A SEMI-DYNAMIC APPROACH FOR THE SLOPE STABILITY ANALYSIS OF RUBBLE-MOUND BREAKWATERS

Introduction

In the late seventies and early eighties, several important breakwaters failed (Sines, Arzew, Tripoli, San Ciprien, …). Consequently at that time major attention was paid to the hydraulic stability of the armour layer and of the crest. Only little attention was paid to the geotechnical stability. However, overall slope instability is also a major failure pattern.

So during the design of the Zeebrugge breakwaters (1977-1987), intensive research, testing and investigation into the geotechnical stability of rubble mound breakwaters has been done.

One of the results is the calculation method, which takes into account the dynamic impact of waves and tides on deep slip surface analysis.

Sensitivity analysis of slope stability

By analysing the slope stability of a breakwater a distinction has to be made between shallow slip surfaces, which develop completely in the breakwater core, and deep slipsurfaces reaching the soil layers below the seabottom. For a breakwater of normal size (height between 10 and 30 m) built on sand or clay deep slipsurfaces are more likely to occur. So most attention will be paid to this deep slipsurfaces.

The main parameters influencing the slope stability are the overall geometry, the soil parameters, the water pressures on the slope and on the seabottom in front of the slope and the pore water pressures in the breakwater core and in the subsoil.

A sensitivity analysis for deep slipsurfaces shows that the main parameters affecting the safety coefficient F are the soil parameters and the pore water pressures in the subsoil underneath the seabottom. As a breakwater is constructed in open sea, the effect of tides and waves has to be considered as well.

This analysis has shown that within a wave period the minimum safety factor is obtained immediately after the maximum wave run-up: i.e. at the moment that the stabilising forces of the wave turn over into seepage forces within the structure (Fig. 1). This clearly contradicts the wide spread opinion that the wave trough in front of the breakwater slope is the most unsafe condition. The latter is only true for shallow slipsurfaces inside the breakwater core.

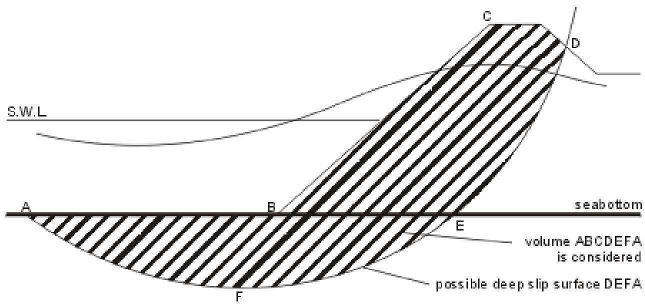

Fig. 1. *Minimum safety factor obtained immediately after maximum wave run-up.*

Pore water pressure variation in the subsoil underneath the sea bottom

The effect of the pore water pressures which are varying within a wave period have been investigated thoroughly by four measuring campaigns in open sea. These campaigns learned that the changes in pore water pressures due to whether tides or waves at the seabottom are transmitted in depth with a certain attenuation which depends mainly on the period of the signal (12h25min for tides, ca 6 s for waves) and soil characteristics (permeability and oedometric compression modulus).

Wave attenuation depends on the wave attenuation factor $A = \sqrt{\dfrac{\rho_w g \pi}{k E_{oed} T}}$. The higher A (i.e. the lower k, E_{oed} and T) the more waves are damped and the higher the overpressures due to wave-action.

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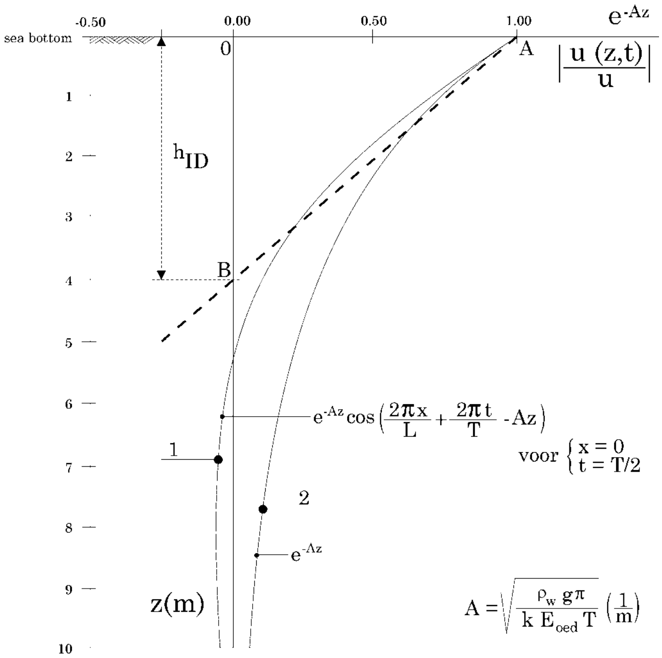

Fig. 2. *Exponential decay of pore pressures with depth in the subsoil underneath the sea bottom.*

The amplitudes of the pore pressure decrease exponentially with the depth (Fig. 2). Curve 1 is valid for x = 0 and t = T/2, while curve 2 is the envelope.
Curve 1 can be replaced by the straight line AB. The distance OB is the so called "influence depth". This influence depth has proved to be a very handsome tool to introduce the variation of the pore water pressure in the subsoil into the slope stability analysis.

Semi-dynamic slope stability analysis

The overall stability of the seaward slope of a rubble-mound breakwater is analysed using the Bishop method taking into account the geometry of the breakwater, characteristics of rubble, characteristics of subsoil and the loading due to tides and waves. The wave action, which plays an important role, is schematised by:

- varying pressures on the slope
- varying pressures on the seabottom in front of the breakwater
- varying pore water pressures in the breakwater core
- varying pore water pressures and consequently the shear resistance in the subsoil

This leads to the so-called "semi-dynamic approach for the slope stability analysis of rubble-mound breakwaters".

Contact

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