WAVE RUN-UP AT SEA DIKES UNDER OBLIQUE WAVE APPROACH

by

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1. INTRODUCTION

Besides wave impact forces, erosion of the inner side of a sea dike is a serious cause of destruction. Therefore, wave run-up and overtopping effects have to be considered with respect to the safety of a dike. Strong relations were found between both these influences (TAUTENHAIN et.al., 1980, 1981, 1982), based on experiments in a wave flume and using an energy conservation concept. However, under natural conditions, an oblique wave approach has to be considered. This paper deals with the influence of wave direction on wave run-up on a smooth dike slope in order to provide a basis for calculating the overtopping rates for both regular and irregular waves.

2. PERFORMANCE OF EXPERIMENTS

The experiments were performed in a wave basin of 18 x 45 m, equipped with a servo-hydraulic wave generator. A dike with a uniform smooth slope of 1:6 was installed (Fig. 1).

The direction of the dike relative to the wave direction was varied stepwise in the range of $\beta = 0$ (normal wave approach) and $\beta = 60^o$. The wave heights and periods were varied between H = approx. 5 to 15 cm and T = 1 to 3 sec., respectively. The water depth was d = 35 cm for all test runs.

For the measurements of wave run-up and down-rush effects, a video-system was used. Wave absorbing elements were installed besides the dike structure to suppress model-induced reflections.

The notations and measured quantities are shown in Fig. 2.

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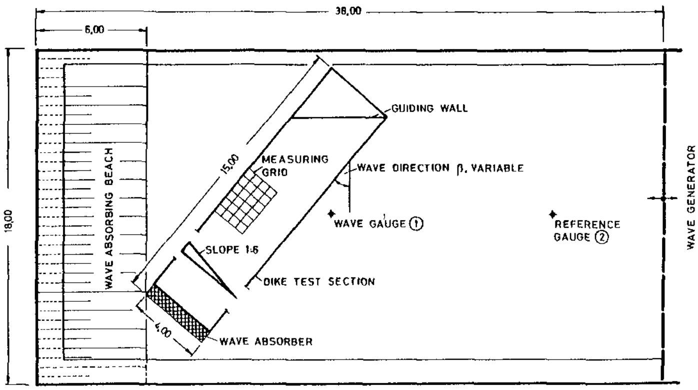

Fig. 1: General test arrangement

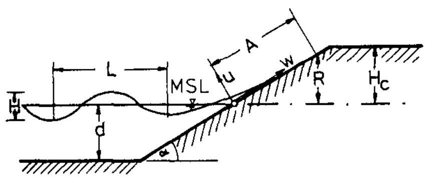

Fig. 2: Notations

3. EVALUATION OF TESTS

As already mentioned, the theoretical background is based on an energy conservation concept which combines the wave parameter in front of the dike and the actual energy of the uprushing wave, and includes the influence of the respective pre-wave of a given time series of incident waves as schematically drawn in Fig. 3.

Assumping that the energy of a monochromatic wave $\tilde{E}$ available for the wave run-up can be equated with the energy E of an equivalent wave of the spectrum, the following equation results (TAUTENHAIN and KOHLHASE, 1980)

$$E_{pot_{A_n}} = 2 \cdot \psi \cdot \tilde{E}_{pot_{A_n}} - E_{pot_{A_{n-1}}} \qquad (1)$$

where A_n = wave run-up of the wave n of a time series and
A_{n-1} = run-up of the pertinent pre-wave
ψ = form parameter

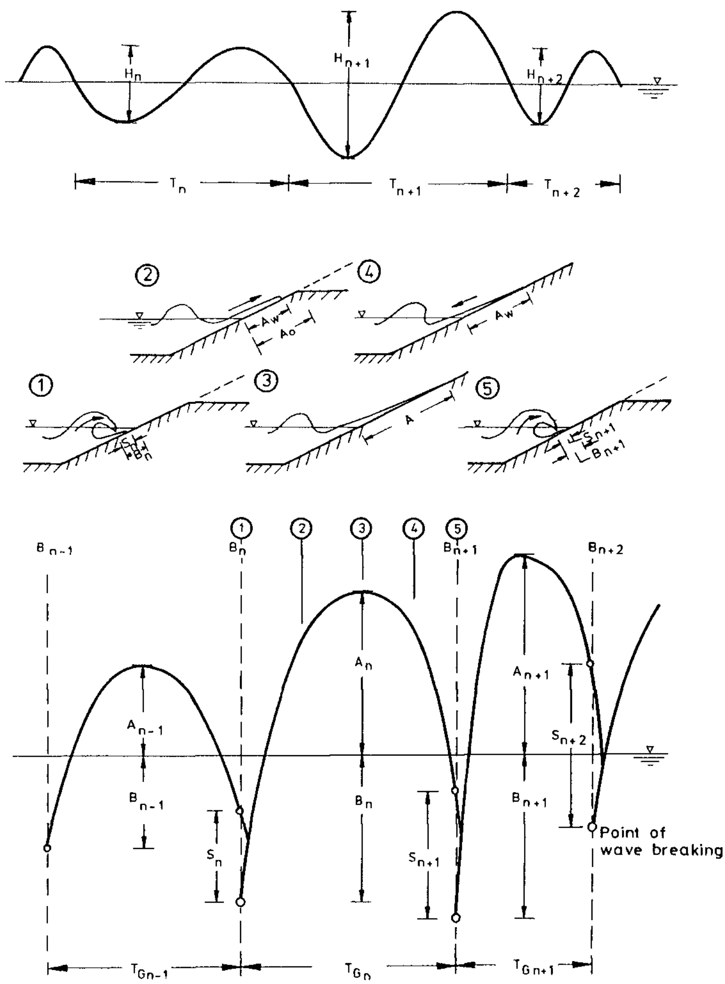

Fig. 3: Phases of wave run-up and down rush and intersections

The wave run-up A_n is given as follows

$$A_n = \tilde{A}_n \cdot \sqrt[3]{2 \cdot \psi - (\tilde{A}_{n-1}/A_n)^3} \qquad (2)$$

From two-dimensional experiments, the form parameter ψ was found (correlation coefficient, r = 0.96) to vary between $\psi = 0.63$ and $\psi = 0.73$ (average $\psi = 0.7$).

The wave run-up $\tilde{A}_n$ is given by

$$\tilde{A}_n = 1.29 \sqrt{H \cdot L_o} \, (1 - \kappa_R')/\cos\alpha \qquad (3)$$

in which κ_R' is the reflection coefficient related to the wave parameter H and L_o in front of the dike.

Equations (1) to (3) have been derived for normal wave approach and must be extended when applied to oblique wave directions.

Considering regular waves, the wave run-up $\tilde{A}_\beta$ was derived as follows

$$\tilde{A}_\beta = \tilde{A}_n \cdot \bar{k}_\beta \qquad (4)$$

where

$$k_\beta = \frac{\tilde{A}_\beta}{\tilde{A}_n} = \cos\beta \cdot \sqrt[3]{2 - \cos^3 2\beta} \qquad (5)$$

is an averaged parameter which includes both refraction and friction effects (wave breaking) as well as the angle of the down-rushing wave in relation to the up-rushing wave.

The parameter $\bar{k}_\beta$ was determined by means of comparative investigations for normal and oblique wave directions, as outlined in the following section.

4. EXPERIMENTAL VERIFICATION

The experiments were performed in two stages. In the first stage, two-dimensional tests were run because of slightly different boundary conditions and the reduced scale of the wave basin compared with previous investigations in a wave flume. The results of these experiments are plotted in Fig.4.

As may be seen in Fig. 4, the experimental results were found to comply well with the wave run-up equation (3). The observed differences of 2.6 % only were not thought to be due to model scale effects but rather to the limited number of tests.

The test results for an oblique wave approach are plotted in Fig. 5 for the measured wave directions $\beta \neq 0^o$. It can be readily seen that the basic equation (3) is also generally fulfilled for an oblique wave direction as indicated by the rather high correlation coefficients between the measured

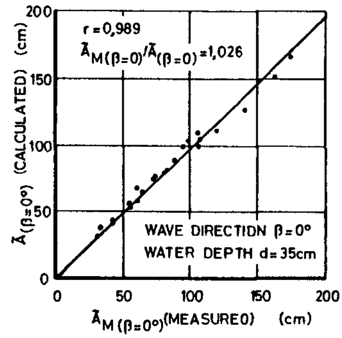

Fig. 4: Verification of equation (3) ($\beta = 0^o$)

wave run-up $\tilde{A}_M$ for $\beta = 0^o$ and $\beta \neq 0^o$, respectively. Therefore, it may be concluded that the influence of the wave direction can be generally summarized by the wave direction parameter $\bar{k}_\beta$, as already illustrated. The effects of wave height and period are of lower order.

The results for all measured wave directions (regular waves) are summarized in Fig. 6.

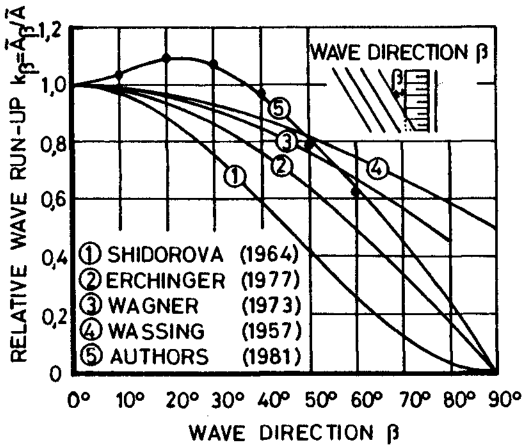

Fig. 6: Relative wave run-up. Summation of results $\beta \neq 0$.

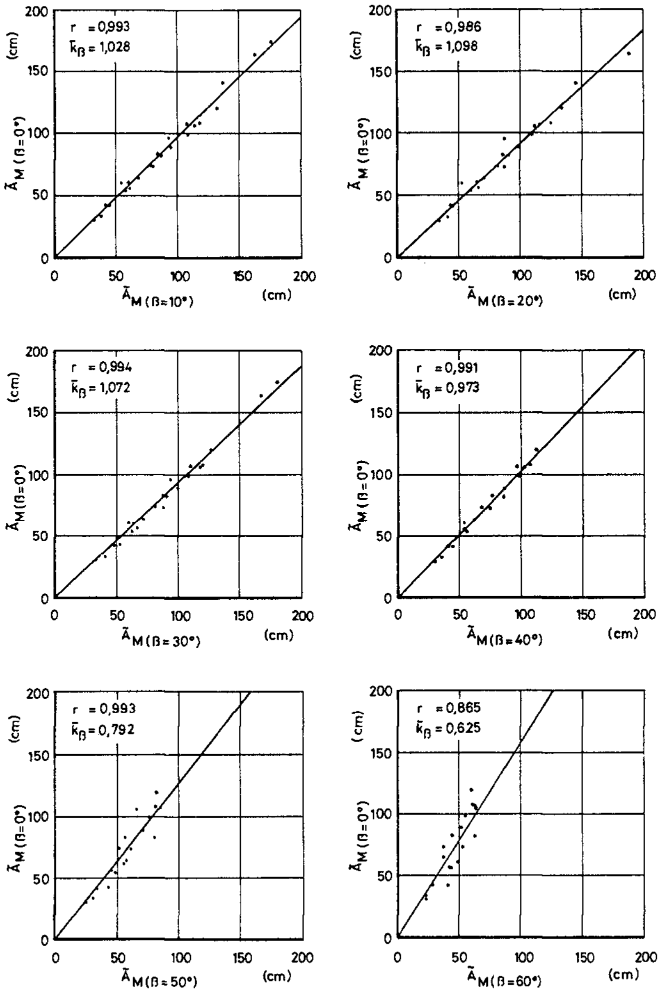

Fig. 5: Influence of wave direction on wave run-up

For the purpose of comparison, the results of a number of authors are also plotted in Fig. 6. The differences between the calculated (equ. 4) and mean measured relative run-up heights are in the order of ± 2 %, which may be neglected.

5. CONCLUSION

With respect to wave run-up at sea dikes, comparative investigations have been carried out for different angles of wave approach. The investigation has clearly shown that, in contrast to previous investigations by other authors, a remarkable increase of run-up heights compared to normal wave approach will occur for wave directions in the range of approx. $0 < \beta \leq 35^{\circ}$.

Since the maximum increase in comparison to normal wave approach conditions is of the order of 10 %, it is important that this effect should be considered in practice.

6. REFERENCES

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