Abstract
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Reconstruction of Tripoli harbour breakwater, Libya: The open solution

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The main breakwater of Tripoli Harbour, Libya was severely damaged by two storms shortly after completion in 1981. Instructed by the owner, the Libyan Maritime and Ports Authority, a complete re-design of the breakwater was developed by NEDECO/De Weger in 1999. The 1999 re-design was an update of the re-design from 1982, by the same consultant, that was never implemented.

The typical breakwater profile at deep water consists of a primary armour layer of 8 m^3 Tetrapods. On top of the breakwater there is a parapet wall structure that is founded on a secondary armour layer of 2-4 t rock. The storms resulted in extensive damage to the primary armour layer and the parapet wall structure. The landfill behind the breakwater suffered from severe erosion due to venting through the secondary armour and overtopping of the parapet wall. The main cause of the damage was the underestimation of the wave height in the original design. The (hindcasted) significant wave height at deep water of the severest storm was more than twice as high as the original design wave height. Another cause of damage was the large permeability of the layer on which the parapet is founded. This layer allowed the water to penetrate easily through the breakwater. The relatively high flow velocity under the base plate caused venting of air and water through the layer, and the high wave pressures endangered the stability of the parapet wall.

The 1999 re-design of the seaside comprised of a complete new single primary armour layer of Accropodes on top of the damaged Tetrapod layer, supported by an extended underwater berm consisting of concrete cubes with a toe of 5-8 ton rock. The stability of the parapet was obtained by reinforcing it with extra mass concrete. A new design criterion in the revision was that part of the harbour area could be used for the collection of the overtopping water. In the light of this new criterion a special re-design was developed for the harbourside, the so-called open solution. The open solution consists of a canal behind the parapet structure with a width of 13 m, filled with 2-4 t rock. The stone canal is directly connected to the secondary armour layer of 2-4 t under the parapet base. In this way controlled venting of air and water can take place in the stone canal. The stone canal also collects water overtopping the parapet wall that is discharged to the sea during wave run-down.

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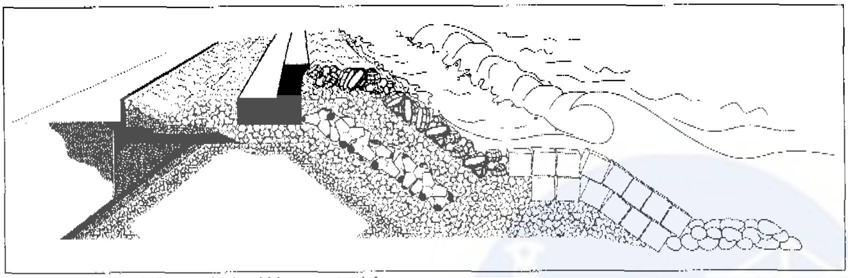

Re-design by NEDECO/De Weger, 1999

The 1999 re-design was tested in a hydraulic scale model. During the model tests the wave pressures at the wave wall and base plate were measured. The model tests showed that the open solution has a clear positive effect on the wave pressures. The reduction of the horizontal and uplift forces, for both quasi-static and impact wave action, is in the order of 30%. The uplift pressures at cross-sections with a landfill, for the open solution and a closed situation, are approximately constant over the base plate. The latter holds for both impact and quasi-static pressures. Furthermore the tests showed that elevating the armour crest height with 2 m, to a fully protected wave wall, results in a reduction of the horizontal impact pressures with approximately 50%.

The empirical formula derived by Jensen (1984) and revisited by Bradbury et. al (1988) to determine the maximum horizontal wave force on a crown wall was fitted to the model test results. For three typical deep water breakwater profiles, including one with an open solution, the empirical coefficients (a) and (b) of the relation were determined.

The water level in the stone canal was measured in the model tests. For moderate wave conditions, when there is no overtopping of the parapet wall nor the retaining wall, the water level in the canal is only determined by the pressure head difference and the friction over the base plate width. Simultaneous measurements of the water level in the stone canal and pressures at the parapet wall unit were performed during the model tests. These measurements were used to verify the applicability of the relation derived by Cohen de Lara (1955) to determine the water flow through the open solution. The calculation agrees rather well with the model test results and the relation can therefore be used to assess the water level in the stone canal.

The general conclusion of the study is that the open solution, as an integral part of the 1999 re-design for the reconstruction of the Tripoli harbour breakwater, provides a good solution to deal with the overtopping and venting problems endangering the present breakwater profile, and helps to reduce wave pressures at the parapet structure.

References

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