


# Geotextile Tubes for Protection of Mangrove Coast in Malaysia

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**Abstract**

Coasts bordered by mangrove trees are common along the west coast of Peninsular Malaysia and many regions of Sabah and Sarawak. The shore and near shore regions are generally composed of fine grained material. Wave energy reaching mangrove-fringed coasts is usually low allowing silt sized material to remain at or near the shore. Fetches and wave approach directions of mangrove-fringed coasts limit wave energy reaching the shore.

Mangrove forests are the natural vegetation of many tropical coasts and tidal inlets. The mangroves form a highly productive ecosystem, maternity and nursery for many marine species. Mangroves survive in the upper tidal zone; approximately above Mean Sea Level to High Water (Spring). Mangroves exist on gentle sloping coasts with moderate wave climate. A striking feature of mangroves is the root system, which offers protection against erosion of the coast by dissipating wave energy. They also provide support and protection of low-lying agricultural land from flooding.

Detached geotextile tubes as one of the soft engineering methods were conceptualised to moderate incident waves and mitigate coastal erosion at mangrove areas. The geotextile tube is basically a close-ended tubular geotextile with filling ports. Sand is hydraulically pumped in through the filling ports. The geotextile tubes are constructed to a height of 1.5m and 50m length. They are spaced 5m apart and aligned parallel to shore. Each tube sits above a scour apron against scouring of the seabed that might undermine the stability of the geotextile tubes installed. The installed geotextile tubes are partially exposed during low tides and completely submerged during high tides. This paper will describe the design and construction of the geotextile tubes.

***Keywords:*** *Erosion, Geotextile tubes, Mangrove, Marine clay*

## 1. INTRODUCTION

Geotextile containment systems may be classified under the form it takes (Yee *et al.* 1999). This includes geobag, geomatress, geotextile tubes, geocontainer, etc. These may be used for construction of underwater dykes. The geotextile tubes are made of sen geosynthetic sheets. They are custom made and supplied in various sizes. Inlet openings on top allow for the attachment of a pipe that transports hydraulic fill into the tubes. If the fill is sandy and the geotextile is very pervious, these inlets should be spaced closely (say, 10 m apart) to assure uniform filling of the tubes. (i.e., water will seep through the tubes hindering the hydraulic transport of sand over along distance). If clayey slurry is used, the fine particles tend to rapidly blind the fabric slowing down the water escape through the geotextile.

## 2. EROSION OF MUD COASTS

As early as 1910, some of the mud coasts along the west coast of Peninsular Malaysia were reclaimed for agriculture and drainage schemes. Extensive bund or levee systems were built to prevent the intrusion of saltwater. Several major drainage schemes in the state of Kedah, Perlis, Perak, Selangor and Johor were built through reclamation in order to cater for paddy planting. Most of these coastal lands were reclaimed by the construction of coastal bunds along coastlines where mangrove forests had naturally propagated. Mangroves grow in the region between Mean High Water and Mean Low Water which is subjected to wave energy. As a protection measure, a mangrove belt of at least 200 meters measured from the seaward edge of the mangroves is kept free from development.

Despite the fact that the typical wave heights along the west coast of peninsular Malaysia are less than 2 meters, erosion continues to occur along the mangrove coasts. The mechanism of failure can be described in the following sequence:

- loss of material at the root level of the seaward line of mangroves creates a scarp and exposes roots;
- instability of the mangrove trees sets in as roots loose grip on the remaining substrate
- continued material loss and increased instability results in trees toppling over.

Over the years, illegal logging in mangrove coasts have contributed to the thinning of the mangrove belts and erosion has often progressed up to the coastal bunds or levees. The challenge in protecting mud or mangrove coasts is in preserving the mangrove belt itself rather than simply protecting the hinterland.

## 3. GEOTEXTILE TUBES AS BREAKWATER

A conventional breakwater would generally be a partially submerged wave resisting rock bund. This rock bund would need to be on a wide scour footing pad of smaller rocks separated from the soft seabed with a heavy-duty filter and separator geotextile. The conventional rock breakwater is considered a hard structure and could pose dangers to small boats and vessels during high tides when it is fully submerged. A conventional rock breakwater can also be relatively quite expensive. Geotextile tubes as breakwater is an alternative solution for this. These geotextile tubes are able to withstand wave impact due to shear weight of the tubes. They are soft structures and resemble a “French bread loaf”.

## 4. DESIGN CONCEPT

Formulation of a geosynthetic tube, filled with pressurised slurry or fluid, is based on equilibrium of the encapsulating flexible shell. The geotextile tubes (single unit) needs to fulfill the following:-

***a) Internal Stability-strength requirement of the geotextile***

The geotextile may be stressed during filling, placement and impact with bottom of the sea. Geotextile overstressing during filling is rarely an issue with geobags but is critical with

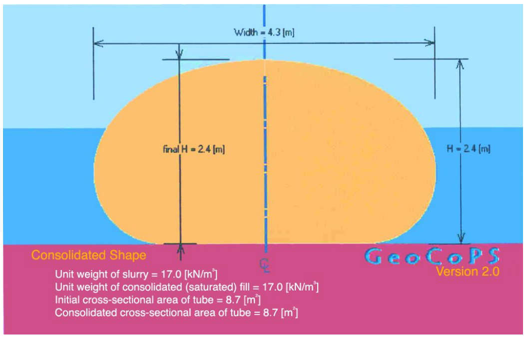


*Figure 1: GeoCops design software*

geotextile tubes. The analysis of stresses during the filling of geotube has been studied in some detail and design software (GeoCops, SOFFTWIN) as indicated in Figure 1. Numerical analysis is based on the equilibrium of an encapsulating flexible shell filled with pressurised slurry. For the stress analysis, it covers different phases e.g. laying, filling and impact with bottom.

***b) Internal stability-hydraulic requirement of geotextile***

The selection of hydraulic performance properties of geotextile has been well documented. The selection is usually based on equating the apparent opening size of the geotextile and the particle size of the contained material. Additional, a minimum permittivity is required of the geotextile.

***c) External stability-hydraulic stability of dyke***

The hydraulic stability design criteria for geotextile tubes depend on the size of the single unit. The bigger the unit, the stable it is.

***d) External stability-geotechnical stability of dyke***

The dyke structure should be designed for sliding, over-turning, bearing and global stability. Potential weakness planes along contact boundaries of geotextile should also be investigated. Settlements should be within acceptable limits of design.

## 5. PILOT PROJECT AT TG PIAI, JOHOR

In 1998, reports were received concerning erosion at Tanjung Piai which is geographically the southernmost tip of the Asian continent (Figure 2). It comprises 926ha of vegetation of which 526ha are mangroves spreading 8km of shoreline. The forest faces both the Straits of Malacca and the Tebrau Straits.

Erosion has been noted in the Pulai Forest Reserve at Tanjung Piai (MCRST, 1992) in the past but since the area has been declared a national park, it has acquired a heritage value that warranted it to be classified as Category 1 or critical designation according to the classification system (EPU, 1986) adopted by the Department of Irrigation and Drainage (DID). Erosion was also reported to have exacerbated purportedly due to extensive port development activities at nearby Port of Tanjung Pelepas. Being a site of specific national interest, the choice of protection required taking into consideration the impact of construction on the environmental, aesthetic and tourism functions of the park.

Tanjung Piai posed a problem for construction. The sensitive environment, and within a national park, meant no access roads could be created in the park for transportation of materials and equipment without affecting the park environment. Therefore, the work site had to be approached from the sea. Hard protection such as rock revetment

*Figure 2: Tanjung Piai, Johor, before installation of geotextile tubes*

Figure 4: Substrate build-up ehind the breakwaters

Figure 5: Breakwaters at Tanjung Piai, Johor

would also diminish the natural state of the mangrove shoreline. Furthermore, knowing that a revetment would essentially lessen the chances of mangrove regeneration, an alternative protection had to be employed. In 2000, the National Hydraulic Institute of Malaysia attempted a mangrove establishment project using mud-filled non-woven geotextile bags (Lau S.M. *et al.* 2002) and brush fascines. These managed to induce substrate build-up for some time until the geotextile bags were damaged by storm waves. The project however proved that the presence of the geotextile breakwaters was a critical component to initiate plant regeneration. The lessons learnt from this project proved beneficial to the design of the geotextile tube breakwater pilot project at Tanjung Piai.

The geotextile tube breakwater at Tanjung Piai comprised of a large diameter tubular shaped sand filled geotextile tube and a scour apron. An apron underneath the geotextile tube breakwater minimises scouring at the toe which is expected to occur due to turbulence generated by the reflected wave energy. Figure 3 shows the design of the geotextile breakwater at Tanjung Piai.

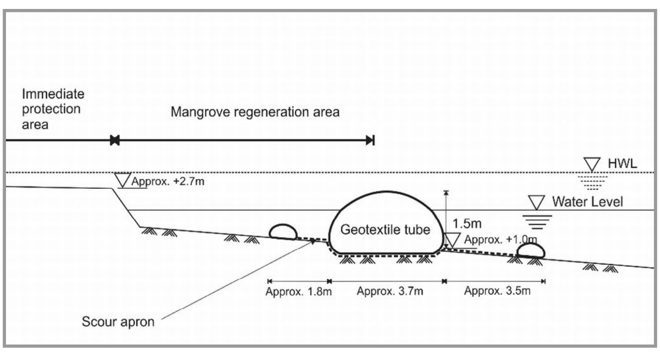


Figure 3: Schematic representation of Tanjung Piai geotextile tube breakwaters

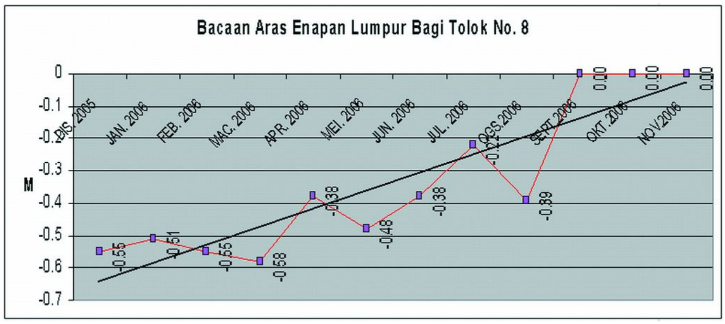


Figure 6: Result of the sediment gauge No. 8

In July 2004, the Tanjung Piai pilot project was completed with geotextile tube breakwaters placed almost parallel to shore at a distance of about 20 meters from the escarpment. The anticipated results are that substrate build-up would occur in the lee of the breakwater due to the lower energy zone created there (Figure 4). It can be observed that the breakwaters create a calmer water surface at the shoreward side of the breakwater (Figure 5). Gaps between breakwaters are necessary so as not to cause ponding and interference of the normal tidal inundation. DID is monitoring the performance of the geotextile tube breakwaters by using survey methods. From observations in 2005-2006, results indicate that substrate build-up has occurred (Figure 6).

## 6. GEOTEXTILE TUBES AT BORDER OF PERLIS-THAILAND

Existing hard protection such as rock revetment here at Batu Puteh Beach diminishes the natural state of the mangrove shoreline. Furthermore, knowing that a revetment would essentially lessen the chances of mangrove regeneration, an alternative protection had to be employed. In year 2005, the Department of Irrigation and Drainage Malaysia attempted a mangrove establishment project using geotextile tubes as breakwaters with a length of 200m and mangrove replanting (Figure 7).

## CONCLUSION

In the past, protection of mud shorelines has been achieved using rock and concrete revetments. However, concerns for the mangrove

*Figure 7: Geotextile tubes as breakwaters and mangrove replanting (Border Perlis-Thailand)*

ecosystem have forced the design philosophy to extend from hard structure to mangrove preservation.

The pilot project using geotextile tubes to protect the mangrove coast of Tanjung Piai, Johor National Park and Border of Perlis-Thailand have proven the capability of geotextile tubes as a main component in erosion control. Although still recent in its implementation, and positive results have been already been noted. ■


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