EXPERIMENTAL STUDY AND NUMERICAL MODELLING OF PORE PRESSURE ATTENUATION INSIDE A RUBBLE MOUND BREAKWATER

Introduction

The main objective is to study the attenuation of the wave induced pore pressures inside the core of a rubble mound breakwater. The exact knowledge of the distribution and the attenuation of the pore pressures is very important for the design of a stable and safe breakwater. Until now no tools have been presented for the detailed determination of the pore pressures and the related porous flow field in the breakwater core. The pore pressure attenuation is studied using experimental data and using a numerical wave flume, and a new calculation method is presented.

Experimental study

Theoretically, the height of the pore pressure oscillation $p(x)$ of a propagating pressure wave decreases exponentially with the distance to the breakwater interface (Biésel, 1950; Oumeraci and Partenscky, 1990) according to the linear damping model:

$$p(x) = p_0 \exp(-\delta \frac{2\pi}{L'} x) \quad (1)$$

where x is the co-ordinate across the core (m); $p(x)$ is the pore pressure height at position x (kPa); p_0 is the reference pore pressure height at x = 0 (kPa), $L' = L/\sqrt{1.4}$ where L is the wave length (m), δ is a damping coefficient (-).

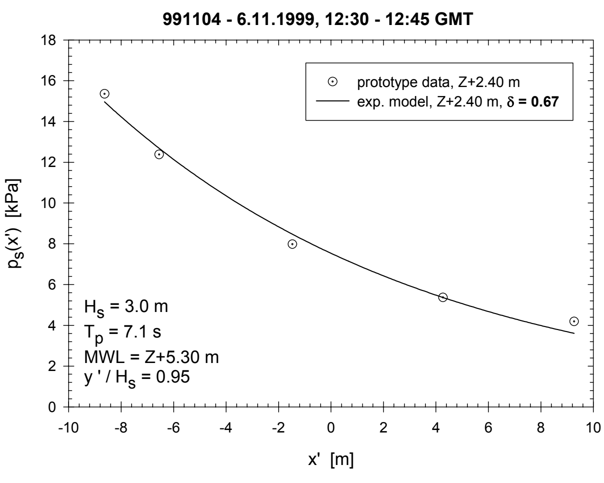

Fig. 1. *Typical pore pressure attenuation inside prototype breakwater core.*

The experimental study includes the analysis of prototype pore pressure data from the Zeebrugge breakwater and large scale data from a physical breakwater model. Both data sets are presented.

The Zeebrugge prototype pore pressure data (Troch et al., 1998) are unique world-wide and have not been analysed before. At the Zeebrugge harbour (Belgium) a cross-section of the NW-breakwater has been instrumented for the study of physical processes related to the behaviour of a prototype rubble mound breakwater in random wave conditions. Wave rider buoys are located in front of the breakwater and measure the incident waves. The water level at the toe of the breakwater is measured by an infra-red wave height meter. Inside the core 13 pressure sensors are installed in the six bore-holes for the measurement of the internal pore pressures induced by the waves.

Fig.1 shows a typical example of the attenuation of prototype pore pressure heights $p(x)$ and fitting of the damping model (1) for a 15 minutes pressure record during a storm. Good agreement is found with the fitted model (1) resulting in a damping coefficient $\delta =$ 0.67. About 16 storms have been analysed this way.

Few measurements on wave attenuation inside a breakwater core are available in literature. There is however one comprehensive large scale data set available (Oumeraci, 1991) for a rubble mound breakwater. The large scale data have been re-analysed in detail with respect to the attenuation characteristics.

A damping coefficient δ has been derived as a function of wave height H_s, wave period T_p and depth y' below mean water level (MWL) by fitting of (1) to the large scale data. The proposed expression is:

$$\delta = a_\delta \, n^{1/2} L_p^2 / H_s b \quad (2)$$

where n is the porosity of the core material (-), b is the core width at depth y', and $a_\delta = 0.0140$ is the slope, obtained by fitting (2) to all damping coefficients derived from the large scale data set (Fig. 2).

Good agreement is observed, especially for smaller δ-values, i.e. for higher y' values (not too close to MWL).

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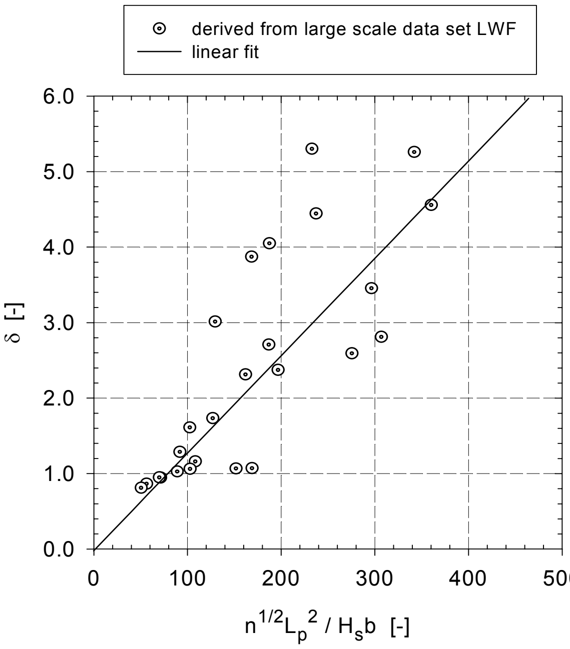

Fig. 2. *Fitting of (2) using large scale dataset.*

The conclusions from the experimental analysis of both data sets are compared and synthesised into a practical calculation method for the attenuation of the pore pressure heights in the breakwater core based on the wave characteristics and the core material characteristics. This new calculation method is the most important result in this paper and is summarised in Fig. 3. The practical use for design applications will be explained.

Numerical study

The attenuation of pore pressures in a breakwater core is also studied in the numerical wave flume VOFbreak[2] (Troch, 2000). In VOFbreak[2] the Navier-Stokes equations and the continuity equation are solved on a 2D rectangular grid, and the Volume-Of-Fluid (VOF) method is used for calculation of the free surface configuration. The validation of the numerical wave flume for the attenuation of the pore pressures inside the breakwater core using physical model data will be presented. The results from the numerical modelling of the wave interaction with the Zeebrugge breakwater will be presented (Fig. 4) and compared to the results from the experimental study.

REFERENCES

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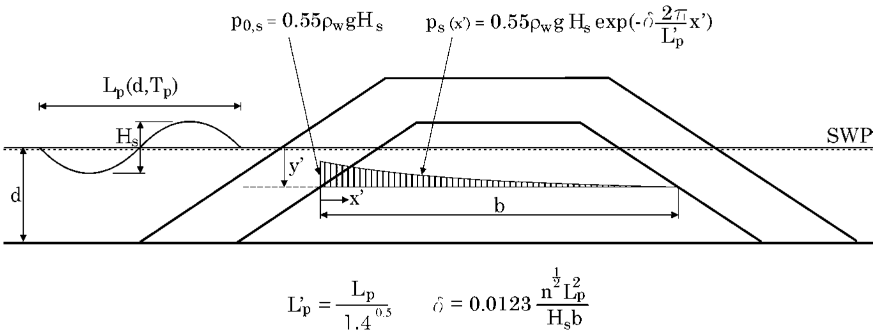

Fig. 3. *Definition sketch for proposed calculation method for pore pressure attenuation.*

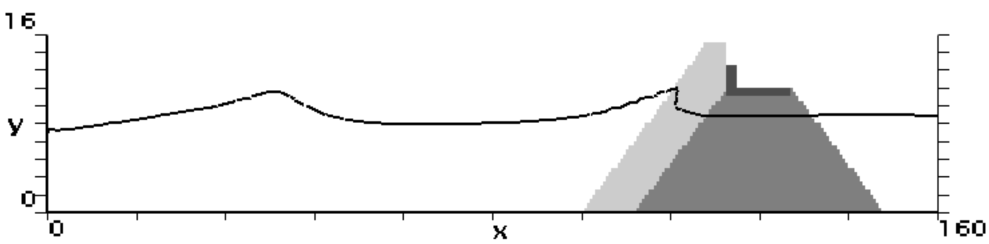

Fig. 4. *Numerical simulation of wave interaction, wave run-up at t = 122 s.*

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