The use of seismic wave velocities in the evaluation of stiffness, damping and anisotropy of geomaterials in routine laboratory and field tests

Cláudio Pereira[1*], António Gomes Correia[1], Sohel Nazarian[2], and Cristiana Ferreira[3]
[1]ISISE, School of Engineering, University of Minho, Campus de Azurém, Guimarães, Portugal
[2]CTIS, Department of Civil Engineering, University of Texas, El Paso, United States of America
[2]CEC, Department of Civil Engineering, University of Porto, Porto, Portugal
cpereira@civil.uminho.pt, agc@civil.uminho.pt, nazarian@utep.edu, cristiana@fe.up.pt

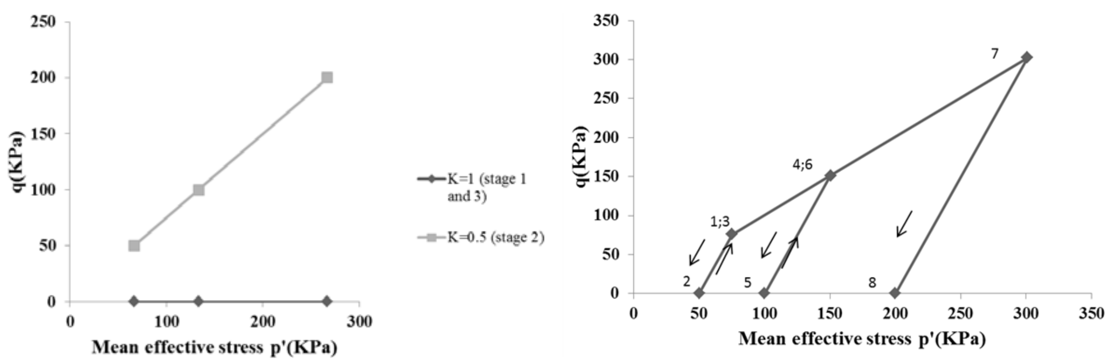
1 Introduction

Seismic wave-based geotechnical engineering tests have received significant attention in the last decades. Bender elements have become increasingly common tools for direct and nondestructive measurement of P and S wave velocities. The elastic stiffness parameters of the material (shear and constrained moduli and Poisson's ratio) can be directly computed with these velocities. Other relevant features of soil behavior, including anisotropy (Ratananikom et al., 2013), sampling quality (Ferreira, et al., 2011), liquefaction potential (Soares, 2014), cementation level, porosity (Zhu & Bate, 2014) and damping, (Karl et al., 2003) can also be detected.

The major goal of the work presented here is the development of a seismic wave-based bender element testing framework and modeling for integrated and advanced geotechnical characterization of a wide range of geomaterials, including stiffness, anisotropy and damping both in the laboratory and in situ. As a first step of this study, the assessment of the inherent and stress-induced anisotropy was carried out on an uniform dry sand submitted to different isotropic and anisotropic stress paths.

2 Materials and Methods

The chosen material was a monogranular sand with a maximum and minimum void ratios of 0.882 and 0.655, respectively, and 2.63 g/cm^3 of soil particle density. Specimens were prepared by the pluviation method. To assess the inherent and stress-induced anisotropy, each specimen was tested at different stages of stress paths (Figure 1).



a) b)

Figure 1: a) Stress path of the first specimen; b) Stress path of the second specimen

The stress states were applied in two triaxial cells using 100 mm and 150 mm diameter specimens to allow scale-effects analysis. For both triaxial cells the small strain stiffness for each stress state was evaluated by means of BE's which were assembled vertically and horizontally for the comparison of the shear wave velocity (Vs) in the two

[*] Corresponding author. Email: cpereira@civil.uminho.pt

directions. For the 100 mm specimens, and additionally to the vertical BE direction of analysis and according to the test setup presented in Martins (2011); Ferreira et al. (2013) and Martins, J. & Gomes Correia, A. (2015), accelerometers (AC) were used in order to improve the accuracy of the obtained results.

3 Results

Under the isotropic stress conditions (stage1), the variations in the shear modulus with the confining stress was assessed. Figure 2 illustrates that the horizontal shear moduli (G_h) is significantly greater than the vertical shear moduli (G_v). Since some level of confinement was applied to the material from the initial stages, these results do not completely illustrate the fabric anisotropy of the material. However, the applied isotropic stress does not alter the material structure (i.e., there is no rearrangement of particles as a result of the applied confining stress), allowing for a comparison between the anisotropy in the early stages of the stress and the fabric anisotropy of the sand. As such, and related to the specimens preparation method, these results are intended to demonstrate the fabric anisotropy of this sand. The variation of the anisotropy with the mean stress is low, ranging between of 1.25-1.27.

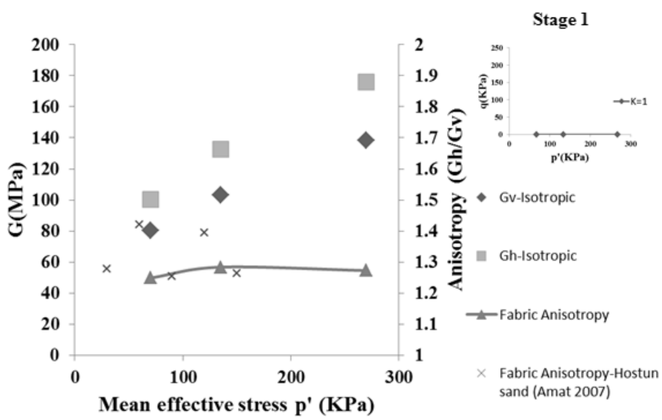


Figure 2: Shear modulus of the sand under isotropic conditions and fabric anisotropy.

References

Ferreira, C., Martins, J. P., & Gomes Correia, A. (2013). Determination of the small-strain stiffness of hard soils by means of bender elements and accelerometers. *Geotechnical and Geological Engineering*, *6*, 1–7.

Ferreira, C., Viana da Fonseca, A., & Nash, D. F. T. (2011). Shear wave velocities for sample quality assessment on a residual soil. *Soils and Foundations*, *51*(4), 683–692.

Soares, M. (2014). Evaluation of Soil Liquefaction Potential based on Laboratory Data. Major factors and limit boundaries. Tese de Doutoramento. University of Porto.

Karl, L., Haegeman, W., Pyl, L., & Degrande, G. (2003). Measurement of material damping with bender elements in triaxial cell. *In Proceedings of the 3rd International Symposium on Deformation Characteristics of Geomaterials*, *1*, 3–11.

Martins, J. (2011). *Compaction and its influence on the structural behaviour of high speed railways*. Universidade do Minho.

Ratananikom, W., Likitlersuang, S., & Yimsiri, S. (2013). An investigation of anisotropic elastic parameters of Bangkok Clay from vertical and horizontal cut speciemns. *Geomechanics and Geoengineering*, *8*(1), 15–27.

Wang, D.-X., Xin, K.-F., Li, Y.-M., Gao, J.-H., & Wu, X.-Y. (2006). Investigation in the effect on wave velocity and attenuation from the water saturation in sand at reservoir conditions. *Chinese Journal of Geophysics*, *49*(3), 802–809.

Zhu, J., & Bate, B. (2014). *Using Shear Wave Velocity to Monitor the Curing Process of Self-Consolidating Concrete by Bender Element*. Rolla