20th IMEKO TC4 International Symposium and
18th International Workshop on ADC Modelling and Testing
Research on Electric and Electronic Measurement for the Economic Upturn
Benevento, Italy, September 15-17, 2014

Experimental measurements of geotechnical systems in 1-g tests

Maria Giovanna Durante[1], Luigi Di Sarno[1], Stefania Sica[1], George Mylonakis[2], Colin A. Taylor[2], Armando Lucio Simonelli[1]

[1] *University of Sannio, Dep. of Engineering, Piazza Roma, 27-1, 82100 Benevento, IT,* mgdurante@unisannio.it, disarno@unisannio.it, stefsica@unisannio.it, alsimone@unisannio.it
[2] *University of Bristol, Queen's Building, University Walk, Bristol BS8 1TR, UK,* g.mylonakis@bristol.ac.uk, colin.taylor@bristol.ac.uk

ABSTRACT

The geotechnical systems are often studied analysing the response of scaled models in 1-g or n-g devices. A crucial aspect in these kind of models is the capability to read the real response of the system using different instrumentations. In this paper are described the main devices used for the interpretation of the dynamic response of a scaled geotechnical model tested at the Bristol Laboratory for Advanced Dynamics Engineering (BLADE) of the University of Bristol, UK, within the framework of the Seismic Engineering Research Infrastructures for European Synergies (SERIES), funded by the 7th FP of the European Commission. The model is formed by a group of five piles embedded in a bi-layer deposit with different pile head conditions, different dynamic properties of the superstructure (connected at the top of the pile group) and input motions. After some details about the whole experimental campaign and the devices used, the paper shows the main procedures adopted to evaluate the response of the whole system in terms of acceleration, displacement and stresses (only for piles).

I. INTRODUCTION

The dynamic behaviour of geotechnical system is often studied looking at the response of scaled system excited by seismic waves through shaking table tests. One crucial aspect in this kind of analysis is the interpretation of the response of the overall system: for this aim it is necessary to use different instrumentations for each aspect to investigate. This paper shows the main aspect of the data interpretation referring to typical shaking table tests. The data refers to experimental tests carried out on scaled models performed on the *3m* x *3m* shaking table of the Bristol Laboratory for Advanced Dynamics Engineering (BLADE), University of Bristol, UK.

The experimental program has been carried out on a group of piles, with and without pile caps. The loading conditions include different input motions, i.e. white noise, sinedwells and earthquakes.

II. EXPERIMENTAL MODEL SETUP

The shaking table (Fig. 1) has 6 degrees of freedom, it consists of a 3 m x 3 m cast aluminium platform weighing *3.8 tonnes*, with payload capacity of *15 tonnes* maximum and operating frequency range of 1-100Hz. Hydraulic power for the ES is provided by a set of 6 shared variable volume hydraulic pumps providing up to *900 litres/min* at a working pressure of *205 bar,* with maximum flow capacity of around *1200 litres/min* for up to 16 seconds at times of peak demand with the addition of extra hydraulic accumulators. The platform is attached to the block by eight hydraulic actuators.

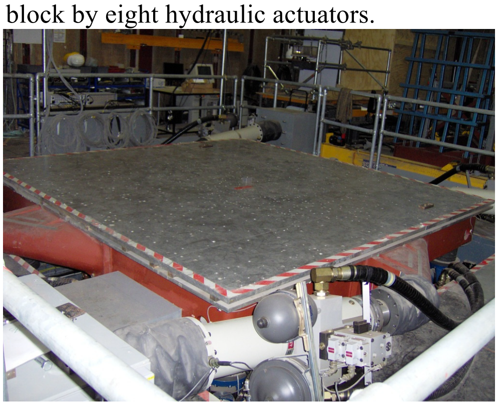

Fig. 1. Shaking table at Bristol University (BLADE)

The container for the soil in the shaking table tests is called Equivalent Shear Beam or shear stack (Fig. 2) [1].

It consists of 8 rectangular aluminium rings, which are stacked alternately with rubber sections to create a hollow yet flexible box of inner dimensions *1.19* m long by 0.55 m wide and *0.81* m deep. The rings are constituted of aluminium box section to minimize inertia while providing sufficient constraint for the K_0 condition. The stack is secured to the shaking table by its base and shaken horizontally lengthways (in the x direction). This type of containers should be ideally designed to match the shear stiffness of the soil contained in it.

ISBN-14: 978-92-990073-2-7

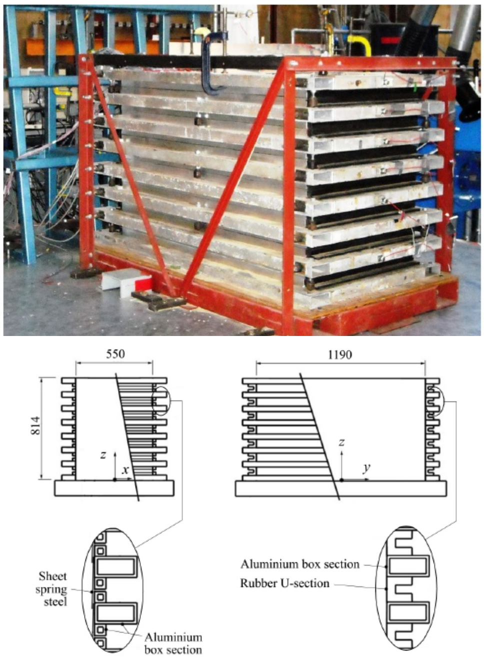

Fig. 2. Equivalent Shear Beam container (ESB – shear stack)

The scaled model is illustrated in Fig. 3, with the type and the positions of the instrumentation used. The model consists of five piles embedded in a bilayer soil (Fig. 3a) with an oscillator on the top: different configurations are considered in the overall experimental campaign [2 - 4]. As shown in Fig. 3c, 18 1-D accelerometers have been used to monitor the accelerations of the shaking table, the shear stack, the soil along vertical array, the pile heads and the mass of the 1-D oscillator. The LVDT transducers in Fig. 3d are used to measure the displacements of the pile in the horizontal direction and of the ground level in the vertical direction. To monitor the bending response of the piles, 8 strain gauge pairs have been attached on the shafts of pile 4 and 5; additionally, 4 strain gauges are placed on the shaft of pile 1 in correspondence to the layer interface (Fig. 2b). Overall, 62 data channels were employed.

The accelerators have a high output capacitance with inbuilt pre-amplifier, a calibrated range equal to +/- 8g and an operating frequency of 0-3000 Hz. The LVDT is a linear variable displacement transformer. The linear strain gauges pattern is 3 mm length. The details of the instrumentation are provided in Table 1.

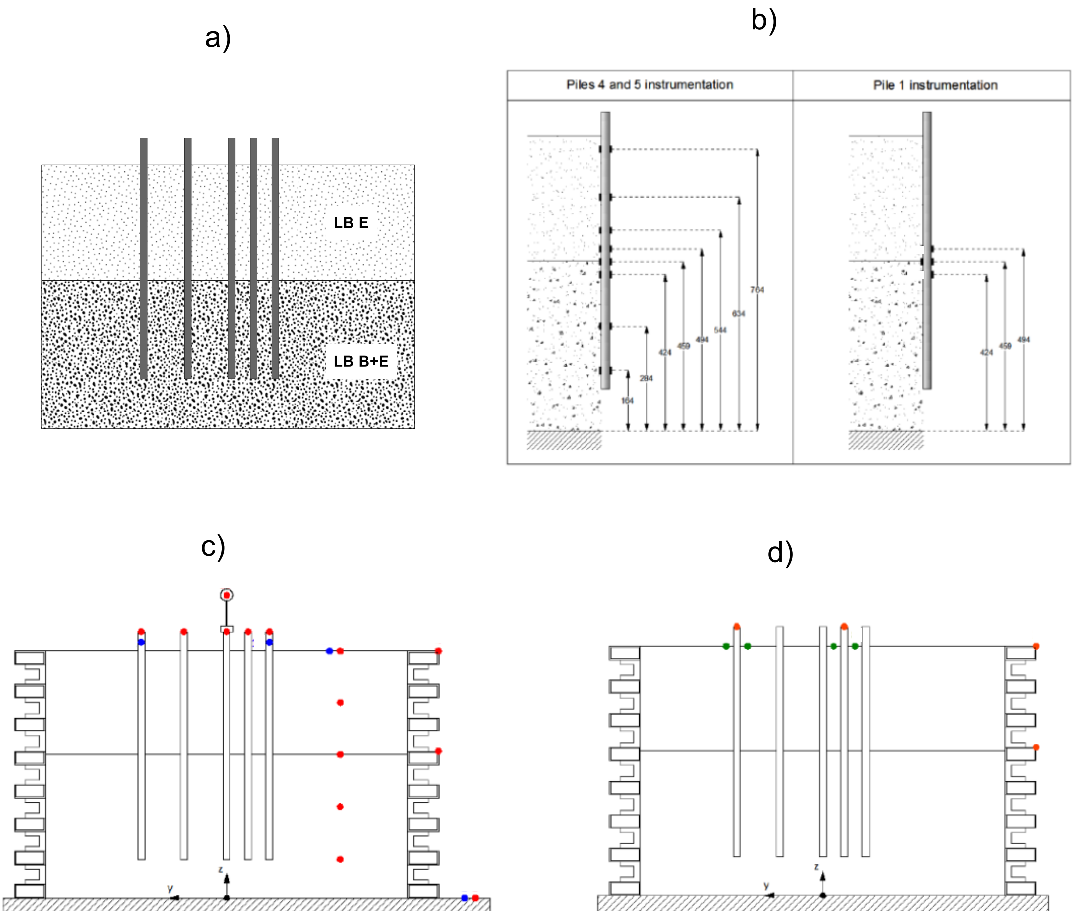

Fig. 3. Model setup: (a) subsoil configuration, (b) strain gauges, (c) accelerometers and (d) LVDT location

Table 1. Instrumentation details

Measured Parameter	Transducer Type
Acceleration	SETRA 141A
Displacement	RDP DCTH
Strain	EA-13-120LZ-120

III. *MEASUREMENTS INTERPRETATION*

The excitation voltage for the displacement transducers and strain gauges was supply by an RDP 600-type modular electronics system. The signal conditioning of the LVDTs will be made via the RDP 611 amplifier modules. These amplifiers allow optimisation of both the excitation voltage and gain and can impart DC offsets in order to zero signals. The completion of the bridge and the excitation voltage for the strain gauges will be made via RDP 628 strain gauge amplifier modules. The SETRA accelerometer signals will be amplified by a set of Fylde 245GA mini-amplifiers. These have multiple gain, variable sensitivity and offset options. The amplified signals will be supplied to a FERN EF6 multi-channel programmable filter that will be set at a common cut-off frequency on all channels (80 Hz). Data obtained in this way, through appropriate calibration factors, give direct measurements of the values of interest. These values can be used directly for the interpretation of the phenomena for the accelerometers (Fig. 4) and the LVDTs (Fig. 5).

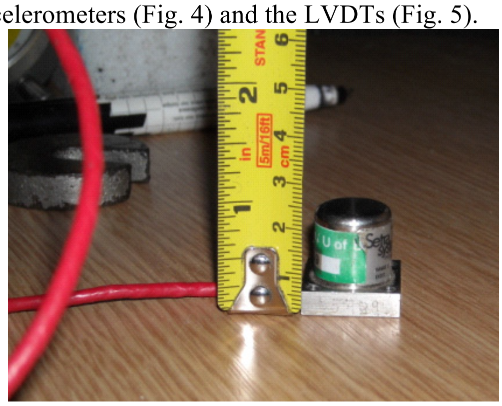

Fig. 4. Accelerometer Setra

Fig. 5. Linearly Varying Differential Transformer (LVDT)

For the case of the strain gauges (Fig. 6) it is necessary to process the data, otherwise these values are not useful for the evaluation of the piles response.

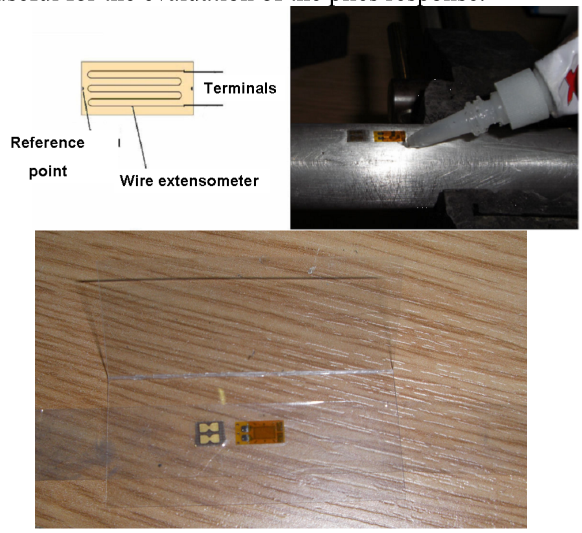

Fig. 6. Strain gauges: schema (top-left) and device (top-right and bottom)

In this paper the strain gauges values are used to obtain bending moments (Fig. 7) and axial force along piles.

As shown in Simonelli et al. 2012 [3] the time histories of the pile bending moment M and axial force N may be obtained from the strain ones at for each depth by the following equations:

$$M = \frac{\varepsilon_1 - \varepsilon_2}{2} \cdot E_p I_p \cdot \left(\frac{2}{D}\right) \tag{1}$$

$$N = \frac{\varepsilon_1 + \varepsilon_2}{2} \cdot E_p A_p \tag{2}$$

where ε_1 and ε_2 are the strains measured on the opposite sides of the pile, E_p, I_p and D are the Young's modulus, the moment of inertia and the diameter of the pile respectively and A_p is the area of the pile cross-section.

D. *CONCLUDING REMARKS*

This paper shown some crucial aspects of a complex experimental setting carried out at BLADE, within the Framework of the Seismic Engineering Research Infrastructures for European Synergies (SERIES).

The data acquisition system is formed by:

- 18 SETRA accelerometers for the direct evaluation of the response of the soil, the shear stack and piles;
- 8 Linear Variable Displacement Transformers (LVDT) for the evaluation of the horizontal and vertical displacement of piles, and horizontal displacement of the shear stack;

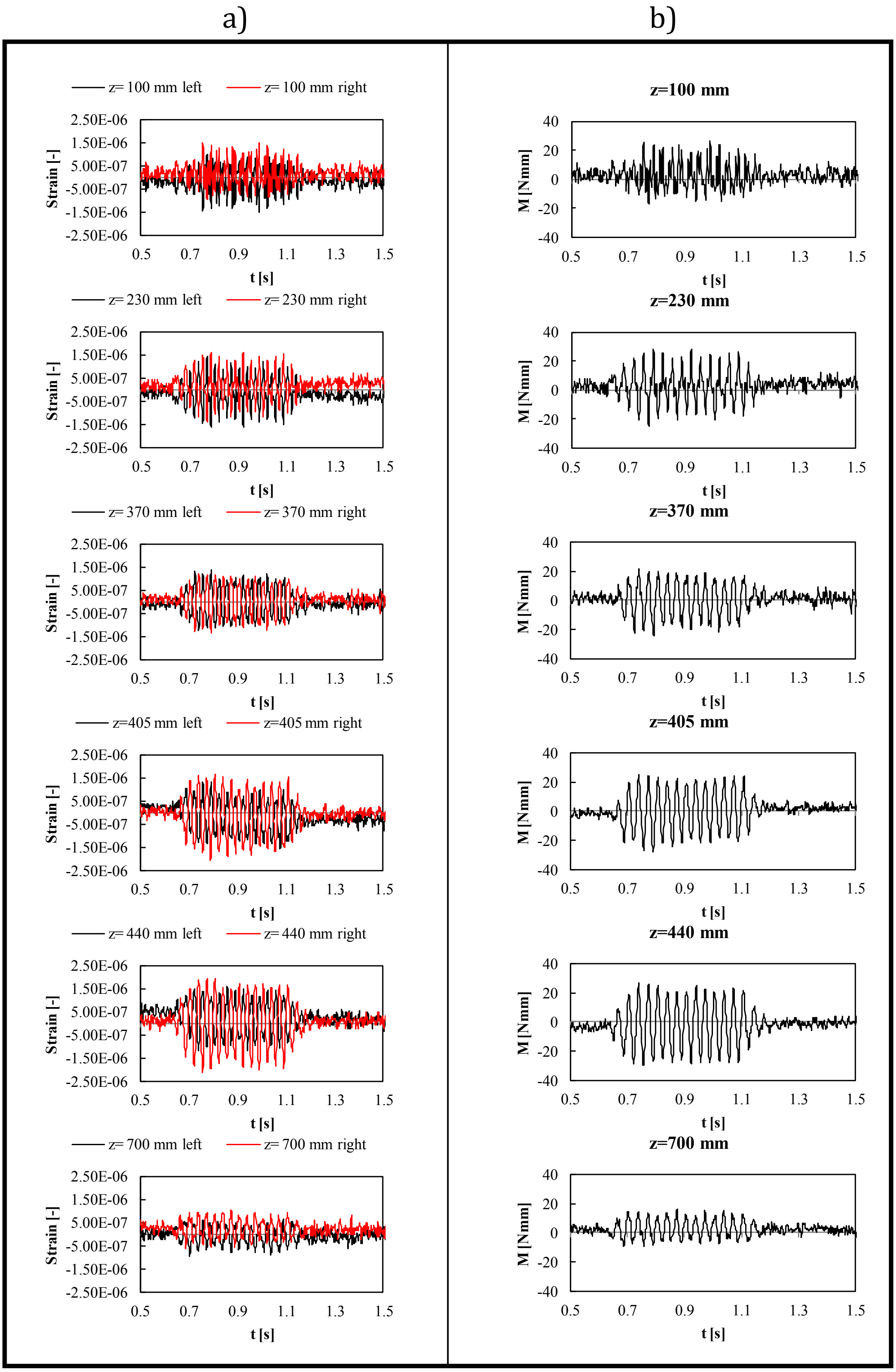

Fig. 7. Typical time histories of strains (a) and bending moments at different pile elevation

- 36 linear strain gauges pattern of 3 mm length for the evaluation of the bending moments and the axial force on the instrumented piles.

For the accelerometers and the LVDT the measured data linear calibration factors are applied to obtain the interested values. Different procedure was used to obtain the response of piles through the strain gauges response taking into account simple equation able to relate this values with bending moment and axial force.

ACKNOWLEDGEMENTS

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 227887, SERIES.

The financial support provided by the project ReLUIS (Task MT2) funded by the Italian Civil Protection is also appreciated.

REFERENCES

[1] Crewe A.J., Lings, M.L., Taylor, C.A., Yeung, A.K. & Andrighetto. 1995. Development of a large flexible shear stack for testing dry sand and simple direct foundations on a shaking table' European seismic design practice, Elnashai (ed), Balkema, Rotterdam.

[2] Simonelli AL, Di Sarno L, Durante MG, Sica S, Bhattacharya S, Dietz M, Dihoru L, Taylor CA, Cairo R, Chidichimo A, Dente G, Modaressi A, TodoBom LA, Kaynia AM, Anoyatis G, Mylonakis G (2014) Chapter 27: Experimental Assessment of Seismic Pile-Soil Interaction. Seismic Evaluation and Rehabilitation of Structures, Geotechnical, Geological and Earthquake Engineering, Volume 26:455-475.

[3] Simonelli, A.L., Di Sarno, L., Durante, M.G., Sica, S., Bhattacharya, S., Dietz, M., Dihoru, L., Taylor, C.A., Cairo, R., Chidichimo, A., Dente, G., Anoyatis, G., Mylonakis, G., Modaressi, A., Todo Bom, L.A. and Kaynia, A.M. (2012). Performance of soil-pile-structure systems under seismic waves. *II Int. Conf. On Performance-Based* Design in Earthquake Geotechnical Engineering, Taormina, I

[4] Simonelli, A.L., Di Sarno, L., Durante, M.G., Sica, S., Bhattacharya, S., Dietz, M., Dihoru, L., Taylor, C.A., Cairo, R., Chidichimo, A., Dente, G., Anoyatis, G., Mylonakis, G., Modaressi, A., Todo Bom, L.A. and Kaynia, A.M. (2012). Experimental investigation of soil-pile-structure seismic interaction. *15th World Conference on Earthquake Engineering,* Lisbon 2012