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LIQUEFACTION CRITERIA FOR SILTS

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SUMMARY

Cyclic load testing and collection of data on the cyclic strength deformation characteristics of silty soils were made. The data points out the difficulty in establishing liquefaction criteria for silts in terms of joint pore pressure and deformation characteristics. Unlike sands, the strains develop before a significant pore pressure increase is recorded. In cases where deformations reach a significant magnitude well before the pore pressures reach 100 percent, "liquefaction criteria" may be defined only in terms of the percent of the strain irrespective of the magnitude of the pore pressures. For loose silts, where 100 percent pore pressure ratio was reached and accompanied by large strains, the liquefaction criteria can be similar to the criteria presently used for sands.

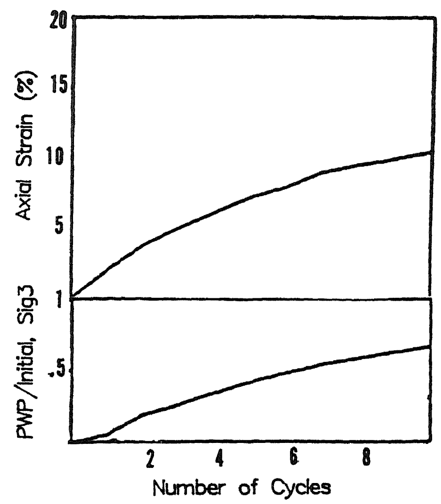
INTRODUCTION

In the pst 20 years the phenomenon of the liquefaction of sand deposits has been the subject of intensive research. As a result, significant improvement has occurred in our ability to measure and predict the probably performance of a wide range of sandy soils during an earthquake. A noticeable gap exists when the soils subjected to shaking are silts and sandy silts.

Data from the testing of undisturbed samples of Valdez silt, Yukon silty soils, soils from tailings dam in Chile, and result of cyclic load testing of loess, were examined (References 1, 2 and 3). In addition, the results of cyclic load testing of silts carried out by Prakash and Puri (1982), Tokimatsu et al (1981) and Zhou (1981) were also examined. Works of Youd and Perkins (1978), Youd (1980) and Seed (1986) on the liquefaction induced deformations of soils were also studied. Experimental studies of the behavior of sands containing various amounts of silts conducted by Chang, et al (1982) were also evaluated. The following sections summarize author's observations on the behavior of silty soils when subjected to cyclic loading.

Figure 1 shows the results of a cyclic triaxial test on a silt sample from Valdez. The upper curve shows the development of strain with increasing numbers of cycles and the lower curve shows the rate of pore water pressure increase. It is readily apparent that the increase in both strain and pore water pressures takes place gradually. This is quite different from the behavior of sands (Seed and Lee, 1966; Singh, Donovan and Park, 1980; and Finn, 1981) where strains which had previously been small start to increase rapidly as the pore water pressure approaches 60 percent or more of the confining pressure.

Figure 2 shows the peak to peak axial strain in percent plotted against the pore water pressure increase, also expressed as a percentage (pore pressure ratio equals 100 percent when the pore water pressure equals the confining pressure) for a wide range of samples. For most of the silt samples (sample #1, 2, 3, 4, 5) whose results are shown in Figure 2 large strains are reached without the development of significant pore pressures. The exception appears to occur for loose silt (sample #6) which approximate the curves for sand (sample #7, 9, 10 and 11) shown on Figure 2. The envelope curves for the grain size of the soils whose test results are given in Figure 2 are shown in Figure 3.



Alyeska Valdez Brg3 Sample 2

Fig. 1

Figure 4 shows a comparison of pore pressure development in a typical silt sample and a typical loose sand sample. For most of the silt samples tested, the trend of pore pressure development was different than for sands. It takes a large number of cycles of loading to reach the 100 percent pore pressure ratio which is similar to the buildup of pore pressures in a dense sand sample. In some of the silt samples a pore pressure ratio of 100 percent was never reached. It is uncertain whether this is a true representation of the soil behavior or a consequence of the difficulty of measuring transient pore pressure changes at the base of a relatively impervious sample.

LIQUEFACTION CRITERIA FOR SILTS

Although pore pressure and deformation characteristics under cyclic loading are closely related, there is a problem in establishing liquefaction criteria for silts in terms of joint pore pressure and deformation characteristics. In almost all the silt samples tested, a gradual softening of the sample was observed right from the start of the test. In cases where deformations reach a significant magnitude well before the pore pressure reaches 100 percent, "liquefaction criteria" may be defined only in terms of the percent of strain irrespective of the magnitude of the pore pressure. For loose silts where the 100 percent pore pressure ratio was reached and accompanied by large strains, the liquefaction criteria can be described by a

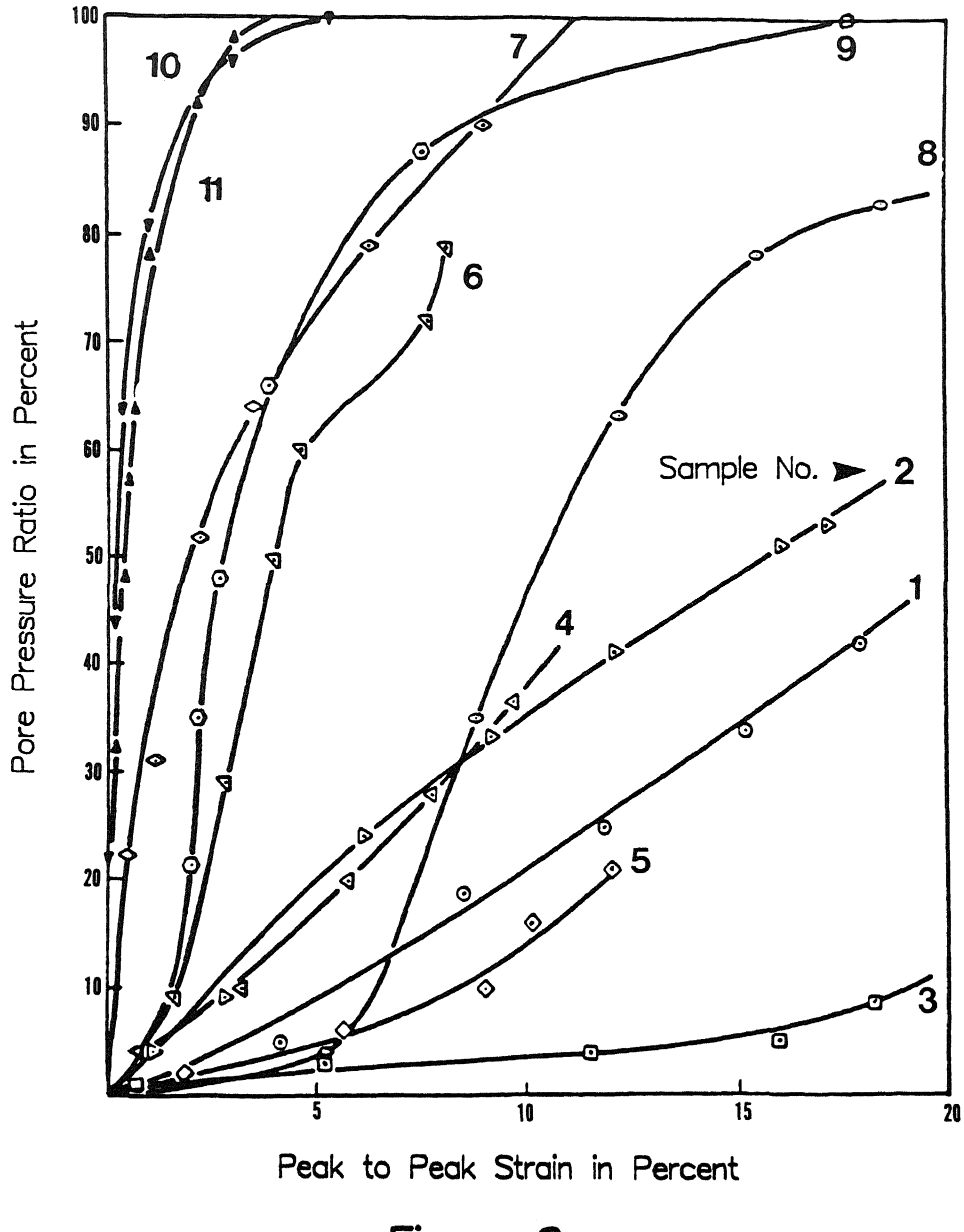
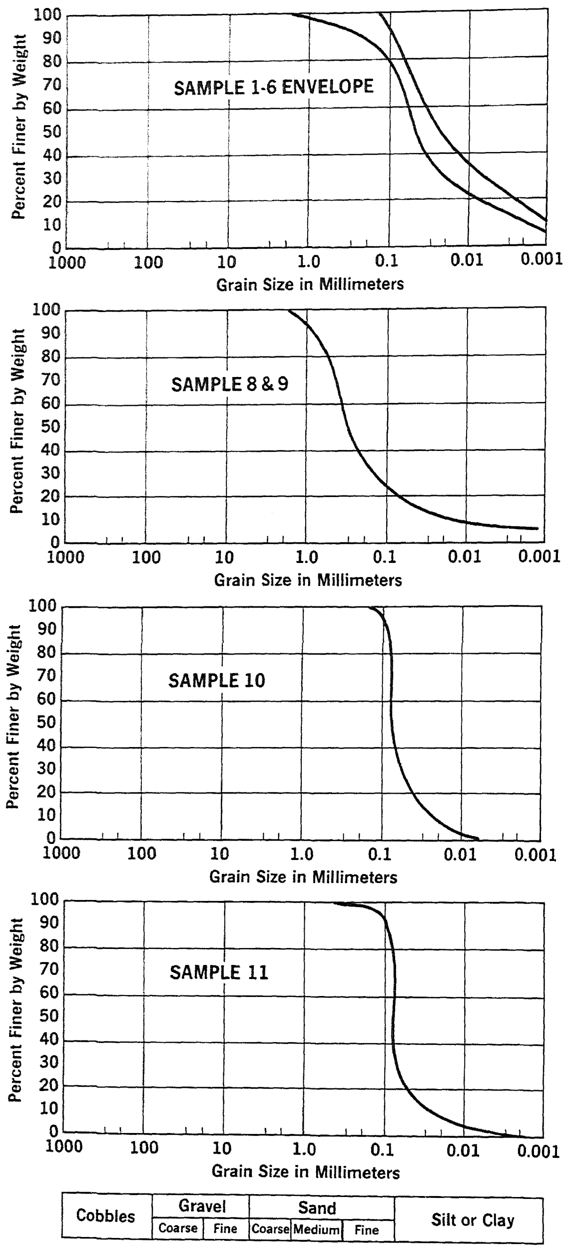

Pore Pressure Ratio in Percent
Peak to Peak Strain in Percent
Sample No.
100
90
80
70
60
50
40
30
20
10
5
10
15
20
1
2
3
4
5
6
7
8
9
10
11

Figure 2



SAMPLE NO.	DESCRIPTION	DRY DENSITY AFTER CONSOLIDATION p.c.f.
1	Gray Silt	98.9
2	Gray Clayey Silt	98.2
3	Gray Silt	98.70
4	Gray Silt	109.0
5	Gray Clayey Silt	107.44
6	Gray Silty Clay to Clayey Silt	81.52
7	Phase II Gray Clay Silt	95.7
8	Layered Silt and Medium Fine Silty Sand	109.3
9	Gray Silty Medium Fine Sand	120.8
10	Silty Fine Sand	92.0
11	Gray Clayey Silty Fine Sand	91.5

FIGURE 3
GRAIN-SIZE DISTRIBUTION
(unified soil classification system)

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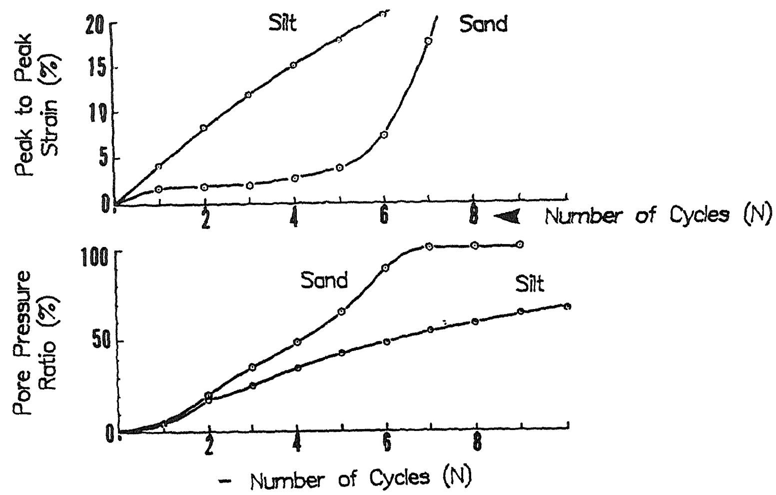

Figure 4

100 percent pore pressure ratio with 10 percent of strain potential. This is similar to the criteria presently used for sands.

CONCLUSIONS

The liquefaction behavior of silts appears to be significantly different from the liquefaction behavior of sands. The following conclusions can be made:

1) There is a problem in establishing criteria for liquefaction in terms of joint consideration of pore pressure and deformation.

2) For sands it is possible to use pore pressure criteria to describe terms such as initial liquefaction and estimated strain potential. For most silts this is not possible because the 100 percent pore pressure increase is not reached during testing. Unlike sands, the strains develop before a significant pore pressure increase is recorded.

3) The differences in permeability and fabric of soils containing various amounts of silts leads to various different pore pressure generation characteristics.

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