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Preliminary results of instrumented laboratory flow slides

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Abstract

The liquefaction tank is an experimental facility developed to conduct physical scale model tests of liquefaction flow slides. We developed the liquefaction tank to evaluate the performance of advanced numerical models for submerged slopes composed of sand. For the long-term, the research with the liquefaction tank aims at composing a database with high-quality experimental results of liquefaction flow slides, in which properties related to the soil, degree of saturation, geometry, triggering and mitigating measures will be varied. This paper addresses the first results obtained with the liquefaction tank. We used a fluidization system to create a uniform, loosely packed sand bed. The liquefaction tank was subsequently tilted uniformly, while measuring the pore pressures at the base of the sand bed. Furthermore, the stability of the slope was monitored using a camera system pointed at the transparent side of the tank. We conducted around 30 tilting tests on a level sand bed while varying consolidation time, density and tilting rate. We were able to reproduce liquefaction flow slides below a particular threshold density. The moment of failure was noted by an instant, uniform liquefaction of the sand bed, preceded by an abrupt increase of excess pore pressures. The results in terms of failure angle and measured pore pressures were consistent and reproducible. The measured failure angle was much lower than anticipated from results of element tests (e.g. triaxial tests) in literature. Future research aims at relating the results to the response during undrained triaxial tests and the effect of mitigating measures.

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1. Introduction

Liquefaction flow slide [1,13] is the main geohazard for subaqueous slopes composed of loose sand. During a liquefaction flow slide the sand instantly transforms from a solid-like to a liquid-like behaving material. The large reduction in shear strength produces a mechanism that may be initiated by a minor trigger, develops rapidly and displaces large volumes of sand over vast distances. It is no surprise that some of the most destructive failures in the history of geotechnics were liquefaction flow failures. For an overview of case histories one is referred to [1].

The currently available methods for assessing liquefaction flow slides [2-5] are unsatisfactory for the complex problems that arise in engineering practice. We attribute this shortcoming to a few factors: the variable state of the subsoil and the lack of means to determine its *in-situ* properties, the coupled and highly non-linear response of the soil during flow liquefaction and the lack of detailed information from case histories. The common methods tend to simplify and decouple the assessment, while relying on a limited, empirical basis. Considering the aforementioned factors, these methods have a narrow range of application with uncertain results outside this range.

As an alternative, more advanced methods, for instance based on the Finite Element Method or related methods, can be employed to assess liquefaction flow slides. These methods are potentially capable of capturing the soil response in detail from the moment a flow slide is triggered to the moment of re-sedimentation at a gentle slope. However, more advanced methods also require a firm basis to verify and validate the results. To this end, the liquefaction tank was developed. The liquefaction tank is a large-scale experimental equipment that facilitates model tests of flow slides. On the long term, the development of the liquefaction tank aims at compiling an open source, high-quality experimental database that can be used by researchers to test the performance of numerical models.

This paper will present the first, preliminary results obtained with the liquefaction tank. The test series were conducted to demonstrate that the liquefaction tank is capable of producing consistent and reproducible data of liquefaction flow slides. The paper will first introduce the set-up by addressing the basis of design, the structure of the tank, the fluidization system, triggering mechanisms and instrumentation. Then, we will discuss the preliminary test results, including details of the testing program and the typical measured response of the soil. The paper will discuss these results in the final section and will draw the future perspectives on the experimental data collection by means of the liquefaction tank.

2. The liquefaction tank

2.1. Basis of design

Physical model tests leave the option of conducting tests in a *1g*-set up or a centrifuge model. We preferred the former for a number of reasons. The preparation of a very loosely packed, uniform sand bed in the centrifuge test is complicated by limited options for preparation techniques, vibrations during spinning up and non-uniformities at higher *g* –levels [6]. The required scaling of the hydraulic conductivity of the saturated soil using a pore fluid with an increased viscosity also affects the free water next to the slope [7-8]. As a consequence, the artificially induced support by the free water will affect the response, particularly at larger deformations. If flow liquefaction is triggered by creep, as observed in element tests, the yet unresolved scaling of creep time complicates flow liquefaction slides in the centrifuge [9]. The same accounts for erosion and sedimentation during the post-liquefaction phase, which lacks experimental validation.

There are only a few, reported cases of physical model tests of liquefaction flow slides in subaqueous slopes [10-12], where we ignore the well-referenced work by Eckersley [13] which concerns unsaturated slopes. Apart from the limited amount of testing, the results lack detailed documentation, control over the preparation of the sand bed and specification of the trigger. Questions have been raised on the reproducibility of the measured response, while particularly the first phase of the liquefaction flow slides was not well-defined. During the development of the liquefaction tank particular attention was paid on the preparation of the sand and the specification of the trigger. In addition, it is recognized that element tests are needed for the interpretation of the measured response and possible extrapolation to field conditions. The main requirements defined during the development of the liquefaction tank are defined as follows: