Evaluation of Dynamic Soil Properties of Sandy Soils

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Abstract- **Determination of Dynamic soil properties is an utmost critical and important aspect of geotechnical earthquake engineering problems. Basically, the damage due to dynamic loading (e.g. earthquake strong motions) is substantially influenced by the response of soil deposits which is governed by the dynamic soil properties. This paper reports a study on the determination of shear modulus and damping ratio of locally available sand under certain amplitude, frequency and confining pressure using stress controlled undrained Cyclic Triaxial test.**

Keywords: Cyclic triaxial test, Dynamic soil properties, shear strain

I. INTRODUCTION

Dynamic soil properties such as shear wave velocity, modulus reduction and damping characteristics of local soils are the essential input parameters for conducting a preliminary ground response analysis. The dynamic response of soil is noticeably nonlinear due to the displacements induced by the earthquake(Bolt 1999). Soil is generally considered as a three-phase system (air, water and solid) whose characteristics are significantly affected due to the interaction of these phases under applied static and/or dynamic load. Behaviour of soil under dynamic loads being significantly different than that as obtained from the static tests, for all geotechnical problems, it is imperative to ascertain the dynamic properties of the soils especially for the earthquake prone regions. These properties further help to assess the vulnerability of the site and the associated structures due to ground shaking. Shear modulus (and its degradation) and the variation of damping ratio with varying shear strain levels are considered to be the most important of the soil dynamic properties. Researches related to such aspect is long-going, however, due to the spatial variability of the soil throughout the world, test results from one soil might not conform to that of the other. When subjected to earthquake or cyclic loading, the shear modulus and damping ratio of the soil are influenced by many factors like soil type, plasticity index, cyclic strain amplitude, relative density, frequency of loading cycle, effective confining pressure, overconsolidation ratio, and number of loading cycles (Kumar et. al., 2013). The above mentioned factors make it necessary to carry out such tests for different type of soils. This paper presents the study on determination of dynamic soil properties of sand using cyclic triaxial testing (Shiv Shankar et.al., 2014).

II. MATERIAL AND TEST PROCEDURE

A. *Materials used*

Sand has been used to determine dynamic properties using cyclic triaxial equipment. The particle size distribution (PSD) is determined using the dry sieve analysis (ASTM D 6913-04), the results of which is enumerated in Table 1. Based on the obtained results, as per the Unified Soil Classification System USCS, the test material been classified as poorly graded sand (SP). Specific gravity has been found to be 2.65 and the maximum and minimum dry densities are obtained as 16.99 kN/m^3 and 13.71 kN/m^3 respectively.

Table.1: sieve analysis results

Sieve size (mm)	cumulative weight of sample retained	% of sample retained	%finer
4.75	0	0	100.00
2.36	0	0	100.00
1.18	110.00	22	78.00
0.6	270	54	46.00
0.425	407	81.4	18.60
0.3	462	92.4	7.60
0.075	500	100	0.00

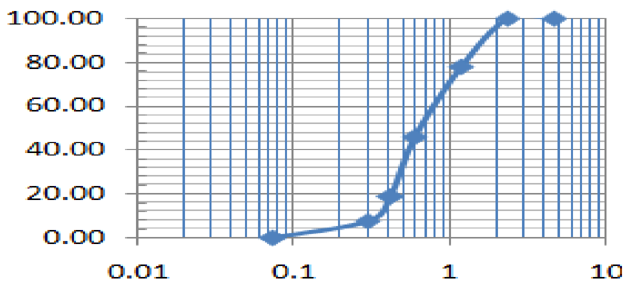

Fig 1: Particle size distribution of sand sample

Table 2: Physical property of sand used

SOIL	D60 (mm)	D50 (mm)	D30 (mm)	D10 (mm)	Cu	Cc
SAND	0.8	0.65	0.49	0.37	2.162	0.81

B. *stress–controlled cyclic triaxial test*

Stress-controlled cyclic triaxial tests have been carried out on cylindrical specimen (75 mm diameter and 150 mm height). Saturation of the sample is achieved with water by applying back-pressure. Saturation is said to be achieved when the Skempton's Bvalue is obtained to be greater than 0.95.

In cyclic strain approach, earthquake-induced loading is expressed in terms of cyclic shear strains (SA γ) (Kramer, 1996; Drenvich, 1970; Kokuso, 1980; Seed and Idriss, 1981; Yu and Richart, 1984; V.Jaya, 2007). In the laboratory, the same has been achieved by converting the applied single-amplitude axial strain (SA ε) which is expressed as in Eqn. 1:

$$\gamma_{SA} = \varepsilon_{SA} \times (1+\upsilon), \quad \varepsilon_{SA} = \Delta L / L_s$$

where, ΔL = single amplitude deformation (mm),
L_S =length of test specimen (mm).

Fig. 2 Cyclic triaxial setup

The Cyclic Triaxial test apparatus used for the present study are as shown in fig.2. To comprehend the strain dependent dynamic behavior of sand stress controlled undrained test was conducted on isotropically consolidated sample.

III. EVALUATION OF DYNAMIC PROPERTIES OF SOIL

Test records of cyclic triaxial tests have been utilized to plot the variation of deviator stress (σ_d) with axial strain (ε) which is typically represented in one complete cycle by a hysteresis loop (ASTM-D3999-11) as shown in fig.3 The following equations can be used to evaluate dynamic Young's modulus (E), dynamic shear modulus (G), shear strain from the applied axial strain based on the Poisson's ratio (υ).

$$E = \sigma_d / \varepsilon = \left(\sigma_{d,\max} - \sigma_{d,\min}\right) / \left(\varepsilon_{\max} - \varepsilon_{\min}\right)$$

$$G = E / \left[2(1+\upsilon)\right]$$

$$\gamma = (1+\upsilon)\varepsilon$$

$$D = \frac{1}{4\pi} \frac{A_L}{A_\Delta}$$

where A_L = area enclosed by the hysteresis loop which represent dissipated energy by soil during its deformation and is a measure of internal damping with in the soil mass (Kramer, 1996) and A_Δ = area of the shaded triangle which represent maximum strain energy stored.
Here, these values are directly obtained from digital acquisition system associated with triaxial equipment. This acquisition system gives all the dynamic properties i.e., shear modulus, damping ratio etc for every cycle of loading separately using which variation of dynamic soil properties of soil with number of loading cycles can be easily analyzed.

IV. RESULTS AND DISCUSSION

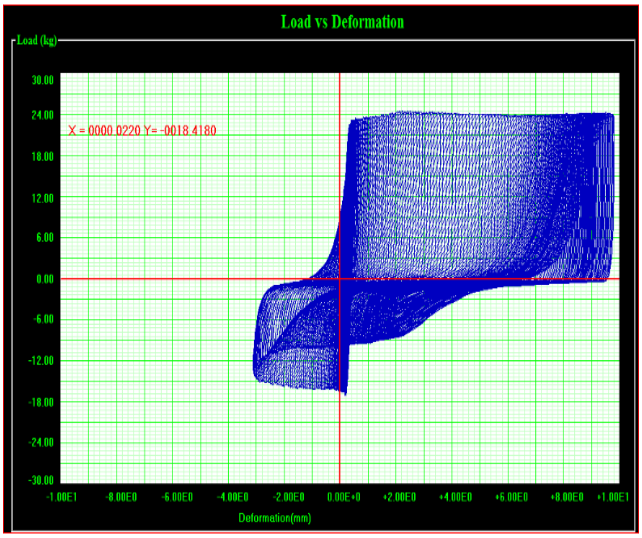

Fig 3: variation of load vs deformation under stress controlled test

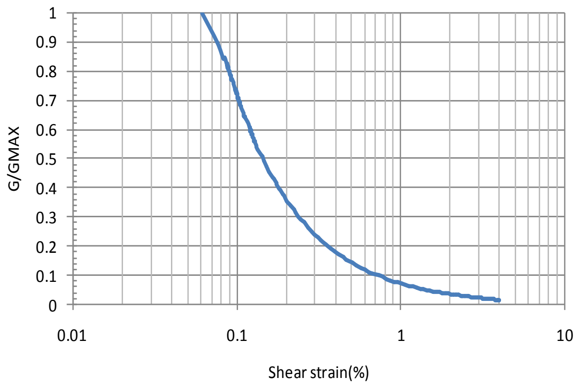

Fig 4: variation of G/G_{MAX} vs shear strain(%) under stress controlled test

The typical dynamic response of a sand at amplitude of 20kg subjected to a loading frequency of 1.0 Hz, effective confining pressure of 100 kPa are as shown in fig 3. Based on 300 cycles of applied stress fig .4 represents the variation of G/G_{MAX} value with axial strain(%). From fig 3, It can be seen that the area of hysteresis loop is decreasing with increasing number of loading cycles. It has also been observed that both mean effective stress and deviator stress reduces due to increase in pore water pressure. Similar outputs have been observed at others shear stess level. The progressive increase in pore water pressure with strain cycles causes reduction in shear stiffness of the soil, which causes the hysteresis loop to become flatter, experimentally observed to represent a liquefaction state (supported by the recorded excess pore-water pressure ratio).

From the results it has been observed that young's modulus(E), shear modulus(G), Damping ratio value of soil varies from 925-14.3kg/cm^2,308-4.7kg/cm^2,24.4-7.72% respectively where poisons ratio was assumed to be 0.5.

V. CONCLUSION

Based on the cyclic triaxial studies, it has been observed that the soil properties such as shear modulus, damping ratio etc decreases with number of loading cycles and at a particular stage deviatoric stress reaches a minimum value showing soil cannot take any load further. Hence, it is necessary to evaluate these dynamic properties in the places where soil is prone to dynamic loading before going for construction.

VI. REFERENCES

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