consisted of 4 minicone tests, 3 standard cone tests and one CPT using a 15 cm^2 cone penetrometer. One borehole was supplemented with SPT and samples were taken to study their properties in the laboratory. In addition, the SPT data from Yatesville dam are presented for comparison.

The last step in this research was to link the cone penetration resistance of silty sands to their cyclic and static behavior determined in the laboratory. Data from the calibration chamber tests were compared with the available correlation charts and used to develop a new relationship of the CPT and the steady state shear strength of silty sand. CPT data from Pepper's Ferry were utilized for liquefaction potential analysis of the site.

9.2. CONCLUSIONS

(1). Laboratory experiments showed that pluviation of silty sand with significant amounts of fines is not suitable for fabrication of triaxial specimen or calibration chamber specimen. A pluviated sample is very loose and does not represent the normal range of density in the field. Consolidation can be regarded as being the best way of obtaining a uniform saturated sample of silty sand for a large scale. This method is similar to the natural alluvial deposition process and applicable to both triaxial specimens and calibration chamber specimens. The only demerit of this technique is that extensive time is needed for the completion of the consolidation.

(2). Laboratory studies on the behavior of Yatesville and Pepper's Ferry silty sands were conducted using monotonic and cyclic loading triaxial tests. The cyclic triaxial tests were performed to find the parameters relating to the cyclic resistance of the soils, and to study the effects of fines as opposed to the clean sands. Consolidated undrained triaxial tests were conducted to measure the steady state shear strength and related parameters, and to investigate the significance of the state parameter on the behavior of silty sands. Several conclusions can be drawn from the laboratory study :

2.1. The cyclic strength of silty sands is similar to those of clean sand. The effects of non-plastic fines are not significant.

2.2. Sample preparation influences the cyclic strength of the material. Samples prepared by compaction and overconsolidated samples show higher resistance to liquefaction. At cyclic stress ratio of 0.3, Yatesville silty sand liquefied at 10 cycles for samples prepared from slurry with OCR = 1. At OCR = 2, the corresponding number of cycles to liquefaction increases to 19 cycles and a compacted sample liquefies at 43 cycles. These findings confirmed previous conclusions drawn by other researchers (Ladd, 1974; Mulilis et al., 1975; Ishihara, 1978).

2.3. The steady state line (SSL) is a unique property of cohesionless material including sands and silty sands (Castro, 1969; Poulos, 1981; Castro et al., 1982; Mohammad and Dobry, 1984). Test results on Yatesville silty sand, Pepper's Ferry silty sand and two other silty sands from the Lower San Fernando Dams show that sample preparation does not affect the SSL. According to Castro, the slope of the steady state line, λ_{ss}, is related to the compressibility, particle shape, and the mineralogy of the soil. The slope for silty sands show a higher values of λ_{ss} than one would expect for a clean sand. This confirms findings by other researchers that finer material normally exhibit a steeper SSL.

2.4. Results from the laboratory study suggest that the state parameter is a good means for normalizing the behavior of silty sands. The stress strain behavior of all silty sands investigated strongly correlated with the state parameter, ψ. Been et al. (1985) have suggested similar conclusions. In this study, it was found that the normalized steady state shear strength and the generated pore pressure during shear also depend on the state parameter. These findings have important implications in that the steady state shear strength could be predicted by means of the state parameter.

2.5. Observation on the dependency of the stress strain behavior of the silty sands investigated lead to a conclusion that samples at state parameters of 0.0 to 0.03 may exhibit contractive or dilative behavior.

(3). Conclusions which may be drawn from the study in the calibration chamber include :

3.1. Cone tip resistances were very low (5 - 30 bars), presumably due to the undrained conditions generated by the presence of fines.

3.2. The normalized tip resistance is a function of the state parameter. This conclusion has been suggested by Been and Jefferies (1986) and Jefferies (1988); however, data from the calibration chamber for Yatesville silty sand shows a steeper slope on the normalized q_c vs. ψ plot than that suggested by Been et al. (1986).

3.3. There is no significant effect of the overburden pressure on the tip resistance of Yatesville silty sand. This may be attributed to the relatively low permeability of the material compared to clean sand. The behavior of the silty sand during penetration is either fully undrained or partially drained. A quantification of this aspect is recommended for further research.

3.4. A comparison of the CPT tip resistances in the calibration chamber to that of the SPT in the field on Yatesville silty sand shows a high degree of consistency. This support the idea that the calibration chamber successfully approximated field conditions.

(4). Field CPT results show that the use of the different sizes of cones do not affect the results and that CPT provided repeatable and reliable test results. Liquefaction potential analyses using the Robertson and Campanella (1985) and Shibata et al. (1988) methods for the Pepper's

Ferry site predicted that the site would liquefy at an earthquake magnitude of 6.8. A comparable analysis using the Seed and de Alba approach (1986) suggested the site would not liquefy even at an earthquake magnitude of 8.5.

(5). The correlation of the liquefaction resistance to the state parameter based on field data from Shibata and Terapaksa (1988) was reviewed. It was found that soils at moderately negative state still possess the potential to liquefy.

(6). A correlation of the steady state shear strength to the CPT was attempted. The correlation has a trend similar to that suggested by Poulos (1988). However, there is much scatter in the correlation, possibly due to the the variations in the void ratio. The undrained steady state shear strength is very sensitive to changes in void ratio. Consequently, this correlation needs to be refined. The correlation of the CPT to S_{us} as measured in the laboratory shows higher values than that of S_{us} back analyzed from the liquefaction flow failure case histories such that presented by de Alba and Seed (1987). This matter needs further research.

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