Measurement of Local Strains of Toyoura Sand using Hollow Cylindrical Specimen

Nguyen HongNam, University of Tokyo
Junichi Koseki, IIS, University of Tokyo

I) Introduction

During triaxial compression tests on a hollow cylindrical specimen (outer diameter of 20cm, inner diameter of 16cm, and height of 30cm) of Toyoura sand, a sudden reduction was observed in the values of drained quasi-elastic vertical Young's modulus E_{eq} and shear modulus G_{eq} that were externally measured by gap sensors at the top cap of the specimen (Koseki et al., 2001). In order to study such peculiar behaviour, a new local measuring device named triangular pin-typed local deformation transducers (triangular P-LDTs) was developed (Hong Nam et al., 2001) to measure four strain components of the hollow cylindrical specimen. Test results on Toyoura sand by using this device are reported herein.

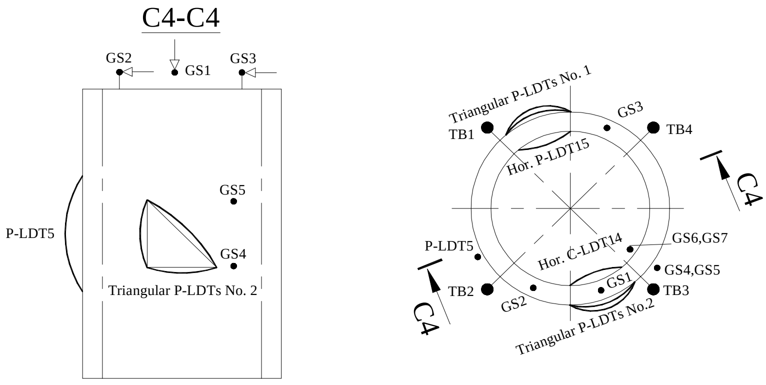

Fig.1 Layout of transducers

II) Test Material and Procedures

Dry Toyoura sand (batch G) specimen at an initial void ratio of 0.700 under confining pressure of 30 kPa was prepared by air-pluviation. Figure 1 shows the layout of the transducers, where strain components ε_z, ε_r, ε_θ and $\gamma_{z\theta}$ were measured locally with two sets of outer triangular P-LDTs and an inner horizontal LDT. In addition, four gap sensors (GS4 through GS7) with a capacity of 4mm were employed to measure the local change in the outer and inner radii. After isotropic consolidation (denoted as IC) up to confining pressure of 450 kPa, the specimen was subjected to drained large cyclic vertical loading (denoted as TC) up to effective vertical stress σ_z' of 400 kPa under constant effective horizontal stresses of σ_h'(=σ_r'=σ_θ') =200 kPa, without/with applying sustained shear stress $\tau_{z\theta}$ of 50 kPa. At several stress states, the specimen was left for about 10 minutes to achieve stable state, and three small unload/reload cycles were applied in the vertical and torsional directions with a single strain amplitude of 0.001% and 0.0015%, respectively, to evaluate E_{eq} and G_{eq}. Measurement of σ_z' and $\tau_{z\theta}$ was made with a two-component loadcell set inside the triaxial cell.

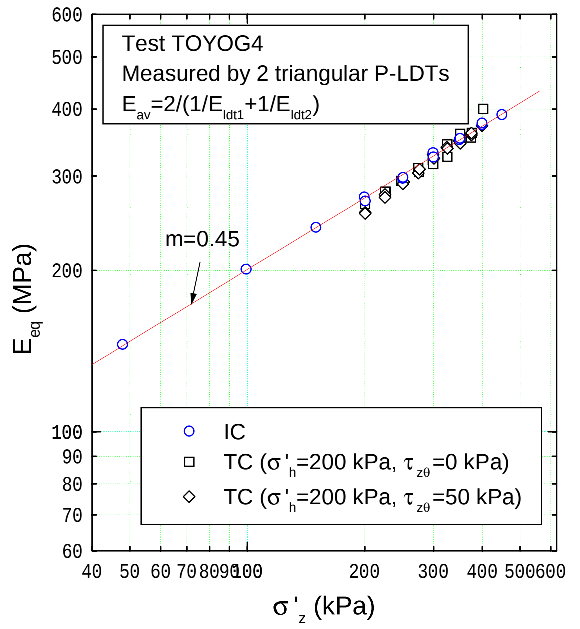

Fig.2 E_{eq} based on average of local strains versus σ'_z

III) Results and discussions

Figures 2 and 3 show the locally measured E_{eq} and G_{eq} values plotted versus σ_z' and $(\sigma_z'.\sigma_h')^{0.5}$, respectively. In Fig.2, the average of two ε_z values that were measured with two sets of triangular P-LDTs was employed. On the other hand, results with a single set of LDTs (Triangular P-LDTs No. 1 in Fig.1) were employed in Fig.3, since the diagonal P-LDT in the other set did not perform properly. It is seen from these figures that E_{eq} and G_{eq} can be approximated as linear functions of σ_z' and $(\sigma_z'.\sigma_h')^{0.5n}$, respectively, with m=0.45 and n=0.47. This m value is consistent with the one reported by Hoque (1996).

Keywords: Hollow cylindrical specimen, local deformation transducer, axial strain, shear strain, Young's modulus, shear modulus
Institute of Industrial Science, Univ. of Tokyo, 4-6-1 Komaba, Meguro-ku, Tokyo 153-8505. Tel: 03-5452-6421, Fax 03-5452-6423

During isotropic consolidation, two ε_z values measured with individual set of LDTs were similar. However, during vertical loading with $\tau_{z\theta}$ =0, sudden distinct changes (decrease on one side and increase on the other side) in these ε_z values were observed, which resulted into a disturbance in the relationships between locally evaluated E_{eq} (E_{ldt1} and E_{ldt2} in Fig.4) with individual set of LDTs and σ_z'. In addition, the externally evaluated E_{eq} values (E_{gs} in Fig.4) with the vertical gap sensor (GS1 in Fig.1) showed qualitatively a similar response to the ones locally measured on the same side of the specimen (Triangular P-LDTs No.2 in Fig.1), while with a larger extent of disturbance, quantitatively. These behaviours suggest that the specimen was not uniform and/or the loading device was not properly aligned relative to the top surface of the specimen. As a result, after applying a certain level of deviator stress (q=100 kPa in the present test), the distribution of vertical stress and strain increments during small cyclic vertical loading possibly became non-uniform, which affected the external measurement results to a larger extent than the local ones.

As shown in Fig.5, by applying a sustained shear stress of $\tau_{z\theta}$ =50 kPa, the degree of degradation in the externally measured E_{eq} values was reduced. This may be the result of redistribution of local stresses caused by application of torque.

IV) Conclusion

Local measurements of strains in hollow cylindrical specimen of dry Toyoura sand were carried out by using newly developed triangular P-LDTs and gap sensors. Locally measured quasi-elastic E_{eq} and G_{eq} values were mainly dependent on the current σ_z' and $(\sigma_z'.\sigma_h')^{0.5}$ values, respectively. Non-uniformity of local stresses and strains in the specimen possibly caused a disturbance in the above relationships, to a smaller extent than the external measurements.

References

1) Koseki,J., Ono,T., Sato,T., 2001, Stress state dependency of small strain Young's and shear moduli of Toyoura sand, submitted to 36th annual meeting of JGS. 2) HongNam,N., Sato,T., Koseki,J., 2001, Development of triangular pin-typed LDTs for hollow cylindrical specimen, ditto. 3) Hoque,E., 1996, Elastic deformation of sands in triaxial tests, Doctoral thesis, University of Tokyo.

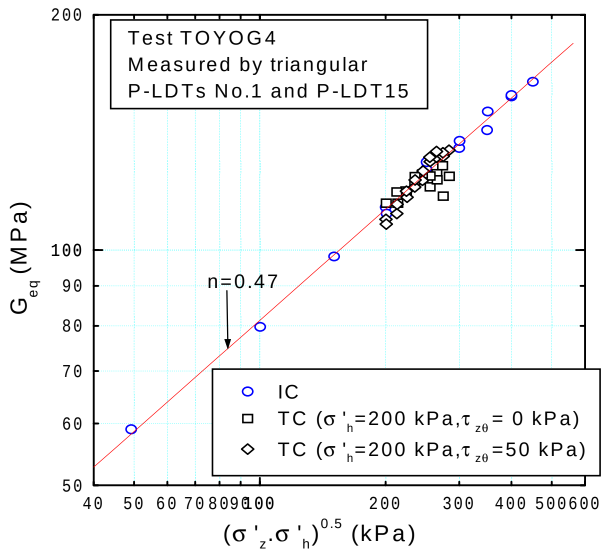

Fig. 3 G_{eq} based on local strain on one side versus $(\sigma'_z.\sigma'_h)^{0.5}$

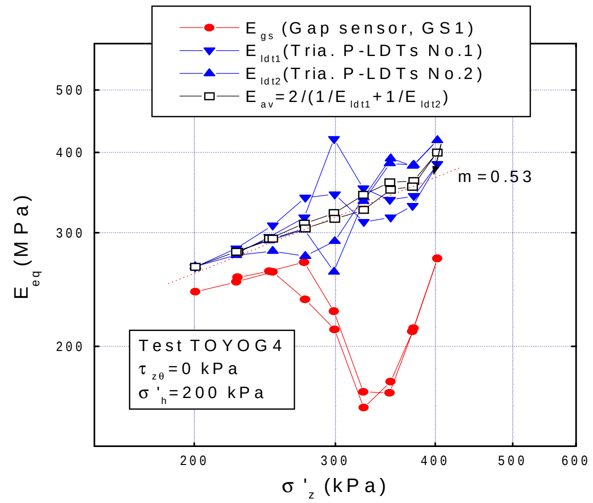

Fig.4 Comparison of E_{eq} during vertical loading at $\tau_{z\theta}$=0

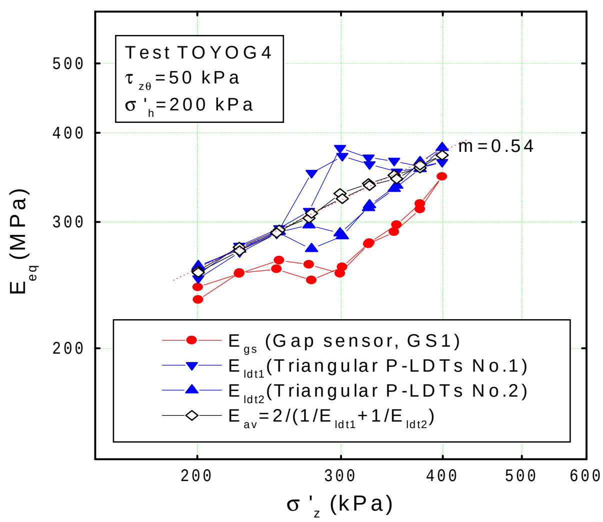

Fig.5 Comparison of E_{eq} during vertical loading at $\tau_{z\theta}$=50 kPa