THE USE OF GEOTEXTILE CONTAINER FOR SHORE PROTECTION WORK AT EAST COAST PARK AND PASIR RIS PARK IN SINGAPORE

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ABSTRACT

The sandy beach at East Coast Park is the favourite haunt for sun-loving Singaporeans. Contrary to popular belief, the beach there is not natural but man-made and a fruition of reclamation works during the period between the 60s and 80s. The beach in the East Coast Park and Pasir Ris Park had been designed based on the concept of a series of headland breakwaters scheme and the formation of crescent shaped pocket beaches between headlands. As the beach is constantly been exposed to incoming swell waves, it tends to show signs of erosion at some stretches of the beach along East Coast Park and Pasir Risk Park. Faced with the prospect of receding shorelines from these wave attacks, the Building and Construction Authority (BCA) has been tasked to restore the beach at East Coast Park and Pasir Ris Park. BCA had appointed the Housing and Development Board (HDB) as their technical agent to carry out the beach restoration works and Surbana International Consultants Pte. Ltd. (Surbana) as the project consultant. BCA/HDB will be jointly referred as Client in this paper. Client has supported a pilot proposal of using sand-filled geotextile containers as revetment instead of the conventional rock revetment at designated stretches of shore in East Coast Park (ECP) and Pasir Ris Park (PRP), Singapore. This is the first beach restoration project in Singapore which is carried out along well developed coast in close proximity of urban habitat. The piloted project of using sand-filled geotextile containers has been successfully implemented at 3 locations of East Coast Park and Pasir Ris Park. They are found to perform satisfactory in protecting the shore from the continuous wave actions and blend with the natural surrounding very well. .

Keywords: Headland, beach and geotextile containers

INTRODUCTION

The East Coast land reclamation was carried out in phases from 1966–1985.

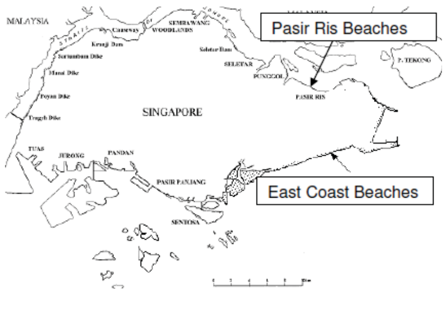

Fig. 1 Reclaimed shoreline along East Coast and Pasir Ris of Singapore

The land created was used for residential and recreational development. East Coast Park is part of the land created for this purpose. Pasir Ris Park which was formed in early 80s is located at the north eastern coast of Singapore. About 9 Km of East Coast beach and 3 Km of Pasir Ris beaches are generally formed by sandy beaches and protected by a series of headland breakwaters (see Fig. 1).

An aerial view of bay beaches at East Coast Park is shown in Fig. 2. In the past, all headland breakwaters have been designed using rock materials and occasionally with pre-cast concrete blocks.

Fig. 2 Aerial view of bay beaches

EROSION OF SHORELINES

The beaches in between the headlands along East Coast Park and Pasir Ris Park had been under constant wave and tidal current actions since its formation in the early 70s. These two stretches of the shorelines have experienced some extent of erosion and change in the beach profile.

In view of the changing coast line due to shorelines erosion and new coastal development in the adjacent areas, Client has initiated and engaged specialist consultant on the Engineering Study in these two areas to better understand the beach formation due to hydrodynamic conditions. The study has identified some shorelines that will continue to be unstable and face further erosion. Surbana then worked closely with Client to produce several options to tackle the eroding shorelines.

DESIGN DEVELOPMENT OF GEOTEXTILE CONTAINER AS REVETMENT STRUCTURE

Building seawall using reinforced concrete or stone revetment along the shoreline has been an effective way to protect the land from erosion. As the affected shorelines are located within the designated park land, full hard edge treatment using seawall or revetment is not suitable. The main objective is to provide opportunity for the public to have easy access to the water for multiple recreational uses, swimming, sand bathing, ball games, boating and etc.

Surbana has studied the overall conditions of the shorelines and recommended that minor extension of the existing headland breakwaters and localized beach nourishment would be able to address the areas that are subject to constant erosion. However, in the popular beaches where public has been visiting, the headland breakwaters and the adjacent beaches have not been fully utilized by the public. The reason could be that the hard edge stone structures have sharp edges and offer little recreation spaces. Therefore, the headland breakwater structures have been generally shunned by the public and are not a conducive area for recreation. Client has requested Surbana to find new method in beach stabilization which should form an integral part of the beach formation and offer easy access to the public. The challenge has prompted Surbana to search extensively for the proven technological development in shore protection structure. Thus, an alternative solution using sand in filled geotextile container revetment was recommended to replace the hard structure for shore protection.

Geotextile container revetment offers the advantages that it is flexible and yet heavy & strong enough to withstand the wave actions. The only drawback is that the geotextile materials are usually made of polypropylene materials (woven or non-woven). The material strengths deteriorate when expose to sunlight, particularly, UV light. To ensure the geotextile containers can perform the same as stone revetment, the materials must be durable when expose to wave actions and sunlight. To meet the Client’s requirements, the materials use for the geotextile container must be able to work well in exposed conditions for a minimum period of ten (10) years.

Surbana has extensive discussions with suppliers, experience contractors and Dr. Chew Soon Hoe who specializes in geotextile research. We concluded that the materials specifications can be met to achieve the design requirements.

After careful consideration, Surbana has recommended the geotextile containers to be implemented at Headland 1 in East Coast Park as shown in Fig. 3 and Headland 3 and 14 in Pasir Ris Park as shown in Fig. 4.

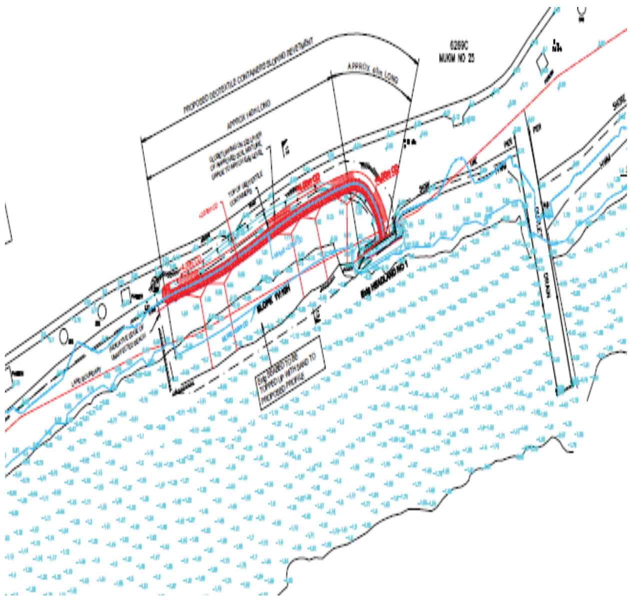

Fig. 3 Headland 1 East Coast Park

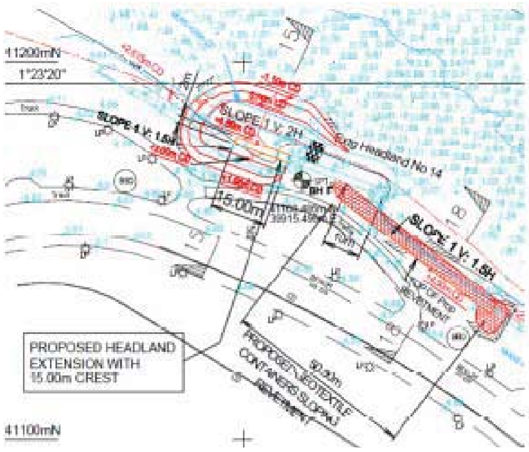

Fig. 4 Headland 14 Pasir Ris Park

The subsequent sections then focus on the design considerations, construction and post construction period in connection with the use of geotextile container as revetment work.

DESIGN CONSIDERATIONS - GEOTEXTILE CONTAINER

To compete with stone revetment, geotextile container revetment must be stable and durable under marine condition with the presence of constant wave action, intense sunlight and possible vandalism. In addition, the slope of the geotextile container revetment must be stable and able to meet the statutory requirements against slip failure. The geotextile material must be strong enough to sustain all environmental factors 10 years after its satisfactory completion.

The slope of geotextile container revetment is designed to be 1V:1.5H, for which the factor of safety for stability is at least 1.5. The chosen size of the geotextile container is approximate 1.5m (W) x 1.6m (L) x 0.4m (H), which is not too huge to handle and install on site, yet heavy enough to sustain the designed wave forces.

To prevent the erosion from exposing the toe of the revetment due to the wave scouring, an additional geotextile container is placed in front of the toe of the revetment with an anchoring geotextile strip not less than 1.0m lapped beneath the stack (see Fig. 5). After installation of geotextile containers, the shore will be covered with beach sand having a gentle 1V:10H slope up to Mean High Water Mark (+2.515 mCD). The sand will protect the geotextile containers below +2.515 mCD from direct wave action. The typical cross section of the geotextile container revetment is shown in Fig. 5.

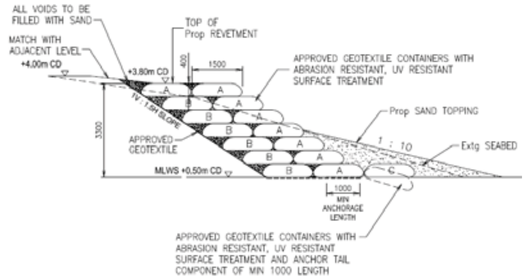

Fig. 5 Typical section of geotextile container revetment

As the external geotextile containers are exposed to the environment, the materials must be durable to protect the in-filled materials from breaking out, thereby compromising the overall stability of the revetment system. With this in mind, the geotextile containers are designed to consist of 2 layers of geotextiles. The outer layer geotextile with higher ultra-violet (UV) resistance will function as a protection and sacrificial layer. In addition, the color of the outer layer geotextile is chosen to blend well with the surrounding beach environment. As for the internal geotextile containers, since they are fully covered without exposing to the sunlight, their material has been design with non-woven geotextile. A close up view of the geotextile is shown in Fig. 6.

Fig. 6 Close up view of geotextile

Some basic designed properties of the geotextile material used in this project are shown in Table 1 below.

Table 1: Minimum requirements of geotextile

Mechanical Properties	Required	ELCOMAX 1009RP (External)	ELCOMAX XP1000 (Inner)
Tensile Strength (kN/m)	>35 (MD) >35 (CD)	40 (MD) 80 (CD)	38 (MD) 70 (CD)
Tensile Elongation (%)	>50	>50	>50
Seam Strength (kN/m)	>35	35	35

Notes: *ELCOMAX XP1000 is BLACK color for inner layer of geotextile containers.*
MD: Machine direction
CD: Cross machine direction

It is found that ELCOMAX has met the design requirement and was accepted to be used for the project)

As part of the quality assurance and long term monitoring of the materials, Surbana has worked with Client to institute a ten years test regime on the geotextile materials. These test requirements formed part of the Maintenance Agreement to be incorporated into the construction tender. The Maintenance Agreement provided a fair and flexible arrangement for client and contractor to carry out repair/ maintenance when the situation arises which could not be anticipated in advance. More details on the Maintenance Agreement will be discussed in the post construction section.

DIFFICULTIES ENCOUNTERED DURING CONSTRUCTION

Prior to full implementation, the proposed method statement for installation of geotextile containers was brainstormed and further refined among contractor, consultant and the appointed site supervisor. Trial was conducted on site to ensure the actual work procedures are both safe and effective in installing the geotextile containers. As evidence of the importance place on the project, supplier M/s Elcorock had specially flew in their specialist to advise the contractor on the best practice on geotextile containers installation jointly among specialist geotextile supplier, competent trained workers, client and consultant. Finally acceptable procedures were made after some difficulties and challenges encountered are satisfactorily addressed and identified, and the method statement for construction was amended to resolve some of the difficulties taking into considerations and requirements of the Contractor, the Client, Technical Agent and the Consultant.

Filling of Sandy Material in Geotextile Container

In the geotextile container revetment work, the most critical activity is the filling up of the geotextile containers. To facilitate the efficient way of the filling operation, An A-frame as shown in Fig. 7 was fabricated to hold the geotextile container in an upright / opening position.

Fig. 7 A-Frame holding geotextile container

This equipment was found to be effective and efficient in expediting the filling operation with minimum workforce.

It was also discovered that some foreign materials, i.e. stone and soft lumpy clay were unintentionally enter into the container. To prevent this, an improvised metal grating as shown in Fig. 8 was place on top of the A-frame to sieve out the unwanted materials.

Fig. 8 Metal grating sieving out unwanted materials

This gadget has shown to be effective in removing foreign materials and hence ensure the quality of the in-filled geotextile container. Otherwise, the presence of foreign materials would hamper the overall long term performance of the container system.

Stitching of Geotextile Container

The geotextile containers supplied to the site by contractor were fabricated with 2 sides of the seam being sewn by machine in the factory leaving one side open to receive in fill sandy materials. The seams were designed to flip inwards so that the yarn (not UV resistance) which is used for the stitching are not exposed. These provisions ensure the seam joints are durable despite being exposed to wave actions and direct sunlight.

Once the container has been filled up to the required height, the container must be sealed to prevent the in-filled materials from leaching out. A mechanical device as shown in Figure 9 is used to stitch together the open edges of container.

Fig. 9 Hand-held stitching machine

To ensure the stitched seam is robust to prevent leaching and vandalism, the project team together with the contractor and his supplier had deliberated and agreed on the method of closing the seam. The pattern would be to provide two parallel stitches 80mm apart running along the open edge followed by 1 'sine-wave' stitch line intersecting the 2 parallel stitch lines with a distance between 2 peak points about 200mm, and a final diagonal locking stitch at the two corners resulted in a properly sealed container. Stitching is a critical step in the quality control of the final product, to ensure consistency; the stitching work was carried out by a designated staff that has been trained for the assigned task. All completed in-filled geotextile containers were inspected by the site supervisors before installation. Special instruction was given to the contractor to place the newly stitched end of the containers to face inward. This arrangement as shown in Figure 10 would help to prevent exposing the seam unnecessary.

Fig. 10 Stitch pattern

Unexpected Presence of Soft Marine Clay

During the construction of geotextile container revetment, unexpected pocket of soft marine clay was exposed during excavation. This unexpected soil conditions were not reflected in the borehole soil investigation conducted in the neighbouring area. In view of the unforeseen site condition, a revised stability analysis was carried out taking into consideration of the latest soil conditions. Despite meeting the minimum factor of safety against slip failure, Surbana has recommended to the client to replace the pocket of 2000mm thick marine clay with sand before laying the geotextile containers. This is necessary to prevent excessive long term settlement of the completed structure.

Installation of Geotextile Containers

Having completed the design and taken all the necessary precautions during construction, it is important to ensure the geotextile containers are being handled in the most delicate manner to prevent damaging the materials or causing the seams to overstress and burst up during installation. The contractor has employed a specilly manufactured equipment as shown in Figure 11 to handle the geotextile containers. The purposed built grab is fitted to the excavator and is designed to spread the stress evenly across the contact surface of geotextile container during handling thereby facilitate accutate placement. The quality finished work on site provided full evident of the effectiveness of the equipment to be employed.

Fig. 11 Grab of container

Placing of Geotextile Containers in Regular Pattern

The geotextile containers are placed against each other in a regular pre-determined configuration. The upper geotextile containers is straddled across two geotextile containers beneath. The recommended pattern would help to minimize uneven settlement of the completed structure and enhance the system's stability through interlocking of the geotextile containers. The completed section of the geotextile containers is show in Fig. 12. The off-white geotextile containers are double layer and are place externally to protect the black containers as mentioned in the previous section on Design Considerations.

Fig. 12 Typical laying pattern of geotextile containers

POST CONSTRUCTION AND MONITORING WORKS

The geotextile containers are constructed close to the designated park land. Hence, it is important that the materials used should not be flammable that become fire hazard. However, barbecue near the beach is one of the favourite activities in ECP and PRP. The heat of the burning charcoal would burn and melt the geotextile as it is made of polypropylene materials. However, without catching fire, the damage is usually localized as the sand filled materials would hamper the spreading of the damage surface. With this in mind, Surbana has incorporated the maintenance agreement in the construction contract to allow the contractor to render services for a period of 10 years whenever the geotextile containers have been vandalized. The geotextile container revetment was completed in November 2010 and is currently under close monitoring.

During the defects liability period, two burnt holes 25mm by 25mm were found at ECP. After investigation, these were found to be caused by burned charcoal. The maintenance regime was called into action. The following section described how the damaged geotextile containers were repaired in a systematic and effective way. .

The repair team used two pieces of geotextile, sealant, and four plastic screws. Firstly, the damaged portion of the geotextile container is cut into a rectangular shape and a marking of 100mm surrounding the cut portion is drawn as shown in Fig 13a.

Fig 13a Cutting and marking

Two pieces of geotextiles, one of which is black color and the other is the same material as the geotextile container, are cut to the same size as the marking area. The thinner black color geotextile is tugged under the cut section as shown in Fig. 13b.

Fig. 13b Inserting inner geotextile (black)

After which, the sealant is applied along the edge of black geotextile and on top of geotextile container within the marked area (see Fig. 13c).

Fig. 13c Applying sealant

Lastly, the second piece of geotextile is placed on top and secured by the 4 plastic screws (see Fig. 13d).

Fig. 13d Geotextile secured by screws

Sealant is applied along the edge of the geotextile to seal the void (see Fig. 13e).

Fig. 13e Apply sealant

The above repair procedures are effective and easy to follow. These have been accepted by Client and Surbana and are documented in the Maintenance Agreement when the situation calls for it to be carried out.

LABORATORY AND FIELD TESTS OF GEOTEXTILE

Tests on Geotextile Materials

The materials proposed by the contractor for the geotextile containers are ELCOMAX1009RP (outer layer) and ELCOMAX1000XP (inner layer) the consistency of the geotextile was checked by extracting the samples randomly and samples of geotextile were tested at the Accredited Laboratory. A comparison of the test results against specifications are in Table 2.

Table 2 Comparison of ELCOMA X1009RP

Mechanical Properties	Specified	Tested result
Tensile Strength (kN/m)	40 (MD) 80 (CD)	52.62(MD) 107.31(CD)
Tensile Elongation (%)	>50	>64

It was found that the test results are consistent and approved to be used on site.

Tests on Field Samples

A programme to test the geotextile performance on site at different times after completion was set up jointly by the Client and contractor with the advice provided by Dr. Chew Soon Hoe, the geotextile specialist. It required placing sacrificial geotextile samples at designated positions on the completed revetment and to be extracted at pre-determined intervals ranging from 6 months to 10 years after its completion.

The results of the samples after 6 months and 12 months exposure are shown in Tables 3 and 4 respectively.

Table 3 Comparison of 6 months samples exposure ELCOMA X1009RP

Mechanical Properties	6 Months Exposure	% Retained
Tensile Strength (kN/m)	47.49(MD) 94.72 (CD)	90.25 88.27
Tensile Elongation (%)	>53.99	84.36

Table 4 Comparison of 12 months samples exposure ELCOMA X1009RP

Mechanical Properties	12 Months Exposure	% Retained
Tensile Strength (kN/m)	43.22(MD) 83.50 (CD)	82.14 88.27
Tensile Elongation (%)	>46.33	72.39

The two set of data collected so far on the sacrificial geotextile materials on site showed the properties of the materials have deteriorated gradually over time. Further tests have been planned for the materials to undergo longer period of exposure to check the sustainability of the geotextile container materials. The materials to be tested have been placed at pre-determined position for ease of identification and extraction at a later date. As it is a piloted project, more test results with different times of exposure are required in order to know the behavior of the materials exposed over long period of time. Surbana is assisting the Client to coordinate the test sample extractions and laboratory tests.

CONCLUSIONS

The geotextile container revetment installed at

Shore of Singapore ECP and PRP are found to be an acceptable option of shore protection structure. It is able to blend pleasantly with the sandy beach as shown in Fig. 14. The completed structure is soft and flexible that poses a lesser risk against injury from falling and unintentional contact as compared to hard stone revetment. It also does not absorb heat so readily. With the step like stacking arrangement, the completed structure provided the public an attractive resting and recreation point between the beach and Parkland. The performance of the geotextile containers will continue to be monitored closely. If these are found to be durable, it provides the engineering consultants with alternative method for shore protection in Singapore.

Fig. 14 Geotextile revetments at ECP of Singapore

ACKNOWLEDGEMENTS

The authors wish to thank the management of Building and Construction Authority, Housing and Development Board, Surbana International Consultants Pet Ltd, Singapore for the technical support in the successful completion of the project and permission in publishing the joint paper. Appreciation also extended to the site supervisors, Sharif Bin Tik and Alan Tan for keeping excellent site records for the construction of the geotextile containers revetment.

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