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4 Riprap stability on the inner slopes of medium-height breakwaters

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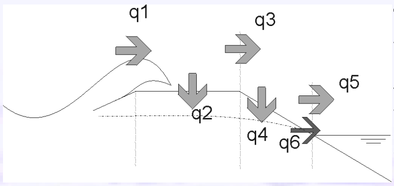
Why this research ?

For the calculation of the stability of the inner slopes of breakwaters only black-box models exist. In order to understand the process, a distinction is made between the understanding of the water movement and the understanding of the rock stability. This research focuses on the stability.



The first step

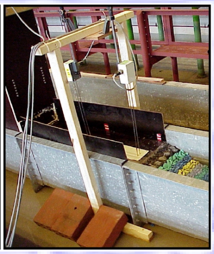
As a first step the discharge by a single wave (q1) is split into the components q2 ... q6. For q1 relative reliable relations can be found in literature. The values q2 and q3 depend on the characteristics of q1, on the crest width and on the permeability of the crest. Then q3 can be separated in q4 and q5. And q6 is a function of q2, q4 and the permeability of several layers in the breakwater.

The values of q2...q6 are determined in separate research programmes. In this research they are considered as given. For the time being, the effect of q6 is not considered. However it is envisaged that q6 may have an additional effect on the stability of the rocks on the inner slope.

The testing device

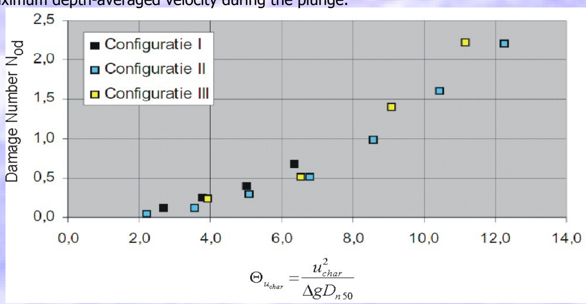
In this device it is possible to generate a single overtopping wave. This wave can be repeated several times. A relation can be looked for between the individual plunge and the stability of an individual rock.

The model is reduced to a rear slope only, on which plunges were simulated by water flowing out of a reservoir with pulses. The type of plunge can be varied in magnitude, duration and intensity, by changing the conditions in the reservoir.

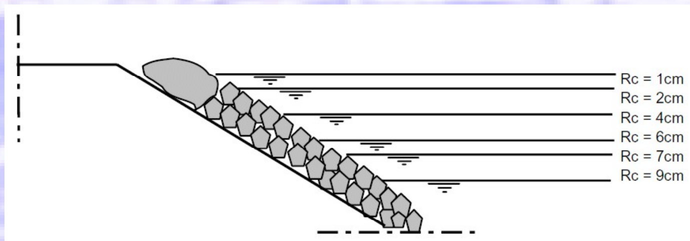


The first findings

In first instance it is tried to fit the results to a Izbash-type of stability relation. From the first results it is clear that this was quite promising, but that not all parameters were in the equation included. The definition of characteristic velocity was also a point of concern. The best results were obtained by using the maximum depth-averaged velocity during the plunge.



The crest freeboard significantly influences the rear slope damage development. Similar series of experiments were carried out for different crest freeboards by varying the water level in the flume. The rear slope stability is least for an intermediate crest freeboard. On average, the sum of the stabilising damping effect of the tailwater and the destabilising lifting effect of the tailwater is least favourable in this situation. Especially in the case of a very low crest freeboard, the rear slope seems less sensitive to collapse than in the case of a high crest freeboard or an intermediate one.

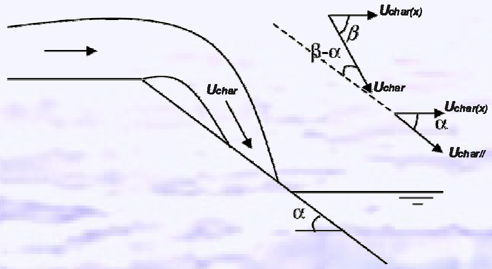


In every step, consisting of three waves, the first wave causes most damage. After the following two waves, hardly any additional damage occurs. The amour stone seems to restructure and will be more stable for this wave size. More stones are needed to cause the same damage. So the step-size is of influence. The more steps there are included in the experiment, the more damage is observed.

In order to incorporate this effect in the stability equation, a parameter $i^{½}$ is included in the equation, in which i is the number of waves (= number of steps) in the experiment.

It is clear that the slope angle of the inner slope should have an influence on the stability. This has been investigated, and adding a factor sin(α) takes this effect into consideration. However, from the analysis followed that not only the slope angle was of importance, but also the angle of impact of the plunge on the slope. This angle is defined as β in the figure.

Unfortunately the determination of β was rather difficult in the experiments, this resulted in a low reliability of this factor.

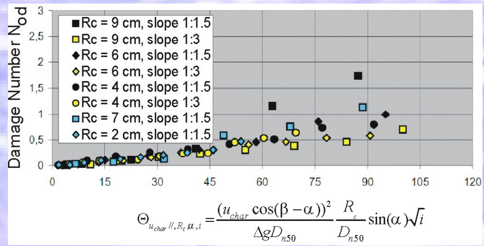


All tests finally resulted in the following overall equation:

$$\Theta_{u_{char}//,R_c,\alpha,i} = \frac{(u_{char}\cos(\beta-\alpha))^2}{\Delta g D_{n50}} \frac{R_c}{D_{n50}} \sin(\alpha)\sqrt{i}$$

in which:

Θ	stability parameter
u_{char}	characteristic velocity of the plunge on the breakwater crest
β	angle of wave impact on the slope
α	slope angle
Δ	relative density of rock
D_{n50}	Nominal diameter of the rock
R_c	Crest freeboard
i	number of waves in a storm

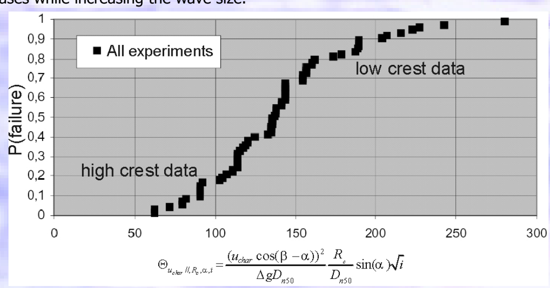


Damage by a single wave

A few experiments were carried out for damage due to one certain wave. Two different crest heights were considered. An even larger spread in damage appeared for these experiments compared to the experiments with cumulative damage development. The larger spread is inherent to the experiment procedure.

Collapse behaviour

Besides damage development, collapse behaviour can be considered. In some experiments, the rear slope collapses for relatively small values of wave size, while in other experiments the rear slope will be able to resist considerable large values of he size of the wave, before collapse occurs. The probability of collapse increases while increasing the wave size.



Results are plotted in the graph above. However, we found that high crest data are on the left side, and low crest data are on the right side. This means that collapse behaviour, contradictory to damage behaviour, is not well described by the stability parameter as derived.

From the above one may conclude that the parameter can be used to determine damage on the inner slope of a breakwater, but that this parameter cannot be used to determine collapse of the inner slope.

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