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Determination of Elastic Parameters due a Dynamic Hertzian Contact

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Extended Abstract

An earthquake is a natural spontaneous phenomenon, representing a threat not only to people but also to the economy and the infrastructure of any country [1]. Effects of seismic activity could be shrunk by improving the uncertainty associated with the measurement of soil parameters [2]. Dynamic behavior of soils is related to some properties such as shear modulus (G), Young's modulus (E) and damping ratio (λ) [3]. There are several techniques to measure these parameters, but some of them are too expensive for daily projects. Consequently, professional practitioners need a wider variety of tests to measure elastic properties and use them as input in computational engineering models.

This research is based on the Hertzian Contact Theory. Specifically, shear and Young modulus of the soil were computed using a wave produced by an impact of a steel sphere. The impact caused by a short transient force generates deformation on the soil surface. As a result, deformation produces two types of waves: body waves and surface waves. Body wave's velocity (i.e., P-wave and S-wave) is related to the material elastic properties [4]. Consequently, P and S-wave's travel time through a medium was measured using two sensors located at the top and at the bottom surfaces of the soil samples.

An accelerometer and a high-frequency transducer were used for travel time measurement in this test. In detail, a high-frequency ICP ® accelerometer was placed on the top sample surface located at 5 mm from the impact point. This accelerometer uses a frequency range between 0.0016 *kHz* and 30 *kHz.* At the same time, either a P or S-wave transducer was placed in the middle of the sample's cross section bottom surface. Specifically, a Pundit Lab Transducer with a frequency range from 20 *kHz* to 500 *kHz* was used for P-waves measurements. Whereas, a shear wave transducer, model V151 –RB was used for S-Waves.

Three clay samples were prepared with different volumetric properties. The clay had a plasticity index of 17.9 *%*, a liquid limit of 35 *%* and a specific gravity of 2.59. The process of soil preparation was made in two phases: water addition, and sieving process. In detail, a No. 8 sieve was used and the passed material was stored in a hermetic plastic bag until the mixture was homogenous. Samples with different densities were prepared by compacting and using three different water content according to the Standard Proctor Method, ASTM D 698 [5]. The samples had a density of 1.98 g/cm3, 2.00 g/cm3 and 1.96 g/cm3 and a water content of 19%, 21% and 22%, respectively. Compacted samples were extracted from the mold and tested without any confinement. Each sample had been tested five times to get a reliable result.

A steel sphere of 6.4 mm of diameter and 1.04 g of weight was dropped from a controlled height of 5 *cm.* Using this procedure and the measured values of waves velocities from the Proctor samples, Young and shear modulus were calculated. Another cylindrical samples of 13.00 mm of diameter and 45.00 mm of height were constructed with the same volumetric properties. These samples were tested using a Reomether TA Instruments Ar 2000, in which the equipment applied a cyclic strain of 1.00×10^{-4}. The Rheometer TA has been used to measure the shear modulus of the soil. The procedure is conducted according to the research conducted by Villacreses et al. 2020 [6]. These values are used to compare the measured values obtained through the Hertzian contact wave propagation. The results of the two sets of samples were compared, and the maximum measured difference was around 25%. This small difference between the results suggest that this experimental technique could be used as an alternative method to measure dynamic soil properties at small deformations.

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