LIQUEFACTION ANALYSIS OF SATURATED SAND DEPOSITS WITH SILT LAYERS SUBJECT TO 1 AND 2 COMPONENTS OF EARTHQUAKE MOTION

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ABSTRACT :

Liquefaction of saturated sand layers has been extensively studied by various researchers. The studies conducted were both experimental and analytical. An important issue identified by the researchers is the simultaneous application of all 3 components of the earthquakes, especially the 2 horizontal components for a better representation of real life cases. In this paper, the behavior of loose – medium dense sand deposits with and without a silt interlayer has been presented in figures using LASS III computer code. In these analyses, the focus is on the liquefaction phenomenon which is one of the most important problems occurring in sandy-silty soils during strong ground motions. The presence of less permeable layers, such as silt seams in sandy soils, results in higher excess pore water pressures increasing the risk of liquefaction. The difference between the outcomes of utilizing one or two horizontal components of the earthquake motion is also presented.

KEYWORDS:
Liquefaction, LASS III, silt seam, pore water pressure, two directional shaking.

1. INTRODUCTION

Liquefaction is one of the most important concerns for geotechnical engineers stemming from the findings of the 1964 Alaska and Niigata earthquakes, and has been studied extensively by various researchers. This phenomenon causes dramatic consequences, such as sand boiling, excessive settlement, lateral spreading, tilting and/or overturning of structures. Extensive liquefaction has been seen been observed in Gölcük and Adapazarı in the wake of the 7.8 magnitude earthquake which struck northwestern Turkey in August 1999. In this study, the liquefaction risk of saturated sand layers with silt seams of low plasticity and hydraulic conductivity has been analysed using a computer code, called LASS III, which utilizes advanced liquefaction models.

2. LASS III CODE

The numerical analyses in this study are performed using the LASS III code (Ghaboussi and Dikmen, 1979) capable of analysing dynamic behavior of horizontally layered soil layers subjected to multi-directional shaking during an earthquake. An earthquake motion is exerted at the base rock under the influence of which time dependent pore pressures, shear strains and stresses, displacements, velocities and accelerations are computed employing total or effective stress analysis. The material model is based on plasticity and developed for investigating the behavior of sands under cyclic loading (Ghaboussi and Karshenas, 1977).

Damping is considered to comprise of two mechanisms in the nonlinear material model, hysteritical damping and pore pressure dissipation with time, and no additional viscous damping ratio is used. The soil deposit is separated into a number of horizontal sublayers with nodal planes and boundaries, which are assumed to remain planar during motion.

The motion of the total system is determined from the motion of nodal planes as the soil sublayers are subjected to two horizontal shear waves and and one vertical pressure wave, and assuming that nodal planes will undergo displacements in three directions. The pore water is considered to move according to Darcy's law only in the vertical direction with a single degree of freedom. Therefore, at each nodal plane four degrees of freedom are considered: three for the granular phase and one for pore water. The program outputs include time histories of shear strains and stresses, displacements, velocities and accelerations in three directions and pore water pressures at nodal planes. The liquefaction time and depth also are identified and specified as outputs.

3. THE PRESENCE OF A SILT SEAM IN SANDY SOILS

Natural sand deposits may include some silt seam and bands which can play an important role on the excess pore pressures being developed; therefore, also be a critical factor in increasing the potential of liquefaction. Thus, it is very important to know the properties of silts encountered in field or used in laboratory testing. If the silt layer has a high plasticity, it can increase the resistance against liquefaction while low plasticity silts may eleviate the potential risk of liquefaction. In this study, a 20 m thick soil layer has been selected to perform the calculations in which both one horizontal component and two horizontal components of an earthquake of 0.3 g peak ground acceleration is used. The earthquake data is from Yarımca recorded during the 1999 earthquake. The results from the analyses have been presented in Figures 1 and 2. The hydraulic conductivity coefficients used in this study are $k=10^{-6}$ m/s and $k=10^{-7}$ m/s for sandy soil and silty interlayer, respectively.

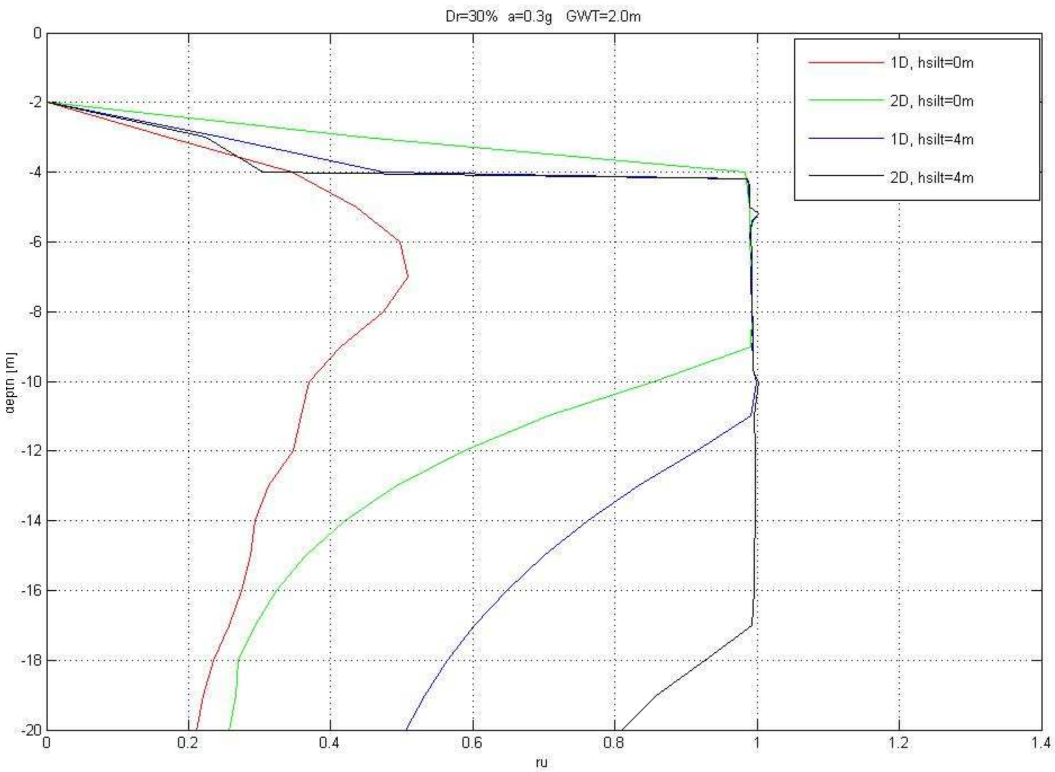

Figure 1 The effect of a silt seam on a sand soil with 30% of relative density

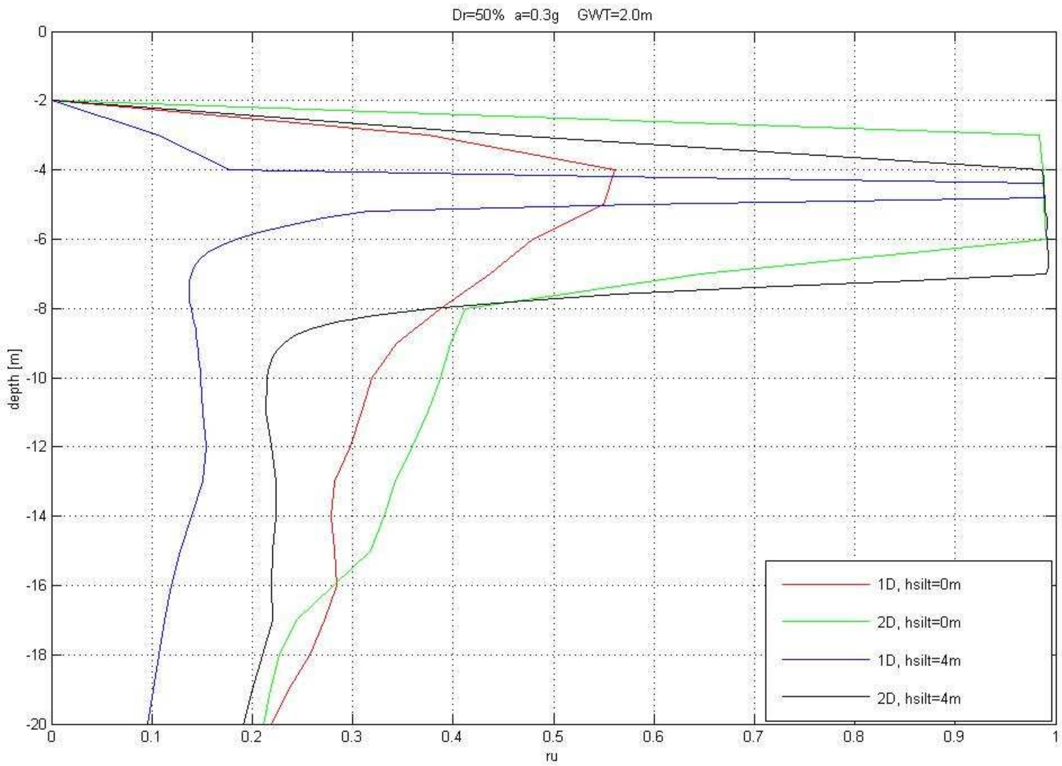

Figure 2 The effect of a silt seam on a sand soil with 50% of relative density

The effects of a silt seam and two directional loading are very clear. When the sandy soil with a 30% relative density and no silt seam is subjected to one directional loading, the accumulated excess pore water pressure coefficient (r_u) remains between 0.2-0.6 (Figure 1). In contrast, the pore pressures increase drastically when the same soil layer is simultaneously subjected to two directional components of the same ground motion. Similar results can be seen in Figure 2, where the sandy soil with a relative density of D_r =50% is subjected to the same ground motion record. As expected, denser soil has higher resistance against liquefaction although it still liquefies under two directional loading.

4. CONCLUSIONS

It is known that liquefaction calculations can be performed using simple equations or computer codes which are capable of computing several significant parameters to understand the mechanism of liquefaction. Furthermore, simple solutions can include two or three components of ground motion. In this study, a comprehensive computer code named LASS III has been used to investigate the risk of liquefaction of a sandy soil with a silt seam and the obtained results have been presented. The liquefaction risk increases when two directional loading is applied simultaneously as well as with the presence of a silt seam having a low plasticity and hydraulic conductivity.

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