# Marine Structures with Extreme Overtopping Rates

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# MARINE STRUCTURES WITH EXTREME OVERTOPPING RATES

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## 1. MOTIVATION

In design of sea defense structures like seawalls, breakwaters and dikes, one of the main objectives is to minimize or even eliminate wave overtopping. For this reason numerous investigations have been performed over the past many years to determine the amount of overtopping occurring for typical sea defense structures. This also means that the vast majority of these investigations have focused on structure designs that minimize the amount of overtopping and wave situations where small or moderate amounts of overtopping occur (see e.g. Burcharth and Hughes (2000) or Van der Meer (1998) for an overview).

For some marine structures, such as "wave pumps" for circulation of water in harbor basins in areas with insufficient tidal range for natural circulation or wave energy devices based on the overtopping principle, it is desirable to maximize the amount of overtopping. Furthermore, a number of the proposed wave energy devices utilizing overtopping are floating structures, which means that the structure is not extending all the way to the seabed, but has a limited draught. It has been found that very little useful information is available in the literature on how to estimate overtopping of such structures.

On this background a physical model study is performed, in which it is investigated how a wide range of different geometric parameters influence the overtopping volume when the structure is subjected to heavily varying wave conditions.

## 2. EXPERIMENTAL SETUP

During the model tests the influence on the amount of overtopping of the following geometrical parameters is investigated (see figure 1):

- Profile shape.
- Draught.
- Crest freeboard.
- Shape of cross section.
- Shape of guiding walls.

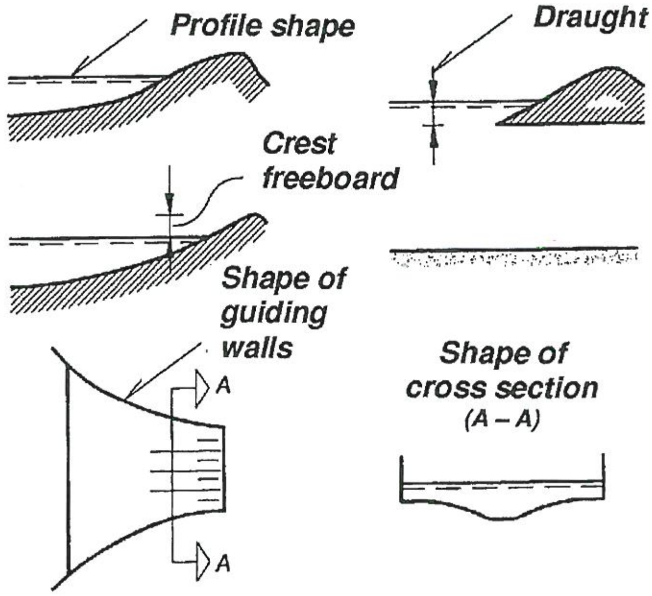


Figure 1: Geometric parameters investigated.

All model tests are performed in a 9 x 15 m wave basin with a water depth of 0.5 m. So far only non-floating structures have been tested.

The amount of overtopping in general depends on a number of wave parameters, such as wave height and period, spectral shape, angle of wave attack, directional spreading, etc. However, in this paper focus will be given to irregular 2-D waves. The irregular waves are generated using the parameterized JONSWAP-spectrum with a spectral enhancement factor $\gamma = 3.3$. Each of the tested geometrical setups have been subjected to 37 different wave situations with wave steepness varying from 0.01 to 0.09. Each of the wave situations consists of 1.100 to 3.600 waves, depending on the wave peak period.

Furthermore, overtopping is dependent on the geometric parameters describing the structure and also on surface roughness and permeability of the structure. However, it is commonly accepted that introduction of surface roughness and permeability decreases the overtopping, and therefore only smooth and non-permeable structures are investigated in this study.

The model study has been divided into two phases. In the first phase tests have been performed with a straight profile. For this type of structure the influence of varying crest freeboard, draught and angle of the slope on the overtopping has been thoroughly investigated. In the second phase focus has been put on the influence of modifications to the slope geometry, in terms of the shape of slope cross section and guiding walls, on the overtopping.

## 3. EXTENDED OVERTOPPING FORMULA

**Overtopping of straight slope**

In the tests in the first phase with a straight slope the ranges for the varied geometrical parameters are as follows:

- Relative crest freeboard ($R_c/H_S$): 0.1 to 2.4.
- Relative draught ($d_r/d$): 0.2 to 1.0.
- Slope angle: 20° to 60°.

In total 13 series of tests with a straight profile have been performed. This corresponds to 481 tests.

From these tests it has been found that an overtopping formula on the same exponential form as proposed by Owen (1980), Van der Meer (1998) and others, describes the non-dimensional average overtopping rate $Q$ well:

$$(1) \qquad Q = \frac{q}{\gamma_\alpha \gamma_{d_r} \sqrt{g H_s^3}} = A e^{-B \frac{R_c}{H_s}}$$

where

$$\gamma_\alpha = \cos^\beta (\alpha - \alpha_m)$$

$$\gamma_{d_r} = 1 - \kappa \frac{\sinh\left(2k_p d\left(1-\frac{d_r}{d}\right)\right) + 2k_p d\left(1-\frac{d_r}{d}\right)}{\sinh(2k_p d) + 2k_p d}$$

and

$A$ found to be 0.17 by best fit.
$B$ found to be 2.2 by best fit.
$\alpha_m$ is the slope angle at which the largest overtopping rates are obtained, all other parameters being equal. Found to be 30°.
$\beta$ is controlling the degree of influence of the slope angle. Found to 3 by best fit.
$\kappa$ is controlling the degree of influence of the limited draught. Found to 0.4 by best fit.
$q$ is the average overtopping rate pr. width.
$g$ is acceleration of gravity.
$H_S$ is the incident significant wave height.
$R_c$ is the crest freeboard.
$\alpha$ is the slope angle to horizontal.
$k_p$ is the wave number $2\pi/L_p$ .
$L_p$ is the local wavelength corresponding to $T_p$.
$T_p$ is the wave peak period.
$d$ is the water depth.
$d_r$ is the draught.

In formula (1) the factors $\gamma_\alpha$ and $\gamma_{d_r}$ has been introduced to take into account the influence of varying slope angles and limited draught.

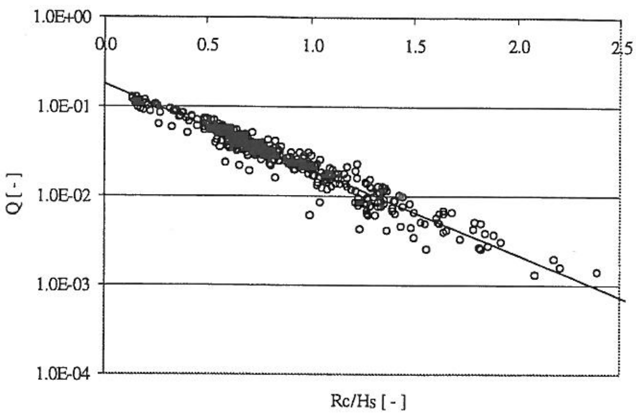


Figure 2: Non-dimensional overtopping rates as measured in model tests with straight slope profile as a function of the relative crest freeboard. The line represents equation (1).

**Tests with modified slope geometry**

For a chosen set of values of crest freeboard, angle of slope and draught, the influence of the following modifications to the slope geometry is investigated:

- Slope with convex upper part (sector of circle, sector of ellipse).
- Slope with concave upper part (sector of circle).
- Converging leading walls (straight).
- Converging leading walls (sector of circle, sector of ellipse).
- Ditch in slope.

Finally, utilizing the results of this investigation the optimal combination of these modifications is tested.

This part of the study was not concluded at the deadline for this summary. However, the final results from this part of the study will be presented at the conference.

## 4. REFERENCES


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