Dynamic Properties of Sandy Soils at Large Shear Strains with Special Reference to the Influence of Non-Plastic Fines

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ABSTRACT

This paper presents the results of the dynamic properties such as shear modulus and damping ratio of sandy soils, especially at large shear strain levels (>0.2%). A series of strain controlled cyclic triaxial tests were carried out on sand samples collected from the earthquake affected areas of Gujarat, India. Laboratory investigations were conducted on natural sand (Base sand) and clean sand samples. The shear modulus and damping ratios have been estimated based on the first cycle information. The effect of different parameters such as number of loading cycles, relative density, confining pressures, and non-plastic fines on the dynamic properties of the soils has been studied. It was observed that shear modulus decreases with an increase in the percentage of non-plastic fines. However, a slight increase in damping ratio was observed with increase in non-plastic fines.

Keywords: Cyclic Triaxial Test, Dynamic Properties, Earthquakes, Sands, Shear Modulus

INTRODUCTION

Strain dependent dynamic properties such as shear modulus (G) and damping ratio (D) are the two major parameters generally used for the analysis of engineering structures subjected to seismic loading. During seismic loading, the response of the soil mass is often dependent on these strain dependent dynamic properties and adequate information of these properties is very important for earthquake engineering problems. For many important problems, particularly those dominated by wave propagation effects, only low levels of strains is induced in soil and for other, such as stability of masses of soils, large strains are induced in the soils. Therefore, evaluation of the strain dependent properties had to carry out not only at low strains, but also at intermediate and high shear strain levels. In the recent past many investigations were car-
ried out to understand influence of different parameters such as cyclic strain amplitudes, effective confining pressures, soil types, plasticity index, density, frequency of loading, number of loading cycles, overconsolidation ratio, degree of saturation and grain characteristics on the dynamic properties of soils (Richart et al., 1970; Seed & Idriss, 1970; Hardin & Drnevich, 1972; Iwasaki et al., 1978; Kokusho et al., 1982; Seed et al., 1986; Vucetic & Doby, 1991; Ishibashi & Zhang, 1993; Stokoe et al., 2004). It has been reported that shear modulus and damping ratio is influenced mainly by cyclic strain amplitudes, effective confining pressures, soil type, and plasticity index. In addition, it has also been reported based on the torsional test (up to shear strain level of 0.015%) that dynamic properties, especially initial shear modulus ($G_{\text{max}}$) is influenced by the degree of fines (Chien & Oh, 2002).

In the present investigation, a comprehensive study has been undertaken to evaluate the strain dependent dynamic properties at large shear strain levels for the sand samples collected from the earthquake affected area of Ahmedabad city of Gujarat state, India. A series of strain controlled cyclic triaxial tests, were carried out on base sand (natural sand) and clean sand. The shear modulus and damping ratios have been estimated based on the first cycle information. The effect of different parameters such as number of loading cyclic, relative density, confining pressures and non-plastic fines on the dynamic properties of the soils have been studied and reported.

**Testing Programme**

The representative natural soil samples (base sand) are collected from earthquake-affected area of Ahmedabad city of Gujarat state in India from the excavated pits close to Sabarmathi river belt where extensive damage to the constructed facilities was observed (Bhandari & Sharma, 2001). The gradation of the original sand particles were determined by dry sieve analysis and the particle size distribution of the base and clean sand samples were presented in Figure 1. The base sand of Ahmedabad city consists of medium to fine sand with non-plastic fines of 9.2%. According to the Indian Standard Soil Classification system (ISSCS) the sand is classified as poorly graded with symbol SP. The clean sand (particle size >0.075mm) was prepared by removing the silt portion by washing from the base sand using 75-micron sieve. The index properties such as specific gravity, maximum and minimum void ratios for the base sand (natural sand) and clean sand was presented in Table 1. The sand samples with non-plastic fines were prepared by adding the non-plastic fines derived from the base sand in different percentage (15%, 30% and 45%) by weight to the clean sand.

In the present investigation, the cyclic triaxial tests were carried out on base sand, clean sand and clean sand samples with various percentage of non plastic fines. The sand specimens of size 50 mm diameters and height 100 mm were prepared by dry pluviation through a funnel by raising it along the axis of symmetry of the specimen by keeping a height of fall of $\approx$ 1 cm in the membrane lined split mould and tapping gently to the sides of the mould to achieve the desired density. After the preparation of specimens, a small vacuum of about 10 kPa was applied to the specimens to reduce disturbance during the removal of split mould and triaxial cell installation. Next, the split mould was removed and the triaxial cell was assembled and positioned on the loading device. The specimens were then saturated with de-aired water using back-pressure saturation. The back pressure was increased gradually while maintaining the effective confining pressure at 15 to 20 kPa. This process was continued until the Skempton’s pore pressure parameter B ($B = \Delta u/\Delta \sigma^c$ in which $\Delta u =$ change in specimen pore pressure and $\Delta \sigma^c =$ change in confining pressure) exceeded 0.97. Following saturation, the specimens were then isotropically consolidated to the required confining pressure. The undrained cyclic triaxial tests were then carried out on these isotropically consolidated soil specimens using strain-controlled technique.
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