FREQUENCY ANALYSIS OF WAVE PROPGATION IN GRANULAR PACKINGS

Mohammad SHARIFIPOUR*, Christophe DANO, Pierre-Yves HICHER

Research Institute in Civil and Mechanics Engineering, Ecole Centrale Nantes – University of Nantes – CNRS, 1 rue de la Noë, BP 92101, 44321 NANTES cedex 3 (France)
*m.sharifipour@ec-nantes.fr

Bender elements are more and more often used in geotechnical engineering to assess the elastic properties of soils [1, 2, 3 & 4]. Although the principle, based on the propagation of compression and shear waves, is simple, the interpretation of the tests requires an educated judgment, in particular in granular soils [5, 6 & 7]. The international parallel test organized by TC29 of the ISSMFE in 2002 thus showed a surprising discrepancy between the values of the shear modulus of Toyoura sand in the same conditions of density, the same state of stresses, the same method of sample preparation, using the same method of interpretation. That interpretation method consists in determining the time of flight of the waves by comparison of the input signal and the output signals.
Further interpretation methods were developed in the recent past to confirm the results of the previous time analysis: cross-correlation and frequency analysis [2, 8 & 9]. Contrary to the time analysis, frequency analysis provides additional relevant information because the whole output signal is considered. The frequency analysis was therefore carried out to analyze the propagation of both compression and shear waves in various granular packings : glass beads, Fontainebleau sand, Toyoura sand …
In this paper, we first present the methodology adopted to analyze the signals, mainly the decomposition of the signal into a coherent part and a random part. The coherent part corresponds to the propagation into an effective continuous medium whereas the random part can be related to the complex interactions at the microscopic scale between the waves and the grains.
Then, we show some experimental results of pulse tests in granular packings at different stress levels. The analysis of the output signals reveals (i) an increase of the wave velocities as a power law of the mean effective stress and (ii) an increase of the peak frequency (peak of maximum magnitude in frequency). We observe that the evolution of the peak frequency follows a power law similar to the one obtained for wave velocities.
Finally, different assumptions are made to explain such an evolution of the peak frequency: the first one is based on the Hertz's theory [10] of contact (microscopic point of view), the second one is based on the natural vibrations of the couple {bender – extender element; surrounding soil}. Additional original tests were carried out to validate or invalidate each of these two approaches. The conclusions are presented and discussed.

Reference

[1] R. Dyvik and C. Madhus, Publication 161 of the Norwegian Geotechnical Institute, 1-7, 1986.
[2] G. Viggiani and J. H. Atkinson, Geotechnique, **45** (1), 149-154, 1995.
[3] V. Jovicic, M.R. Coop and M. Simic, Geotechnique, **46** (2), 357-362, 1996.
[4] E.G.M. Brignoli, M., Gotti and K.H. Stokoe, Geotechnical Testing Journal, **19** (4), 384–397, 1996.
[5] J. Duffy and R.D. Mindlin, Journal of Applied Mechanics, **24**, 585-593, 1957.
[6] J.D. Goddard, Proceedings of the Royal Society, London, A430, 105-131, 1990.
[7] X. Jia, C. Caroli and B. Velicky, Phys. Rev. Lett., **82** (9), 1863-1866, 1999.
[8] A.K.M. Mohsin and D.W. Airey,Proc. 3rd International Symposium ISLyon, 73-80, 2003.
[9] P. D. Greening and D. F. T. Nash, Geotechnical testing journal, **27** (3), 288-294, 2003.
[10] H. Hertz, J. reine und angewandte Mathematik, **92**, 156-171, 1882.