ESTIMATION OF ELASTIC WAVE VELOCITIES THROUGH GRANULAR SOILS DURING MONOTONIC LOADING

University of Tokyo Student Member Troyee Tanu Dutta
University of Tokyo Regular Member Masahide Otsubo
University of Tokyo Regular Member Reiko Kuwano

1. INTRODUCTION

The precise estimation of the wave velocities and stiffness of geomaterials is an essential prerequisite for the accurate design of structures as well as authentic geotechnical characterization of sediments. The development of the geophysical testing method is important to assess the mechanical properties of in-situ soils. Measurement of elastic waves by means of piezo-ceramic elements has been popularized by Shirley and Hampton (1978), when they developed bender elements to detect shear waves in sediments. However, the bender element technique has limitations; it causes remarkable disturbance near the place of insertion, and it is not suitable for coarse grained materials (e.g. gravels) and undisturbed or cemented specimens. To overcome the limitations, disk-shaped transducers have been adopted and installed at the boundaries of the specimen (Brignoli et al. 1996; Ismail and Rammah; 2005; Suwal and Kuwano 2013). In the present study, wave velocities are measured using disk transducers during monotonic loading in a conventional triaxial apparatus. Fig. 1 presents a schematic design of the disk transducers placed in top cap of the triaxial apparatus.

2. MATERIAL AND SAMPLE PREPARATION

Referring to Fig. 2, an angular silica sand with diameters ranging from 1.4 to 2 mm was used (specific gravity = 2.64, the maximum and minimum void ratios = 1.023 and 0.712).
Cylindrical sand specimens of size 75×150 mm were prepared using a split mold. Sands were poured inside the mold in five equal layers, and side tapping method has been adopted to obtain the desired relative density. Two types of specimens were discussed in the present study: 1) loose specimen having a void ratio (e) and relative density (D_r) of 0.921 and 33%, respectively 2) highly dense specimen having e and D_r of 0.712 and 100%, respectively.

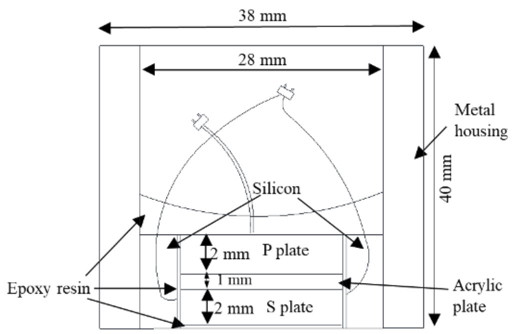

Fig. 1 Schematic of metal housing with the disk transducer in top cap

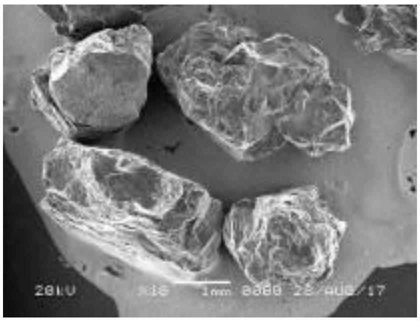

Fig. 2 SEM image of tested silica sand

3. TEST METHOD

Samples were first consolidated to isotropic confining pressures of 50 kPa and 100 kPa, and wave measurements were undertaken. Later, samples were compressed monotonically at an axial strain rate of 0.0003% per sec, while keeping the cell pressure consant at 100 kPa, and wave measurements were conducted. The excitation wave signals in the present study were generated using a digital function generator and amplified by an amplifier. The peak-to-peak method was adopted to evaluate the arrival time for S-wave signals (Fig. 3(a)) as the rise points are affected by the presence of a near-field effect. Rise-to-rise method was adopted to determine the P-wave arrival time (Fig. 3(b)) (Brignoli et al. 1996).

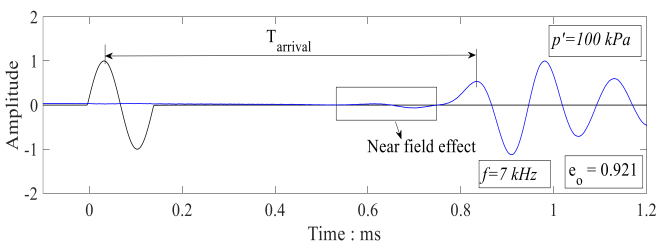

Fig. 3 (a) S wave (ε_a=0 %)

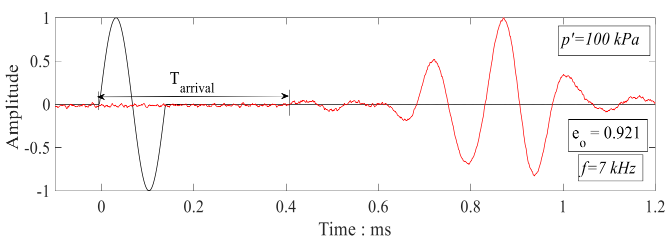

Fig. 3 (b) P wave (ε_a=0 %)

Keywords: Disk transducers, wave measurement, Poisson's ratio, stress anisotropy, silica sand
Contact address: Institute of Industrial Science, 4-6-1, Komaba, Meguro, Tokyo 153-8505, Japan, Tel: 03-5452-6843

4. RESULTS AND DISCUSSIONS

Figure 4 (a) shows the relationship between deviatoric stress (q) and axial strain (ε_a), and between volumetric strain (ε_v) and axial strain (ε_a). Referring to Fig. 4 (b), for the dense sample V_s increases sharply with the increase in axial strain (up to about 0.2 %), but with further increase in the axial strain, V_s drops gently. For loose specimen, V_s increases with strain level up to about 2.2 %, but with further increase in strain level V_s drops gradually. The rate of drop in V_s for the loose specimen is lower than the dense specimen, and at high strain level, V_s of both the specimens tend to converge. The axial strain level at which the V_s drops can be hypothesized to be similar to the axial strain level at which the changes in the fabric of the specimen takes place, i.e. the strain level at which the specimen shows a dilative behavior (from Fig. 4 (a)). Furthermore, V_p values of both the dense and loose specimens also tend to converge at large strain levels (Fig. 4 (c)). It can be hypothesized that there exists a critical state wave velocity which the specimens tend to reach during shearing.

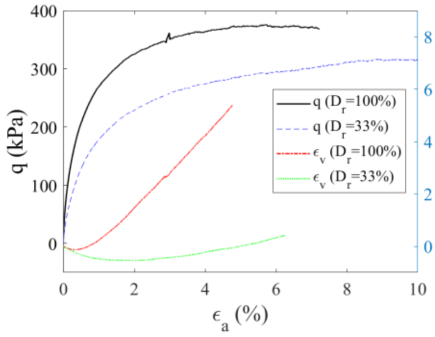

Fig. 4 (a) q vs. ε_a

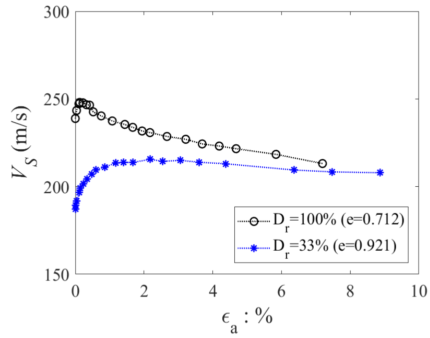

Fig. 4 (b) V_s vs. ε_a

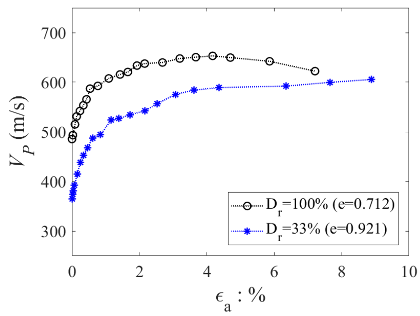

Fig. 4 (c) V_p vs. ε_a

Poisson's ratios of both loose and dense specimens increase monotonically with the increase in axial strain (from Fig. 5(a)). This shows that the increment of the normal stress (σ_1) has a significant effect on compression wave velocity as compared to shear wave velocity. From Figure 5(b), it is observed that V_s of both loose and dense sand specimens tend to converge at large anisotropic stress. As the compression wave velocity is greatly dependent on the normal stress acting in the same direction, it is observed that V_p increases significantly with the increase in normal stress (σ_1) (from Fig. 5(c)).

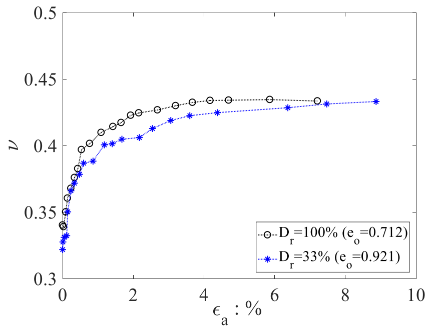

Fig. 5 (a) ν vs. ε_a

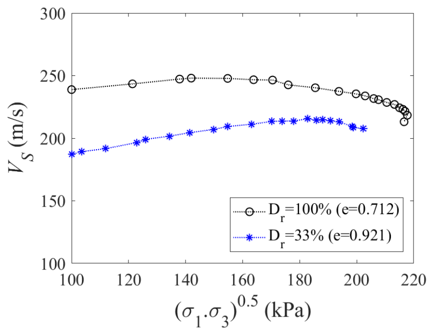

Fig. 5 (b) V_s at anisotropic stress

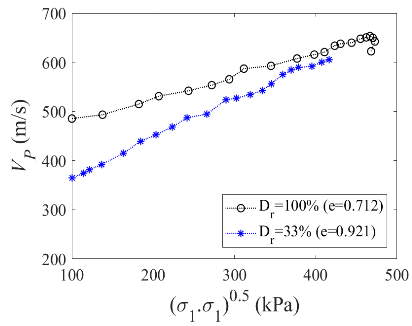

Fig. 5 (c) V_p at anisotropic stress

5. CONCLUSION

In the present study, piezo-ceramic disk-shaped transducers have been employed to measure shear wave and compression wave velocities of silica sand at different anisotropic stress states. Wave velocities of loose and dense specimens at large axial strain tend to converge similar to the stress-strain relationship. The increment of normal stress component has a significant influence on compression wave velocity as compared to shear wave velocity. This results in the increase of the Poisson's ratio (ν) with increased axial strain. As the variation of V_p, V_s and ν with axial strain was measured successfully using the proposed disk-shaped transducers, this technique can be adopted for assessing and monitoring of in-situ ground conditions for a long term.

REFERENCES

Brignoli, E., Gotti, M., and Stokoe, K. (1996). Measurement of shear waves in laboratory specimens by means of piezoelectric transducers. Geotechnical Testing Journal, 19 (4), 384-397.

Ismail, M.A., and Rammah, K.I. (2005). Shear-plate transducers as a possible alternative to bender elements for measuring G_{max}. Géotechnique, 55(5), 403-407.

Shirley, D.J., and Hampton, L.D. (1978). Shear-wave measurements in laboratory sediments. Journal of Acoustical Society of America, 63(2), 607-613.

Suwal, L.P., and Kuwano, R. (2013). Disk shaped piezo-ceramic transducer for P and S wave measurement in a laboratory soil specimen. Soils and Foundations. 53(4), 510–524.