LARGE SAND FILLED GEOTEXTILE CONTAINERS AS A CONSTRUCTION AID OVER POOR QUALITY MARINE CLAY

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Abstract: The use of geotextile containers filled onsite with sand (or other sediments) as key components in civil engineering projects is increasing, however design is difficult as few detailed studies of their behaviour have been documented. As rock becomes increasingly more difficult to obtain and expensive, there will be increased demand for reliable design guidelines for geotextile containers.

The Alliance type contract for the extension of the Port of Brisbane's Fisherman Island complex by a further 230 hectares requires innovative thinking and worlds best practice. Full-scale trials of large sand filled geotextile containers as well as rock are being carried out as part of the comprehensive design process for the 4.5km long bund and seawall to encapsulate the new reclamation area. The Seawall Alliance design team were faced with two significant challenges:

- Very soft marine clay foundation (large settlements)
- Close proximity to a marine park (no mud waves to propagate into park and turbidity < 25% above background)

Two 3.5m diameter x 19m long geotextile containers filled with dredged material from the new wharf area have been placed on the very soft marine mud seabed. The following data has been collected:

- Turbidity levels during filling
- Rate of filling of container
- Turbidity levels during release and impact with the sea bed
- Shape of container
- Settlement of container
- Extent of mud wave

Keywords: Geotextile Container, Container Settlement, Container Volume, Turbidity

INTRODUCTION

The use of geotextile containers filled onsite with local sediments as key components in coastal engineering projects is increasing (Heerten, 2000). The use for groynes, breakwaters [emerged and submerged] and retaining walls is now common. However, design with these units in the coastal zone is still more difficult than for conventional materials such as rock as they behave very differently and few detailed studies of their actual behaviour have been well documented.

As rock becomes increasingly more difficult and expensive to obtain, there will be increased demand for reliable design guidelines for large geotextile containers for an increasing number of applications. In recent years, a number of port expansion projects in Australia have considered the use of large sand filled geotextile containers to replace rock in the core or the whole of the new perimeter retaining / bund walls (Figure 1).

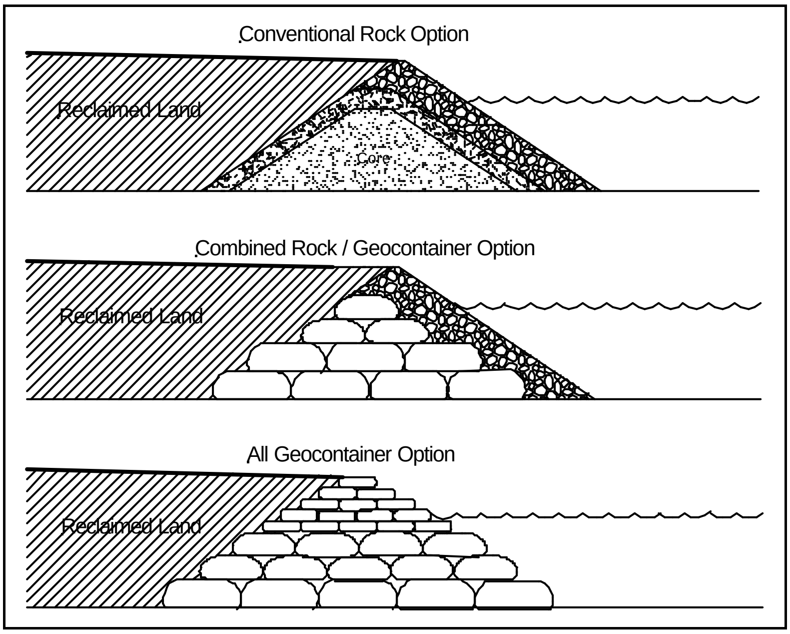

Figure 1. Typical reclamation profiles for rock and sand filled geotextile containers.

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 recognised 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. While small scale physical modelling can give a reasonable indication of certain factors such as stability and long-term durability, issues such as effects from container impact with the seabed and settlement of the container into a very soft marine mud are best monitored using a full-scale trial.

The proposed 230 ha extension of the Fisherman Island complex at the Port of Brisbane [Australia] led to the formation of a project alliance design and construction team to ensure innovative thinking and world's best practice. The Seawall Alliance was faced with two significant site challenges:

- Very soft marine clay foundation (large settlements)
- Close proximity to a marine park (no mud waves to propagate into park and turbidity < 25% above background)

The potential of geotextile containers for significantly reduced settlement in very poor sub-grade conditions, associated cost savings and reduced environmental impacts resulted in the Alliance undertaking full scale trials of both large sand filled geotextile containers and rock as part of the comprehensive design process for the 4.5km long bund and seawall which is to encapsulate the new reclamation area. To achieve this, two trial geotextile containers [9.3m circumference x 19m long] were filled with dredged spoil material from the new wharf area and placed (figure 2). The following data has been collected:

- Turbidity levels during filling
- Rate of filling of containers

- Turbidity levels during release and impact with the sea bed
- Shape of containers
- Settlement of containers
- Extent of mud waves

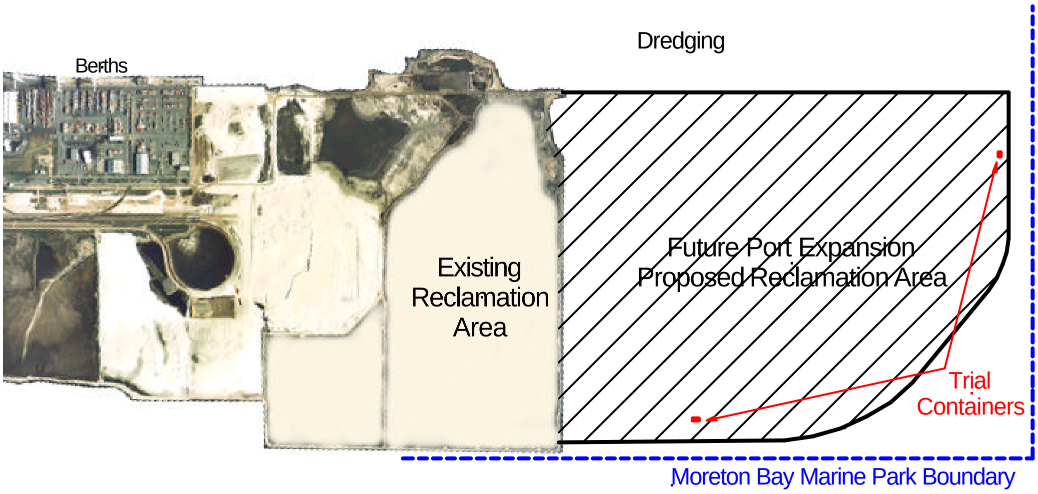

Figure 2. Locality Plan

GEOTECHNICAL INVESTIGATION

Preliminary Geotechnical investigation of the characteristic ground conditions underlying the proposed seawall relied on the analysis of results from geotechnical boreholes and static (piezocone) penetrometer test probes (CPTu).

Based on the testing above a general profile for the site was found to be as follows:

Upper layer - 0.5 – 2m thick layer of closely interbeded, loose to medium dense fine to coarse sand with layers of soft silt and clay.

Lower layer - 7 – 25m thick layer of very soft marine clay with some shell fragments. Very low shear strength and foundation bearing capacity. Compressible and prone to extreme settlements.

The results of two cone penetrometer tests carried out in the vicinity of the placement sites are shown below (note results begin from 2.8m and 4.2m below seabed as the CPT apparatus fell to that depth under its own self weight).

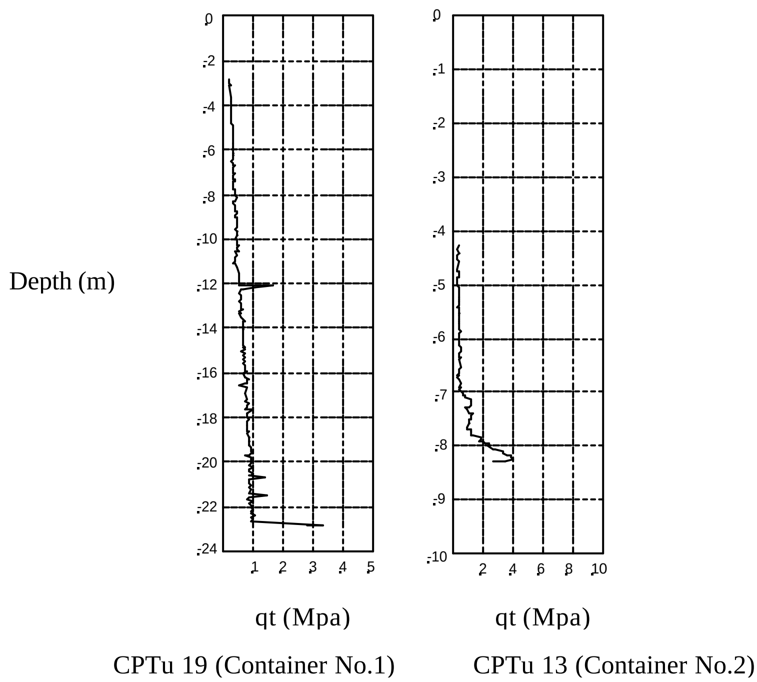

Figure 3. Cone Penetrometer Test Results

CONTAINER DETAILS

The Mega Sand container used was constructed from heavy-duty UV stabilised polyester Terrafix® nonwoven needle punched staple fibre geotextile. The Containers are designed for direct hydraulic filling utilising a dredge. The container specification for this project was as follows:

Container	Geotextile
Length: 19m	Tensile Strength: 68/38 kN/m
Circumference: 9.4m	Tensile Elongation: 70/100 %
Theoretical Volume: 151m^3	Pore Size: <75 μm
Material: Nonwoven Staple Fibre Geotextile	Through Flow: 28 l/m^2/s
	Seam Strength: >80% of parent material
	Abrasion Resistance: >80 % strength retained

FILLING & PLACEMENT

Filling and placement was carried out using the purposed fitted 42m long split hulled hopper dredge "Faucon", supplied by McQuade Marine. This vessel has a 21 metre long working hopper. A 300mm discharge pipe is connected directly into the container inlet during dredging. The filling time of the container is heavily dependent on the characteristics of the dredge material. In this case, the material consisted of fine-grained sands mixed with marine mud and some shells. Due to the cohesive nature of the seabed material, the filling rate of this size container was relatively slow (average 2hr: 20min) when compared to sand (~1hr), although this could be reduced with drag head and jet water modifications.

As the dredge is fitted with DGPS and side thrusters, accurate placement (<<1m, which is more than adequate for this type of work) is generally achieved, even in swell conditions. With monthly spring tides at the site generally over 2.4m and with the loaded draft of the dredge being 1.8m, the containers can be placed with their crests above average low tide. Container 1 was not fully filled due to operational problems and was placed on a falling tide (with difficulty) in the shallower section of the proposed bund with its crest at ~0.6m above LAT. Container No.2 was placed in the deeper section of the proposed bund with its crest at ~1.5m below LAT.

TURBIDITY

During the filling and placement operations the turbidity of the surrounding water was monitored by the Seawall Alliance. The investigation was carried using two methodologies namely turbidity buoys and drogue tracks. Data collected was reduced in a standard spreadsheet package to provide a degradation curve in terms of time and distance. The monitoring was broken down into two phases, dredging & filling and placement.

Dredging of fine-grained silty material (10-15% <0.075mm) over a large area (500m x 100m) in relatively shallow water ± 2m resulted in an extensive plume. The vessels prop and bow thruster was in shallow waters added considerably to the resuspension of bed sediments and inhibited settlement. During the first dredging trial the plume extended some 250m from the dredge area, with initial levels in the order of 60-80 NTU, dropping rapidly to 20-30 NTU.

Placement of the shallow container (Container No.1) was complicated by the use of thrust and bow thrusters combined with the grounding of the vessel, initial concentrations were 20-30NTU, dropping rapidly to 15-20 NTU (Figure 4.)

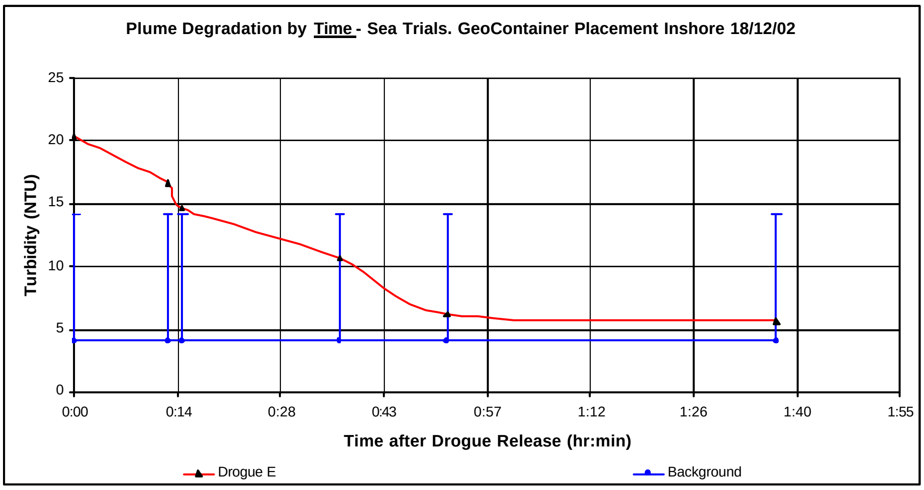

Figure 4. Turbidity Degradation Curve (Container No.1)

Placement of the second container indicated the generated plume was limited in extent and duration, the majority of the plume was created as the container made contact with the bed. Degradation of the spot plume generated by the drop was rapid, with levels approaching background within 10-15mins (Figure 5.).

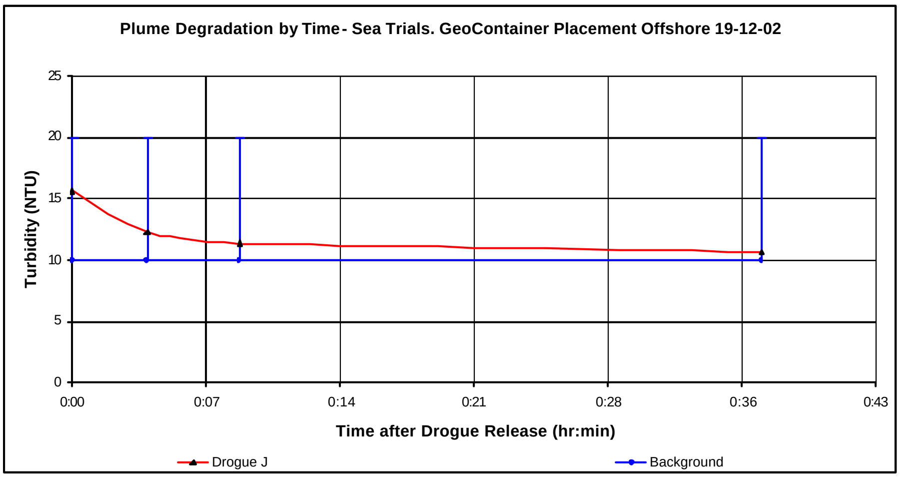

Figure 5. Turbidity Degradation Curve (Container No.2)

CONTAINER SHAPE & SETTLEMENT

The final shape of containers, after release from the hopper and impact with the seabed, was unknown prior to this trial. The aim was to compare the theoretical shape obtained from the GeoCoPS (2.0) Software for Design of Geosynthetic Tubes and actual container shape after placement. Factors such as what effect geotextile elongation, considered to be an issue when using high elongation nonwoven staple fibre geotextile containers, has on the container circumference, height and width was analysed.

Four hydrographic sonar surveys were carried out, to assess the depth of settlement of the container due to consolidation. An initial survey of the seabed was carried out prior to placement of the container and immediately after (1day) placement. Two subsequent surveys were carried out at 26 days and 143 days, dependant on the survey vessel. . The ± 100mm accuracy in the vertical and horizontal direction did not allow for sufficiently accurate definition of the shape of the containers and a more accurate survey of the containers using a conventional staff and DGPS was carried out 157 days after the placement of the containers.

The results of these surveys provided an accurate picture of the shape of the containers. The survey was carried out 157days after the placement of the containers. Survey equipment used was a Trimble 5700 Real Time Kinematic (RTK) survey instrument, which was able to achieve accuracies of ±10mm vertically and ± 25mm horizontally. This survey was only carried out on the shallow Container No.1 as the depth of water over Container No.2 (± 4m) limited access.

None of the surveys showed the level of the base of the containers below the seabed and this was established by jetting a steel rod down through a cut (subsequently patched) in the top of Container No 1 and measuring the depth to the bottom of the container. Results showed that Container No 1 has only settled approx. 115mm and that the depth of the base was uniform along the length of the container, with a variation of less than 25mm over the length. While this settlement will undoubtedly increase with the surcharge with the completed bund, the initial settlement is still comparatively small.

Comparison between actual container shape vs. theoretical container shape (derived from GeoCoPS (2.0)) is shown in Figure 6 below. As can be seen the actual shape is reasonably close to the theoretical even though the theoretical shape does not allow for the container being dropped out of the hopper. The maximum increase in the circumference of Container

No.1 was 0.9m or 9% strain while the increase in Container No.2 was 1.2m or 11%. The elongation is well below the elongation at failure of 70% and shows that the geotextile is not overstressed during filling and placement.

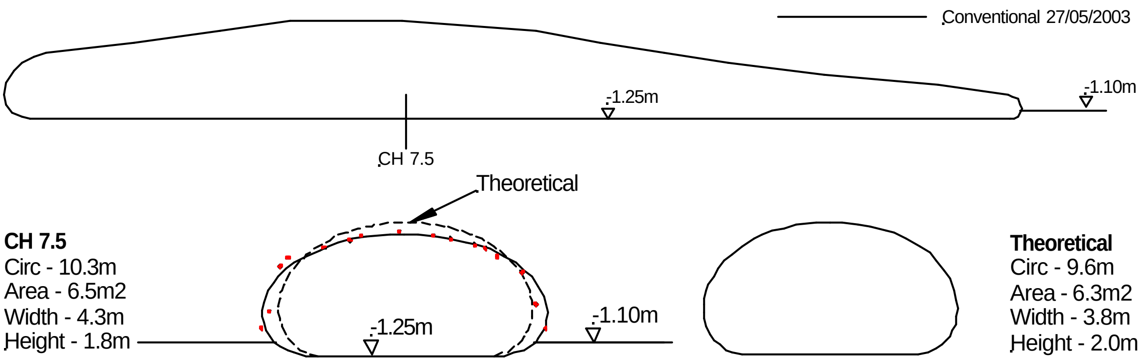

Figure 6: Container No.1 Long & Cross Section

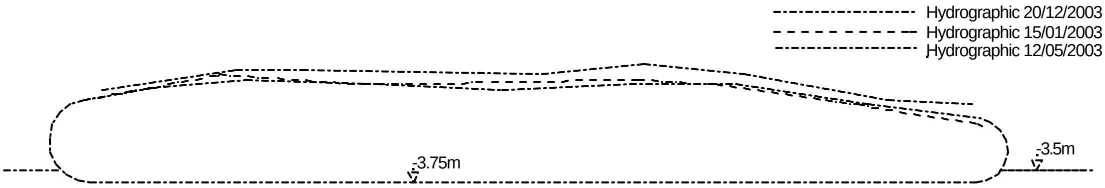

Figure 7: Container No.2 Long Section

Detailed cross-sections were taken along the length of each container and an accurate measure of the fill volume was obtained, note Container No.1 was not filled to capacity due to dredging and timing difficulties while Container No.2 was filled to capacity. Results are as follows:

Container No.1
Theoretical fill volume – 151m^3
Actual fill volume – 94m^3
Percentage fill volume - 62%

Container No.2
Theoretical fill volume – 151m^3
Actual fill volume – 122m^3
Percentage fill volume - 81%

What is of interest is that the material within the container does not appear to have been redistributed along the length of the container during the placement operation but rather retains the shape achieved in the hopper.

Container No's 1 & 2 have settled between 115mm and 250mm, as can be expected initial settlement was rapid but has stabilized and the containers are not expected to settle significantly below their current position.

CONCLUSION

Turbidity; Considering that dredging can be an issue in sensitive areas where the dredge material has high silt content and the water depth is limited, dredging may have to be limited to suit tides and currents. Turbidity due to placement of the containers was insignificant particularly in deeper water, and turbidity was restricted to a single pulse or plume. Turbidity during placement in shallow water could be an issue due re-suspension of silts by the propeller and bow thrusters, however once again the placement operation is short and the turbidity duration is limited.

Filling Rate; Fines content of dredged materials do have an affect on the filling rates of the containers, increasing filling rates from ±1hr for course sand to ±2:20min for the cohesive marine mud's present in the dredge zone. Changes to the dredge equipment could however improve this rate and bring it closer to the optimum filling rate of 1hr.

Container Shape; The theoretical dimensions obtained from GeoCoPS are surprisingly close to the actual shape when one considers that the program defines the shape of a container filled insitu. The containers manufactured from high elongation nonwoven staple fibre geotextile elongated by approximately 11%. GeoCoPS does not allow for elongation of the geotextile and when using this program to design with nonwoven geotextiles the designer should allow for approximately 11% in the circumference of the container.

Container Settlement; Settlements of 115mm for Container No.1 and 250mm Container No.2 occurred however this was less than was expected considering the quality of the subgrade material. This is realistically due to the large surface area of the container footprint and the relatively light (when compared to rock) sand fill material.

Mud Waves; Both hydrographic and conventional surveys showed the formation of a small mud wave of approximately 100mm high within 1m of the container which dissipated to natural levels within 2m of the container.

The potential for sand filled geotextile containers to fulfill a roll as construction elements in port and seawall projects is furthered by this investigation. Final selection of this construction method will naturally be influenced by cost efficiencies and construction practicalities. Site specific tuning of the dredge equipment will ensure consistent and repeatable filling, and placement of containers, together with improved turnaround times. Initial analysis in consideration of these aspects strongly supports continued monitoring and further studies of this construction concept utilizing nonwoven geotextile containers in providing an engineered solution, and versatile construction alternative.

ACKNOWLEGEMENTS
Mr. Wayne Young & Mr. Robert Slater, Port of Brisbane Corporation
Mr. Keith Jordan, Mr. Mick Mc Millan & Mr. Steve Robinson, Leighton Contractors Pty Ltd
Mr. Mike McQuade, McQuade Marine

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