DEVELOPMENT OF DISK SHAPED PIEZO-CERAMIC PLATE TRANSDUCER FOR ELASTIC WAVE MEASUREMENTS IN LABORATORY SPECIMENS

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ABSTRACT:

The initial tangent modulus of geo-material is also known as the small strain stiffness modulus of geo-material. It is the mostly used parameter in geotechnical engineering. Recently, many people are conscious about the deformation or settlement of structures. In calculation of deformation/settlements, the small strain stiffness parameters are mostly used. So many researchers are interested on measurement of these parameters and being involved on experiments. This study was made to develop a new plate transducer for Elastic wave measurement. This can adopt on measurement of P-wave as well as S-wave on single specimen. A disk shaped PS-type plate transducer was developed at the laboratory of IIS. A series of tests are conducted applying this plate transducer to know the performance on two granular materials.

INTRODUCTION:

When a mechanical stress was applied on piezoelectric materials, electrical charges appeared and this voltage was proportion to the stress. This behavior was discovered by Pierre curie in 1883. This property is the prime factor of suitability of using piezo-electric materials in transducers. Various types of piezo-electric transducers are being extensively used on the study of geo-materials on laboratory specimen. Among them, Bender Element is more popular than others. In this study, a disc type piezo-ceramic element was employed. P-type as well as S-type piezoceramic element is available in market. This can employ P-wave and S-wave measurement individually. This study intended to develop a single piezoelectric transducer which can measure p-wave as well as S-wave on a single specimen. P-type and S-type piezoelectric elements were merged as a single element (PS-type) with good bond of Araldite. Details of assemble are shown in fig.1 to fig.3.The PS-type piezo-ceramic transducer, named as plate transducer was applied on this study. This study includes the study of Toyoura sand and Hime gravel by employing PS-type piezo-ceramic plate, Trigger Accelerometer and static measurement simultaneously. Plate transducers of diameter 10mm.thickness 2mm and 1mm had already employed on Φ50mmX100mm specimen of Toyoura sand. (Mulmi et al, 2008)Piezo-ceramic element of diameter 20mm, thickness 2mm and 5mm were used on Φ75mmX150mm specimen in this study.

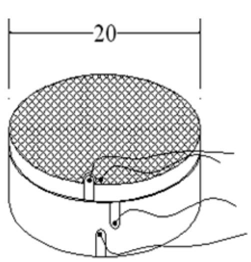

Fig. 1: PS-type plate

Fig.2: Plate transducer

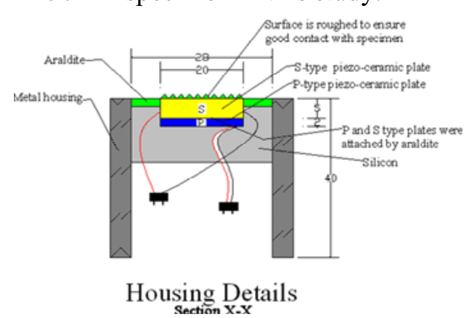

Fig.3: Section A-A

MATERIALS, TESTINGAPPARATUS AND METHODOLOGY.

Toyoura sand is fine-sized, uniformly graded sand. The source of this sand is Toyoura Beach area of Yamaguchi prefecture, Japan. Hime gravel is poorly sorted, and the grains are angular. It was taken from Hime River, Otari, Kitaazumi, Nagano, Japan. It is derived from sandstone, chert, granite, sill quart etc. A gear driven, strain controlled triaxial apparatus was used for conducting the experiments. The specimens of Φ75mmX150mm were prepared by pluviating the sand through air. Same procedure was applied for both

Toyoura sand and Hime gravel. The samples were made at an isotropic stress state of 25 kPa. The stress was increased to 50, 100, 200 and 400kPa. Static measurements as well as dynamic measurements during a creep stage were performed at every stress state. In static small strain stiffness measurement, 11 cyclic loadings with peak to peak strain amplitude of 0.001% were applied in vertical direction. Deformation were measured by local deformation transducers(LDTs) developed by Goto et al(1991),which measured local strain in higher accuracy and free from bedding errors. A series of experiments were preformed with PS-type plate transducer and results were compared.Cyclic Young's modulus (E_{cyc}) was derived by fitting a straight line to the stress-strain curve. The stress-strain curve of 5th cycle and 10th cycle were utilized to analyze E_{cyc}. The average results of 0.001% strain amplitude were reported as E_{cyc} here at each stress state.
For getting cyclic shear modulus (G_{cyc}). The young's modulus obtained was converted to G_{cyc} by using the equation as shown below;

$$G_{cyc} = \frac{E_{CYC}}{2(1+\nu)} \qquad (1)$$

Where**,** ν is the Poisson's ratio adopted as 0.17(Hoque et al, 1996) for Toyoura sand and 0.2(De Silva et al, 2004) for Hime gravel. For the calculation of dynamically obtained young's modulus and shear modulus, the following equations are applied;

$$E_{TA-P} = \rho.Vp^2 \qquad (2)$$

For P waves, the triggers were attached on the top cap which impact whole area during excitation. So the waves could be considered as unconstrained and unconstrained young's modulus could be achieved with formulation of eqn. (2). Plate transducer was fixed at the center of the top cap and pedestal. So the P waves generated were assumed as constrained.The constrained vertical modulus (M_{PT-P}) could be achieved by eqn (3). The constrained modulus was converted to the unconstrained modulus by using the eqn. (4).

$$M_{PT-P} = \rho.Vp^2 \qquad (3)$$

$$E_{PT-P} = \frac{M_{PT-P}(1-2\nu)(1+\nu)}{(1-\nu)} \qquad (4)$$

$$G_{TA-S}, G_{PT-S} = \rho.Vs^2 \qquad (5)$$

$$V_p, V_s = \frac{L}{T} \qquad (6)$$

G_{TA-P} and G_{PT-P} were obtained by converting E_{TA-P} and E_{PT-P} with help of eqn. (1)
Where, ρ is the dry density of specimen, V_P is compression wave velocity (P-wave velocity), V_s is the shear wave velocity(S-wave velocity), L is the travel length and T is travel time. Rising to rising time was considered as the travel time in analysis. G_{cyc} and E_{cyc} is the stiffness obtained by cyclic loading. E_{PT-P}, G_{PT-P} and G_{PT-S} are dynamically measured stiffness by PT method. E_{TA-P}, G_{TA-P} and G_{TA-S} are dynamically measured stiffness by TA method. For the comparison of stiffness modulus of different dry densities, the void ratio function as proposed by Hardin and Richart, 1963 was used in this study.

$$f(e) = \frac{(2.17-e)^2}{1+e}$$

Where, e is void ratio.

TEST RESULTS AND DISCUSSIONS:

Three tests, two tests on Toyoura sand and one on Hime gravel through PS type Plate transducer were conducted successfully. In the test of Toyoura sand, the input frequency range of 7.8 kHz to 31.25 kHz was actuated at each stress state of isotropic consolidation while exciting through PS type Plate transducer and the input signal of frequency 1.85 kHz to 7.4 kHz was actuated for TA. The results achieved from each test are plotted in shear modulus verses stress state as shown in fig. 4 and fig.6.The results of tests shows that the Plate transducer's results are more consistent and have a same tendency of the other mode of measurements.

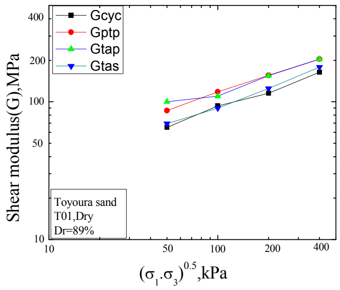

Fig.4: Result of T01

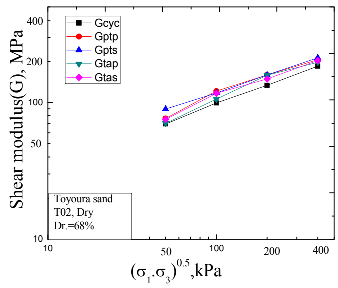

Fig.5: Result of T02

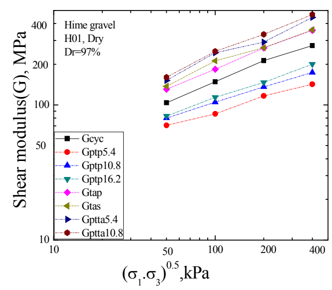

Fig.6: Result of H01

CONCLUSIONS:

This study was conducted to know the performance of Plate transducer on two granular materials. The tests on Toyoura Sand were successfully performed and the results are compared with those obtained from other type of stiffness measurement. A trial test on Hime gravel was performed and outcome is presented. More detailed studies are required to interpret clearly. Evaluating the results, it is concluded that PS type plate transducer is good as good as others. The results of Toyoura sand show it performance on fine grained geo-materials, which is not different than others. In case of coarse grained geo-materials, it is not sufficient to conclude based on one test. A detailed study is needed to clarify more. Considering the performance, easy handling, applicable to cemented or undisturbed samples and less liability of errors like as Bender Element has to be inserted into specimen, which may affect on the results by bedding error and accelerometers are glued to the lateral surface of membrane and its influence is not clearly known. So, its scope can't be minimized as future's leading tool for Elastic wave measurement on laboratory specimen.

REFERENCES:

1. Mulmi,S.,Kuwano,R.,Sato,T., 2008 "Performance of Plate-ceramic Transducers for Elastic Wave measurements in Laboratory Soil specimens" Seisan Kenkyu, Bimonthly Journal of Institute of Industrial Science, The University of Tokyo, Vol.60-No.6 pp.565-569
2. Wicaksono, R.I., 2007 "Small Strain Stiffness of Sand and gravel Based on Dynamic and static Measurements" Master's degree Dissertation, The University of Tokyo.
3. Mulmi, S., 2008 "Small-Strain Stiffness Measurement of Geo-materials By Elastic Waves" Master's degree Dissertation, The university of Tokyo.
4. Tatsuoka, F and Shibuya, S., 1992 "deformation characteristics of Solid and Rocks from Field and Laboratory Tests", Proceeding of 9th Asian Regional Conference of SMFE, Bangkok, Vol.2, pp.101-170.
5. Goto, S., Tatsuaka, F., Shibuya, S., Kim, Y-S., and Sato, T., 1991," A simple Gauge for local small strain Measurements in the laboratory", Soils and Foundations, Vol.31, No.1, pp.169-180.
6. De Silva, L.I.N., 2004, "Locally Measured Quasi-Elastic Deformation Properties of Geo-materials under Torsional Shear and Triaxial loadings, "Master's degree Dissertation, The University of Tokyo.
7. Hoque, E, 1996, "Elastic deformation of sands in triaxial tests, "Doctor's degree Dissertation, The University of Tokyo.
8. Hoque,E.,Tatsuoka,F and Sato,T.,1996, "Measuring anisotropic elastic properties of sand using a large triaxial specimen, "Geotechnical testing journal,GTJODJ,19(4),411-420
9. Hardin, B.O. and Richart, F.E., 1963,"Elastic wave velocities in Granular Soils," Journal of Soil Mechanics and Foundations, ASCE, 89 (1).33-65.