Point wave energy converter for coastal protection and electricity generation

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Work stream 4: Arrays Wakes and Near Field Effects

Summary

During the last decade there has been increased investment in the research of Wave Energy Devices (WEC). However due to the nature of the marine environment and the inherent technologies applied in WEC, the unit cost of energy from these technologies tend to be higher than other sources. Unit energy costs may be reduced by development of more efficient devices, and by capital and operating cost reduction. Besides this, higher energy costs may be justified by considering other functionalities in addition to the energy production of the WEC. One consideration is coastal erosion which is an increasing problem for nearshore communities. Erosion is known to be dominated by storm events and coastal protection structures such as breakwaters are widely used to mitigate damage. The objective of this project is to relate these two problems by investigating the influence of wave energy devices on the local wave field and hence on erosion processes.

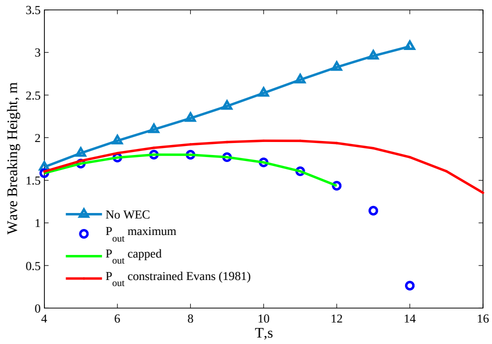

Figure 2 – Wave breaking height for different incident wave periods, T, and WEC power definitions. For all models, the Weggel [4] wave breaking index is used, WEC diameter D=10m, the deep water wave height is 2m, deep water incident angle 0º, slope of seabed tanβ = 0.01. For the constrained cases, spacing between devices is 12D and amplitude constraint δ = 0.5 defined in [2].

First models

The first part of the project is to apply linear wave theory in a constant slope beach to identify the modifications of breaking wave height that occur when a wave energy device is deployed. The interaction between the wave propagation and the WEC was done by means of a power balance and the breaking have height, H_1 can be determined by (1), where P_{out} the power extracted by a wave device, γ is a breaking index. Breaking indices proposed by McCowan [3] or Weggel [4] result in small differences in the breaking wave height as shown in Fig. 3.

$$H_1^{\frac{5}{8}} = \frac{\left(P_0^{waves} - P_{out}\right)\rho}{8\cos\left(\theta_1\right)n_1}\left(g\,\gamma\right)^{\frac{1}{2}} \qquad (1)$$

In this initial study, only one device within a long array was studied, devices were spaced at 12 diameters and it was also assumed that the devices were not interacting with each other. The power extracted from the WEC, P_{out}, is based on three approximations. The maximum power that a axisymmetrical body is able to extract from the waves is represented in equation (2) [1], where P_{in} represents the incoming wave power per unit crest and k is the wave number. Subsequently, this power was capped to the incoming wave power and to physical constraints (using equation (3) [2] where δ is the amplitude constraint).

$$P_{out} = \frac{P_{in}^{wave}}{k} \qquad (2)$$

$$P_{out} = P_{out}^{noconst}\left\{1 - \left(1-\delta\right)^2 H\left(1-\delta\right)\right\} \qquad (3)$$

In Fig. 2 the influence of these different WEC power definitions *on* the wave breaking height is presented. A reduction of wave breaking height is noticeable when the WEC is deployed.

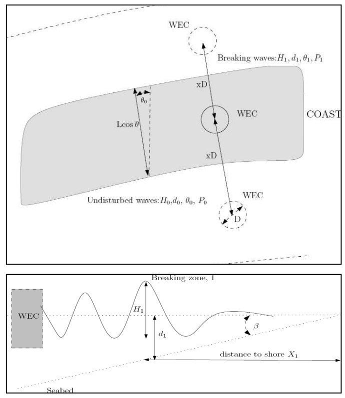

Figure 1- Scheme for the first linear model used. Constant seabed slope, tan β.

Future Work

The aim of this study is to investigate the use of WEC for mitigation of coastal erosion. Preliminary studies have been completed using a simplified model based on linear theory. Using the code SWAN, which allow to simulate waves nearshore using directional spectrums, and other physical properties. Also the interaction of the devices with the wave devices is going to be studied based on the reflected , transmitted and radiated waves and their dissipation by the devices. This is going to be done by a set of experiments in the wave flume. Later stages will include investigation of long-term sediment transport, and an assessment of the economic feasibility of a combined WEC and coastal protection scheme.

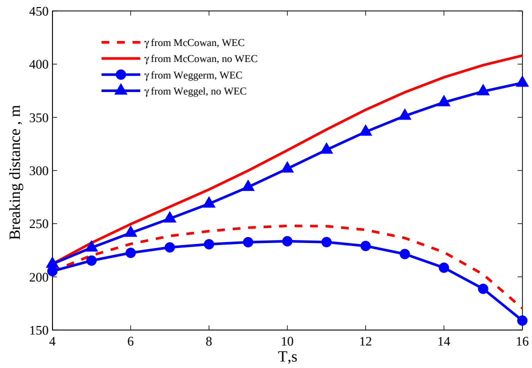

Figure 3 - Distance to shore of the wave breaking zone for various T using different breaking indexes: McCowan and Weggel approximations. All variables as Figure 2. Power output as amplitude constrained with δ=0.5.

References

[1] Budal K. and Falnes J. A resonant point absorber of ocean waves. *Nature*, 1975. 256:478–479,1975.

[2] Evans D. V. 'Maximum wave-power absorption under motion constraints' *Applied Ocean Research,* 1981, Vol. 3, No.4

[3] McCowan J., On the highest wave of permanent type, *Philosophical Magazine 38* 1894, pp. 351–358.

[4] Weggel, J.R. Maximum breaker height, *Journal of Waterways, Harbors and Coastal Engineering Divison, ASCE* 98 (1972), pp. 529–548.

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