CERIS Civil Engineering Research and Innovation for Sustainability

Coupled experimental and numerical approaches for the optimisation and interpretation of bender element experiments in soils

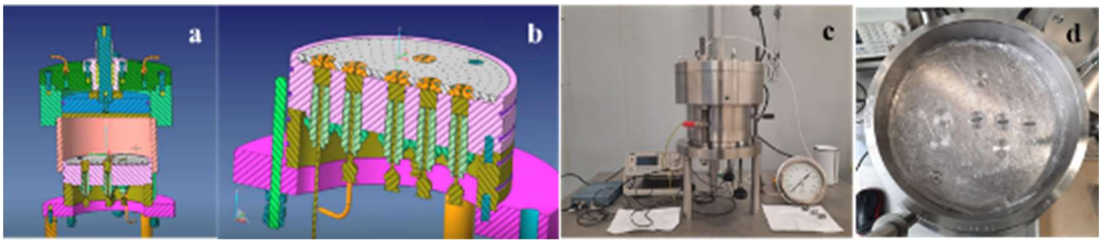
Summary

The shear modulus is an important characteristic of geomaterials. It is typically measured under laboratory conditions using resonant column apparatus or bender element (BE) experiments. BEs are much cheaper and more flexible than the resonant column apparatus. They can be installed in oedometers, triaxial devices, direct shear apparatus, and even cubical cell apparatuses. However, the BE test still has several limitations, which require further research. In the experimental setup, several issues remain open such as the best location of the receiver, the optimal shape of the BEs, the nature of the input excitation, the effect of specimen size and boundary conditions on wave propagation, and the mixed radiation of both compression and shear waves, leading to the uncertain detection of the first arrival. Two BEs are used in a typical setup: one generates a shear wave (transmitter) and the other one reads its arrival at another point of the geomaterial (receiver). The travelling time of the wave gives the velocity used to calculate the shear modulus. The objective of this research project CEN-DynaGeo aimed to exploit the favorable properties of the hybrid-Trefftz finite element models for the optimization of the experimental configuration in BE tests and the automatization of the interpretation of the results. Therefore, a toolbox for the automatic computation of the small strain shear moduli, as well as a modified Rowe cell device for echo-based BE testing of geomaterials are developed.

The first part of the project introduces the novel computational platform *GeoHyTE*. GeoHyTE is a new toolbox for the automatic interpretation of the output signal in BE tests. This platform correlates two output signals, namely the experimental output signal obtained in the lab and the numerical output signal, obtained using hybrid-Trefftz finite elements models. The toolbox receives the former and information on the testing conditions, and automatically estimates the shear modulus that maximizes the correlation. Instead of conventional extremum finding techniques, which are unable to distinguish between local and global extrema, this procedure searches for the fixed point of the maximum cross-correlation function. The method is objective as minimal user intervention is required. Moreover, the wave propagation process is modelled in full, and signals of the same nature (output) are correlated. Additionally, GeoHyTE is nearly insensitive to grossly erroneous input by the user, both in terms of the starting point of the iterative maximisation process and refinement of the finite element model. GeoHyTE is developed in the Matlab environment. It features a user-friendly interface and can be deployed as a Matlab App or as a standalone executable. The second part of the project presents a novel modified Rowe cell apparatus for the estimation of the shear modulus. The modified Rowe cell uses transmitter and receiver BEs on the same boundary of the sample to estimate the shear modulus in echo mode. Additionally, the modified Rowe cell allows the flexible installation of the receivers and enables the use of multiple receivers, possibly with distinct orientations, to improve the accuracy of the compression and shear wave readings. Furthermore, the top boundary of the specimen is controlled using a different soil apparatus interface (rigid or flexible boundary). The rebound measurements are a new concept in the BE experiment and were proven to be particularly convenient in the context of Rowe measurements.

Keywords

Small strain shear modulus, bender element, modified Rowe cell, dynamic interface.



(a) Axial stress and pore pressure control; (b) base platen and transducers housing; (c) modified Rowe cell apparatus and dynamic acquisition system; (d) installation of the BE transducers.

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