Shore parallel pile row breakwaters, an example of an effective coastal protection scheme

ir. J.S. Reedijk, senior coastal engineer and drs P. Boswinkel, coastal engineer.
Delta Marine Consultants bv. Gouda, The Netherlands.

Summary

Along the beach of the Pelangi beach resort, Langkawi, Malaysia, serious erosion did occur. To stop this erosion, an innovative pile row breakwater has been designed by DMC. Construction was carried out under supervision of DMC. The effectiveness of the pile row breakwaters in stabilising the shoreline has been monitored. The performance of the breakwaters is very good, even better than expected.

Description

The Pelangi Beach resort at the Malay island of Langkawi was constructed on an existing spit in the lee of two small islands. Waves diffract around the two offshore islands. Therefore in the lee a cuspate spit has developed naturally. The location is given in Figure 1.

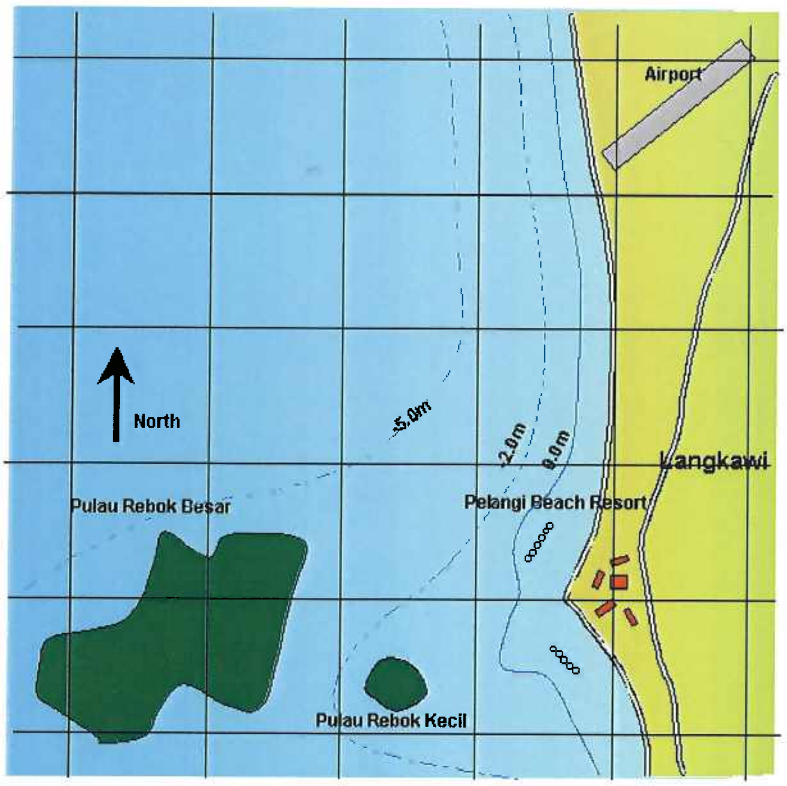
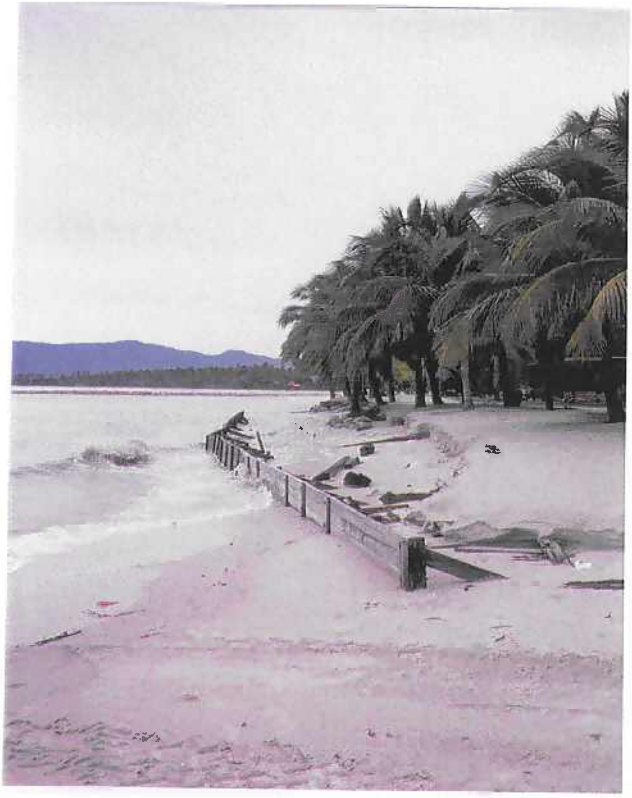


Figure 1 ***Location of the site***

The tip of the spit is a beautiful location and therefore it was decided to construct the resort over there. However this spit is also a morphological sensitive area, it turned out that the spit had been eroding slowly over the years.

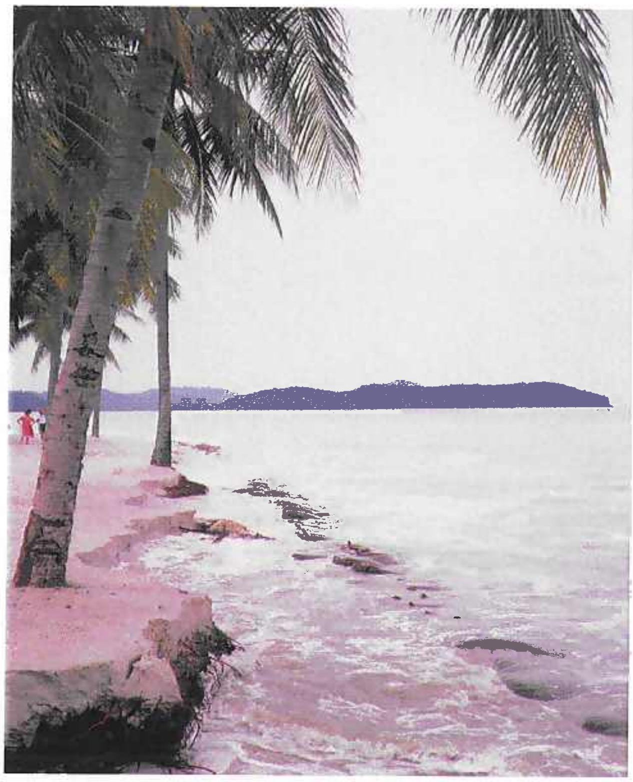
During construction of the resort, it was decided to enlarge the spit by reclamation, based on the architectural layout. Since the new layout was not a stable situation, in the local wave climate, the coastline of the resort eroded rapidly. The situation deteriorated within a few years.

The beach disappeared over a stretch of 300m and palm trees toppled over into the sea. Because of the shoreline erosion, wave attack increased and flooding of the swimming pool by overtopping waves occurred.



Before the Client contacted Delta Marine Consultants several measures had been tried to halt the erosion, none of them were successful. First interlocking concrete blocks were put on the beach, but these disappeared below the sand after a storm. The remaining blocks are now in use as pavement for footpaths. Then wooden walls were applied, but these were overtopped and undermined. Finally sand bags and rock were put on the beach, providing an unsightly view. After each storm new sand bags had to be placed, and the beach had to reshaped with bulldozers. This was not the favourite task of the sports department. Some of the failed measures are shown in the photographs.

Photograph 1. Failed wooden wall



To provide a final solution which would stop the erosion of the shoreline, a system was designed by Delta Marine Consultants which retained the beach in a natural way. Initially the option of providing more shelter by adding breakwaters to the offshore islands was considered. However, this option was rejected from an economical point of view. As an alternative, two parallel breakwaters were designed 75 m offshore, near the Lowest Astronomical Tide line [tidal range 2.0m].

Photograph 2. Sand bag protection

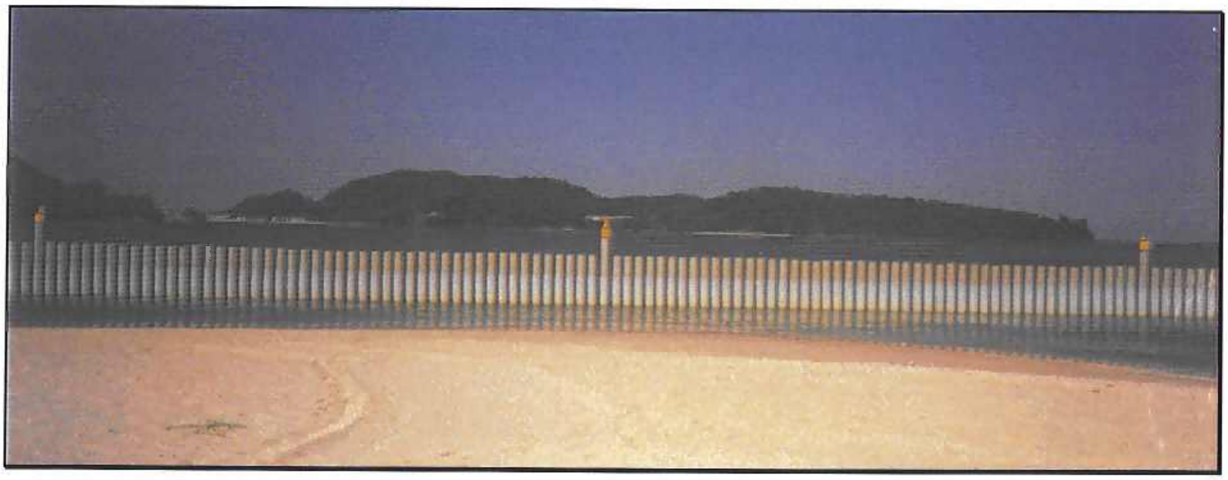
Design

The recreational use of the beach required that a solution should have minimum impact on the beach, and would not endanger recreation along the beach. A number of alternative solutions were developed. Finally a choice was made to construct two pile rows as breakwaters at the outer sides of the existing spit. In this way the spit is stabilised in its present geometry and the erosion is halted. Additional a replenishment of the beach was foreseen, so the final equilibrium beach plan shape would be reached directly after construction and the impact on neighbouring beaches would be minimal.

The concept of pile rows was developed to have a "light" protective structure on the beach, which would not have a large visual impact. Conventional rubble mound breakwaters would be quite massive, and would block the view from the beach to the offshore islands. Also closed parallel breakwaters lead to rip currents near the breakwater heads which are dangerous for swimmers. The pile row breakwaters consist of individual piles with gaps in between. The height of the piles is 1,5 to 2 meters above the lowest low water line. The top of the piles is located at the Highest Astronomical Tide level. At low tide, when people can walk up to the pile row, it is still possible to see through the pile rows because of the 60 mm gap between the piles. At high tide the pile rows are hardly visible.

Another advantage of the pile rows compared to rubble mound breakwaters is that the pile row does not block cross shore sediment transport. Normally with closed breakwater types scour holes develop in front of the breakwaters due to wave reflection. Scour protection has to be provided to prevent slip circle failure. With the transparent pile rows only local scour around the piles occurs. This scour is limited to a depth less than the pile diameter.

The pile rows at Langkawi are designed to provide in a salient sand body in the lee side of each pile row. No direct connection [tombolo] above the high water mark is foreseen.



Photograph 3. Pile row at low water level

The pile rows are 120 m in length and consist of • 350mm concrete spun piles with an intermediate spacing of 60mm. In this way, the shore parallel breakwater is a half open structure; some of the wave action is capable of penetrating through the pile row. It is not necessary to block all wave action. With the 60 mm gap between the piles the transmitted wave height is about 50 percent of the incoming wave height. The wave energy at the beach, which dominates the sediment transport, is reduced by 75%. This is sufficient to stabilise the beach. Because the pile rows are transparent, sediment transport can also take place through the pile row. *The shore parallel breakwater is not blocking the cross shore transport.* This performance is unique for the structure compared to traditional shore parallel breakwaters.

Photograph 4. Overview of the beach resort with pile rows.

Since no differential water levels can exist between front and back of the pile row, the intensity of rip currents is negligible. No large scour holes develop near the breakwaters and no hazardous situations exist for the resort guests.

Originally it was planned to build the pile rows using suitable hard wood piles. However, even in a hard wood producing country as Malaysia the price of concrete piles is lower than of hard wood piles. Therefore the construction took place with concrete spun piles.

The construction cost of the pile rows was approximately US$ 200.000, or US$850/m. This is low compared to conventional parallel breakwaters with the same height.

Driven by financial considerations, the decision was made by the client not to replenish the beach directly after the construction of the pile rows. Besides, no monitoring campaign was planned