EFFECTS OF DIFFERENT UNITS AND PLACEMENT METHODS ON WAVE OVERTOPPING ON MOUND BREAKWATERS

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INTRODUCTION

Most of the existing and widely used wave run-up and overtopping formulas reflect the effect of different units placed at the armor layers of mound breakwaters utilizing a roughness coefficient (γ_f) specifically assigned for the unit type (see e.g. TAW, 2002; EurOtop, 2018). However, the effect of the different armor placement methods has not been fully addressed in these approaches. The purpose of the present study is to investigate the effects of different placement methods and packing densities of different armor units on wave overtopping. Within this scope, an experimental study was carried out using quarry rocks, tetrapod and Antifer units along the armor layer of conventional mound breakwater cross-sections having two different face slopes. In the experiments, both the mean overtopping discharges (q) and individual overtopping volumes (V_{ind}) were measured. The experimental results are compared with the computations based on the most prevalent formulas in practice.

METHODOLOGY

The physical model experiments were carried out at METU, Department of Civil Eng., in a wave flume having 26.9 m length, 6.0 m width, and 1.0 m depth. The experimental setup is presented in Fig. 1.

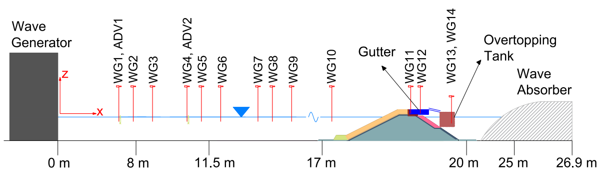

Figure 1 - Experimental setup

The water surface elevations were measured at 10 different locations along the wave flume. Furthermore, four wave gauges were used to measure the individual wave overtopping volumes along the gutter and the overtopping tank. The individual wave overtopping measuring system was set-up at the breakwater crest following a similar methodology to Koosheh et al. (2022). Two cameras that were placed in different locations were used to observe the wave overtopping events in detail and follow the quality of the measurements. A close view of the cross-section in the wave flume is given in Fig. 2.

Figure 2 - A close view of the cross-section in the wave flume (a) front view, (b) side view. (In this figure, the irregular placement of the Antifer units is shown.)

Two different face slopes of 1:2 and 1:1.5 were studied during the experiments. The tested units, placement methods and corresponding packing densities are summarized in the experimental program given in Table 1, together with the face slopes tested for each unit and placement method.

Table 1 - Experimental program.

Armor Placement Method	Case Name	Packing Density	Face Slope	
			1:2	1:1.5
Regular Double Pyramid	DP1	54.8%	x	x
	DP2	61.5%	x	
Staggered Double Pyramid	DP3	54.8%	x	x
	DP4	61.5%	x	
Close Pyramid	CP1	54.8%	x	x
	CP2	49.8%	x	
Irregular	IR1	57.1%	x	x
	IR2	61.1%	x	x
Tetrapod	TP1*	54.1%		x
	TP2*	41.7%		x
	TP3	41.7%		x
Natural Rock**	NR	43.8%		x

*Two different unit sizes were tested.
**The same method was tested three times due to randomness.

In the experiments, six irregular wave series with the wave steepnesses ($H_{m0}/L_{m-1,0}$) ranging in between 0.025-0.038 and the relative crest heights (R_c/H_{m0}) in between 0.68-1.35 were used. It is also noted that the free-crest height

(R_c) was also changed during the experiments. Each experimental case given in Table 1 was repeated twice to increase the reliability of the measurements. In total, 438 number of experiments were conducted.

RESULTS

At this stage, the analysis of the tests with a face slope of 1:2 utilized Antifer units (see Table 1) were completed, and the summary of the results from these tests are presented in what follows to give the first insights from the experiments. Considerable change in wave overtopping discharges for different Antifer placement methods and packing densities was observed. Change of non-dimensional mean wave overtopping discharge measurements ($q/(gH_{m0}^3)^{0.5}$, where g is the gravitational acceleration and H_{m0} is spectral significant wave height) with respect to relative crest heights (R_c/H_{m0}) is presented in Fig. 3 for all Antifer placement methods regardless from the packing densities. In Fig. 3, the measurements were given in comparison with EurOtop (2018) formula for different roughness coefficients.

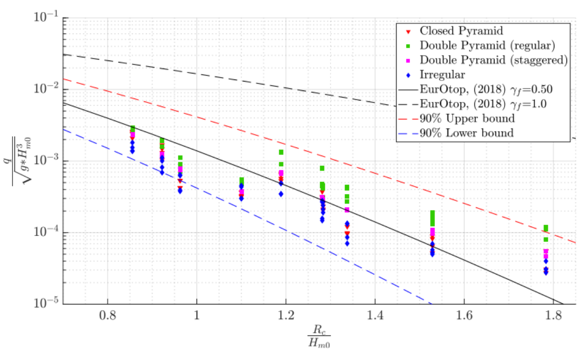

Figure 3 – Non-dimensional mean wave overtopping discharges for all Antifer placement methods.

The mean overtopping rate for regular double pyramid (DP) placement method was observed as the highest and it is 50% larger than irregular (IR) placement method which showed the least mean overtopping rate. On the other hand, 15% and 30% less overtopping discharge was observed when the close pyramid (CP) placement method was used rather than regular double pyramid and staggered double pyramid placement method, respectively. An increase in mean overtopping discharge was observed when regular double pyramid was used instead of staggered double pyramid method by 20%. For the different packing densities, all placement methods were analyzed individually. Accordingly, for the regular and staggered double pyramid methods, increasing packing density caused an increase in mean overtopping discharge due to reduction in gaps between Antifer units. Changing the packing densities of the close pyramid method introduced different behavior for different R_c values. For the given tests, no clear correlation between packing density and mean overtopping discharge was observed within the present dataset. Similar results were observed between the irregular and double pyramid placement methods regarding the packing densities. Therefore, further experiments are suggested to correlate packing density and mean overtopping discharge for the irregular placement method due to the randomness of the placement method. In Fig. 3., comparisons with the EurOtop (2018) formula showed that although the overall behavior is captured by the formula (within the 90% upper and lower bounds), the Antifer placement method may affect the mean overtopping results significantly. It is also noted that the available roughness coefficients for Antifer units were determined for a face slope of 1:1.5 and using TAW (2002) formula.

In Fig. 4, non-dimensional maximum individual overtopping volumes ($V^*=V_{max}/(gH_{m0}T_{01}^2)$, where V_{max} is the maximum individual overtopping volume and T_{01} is mean wave period) are presented with respect to the relative crest heights for all Antifer placement methods, together with the EurOtop (2018) approach that predicts the maximum individual overtopping rates. The maximum V^* was observed for regular double pyramid placement, and it is 30% higher than the irregular placement method. On the other hand, reduced V^* was observed for irregular placement than close pyramid and staggered double pyramid placement methods.

Further investigations are carried out based on the additional data with different face slope and armor units. The experimental results will be compared with the other available methods in the literature, to evaluate the performance of the mean overtopping and the maximum individual overtopping volume prediction formulas.

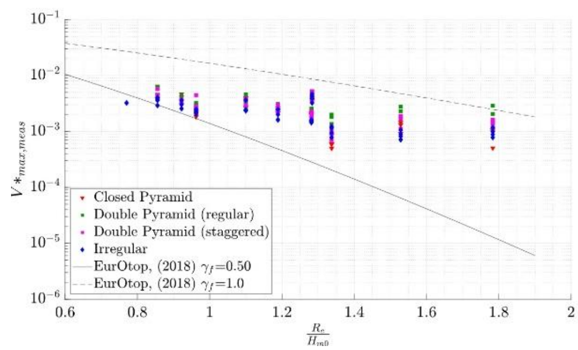

Figure 4 - Distribution of individual overtopping volumes (V_{ind}) for all placement methods

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