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EFFECT OF DIFFERENT PARAMETERS ON LIQUEFACTION POTENTIAL OF SOILS UNDER CYCLIC LOADING

EFFET DE DIVERS PARAMETRES SUR LE POTENTIEL DE FLUIDIFICATION DES SOLS SOUS CHARGEMENT CYCLIQUE

*U.D. Datir*¹ *N.K. Ingreji*²

¹Joint Director, ²Assistant Research Officer
Gujarat Engineering Research Institute, Vadodara, Gujarat, India

SYNOPSIS : Failures of many structures are reported all over the world resulting from Liquefaction. Research efforts to understand this complex phenomenon are in progress at the Global level. Laboratory studies on the liquefied soils as well as standard sands and also model materials like glass beads, carborandum etc. are conducted to observe the effect of different parameters on their Liquefaction susceptibility. The laboratory experiments for the present work were conducted on a sophisticated cyclic triaxial test system using one standard sand, two in-situ soils, which are typically prone to Liquefaction. The observed effects of different parameters on Liquefaction potential are in general agreement with those reported by researchers. There is a scope for studying the effects of other parameters, namely, Saturation, Sample Preparation Technique, Particle size, Admixtures etc.

INTRODUCTION

Seismically induced liquefaction is viewed as a great threat to the safety of civil engineering structures. During last three decades a progressive research has taken place all over the world to understand the complex mechanism of liquefaction. Liquefaction is a phenomenon wherein a mass of soil loses a large percentage of its shear resistance when subjected to undrained monotonic, cyclic or shock loading and flows in a manner resembling a liquid. Liquefaction also involves the destruction of a metastable microstructure of the soil mass. The authors have studied the effect of Relative Density, Confining Pressure, Cyclic Load Amplitude and Cyclic Stress Ratio on liquefaction potential of Sipu Project soil, soil collected from bed of river Sabarmati of Gujarat and standard Ennore (fine) sand.

EXPERIMENTAL SET-UP

Laboratory experiments were conducted on a sophisticated electro-hydraulic, servo-controlled, closed loop test system called Standard Vibration Triaxial Compression Testing Machine, made in Japan. It provides a facility of cyclic load application in axial and/or lateral directions in three different wave forms, namely, Sinusoidal, Triangular and Rectangular. A six-channel Oscillograph and a two-channel Visigraph are provided. Other special features of the system are facilities of Vacuum and Back pressure. An overview photograph of the test system is shown as Fig.1.



Fig.1 Overview of Cyclic Triaxial Test System

Properties of Test Materials

The physical properties of the Test materials are given in Table-1.

Their particle size distribution curves are shown as Fig.2.

Table-1 Physical Properties of Test Soils

Soil Type	Particle Size Parameters		G	k x10 ⁻² cm/s
	Cu	Cc		
River Sabarmati	2.91	0.81	2.64	1.69
Sipu Project	4.75	0.87	2.66	1.24
Standard Ennore (Fine)	2.13	1.02	2.64	0.50

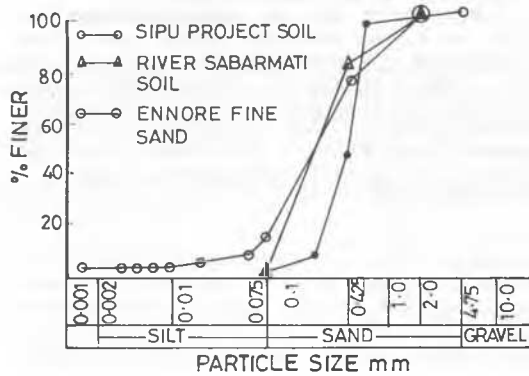


Fig.2 Particle Size Distribution Curves

In view of the values of the particle size parameters, namely, % fines, D60, Coefficient of Uniformity, Cu; theoretically the soils are prone to liquefaction.

Test Parameters

In general, the Test parameters were fixed as under :
 Skempton's B-Value : 0.96 (minimum)
 Initial effective confining pressure 0.75, 1.0 and 1.25 kg/cm²
 Loading wave form : sinusoidal
 Frequency of cyclic loading : 0.5 Hz
 Double Amplitude of Cyclic loading : 15kg, 20 kg and 30 kg
 Average RD after consolidation : 65% (Sabarmati River Soil and Sipu Project Soil)
 50% (Standard Ennore Fine Sand)
 40% (Sipu Project Soil)

Test Procedure

Sample preparation

Dry pluviation method was used for remoulding the sample of 50mm diameter and 125mm height. Vacuum was utilised in preparing the cohesionless sample.

Saturation and consolidation

Initially the sample was saturated by flushing with de-aired water for about 30 minutes. Confining pressure and back

pressure were then raised simultaneously in small increments of 0.50 kg/cm². A minimum B-value of 0.96 was ensured by performing a check under closed drainage condition. Thereafter the sample was consolidated isotropically under an effective confining pressure as prescribed for an individual test. The changed post-consolidation values of volume and height of the sample were recorded for calculating the post-consolidation area and relative density.

Cyclic loading

The loading piston was rested on top of the sample. Load frequency of 0.5 Hz, sinusoidal wave form, cyclic load amplitude and probable number of cycles to cause liquefaction were set. All the valves leading to the sample except the one for pore water pressure measurement were closed. Clamping bolt was loosened and dynamic loading was started in load-controlled mode. The number of cycles required to cause initial liquefaction were recorded on Direct print oscillogram. Loading was then stopped. Fig.3 shows an Oscillographic record obtained during a test.

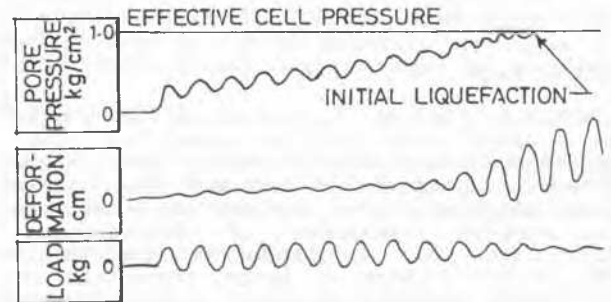


Fig.3 Oscillographic Record

ANALYSIS

Different plots are prepared based on the experimental data.

Effect of Relative Density (RD)

Fig.4 shows the relationship between percent RD and number of cycles causing liquefaction for Sipu Project soil.

This relationship is obtained for two sets of samples, tested under different cyclic load amplitudes of 20 Kg and 25 Kg, maintaining the same initial effective confining pressure of 1.0 Kg/cm². In both the cases, with increase in RD, the strength in terms of number of cycles required to cause liquefaction increases, that is, the liquefaction potential decreases. The figure also reveals that effect of RD on strength is more pronounced at low axial cyclic load amplitude (ACLA) than for high cyclic amplitude.

Effect of Cyclic Load Amplitude

The relationship between ACLA and number of cycles causing liquefaction is shown in Fig.5.

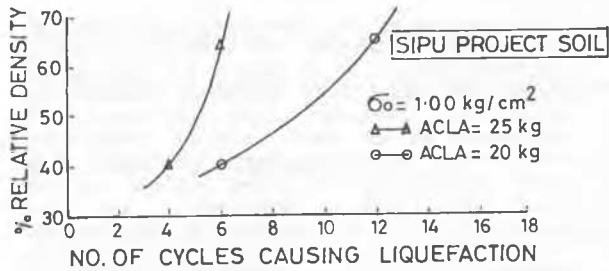


Fig. 4 Relationship Between Relative Density and Number of Cycles causing Liquefaction

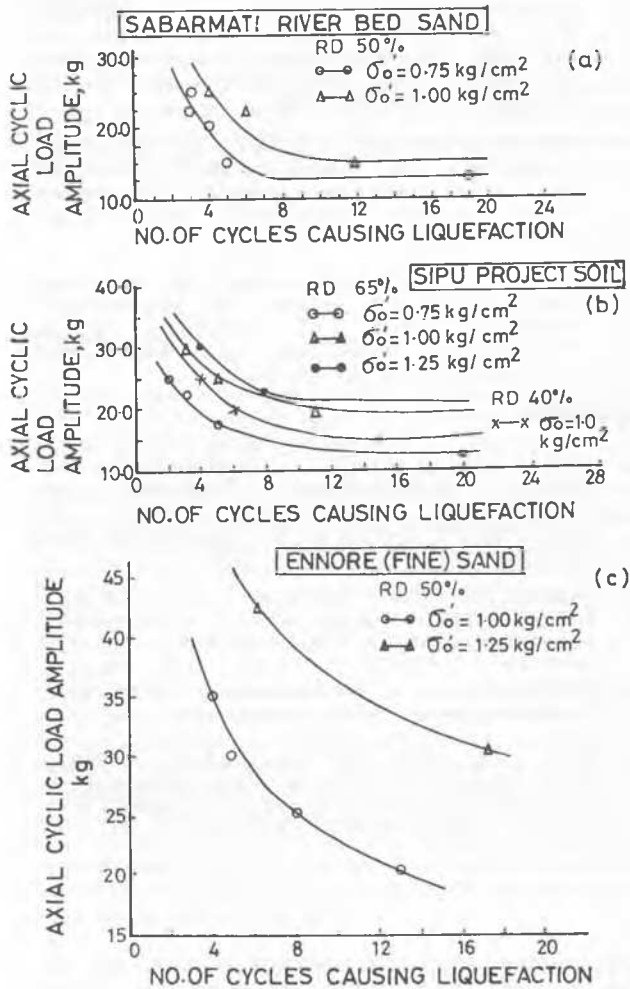


Fig. 5 Relationship Between Axial Cyclic Load Amplitude and Number of Cycles causing Liquefaction

Fig. 5 (a) is for River Sabarmati soil at average RD 65%. Fig. 5 (b) is for Sipu Project soil at average RD 65% and 40% and Fig. 5(c) is for Standard Ennore (Fine) sand at average RD 50%. It is revealed from all these figures that with increase in cyclic load amplitude, the strength in terms of number of cycles causing

liquefaction decreases, that is, the liquefaction potential increases. Fig. 5(a) further indicates that at low axial cyclic load amplitude there is a pronounced effect of decrease in initial effective confining pressure on strength than at higher cyclic load amplitude. Fig. 5(b) also indicates similar trend. It also shows that at low axial cyclic load amplitude, there is a pronounced effect of decrease in RD on strength. Fig. 5(c) also exhibits effect of initial effective confining pressure as discussed above.

Effect of Confining Pressure

The relationship between the initial effective confining pressure and number of cycles causing liquefaction is shown in Fig. 6(a), 6(b) and 6(c) for River Sabarmati soil, Sipu Project soil and Standard Ennore (Fine) sand respectively.

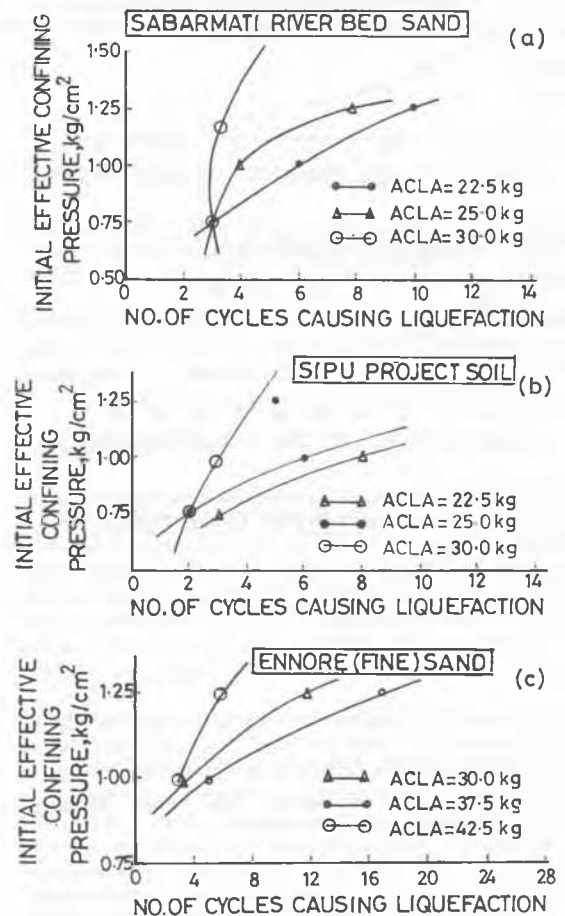


Fig. 6 Relationship Between Initial Effective Confining Pressure and Number of Cycles causing Liquefaction

Each plot is formed by three curves, each generated for a set of samples tested under particular axial cyclic load amplitude; but the samples in all the curves are remoulded at the same RD. It is revealed

that with increase in confining pressure, the strength in terms of number of cycles causing liquefaction increases, that is, the liquefaction potential decreases. The figures also reveal that as the axial cyclic load amplitude increases the effect of increase in initial effective confining pressure on strength diminishes.

Effect of Cyclic Stress Ratio (CSR)

Each test soil was subjected to a series of cyclic load amplitudes at constant confining pressure. From this test data, a relationship is developed between CSR (the ratio of cyclic shear stress and effective confining pressure) and number of cycles causing liquefaction. This is shown in Fig.7(a), 7(b) and 7(c).

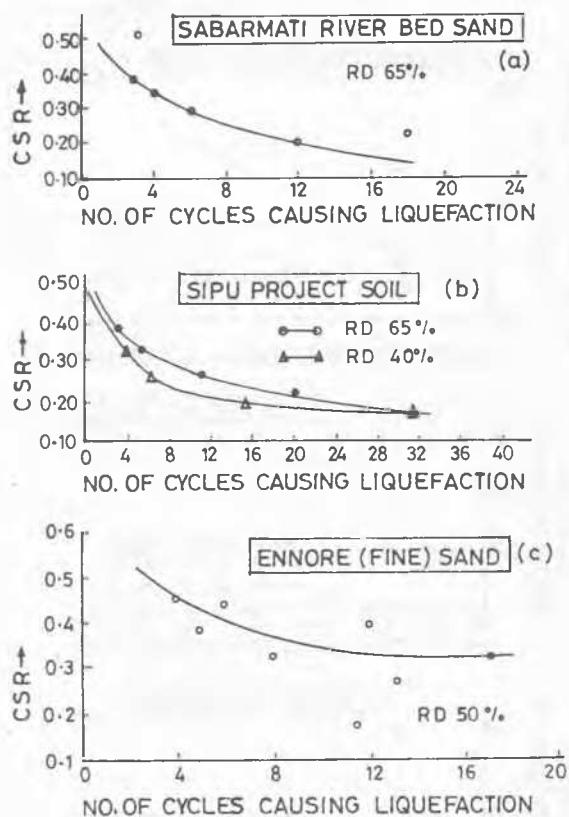


Fig.7 Relationship Between CSR and Number of Cycles Causing Liquefaction

The strength of a soil in terms of number of cycles causing liquefaction decreases with increase in CSR. Indirectly, this gives a critical stress level below which liquefaction will not occur. Fig.7(b) further exhibits effect of RD on strength at low and high CSR. At low CSR the effect is pronounced.

CONCLUSIONS

- (a) The strength of the test soils/sand in terms of number of cycles causing liquefaction is seen to increase with increase in RD and confining pressure. However, the effects of decrease in RD and initial effective confining pressure on strength are more pronounced at lower axial cyclic load amplitudes. Moreover, as the axial cyclic load amplitude increases, the effect of increase in initial effective confining pressure on strength diminishes.
- (b) The strength of the test soils/sand in terms of number of cycles causing liquefaction is seen to decrease with increase in cyclic load amplitude and CSR. It is further observed that at lower CSR, the effect of RD on strength is pronounced.
- (c) The observations on effect of different parameters on liquefaction potential of soils are in general agreement with those obtained by other researchers.
- (d) There is a further scope of studying the effects of Degree of Saturation, Particle Size of soils, Sample Preparation Techniques and Admixtures on liquefaction potential.

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