Characterization of damage progression using the alternative similarity parameter in rubble mound breakwaters

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INTRODUCTION

The increasing need to protect coastal areas as climate change intensifies, makes it necessary to attain an accurate formulation for damage evolution in breakwater structures. Following dimensional analysis, recent studies have revealed the importance of the relative water depth in the transformation processes of sloped coastal structures, see Díaz-Carrasco (2019, 2020) for wave energy transformation, Moragues (2021)$_a$ for breaker types, Moragues (2021)$_b$ for runup and rundown, and Losada (2021) for damage progression. Those studies bring to front the fact that the alternative slope similarity parameter $\chi = (H/L)(h/L)$ is a governing factor for wave energy transformation, flow characteristics and slope stability.

The main objective of this study is to assess the joint effect of the relative wave height, $\gamma = H/h$ and the alternative similarity parameter χ, Díaz-Carrasco (2020), on the slope stability, based on progression of breaker types, and the incident wave energy transformation. For this purpose, measurements of damage evolution from the start of damage until stabilization were made for pairs of γ and χ on a rubble-mound, non-overtoppable, homogeneous breakwater.

METHODOLOGY

Tests have been conducted in the wave-current flume at the Hydraulics Facility of the Environmental Fluid Dynamics Group, University of Granada. The water depth was kept constant at h=0.4m during all the tests. Three values of χ for a constant γ were chosen to study the stability.

Measurements of damage were taken for each pair of values of χ and γ, namely every 200 waves during the first 1000 waves, every 500 waves until 2000 waves and every 1000 waves until 5000 waves. Then, the breakwater model was rebuilt, and the next series was tested.

The eroded area was surveyed using an RGB-D camera, generating a 3D image of the structure. Dissipation and reflection coefficients were calculated using a series of gauge-level sensors.

PRELIMINARY RESULTS

SLOPE STABILITY

Figure 1 shows the measured damage S vs the number of waves Nw for a constant value of γ and three different values of χ. It is worth highlighting the effect of the breaker type on the slope stability. Can be observed that the highest period has the lowest damage in Figure 1. This is due to the variability associated with the transition domain of breakers.

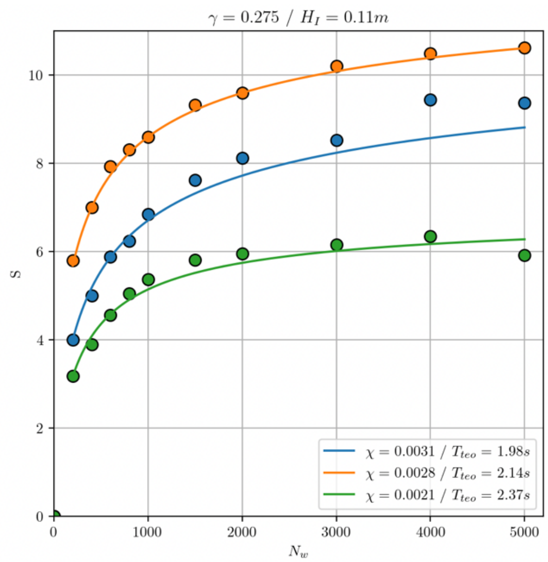

Figure 1 - Evolution of damage (S) as a function of the number of waves (Nw).

Figure 2 shows the evolution of the variation of damage with the number of waves as a function of S.

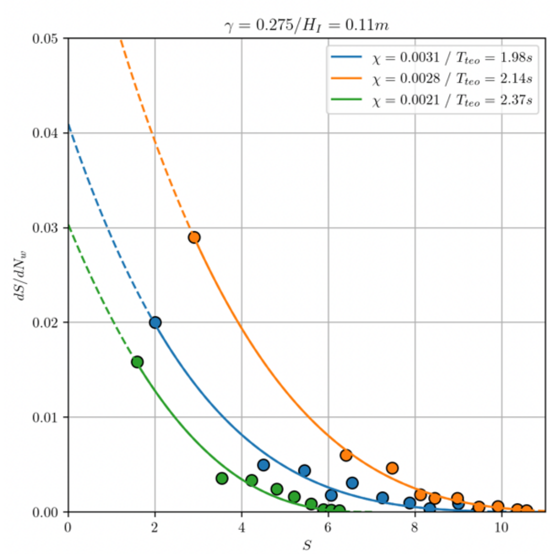

Figure 2- Variation of damage (dS/dNw) as a function of S.

It is proposed the following curve fitting of the data included in Figure 2:

$$\frac{dS}{dN_w} = \begin{cases} A(S_{max} - S)^B, & S \leq S_{max} \\ 0, & S > S_{max} \end{cases} \qquad (1)$$

In which S_{max} is the maximum possible value of S for each pair of values of χ and γ and should be obtained experimentally. A and B are the fitting coefficients.

ENERGY BALANCE

Evolution of the dissipation coefficient D^* during the test series is plotted in Figure 3. The dissipation increases as the number of waves Nw increases, then stabilizing for $\chi = 0.0028$ and finally decreasing for $\chi = 0.0021$.

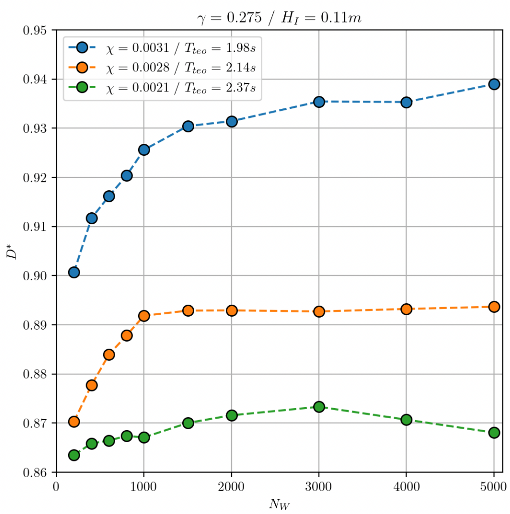

Figure 3 - Evolution of dissipation coefficient (D*) as a function of the number of waves (Nw).

Figure 4 shows there is an essentially linear dependence between D^* and damage S, even reaching a constant trend for $\chi = 0.0028$.

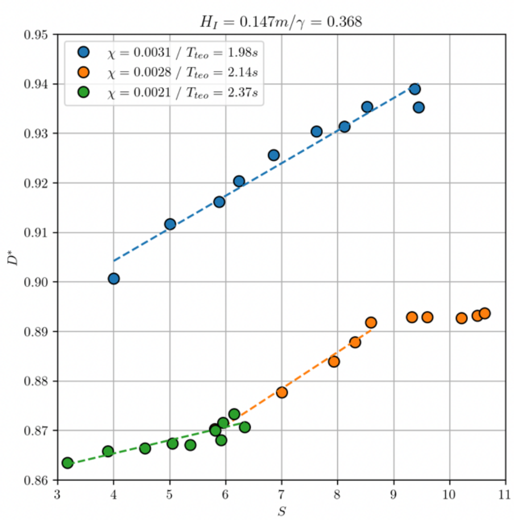

Figure 5 - Evolution of the dissipation coefficient D^* as a function of damage (S).

CONCLUSIONS

Slope stability prediction is a complex process in which the interplay of different variables such as χ, γ, the breaker type, reflection, dissipation and transmission coefficients play a governing role. The presented results show a preliminary fitting of the observed data of damage and the relationship between dissipation and damage.

At the conference, a complete set of results will be presented, for different values of χ and γ. The relationship between D* and S will be studied. Moreover, the fitting of S data will be adapted to Castillo (2012)'s methodology for damage evolution prediction and will also be presented.

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