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EXPERIMENTAL AND NUMERICAL STUDY OF THE RESPONSE OF A SANDBED BENEATH A CAISSON BREAKWATER SUBJECT TO CYCLIC WAVE LOAD

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1. INTRODUCTION

The foundation design of marine structures is one of the most demanding tasks for coastal or geotechnical engineers. Due to the dynamic and cyclic loading conditions a variety of governing processes have to be considered, some of them beeing difficult to assess. Furthermore, the determination of relevant loading parameters and dynamic response parameters of the structures and their foundations is often imprecise. The quality of the results is also determined by the soil model used to describe the response of the subsoil. All these will affect an adequate assessment of the overall stability. In view of the considerable costs of breakwaters, it is obvious to optimize the design process. For this purpose, it is important to improve the knowledge of the processes involved, to assess more precisely the quantitative influence of crucial parameters and to select an appropriate constitutive law for the calculations.

One of the most important task is to determine the liquefaction potential of the foundation soil and to asses the increase in mean pore water pressure under cyclic load. The latter phenomenon is mainly responsible for the weakening of the soil stiffness. Subsequently this might lead to intolerable displacements or even to the complete failure of the foundation, due to the increasing risk of geotechnical failure modes possibly including liquefaction of the supporting foundation soil. In order to better understand the processes leading to liquefaction in the sand bed underneath a caisson breakwater, large-scale model tests were performed within the European project LIMAS (Liquefaction around Marine Structures).

First, the paper will provide an overview of the key processes associated with the seabed response. They were derived from the experimental results. Then, theoretical models for the description of the seabed response are analyzed in order to check, how far they are able to describe these key processes. As a result, a numerical model with an appropriate soil model is selected in order to reproduce the most relevant processes observed in the experiments and to use the model for a more detailed parameter study.

2. KEY PROCESSES ASSOCIATED WITH THE SEABED RESPONSE

The experimental investigations were conducted in the Large Wave Flume (GWK) in Hanover, Germany. The caisson breakwater was located on a 2.45 m sand bed. The applied measuring devices provided information about the wave conditions, the wave load at the structure, the caisson motion and the induced pore water pressure and mean total stress inside the soil (for more details see Kudella & Oumeraci 2004).

From the measurements several key results were derived:

1. A comparative analysis of the vertical motions of the caisson, the pore pressure underneath the caisson edges and the wave load at these locations showed, that the pore pressure response underneath the structure is dominated by the caisson motions. This particularly holds for wave impact loads (Kudella & Oumeraci 2004a).

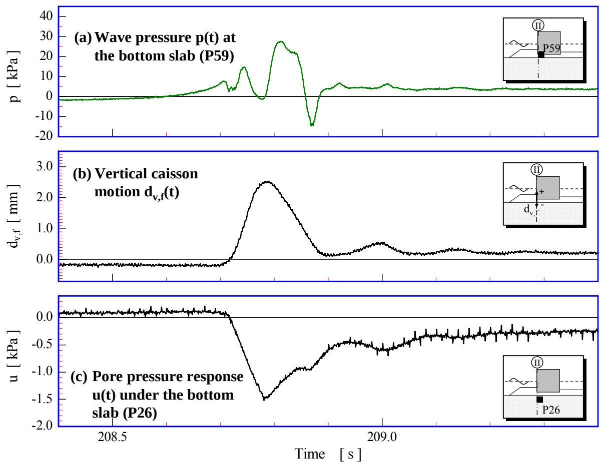

Fig. 1: Relative contributions of wave load and caisson motion to pore pressure response in the seabed for breaking wave impact load

2. The development of residual pore pressure is significantly determined by the type of wave load (residual pore pressure was observed only under impact load), the density state of the subsoil and the

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drainage condition, as characterized by the drainage period T_{drain}

$$T_{Drain} \approx \frac{d^2}{c_v}$$

with d = length of the drainage path and c_v = consolidation coefficient (Kudella & Oumeraci 2006).

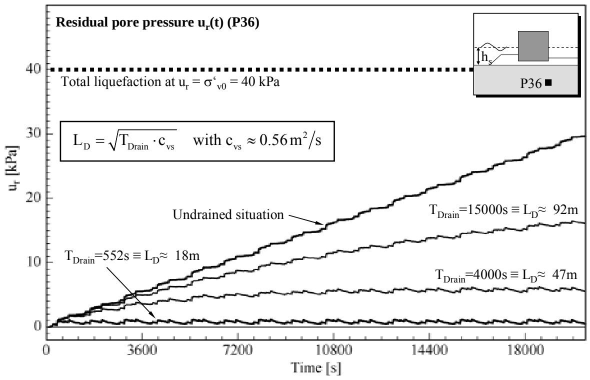

Fig. 2: Development of residual pore pressure under irregular wave load for different drainage periods

3. Under the development of residual pore pressure the stiffness of the foundation soil decreases This will subsequently increase the motion amplitudes of the caisson. Furthermore, the results also indicate that the favorable effect of simultaneous drainage should always be considered.

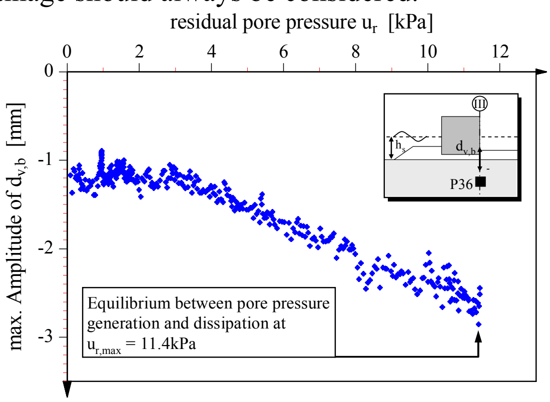

Fig. 3: Relationship between residual pore pressure and caisson motion for a selected test with regular wave impact load

3. NUMERICAL INVESTIGATIONS

Quantitative and more general conclusions for different loading-, soil- and drainage conditions could not be derived from the measurements alone. In order to select a numerical model with an appropriate constitutive law for further investigations, a comprehensive literature study was performed. All analytical models dealing with the soil response due to gravity waves are based on a *poro-elastic approach* and don't consider any compaction of the sand bed. The formulation of *elasto-plastic behavior* can only be achieved by applying elasto-plastic soil models, which are usually implemented in numerical methods. It is necessary that the selected model is able to formulate the key processes described above, in particular to describe residual pore pressure due to soil compaction and simultaneously including dissipation. Moreover, a hardening law must be included to simulate the pre-shearing effect. Therefore, the finite-element model DIANA-SWANDYNE II (Chan 1995) was selected. It uses the fully coupled Biot equation with v-u-simplification (ignoring fluid acceleration relative to the soil skeleton) and has already been used successfully for wave-induced liquefaction analysis around pipelines (Dunn et al. 2006).

The main focus of the paper will be set on the following aspects:

1. Quantify the influence of wave- and caisson motion on the development of instantaneous and residual pore pressure
2. Study the influence of residual pore pressure on the cyclic and residual deformation of the structure in order to assess the stability and feasibility of the breakwater

5. REFERENCES

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