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Experimental study and analysis of wave parameters effect on rubble-mound breakwater toe

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Abstract
Physical Model study is an important tool to evaluate the dominate parameters, formulas and also optimizing the design criteria on coastal structures. This experimental study deals with the 2D toe stability and scour depth at the trunk section of rubble-mound breakwater in a wave flume. Two breakwater models with slopes of 1:1.2 and 1:0.66, different conditions of bed, waves and water level (8cm≤H≤12cm, 2s≤T≤4s, 48cm≤h≤54cm) are employed to analyze the toe stability and scour depth. The tests are conducted with regular waves. It is found that the scour depth in front of the rubble-mound breakwater depends on wave height, structure slope, water level and wave period, but the results reveals that the effect of wave period on scour depth is more than others. Countermeasures for toe stability are also investigated for the different conditions. The results shows that the effect of period must be taken into account as a significant parameter on damage of rubble-mound breakwater toe, so that long period waves with more energy can be a threat for rubble-mound breakwater. Also the results of the toe stability and scour depth are given in the form of diagrams.

1- Introduction
One of the important parts of rubble mound breakwater is toe. A toe contains two basic functions: The first is that it supports the above laying armour layer and another one is that toe prevents erosion of underlying layers. When waves attack at right angles to the breakwater, processes around the toe will be two-dimensional. In the past decades, the two-dimensional scour in front of breakwaters and toe stability investigated experimentally by researchers such as [1], [2], [3] and [4].

2- Experimental set-up
Experimental setup for the trunk (2-D) tests flume and model structure were conducted in a wave flume (Fig.1). The displacement of toe stones and the bed profile was measured at the whole of the flume, using a point gauge and laser bed profiler (LBP)1 respectively. The test conditions are summarized in Table 1.

1- Laser Bed Profiler

Fig. 1. Breakwater model (slope 1:0.66), side view.

Table1) Test conditions for h = 54cm; α= 1:0.66. H = 8cm, (star,*, indicate test results for rigid bed).

Run	Depth h (cm)	Slope of Break water	Incoming wave height H (cm)	Incoming wave period T (s)	Wavelength L (m)	Depth to wavelength h/L	Scour depth at the breakwater S (cm)	Normalized scour depth S/H	Stability Number*	Damage Parameter* $N_{\%}$
R1	54	1:0.66	8	2	4.18	0.129	2.3	0.287	1.97	1.19
R2	54	1:0.66	8	3	6.62	0.081	2.4	0.3	1.97	1.83
R3	54	1:0.66	8	4	8.99	0.060	2.6	0.325	1.97	2.12

3- Definitional equations

The maximum scour depth in the case of the ‘‘coarse sand’’ (no-suspension mode sand transport) in the rubble-mound breakwater can be depends on the breakwater slope α:

$$\frac{S}{H}=\frac{f(\alpha)}{\left(\sinh\left(\frac{2\pi h}{L}\right)\right)^{1.35}} \quad (1)$$

In which f (α) is:

$$f(\alpha)=0.3-1.77\exp\left(-\frac{\alpha}{15}\right) \quad (2)$$

In which α is the breakwater slope in degrees, in the range of $30^\circ \le \alpha \le 90^\circ$, S is scour depth, H is wave height, h is water depth and L is wavelength. Toe damage is also mainly influenced by the following three aspects: 1- The wave load is the hydraulic forcing at the structure, wave height and wave period. 2- The stability of the toe material is defined by its strength, its stone size and density. 3- Geometrical variables do influence the value of damage development.

$$Dmage = f\left(\frac{WaveLoad}{Strength},(Geometry)\right) \quad (3)$$

4- Conclusions

2-D experimentally investigation of the trunk section of rubble-mound breakwater on the toe stability and scouring is performed in the present work which some of important notes for Influence of wave period, Influence of toe depth, Influence of structure slope are summarized below:

- The important parameter on stability of rubble-mound breakwater toe is wave period. One of the significant results is that the maximum scour depth and damage occur in the longer wave.

- The scour depth and the damage on the toe increase with increasing slope of the rubble-mound breakwater.
- Additional scour and damage occur t at the two ends of the trunk section.

- In the rigid bed condition both long and short waves cause the stones to move downward but only the long waves can push the stones to upward direction.
- Small size stones develop more damage for the same condition tests.
- The displacement of stones in the case of rigid bed is more compared with fine bed.

5- References

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