On the Modelling of Wave-induced Liquefaction, Taking into Account the Effect of Preshearing

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ABSTRACT

A model is described to calculate the amount of excess pore pressure in the seabed. In the model the combined effect of generation and dissipation of excess pore pressures is taken into account. Also the effect of preshearing can be taken into account. The numerical model is validated with the results of model tests. Parameter determination, test results and calculation results are described. The comparison shows a good agreement with the test results. Calculation results show that taking into account the preshearing greatly reduces the calculated amount of excess pore pressure. This allows for a more economical design of the pipeline and the burial depth.

KEY WORDS: pipeline; liquefaction; preshearing.

INTRODUCTION

Offshore pipelines in are often buried in order to protect them against damage by fishing equipment or drag anchors or for isolation purposes. Cyclic loading of the soil, e.g. due to wave loading, induces excess pore pressures that may cause partial or full liquefaction of the soil. These excess pore pressures may endanger the stability of pipelines buried in the seabed and, more precisely, it poses the risk of floatation of the pipelines. A vital aspect of buried pipeline design is therefore the assessment of pipeline floatation potential under design storms.

In order to check the risk of floatation, and thus the required measures, one needs to predict of the amount of excess pore pressures during storm loading. An aspect often overlooked in other models is the effect of preshearing on the generation of excess pore pressures.

PRESENTLY USED METHODS

Pore pressures in the seabed can be separated into average and instantaneous (or momentary) pore pressures. Instantaneous or momentary pore pressures are fluctuating with the load, but not necessarily in phase with the load. They are dominated by elastic soil behavior. Average (residual) pore pressures are gradually increasing or decreasing and are in most cases mainly due to accumulation of plastic volume strains of the soil skeleton.

This paper focuses on liquefaction caused by the residual or average pore pressures. The term residual is slightly misleading, as positive residual excess pore pressures usually disappear sooner or later thanks to drainage. Aspects are the duration of the storm, the combined effect of pore pressure generation and dissipation and the preshearing effect.

The aspect of excess pore pressures in the seabed has been the subject of different papers, e.g. (Seed and Rahman, 1978), (Barens and Calle 1985), (Spierenburg 1987), (Sumer et al 2011), (Jeng and Seymour 2007). Mostly these papers describe the instantaneous variation of the pore pressure during a single wave. Most approaches are based on the work by (Seed and Rahman 1978). In the models the excess pore pressure is the effect of two mechanisms: the pore pressure generation due to the continuous densification of the soil and the dissipation/drainage of the excess pore pressure.

The used model for the generation of excess pore pressure is based on the result of undrained cyclic triaxial or DSS testing on virgin samples. In undrained tests the effect of dissipation of excess pore pressure on the liquefaction resistance is not taken into account. A limited number of test results with intermediate drainage is available (Finn et al 1970), (Lee and Focht 1975), (Smit et al 1978), (Bhatia 1982), (O-Hara et al 1985), (Mitchell and Dubin 1986), (Sato et al 1997), (Meijers 2007). The tests show a large increase in resistance against liquefaction when, after some excess pore pressure has been generated the sample is drained. Obviously there will be some densification of the sample due to the drainage of the excess pore pressure. However the beneficial effect of the preceding load cycles (preshearing) is much larger than follows from the (small) increase in density only. The strengthening is attributed to a change in soil structure. The effect is known as ‘preshearing’ or ‘history’ effect. It is however also demonstrated by some researchers (Finn et al 1970), (Tokimatsu and Hosaka 1986), (Meijers 2007), that, reaching large shear strain amplitudes (in excess of about 0.5% cyclic shear strain) or when applying a large shear strain before resuming cyclic undrained loading the beneficial effect of preshearing is erased. Then the pre-shearing may even have a detrimental effect on the cyclic shear strength.

The beneficial effect of preshearing is demonstrated in a number of model tests with regular wave loading (e.g. (Sassa and Sekiguchi, 1999), (Sumer et al 1999). These tests show that the excess pore pressure reaches a peak shortly after the start of loading, followed by a