

# The use of geosynthetic containers for disposal of dredged sediments – a case history

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**Keywords:** geosynthetic, contained, disposal, marine, trials

**ABSTRACT:** Dredging for marine works inevitably requires marine disposal of the dredged arisings, this being of environmental concern, particularly if the sediments are contaminated. For this reason, marine and environmental control mechanisms for dredging and disposal are usually put in place by the relevant authorities. Highly contaminated sediments require either pre-treatment to render the sediments suitable for open sea disposal, or special disposal techniques to prevent loss of contaminants to the marine environment during disposal. One possible technique for special disposal is to contain the dredged sediments during the dumping process. The use of geosynthetic containers for this purpose, following similar use in other parts of the world for various applications, was further developed in Hong Kong under the Wan Chai Development Phase II project, for bulk disposal of contaminated sediments. Field trials were carried out to determine the optimum handling method and to confirm the technique's suitability under local Hong Kong conditions. Several trial disposal operations were carried out using different geosynthetic fabrics, container designs and container sizes. A monitoring programme, including the innovative use of polystyrene balls, was implemented to identify any rupture of the containers. The initial trials highlighted a few problems in the container design and deployment; these were soon overcome. Further trials demonstrated that this disposal technique could be employed effectively. The results of these field trials will enable this technique to be used with confidence in meeting requirements for contained disposal of contaminated sediments.

## 1 INTRODUCTION

In Hong Kong, the Environmental Protection Department imposes strict control over the marine disposal of dredged sediments. Sediments with low levels of contamination are deemed suitable for open sea disposal. Higher levels of contamination require confined marine disposal at specially designated disposal areas. Of particular concern are sediments with very high levels of contamination, that are considered to pose significant risk to the marine environment during disposal. These highly contaminated sediments require either pre-treatment or special disposal.

Pre-treatment is used to render the sediments suitable for marine disposal by reducing the level of contamination. Special disposal methods, rather than treating the sediments, have the objective of keeping the loss of sediment to the surrounding marine environment to a minimum during the disposal operations. It is this 'special disposal' approach that is being pursued under the Wan Chai Development Phase II (WDII) project in Hong Kong.

The special disposal method as proposed in the WDII project involves essentially sealing the dredged sediments in geosynthetic containers and, at the disposal site, dropping these containers into a contaminated mud disposal pit, where they would be covered by further on-going mud disposal and later by the mud pit capping, thereby meeting requirements for fully confined mud disposal.

The use of geosynthetic containers is not new. Geosynthetic containers have been successfully used for coastal engineering (containment dykes, river groynes, breakwater core construction, etc) and sediment disposal applications in many parts of the world. Notwithstanding, and in recognition of the fact that this method had not yet been used in Hong Kong as well as possible limitations that may be imposed by local operating constraints, field trials were conducted under the WDII project to determine the optimum handling method under local conditions.

This paper presents a review of the field trials that were carried out in Hong Kong for the bulk disposal of dredged marine sediments using geosynthetic containers.

## 2 THE DISPOSAL METHOD

The disposal method is based on the use of a geosynthetic container made of a composite geotextile material that is designed to retain the enclosed sediments during the disposal process. The container is partially prefabricated in a factory to form an elongated 'box' with an open 'lid' (top cover). The container is placed in the hopper of a split hopper barge, filled with dredged marine sediments and then sealed by insitu sewing. After towing the barge to the disposal site, the container is released by opening the split hopper and the container falls to the seabed.

The plant and equipment used in the field trials included a grab dredger, split hopper barge, supporting derrick barge, etc, all of which are commonly available in Hong Kong and typical of the plant that would be used in a local dredging contract; therefore, the disposal method is one that can be readily applied in the local context.

Acceptance criteria for determining the success of the field trials were, essentially, that there should be no significant loss of material from the container when dropped from the barge, or on impact with the seabed, outside the confines of the disposal area.

## 3 THE GEOSYNTHETIC CONTAINERS

Composite containers were manufactured using a non-woven inner lining (Mirafi 160 N) for retention of the contained material and an outer layer of woven polypropylene geotextile to provide strength and rupture resistance (two outer layer geotextiles were tested: Geolon PP120S and Geolon PP200S).

A total of five containers were used for the trials. For reference, these were labelled as A to E, with the following key properties:

- Container A had a notional volume of 600 m<sup>3</sup> with outer layer fabric tensile strength of 120 kN/m
- Container B had a notional volume of 300 m<sup>3</sup> with outer layer fabric tensile strength of 120 kN/m
- Containers C, D and E all had a notional volume of 300 m<sup>3</sup> with outer layer fabric tensile strength of 200 kN/m.

## 4 BARGE MODIFICATION

A 1,000 m<sup>3</sup> split hopper barge, typical in Hong Kong, was used for the deployment and disposal of the geosynthetic containers, with the hopper modified to accommodate both the 600 m<sup>3</sup> and 300 m<sup>3</sup> containers.

Barge modification comprised the installation of longitudinal bulkheads along the full length of each side of the hopper, such that the width of the hopper

was reduced to around twice the maximum openable width of the hopper gate; the intention being to minimize the chance of containers 'hanging' in the hopper after it opens. These longitudinal bulkheads also provided for safe working platforms along each side of the hopper. The resulting reduced hopper dimensions gave an effective 600 m<sup>3</sup> hopper volume, for deployment of the larger container.

For the 300 m<sup>3</sup> containers, the barge was further modified by installing transverse bulkheads, as illustrated in Figure 1.

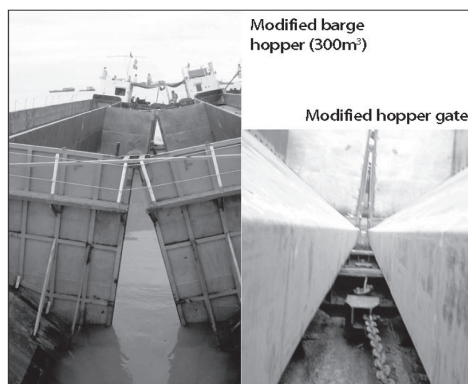


Figure 1. Modified hopper barge.

It is also important that the bottom opening of the hopper (the hopper gate) should be smooth and free of protrusions, to avoid damage to the container fabric as it passes through this narrow opening. Initially, rubber gaskets were installed along the hopper gate to provide protection from sharp edges. These were found to be inadequate and the hopper gate was therefore further modified by welding in new steel plates with rounded edges to provide a completely smooth exit surface (Figure 1).

## 5 PERFORMANCE MONITORING

### 5.1 Diver inspections

Due to poor visibility at the disposal site, it was not possible to take underwater photographs or videos of the container disposal. Instead, divers carried out close visual inspections of the containers on the seabed, after each disposal operation, to examine them for signs of rupture and to report on the general condition and lie of the containers on the seabed.

### 5.2 Polystyrene balls test

An innovative means of detecting any rupture of the geosynthetic containers during disposal was developed for the field trials: the 'polystyrene balls test'. Polystyrene balls were placed inside the containers

along with the dredged sediments. In the event of any rupture of the container during the disposal process, some of the sediments together with the polystyrene balls would be ejected from the container. The polystyrene balls would float to the sea surface and act as a visual indicator of damage or rupture of the container.

The balls were marked to identify where in the container they were placed; when recovered after escaping from the container, the approximate location of the rupture could then be deduced. The number of balls escaping from the container also gave an indication of the extent of the rupture or loss of material. In addition, the time taken for the balls to appear on the surface revealed whether rupture occurred on exit from the hopper or on impact with the seabed.

### 5.3 Water quality monitoring

A water quality monitoring programme was put in place to capture any sediment plumes which might extend beyond the confines of the disposal zone, resulting from either loss of sediments from ruptured containers or re-suspension of seabed sediments caused by impact of the containers when landing in the mud pit.

## 6 FIELD OPERATIONS

The containers were unpacked in a derrick lighter alongside the hopper barge and then hoisted across to the barge and laid out along one side of the hopper. After lining the hopper with slip sheets, the containers were manually placed in the barge hopper and secured to the hopper coaming using G-clamps.

The containers were filled with dredged sediments from a storage barge moored alongside, using a 2 m<sup>3</sup> grab. Filling was carried out in even layers and the polystyrene balls were placed around the periphery

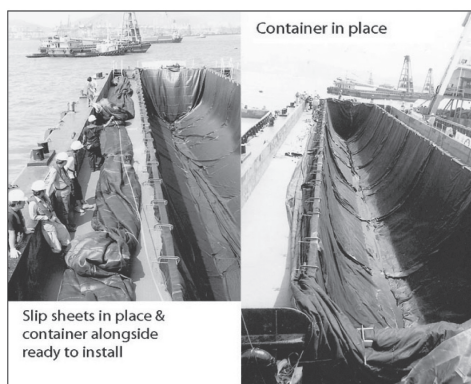


Figure 2. Container installed in barge.

of the container together with these layers. The containers were not completely filled; a void was left at the top to allow for the sediment movement as the container was 'squeezed' out through the hopper gate, and to take up any resultant pressure build-up. Generally, the containers were filled to around 70% of the hopper capacity.



Figure 3. Container sealed & ready for disposal.

After filling, the cover of the container was drawn across the top of the sediments and sewn closed. Once the container had been sealed, the barge was towed to the disposal site and the container released through the hopper into the mud pit.

## 7 RESULTS OF THE FIELD TRIALS

The initial trials highlighted a few problems in the container design and deployment and with the hopper barge. These only became apparent during the course of the trials, under local conditions and due to the properties of the dredged sediments (very soft marine mud rather than sandy material). However, once these initial deficiencies had been overcome or rectified, the later trials of the disposal of sediments using the geosynthetic containers were successful. The following paragraphs highlight the results and findings of the trials.

### 7.1 Container A (600 m<sup>3</sup> & 120 kN/m outer fabric)

The container descended very unevenly through the hopper, and extremely quickly (over half the container had already passed through the hopper gate when the opening was only around 0.5 m wide). The geosynthetic fabric ruptured on exit from the hopper barge, with a loss of around 40% of the polystyrene balls that were placed in the container, most of which appeared on the surface immediately after the container had left the hopper. Water quality monitoring detected an elevation of sediment levels immediately downstream, which would have been due to the loss

of sediments from the container. The divers inspecting the container on the seabed found an approximately 10 m longitudinal rupture in the geosynthetic fabric.

Inspection of the hopper gate after the trial found that the rubber gaskets that were installed to provide protection from the sharp edges were torn off, and a sample of the ruptured fabric retrieved by the divers indicated stress-induced failure of the woven fabric.

Remedial action included modification of the hopper gate by welding on smooth steel plate covers. The containers used in the following trials were also changed to the smaller 300 m<sup>3</sup> size, which were considered to be more manageable than the large 600 m<sup>3</sup> container.

#### 7.2 Container B (300 m<sup>3</sup> & 120 kN/m outer fabric)

The container descended evenly through the hopper without any apparent problem, but ruptured on impact with the seabed. Around 6% of the polystyrene balls that were placed in the container escaped, with the first ball appearing on the surface around 60 seconds after the container had left the barge. The divers found a parted transverse seam; a sample retrieved by the divers showed that the stitching along the seam had been torn. The cause of failure was therefore attributed to seam failure due to inadequate seam strength to resist bursting pressures on impact with the seabed.

Remedial action required an increase of the strength of the geosynthetic container, in particular the seam strength. New geosynthetic containers were therefore fabricated using a stronger woven outer layer fabric with tensile strength of 200 kN/m and with a stronger flat (overlap) seam design giving a seam strength of around 70% of the parent fabric strength, ie 140 kN/m seam strength.

#### 7.3 Container C (300 m<sup>3</sup> & 200 kN/m outer fabric)

At the final stage of the exit, as the container dropped through the hopper, a pressure 'bubble' formed in the top of the container. The pressure bubble was concentrated at the rear end of the container (the last section to pass through the hopper gate). Six polystyrene balls (1% of the total) appeared at the surface to the rear of the barge soon after exit. The markings on the balls indicated that they were all from the rear end of the container.

It was therefore clear that some minor leakage had occurred through the rear end due to high pressure at the time of exit. The very minor loss of balls suggested that there must have been a very small gap which, under high pressure, allowed some balls to be ejected. The fault was considered to lie with the hand stitching at the end of the container, which, due to the confluence of a number of seams and material folds, was a difficult area to seal.

This finding was supported by the divers' inspection, which found no signs of rupture or other damage to the container on the seabed. No sediment

plumes were detected by the water quality monitoring.

Notwithstanding this minor loss of polystyrene balls, the results of the field trial for Container C demonstrated that the container design and disposal process were on the right track, with the container structurally sound and remaining intact on the seabed.

Remedial action for the subsequent field trials included paying greater attention to sealing the ends of the containers, with additional stitching and rope knots to eliminate any possible minor openings, and a larger void was provided at the top of the container in order to better absorb any pressure build-up.

#### 7.4 Containers D & E (300 m<sup>3</sup> & 200 kN/m outer fabric)

These trials were adjudged a complete success. The containers dropped through the hopper evenly and without any sign of distress. There was no loss of polystyrene balls and the divers' found no damage to the containers on the seabed. No loss of sediment was detected by the water quality monitoring.

## 8 CONCLUSION

A geosynthetic container of notional size 300 m<sup>3</sup>, with a composite fabric design comprising a non-woven inner lining and a woven outer layer with tensile strength of 200 kN/m having a seam strength of 140 kN/m, disposed of using a modified hopper barge with all surfaces smooth and protuberance free, was found to be a successful means of contained sediment disposal under local conditions. This container system has been demonstrated, through the field trials, to be able to retain dredged sediments without any significant loss due to rupture or damage of the container.

The use of these geosynthetic containers is therefore considered able to meet requirements for special disposal arrangements in ensuring negligible loss of sediments to the surrounding marine environment during disposal.

## ACKNOWLEDGEMENT

The authors would like to thank the Project Manager, Hong Kong Island & Islands Development Office of the then Territory Development Department, Hong Kong SAR Government, for his, and his department's support in conducting the field trials.

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