ESTIMATION OF SMALL STRAIN STIFFNESS BEHAVIOR OF SAND USING PIEZO-CERAMIC DISK TRANSDUCERS

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1. INTRODUCTION

The determination of small strain properties of soil is of paramount importance for the reliable geotechnical analysis and design. A myriad of techniques is available to estimate the small strain properties of soil from both laboratory as well as field tests. The wave propagation method is one of the most popular methods to determine the small strain properties of soils (Dyvik et al. 1985, Viggiani et al. 1995, Kuwano et al. 1998, Suwal et al. 2013). In the present study, flat shaped piezo-ceramic transducers are used to determine the small strain shear modulus (G_o), small strain Young's modulus (E_o) and Poisson's ratio (ν) of Toyoura sand and a comparison is drawn with the resonant column test results on a uniformly graded Indian sand which are reported in the paper by Dutta et al. (2016). These flat shaped piezo-ceramic transducers, known as disk transducers, were developed in Institute of Industrial Science, University of Tokyo and can be used for accurate measurement of elastic waves. The prime significance of this type of disk transducer is that it has both p and s type elements housed inside the top cap and bottom pedestal of the triaxial apparatus.

2. MATERIAL PROPERTY

The soils described in the present study are Toyoura sand and a uniformly graded Indian sand. The specific gravities of Toyoura sand and Indian sand are 2.62 and 2.63 respectively. The maximum and minimum void ratios of Toyoura sand are 0.946 and 0.637 respectively. The maximum and minimum void ratios of Indian sand are 0.88 and 0.66 respectively. Figure 1 depicts the grain size distribution of the two sands. The mean diameters (D_{50}) of Toyoura sand and Indian sand are 0.19 mm and 1.10 mm respectively. The coefficient of uniformities (C_u) of Toyoura sand and Indian sand are 1.61 and 2.55 respectively.

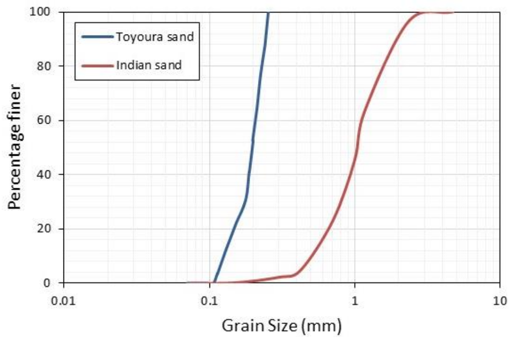

Fig. 1 Gradation curve

3. TEST METHOD

Specimens were prepared by means of split mold in dimensions of 75×150 mm. Dry tamping method was used to achieve the desired relative density (RD). Prepared specimens were first consolidated to the desired isotropic confining pressure. A function generator was used to generate the signal of the transmitted waves. In this study, sine waves of amplitude 7 volts measured from peak to peak was employed. The frequency of sine wave was varied from 2 kHz to 20 kHz. Before feeding the input signal to the transmitter located at the top cap, the signal was amplified by means of an amplifier. The received signal at the bottom pedestal was then recorded and displayed by means of an oscilloscope.

In this study, time domain technique is employed to analyze the data and determine the arrival time of S and P waves. Time domain method involves obtaining the travel time based on observation of the plot of electric voltage versus time (Viggiani et al. 1995). The travel time is considered for both first major rise to rise and first major peak to peak cases.

4. RESULTS AND DISCUSSIONS

Figures 2 (a) and 2 (b) present the obtained S waveform and P waveform respectively of Toyoura sand for frequency of 12 kHz; confining pressure and relative density of 100 kPa and 75 % respectively. Travel times based on peak to peak method (T_{ptp}) and rise to rise method (T_{rtr}) have been shown in the figure. Figure 3 (a) shows variation of small strain shear modulus and Young's modulus with frequency for Toyoura sand subjected to a confining pressure of 100 kPa and prepared at relative density (RD) of 75 %. The influence of frequency on shear modulus and Young's modulus is found to be very small. It has been further observed that for frequencies up to 8 kHz, there has been scatter in the data of small strain Young's modulus values.

Keywords: Wave propagation, shear modulus, Young's modulus, Poisson's ratio, frequency
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However, Young's modulus calculated using rise to rise method show a gentle increasing trend with the increase in frequency. The difference between shear modulus calculated from peak to peak and rise to rise method is small. The average difference in shear modulus calculated from those two methods is found to be 1.7 %. On the other hand, the difference in Young's modulus value calculated from the two methods is quite appreciable; having an average difference in Young's modulus of 9 %. By performing resonant column tests on the uniformly graded Indian sand, Dutta et al. (2016) recorded a small strain shear modulus and small strain Young's modulus of 96 MPa and 226 MPa respectively, at the same confining pressure of 100 kPa and void ratio of 0.72 (RD=75%). The small strain stiffness values of Indian sand are quite comparable to those obtained for Toyoura sand calculated using peak to peak method.

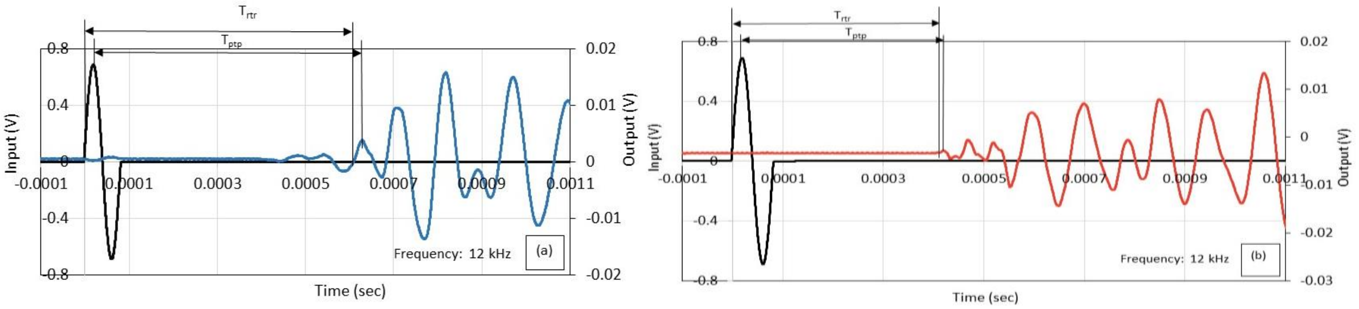

Fig. 2 (a) S waveform (b) P waveform (frequency = 12 kHz, confining pressure =100 kPa and RD=75%)

Figure 3 (b) shows the variation of Poisson's ratio with frequency of Toyoura sand for confining pressure of 100 kPa and relative density (RD) of 75 %. It is seen that Poisson's ratios calculated from two methods show a decreasing trend with increase in frequency. This might be due to the scatter present in the small strain Young's modulus values for frequencies up to 8 kHz. Poisson's ratios calculated from peak to peak method are observed to be considerably higher than those obtained from rise to rise method, with an average increase of 40 %. At the same confining pressure and void ratio, Dutta et al. (2016) obtained a Poisson's ratio of 0.18 from resonant column test on Indian sand. Poisson's ratio calculated from resonant column test is found to lie between the values obtained from peak to peak and rise to rise method.

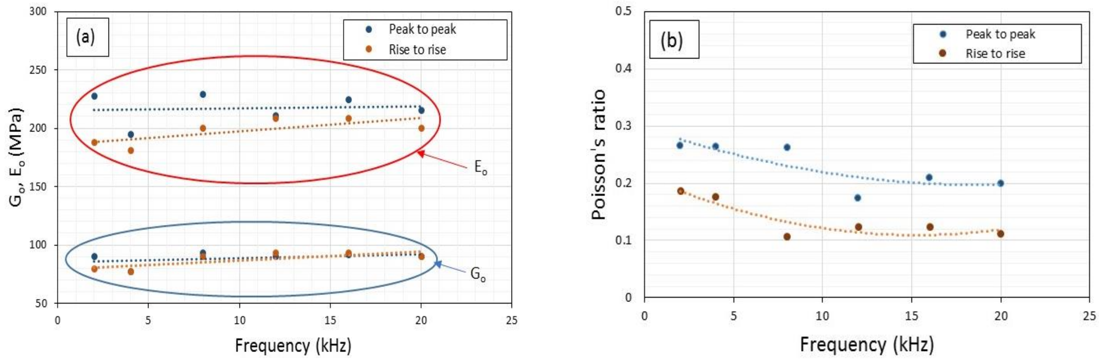

Fig. 3 (a) G_o and E_o vs. frequency (b) Poisson's ratio vs. frequency (confining pressure =100 kPa and RD=75%)

5. CONCLUSION

The influence of frequency on the small strain shear modulus and Young's modulus is found to be small. The average difference between shear modulus calculated from peak to peak and rise to rise method is about 1.7 %. However, the average difference in Young's modulus value calculated from the two methods is found to be higher, about 9 %. The small strain stiffness values calculated from piezo-ceramic disc transducer is found to be quite comparable to those obtained from resonant column tests at similar confining pressures and void ratios. Poisson's ratio shows a decreasing trend with increase in frequency. Moreover, Poisson's ratio determined by using peak to peak method is found to be considerably larger than those obtained from rise to rise method, about 40%.

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