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GEOSYNTHETICS AND MODERN MATERIALS
IN COASTAL PROTECTION
AND RELATED APPLICATIONS

Design and Construction of Low Crested Reef Breakwaters using Sand Filled Geotextile Containers

Angus Jackson
Principal Engineer and CEO, International Coastal Management
Adjunct Research Fellow Griffith University, Australia
a.jackson@coastalmanagement.com.au

1. INTRODUCTION

Naturally occurring nearshore reefs can act as breakwaters and groynes mitigating wave transmission and sediment transport. Natural examples are found worldwide along coastlines and around atolls. With better design tools, low crested structures are being increasingly used for beach protection and beach improvement.

Artificial low crested "reef" breakwaters have been used since Roman times to protect coastlines and harbours. Often they are constructed on existing low natural reefs to improve the natural wave protection in storms. The term "reef" breakwater is generally used for low crested [fully submerged or semi-submerged]- breakwaters although the term has sometimes been used [wrongly in my opinion] for conventional high crested fully emerged breakwaters, particularly in the UK. They can provide, in the right conditions and with correct design and construction methods, a very good solution at a significantly lower cost and impacts than conventional high crested breakwaters.

"Reef" breakwaters are used extensively in Japan and more increasingly in Europe and Australasia as design guidelines for low crested structures (LCS) are more widely available, and coastal engineers better understand their behaviour and benefits. A design manual for reef breakwaters was first produced in Japan in 1988 and often multiple breakwaters are used to protect beaches or seawalls (Figure 1).

As they are entirely offshore there are no structures on the beach to impact the visual landscape and amenity and safety of the beach itself. Even if the structures are not fully submerged at all tides, the relatively low crest levels provide little visual impact. These types of structures also have the potential to improve the local ecology and recreational amenity -i.e. snorkeling and diving. (Figure 2).

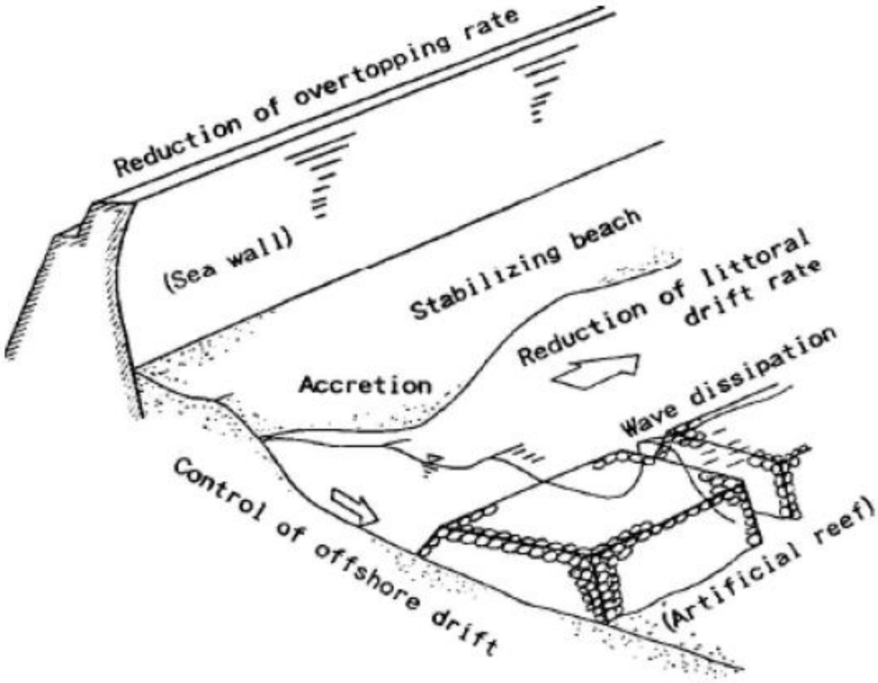

Figure 1 Typical multiple reef layout used in Japan (Pilarczyk 2003)

Figure 2 Example of semi submerged reef breakwater constructed of sand filled geotextile containers in the UAE.

A major hindrance to their more wide spread use of low crested breakwaters is that they are difficult to design and construct as they behave VERY differently from conventional fully emerged breakwaters and overtopping can cause damage to the crest. Fully emerged breakwaters are a very common coastal control structure, although not as common as groynes due to the higher cost of offshore construction and potential adverse impacts such as strong rip currents and the interruption of sea views.

2. DESIGN

The effects which natural and artificial reefs have on the shoreline vary depending on:

- site conditions
    - bathymetry

   - waves
   - currents, etc
- submergence depth / wave transmission,
- length,
- width,
- water depth, and
- distance offshore.

Empirical numerical models have been developed from the behaviour of natural reefs, artificial reefs and physical model studies. Where multiple reefs are used, the gap spacing is also important. One reason often cited for not using reef breakwaters is that setup can cause scour inshore. However, provided the reefs are far enough seaward, a salient develops and wave set up can be dissipated without strong currents.

3. WAVE TRANSMISSION BEHAVIOUR

Correctly designed, they can provide wave energy dissipation in storm events to mitigate storm erosion with no adverse visual impacts or reduced beach amenity. Typical emerged breakwaters have little or no overtopping and a wave transmission Coefficient, Kt = 0 for all wave and water level conditions. Low crested breakwaters do not stop all wave transmission but reduce the wave height [1> Kt >0] rather than stopping all of the wave energy in the lee of the breakwater (figure 3 and 4). Even waves that pass over without breaking also have a reduction in energy and wave height resulting in lower sediment transport and a salient / wider beach (Figure 2).

The percentage of energy reduction is less than for emerged breakwaters, but increases with incident wave energy – i.e. it works most efficiently when required, say in storm events. However, wave energy and sediment transport is proportional to H^2. Thus even a small reduction in transmitted wave height significantly reduces the transmitted energy and sediment transport.

Energy reduction is related to factors including:

- Wave height
- Wave period
- Crest width
- Crest height
- Permeability / roughness

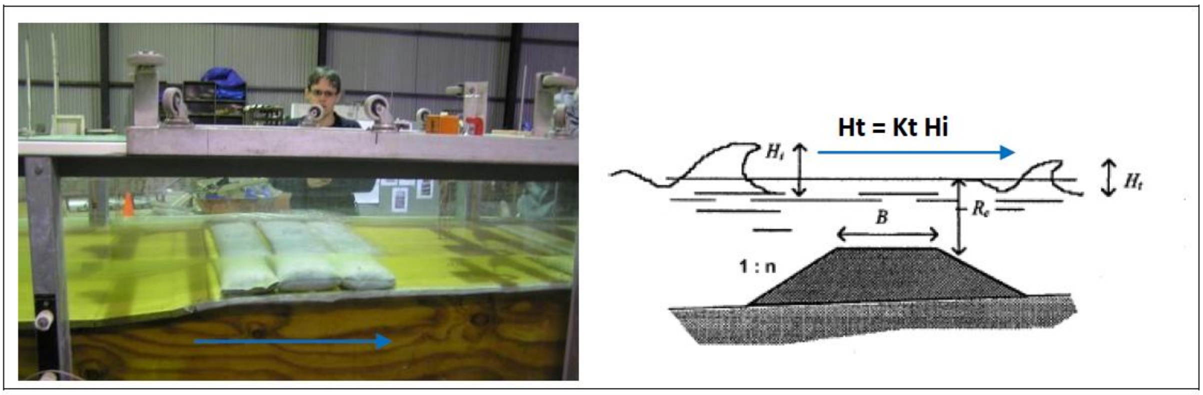

Figure 3 Measuring Kt in flume for various wave heights for a submerged reef constructed of mega geocontainers - 3 wide

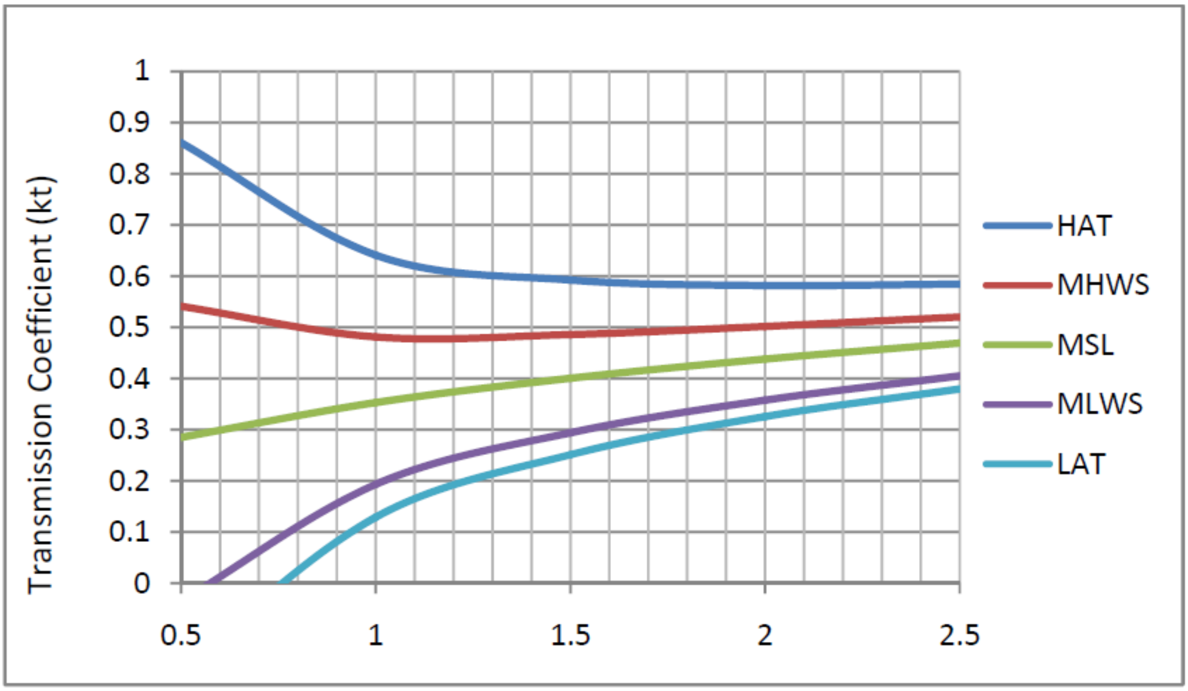

Figure 4 Typical Kt design curves for a semi emerged low crested reef breakwater

However, they are much more difficult to design effectively than emerged breakwaters and groynes. Various calculation methods will be presented and papers are included in the references. Also, as reef type structures need to be constructed from a marine platform rather than directly off the shore, they often have a much higher construction cost than shore-based structures, such as groynes.

4. CONSTRUCTION

The design and construction processes need to be tightly integrated. Recent advances in design and construction techniques using sand filled geo-containers have made artificial reef breakwaters a feasible cost option for low impact and sustainable coastal protection. The use of sand filled geotextile units as permanent construction elements in coastal works as a replacement of rock or concrete armour units elements is already more than 50 years old. Such reefs can be user friendly and multifunctional, providing a range of benefits. For example, the Narrowneck multi-functional artificial reef [MFAR] on the Gold Coast in Australia has provided a successful prototype for effective eco-friendly and multifunctional coastal protection.

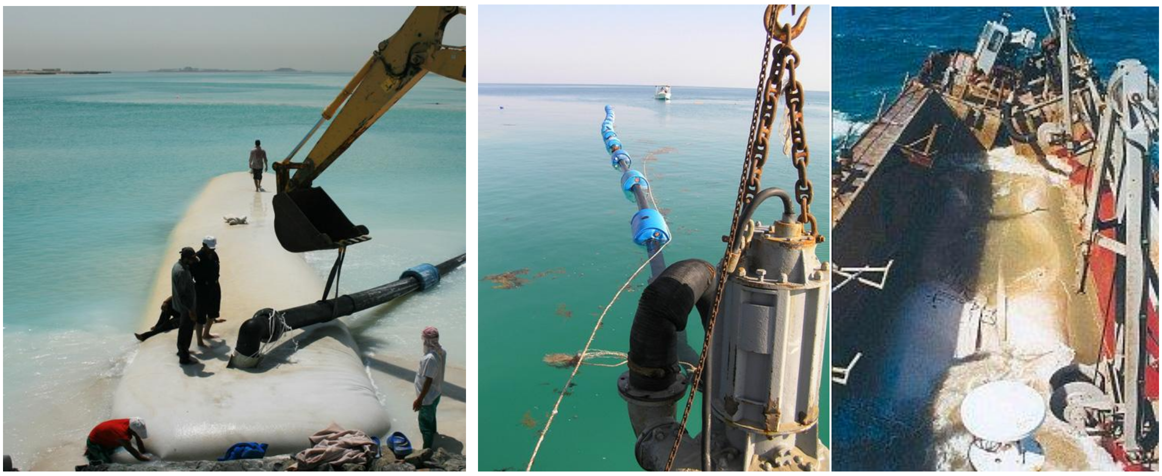

Figure 5 Various construction methods – Filling above water, filling in shallow water with divers, filling in split hull hopper barge and placing in deep water.

To achieve success with the mega sand filled containers various disciplines have needed to cooperate and special attention had to be paid to the seams and the prefabrications of the inlets and outlets for the filling process. Special threads and stitching methods are used to achieve a firm seam with sufficient flexibility however for the prefabrication of the mega sand bags. Basically, the use of mega sand filled containers made of heavy geotextiles - prefabricated in the shape of tubes - provides a lot of new, not yet assessable possibilities for the construction of special purpose coastal engineering structures and also the useful deposition of contaminated dredging material.

5. ENVIRONMENTAL BENEFITS

With the increasing cost of the “conventional“ construction materials and environmental awareness of coastal engineering activities, the use of sand filled geotextile containers and tubes especially made of nonwoven and woven staple fibre geotextiles has increased. Sand filled geocontainers and tubes forming “soft“ structures have proven to have significant environmental advantages over conventional “hard“ rock, so that they have also been used in areas where rock is readily available at a reasonable cost.

Composite high strength geotextile materials used for geo-containers can provide a suitable substrate for the growth of “soft” flora such as kelps and macro algaes which provide a good breeding and feeding habitat. The gaps between the bags increase habitat complexity, providing protection for fish, lobsters, rays and turtles. With the ecological monitoring data, the reef is to be eco-engineered to include a wider range of substrates and complexity in order to broaden habitat value – see references.

Figure 6 Typical soft growth on geotextile more biodiversity than hard surfaces

6. RECREATIONAL BENEFITS

Recreational amenity includes fishing, snorkelling and scuba diving as well as a range of surfing types.

Figure 7 Recreation on reef breakwaters

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Links to papers and information can be found at www.coastalmanagement.com.au