HYDRAULIC STABILITY OF ANTIFER BLOCK ARMOUR LAYERS

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1. Introduction

Several evidences of the influence of placement method on the stability of antifer block armour layers are well known and studied. The primary aim of the study is to experimentally investigate the stability performance of antifer block armour layers on a 1:1.5 slope, under the effect of irregular waves using a JONSWAP spectrum, for different placement methods.

The results demonstrate a better performance of the regular placement method. However, in the regular placement method, the reflected significant wave heights are higher than in the semi-irregular placement method.

2. Model Setup and Placement Method

The experimental research was performed in the wave flume of the hydraulic and environment laboratory of Instituto Superior Técnico (IST). After building the model, the placed antifer layers were tested for a peak wave period (T_p) of 1.4s with different significant wave heights (H_s), i.e. 10cm, 12cm, 14cm, 16cm and 18cm. The duration for each test was defined for 2000 waves.

A validated physical model can be used to predict the prototype's behaviour under a specified set of conditions. However, there is a possibility that the rubble mound model may not represent the prototype behaviour due to viscous scale effects and laboratory effects. Viscous scale effects can be neglected if the Reynolds number is greater than 30000 (Hughes, 1993). The physical model was designed using the Froude criterion.

About 600 antifer cubes were used in the construction of the rubble mound breakwater armour physical model layer. The blocks are made of concrete, filled up with small spheres of metal and were painted to avoid friction scale effects and to record more easily their displacement. The blocks have a nominal diameter (D_n) of 4.33cm and an average mass of 199g.

Graded rock was used in the construction of the breakwater under layer (limestone). The standard Froude scaling method for the under layer is based on the relation between the armour layer weight ant the under layer weight. The typical value recommended to the weight ratio is around 10 to 15. The graded rock has a nominal diameter of 1.78cm and an average mass of 14.6g.

The material of the core was manufactured using a mix of 5 types of gravel with different gradations, to obtain a quarry run, the nominal diameter obtained (D_{n50}) is 0.68cm and the medium mass is 0.81g.

In this study three different placement methods for blocks were analysed. Each placement method was designed to have porosity around 50%. For values above 50% the stability may be insufficient and for values below a paving action occurs (leading to greater overtopping).

The spacing between blocks along the upslope (upper and lower blocks in the layer) was null and the configuration of the lower blocks of the armour layer (regular pattern) is the same for all placement methods. However, the horizontal distance between the centre of blocks is different for some placement methods, leading to a different armour layer thickness (t).

The assessment of the damage was done between ± H_s around Still Water Level and the classification of the armour units movements was based on the displacement of each block, considering distances equal and higher than 1 D_n.

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3. Results and Concluding Remarks

Reflection coefficients for fast Fourier transform with 256, 512 and 1024 points were obtained in the reflection routine and the incident significant wave heights ($H_{s,i}$) calculated. To check the accuracy of the results, the reflection coefficients were assessed using also the incident and reflected wave spectral energy in order to obtain the incident significant wave heights. The Hudson stability parameter (K_D) was calculated for each placement method using the Hudson equation (1) (CIRIA *et al.*, 2007).

$$N_s = \frac{H}{\Delta D_n} = \left(K_D \, cotg \, \alpha\right)^{1/3} \tag{1}$$

where N_s is the stability number (-), α is the slope angle (°), Δ is the relative density (-) and H is the wave height (m).

For semi-irregular placement method (Figure 1), the upper layer of blocks in the layer is placed by drooping the blocks above the holes. For regular placement method 1 and 2 (Figure 2 and **Error! Reference source not found.**) the antifer blocks are placed by hand row by row. The blocks in the first layer are placed with their grooves perpendicular to the slope and the blocks of the second layer are placed on a diagonal for the first row pointing to the left and for the following row to the right.


Figure 1. Semi-irregular (t=8.6cm)

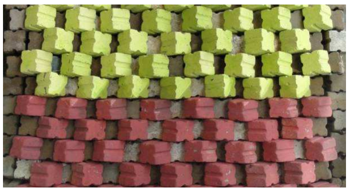
Figure 2. Regular 1 (t=8.6cm)

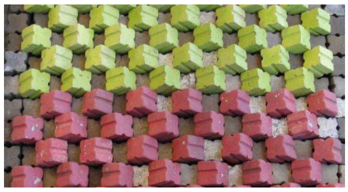
Figure 3. Regular 2 (t=7.9cm)

In semi-irregular placement the Hudson stability parameter was calculated for a damage of 5%, for the first wave series were the first displacements were observed, finding K_D=2.1. In regular placement 1 the Hudson stability parameter was calculated for a damage of 0.8%. Therefore that value was determined for the last test (N_s=2.06) where the displacements observed was low, almost null. From this follows K_D=5.8. For regular placement 2 the Hudson stability parameter was calculated for a damage of 0.6%. That value was determined for N_s=1.99, which is associated to the lowest displacements. From this follows K_D=4.0.

The following conclusions can be drawn from the present study:

- For the regular placement method 2, the values of reflection coefficients are greater when compared with the regular placement method 1, due to the fact that the first layer is more exposed to wave breaking.
- For the semi-irregular placement method K_D=2.1 is suggested for a damage of 5%, since in this placement method it is easy to repair the armour layer by replacing the displaced block.
- For regular placement methods 1 and 2, the values K_D=5.8 and K_D=4.0 are suggested, respectively. These values were obtained for almost null damage, due to the fact that the armour layer cannot be easily repaired by filling up the holes, because the blocks above tend to slide down the slope (as in a chain reaction).

Acknowledgements

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References

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