Wave Run-Up on Sloping Coastal Structures

prototype versus scale model results

Rouck, J. De; Troch, P.; Ronde, J. De; Frigaard, Peter

Publication date:
2001

Document Version
Early version, also known as pre-print

Wave run-up on sloping coastal structures: prototype versus scale model results

De Rouck Julien[1], Troch Peter[1], De Ronde John[2], Frigaard Peter[3], van Gent Marcel R.A.[4]

[1]Ghent University, Dept. of Civil Engineering, Technologiepark 9, B-9052 Zwijnaarde, Belgium
[2]Rijkswaterstaat, Kortenaerkade 1, PO Box 20907, NL-2500 EX The Hague, the Netherlands
[3]Aalborg University, Dept. of Civil Engineering, Sohngaardsholmsvej 57, DK-9000 Aalborg, Denmark
[4]Delft Hydraulics, Marine and Coastal Infrastructure, PO Box 177, NL-2600 MH Delft, the Netherlands

Introduction

Wave run-up is one of the main physical processes which is taken into account in the design of the crest level of sloping coastal structures. Until recently, solely physical scale model results were used for the crest level design. However, prototype measurements have indicated that scale models underestimate wave run-up [1]. Therefore wave run-up is studied in detail comparing prototype measurements and physical modelling.

Prototype measurements

In Zeebrugge (Belgium) prototype measurements are carried out on a rubble mound breakwater armoured with grooved cubes [2]. Two different measuring devices are used for the measurement of wave run-up: a "spiderweb" system and a run-up gauge. The "spiderweb" system is a set of 7 vertical step gauges placed between the armour units and the measuring jetty. Each step gauge measures the surface elevations of the uprushing water tongue. The wave run-up levels are computed from these measurements. A run-up gauge is mounted along the breakwater slope on top of the armour units. Both measuring devices yield comparable results.

Along the Dutch coast prototype measurements are performed at the Pettemer sea defence [3]. This structure is a smooth sloping dike covered with basalt blocks and asphalt. The location is of special interest because of the shallow foreshore with a bar on which considerable wave breaking occurs. Wave run-up is measured by a step gauge which is worked into the revetment of the dike.

Wave data and wave run-up on the breakwater and the dike during several storms are analysed and used for comparison with physical model tests.

Physical model tests

The two types of structures have been modelled in 5 laboratories. Recorded prototype storms are reproduced and parametric model tests are carried out. Both two and three dimensional tests are performed.

In the laboratories various measuring devices have been employed to determine the wave run-up: several wire gauges placed at different heights above the surface of the breakwater slope and a novel developed step gauge. The step gauge is a comb of which the needles can be adjusted to the profile of the breakwater. With latter measuring device a more accurate determination of the wave run-up level is obtained.

Results

Allsop (1985) fitted the formula of Losada & Gimenez-Curto $\frac{Ru_{2\%}}{H_s} = A.(1-\exp(B.\xi))$ to the results of laboratory tests in which the model setup looks very much alike the Zeebrugge breakwater geometry and obtained A = 1.52 and B = - 0.34. With the average of the recorded prototype values of ξ_p = 4.70, $\frac{Ru_{2\%}}{H_s}$ equals 1.21. At the Zeebrugge breakwater, a mean prototype $\frac{Ru_{2\%}}{H_{mo}}$ value of 1.80 is obtained at high tide. When water depth decreases, the dimensionless wave run-up values tend to increase. At mean water this value has increased up to 2.25. Two dimensional and three dimensional scale model tests yield almost the same $\frac{Ru_{2\%}}{H_{mo}}$ = 1.40 at high tide, but diverge when water depth decreases (Fig. 1). A clear underestimation of prototype results by these laboratory tests is seen. The pattern of the armour units has a very big influence on the results. Next to the $Ru_{2\%}$ value, the other $Ru_{x\%}$ values are looked into detail.

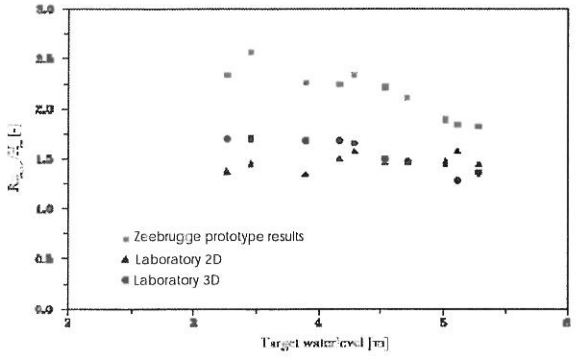

Fig. 1: Comparison of prototype measurement and scale model test results (Zeebrugge site)

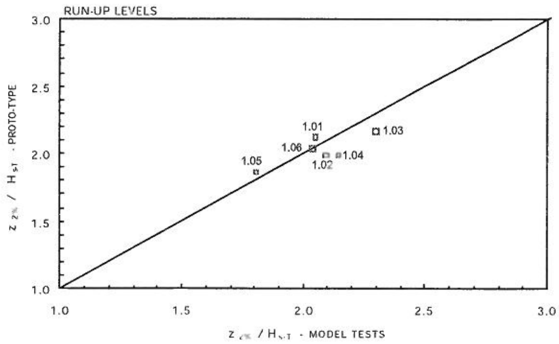

Fig. 2: Comparison of prototype measurement and scale model test results (Petten site)

The formula of Van der Meer & Stam (1992) $\frac{Ru_{2\%}}{H_{mo}} = 1.97$ for the average prototype value $\xi_m = 3.61$ predicts a slightly higher value than the prototype results. However, this formula is obtained by tests on rip-rap slopes. The dimensions of the rock are much smaller than the wave height. In Zeebrugge, the dimensions of the armour units are of the same magnitude as the significant wave height.

A rather large reduction of the deep water wave height is seen at the toe of the Pettemer dike. The considerable changes in wave energy spectra and wave height distributions that occur when waves propagate over shallow foreshores affect wave run-up for coastal structures. In the model tests the wave energy spectra that occurred in prototype were reproduced in the flume. Comparison of the wave run-up levels measured in prototype storms and in the model tests, show a very good agreement with only 4% difference on average. The mean $\frac{Z_{2\%}}{H_{s-T}}$ value equals 2.0 (Fig. 2).

Conclusions

The development of a novel wave run-up measuring device led to a more accurate determination of wave run-up levels in physical model tests. Prototype measurement and scale model test results agree very well for the Pettemer sea dike. A clear difference between prototype and scale model test results is observed for the Zeebrugge rubble mound breakwater. Improved design formulae for the crest level design of sloping coastal structures are elaborated.

Acknowledgement

The results are obtained through the EC-funded MAST 3 project 'OPTICREST' ('The optimisation of crest level design of sloping coastal structures through prototype monitoring and modelling.' – contract number MAS3-CT97-0116). The financial support of the European Community is very much acknowledged.

References

[1] De Rouck J., Verdonck R., Troch P., Van Damme L., Schlütter F., De Ronde J., Wave run-up and overtopping: prototype versus scale models, Proc. ICCE 98, pp. 1039-1052, 1998.

[2] Troch P., De Rouck J., Van Damme L., Instrumentation and prototype measurements at the Zeebrugge rubble mound breakwater, Coastal Engineering 35, pp. 141-166, 1998.

[3] Wolf, F.C.J., Description of field sites for the measurement of wave run-up, RIKZ report 98.138x, 1998.

[4] Allsop H.W.H., Hawkes P.J., Jackson F.A., Franco L., Wave run-up on steep slopes – model tests under random waves, Report SR2, 1985.

[5] De Waal, J.P., van der Meer J.W., Wave run-up and overtopping on coastal structures, Proceedings ICCE '92 Venice, Vol. 2, pp. 1758-1771, 1992.

[6] van Gent, M.R.A., Physical model investigations on coastal strucutres with shallow foreshores – 2D model tests on the Petten Sea-defence, Delft Hydraulics Report H3129, 1999.