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A novel vibratory roller compactor for geotechnical centrifuge

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ABSTRACT: Vibratory roller compaction is one of the most widely used methods in construction projects worldwide. However, soil behaviour during compaction is still often studied through field tests, laboratory sampling, or continuous compaction control coefficients. These methods fail to consider the real stress paths imposed on the soil by the equipment, the anisotropic nature of layered compaction, and the development of capillary forces due to the unsaturated nature of the soil. For this reason, a new reduced-scale vibratory compactor was designed and built for use in a geotechnical centrifuge. This compactor allows for the study of soil behavior during real compaction paths by measuring volumetric deformations, the evolution of suction, and the relationship between these factors and compaction control coefficients.

1 INTRODUCTION

Soil compaction is an activity that has been carried out for hundreds of years to improve the mechanical behaviour of materials (Lay et al., 2020). The first vibratory compactors appeared during World War II (Ebels et al., 2004)), and in the 1970s, Heinz Thurner developed the concept of continuous compaction control by installing accelerometers on a vibratory roller (Carder et al., 2009). Despite all these developments, even today soil stiffness is measured through field tests, sample extraction and laboratory tests, or by relationships with continuous compaction control coefficients. The study of compaction with vibratory rollers under controlled conditions in the geotechnical centrifuge is therefore an alternative to improve the understanding of soil behaviour during real compaction paths, allowing the measurement of soil deformations in real time, as well as the evolution of capillary forces, and all this related to the continuous compaction control coefficients.

2 MINIATURE COMPACTOR DESIGN

The most recent research on compaction with centrifugal rollers was conducted by Escobar et al., (2021), where the static indentation of a cylinder driven by a pneumatic actuator was evaluated at a 1:10 scale. However, this configuration did not allow for horizontal movement of the roller or the application of continuous vibratory loads. To ensure the model's representativeness with respect to real compactors, a statistical analysis of the commercial characteristics of equipment with compaction control was performed, and the characteristics presented in Table 1 were defined.

Table 1. Features of the miniature compactor

Parameter	Scale 1:15
Drum Width (cm)	14.20
Drum Diameter (cm)	10.10
Drum Mass (kg)	1.60
Operating Amplitude (mm)	0.098
Operating Frequency (min) (Hz)	425.6
Operating Frequency (max) (Hz)	503.6
Centrifugal Force (min) (kN)	0.75
Centrifugal Force (max) (kN)	1.30

3 MAIN FEATURES OF THE MINIATURE COMPACTOR

The equipment is presented in Figure 1 and corresponds to a 1:15 scale vibratory compactor, developed at the Los Andes university in Colombia. The vibration system is based on an APA120ML piezoelectric actuator that lifts a moving mass of up to 1.0kg and allows it to apply a force of up to 400N to the soil at a frequency of 500Hz. The instrumentation is based on two accelerometers (one to determine the force and the other the displacement), a PCB208C load cell, and an Eddy current magnetic sensor was used to calibrate the displacements.

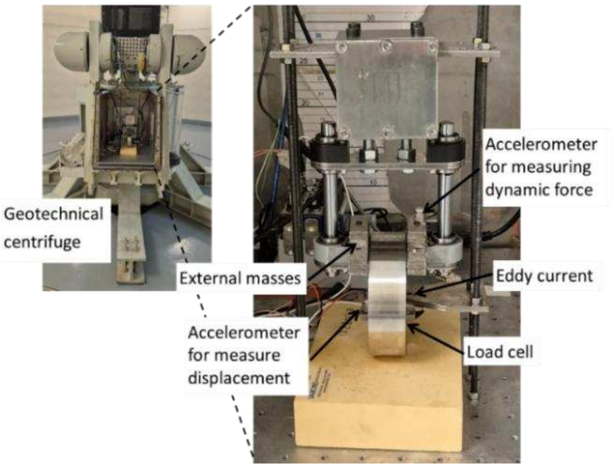

Figure 1. Miniature roller compactor used in the research

4 EQUIPMENT CALIBRATION

The equipment calibration was based on verifying the accuracy of the force and displacement measurements, as well as the repeatability of the test. For force verification, a piezoelectric load cell was used as the measuring element, along with an accelerometer located on the moving masses for verification. The results obtained are shown in Figure 2, using two different polyurethanes commercially known as sawbones®.

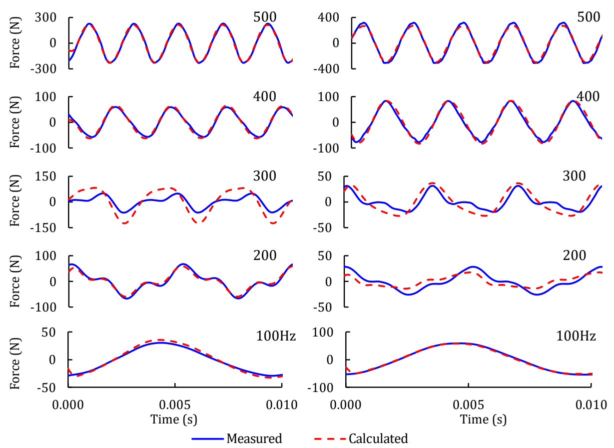

Figure 2. Variation of measured and calculated force versus time for two different polyethene's (right and left)

For displacement verification, an accelerometer located at the base of the compactor and a parallel magnetic sensor were used, yielding the results shown in Figure 3. The displacements from the accelerometer signal were calculated by double integration of the signal, removing the integration drifts by applying high-pass filters, and fitting to a high-degree polynomial.

To verify repeatability, 50 tests were performed under the same conditions, obtaining a coefficient of variation less than 0.05.

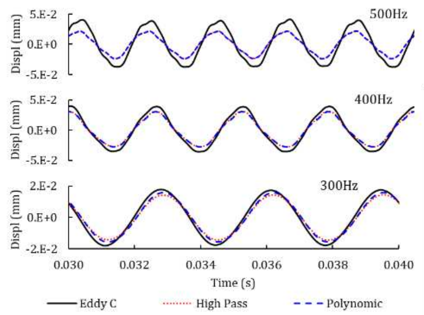

Figure 3. Displacements measured with the magnetic sensor (Eddy C) compared to the two different methods based on the accelerometer reading.

5 CONCLUSIONS

The miniature compactor designed at the Los Andes University allows for the study of soil behaviour along known compaction paths, ensuring the application of the same force as commercial compactors. The equipment enables the study of volumetric deformations and capillary forces during the passage of a vibratory roller compactor and also allows for the determination of the relationship between measured soil modulus and compaction control coefficients.

6 REFERENCES

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