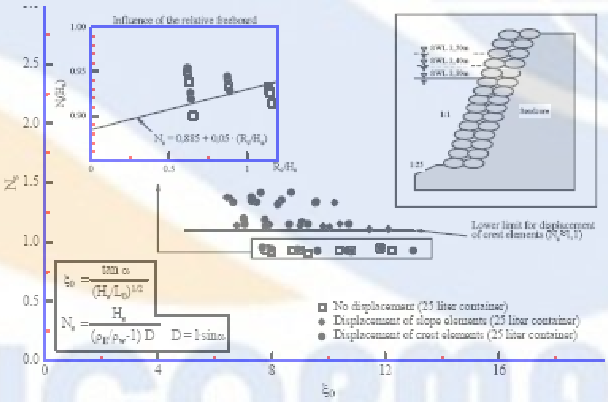

Figure 7: Stability of sand containers in test phase II [5]

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

$$N_s = \frac{H_s}{(\rho_E/\rho_W - 1)\times D} \leq 1 \quad (3)$$

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

$$N_s = \frac{H_s}{(\rho_E/\rho_W - 1)\times D} \leq 0.885 + 0.05\frac{R_C}{H_s} \quad (4)$$

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

6- Concluding Remarks

The use of geosynthetic containers is still a relatively new science; however a number of approaches for planning and design are available. Until now, there are a large number of examples in operation that prove the long term stability of both the material and the entire structure. However, a great deal can still be learnt from the few cases of failure and from any new structure. So taking into account the advantages in so many cases, everybody should be encouraged to think about such alternative construction methods.

The analysis of the large-scale model tests in the Large Wave Flume of Hannover (GWK) has allowed identifying 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.

7- REFERENCES

[1]- Restall, S.J., Jackson, L.A., Heerten, G., Hornsey, W.P., (2002) case studies showing the growth and development of geotextile sand containers: an Australian perspective, Geotextiles and Geomembranes 20, pp 321 – 342

[2]- Turner I.L., (2003) Applications of coastal imaging technology to Coastal Engineering and Coastal Management. Coasts and Ports, Auckland, New Zealand.

[3]-Saathoff, F., 2001: Geotextile sand containers in hydraulic and coastal engineering -German experiences-, 7th IGC, International Geosynthetic Conference, Nice, France, 2002

[4]- Oumeraci, H.; Bleck, M.; Hinz, M., (2002) Untersuchungen zur Funktionalität geotextiler Sandcontainer. Berichte Leichtweiß- Institut für Wasserbau, Technische Universität Braun-schweig, Nr. 874, Braunschweig, Germany, unpublished (in German).

[5]- Oumeraci, H.; Bleck, M.; Hinz, M.; Möller, J., (2002) Theoretische Untersuchungen zur Anwendung geotextiler Sandcontainer im Küstenschutz. Berichte Leichtweiß-Institut für Wasserbau, Technische Universität Braunschweig, Nr. 866, Braunschweig, Germany, unpublished (in German).