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Design and Construction of a Submerged Breakwater and Terminal Seawall for Beach Stabilisation

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Abstract

For a large 5 star beach resort in the UAE on an exposed section of the Arabian Gulf coastline, a resilient low-maintenance sandy beach is critical to providing amenity to their guests subsequent to storm events. Impacts to visual appeal, access and recreational amenity (particularly on the upper beach) can be problematic and also need to be closely considered.

After concept design and numerical modelling, it was determined that to meet these design requirements, a wide-crested submerged breakwater (with crest at low tide) would effectively mitigate the wave energy during all but the most severe events. To address erosion during these severe events without raising the crest height of the breakwater, it was decided to incorporate a terminal seawall within the nourished profile to limit the extent of the landward erosion, utilising "soft" geotextile sand containers to minimise user impacts and bulk fill Trapbags ® to provide stability in the event of overtopping.

Construction of these works were successfully undertaken within a limited timeframe during the storm season. Subsequent monitoring during multiple storm events has shown that, to date, beach stability and wave dissipation have been equivalent or greater than that predicted by the modelling.

Keywords: Submerged breakwater, nourishment, terminal seawall, rock, geotextile container, Trapbag

1. Introduction

The site is a large 5 star beach resort in the United Arab Emirates on an exposed section of the Arabian Gulf coastline (Figure 1).

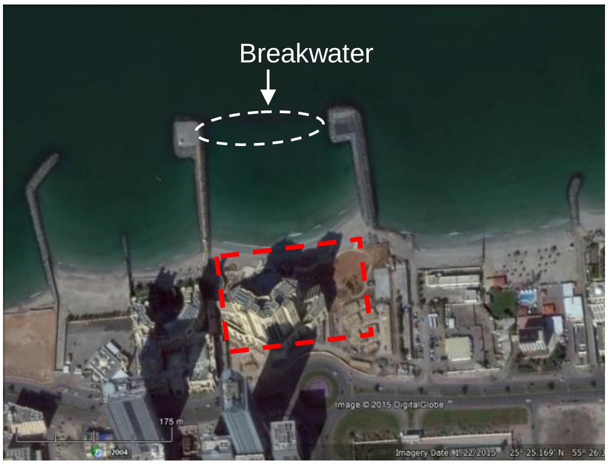

Figure 1 Site with existing groynes and low crested submerged breakwater

A low crested rip rap breakwater had been constructed between the boundary groynes to protect the hard landscaping and beach nourishment works. These structures did not provide sufficient protection during storms (shamals) to support the wide stable beach envisaged for the resort or to protect the hard landscaping of the resort itself from storm erosion (Figure 2).

Figure 2 Storm (shamal) wave in January 2015 eroding recently nourished beach up to hard landscaping.

2. Design

The client's design criteria was for a resilient "5 star" nourished beach to seaward of the new hotel requiring minimal maintenance so as not to impact on resort amenity during and after storms. Also, to avoid impacts on the sea view vista, the client had a preference for any additional works to be below low tide.

Time was also an issue as only 14 weeks were available for design and construction before the scheduled resort opening on 1st May 2015.

2.1 Concept Design

Local wave climate is typically mild with larger shamal events giving a 100 year ARI wave height (Hs) of approximately 2.6m (Figure 3) with a 100 year ARI surge level of approximately 2.6m above Lowest Astronomical Tide (LAT). [1]

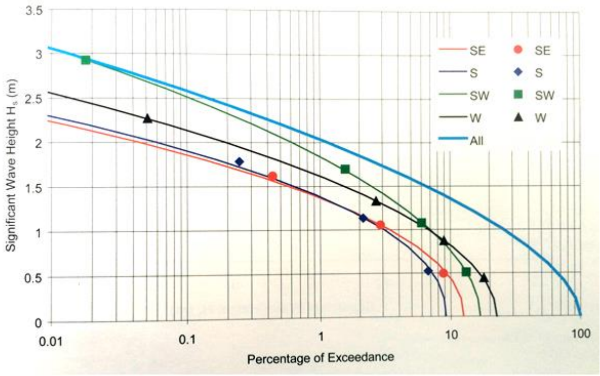

Figure 3 Hs vs % exceedance (Coastal Development Guidelines for Dubai Coastline, 2010)

A number of concept designs were developed assessing the potential benefits which might be expected from a wave attenuating structure of varying crest levels. Given the requirements from the client for low visual impact, breakwater options with the crest exposed were not considered for detailed design. The terminal wall crest height was also limited to beach height.

2.2 Modelling

STWAVE (a steady state spectral wave model developed as part of the CEDAS package by the US Army Corps of Engineers) was used to model the effects of the submerged breakwater and nourished slope on wave dissipation and refraction.

SBEACH (Storm-induced beach change model which also forms part of the CEDAS package) was used to model both wave attenuation over the low crested breakwater and the likely erosion of the foreshore.

The following conditions were modelled to evaluate the performance of the proposed structure:

- “Typical” NW.MHW
- “Typical” NE.MHW
- ARI 1yr NW [Shamal]
- ARI 10yr NW [Shamal waves plus storm surge]
- ARI 100yr NW [Shamal waves plus storm surge]

The model was calibrated and validated using the existing breakwater conditions, nourished beach and observed erosion. Modelling of a range of low-crested breakwater configurations was undertaken. The design nourished beach slope was based on adjacent natural beach slopes.

As expected, the extent of erosion and losses over the toe were sensitive to the sand grain size characteristics. With crest height at LAT, a wide crest (min 6m) and similar sand characteristics and profile to neighbouring beaches, erosion and sand losses were acceptable except in the 1 in 100 year ARI conditions. To limit erosion of the upper beach in these conditions, a buried terminal wall [2] was incorporated to effectively limit storm cut during extreme events and stabilise a 15-20m wide upper sandy “beach” to seaward of the hard landscaping (Figure 4). Maintenance of the beaches would be required after severe events. Overtopping and scour behind the low crested terminal wall were predicted to occur in extreme events. This required a wall design that could accommodate overtopping and scour behind to preserve the wall integrity.

2.3 Submerged Breakwater Design

The submerged breakwater was designed for expected wave forces, toe scour and overtopping (Figure 5). The breakwater was constructed by armouring the existing slumped rip rap breakwater with larger sized armour to provide:

- A higher crest (at approximately low tide).
- A wider crest (approximately 7m).
- A larger more stable armour layer (3-6t).
- A wider scour apron to seaward.

2.4 Terminal Wall Design

The wall was designed for expected wave forces, toe scour and overtopping. Given the location on the resort’s beach, the wall also needed to be user friendly. As such, 2.5m^3 sand-filled geotextile containers were preferred, providing adequate wave stability and “softer” stepped face which would be safe and provide a level of access/ egress during the short periods when it would be exposed. To provide improved stability of the wall during overtopping conditions and scour, a mass-filled free-standing “Trapbag” wall was used as a core to the structure. These elements can be rapidly constructed and are very cost-effective (Figure 6). The front face 2.5m^3 bags can slump and provide toe scour resistance in severe events and need to be restacked after.

3. Construction

International Coastal Management provided construction supervision and project management throughout. The works were constructed by local contractor, Merit International. The construction works included:

- 140m submerged rock breakwater
- 180m terminal wall [constructed using sand-filled geotextile containers & Trapbags]
- 26,000m^3 beach nourishment

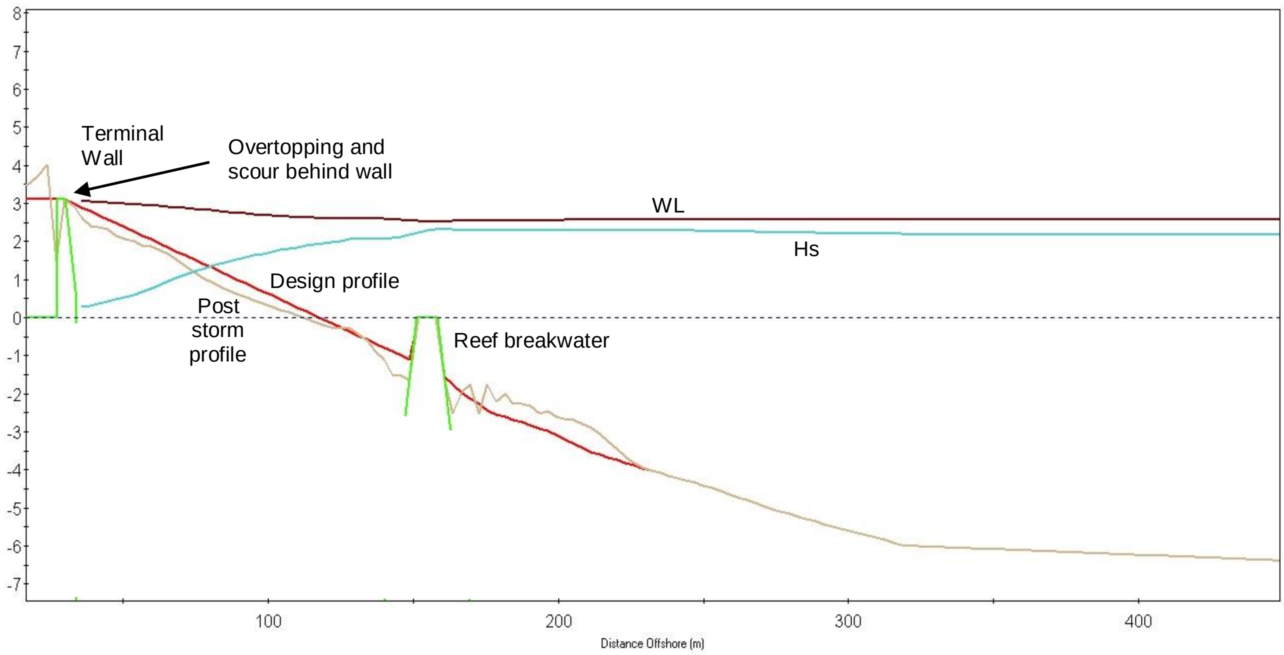

Figure 4 S-Beach modelling output of profiles with reef breakwater at MSL and terminal seawall in 100 year ARI Conditions

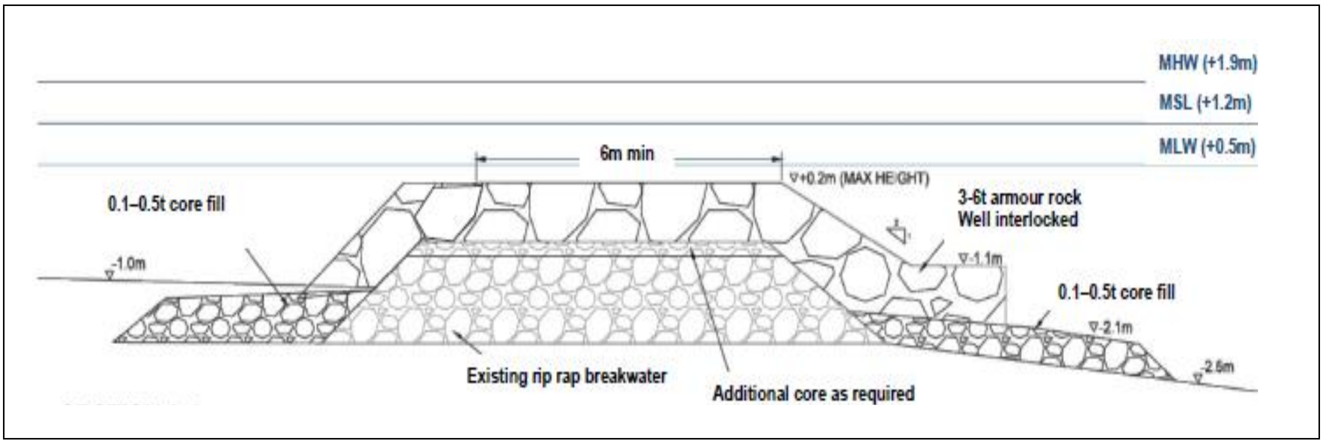

Figure 5 Submerged Breakwater Typical X-Section

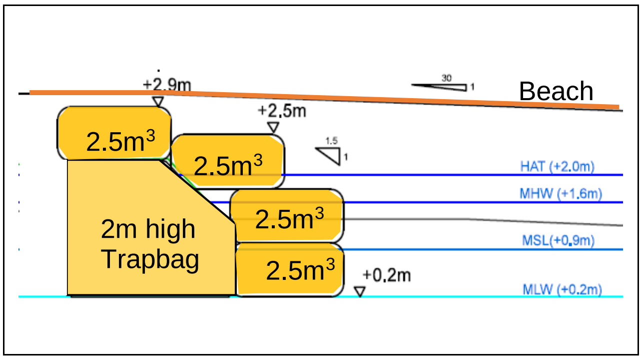

Figure 6 Buried terminal wall design using core of Free-Standing Trapbags and Outer Layer of Sand-filled 2.5m^3 Elcorock Geotextile Containers.

3.1 Breakwater Construction

The construction sequence was developed to meet the available construction timeframe and accommodate expected storm (shamal) periods with the local contractor’s plant and capabilities. The methodology was as follows:

- Stockpile core rock on beach and move to end of groyne with shovel loaders.
- Construct platform between the 2 groynes using core rock at low tides between storms with excavators.
- Stockpile armour rock on beach and move to end of groyne with shovel loaders.
- Trim core rock from south end and place removed core to seaward as a toe berm.

- Progressively place armour underwater to required crest levels and fill large voids with core rock. (Figure 7).

This methodology worked well and the works were completed to design and on schedule.

Figure 7 Placing 3-6t armour rock tightly at low tide

3.2 Nourishment

The design profile was based on survey of stable profiles of the adjacent beaches. 26,000m^3 of clean beach standard sand was trucked to site, placed and profiled. To achieve the required “5 star beach”, the sand quality was of key importance and three suppliers were used to achieve the quality within the deadline.

3.3 Terminal Wall Construction

The 180m terminal wall was constructed after the bulk of the nourishment was placed and subsequently buried.

The Trapbags® were custom manufactured for the project with a double layer of woven geotextile on the seaward face. The sand-filled geotextile ELCOROCK® 2.5m^3 containers were fabricated with the heavy duty composite non-woven “RP” geotextile. This provided a very robust system, able to withstand construction and in-service conditions during short periods when the structure was expected to be partially exposed.

The Trapbags were placed and filled first as the stable core (Figure 8) and subsequently armoured with the ELCOROCK® 2.5m^3 sand-filled geotextile containers (Figure 9). The system proved to be rapid and easy to construct with relatively unskilled labour.

Figure 8 Filling “Trapbags” containers as freestanding core

Figure 9 Placing 2.5m3 sand filled geotextile containers over Trapbag core

4. Monitoring

Monitoring was undertaken during the construction period and in the 1 month subsequent to completion of works. There have been a number of storms during this period.

Visual measurement indicates:

- Wave heights > ~1m break on the submerged breakwater across the full tidal cycle (Figures 10 and 11).
- As expected, greatest wave dissipation is observed at low tide when essentially all of the wave energy is dissipated.
- Wave transmission at high tide appears to be lower than modelling indicated.

- Wave heights ~1.5m at mid-tide break on the submerged breakwater, subsequently breaking directly on the shoreline (Hs <0.5m) (Figure 11)
- Nearshore waves are much smaller compared with the adjacent unprotected beaches (Figure 12).
- Flushing appears adequate.

Overall, the width and roughness of the breakwater crest is proving highly effective in reducing inshore wave energy and subsequent breaking wave heights on the beach.

To date the nourished profile has remained stable with no signs of erosion or significant re-profiling.

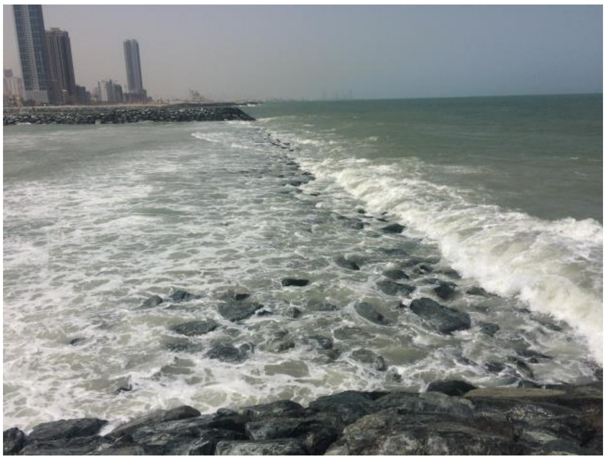

Figure 10 Photo of performance of submerged breakwater during low tide (0.1m LAT) with wave breaking (Hs ~ 0.7m)

Figure 11 Photo of performance of submerged breakwater during mid-tide (0.9m LAT) with wave breaking (Hs ~ 1.5m)

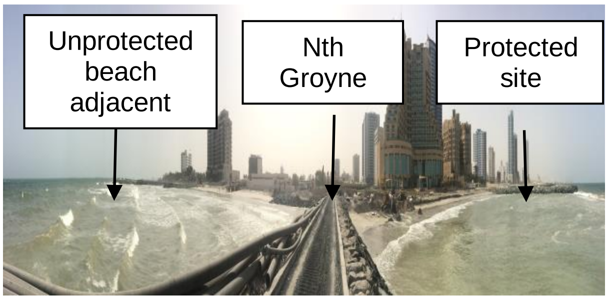

Figure 12 Wave breaking at site (right) compared with neighbouring beach (left) shows effectiveness of submerged breakwater at dissipating wave energy. Photo taken with fisheye lense during construction.

5. Conclusions

For 5 star resorts, ensuring continuous beach amenity regardless of erosion events can be critical to commercial operations. In this case, a suitable solution was effectively provided using an integrated management strategy that included the existing boundary groynes, a submerged rock breakwater, beach nourishment and a buried “soft” terminal seawall to limit landward erosion in the most severe events (Figure 13).

Monitoring indicates that the submerged breakwater is dissipating wave energy even more effectively than anticipated and is successfully providing a wider, stable beach and safe lagoon swimming area (Figure 14).

Figure 13 Completed works with waves breaking on breakwater and terminal wall buried under nourished beach.

Figure 14 Wide stable beach at low tide, submerged breakwater visible through water on clear day

6. References

[1] Coastal Development Guidelines for Dubai Coast, 2010, Dubai Municipality, Environment Department Coastal Zone & Waterways

[2] Mulcahy, M. Corbett, B & Jackson, L.A. 2015. Terminal Seawalls as a strategy for uncertainty and sea level rise. Proceedings of the Australasian Coasts & Ports Conference