Testing Soil Compaction – High-speed Measurements of scaled Falling Weights

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1 Introduction

In order to ensure the bearing capacity of buildings, target values of the compaction of subsoil have to be achieved using suitable methods. Focus of the investigations are mainly soil compactors working with drop weights, such as Dynamic Compaction and Rapid Impact Compaction. Next to testing in real scale, numerical models in Abaqus Explicit have been developed and used for optimization (Pankrath et. al. 2015). Falling weights have been downscaled for measurements during the compaction process and below the compactor. Therefore, the PIV/DIC method (Particle Image Velocimetry, Digital Image Correlation) at a section plane has been adapted for high-speed measurement. In addition, acceleration sensors are used to extend the measurements of soil and of the device.

The results of the scaled tests shall be used for extrapolating improvements of real compactors. Also the work should contribute to a better understanding of the kinematics of soil, caused by falling weights. The contribution presents methods and results from tests with small scaled falling weights and the use of high-speed measurements.

2 Experimental Setup and Processes

In two test stations in the scale S (small) and M (medium) at a sectional plane, the soil reaction is recorded and assessed below and during compaction contactless and extensively (Figure 1). Therefore, images with high-speed cameras are evaluated with the PIV/DIC method and supplemented by punctual acceleration measurements. These measurement methods are also used for detecting the movements of the device. Consequently, the interaction between soil and equipment is measured and conclusions to a successful compaction work are enabled.

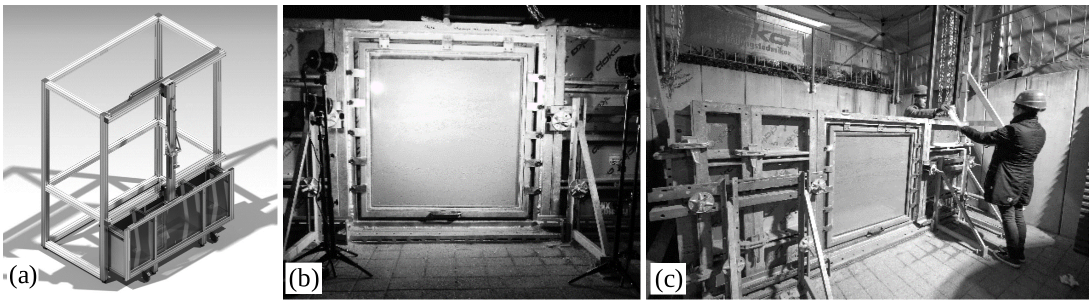

Figure 1: Test setups with transparent section plane for optical measurements with the PIV method (a) test station S (small) for a volume of test soil up to 0,4m³ and, (b, c) test station M (medium) for volume of test soil up to 5 m³, laying on natural soil

Currently on the test stations, guided freefall weights can be tested from heights up to 1.2m and with weights between 4.5kg and 6.75kg (test station S) and between 26kg and 70kg (test station M). Tested soil is a regional dry sand (C_U = 2.9-3.1, C_C = 0.88-0.98), which is reproducible installed by trickling in a defined bulk density. Interferences, caused by vibrations at the test stations are reduced by dampers on contact points or support points.

For the optical measurements high-speed cameras with max. 1,920x1,440 pixels at max. 1,603fps are used. Operating in pulsed mode, a flicker-free lighting is ensured by 4 high-area LEDs, each with up to 15,000lm. The calibration and image correlation is performed in Istra4D (Dantec Dynamics). For detecting the acceleration, high resolution 3-axial sensors are connected to the compactor and arranged in the soil at defined positions.

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3 Test Series with scaled Falling Weights

For extrapolating improvements of real compactors several energy levels of weights between 4.5kg to 70kg and drop heights between 0.3m and 1.2m are tested and connections between energy input and diameter of the compactor are evaluated. Further studies focus on different geometries of compactors and potentials to improve the area efficiency. In addition, with the test series basic soil mechanical laws of kinematics of soils with propagation of body waves are examined by involving selective acceleration measurements.

Valuation of the optical measurement results is based on the total displacements. Strains and change of density can be calculated in further steps. Figure 2 shows PIV/DIC evaluation of the total displacement for a range of values. The results demonstrate the increase of compaction work after every single drop, but also the propagation of small deformations with millisecond precision. With the selective acceleration measurement, caused by the drop, a compression wave could be detected in the vertical direction. Based on the location of the pair of acceleration sensors at a distance of 150mm, results in a wave velocity V_P of 166m/s could be obtained, comparable to Nazhat (2013).

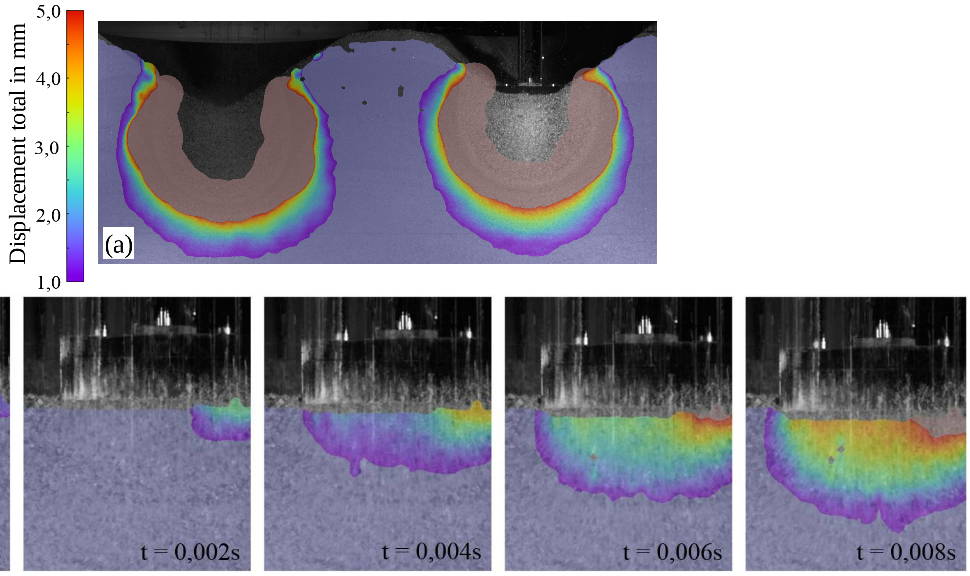

Figure 2: Test station S, PIV/DIC evaluation of the total displacement, (a) after 12 + 12 drops at two locations, (b) drop 1 at selected points in time

4 Conclusion

Results of small-scaled tests cannot be extrapolated linearly to large systems. However, the test series at different scales indicate relationships in terms of compaction performance and potentials for improvement equipment of case plates. Based on high-speed imaging, the PIV/DIC method enables measurements in a millisecond range with a special insight into the deformation behavior of soils. Based on this, the energy spread in the soil as well as temporary elastic effects of soil deformation can be located and measured.

References

Nazhat, Y. (2013). Behaviour of sandy soil subjected to dynamic loading. Doctoral thesis. University of Sydney, Sydney. Faculty of Engineering & Information Technologies.

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