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Effect of Fines on Liquefaction Resistance in Fine Sand and Silty Sand

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ABSTRACT
It is required to recognize the conditions that exist in a soil deposit before an earthquake in order to identify liquefaction. Soil is basically an assemblage of many soil particles which stay in contact with many neighboring soil. The contact forces produced by the weight of the overlying particles holds individual soil particle in its place and provide strength. Occurrence of liquefaction is the result of rapid load application and break down of the loose and saturated sand and the loosely-packed individual soil particles tries to move into a denser configuration. However, there is not enough time for the pore-water of the soil to be squeezed out in case of earthquake. Instead, the water is trapped and prevents the soil particles from moving closer together. Thus, there is an increase in water pressure which reduces the contact forces between the individual soil particles causing softening and weakening of soil deposit. In extreme conditions, the soil particles may lose contact with each other due to the increased pore-water pressure. In such cases, the soil will have very little strength, and will behave more like a liquid than a solid - hence, the name "liquefaction".

Keywords - Liquefaction, Plasticity, Liquefaction Resistance, and Plastic fines etc

I. INTRODUCTION

In general, fine uniform sands are found to be most susceptible for liquefaction in term of grain size. It can be stated that soils containing less than10% fines(silt and clay sizes), D60 between 0.2mm to 1.0mm,uniformity coefficient Uc between 2 to5 are most susceptible to liquefaction for given relative density of soil and intensity of earthquake. Thus uniformly graded materials are more susceptible to liquefaction than well graded materials. Also fine sands are more susceptible than gravely soils, silty sands, silts or clays. In general the size of soil grain and its looseness in primarily considered to be main reason for liquefaction thus all coarse grained non cohesive soil are very prone to liquefaction while cohesive soils are not seriously affected on this accounts. Several studies have been conducted for establishing the liquefaction potential of coarse grained soil/ fine sand soils. These studies as on date indicate that sandy soil is more sensitive and prone to liquefaction then that of silty sand. Further the researches carried out also established that the presence of larger void ratio in loose fined sand is responsible for developing higher water pressure and hence easily liquefy. On the other hand as percentage of fines increases in the given volume of soil, the fine sand changes to silty sand in which voids are filled with there fines resulting in decreased void ratio and soil becomes less prone to liquefaction. Thus it is understood that decrease in void ratio by the fines in directly responsible for safeguard against liquefaction. The SPT value and the class of the soil have been used for prediction of probable liquefaction. The present study is directed to investigate the liquefaction potential of fine sand, silty sand in different proportion of fined content and with variable compactness of the soil for assessment of liquefaction and to proposed a relation in terms of grain size void ratio and percentage of fine content to expressing liquefaction. Stress history is also crucial in determining the liquefaction resistance of a soil. For example, soil deposits with an initial static shear stress i.e. anisotropic consolidation conditions are generally. Liquefaction resistance of a soil deposit increases with depth as overburden pressure increases. That is why soil deposits deeper than about 15m are rarely found to have liquefied (Krinitzky et al.1993)[2]. Characteristics of the soil grains like distribution of shapes, sizes, shape, composition etc influence the susceptibility of a soil to liquefy (Seed 1979) [1]. While sands or silts are most commonly observed to liquefy, gravelly soils have also been known to have liquefied. Rounded soil particles of uniform size are mostly susceptible to liquefaction (Poulus et al.1985) [3]. Well graded soils, due to their stable inter-locking configuration, are less prone to liquefaction. Natural silty sands tend to be deposited in a looser state, and hence are more likely to display contractive shear behavior, than clean sands.

1.1 Effects of Fine Content and Plasticity on Liquefaction Resistance:

Both clean sands and sands containing fines have been shown to be liquefiable in the field (Mogami and Kubo (1953[4]); Robertson and Campenella (1985) [5]; and Holzer et al.(1989) [6] and in the laboratory (Lee and Seed (1967a) [7]; Chang et al. (1982) [8]; and Koester(1994) [9]. Additionally, non-plastic silts, most notably mine tailings, have also been found to be susceptible to liquefaction (Dobry and Alvarez (1967) [10]; Okusa et al. (1980) [11]; and Garga and McKay (1984) [12]. A review of the literature, however, shows conflicting evidence as to the effect which fines have on the liquefaction resistance or cyclic strength of a sand. The main factors that are reviewed here are the effects of non-plastic fines content and the effects of plastic fines content and plasticity.

1.2 Field Studies:

Field studies following major earthquakes have produced conflicting evidence as to the effects of silt on the liquefaction resistance of sands. Based upon case histories of actual soil behavior during earthquakes, there is evidence that soils with greater fines contents are less likely to liquefy in a seismic event. Okashi (1970) [13] observed that during the 1964 Nigata earthquake in Japan, sands were more likely to liquefy if they had fines content of less than 10 percent. Additionally, Fei (1991) [14] reports that for the 1976 Tangshan earthquake in China the liquefaction resistance of silty soils increased with increasing fines content. Finally, Tokimatsu and Yoshimi (1983) [15] found in a study of 17 worldwide earthquakes that 50 percent of the liquefied soil had fines contents of less than 5 percent. They also found that sands with fines contents greater than 10 percent had a greater liquefaction resistance than clean sands at the same SPT blow count. While some research has shown that an increase in fines content results in an increase in liquefaction resistance, other research has shown the opposite effect. Tronsco and Verdugo (1985) [16] report that mine tailings dams constructed of soils with higher silt contents are more likely to liquefy than similar dams constructed of sands with lower silt contents. Chang, Yeh, and Kaufman (1982) [17] note that case studies reveal that most liquefaction resulting from earthquakes has occurred in silty sands and sandy silts. Dobry and Alverez (1967) [18], Okusa, Anma, and Maikuma (1980) [19], and Garga and McKay (1984) [20] each report cases of mine tailings dams constructed with up to one hundred percent silt-sized particle liquefying during earthquakes in Chile and Japan. All of the fines involved were either silts of low plasticity or non-plastic silts. Field based methods for determining liquefaction susceptibility, such as methods based on SPT blow counts or CPT measurements, must account for the presence of fines in the soil (Tatsuoka et al, 1980) [21]. Seed et al (1985) [22] modified the cyclic stress ratio (CSR) versus normalized SPT blow count curves originally proposed by Seed and Idriss (1971) [23] to account for the increase in liquefaction resistance provided by an increased fines content. The revised chart provides a series of curves for 5 percent, 15 percent, and 35 percent fines. These curves indicate that, for a given blow count, a larger CSR it required to liquefy a soil with a higher fines content.

1.3 Effects of Plastic Fines Content and Plasticity And Plasticity Based Liquefaction Criteria:

There is general agreement in the literature as to the effect which the quantity and plasticity of the fine-grained material has on the liquefaction resistance of a sandy soil. There is agreement that whether the fine grained material is silt or clay, or more importantly, whether it behaves plastically or non-plastically, tends to make an important, consistent difference in the cyclic strength of the soil. The majority of studies have shown that the presence of plastic fines tend to increase the liquefaction resistance of a soil. Jennings (1980) [23] presents a listing of the “thresholds to liquefaction” used by engineer’s in the People’s Republic of China to separate soils which are considered liquefiable from those considered non-liquefiable. Soils meeting these criteria are considered to be non liquefiable and include those with plasticity indexes greater than 10, clay contents greater than 10 percent, relative densities greater than 75 percent, and void ratios less than 0.80. Other criteria presented are related to epicentral distance, intensity, grain size and gradation, the depth of the sand layer, and the depth of the water table. Seed et al. (1973) [24] in their review of the slides that occurred in the Lower San Fernando Dam during the February 1971 San Fernando earthquake presented a modified form of the Chinese criteria. As reported by Marcuson et al. (1990) [25], soils with greater than 15 percent material finer than 0.005 mm, liquid limits greater than 35 percent, and water contents less than 90 percent of the liquid limit should be safe from liquefaction. Finn, Ledbetter, and Wu (1994) [26] recommended that changes to be made to the Chinese criteria to account for uncertainty and differences in the liquid limit determination between the ASTM and the Chinese standard. They recommended decreasing the fines content by 5 percent, the liquid limit by 1 percent and the water content by 2 percent.14 Koester (1994) [27] recommend that a further change be made to the criteria proposed by Finn, Ledbetter, and Wu (1994) [26] to better account for differences in the liquid limit determination between the ASTM and the Chinese standard. He suggested increasing the liquid limit criteria to a value of 36 percent.

II. The Effects of Non-Plastic Fines:

Liquefaction resistance until some limiting fines content is reached, and then increases its resistance. There is no clear consensus in the literature as to the effect which increasing non-plastic fines content has upon the liquefaction resistance of sand. Both field and laboratory studies have been performed, and the results of these studies indicate that increasing the non-plastic fines content in a sand will either increase the liquefaction resistance of the sand, decrease the liquefaction resistance of the sand, or decreases the liquefaction resistance until some limiting fines content is reached, and then increases its resistance. During the past 40 years the liquefaction of clean sands under seismic loads has been studied and a sound understanding of its mechanisms and the parameters which affect it has been developed. Unfortunately, the understanding of the liquefaction of sands containing fine-grained material is less complete. A review of the literature shows that there is no clear consensus as to what effect an increase in non-plastic silt content has upon the liquefaction resistance of a sand. Both clean sands and sands containing silt have been shown to be liquefiable in the field (Mogami and Kubo, 1953[4]; Seed and Lee, 1966[28]; Youd and Bennett, 1983[29] and in the laboratory Lee and Seed, 1967a[7]; Casagrande, 1975[30]; Koester, 1994[35]. Non-plastic silts, most notably mine tailings, have also been found to be susceptible to liquefaction (Dobry and Alvarez, 1967[18]; Okusa et al., 1980[19]; Garga and McKay; 1984[20]). Numerous laboratory studies have been performed, and have produced what appear to be conflicting results. These studies report that increasing silt content in a sand will either increase the liquefaction resistance of the sand (Chang et al., 1982[17]; Dezfulian, 1982[31]), decrease the liquefaction resistance of the sand (Shen et al., 1977[32]; Tronsco and Verdugo, 1985[16]; Finn et al., 1994[26]; and Vaid, 1994[33]), or decrease the liquefaction resistance until some limiting. Silt content is reached, and then increase its resistance (Law and Ling, 1992[34]; Koester,1994[35],). Additionally, several studies (Shen et al., 1977[32],; Tronsco and Verdugo, 1985[16],; Kuerbis et al., 1988[36],; and Vaid, 1994[33],) have shown that the liquefaction resistance of a silty sand is more closely related to its sand skeleton void ratio than to its silt content.

III. CONCLUSIONS

From the above details and the discussion it is clearly comes to the surface that the fines associated with plasticity do exhibits liquefaction of the soils. The fines with plasticity index greater than 10 and the clay contents above 10 percent possessing the relative densities beyond 75 percent shows the liquefaction of these soils. Besides, the presence of non plastic fines also greatly influences the liquefaction phenomenon in a way that as the percentage of fines increase the resistance to liquefaction also increases. And under the condition when all the voids are fully packed by fine the resistance to liquefaction gets maximized for the given condition of the sandy soil.

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