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VERTICAL DISTRIBUTION OF WAVE OVERTOPPING FOR DESIGN OF MULTI LEVEL OVERTOPPING BASED WAVE ENERGY CONVERTERS

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1. INTRODUCTION

Over the recent years an increasing number of developers of wave energy converters (WEC's) have been focusing on utilizing wave overtopping for production of electrical power. The primary focus has so far been on investigation of overtopping with respect to optimization of the amount of potential energy obtained in the overtopping water for a single reservoir layout, Kofoed & Burcharth (2002). This approach is used in the design of e.g. the Wave Dragon (WD) WEC, Sørensen et al. (2003) and Friis-Madsen et al. (2005).

However, overtopping based WEC's using multi level reservoirs have also been suggested, since these will have a higher overall efficiency, compared to a similar single reservoir structure. The Seawave Slot-cone Generator (SSG) under development by the Norwegian company WaveEnergy AS is such a WEC utilizing a total of three reservoirs placed on top of each other. The SSG is designed as a near-shore concrete structure with the turbine shaft and the gates controlling the water flow as virtually the only moving part of the mechanical system, see figure 1. A prototype plant is planned for deployment at the west coast of Kvitsøy, Norway (near Stavanger) during 2006.

In the design of such of structures the available overtopping prediction formulae available in the literature are not sufficient, as these are typically only valid for single reservoir layouts and hold no information of the vertical distribution of the overtopping above the lowest reservoir crest. Furthermore, the geometry of the fronts on the individual reservoirs above the lowest one also influences the overtopping rates into the individual reservoirs.

On this background physical model studies have been performed in which it is investigated how a wide range of different geometrical parameters influence the overtopping rates for the individual reservoirs when the structure is subjected to heavily varying wave conditions. Furthermore, it is investigated how these new results fits in the results reported in the literature.

The work described in the paper has been used to optimize the crest levels and geometrical layout of the SSG structure in a combination of irregular wave conditions, focusing on maximizing the obtained potential energy in the overtopping water.

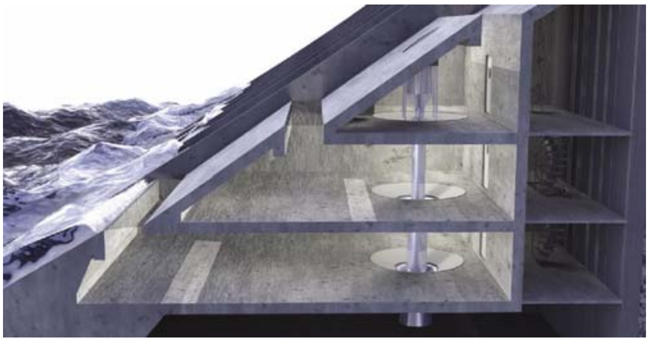

Figure 1. Sketch of the SSG principle, courtesy of WaveEnergy AS.

2. EXPERIMENTAL SETUP

In two rounds model tests have been performed in a 3-D wave tank at Aalborg University (AAU), however, only irregular 2-D waves have been applied in this study. During these tests average overtopping discharges into the individual overtopping reservoirs as well as the waves have been measured.

The model test setup is shown in figure 2.

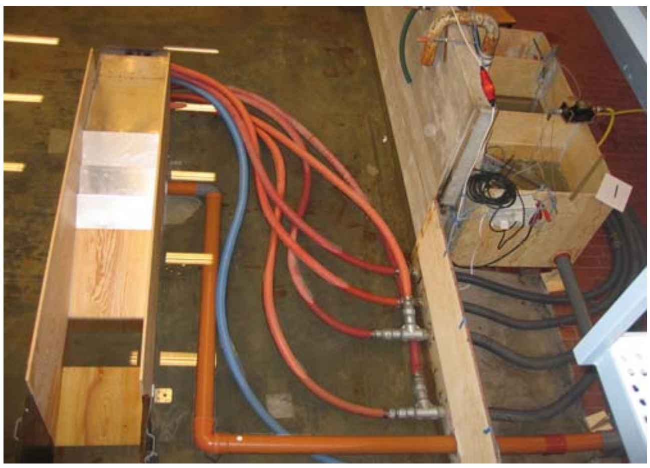

Figure 2. Model test setup.

A total of 17 different geometrical layouts have been tested (10 during first round and 7 in the second). Each of the geometries has been subjected to 3-6 irregular wave conditions (consisting of 1000-2000 waves, 30 min. tests, model scale).

3. RESULTS

Based on dimensional and regression analysis Kofoed (2002) suggested an expression for prediction of the vertical distribution of overtopping on the form

$$Q' = \frac{dq/dz}{\sqrt{gH_s}} = Ae^{B\frac{z}{H_s} + C\frac{R_{c,1}}{H_s}} \quad (1)$$

(where *Q'* is the dimensionless derivative of the overtopping discharge with respect to the vertical distance *z*, $R_{c,1}$ is the crest freeboard of the lowest reservoir and H_s is the significant wave height). The coefficients *A*, *B* and *C* were fitted to experimental data by Kofoed (2002) for the case with no fronts on the reservoirs above the lowest one (0.37, -4.5 and 3.5, respectively)

In the current study, where tests have been performed with fronts on the individual reservoirs, analyses of selected data sets, where the only the crest freeboards have been varied, have lead to a new set of coefficients *A*, *B* and *C*. These are 0.197, -1.753 and -0.408, respectively.

The overtopping rates for the individual reservoirs q_n can be calculated as (based on eq. (1))

$$q_n(z_1, z_2) = \sqrt{gH_s^3}\,\frac{A}{B}e^{C\frac{R_{c,1}}{H_s}}\left(e^{B\frac{z_2}{H_s}} - e^{B\frac{z_1}{H_s}}\right) \quad (2)$$

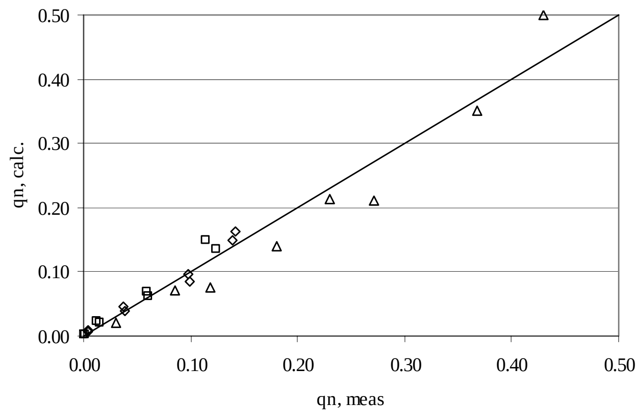

Figure 3. Comparison of measured vs. predicted overtopping rates for individual (according to eq. (2)) reservoirs with fronts.

The measured overtopping rates have also been compared to the by Van der Meer and Janssen (1994) for non-breaking waves (deepwater surf similarity parameter corresponding to the peak period $\xi_{p0} > 2$) with the correction factor for small relative crest freeboards λ_s (given in Kofoed and Burcharth, 2002) applied, see figure 4. Here, the non-dimension overtopping rate *Q* is based on the sum of the overtopping of the individual reservoirs, and the relative crest freeboard *R* is based on the crest freeboard of the lowest reservoir.

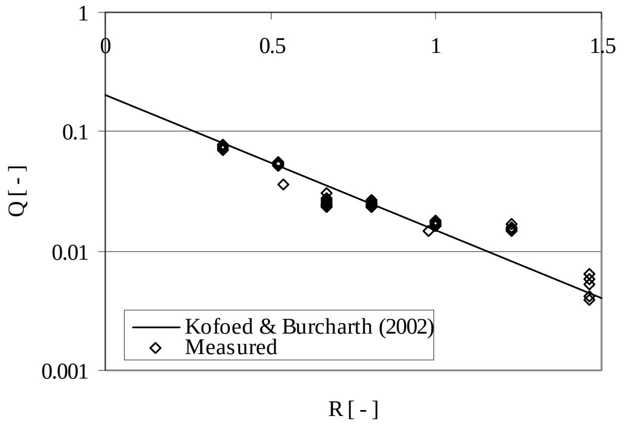

Figure 4. Measured total overtopping rates compared to expression by Kofoed and Burcharth (2002).

4. CONCLUSIONS

By use of model tests the expression describing the vertical distribution wave overtopping by Kofoed (2002) has been applied and adjusted to allow prediction of overtopping rates for individual multiple reservoirs with fronts.

By using the proposed expression a numerical optimization of the geometry of the SSG WEC (in terms of maximizing the obtained potential energy in the overtopping water, by adjusting the crest freeboards of the individual reservoirs, for a given set of wave conditions with corresponding probability of occurrence).

5. ACKNOWLEDGEMENTS

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