1st IMEKO TC-4 International Workshop on
Metrology for Geotechnics
Benevento, Italy, March 17-18, 2016

Dynamic behaviour of the Leighton Buzzard Sand-B under very low confining stresses

Augusto Penna[1], Gianmario Sorrentino[1], Anna d'Onofrio[2], Francesco Silvestri[2] e Armando L. Simonelli[1]

[1] *University of Sannio, Benevento (Italy), apenna@unisannio.it, alsimone@unisannio.it*
[2] *University of Naples Federico II, Napoli (Italy), donofrio@unina.it, frasilve@unina.it*

Abstract **– The dynamic response of cantilever retaining walls under seismic actions was studied by means of 1-g shaking table at the Earthquake and Large Structures Laboratory (EQUALS) which is part of the Bristol Laboratories of Advanced Dynamics Engineering (BLADE), of the University of Bristol. The soil material used to build the geotechnical model consists of dry, yellow Leighton Buzzard (LB) Fraction B. This soil has been used extensively in experimental researches on shaking table. However, no information on the dynamic behaviour at low confining stress is available for this soil. To fill this gap, dynamic laboratory tests were performed at the Soil Dynamic Laboratory (DynaLab) of the University of Naples Federico II. The main purpose of this experimental activity was to evaluate the dynamic soil behaviour of LBS-fraction B, by means of Resonant Column tests (RC) and Torsional Shear tests (TS) at several confining stresses and different strain levels.**

I. INTRODUCTION

In the last years, a wide experimental study on the dynamic response of cantilever retaining walls under seismic actions was conducted by means of 1-g shaking table at the Earthquake and Large Structures Laboratory (EQUALS) which is part of the Bristol Laboratories of Advanced Dynamics Engineering (BLADE), of the University of Bristol [1], [2], [3], [4], [5].
The soil material used to build the geotechnical model consists of dry, yellow Leighton Buzzard (LB) sand BS 881-131 (silica sand with sub-rounded grain shape), Fraction B (*Dmin = 0.6mm, Dmax = 1.18mm, D50 = 0.82mm, Gs = 2640Mg/m3, emin = 0.486, emax = 0.78*), poured in a shear-stack box at different relative density to make different base and backfill layers.

This soil has been used extensively in experimental researches on shaking table and a wide set of density and resistance data is available [6].
On the other hand no information on the dynamic behaviour at low confining stress have ever been achieved.
To fill this gap, dynamic laboratory tests were performed at Soil Dynamic Laboratory (DynaLab) of the University of Naples Federico II. The main purpose of this laboratory experiments was to evaluate the dynamic soil behaviour (LBS-fraction B) performing Resonant Column tests (RC) and Torsional Shear tests (TS) at several confining stresses and different strain levels.
The THOR (Torsional High Output Rig) cell was adopted for the tests. This device is provided with two pairs of proximity transducers (proximitor 3000) with a full scale of ± 1 mm and ± 0.1 mm: in this way measures of small strain could be achieved during cyclic torsional shear test spanning from $\gamma=10^{-4}\%$ to $\gamma=10^{0}\%$.
Specimens to test were made by "pluviation" method, at the desired density.
Two levels of density to be tested were selected: *loose* (15.07 kN/m^3 or less) for the backfill soil and *dense* (16.14 kN/m^3 or more) for the foundation layer.

II. TESTS PERFORMED & RESULTS

To apply the confining stress, a special device to operate with vacuum was set up.
Controlling the vacuum pressure, G_0 and D_0 on the same sample at several confining stresses p' could be measured.
From this data the G_0(p') (Fig. *1*) and D_0(p') (Fig. *2*) relationships were carried out.
As expected, torsional shear results show that the more the confining stress is high, the more the modulus shear is high, but the quantitative relationship depends on Relative Density (R_D) of the specimen.

ISBN: 978-92-990075-0-1

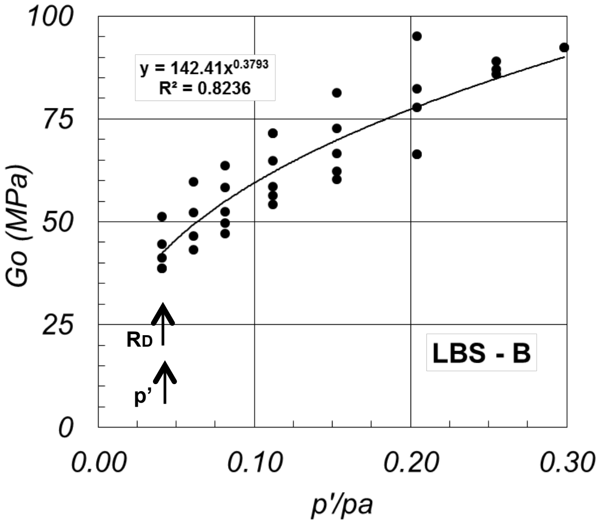

Fig. 1 Shear modulus versus confining pressure

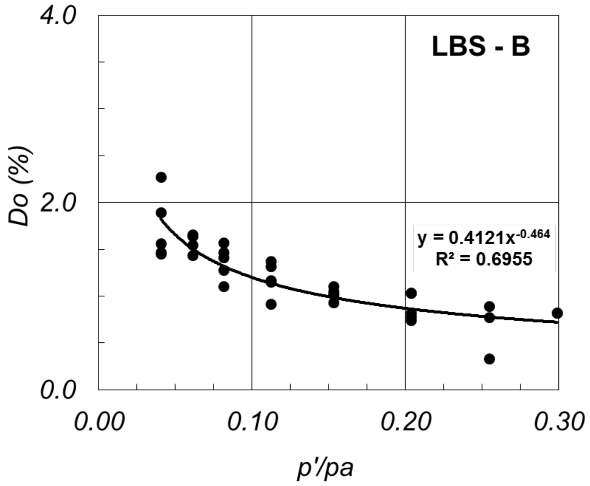

Fig. 2 Damping ratio versus confining pressure

III. RELATIVE DENSITY EFFECTS

To take into account the R_D effect a G_0/f(e)-p' relationship (where f(e) is a function of the void ratio) could be used [7].
An f(e) function "ad hoc" for the material (LBS-Fraction B) can also be defined to better interpolate the data.

At this purpose, a Vs-e-p' relationship was obtained from the available data: that is a linear relationship where the parameters are useful to get f(e) function.
Fig. *3* shows the measured shear wave velocity values as a function of void ratio. Hence, based on these measurements, the relationship between the shear wave velocity, void ratio and mean effective stress can be expressed as:

$$V_s = C(B - e)\,(\sigma'_{m0}/p_a)^{n/2} \qquad (1)$$

where C, B and n are material constants and p_a is atmospheric pressure (typically p_a= 1000 kPa).

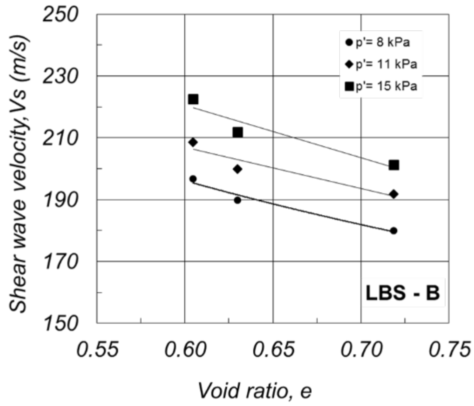

Fig. 3 Shear wave velocity versus void ratio

The best fitting values obtained for C, B and n are 480, 1.835 and 0.35, respectively.

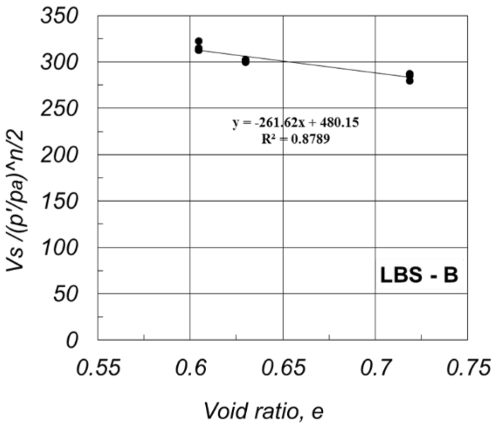

Fig. 4 Shear wave velocity ratio versus void ratio

According to the “Elastic theory”, the small strain shear modulus G_0 can thus be calculated as

$$G_0 = \rho_g C^2 F(e)\,(\sigma'_{m0}/p_a)^n \qquad (2)$$

where ρ_g is the density of soil particle, and the F(e) function is

$$F(e) = (B - e)^2/(1 + e) \qquad (3)$$

To take into account the effect of void ratio on the shear modulus, the measured G_0 was corrected by the function (3). The results are plotted in Fig. *5*.

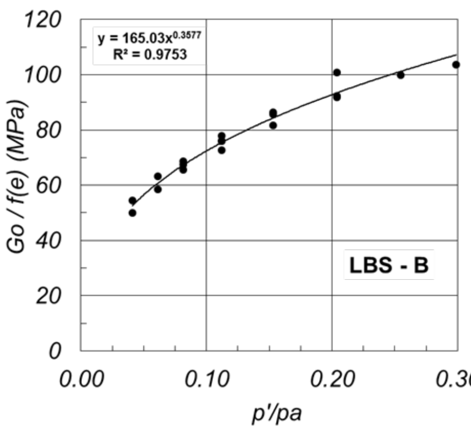

Fig. 5 Dependence of $G_0/F(e)$ on confing pressure

IV. G-γ & D-γ RELATIONSHIPS

From data, G-γ relationships at different confining stresses were also evaluated (Fig. *6*).
The experimental results show different G-γ relationships with the confining stress and the relative density, and a very sharp G/G_0-γ relationship, where the experimental points are well interpreted by a Ramberg-Osgood model (*Fig. 7*).

Damping ratio evolution with confining stress and strain level was also obtained from experimental data, since a complete description of dynamic behaviour of the Leighton Buzzard sand-fraction B was achieved at the typical shaking table confining stresses (*Fig. 8*) .

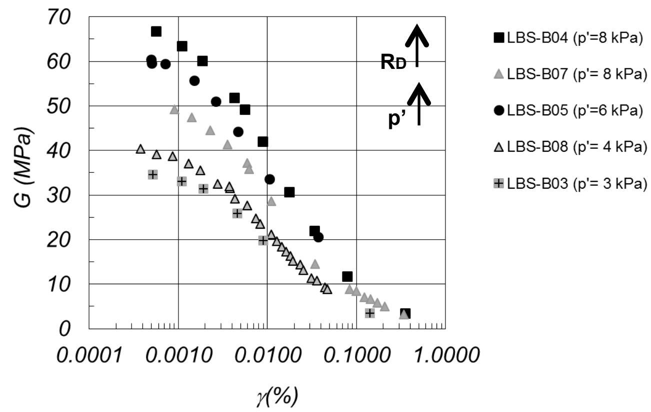

Fig. 6 G-γ relationships at different confining stress

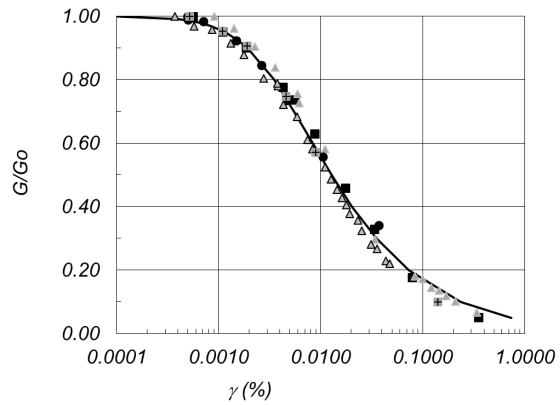

Fig. 7 G/G_0-γ relationships

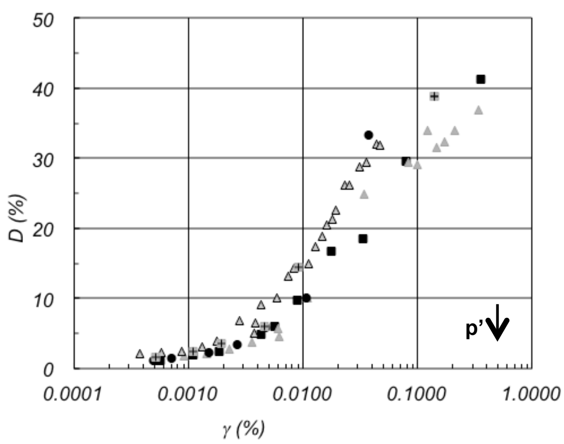

Fig. 8 D-γ relationships

V. CONCLUSIONS

In conclusion, for the tested soil the G_0-p'-e relationship can be written as:

$$Go_{[MPa]} = 150 \cdot \frac{(1.835 - e)^2}{1 + e} \cdot \left(\frac{p'}{p_a}\right)^{0.35} \quad (4)$$

According to Ramberg-Osgood model, the G-γ relationship can be written as:

$$\gamma(\bar{G}) = \left(\frac{1-G}{C\bar{G}^R}\right)^{\frac{1}{R-1}} \quad (5)$$

where:

$$\bar{G} = \frac{G}{Go} \quad (6)$$

and, for the tested soil:

$$R = 2.67 \approx 8/3 \qquad C \approx 10^8 \quad (7)$$

By means of these results, the gap in the knowledge of the Leighton Buzzard sand behaviour at very low confining stresses can be filled and a better interpretation of phenomena recorded during the shaking table tests can be performed.

REFERENCES

[1] Kloukinas P., Scotto di Santolo A., Penna A., Dietz M., Evangelista A., Simonelli A.L., Taylor C., Mylonakis G., "Investigation of Seismic Response of Cantilever Retaining Walls: Limit Analysis vs Shaking Table Testing,", Soil Dynamics and Earthquake Engineering 77 (2015) 432–445

[2] Kloukinas P, Penna A, Scotto di Santolo A, Bhattacharya S, Dietz M, Dihoru L, et al. Experimental investigation of dynamic behaviour of cantilever retaining walls. In: Proceedings of the second international conference on performance based design in earthquake geotechnical engineering. Taormina Italy; 2012.

[3] Scotto di Santolo A, Penna A, Kloukinas P, Bhattacharya S, Dietz M, Dihoru L, et al. Experimental investigation of dynamic behaviour of cantilever retaining Walls. In: Proceedings of the 15th world conference on earthquake engineering. Lisbon; 2012.

[4] Kloukinas P, Penna A, Scotto di Santolo A, Bhattacharya S, Dietz M, Dihoru L, et al. Experimental investigation of dynamic behaviour of cantilever retaining walls. In: Proceedings of the fourth ECCOMAS COMPDYN thematic conference on computational methods in structural dynamics and earthquake engineering. Kos Greece; 2013.

[5] Kloukinas P, Penna A, Scotto di Santolo A, Bhattacharya S, Dietz M, Dihoru L, et al. Experimental investigation of dynamic behaviour of cantilever retaining walls. In: Ilki A, Fardis MN, editors. Seismic Evaluation and Rehabilitation of Structures, Geotechnical, Geological and Earthquake Engineering, 26. Switzerland: Springer International Publishing; 2014http://dx.doi.org/10.1007/978-3- 319-00458-7_27.

[6] Cavallaro A, Maugeri M, Mazzarella R. Static and dynamic properties of Leighton Buzzard sand from laboratory tests. In: Proceedings of the fourth international conference on recent advances in geotechnical earthquake engineering and soil dynamics and symposium in honour of Prof. WD Liam Finn. San Diego California; 2001.

[7] Hardin, B.O., and Black, W.L. (1968). Vibration modulus of normally consolidated clay. Journal of the Soil Mechanics and Foundations Division. ASCE 94:2, 353-369.