Coastlab12, 2012, Ghent, Belgium. Book of Abstracts of the Fourth International Conference on the Application of Physical Modelling to Port and Coastal Protection. ISBN 978 90 382 2008 6

UPLIFT FORCES ON A VERTICAL STRUCTURE WITH AN OVERHANGING HORIZONTAL CANTILEVER SLAB

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1. Introduction

The Pier of Blankenberge which is located along the Belgian coast is a coastal structure consisting of a vertical core attached to an overhanging horizontal cantilever slab. Throughout high tides and storms, the structure is exposed to violent wave impacts, including waves running up against the vertical core and slamming on the horizontal deck. The structure prevents most of the overtopping due to its particular geometry involving closed angles, which does not allow incident waves to dissipate. This introduces an important uplifting force. The lift forces consist of impact loads of high magnitude and short duration. It is reasonably impossible to substitute these impact effects by a static equivalent.

In opposition to a single vertical or horizontal surface type structures, structures consisting of both vertical parapets and horizontal cantilever slabs have scarcely been considered. One of the rare example of research with this combined type is the work of Kortenhaus et al. (2001), who made tests to reduce overtopping on vertical walls with adding an overtopping parapets at the top of the wall. Another one is the work of Wood and Peregrine (1996), who consider an analytical approach, based on the pressure-impulse method for a flat deck close to the mean water level. In general, a consensus on the necessary approach for the research on this combined type of structure lacks completely. Recently, Kisacik et al. (2012) described the loading conditions due to violent wave impacts on a vertical structure with an overhanging horizontal cantilevering slab based on the data, measured at a single water depth.

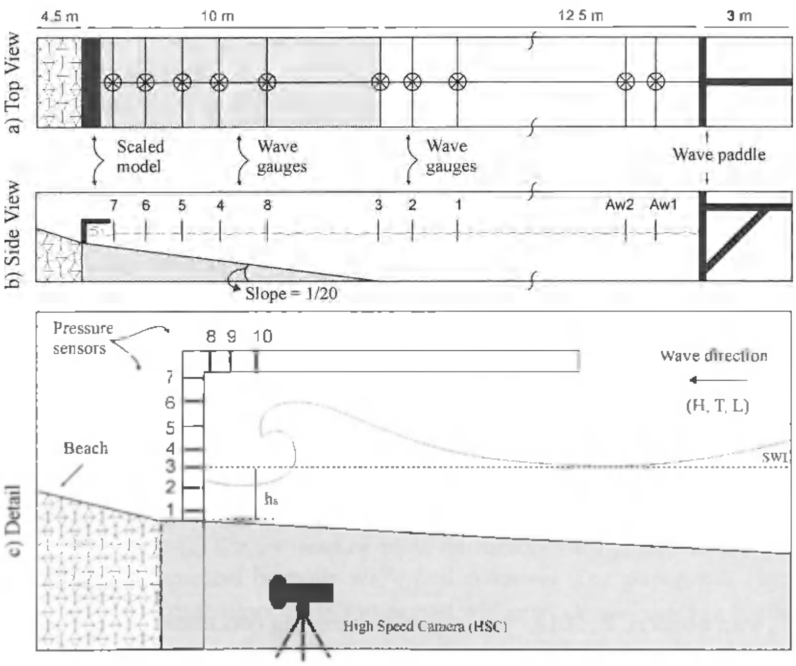

Figure 1. Small-scale model set up. a) is the top view, b) is the side view and c) is detailed view of model

The main objective of the present research is to develop a semi empirical model is to predict the vertical uplift impact forces on a vertical wall, including an overhanging horizontal cantilever slab. The model is based on the correlation between the kinematics of breaking waves and the height, distribution, duration and characteristics of the violent wave impacts. To achieve the above goals, small scale model tests were carried out.

The main parameters used in the parameter map for the determination of the wave loading on a structure are the wave height (H), water depth at the model toe (h_s), wave period (T) or wave length (L), impact velocities of the fluid mass (u and v) and the geometrical parameters of the structure. The ratios of any of these parameters, like the relative wave height H/h_s, are important for the normalization of the results.

In this paper, based on structure geometry and wave conditions, a set of basic parameters and some combination of them, responsible for the prediction of the wave loading on a vertical wall with a cantilever slab, is presented. The parametric investigation is based on data from a series of small-scale model tests discussed. Further developments of these parameters, investigation of the used dimensionless parameters and the definitions of wave loading types are discussed. Finally, a semi empirical model is developed to predict vertical impact forces on the horizontal part and the predicted values are compared with the measurements.

2. Uplift forces

In the following, a formula for the maximum uplift impact forces beneath the horizontal part is derived based on the impulse theory and solitary wave theory. The forward momentum of a fluid mass ($M = qT\rho$) hitting beneath the horizontal part with a vertical average velocity V_{av} will induce a vertical force impulse. A linear relation is obtained between the natural logarithm of F_{v_max} and $2(qT\rho)V_{av}/t_r$ in Equation 1.

$$F_{v\_max} = exp\left(\beta_1 ln\left(\frac{2(qT\rho)V_{av}}{t_r}\right) + \beta_2\right) \qquad [1]$$

where, β_1 and β_1 depend on $\left(\frac{c}{h_s}\right)^2$, $\beta_1 = -0.015\left(\frac{c}{h_s}\right)^2 + 0.22$, $\beta_2 = -0.074\left(\frac{c}{h_s}\right)^2 - 2.2$

Figure 2. shows natural logarithm of maximum vertical forces (F_v) versus natural logarithm of $2MV_{av}/t_r$ for water depth ($h_s = 0.135\ m$). The linear relation between the parameters is represented by Equation 1. The lower and upper lines show the lines of non exceedance at level 99.6% and 0.04.

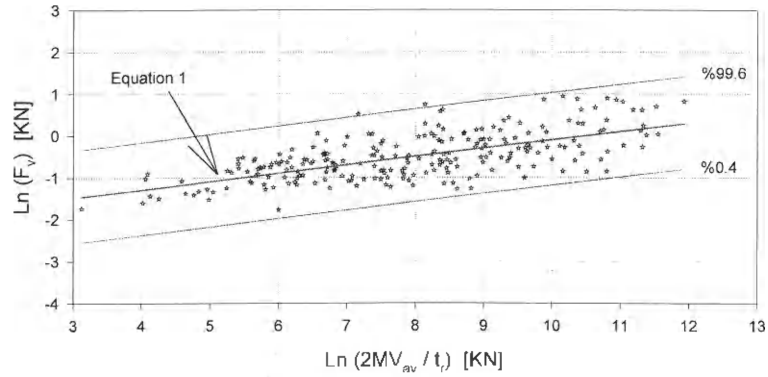

Figure 2. Natural logarithm of maximum vertical forces (F_v) versus natural logarithm of $2MV_{av}/t_r$ and comparison of data with Equation 1, ($h_s = 0.135\ m$)

3. Conclusion

Based on the impulse theory and experimental investigations on breaking wave kinematics and impact loads, prediction formulas for impact forces have been derived for vertical forces below the horizontal part of a vertical wall with overhanging horizontal cantilevering slab. The design concept for breaking wave loads is developed. Hydraulic model tests have been performed to assess the vertical averaged velocities involved in the impact process and to verify the results obtained from theory. It was found that the proposed formula represents the mean value of the measurement results.

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