

## Wave run-up and wave overtopping on a rubble mound breakwater

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Many physical processes concerning the land-ocean interaction such as wave run-up and wave overtopping are not yet fully understood. These are very important in the design of the crest height of sloping coastal structures. Nowadays, this design is solely based on small-scale model tests. A clear difference between prototype measurement results and laboratory test results is noticed.

Prototype measurements are carried out at the northern part of the Westdam of the outer harbour of Zeebrugge. The structure is a conventional rubble mound breakwater armoured with 25 ton grooved cubes. The breakwater is fully instrumented for the measurement of the sea state, wave run-up and wave overtopping. On the one hand, wave run-up is measured by a spiderweb system, i.e. a set of seven vertical step gauges placed between the measuring jetty and the armour units, measuring the water surface elevations. Out of these measurements, the wave run-up level is calculated. On the other hand, a run-up gauge placed on top of the armour units detects the wave run-up directly. A good agreement between the results obtained by both measuring devices is found. Behind the crest of the breakwater an overtopping tank of about 28m<sup>3</sup> is constructed in order to collect the overtopping discharges. A compound weir with a thoroughly investigated cross section controls the outflow of the water. From the measurement of the water level in the tank and the calibration formula of the weir, the overtopping discharge and the volumes of the individual overtopping waves can be calculated.

Up till now, 13 storms (between 28/08/1995 and 23/01/2000) have been observed at the Belgian coastline. The dimensions of the armour units and the attacking significant wave height are of the same order of magnitude.

Three scale models of the Zeebrugge breakwater are built and tested. At Aalborg University (Denmark) a three-dimensional model is built in the wave basin on scale 1:40 and in Flanders Hydraulics (Belgium) and in Universidad Politécnica de Valencia (Spain) a two-dimensional 1:30 scale model is tested in the wave flume. By means of a novel laboratory step gauge, wave run-up levels can be detected more accurately. The distance between the armour units and the electrodes of the step gauge is less than 2mm, whereas in case of a traditional run-up gauge this distance is much larger. The measured prototype storms are reproduced in the laboratories.

Analysis of prototype data, gathered at a two-hour period around high water shows that the dimensionless wave run-up value  $\frac{Ru_{2\%}}{H_{mo}}$  equals 1.80.  $Ru_{2\%}$  is the wave run-up level exceeded by 2% of

the waves and  $H_{mo}$  is the significant wave height. When a whole tide cycle is analysed, dimensionless run-up values increase when water depth decreases. At mean tide the dimensionless wave run-up value becomes larger than 2. Wave run-up is Rayleigh distributed. Laboratory experiment results show a clear underestimation of reality: two and three-dimensional testing yield almost the same dimensionless wave run-up value of 1.5 at high water. However, results diverge when water depth decreases. Laboratory tests also show that their results are clearly dependent on the value of the spectral width parameter  $\epsilon$  and the placement pattern of the armour units on the one hand and the type and relative position of the measuring devices on the other hand.

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