III-A 21

Strength anisotropy of Silver Leighton Buzzard sand and Toyoura sand by Biaxial Tester

K.Umetsu, Lecturer, Dept. of Civil Engg., Nihon University
S.J.M.Yasin, Graduate student, IIS, The University of Tokyo
T.Dunstan, Senior Lecturer, Dept. of Civil and Environmental Engg.,University College London, UK
F.Tatsuoka, Professor, The University of Tokyo

1. Introduction: Strength anisotropy of Silver Leighton Buzzard (SLB) sand and Toyoura sand was investigated by using a Biaxial Tester (BT) (Ogunbekun,1988), which is a plane strain compression apparatus, having flexible σ_1 and σ_3 boundaries and lubricated rigid σ_2 boundaries. The results are compared with those obtained by conventional plane strain compression (PSC) tests by Park (1993), which had lubricated rigid σ_1 and σ_2 surfaces and flexible σ_3 surfaces.

2. Materials and testing methods: SLB sand, from an aeolian deposit in Leighton Buzzard, UK, is coarse, almost closely graded between sieve sizes 650-800μm and has sub-round particles. Two batches D and U were tested. Batch-IIS was used in conventional PSC tests (Park 1993), while other batches were used in the previous tests at UCL.

Toyoura sand is also a uniform sand having sub-angular particles and is finer than SLB sand, almost closely graded between sieve sizes 106-355μm. Batch-3 was tested (Fig.1). Batch-E was also used in conventional PSC tests (Park 1993).

In BT (Fig.2) σ_1 and σ_3 were applied with pressure bags which had Make & Break (M&B) contacts. Initially M&B contacts on both of the σ_1 surface were in touch, whereas those on σ_3 surfaces were separate. If the σ_1 air pressure increased, the M&B contacts separated and the cylinder behind the pressure bag pushed the frame until the M&B contact touched again. Due to an increase in σ_1, if a σ_3 surface is displaced causing the M&B contact on that surface to touch, the cylinder pulled the frame until that M&B contact separated again. In the σ_2 direction, the specimen was confined by plates (Fig.2). Deformation of the specimen in the σ_1 and σ_3 directions were obtained by measuring the displacement of the pistons with the dial gauges as in Fig.2. All surfaces of each specimen (10cm×10cm×10cm) were covered with rectangular membrane (0.3 mm thick). In the σ_1 and σ_3 directions, both surfaces of the specimen and the pressure bags were cleaned with ethanol so that the membrane and the face of the pressure bag expanded and contracted as one body and no membrane force was exerted. Each surface in the σ_2 direction was lubricated by using a 0.3mm thick single latex rubber sheet smeared with grease on both sides.

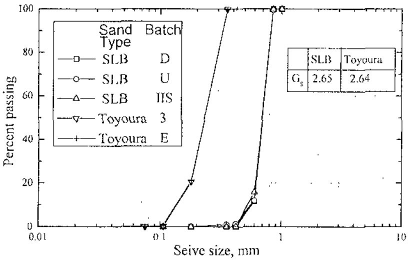

Fig.1 Grain size distributions of SLB and Toyoura sand

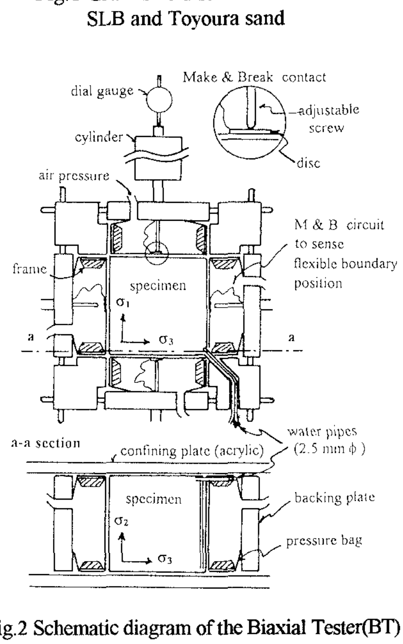

Fig.2 Schematic diagram of the Biaxial Tester(BT)

In order to evaluate strength anisotropy, dry sand particles were pluviated into a mold (10cm×10cm×10cm) in several directions, moistened and subsequently frozen (Park 1993). After freezing, one edge of the specimen was trimmed and then the specimen was covered with a membrane which was attached to two 2.5mm dia water pipes (for supplying and draining water). OC specimens (OCR=6.67) were then thawed under a vaccum of 1.0 kgf/cm^2, placed into the apparatus under 0.15 kgf/cm^2 confining pressure applied by pressure bags and saturated. NC specimens were first placed in the apparatus, then thawed under 0.15 kgf/cm^2 confining pressure and saturated. Then drained stress controlled tests were performed. The effect of this saturating on the strength and deformation characteristics of SLB sand and Toyoura sand in BT tests were examined and was found negligible.

3. Results and discussion: In Fig.3, the angle of internal friction, $\phi_{max}=\arcsin\{(\sigma_1-\sigma_3)/(\sigma_1+\sigma_3)_{max}\}$ is plotted against initial void ratio for different angles δ, the angle of the direction of σ_1 during a test relative to the bedding plane direction.

Fig.4 shows ϕ_{max} of SLB sand plotted against δ at e_0=0.52 (□,○,◆,▼). Horizontal broken lines(- - -) show the ϕ_{max} values of the specimens having the bedding plane parallel to the confining plate (the σ_2 surface). In the same figure, the results obtained from the conventional PSC tests (Park,1993) and another type of flexible boundary plane strain apparatus (Arthur and Assadi, 1977), which may involve non-negligible effects of membrane force, were also plotted. The batches

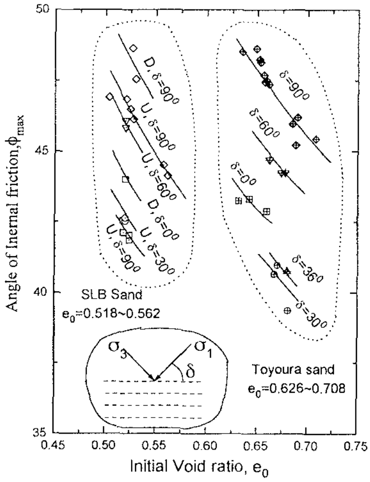

Fig.3 Relationship between ϕ_{max} of SLB and Toyoura sand

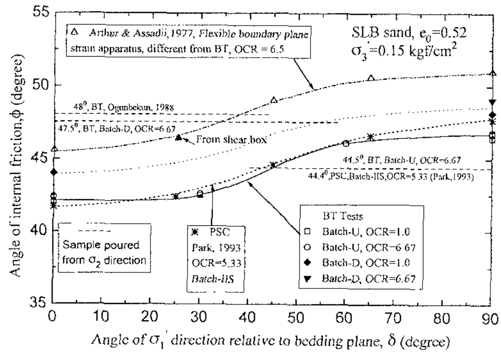

Fig.4 Strength anisotropy of SLB sand

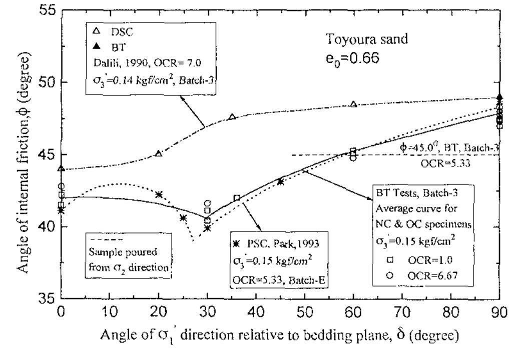

Fig.5 Strength anisotropy of Toyoura sand

for the tests by Arthur and Assadi and that by Ogunbekun are different from batches U and D. Fig. 5 shows ϕ_{max} of Toyoura sand plotted against δ at e_0=0.66 (□,○,◆,▼). Horizontal broken line(- - -) shows such ϕ_{max} values as shown in Fig. 4. In this figure, the results obtained from the conventional PSC test (Park, 1993) and those from DSC tests and BT with using Batch-3 (Dalili,1991) were also plotted.

The following results were obtained. (i) For both types of sand and for both BT and PSC, the value of ϕ_{max} is the maximum at δ=90° and decreases as δ decreases. (ii) For both BT and PSC, SLB sand has no minimum of ϕ_{max} between δ=0 and 90°, while Toyoura sand has as have been shown by another series of PSC tests (Tatsuoka et. al.,1986).

The results by Dalili (Fig.5), however, do not show this minimum, but this is not conclusive since two types of testing methods are used for δ=0 ~ 90°. (iii) For both of types of sand and for both BT and PSC, under otherwise the same tests conditions, the ϕ_{max} value when the σ_2 direction was normal to the bedding plane was in between the ϕ_{max} values at δ=0° and δ=90° obtained when the σ_2 direction was parallel to the bedding plane.

Note the similarity of PSC tests (Park,1993) and BT tests for both SLB sand (Fig.4) and Toyoura sand (Fig.5), this is due to the balancing of the effects of different batches and different apparatuses (Yasin et al.,1996 a,b).

4. Conclusion: With respect to the strength anisotropy of SLB sand and Toyoura sand, the results from tests using BT and PSC apparatuses were very consistent to each other, while the two types of sand exhibited a slightly different trend and different batches showed different ϕ_{max} values.

Acknowledgment: The experiments by BT were performed at University College London under the guidance of Professor J.R.F. Arthur. The authors gratefully appreciates his guidance and would like to gratefully acknowledge for the kindness of Mr. John Ford and Mr. William Vines, staffs of UCL.

References

Arthur,J.R.F. and Assadi,A.(1977): "Ruptured sand sheared in plane strain", Proc. 9th Int. Conf. SMFE, Tokyo, Vol. 1, pp.19-22.

Dalili.A. (1991):"Disparate particulate materials subjected to principal stress rotation", Ph.D. Thesis, University of London.

Ogunbekun,O.O.O.(1988): "The influence of boundary constraints on the shearing characteristics of particulate solids at extremely low pressure levels", Ph.D.Thesis, University of London.

Park,C.S. (1993): "Deformation and strength characteristics of a variety of sands by plane strain compression tests", Doctoral thesis, The University of Tokyo.

Tatsuoka.F., Sakamoto,M., Kawamura,T., Fukusima,S. (1986): "Strength and deformation characteristics of sand in plane strain compression at extremely low pressures", Soils and Foundations, Vol.26, No.1, pp. 65~84.

Yasin.S.J.M., Umetsu,K., Dunstan,T., and Tatsuoka,F. (1996 a): "Strength and deformation of Toyoura sand obtained by two types of plane strain compression tests", Paper submitted for the 31st annual conference of JGS in Kitami, July 1996.

Yasin.S.J.M., Umetsu,K., Dunstan,T., and Tatsuoka,F. (1996 b): "Strength and deformation of SLB sand from two types of plane strain compression tests", Paper submitted for the 51st annual conference of JSCE, in Nagoya, September 1996.