Detection and characterization of superficial cavities by numerical and experimental laboratory approach using homogenization principle

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Résumé

The first layers of the Earth's subsurface are particularly heterogeneous and attenuating for seismics waves because of altered rocks and unconsolidated soils. This last characteristic leads to the use of low frequencies and therefore long wavelengths compared to the heterogenities sizes for seismic methods implemented at these scales. Thus, the characterization and detection of small heterogeneities of subsurface is tricky while they are higly required for various issues such as natural hazards. In this context and within the framework of my thesis, we propose an innovative approach based on the principle of homogenization to image small surface anomalies, modeled in this study by an empty cylindrical cavity.
In previous works based on the homogenization principle (Capdeville *et al.*, 2020), it has been shown that small heterogeneities effects for long propagating wavelength are more visible on spatial deformation than on seismic particular displacement. For this reason, we develop in my thesis work, an inverse problem to estimate the first order corrector of the homogeneised data which contains information of a heterogeneity in the subsurface by using spatial deformation data.
A combined approach between numerical simulation and laboratory scale experimentation has enabled us to identify the feasibility of this method in the case of empty cavities. The numerical tests make possible the identification of an anomaly at the cavity position by using a code based on the 2D spectral finite element method. The laboratory study was conducted on the MUSC (Measurement at Ultrasonic SCale) seismic simulation bench available at the Gustave Eiffel University, which allows to perform seismic physical simulations in controlled environments. The MUSC bench provides an intermediate step between the study of numerical data and field data which are particularly complex. From the first results obtained by combining these modeling devices we have identified the feasibility and limitations of this approach. For example, considering a numerical simulation of a cavity with a 8mm diameter which is 7mm deep, the process using a central wavelength of 28mm performs a distinct positive anomaly in the plumb of the cavity position with a significant amplitude of 0.62. For the same test in scaled down experimentation, we find a positive anomaly of amplitude 0.4, which is twice the noise amplitude in the experimental measurement conditions.
Note that even if classical seismic recordings (e.g. using geophones) measure the particular displacement, this approach seems particularly interesting in the context of the increasing use of the optical fiber as a new seismic sensor that directly measures the spatial deformation of the medium. Yann Capdeville, Paul Cupillard, Sneha Singh. An introduction to the

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