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CONSIDERING THE STRESS OF FILTERS IN THE CONSTRUCTION OF SEA DIKES
BEANSPRUCHUNG VON FILTERN IM SEEDEICHBACH
SOLLICITATION DE FILTRES DANS LA CONCEPTION DES DIGUES

Only a few investigations had been done about stress and strains of soil due to breakers. Therefore the dimension of filters under sea dike revetments were constructed by not taking the stress on the filter-layer under rough sea conditions into consideration. This paper presents some results of investigations on this field which were carried out in the Great Wave Channel (GWK) in Hanover, Marienwerder, FRG. The filter-layer underneath an asphalt concrete revetment is stressed by two factors under rough sea conditions: firstly a quasi-static change of stress due to periodic change of the free water level and secondly a dynamic change of stress due to wave impact. It can be demonstrated by these tests that the revetment and the soil underneath oscillates due to wave impact with its first eigenfrequency.

INTRODUCTION

The modern 1:6 slope of sea dikes is originated from the realization of observation and analysation of damages due to gale-swept tides. In particular wave impact is the most important factor which has given shape to the modern sea dike. Until now the transmission of wave impact passed on revetment and underlay was not taken into consideration.

Stress on revetment and sandfill due to rough sea conditions are carried out in the GWK under the special research programm (SFB) 205 "coastal engineering" at the University of Hanover. By using the large wave tank and laboratories of the GWK very good conditions are given: test installations can be built in the scale 1:1 to simulate soil stress under rough sea conditions.

From the results of measurements of the first tests a new problem in the design of sea dike construction can be inferred: the dynamic stress in filter-layers with simultaneous hydrodynamic flow.

WAVE LOAD

For the general understanding of stress fields in filter-layers underneath sea dike revetments some explanations of wave load are usefull.

Characteristic values of a deep water wave are the wave height "H_o" and the wave length "L_o". By diminishing water depth "d" waves become more and more steeper; the included angle at the top of a wave becomes smaller. The breaking starts when water depth falls short of critical depth d_{crit} and the wave crest overhauls the wave trough. As a spilling-, plunging- or surging breaker the wave reaches the slope and the free falling breaker causes impact stress on the slope. This process is shown in Fig. 1.

Wave load on sea dikes is therefore composed by two components:

- hydrostatic load due to changing water level
- wave impact

Until now it was assumed that wave impact has to be regarded only with permeable revetments. By hydrodynamic transmission in water-filled fractures wave impact can course deformations like splitting effects in the macrostructure of stone revetments. Up to now the effect of this shock pressure in partly saturated sandfill of sea dike was not considered in technical standards (1).

Research in the GWK has demonstrated that wave impact generates even on asphaltic concrete revetment important mechanical stresses in the drained sandfill.

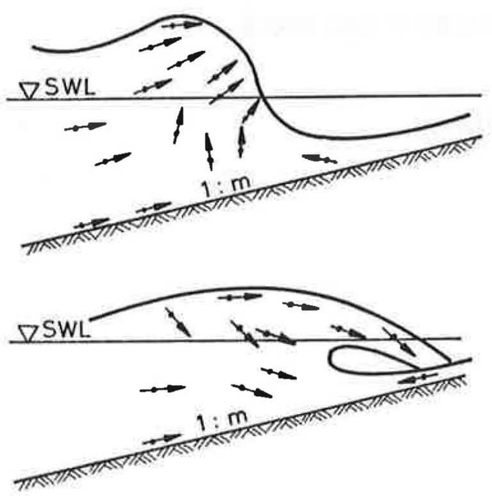

Fig.1: kinematics of wave run-up on slope

STRESS RATES UNDERNEATH REVETMENT DUE TO ROUGH SEA CONDITIONS

Under the special research programm SFB 205 "coastal engineering" and the projekt A 3 "wave induced stresses in soils" 16 soil- and pore water pressure transducers in a sea dike cross section in scale 1:1 have been installed. Fig. 2 shows the configuration of the transducers in the sandfill underneath an asphaltic concrete revetment.
Filter-layers are usually installed near level A (0,4 m under ground level) but in the series of tests presented in this paper a 2-layersystem without a filter has been investigated.

All measured values of the transducers are digitized with 50 Hz at the same time. There are 800 measured values per second which are recorded by computer. Fig. 3 shows the lay-out of the testing equipment.

The stresses upon sandfill shown in Fig. 4 are characteristic for the change of stress and they are exemplarily for measured values in the measuring profile 2/level B.

The basic figure of change of stress conforms to hydrostatic change of wave load. The wave period causes an in- and decrease of pressure upon soil; this stress is comparable to pulsating stress of pressure; those are the so called "cyclic changes of stress". Additionally wave impact effects another change of stress not according within a given time of this load. Within about 1 second there is a repeated, strongly damped change of amplitudes. Time of oscillating is short compared with the wave period; the wave impact produces longitudinal vibration in the sandfill. The reaction of the 2-layersystem is dynamic due to shock pressure lasting about 0,01 to 0,1 seconds.

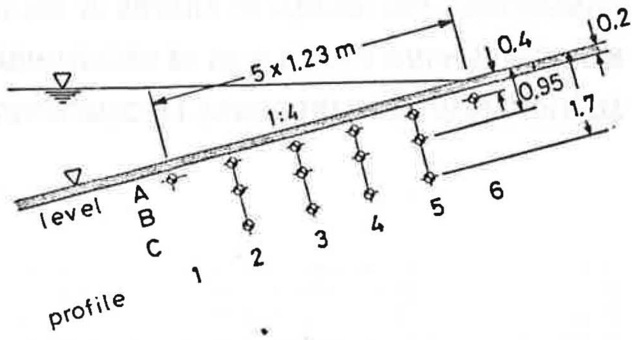

Fig.2: test field in the Great Wave Channel, Hanover-Marienwerder, FRG

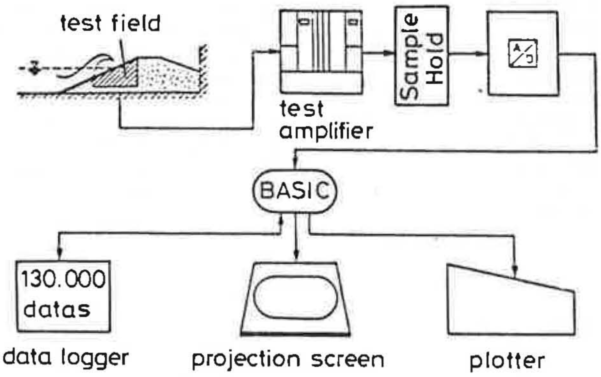

Fig.3: lay-out of sequential computer

CHARACTERISTICS OF STRESSES DUE TO WAVE IMPACT

The above mentioned basic results are confirmed for all measuring points in GWK-sandfill (Fig. 2). The relation of quasistatic and dynamic change of stress depends on the position of the measuring points in sandfill to the point of impact on the slope. This relationship is shown in Fig. 5.

The profiles 1 and 2 are installed in the sandfill in the zone of continous change of water level due to cyclic wave load. Next to the breaking point and especially to the zone of wave impact the quantity of dynamic stress is higher than the quantity of cyclic stress at the same measuring point. Near stillwater level the cyclic change of stress infers from wave run-up.

Stress ratio is just as important for filter lay-out as the absolute quantity of pulsating stress. Stress ratio is the first derivation from time of changes of stress, i.e. velocity of change of stress and this is shown in Fig. 6 exemplarily for the measuring values in Fig. 4. According to the low frequency of stresses (Fig. 4) the stress rates of this type of load are rather small, while the stress rates of wave impact grow up to the 30-fold values and indicate in this way the local stress changes during short time increments. The frequency range of dynamic stresses has been defined by Fast Fourier Transformation (FFT). The characteristic types of stress distribution near the breaking point is plotted in Fig. 7. Fig. 8 shows the result of FFT as the spectrum of amplitudes. Following the frequency range of quasistatic stresses (wave period T=4 sec - 0,25 Hz with harmonic vibration) the spectrum of amplitudes is in accordance with the dynamic stresses (2,5 Hz to about 9 Hz). This qualitative spectrum of amplitudes (Fig. 8) is characteristic for the dynamic stressed section in sandfill of the model sea dike.

CONCLUSIONS FOR STRESSES ON REVETMENT AND FILTERLAYER

In (1) FRANKE already refers that within the design of the slope revetment of sea dikes there are contrary demands to be considered. On the one side an open revetment with filterlayer placed underneath is always useful because of the inner dam pore water pressure. On the other side there are always objections against this construction because in permeable revetments wave impact can cause extremly high hydraulic stresses (3). In the same sense it is in (4) commended to design asphaltic concrete revetments only above MTHw and to install the revetments permeable below this mark. In the sea dike construction filterlayers are usually designed as soil-geotextile filters; the different types of filters used in practice are well known.

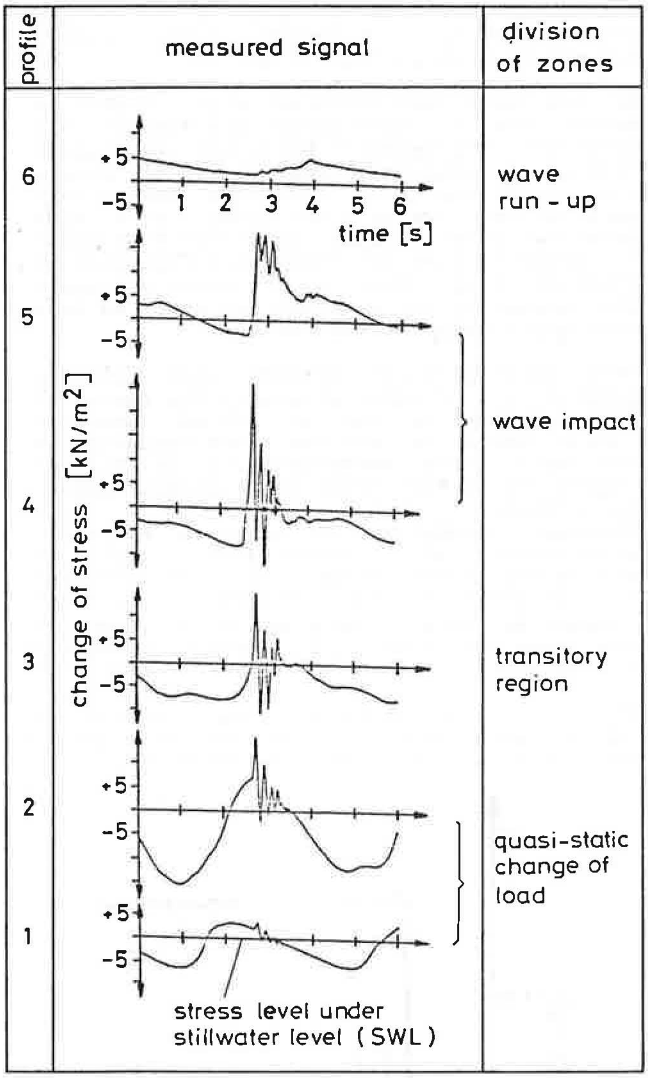

Fig.5: change of stresses in level A, profiles 1 to 6, H=1.75 m and T=6 s

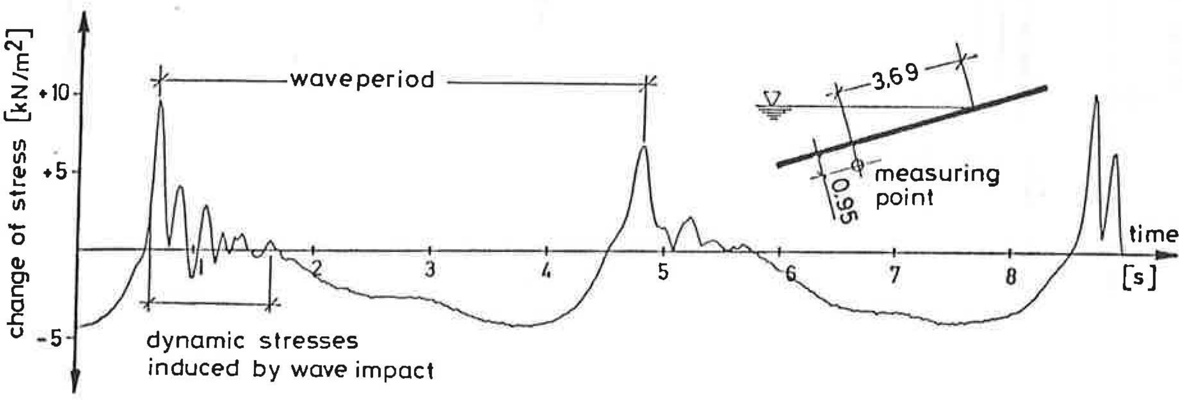

Fig.4: change of stress in level B, profile 3 (see Fig.2) due to wave H=1.25 m and T=4 s

There are new unknown aspects due to the above mentioned wave impact for the interrelations between geotextile and soil.

It has been demonstrated that changes of stress due to wave impact are dynamic; the revetment and sandfill below are oscillating (impuls excitation). The state of stress changes within soil structure during this oscillation, while returning with each breaking wave. Forces transfered from grain to grain of sand are changing pulsatingly in shortest time. Next to the point of impact the superposition stresses are small so that they might become infinitesimal.

This appearance is already well known in seismic and dynamic stresses. The result of this process is the so called "liquefaction". Hence it follows a new valuation of the well known determinations of filterlayers by simultaneous undiminished hydraulic stress.
Mechanic stability as well as hydraulic efficiency of filterlayers must be guaranteed under rough sea conditions even if the grain of soil looses friction contact caused by wave impact and at the same time the pore structure of the geotextile used is not in right shape.

Research on filterlayers which considers the above mentioned stresses are not yet on hand, but solitarily are set about (5).

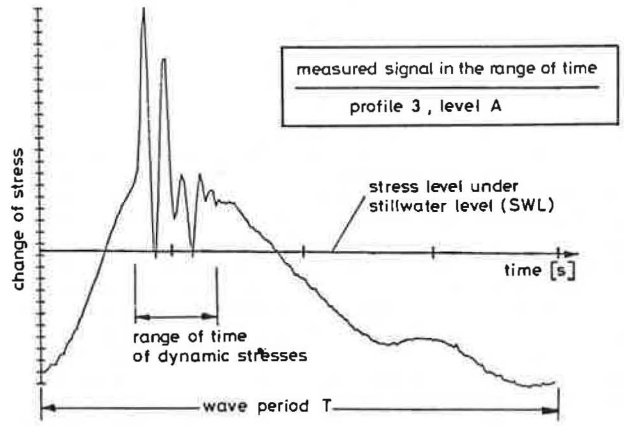

Fig.7: characteristic stress sequence near to the breaking point

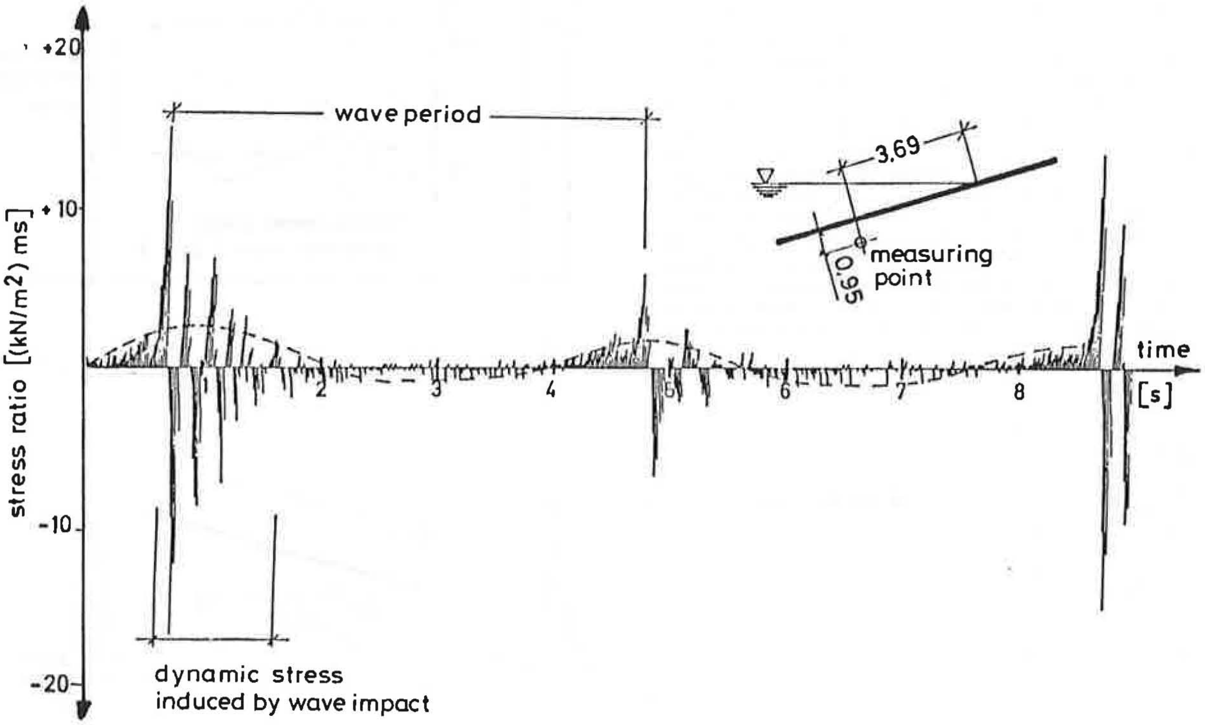

Fig.6: stress ratio of change of stress in Fig.4, level B, profile 3 (see Fig.2) dueto wave H=1.25 m and T=4 s

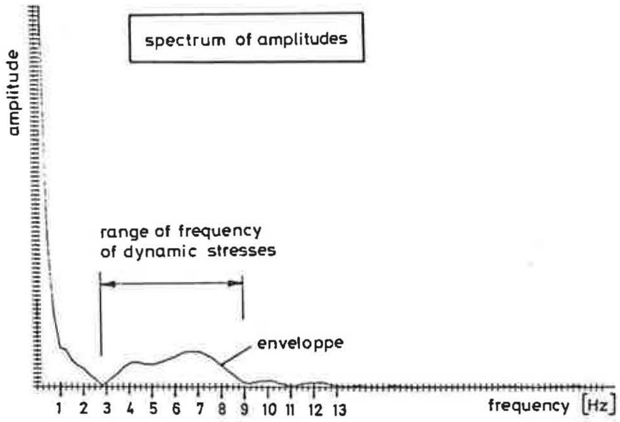

Fig.8: spectrum of amplitudes of stress sequence in Fig.7; determined by Fast Fourier Transformation (FFT)

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