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Multi-chamber OWC Devices to Reduce and Convert Wave Energy in Harbour Entrance and Inner Channels

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ABSTRACT

Physical model tests on a new Italian concept of wave energy converter named SeaBreath were carried out in the 36 m x 1.0 m x 1.4 m wave flume of Padova University. Beside energy harvesting, the device has a secondary purpose, i.e. it plays the role of a small floating breakwater. An example application is proposed for the deep "Petroli Channel" in the Venice Lagoon, that is plagued by continuous bank and marsh erosion induced by excessive waves generated by boats and ships.

KEY WORDS: Wave Energy Converter; Floating Breakwater; Oscillating water column; Ship generated waves; Wave flume tests; Wave transmission; Venice Lagoon.

INTRODUCTION

The Sea Breath is a patented Italian device of the Multi-chamber Oscillating Water Column (M-OWC) attenuator type, www.seabreath.it.
Demonstration phase (i.e. the phase following research and development) for Wave Energy Converters (WECs) requires that devices are tested for several hours at sea, in locations easily and frequently accessible (Kofoed and Frigaard, 2009).
At the earlier stage, economic opportunity suggests that the scale of the device used for demonstration is included in the range 1:4 to 1:10, since several parts of the structure are likely to be substituted. Due to scaling reasons (the weight scale is equal to the geometrical scale to the power 3 and the energy scale to the power 3.5) such systems produce far too little energy (i.e. from $4^{3.5}$=128 to $10^{3.5}$=3160 times lower) to justify their construction costs.
In order to support the testing of these devices, it is worthwhile to find a useful combined application and thus increase the chances of its initial installation. Under these circumstances, even a failure of the WEC (resulting in learned experience) may not result in a complete fiasco (if the secondary function is satisfactorily fulfilled).
One possible application is to couple the WEC to a floating breakwater (FB), and enhance the performance (reduce wave transmission) by means of the conceptual device used to harvest energy.

It is intuitive that if the WEC is capable of converting a large amount of the incident wave energy into electricity, the wave transmission past the device must be significantly reduced, possibly more compared to a mere FB.
The classical FBs is referred to as a "passive" device, whereas a floating body equipped with an energy harvesting device is referred to as "active".
This research topic is developed by the Authors within the support of the EU FP7 Theseus "Innovative technologies for safer European coasts in a changing climate" (THESEUS). The main applications are directed towards the protection of marinas subject to long waves, or towards the protection of coasts from flooding.
A similar application, at a smaller scale, is here proposed: the FB aims at reducing the wave agitation in the ecologically sensible Venice lagoon, where waves are generated by boats, frequently sailing along the lagoon channels, and, to a minor degree, by ships entering the Venetian Port.
It is generally believed that ship generated waves, being less frequent compared to wind waves, have a marginal contribution to erosion. In the Venice Lagoon, due to its the peculiar dynamic, this is not entirely true. It is well known that the bed level tend to deepen and the effect of both wind and ship waves is critical for the environment (Rinaldo, 2001, Zonta et al., 2007).
For example, in order to protect the lagoon from boat generated waves, different kind of structures were tested along the Canale Somenzera S. Giacomo, close to Burano island.
Large vessels, or ships, that may occupy a significant fraction of the cross-sectional area of the channel, are more dangerous as they generate both a long wake that propagates into very shallow water and, on top of this, a train of direct and transverse short waves of considerable height. Over the shoals, the long wakes produce high, near-bottom current velocities (Bauer et al., 2002), leading to substantial sediment resuspension and consequent increase dredging demand. Short waves are responsible for the sediment pick up, thus significantly enhancing the negative effects. The combined effect of wind waves and tidal currents is known to have a maximum at the Petroli Channel (Umgiesser et al., 2004), that is therefore a suffering environment.
Evaluation of the propagation of low and high frequency waves generated by vessels in the lagoon can be carried out with fairly simple methods (e.g. mild slope equations, see Ohyama and Tsuchida, 1997).
Aims of this contribution are: