Cyclic Triaxial Tests On Kolkata Clay

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Abstract

Stress controlled cyclic triaxial tests were performed under different cyclic stress ratios (CSR) and confining pressures of 50 kPa and 100 kPa on a locally available clay to study the axial strain and pore pressure response under these loads at frequency of 0.1Hz. It was observed that increase in axial strain was not much upto CSR of 0.3, thereafter the increase was appreciable. There is insignificant effect of effective confining stress on the axial strain and pore pressure response of the soil. The degradation index of the soil is within a range of 0.16 to 0.3.

Keywords: Cyclic stress ratio, pore pressure ratio, degradation index

1. Introduction

Soil under cyclic loading undergo deformation or pore pressure increase ultimately leading to failure either due to excessive deformations or pore pressure increase. The stress- strain-pore pressure behavior of clay has been studied under constant stress and constant strain amplitudes for both one way and two way cyclic loading [1,2,3,4,5,6]. A critical level of cyclic loading has been identified above which the strain and pore pressure increases with increasing number of loading [2, 3, 4, 6]. Below this critical loading strain and pore pressure reaches non-failure equilibrium. Matsui et al, Ozaydin and Erguvanli, Ansal et al [4,7,8] reported significant influence of rate of loading on the response of soil under cyclic loading. The degradation response was found to depend on the imposed cyclic strain as well as the relative stiffness of soil [9].

The response of Kolkata soil under repeated loading has not been well addressed in literature and hence this study has been undertaken to fill the gap.

2. EXPERIMENTAL WORK

In this study reconstituted clay samples were prepared using locally available clay. The specific gravity and plasticity index of the soil was found to be 2.62 and 23% respectively.

Water was added to air dried pulverized soil to make soil slurry and consolidated in a mould of length 300mm and inner diameter 75mm under vertical pressure of 50, 100, 150 or 200 kPa, as required, for a period of two days. Specimens of 75mm diameter and 150 mm height were trimmed from the sample obtained from the mould and used for conducting the tests. The bulk density and final moisture content were found to be 1.81-1.87 gm/cc and 32-36% respectively.

Table 1 shows the results of undrained static triaxial tests conducted on samples consolidated at effective confining stress of 50, 100, 150 and 200 kPa.

A computer controlled cyclic triaxial system was used for conducting the cyclic tests. The samples were consolidated in the cell of the cyclic triaxial set up consolidate isotropically for one more day by applying cell pressure and back pressure simultaneously as required to maintain the effective confining pressure.

Cyclic triaxial tests were conducted by applying one-way cyclic deviator stress of different magnitudes at frequencies of 0.1 Hz under effective confining stress 50 and 100 kPa until the displacement stabilized or the sample failed due to excessive deformation.

Table 1. Results of undrained static triaxial test

Effective Confining stress (kPa)	Deviator stress at failure (kPa)	Pore pressure (kPa)
50	38.6	26
100	72.1	54
150	102.2	87
200	136.3	115

Table 2. Test Program of cyclic triaxial tests

Soil	Confining pressure p_o'(kPa)	CSR
Clay	50	0.18, 0.22, 0.3, 0.37, 0.42.0.45
(RC)	100	0.17,0.23, 0.3, 0.34, 0.37, 0.40, 0.45, 0.48

Deformation of the sample was measured using LVDT having sensitivity of 0.01mm and range of 20mm and pore pressure was measured using pore pressure transducer connected at the bottom of the specimen.

The test program for the present investigation is given in Table 2. A combination of different cyclic stress ratios(CSR) varying from 0.16 to above 0.4 have been applied to study the response of axial strain and pore pressure at these varying CSRs. CSR is the cyclic stress normalized by the effective confining stress. Pore pressure is depicted in terms of pore pressure ratio which is the excess pore pressure generated normalized by the effective confining stress.

3. Undrained cyclic triaxial tests

The soil is subjected to different cyclic stress ratios and the response of the peak axial strain and pore pressure with the number of cycles are studied. Figs. 1 shows the typical variation of cyclic deviator stress with respect to time at confining pressure of 100 kPa and frequency of 0.1 Hz for CSR of 0.34.

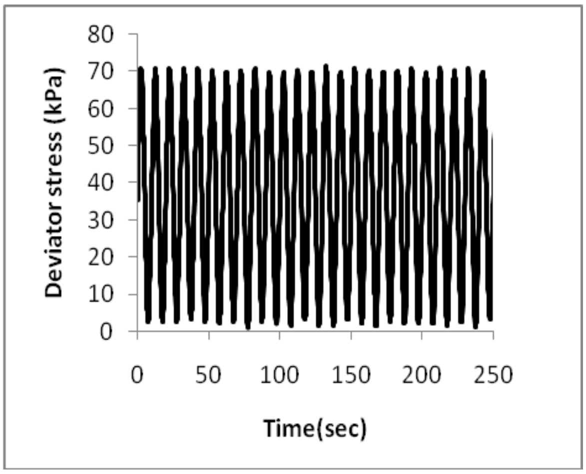
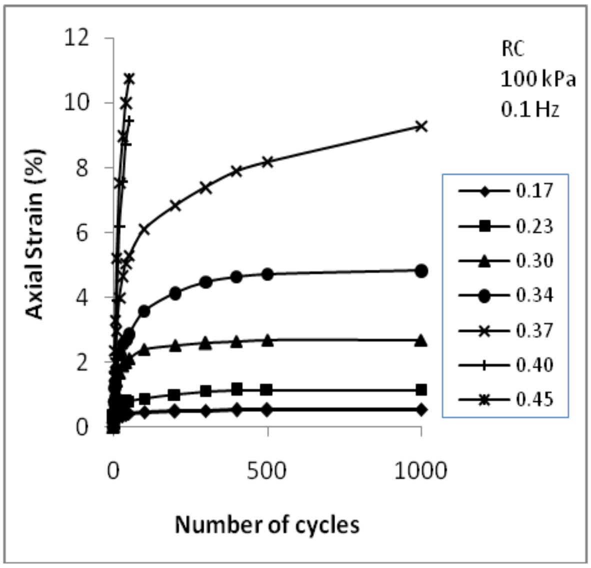
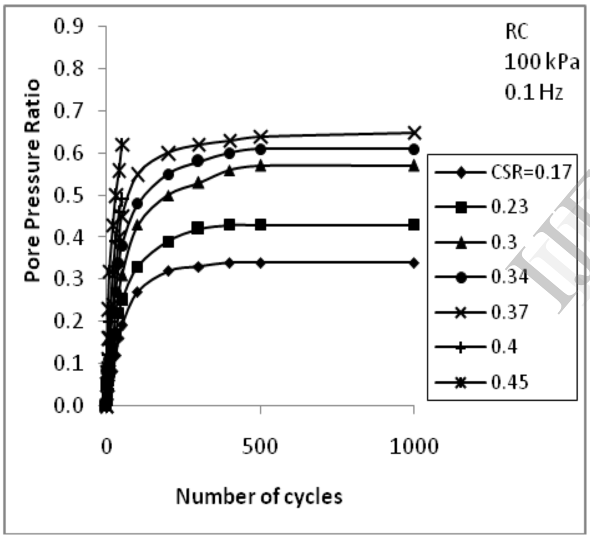


Fig.1 Typical cyclic deviator stress vs. time at CSR of 0.34

The peak axial strain response with number of cycles at effective confining pressure of 100 kPa and frequency of 0.1 Hz for different CSRs is shown in Fig. 2(a) and



(a)



(b)

Fig. 2 (a) Axial strain and (b) pore pressure ratio response at different numbers of cycles during cyclic loading.

the pore pressure ratio response in Fig.2(b). It is observed that for CSRs of upto 0.34, the axial strain increases with increase in number of cycles and tend to stabilize at some final value at high numbers of cycles. These final axial strain at which the soil tend to stabilize increases with increase in number of cycles. At CSR of 0.37, the axial strain keep on increasing without stabilizing although the rate of increase in axial strain is small. At CSR of 0.4 and 0.45 there is a sudden increase in the axial strain and the soil fails due to excessive strain.

The pore pressure developed in the soil is similar to the development of the strain at different CSRs. The pore pressure ratio increase as the CSR increase and stabilize at some value. At CSR of 0.37 where the rate of axial strain increase is slower than at 0.4, the pore pressure reached a stabilized value whereas at CSR of 0.4 and above, a sudden increase in pore pressure ratio is observed where there was a sudden increase in axial strain. The pore pressure at CSR below 0.3 is less than 54 kPa which was developed during static loading at the same effective confining stress. At CSR 0.34 the pore pressure is about 60 kPa which is more than the pore pressure developed in static condition at the same effective confining stress is showing that more pore pressure is generated during cyclic loading.

Fig.3 shows the stress path diagram defined by p′-q′ where p′ is defined $(\sigma'_1+2\sigma'_3)/3$ and q′ as $(\sigma'_1-\sigma'_3)$. The p′ and q′ values taken at the point of maximum deviator stress at different cycles are shown for different CSRs. The critical stress line (CSL) from static triaxial test is also shown alongside for comparison. It is observed that the p′ line slowly shifts towards CSL but for lower CSRs it does not reach the CSL and the soil stabilizes before reaching the CSL. As CSR increases, the p′ line moves nearer the CSL and at CSR of 0.34 it just touches the CSL. The p′ line crosses the CSL at CSR of 0.37 indicating failure of the sample.

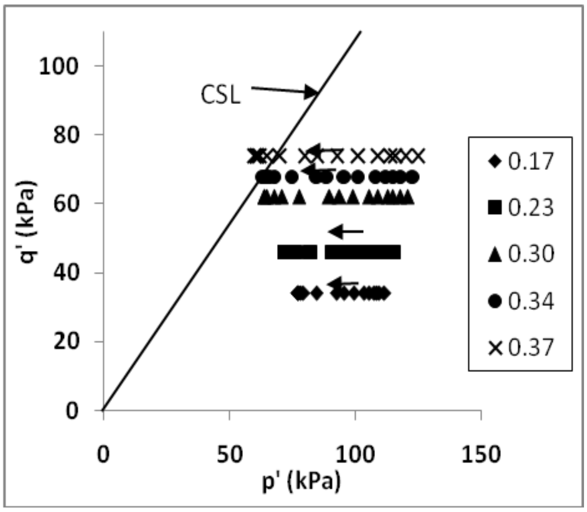


Fig.3 Stress path at maximum deviator stress for different CSRs.

4. Effect of confining stress

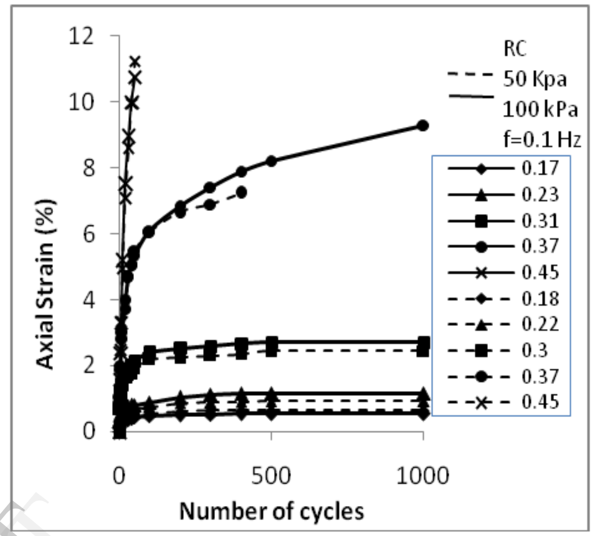
Fig.4(a) and 4(b) show the axial strain and pore pressure ratio at effective confining stress of 50 kPa and 100 kPa. It is observed from this Figs. that there is little influence of effective confining stress on the response of the soil to cyclic loading.

5. Degradation during cyclic strength

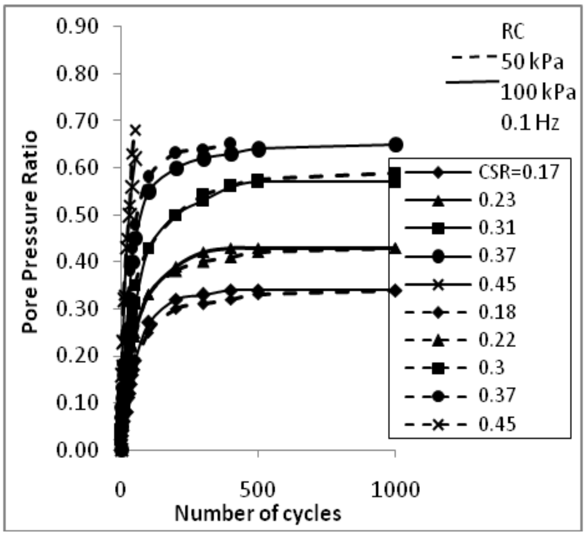
The degradation in the soil during cyclic loading can be studied using the degradation index as defined by Idriss et al. (1978) as

$$\delta = \frac{E_N}{E_1} = \frac{\varepsilon_1}{\varepsilon_N}$$

where E_1 and E_N are the secant modulii at cycles 1 and N respectively; ε_1 and ε_N are the axial strains at cycles 1 and N respectively. The degradation index is a measure of the degradation occurring in the structure of the soil. Fig.3 shows the variation of degradation index at different numbers of cycles for different CSRs. It s observed from this figure that there is steep reduction in the degradation index in the initial 80 to 100 numbers of cycles after which the reduction becomes almost stable. A definite relationship of degradation index with CSR cannot be ascertained from the results obtained, however it stabilizes within a value of 0.16 to 0.3.



(a)



(b)

Fig.4 Effect of effective confing stress on (a)axial strain and (b) pore pressure ratio

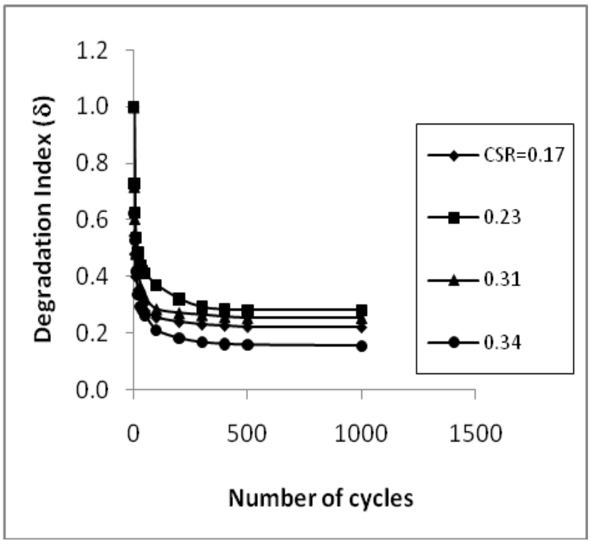


Fig.5 Variation of degradation index with number of cycles.

4. Conclusions

On the basis of above studies following conclusions may be drawn :

(1) The axial strain developed is not much upto CSR of 0.3 after which there is an appreciable increase in the strain. The soil fails at CSR of 0.37.

(2) Both the axial strain and pore pressure are affected by the number of cycles.

(3) There is insignificant effect of effective confining stress on the response of soil under cyclic loading.

(4) The degradation index value is within 0.16 to 0.3

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