Chapter 36

EXPERIMENTAL DATA ON THE OVERTOPPING OF SEAWALLS BY WAVES

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INTRODUCTION

In the past it has been found that serious damage and breaching of seawalls is most frequently caused by overtopping. Hence for the design of seawalls data must be available about the overtopping by waves of the different profiles that might be possible. Naturally the conditions under which damage is caused to the seawall also depend on the type of construction and the materials used, for example: the stability of grass covered dikes can be endangered seriously by water flowing over the inner slope.

In many designs the necessary height of a seawall has been defined such that not more than 2% of the waves overtop the crest, under chosen design conditions. This criterion has been determined on the assumption that the overtopping must remain very small. Some overtopping has to be accepted because no maximum value for wave height and wave run-up can be given, unless of course the wave height is limited by fore-shore conditi ons.

Unfortunately this criterion gives no information about the volume and concentration of water overtopping the crest in each instance. Moreover it is of interest to know how this overtopping varies with other conditions, such as changes in the significant wave height.

Information about the overtopping by waves was obtained from model investigations on simple plane slopes with inclinations varying from 1:8 to 1:2. The experiments were made in a windflume where wind gene ated waves as well as regular waves were employed.

Using wind generated waves, conditions from nature regarding the distribution of wave heights could be reproduced. It appeared that the overtopping depends on the irregularity of the waves and that the same effects cannot be reproduced using regular paddle generated waves.

In this paper a description of the model and the results of these tests are given. Investigations are in progress on composite slopes, including the reproduction of conditions for a seawall which suffered much overtopping but remained practically undamaged during the flood of 1953.

WAVE CHARACTERISTICS

The heights of a series of wind waves are often characterized by the value of the significant wave height H1/3, that is the average of th highest third part of such a series. More information is obtained by mea of a wave height distribution curve. For this purpose the value H has been defined as the height which is exceeded by n% of the waves of a series (e.g. H_{10} is the height exceeded by 10% of the waves). It has been found approximately that $H_{1/3} = H_{13}$.

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Wave height distribution curves are given in figure 1 for wind velocities of 4, 6, 8 and 10 m/sec in the wind flume, with a fetch of 50 m. A comparison between the different wave height distributions is made in figure 2, where, instead of the absolute value of the wave height, the ratio Hn/H50 has been plotted. From this it appears that for lower wind velocities the waves become more irregular.

Similar distribution curves were obtained from wave-records made along the Dutch coast, examples are given in figure 3. It can be seen from these figures that the wave height distribution of nature can be reproduced in the windflume.

In many experiments the wind velocity has been chosen according to the wave height distribution to be reproduced. Then no direct relationship between the wind velocities in prototype and model exists and it has often been found that the wind velocity in the model is greater than that given by the Froude model law. This seems to be due to the fetch not being to scale.

In studying wave run-up and overtopping, attention should be paid to the wind velocity just in front of and above the model.

The wave period is determined as the mean value of a series of waves. The mean wave length can be found from period and water depth. For wind generated waves in the windflume the mean period varies from 0.65 sec with a wind velocity of $4m/\sec$. to 0.85 sec with a wind velocity of 10 m/sec.

When the wave height and period, using wind only, is too small, a regular paddle generated swell can be applied in combination with a rather high wind velocity to obtain the required period and wave height distribution.

In these experiments only wind was used.

CONSTRUCTION OF THE MODEL

The model was arranged as shown in figure 4; the lower part of the slope was made of plywood while the upper part which was integral with the collecting tank was made of steel sheet. The height and inclination could be readily adjusted.

The model had a width of 0.5 m and was placed in a glass wall flume, which formed part of a windflume, 4 m wide and 50 m long.

Before the model was placed, series of tests showed that the subdivision of the main flume had no effect on measured wave characteristics.

During the tests the wave heights were measured by means of a parallel wire resistance gauge and recorded by a pen-writer. The gauge was located in the portion of the flume not occupied by the model. The overtopping was measured as the volume of water passing the crest during each test.

EXPERIMENTS

Each series of tests consisted of measurements with a fixed inclination, varying crest height and a constant wind velocity. For every

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height of the crest the overtopping was measured as the volume of water passing the crest during 600 sec, from which an average value per secon could be determined. Also the number of overtopping waves, as a percent of the total number was determined. During each run waves were registra for 120 sec. In this way an average distribution from about 2000 wave heights was obtained for each slope and wind velocity.

Slone	Wind velocity in m/sec (model)						Regular
STODE	4	6	8			10	waves
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	x	x x x	x	x x x x x x x x	x	x x x x x x x x	x x
water depth (m)	0.30	0.30	0.25	0.30	0.35	0.30	0.30

Tests were carried out for the following conditions:

Moreover an investigation was made in which, for series of wind generated waves, those waves causing overtopping were indicated on the wave recording.

RESULTS

OVERTOPPING BY WIND GENERATED WAVES.

An attempt has been made to express the results of these tests in terms of dimensionless parameters as follows. The height of the crest (the seawall above still water level, h, was expressed as the ratio

h/H₅₀•

It was found that the overtopping could be related to the dimensions of the waves using the ratio.

$$\frac{2 \pi Q T}{H_{50} L}$$

In these parameters means:

- h = height of the crest of the seawall above still waterlevel :
- $Q = overtopping in m^3/sec per m length of the seawall$

T = wave period in sec.









Fig. 3. Distribution of relative wave heights at Katwijk.



Fig. 4. Arrangement of the model.



Fig. 5. Overtopping for different slopes. Numbers in brackets indicate wave steepness in %. Plain numbers indicate percentage of waves overtopping.



Fig. 6. Overtopping as function of $\frac{h (\cot a \alpha)^{3/2}}{H_{50}}$

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 H_{50} = wave height exceeded by 50% in m. Ľ = wave length in m. Q T = average overtopping per wave. HL $\frac{1}{2\pi}$ = area, in cross section, of a sinusoidal wave above mean water level.

These results are given in figure 5. For each slope curves for different average wave steepness were obtained, as various wind velocities were applied. Also the percentage of the waves causing overtopping is inducated. From the tests carried out on a slope of 1 : 5, the same results were obtained for a water depth of 0.25, 0.30 and 0.35 m. The wave length in deep water, L_0 , according to the periods used in these tests was approximately 1.2 m, so no influence of the water depth, d, was found for $d/L_0 \ge 0.21$.

In comparing the results for the different slopes, in order to establish the influence of the angle of inclination α , it appeared that the volume of water overtopping the crest is not proportional to tan a. (From former investigations it appeared that the wave run-up exceeded by 2% of the waves, Z_2 , could be expressed as

 $Z_2 = 8 H_{1/3} \tan \alpha$. The best results have been obtained using the assumption that the overtopping is proportional to $(\tan \alpha)^{3/2}$, which is shown in

figure 6 where, instead of h/H_{50} , $\frac{h (\cot a \alpha)^{3/2}}{H_{50}}$ has been plotted.

It is seen that with slopes varying from 1 : 3 to 1 : 8 the results can be represented by a single line. But for a slope of 1 : 2 the results are completely different, possibly due to greatly increased reflection of wave energy for the steeper slopes.

Restriction.

It should be noted that there are probably limitations to the applicability of these results and that the experiments reported here were limited to the ranges:

$$0.03 < \frac{H_{50}}{L_{0}} < 0.06$$

 $d/J_{0} \ge 0.21$ in which:

and

d = water depth L = wave length in deep water

Although the full range to which the results can be applied is not known, it is evident that for small water depths the ratio. T/L approaches a constant value so that the parameter $2 \frac{\pi}{H_{50}} \frac{Q}{L}$ is no longer valid since



Fig. 7. Overtopping of regular and wind waves.



Fig. 9. Distribution of all wave heights (full line). Distribution of overtopping wave heights (dotted).

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it does not include the influence of wave length and period.

OVERTOPPING BY REGULAR AND IRREGULAR WAVES.

The overtopping has been measured for regular and irregular waves with the same mean height. The results are given on figure 7.

As could be expected, the irregular waves produced more overtopping. It can also be seen from this figure that there is no simple relationship between the height of a regular wave which will give the same overtopping as a given irregular wave, because the height of the seawall crest must also be taken into account.

If there was a direct relationship between the overtopping and the height of individual waves it would still be possible to estimate the total overtopping from a series of tests with regular waves of various heights by multiplying each overtopping quantity in proportion to the percentage of waves of that height occurring in the spectrum.

Figure 8 gives an example of a wave record in which the overtopping waves are indicated and from which it can be seen that the overtopping does not depend only on the height and length of the individual waves. This is also illustrated in figure 9 where as a result of these tests wave height distribution curves are given for all the waves exceeding H₁₀ and for the overtopping waves. The percentage relates to the total number of waves in the series. When n% of the waves causes overtopping it is certainly not the highest n% which is involved. So a direct relationship between the overtopping and the height of individual waves does not exist.

Obviously these effects of irregular waves cannot be reproduced by regular waves.

CONCLUSIONS

- a. The overtopping of seawalls depends largely on the irregularity of waves. The effects cannot be reproduced in a model using regular waves.
- b. Statistical distributions of wave heights in nature, can be reproduced in a windflume of suitable dimensions.
- c. In the design of seawalls a better idea about the probability of failure is obtained taking as a criterion the volume of overtopping water as well as the percentage of overtopping waves.
- d. When the height of the crest is based on the criterion of 2% of waves overtopping, the quantity of overtopping water is very small.
- e. For tan $\alpha < 1/3$, the volume of overtopping water was found to be proportional to $(\tan \alpha) 3/2$.

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