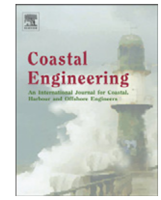
Coastal Engineering 56 (2009) 180–189

Contents lists available at ScienceDirect

Coastal Engineering

journal homepage: www.elsevier.com/locate/coastaleng




# Three-dimensional investigations of wave overtopping on rubble mound structures

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ARTICLE INFO

Available online 8 May 2008

*Keywords:*
Wave overtopping
Rubble mound breakwater
Wave obliquity
Directional spreading
Physical model tests

ABSTRACT

To study the influence of wave obliquity and directional spreading on wave overtopping of rubble mound breakwaters a total of 736 three-dimensional model tests were carried out at Aalborg University. The results of these tests are presented and analysed in this paper yielding a new empirical reduction factor to describe the influence of wave obliquity and directional spreading on the average wave overtopping discharges. The study shows that perpendicularly incident, long-crested waves result in conservative values of the overtopping discharge for the tested cross-section.



## 1. Introduction

In the CLASH project a neural network model for predicting wave overtopping discharges on coastal structures was developed (van Gent et al., 2007). During the development of the neural network model overtopping data were collected from a lot of laboratories. After parameterization the data were stored in a database (van der Meer et al., 2009-this issue). Subsequently the database was screened, and white spots were identified where additional data where needed. The two most important white spots were selected for further investigations. One is the combined influence of wave obliquity and directional spreading on overtopping of rubble mound structures, dealt with in the present paper. The other is the influence of surface roughness dealt with by Bruce et al. (2009-this issue). Most data in the database and in the literature are from tests with long-crested waves although wind generated waves are short-crested. Literature on the effect of oblique short-crested waves on overtopping of rubble mound structures does not seem to exist. The objective of the present study is to show if the directional spreading is an important parameter to include in overtopping prediction methods in the sense that it will lead to identification of significant differences in overtopping between long-crested and short-crested waves. To cover this white spot more than seven hundred 3-D physical model tests with a rock and cube armoured breakwater were carried out at Aalborg University. The results are presented in the present paper.

## 2. Existing knowledge

The influence of wave direction and directional spreading on wave overtopping of sloping structures has been studied by various authors. However, most of these studies consider long-crested waves and/or smooth slopes only.

Van der Meer and Janssen (1994) give the following formula, Eq. (1), to calculate the average wave overtopping discharge on dikes in case of non-breaking waves on the structure:

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.2 \cdot \exp\left(-2.6 \cdot \frac{R_c}{H_{m0}} \cdot \frac{1}{\gamma}\right) \quad (1)$$

where $q$ is the average discharge per metre width of the structure, $H_{m0}$ is the significant wave height calculated from the wave spectrum and $R_c$ is the crest freeboard. $\gamma$ is a product of reduction factors to take into account a berm, oblique wave attack ($\gamma_\beta$), and roughness ($\gamma_f$). The reduction factors for oblique long and short-crested wave attack given in Eqs. (2) and (3) are based on the data from de Waal and van der Meer (1992) covering smooth 1:2 and 1:4 slopes.

$$\text{For short crested waves}: \gamma_\beta = 1 - 0.0033 \cdot \beta \quad (2)$$

$$\text{For long crested waves}: \gamma_\beta = \begin{cases} 1.0 & \text{for } 0^\circ \le \beta \le 10^\circ \\ \cos^2(\beta - 10^\circ) & \text{for } 10^\circ \le \beta \le 50^\circ \\ 0.6 & \text{for } \beta > 50^\circ \end{cases} \quad (3)$$

where $\beta$ is defined as the angle between the direction of propagation of waves and the axis perpendicular to the structure (for perpendicular wave attack: $\beta=0^\circ$).

The proposed reduction factor for long-crested waves is fairly constant in the range of angles between 0° and 20°, before falling to

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doi:10.1016/j.coastaleng.2008.03.007

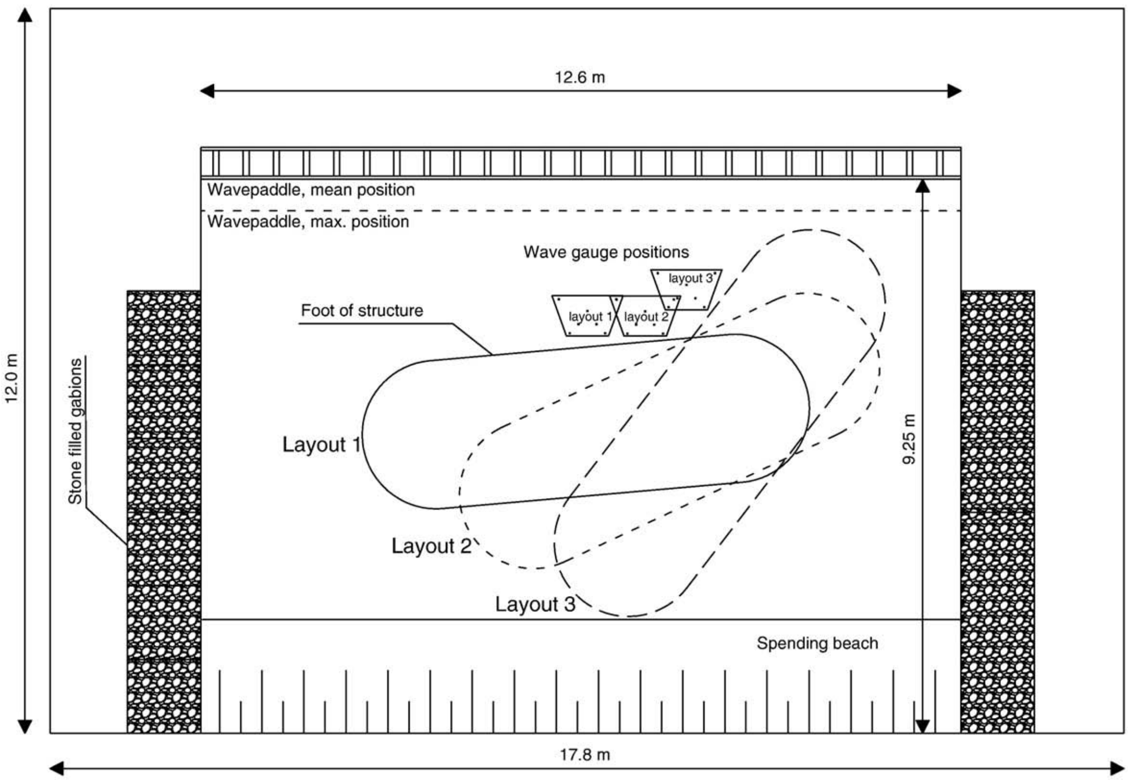


**Fig. 1.** Top view of the three different models in the basin.

significantly smaller values for larger angles. For very oblique waves the reduction in overtopping is much less for short-crested waves than for long-crested waves.

Hebsgaard et al. (1998) tested six different angles of long-crested wave attacks (0, 10, 20, 30, 40 and 50°) on a rock armoured rubble mound breakwater resulting in the following formula for calculating the average overtopping discharge ($q$):

$$\frac{q}{\sqrt{g \cdot H_s^3}} = k_1 \cdot \ln(s_{0p}) \cdot \exp\left(k_2 \cdot \cot^{0.3}(\alpha) \cdot \frac{2 \cdot R_c + 0.35 \cdot G_c}{H_s} \cdot \frac{1}{\gamma_f \cdot \sqrt{\cos(\beta)}}\right) \quad (4)$$

where $k_1 = -0.01$ and $k_2 = -1.0$ for breakwaters with a superstructure. $\alpha$ is the front slope angle of the breakwater and $\gamma_f$ is the roughness coefficient. $R_c$ and $G_c$ is the crest freeboard and the crest width, respectively. $H_s$ is the significant wave height, $s_{0p}$ is the deep water wave steepness and $\beta$ is the angle of wave attack. Therefore, the reduction factor ($\gamma_\beta$) used by Hebsgaard et al. (1998) is:

$$\gamma_\beta = \sqrt{\cos(\beta)} \quad (5)$$

However, the structure of the overtopping formula is not identical to that of Van der Meer and Janssen (1994), and therefore the expressions Eqs. (3) and (5) are not directly comparable.

Galland (1994) studied overtopping on steep (1:1.33 and 1:1.5) rubble mound breakwaters for long-crested wave attack. Four armour types and six angles of wave attack were tested. Galland found that the overtopping discharge was almost identical for perpendiculary

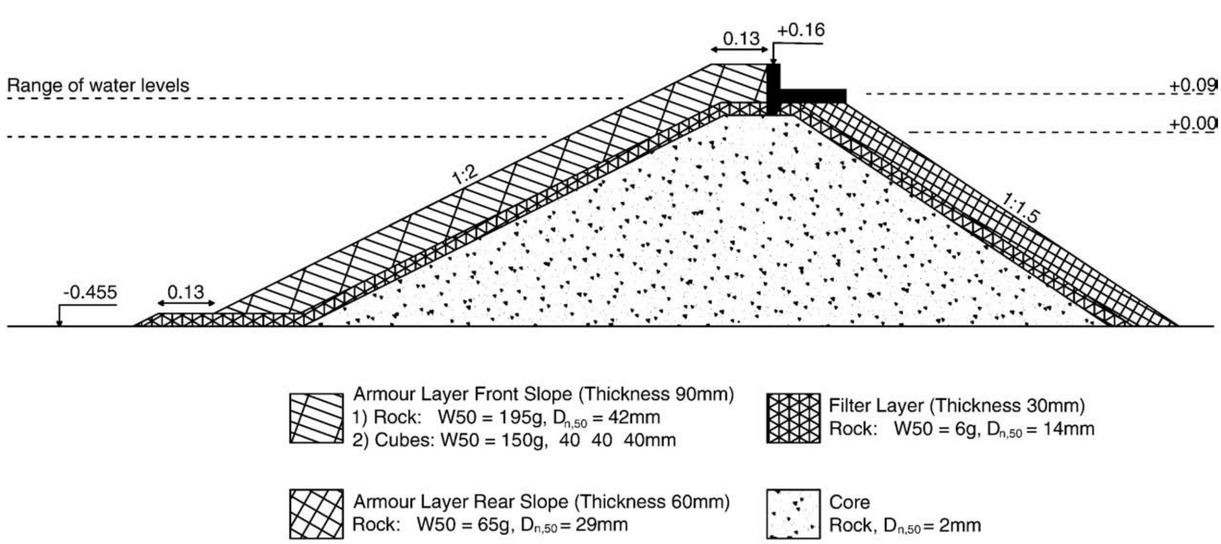


**Fig. 2.** Cross-section of model. Unless otherwise specified measures are in meters.