Rock Armour Stability in Shallow Water

Background

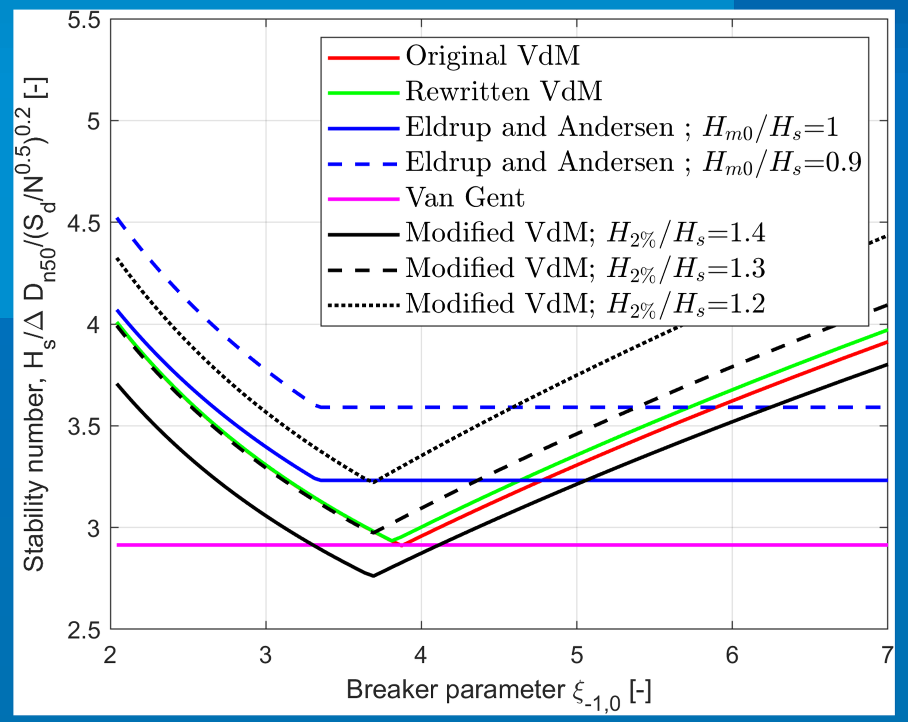
In recent times, it has become increasingly relevant to investigate breakwaters under shallow water conditions, as climate change leads to challenges such as rising sea levels and more extreme weather. These challenges contribute to making the world's coastal areas more vulnerable to erosion, flooding, and damage to infrastructure. Since rubble mound breakwaters are the type typically used near coastlines and harbours, it is important to examine their stability under shallow water conditions. Rubble mound breakwaters are often placed at lower water depths and are therefore frequently exposed to shallow water conditions.

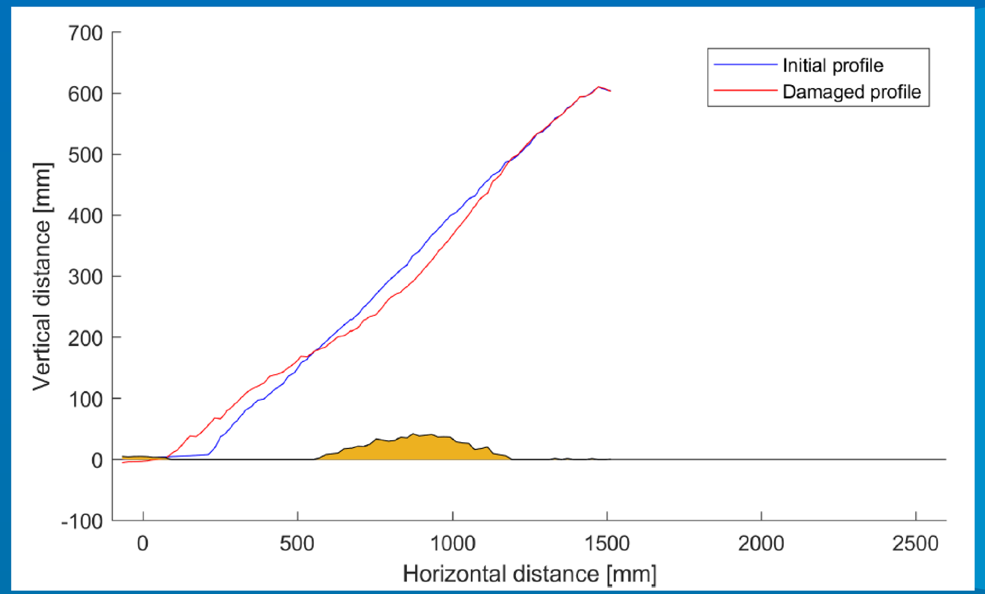
The Problem

The problem with rubble mound breakwaters being exposed to wave attack in shallow water conditions, where $h/H_{m0\ deep} < 4$, is that the current design method was developed for deep water waves, where $h/H_{m0\ deep} > 4$. Therefore, it remains unclear how the stability of the breakwater actually behaves under these conditions. As breaking waves often define the design conditions for such structures, subjecting them to forces significantly different from those encountered in deeper water environments.

The current design methods are shown in the figure, where the most commonly used formulas are the original and the rewritten Van der Meer formula. It is shown in the figure that almost all the design tools imitates original formula from Van der Meer, except the one from Van Gent and the one from Eldrup and Andersen.

At this point in time, is the formula from Van der Meer the preferred design tools, but it is only validated for use in wave conditions where h/Hm0 is greater than 1.5





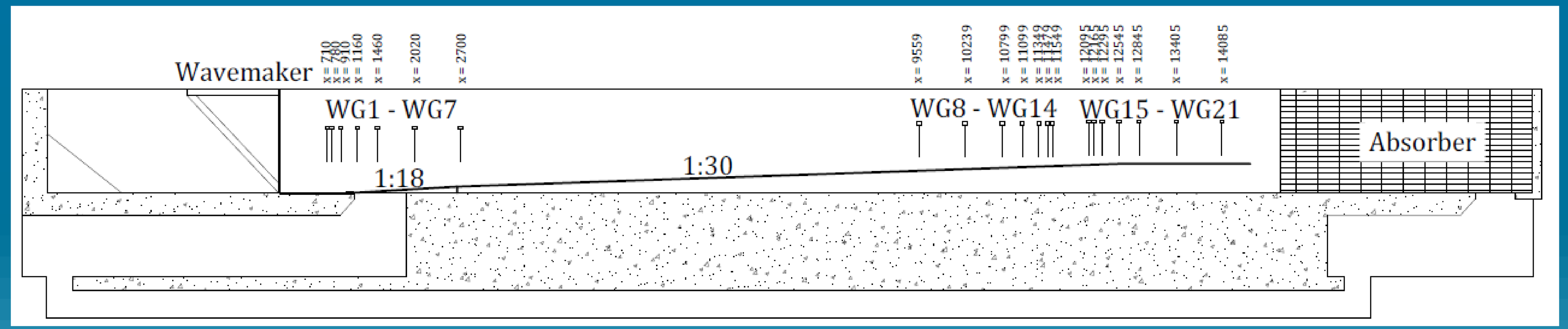
How is the problem addressed?

In this project, the problem has been investigated through experiments, first by determining the design wave conditions through calibration tests, and subsequently through model tests to determine the stability of the breakwater.

When performing the stability test, the same waves used in the calibration test were applied to damage the breakwater. The stability is assessed by observing how many stones are displaced from their original positions. Therefore, the breakwater models were scanned using an erosion profiler to determine both the initial and the damaged cross-sections. These cross-sections were then compared to calculate the difference in area, and the armour stone size was used to quantify the damage level. This damage level was subsequently used in the stability formula, together with the wave conditions, to determine the stability number.

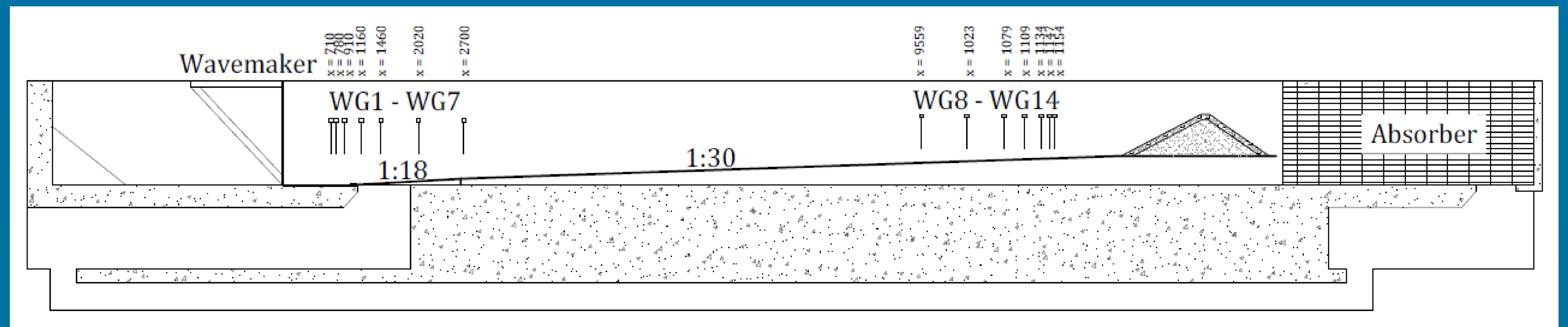
Calibration Test Setup

The setup consists of 3 arrays with 7 wave gauges in each. The first array, WG1-WG7, is placed close to the wavemaker to measure the non-breaking deep-water conditions. The second array, WG8-WG14, is placed so it can get the effects of shoaling over the foreshore, and it still can be there when the stability test are performed. The last array, WG15- WG21, is the most important, as WG18 must be location where the toe of the breakwater model will be constructed, as the test are performed without a breakwater model in the flume.



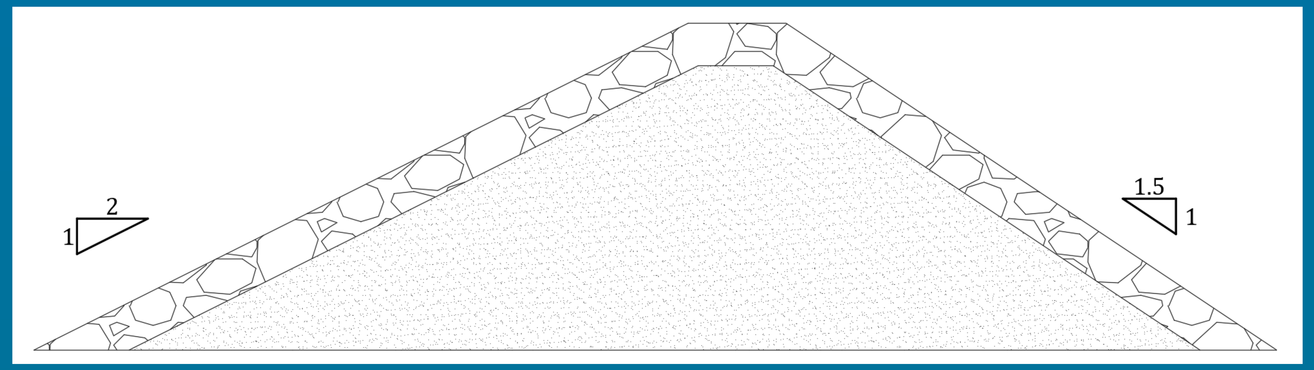
Stability Test Setup

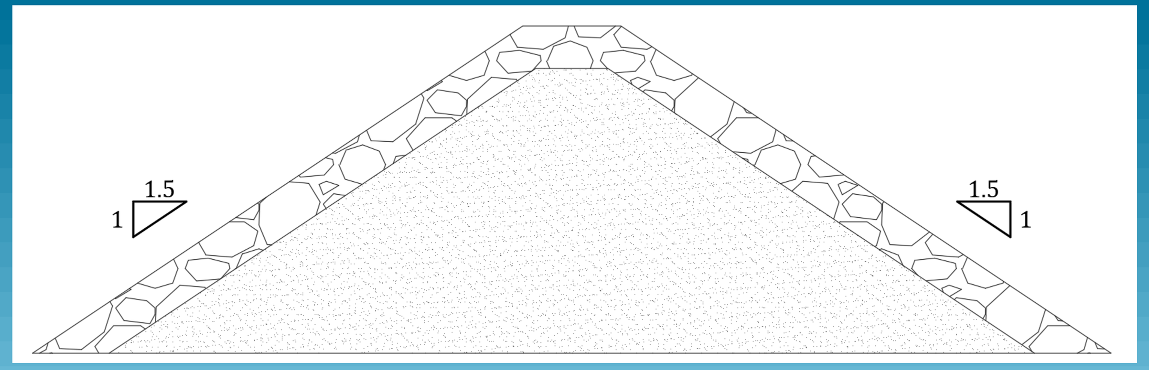
The test setup for the stability test are more or less the same as for the calibration test, but the last array is replaced by a model of a breakwater. Here was it crucial that the toe of the breakwater was placed where WG18 was for the calibration test.



Models

The models used in the stability test are constructed as typical permeable breakwater with an armour layer and a core, P=0.5. The armour layer thickness se equal to $2D_{n50}$. There have been used 4 different model in this study, a High and a Low model for each seaward slope. The seaward slopes covered was 1:1.5 and 1:2. The stone size for the armour layer was determined to be 0.0370m for the High model and 0.0261m for the Low model.





Conclusion

Based on the experiments, it was concluded that none of the existing design methods for assessing the stability of rubble mound breakwaters could accurately describe the stability in shallow water.

What does a solution mean?

A solution to this problem may require the development of new design tools for structures exposed to shallow water conditions. This could potentially involve an addition to or modification of existing design methods, such as the rewritten Van der Meer formula.

It may also necessitate a re-evaluation of existing structures in terms of their stability, as a solution could reveal that these structures are either overdesigned or underdesigned relative to the wave conditions they are exposed to.

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