SAND FILLED GEOTEXTILE STRUCTURES: DESIGN AND DURABILITY

W.P. Hornsey[1] and J. T. Carley[2]
[1]Geofabrics Australasia (Pty) Ltd, Gold Coast, [2] Water Research Laboratory UNSW, Manly Vale

ABSTRACT

The use of geotextile sand containers (GSC's) as shoreline protection systems has grown moderately since the first applications in the 1970s. This can be attributed to two factors; firstly, the lack of understanding of coastal processes and design fundamentals by the larger Geosynthetic community in order to provide coastal engineers with suitable solutions and secondly there has been very little rigorous scientific wave flume testing with which to analyse the wave stability of geotextile sand containers.

The application of geotextile containers in coastal protection works can be traced back to early works carried out in 1970s. The application of these types of structures was somewhat haphazard as very little was understood about the wave stability and durability of the structures. Early wave stability work was carried out Ray (1977) and Jacobs (1983) with small containers, however the testing programs were limited and did not provide sufficient confidence in the product to carry out comprehensive engineering design. As a result, the technology until recently has relied on manufacturers design suggestions based on monitoring of actual structures. Over the past five years, the global warming and the sea level rise debate has resulted in more emphasis being placed on shoreline protection systems. Geotextile manufacturers have responded to the challenges put forward by design engineers and intensive research has been carried out in the field.

This paper covers the key issues which will ensure the long term integrity of a geotextile shoreline protection system is maintained, these issues include:

> Wave stability
> Detailed analysis of recent large scale wave flume testing which assess filling capacity, size of container, structure slope and scour protection etc.
>
> Container/geotextile durability
> Methods and specifications used to limit the effects of the fundamental factors affecting the life span of geotextile containers such as vandal resistance, UV degradation and abrasion resistance etc.

This paper outlines the "state of the art" in terms of the design and specification of geotextile sand containers (GSC).

1 INTRODUCTION

The appeal of living or playing alongside the water whether it is the beach, river or canal has placed these amenities under considerable pressure, exacerbated by sea level rise and changing weather conditions. Issues such as maintaining property boundaries while providing safe public access are important for many stakeholders.

The Australian trend in population movement is away from inland towns or large cities towards coastal communities. The rate of growth in coastal areas is 60% higher than the national average. This phenomenon known locally as 'sea change' has placed considerable pressure on the valuable foreshore environment and amenity. Where beaches were previously allowed to erode or accrete naturally depending on the natural coastal processes, ongoing development has placed man made boundaries on the extent to which the erosion can take place, resulting in the construction of revetments (sea walls), groynes and other structures to protect this development. Traditionally these structures have been constructed using rock, concrete or wood however a combination of limited access to suitable natural materials to construct these features and the beach user's demand for more user-friendly materials has led to the development of geotextile sand containers (GSC) for shoreline protection.

The choice of which erosion control system to adopt, has traditionally revolved around the use of rock and concrete, which, while effective, is not currently considered environmentally or user-friendly. The demand for alternative solutions has lead to the development of a number of innovative products, one of which is sand filled geotextile containers. The use of geotextiles in erosion control structures is not new, however, their use as the primary defence against erosion has resulted in the development of specialised materials, which can withstand harsh exposed conditions. The use of sand filled geotextile containers provides the designer with an alternative "soft" solution, which provides effective erosion control whilst maintaining a user-friendly amenity.

The first large scale projects using geotextile sand containers were carried out in Australia in the late 1980s and early 1990s. This experience consisted mainly of exposed structures constructed using small diameter (1.2 m) dredge filled tubes. Projects such as Kirra Groyne (1985) and Russell Heads Groyne (1993) (Restall *et al.*, 2002) amongst others provided invaluable data on the strengths and limitations of these types of structures. In the late 1990s and early 2000s the method of manufacture of the geotextile containers was changed in order to overcome the limitations which became apparent after some years of monitoring of the aforementioned structures. The tubes were replaced by dry filled smaller 0.75 m^3 and 2.5 m^3 individually stacked containers, as the preferred method of construction, which overcame issues associated with exposed geotextile tube structures.

The design of geotextile shoreline protection systems can be divided into two distinct sections:

- Wave Stability
    - Wave flume analysis
    - Size / Filling capacity and structure slope
    - Sand retention
    - Scour protection
- Durability
    - Strength
    - Damage resistance,
    - UV degradation
    - Abrasion resistance

2 WAVE STABILITY

It has long been recognized that Hudson's formula (used for preliminary sizing of rock armour) was not an appropriate method to assess the stability of geotextile container structures and that the absence of rigorous testing had limited the extent to which these systems could be applied. The latest research has concentrated on the development of design curves for small (0.75 m^3 and 2.5 m^3) ELCO**ROCK**® sand filled containers manufactured from staple fibre geotextile.

2.1 WAVE FLUME ANALYSIS

To date the global stability information has been limited primarily due to the significant costs associated with carrying out large scale wave flume modelling. Secondly, cooperation between installers and academics is required to ensure accurate and valid scaling of the containers and ultimately accurate forecasting of the performance of the system. In 2008 the Water Research Laboratory of the University of New South Wales, based in Sydney, Australia, carried out detailed analysis of the wave stability of two small container options, nominal size 0.75 m^3 and 2.5 m^3. These specific containers sizes were chosen as they represented the normal state of practice for small geotextile containers used as shoreline protection systems in Australia over the past 10 years. The aim of the research was to provide engineers with proven data which will allow designs to be carried out with confidence. The research consisted of four key components; scaling, initial wave flume testing, long term testing and design curves and design methodology.

2.1.1 Field Scaling

Scaling and accurate dimensioning of the containers was viewed as the key to providing representative results, and this was proven during the test program. In previous wave flume testing there has been limited emphasis placed on determining the fill capacity and final dimensions of the full size containers.

It should be noted that there will always be some variation on the final dimension of the containers; however the aim should be to fill the container to capacity. Reasons for variations in dimensions are listed below:

- Geotextile elongation – The inherent elongation (stretch) associated with staple fibre geotextiles means that if the container is over handled during installation the geotextile will stretch resulting in different dimensions to other containers which have been handled less,
- Fill material – The grading of the fill material will have an influence on the *in situ* density and final dimensions of the container. A fine grained material will behave differently to a coarse grained fill material, during filling and placement. Depending on the level of saturation this will affect the dimensions,
- Filling and placement equipment – The filling and placement equipment undoubtedly has the largest impact on the final dimensions as the equipment controls the extent to which the container can be filled and the stress which can be exerted on the geotextile.

A detailed analysis of the full scale containers (0.75 m^3 & 2.5 m^3) was carried out by "Blacka *et al*. (2006)" details of which are summarised in Table 1 and represented graphically in Figure 1.

Table 1: Field Measured Parameters.

Property (mean)	2.5 m^3 (Nominal)	0.75 m^3 (nominal)
Container Volume	2.76 m^3	0.87 m^3
Saturated GSC weight	4,616 kg	1,507 kg
Inferred dry weight	3,585 kg	1,154 kg
Saturated GSC bulk density	1,674 kg/m^3	1,729 kg/m^3
Inferred dry bulk density	1,302 kg/m^3	1,327 kg/m^3
Dimensions of the GSC (typical)	2.6 m(L) x 1.9 m(W) x 0.58 m(D) (2.4 m x 1.8 m x 0.65 m)	1.8 m(L) x 1.5 m(W) x 0.42 m(D) (1.6 m x 1.2 m x 0.4 m)

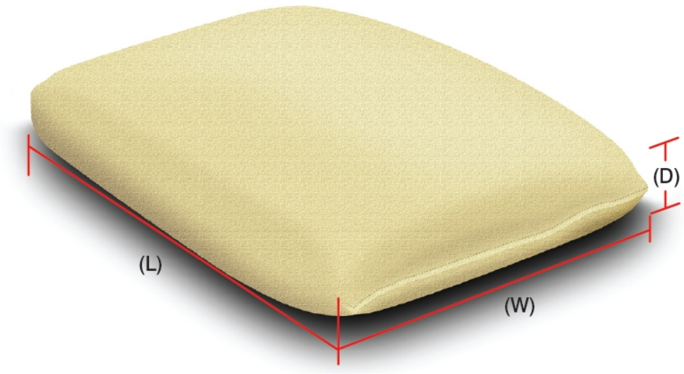

Figure 1: Graphical representation of the container dimensions

From this data model scaling was developed (Table 2) for the large scale wave flume testing. Scaling of the containers provides two important functions, ensuring that the scale model containers are representative of full size Geosynthetic sand container and that failure of the system is possible using the available equipment, giving the limitation of the individual container system.

Various aspects need to be scaled to ensure representative results, including dimensions, mass, density and frictional interaction. The first part of the research and development program measured field representative Geosynthetic sand containers. The second stage was designing a container that would fail using the flume.

2.1.2 Wave Flume Scaling

Initially, basic flume testing was carried out on model 0.75 m^3 containers at 1:4 to 1:8 geometric scale until failure was induced. The second phase concentrated on the characteristics of the geotextile and also the sand fill used inside the containers to try and match full size characteristics. It was noticed that at a 1:8 geometric scale, failure was not always able to be induced by the largest waves possible in the flume, so the final scale was reduced to 1:10 (for the 0.75 m^3 containers) and 1:13 (for the 2.5 m^3 containers). Other characteristics, geotextile and sand fill properties, were scaled according to Froudian similitude. See the following table (Table 2) for actual Geosynthetic sand containers properties and model comparisons.

Table 2: Field and Model Comparisons.

Property	2.5m^3 Prototype	2.5m^3 Model (1:13)	0.75m^3 Prototype	0.75m^3 Model (1:10)
Volume	2.76 m^3	2.22 m^3	0.87 m^3	1.01 m^3
Saturated GSC weight	4,616 kg	5,577 kg	1,507 kg	1,628 kg
Dry weight in air after filling	3,585 kg	2,746 kg	1,154 kg	1,250 kg
Saturated GSC bulk density	1,674 kg/m^3	1,612 kg/m^3	1,729 kg/m^3	1,612 kg/m^3
Length	2.6 m	2.15 m	1.8 m	1.65 m
Width	1.9 m	1.82 m	1.5 m	1.4 m
Depth	0.58m	0.56 m	0.42 m	0.43 m

2.1.3 Wave Flume Test Regime

As each site is different, long term structural performance requires site specific conditions to be accounted for in the design. To prevent limiting the design envelope produced in the program to a small range of conditions or sites, a range of variables was tested, including different wave conditions, types, foreshore slopes and revetment slopes. This widened the design envelope to encompass many conditions likely to be encountered worldwide.

The following table (Table 3) represents the tested conditions on the 1:10 scale 0.75m^3 Geosynthetic sand containers.

Table 3. Test Programme Variables.

Test Condition	Variable
GSC Size	0.75 m^3 model
Revetment Structure Slope	1V:1.0H, 1V:1.5H, 1V:2H
GSC packing technique	Stretcher bond, long axis perpendicular to the wave attack
Number of GSC layers	Single and double layer
Foreshore slope	1V:5H, 1V:10H, 1V:20H
Toe level	-1.0m AHD
Still water level	0m AHD, 1.5 m AHD & 3.0 m AHD
Peak spectral wave period, T_p	5 s, 10 s, 15 s
Significant wave height at the structure, H_s	0.5 m to 2.0 m

(AHD is Australian Height Datum and is ≈ MSL – mean sea level)

Another important aspect that needs to be identified is the structural arrangement and construction methodology of the model revetment. In addition to those aspects identified above, important design considerations should be representative in the model including; toe scour protection, particularly important in the dynamic coastal environment, and reducing as much as possible, boundary effects from the testing apparatus. See Figure 2 for the typical arrangement.

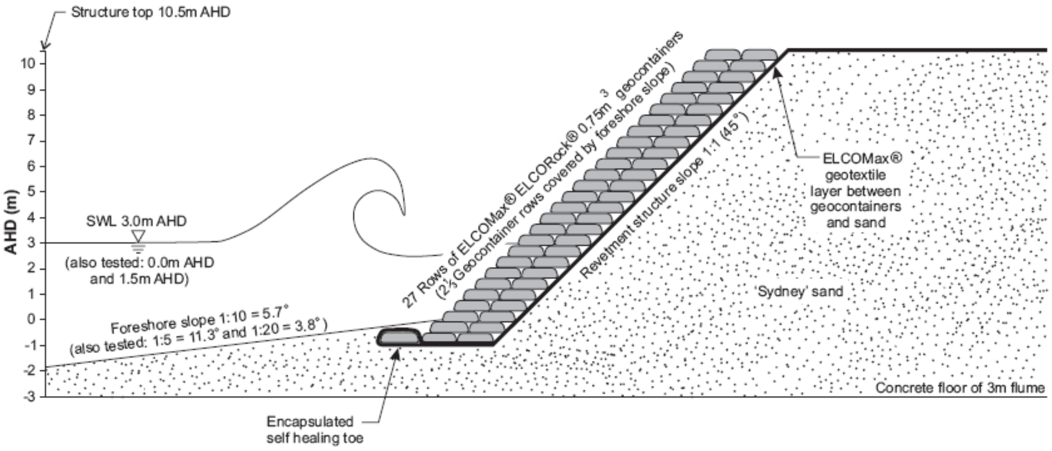

Figure 2. Test Configuration

Once the variables and structural profile were determined, a failure classification of the structure needed to be identified. To be compliant with existing systems, a similar failure classification to interlocking concrete armour units "(U.S. Army Corps of Engineers (2006)" was selected. This identifies specific failure modes depending on displacement or loss of armour rock, units or in this case Geosynthetic sand containers. See Table 4 for failure or structural damage criteria.

Table 4. Structural Damage Classification.

Armour Layers	Slope	No Damage	Initial Damage	Intermediate Damage	Failure
Single	1:1 - 1:2	0 %	0-1 %	1-10 %	>10 %
Double	1:1 – 1:2	0 %	0-2 %	2-15 %	>15 %

The test program undertaken on each structure, with different characteristics as identified in Table 3, consisted of both monochromatic and irregular waves totalling 1,100 per test. The test duration of 1,100 waves gave a probability of 99% that deepwater maximum wave height (H_{max}) was approximately 1.87 times the significant wave height at structure (H_s), thus giving the highest confidence that the structure has been exposed to the highest possible waves within the random spectrum. This many waves (1100) also corresponds to approximately 2 to 3 hours in the real world, which represents the peak of the tidal cycle during a storm event.

The change in still water level, wave height and period enabled different types of waves to be impacted on the revetment; unbroken, broken and breaking waves, exposing the structure to all types of conditions.

2.1.4 Design Curves

The results from the testing program (77 tests on the final structure) will be used to generate a design guideline using the Geosynthetic sand containers. The results are based on the “Initial Damage” criteria as discussed in the previous section (i.e. 0-2% on the double layer system). The following figures (Figures 3-6) demonstrate the testing process, before, during and after wave attack.

Figure 3. Model container structure

Figure 4. Water added to flume

Figure 5. Model during wave attack (H_s ~ 1.4m)

Figure 6. After wave attack (~ 15% damage)

The following charts (Figures 7 and 8) represent the results, design charts, from the irregular wave tests (1,100 waves) on the structure conducted with different revetment slopes, foreshore slopes, still water levels and wave periods. The charts are based on the more stable double layer geosynthetic sand container revetment structure.

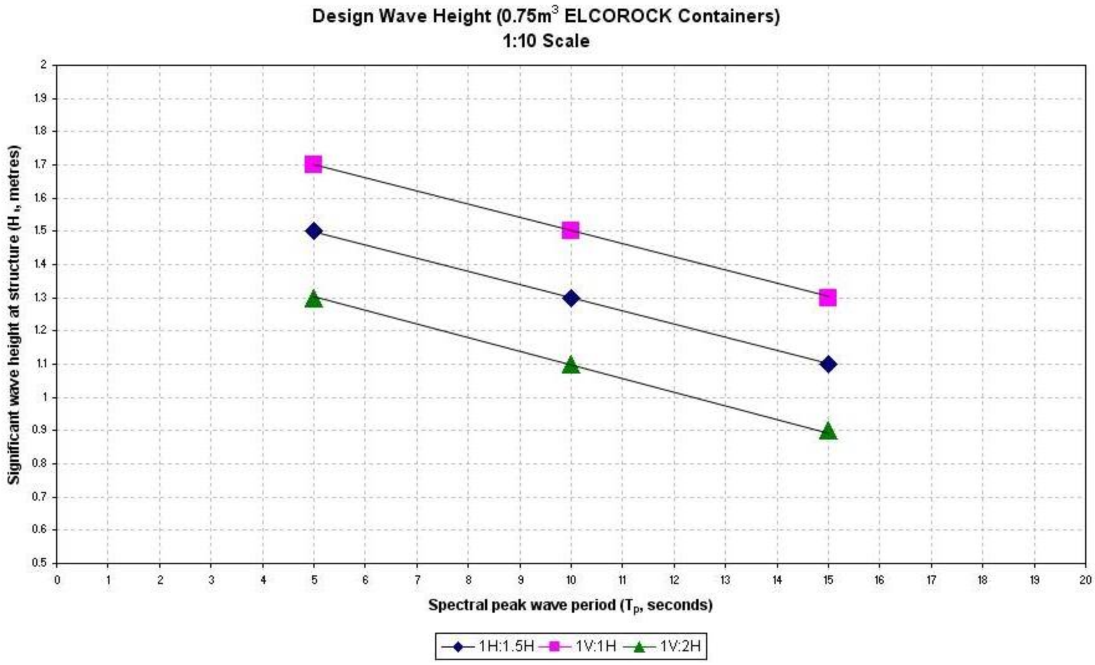

Figure 7: 0.75 m^3 container stability chart (<2% damage)

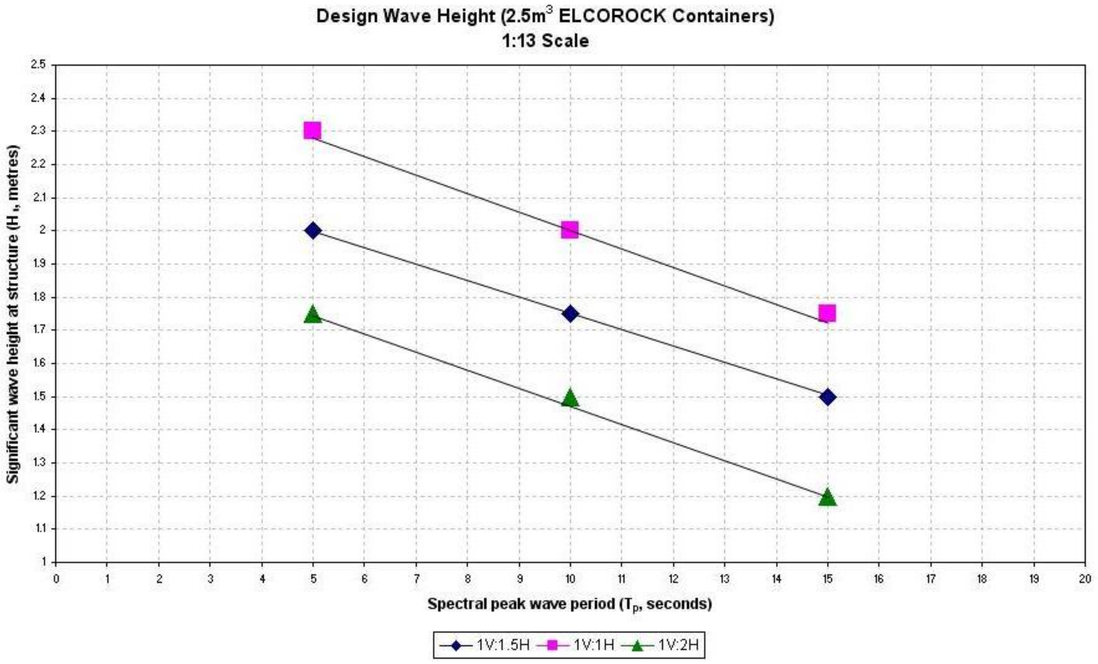

Figure 8: 2.5 m^3 container stability chart (<2% damage)

2.1.5 Filling Capacity

It should be noted that these curves only apply to containers manufactured from the same geotextile and filled using the same method which achieve similar fill capacities. Monitoring of the failure mechanisms during the testing confirmed the hypothises put forward by Oumeraci *et al.* (2003) that failure is due to forward displacement of individual containers and that this phenomenon is controlled by the contact surface area between containers and the interface friction of the upper and lower geotextile surfaces of the containers i.e. geotextile vs. geotextile. Similarly the significance of fill capacity of the container can be shown in Table 5 below where the Water Research Laboratory results (Carley *et al.*, 2008)" and Oumeraci *et al.* (2003) results are plotted on the same axis. Oumeraci *et al.* (2003) used a nominal 80% fill value for the container (based on German construction practice) rather than the fill to capacity applied in the WRL results (based on Australian construction practice).

Table 5: 80% fill capacity (Oumeraci *et al.*, 2003) vs. fill to capacity

Revetment Structure Slope	Peak Wave Period T_p (s)	Design significant wave height, H_s (m) for <2% damage	
		Oumeraci *et al.* (2003) stability equation	WRL Physical model Results
1V:1.0H	5	1.73	1.7
	10	1.09	1.5
	15	0.83	1.3
1V:1.5H	5	1.56	1.5
	10	0.98	1.3
	15	0.75	1.1
1V:2.0H	5	1.29	1.3
	10	0.81	1.1
	15	0.62	0.9

When comparing the results of this test regime with the *Oumeraci et al.* results it becomes clear that as the wave period increases the stability of the 80% filled containers for a particular wave height drops off significantly when compared with the containers filled to capacity.

2.2 SAND RETENTION

As shown above the fill capacity of the container has a significant impact on its stability; it is therefore critical that this fill capacity be maintained for the life of the structure. One area often overlooked by designers is the sand retention capacity of the geotextile which will influence the long-term fill capacity of the Geosynthetic sand container.

Geosynthetic containers and the sand contained within are exposed to the most aggressive flow conditions a Geosynthetic filter system is likely to encounter. The geotextile is likely to undergo some deformation due to either installation or sand movement during wave attack, Edwards and Hsuan (2010) showed biaxial stress on a woven geotextile can alter the pore size on the geotextile, which could impact on its sand retention capacity. The high pore water pressure loads exerted under wave impact combined with sand movement within the container which depends on the direction of wave attack means that the traditional filter zone is never developed. The entire body of sand within the container remains effectively mobile during the life of the structure and this sand is subjected to large suction forces during wave and tidal drawdown. Good sand retention behaviour of the geotextile is therefore particularly important.

In order to accurately assess the long term sand retention capacity of the geotextile it is recommended that 95% retention be achieved when tested according to the Hydrodynamic Test NFG 38-017-1989. The test method forces water though the geotextile and sand in two directions which does not allow a stable filter zone to form within the sand. Experience has shown that this test best mimics the actual field conditions to which the container is likely to be subject to.

2.3 SCOUR PROTECTION

As with all coastal structures, toe stability is critical in ensuring the survival of a geotextile sand container structure. From studies in the United Kingdom in the late 1980s and early 1990s, CIRIA/CUR found that "around 34% of seawall failures arose directly from erosion of beach foundation material, and that scour is at least partially responsible for a further 14% of failures, That is, approximately 48% of seawall failures in the UK could be wholly or partly attributed to toe scour.

The toe of the structure should be located at a level where it can not be undermined, in most cases (for a seawall at the back of a beach) if the base of the structure is founded at 0 m LAT the structure will perform adequately. However in extreme storm events large scale erosion can occur at the toe of the structure and in order to overcome this issue it is recommended that an additional scour container in the form of an encapsulated self-healing toe be incorporated in the design which will prevent undermining of the structure (refer Figure 2).

The size of this toe container should be compatible with the wave conditions expected at the toe of the structure. Weerakoon *et al.* (2003) showed that using too small a toe protection container lead to damage and failure of the structure.

3 DURABILITY

Geotextile sand containers are exposed to the elements for long periods of time, in some cases for more than 25 years and are expected to retain their key functions for the full period, unlike an application such as separation where the geotextile is buried soon after installation and expected to perform the filtration and reinforcing function only until consolidation of the subgrade has occurred. Therefore the geotextiles used in the manufacture of geotextile sand containers must be a number of orders of magnitude more durable than geotextiles used in traditional separation and drainage applications.

The key factors influencing the long term durability of the geotextile sand containers are discussed in the following sections.

3.1 STRENGTH

When designing geotextile container structures a large redundancy factor must be built into the required strength of the geotextile material in order to account for the ongoing degradation of the material due to exposure to the elements. In most cases the filling and placement operation places the most stress on the container and the *in situ* strength requirements are somewhat lower than the initial strength requirements. It should be noted that the container durability is highly dependent on the seam strength of the container, as this is generally the weakest part of the container.

Therefore designers should consider all the factors which could influence the strength of the base geotextile and the seam. Allowances should be made for the reduction of strength such that the container remains intact until the end of its design life.

3.2 DAMAGE RESISTANCE

Exposed to the elements to a far higher degree than most other geotextile applications, such as drainage and separation, means damage to sand filled geotextile containers is unavoidable and without question the key factor limiting the life of a geotextile container structure. The type of damage which is likely to occur can be categorised into two broad segments, namely:

- Incidental damage (from driftwood or boat damage)
- Vandalism (knife cuts and punctures)

In both these cases limiting the extent and the amount of this damage has a significant impact on the durability of the structure as a whole. Experience has shown that a structure consisting of a larger number of relatively small containers is far less likely to sustain a single catastrophic damage event, and that the choice of geotextile used for the manufacture of the containers has a marked influence over the long term survivability of the structure. Repairs can be affected to the containers. However, experience has shown that clients are less likely to apply complex patch methods. Two simple repair methods have been developed for wet or dry applications to ensure the long term durability of the structure.

3.2.1 Incidental Damage

The relevance of incidental damage will vary from site to site, but is a key factor when structures are constructed on river banks or adjacent to boat launching facilities. In this application, limiting the amount of the damage is critical; this can be achieved by choosing a geotextile which is less susceptible to damage. In both Australia and America the survivability of a geotextile is based on the % elongation i.e. the higher the elongation, the lower the damage potential. In order to accurately compare the damage resistance “Koerner (2005)” suggested the use of impact energy as an effective measure of the relative damage resistance of various geotextiles. Impact energy takes into account both strength (force) and elongation (distance) which can be calculated using the CBR test method which measures the force (N) and the elongation (mm) for a given geotextile. Examples of impact energy of 3 common generic geotextiles of the same CBR strength are provided in Table 6:

Table 6. Impact energy comparisons

Geotextile	CBR Strength (N)	Elongation (m)	Impact Energy (J)
Staple Fibre	3800	0.07	266
Continuous Filament	3800	0.055	209
Woven	3800	0.035	133

This methodology allows designers to carry out simple comparisons of the relative damage resistance of the geotextiles proposed for the manufacture of geotextile sand containers.

3.2.2 Vandalism

In Australia and New Zealand vandalism, primarily knife cuts, is the greatest threat to Geosynthetic sand containers. Standard geotextiles (woven or non-woven) provide limited resistance to knife attack and a number of high profile projects such as Kirra Groyne and St Clair revetment (Figure 9) have ultimately failed due to vandalism. Various coatings have been trialled since the late 1990s to improve the vandal resistance of the geotextiles, including polyurethane spray on coating, which provided limited improvement with considerable cost implications.

Figure 9: Vandalised geotextile tubes – St Clair Beach, New Zealand

In 2001 a composite geotextile (Figure 10) was developed which consisted of a standard inner geotextile with a coarse fibre geotextile bonded by needle punching to the outer surface; the coarse outer layer allows sand to be trapped within the geotextile and this trapped sand provides protection from knife cuts. It is important that the outer layer is correctly bonded to the inner layer as poor bonding will allow stripping of the outer layer and loss of protection of the container. The coarse outer layer is also sand coloured (Figure 10) which offers improved aesthetics.

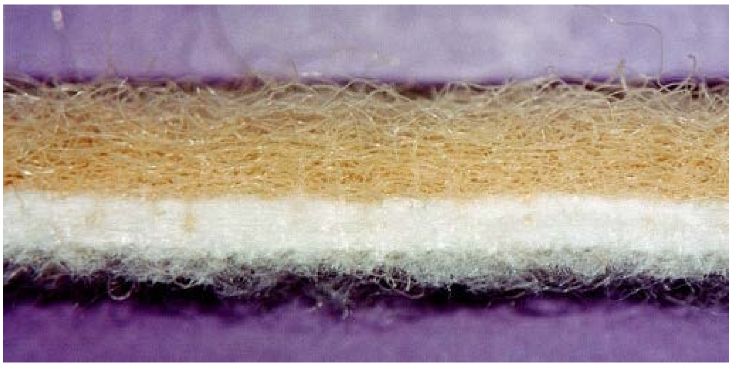

Figure 10: Composite Geotextile

At present there are no indicator tests available which predict resistance to puncturing or cutting of the containers with a knife or sharp instrument, hence there is limited information available to engineers upon which to base a vandal resistance specification. One solution proposed is to modify the current ASTM D4833-00 Rod Puncture test to create a sharp point and thereby mimic a puncture with a sharp instrument (Figure 11). Testing carried out using this method has shown that adding more geotextile mass increases the puncture resistance moderately, however, the inclusion of sand which becomes naturaly trapped in the coarse fibre outer layer provides significant improvement, see Table 7.

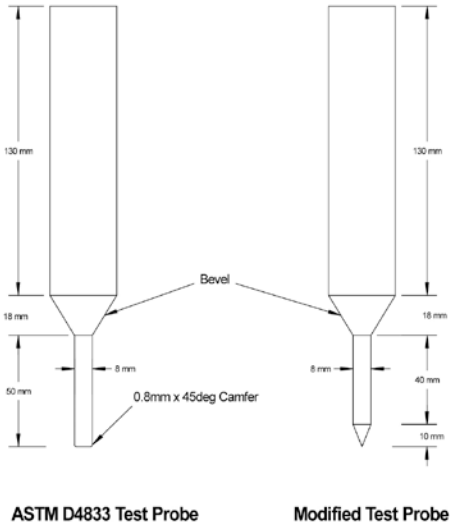

Figure 11: Modified Rod Puncture Apparatus.

Table 7: Sharp Instrument Puncture Resistance

Product: Staple Fibre Geotextile	units	Test Method: Modified ASTM D4355	Geotextile mass increase	Puncture resistance increase
600 g/m^2	N	166	-	-
800 g/m^2	N	215	33 %	29 %
1200 g/m^2	N	328	50 %	53 %
2100 g/m^2	N	419	75 %	27 %
2100 g/m^2 + 3000 g/m^2 sand	N	718	75 %	119 %

The quantity of sand contained within the outer geotextile has an impact on the ultimate puncture resistance of the geotextile i.e. lower outer geotextile mass results in less sand capture capacity and lower modified puncture resistance. Trials with a range of outer geotextile masses have shown that a 900 g/m^2 outer layer provides the best solution in terms of sand capture, protection and cost.

3.3 UV DEGRADATION

Unlike other geotextile applications such as separation and drainage where the geotextile is buried and UV exposure is limited to a maximum of 2-3 months, geotextile sand containers are expected to withstand the effects of UV Radiation for many years. Projects such as the Russell Heads groyne (1993) and Stockton Beach revetment (1996) have proven the medium term performance of the containers. The ultimate life of these containers in terms of UV exposure is yet to be determined and improvements in polymer technology are expected to continue to improve the durability of the containers.

At present a designer must rely on accelerated UV degradation to assess the long term performance of a geotextile sand container structure. The current ASTM D4355 defines long term testing as the strength retained after 500 hours exposure, however, this definition is based on the exposure for standard separation applications described above. Extended accelerated testing has been carried out on a range of staple fibre geotextiles used in Australia for the manufacture of geotextile sand containers, results of which are shown in Figure 12.

The correlation between accelerated and real time performance is difficult due to differing climatic conditions and methods of geotextile manufacture, with reported correlation factors ranging from 6 months to 1 year being equivalent to 500 hours exposure. It is important to specify the geotextile with UV exposure rates far higher than the requirement for buried applications and some engineering judgement is required in terms of the required values and duration of the accelerated testing regime.

For geotextile sand containers which will be expected to be exposed and perform their design function for a number of years, extended testing beyond the maximum 500 hours to a minimum of 2,000 hours is recommended.

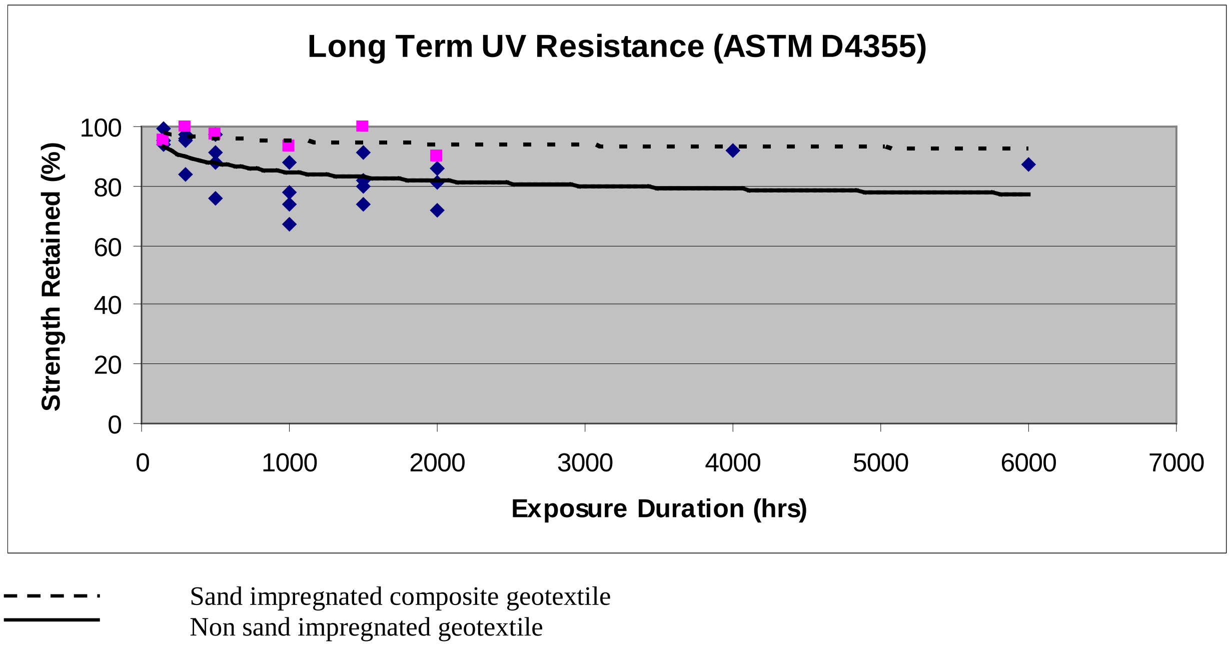

Figure 12: Long Term UV Exposure Testing

3.4 ABRASION RESISTANCE

Abrasion due to water borne sand, shell and coral fragments is a threat unique to geotextile sand containers. This abrasion can be a significant factor for containers located in near shore surf zone where the movement of water and coarse material is continually occurring and is particularly noticeable in containers located at sea bed level. Underestimating the effect of the abrasion forces in coastal applications can limit the life of the individual containers and ultimately the structure as a whole.

A number of textile abrasion test methods are available However, these are based on a modified Stoll abrasion test which is used to determine the abrasion resistance of women's woven and knitted stockings. The test method which best mimics actual field abrasion is the German Rotating Drum test method (BAW Federal Waterways Engineering & Research Institute, 1994), which was developed specifically for geotextiles used in coastal and waterway applications. This test subjects the geotextile to 80,000 abrasion cycles with a mixture of water and fine gravel and measures the % strength retained on completion of the test.

The relative abrasion resistance of various generic geotextile classes i.e. staple fibre, continuous filament or woven is noted. Minimum strength retention of 80% after 80,000 cycles is recommended for geotextile sand containers in exposed coastal applications.

4 CONCLUSION

Experience and engineering judgment dictates that the coastal environment is a very harsh place. Structures built in these areas, especially those designed as protection structures should be constructed with materials that are not only cost effective, but also resistant to the many forces discussed in this paper, to ensure a long term, stable investment. The use of Geosynthetic sand containers on coastal structures is increasing and confidence in the systems is required from an engineering and stakeholder point of view. The recent advances in Geosynthetic technology, continual laboratory testing and site monitoring of installations leading to the development of a robust design methodology now allows engineers to design geotextile sand containers with confidence.

However as a minimum the following checks should be carried out on the proposed structure in order to assess the suitability/durability of the geosynthetic solution as a whole for the application:

Stability

Wave stability – based on actual testing and container fill volumes.
Scour protection – providing adequate protection to the toe of the structure.
Sand retention – based on high impact two way flow conditions.

Durability

Material and Seam Strength – to withstand installation forces and to retain sufficient strength for the life of the structure
Damage resistance – both incidental and vandalism
UV degradation – long-term accelerated testing & real time analysis
Abrasion resistance – based on accelerated testing & real time analysis

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