Laser-Doppler acoustic probing of analogue models with in-depth property gradient and varying pore pressures

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Abstract

Granular materials are widely used for both geological and physical modelling purpose. Natural sand, granular silica or glass beads provide acceptable analogues in various experiments (*e.g.* accretionary wedges modelling, gravitational spreading and gliding simulations (Mourgues *et al.*, 2009), hydraulic fracturing studies (Gressier *et al.*, 2008; Gressier *et al.*, 2010), hydrogeological modelling, *etc.*). Advances in optical techniques and digital imaging methods enable accurate measurements of models topography, or high-resolution strain monitoring (Crave *et al.*, 2000; Adam *et al.*, 2008; Graveleau *et al.*, 2008). Such observations remain confined to the material surface and mostly address the plastic behaviour of materials involved in studied processes. The knowledge of material elastic parameters, before and during the experiments, would highly improve results interpretation as well as the implementation of joint analytical or numerical analyses.

In this work, we address the ability of laser-Doppler experiments in the systematic characterization of granular materials involved in analogue modelling. Our methodology is developed and validated on an unconsolidated granular laboratory medium, perfectly characterised in terms of Pressure- and Shear-wave one dimensional (1D) velocity profiles with depth (Jacob *et al.*, 2008). The flexibility and high density sampling abilities of non-contacting measurements (Bodet *et al*, 2009a) make it possible to simulate a small scale seismic line at the surface of the model (Figure 1a). Pressure-wave first arrival times and surface-wave dispersion are then inverted for a 1D velocity structure (Bodet *et al*, 2009b). Inferred profiles appear to match previously thoroughly estimated properties of the probed medium, thus validating our approach (Figure 1b).

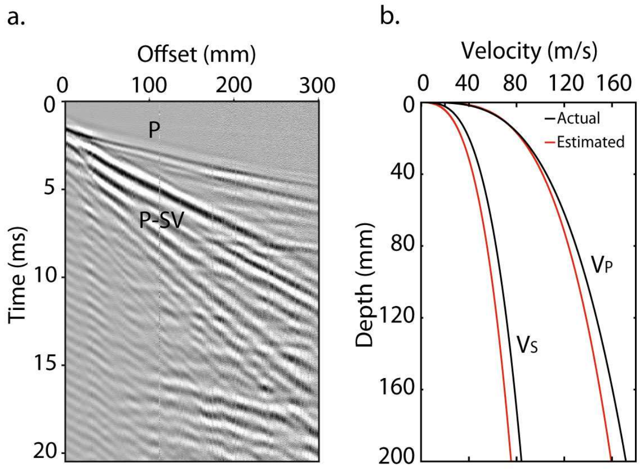

Fig.1: *(a) A small-scale seismogram is recorded at the surface of an unconsolidated granular laboratory medium. P and P-SV waves are inverted for a 1D velocity structure. (b) Estimated models are in good agreement with previously thoroughly estimated velocities, within errors lower than 9% at depth.*

Similar experiments are currently performed to monitor analogue models involving pore overpressure. The experimental set-up is used with an air reservoir at its bottom to generate a pore pressure gradient in the granular material (Figure 2a). Seismograms are recorded at the model surface for different reservoir pressures, as presented on Figures 2b and 2c. The methodology described above is reproduced to infer elastic parameters of the medium and gives the opportunity to study the influences of pore overpressure on wave propagation at very low confining pressure.

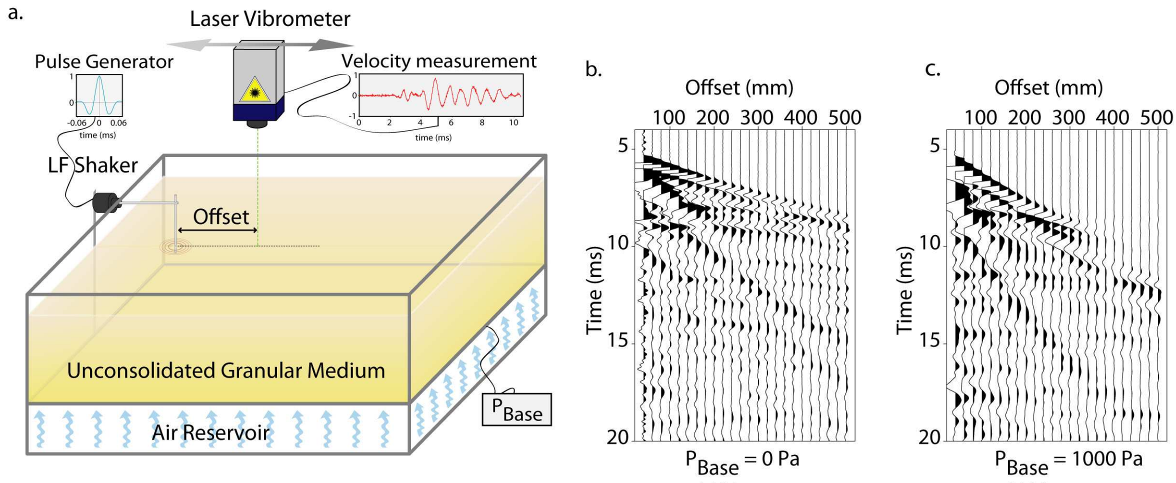

Fig.2: *Experiments involving pore overpressure. (a) An air reservoir is used to generate a pore pressure gradient in the model. (b) The recorded seismograms illustrate the decrease of wave velocities consequently related to a decrease of effective pressure.*

The use of such experiments appears to be of great interest as well in the physical modelling of wave propagation to address a wide range of theoretical and practical issues (*e.g.*, heterogeneous media, complex structures, pore fluids, *etc.*). This work should for instance enable the validation of recent numerical developments in the context of wave propagation in viscoelastic media (Dhemaied *et al*., 2009), and will soon be applied to hydrogeological prospecting issues.

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