

CCC with Oscillating Rollers – Fundamentals and Application in Experimental Field Tests

J. Pistol¹, D. Adam¹, F. Kopf², W. Völkel³

¹ Institute of Geotechnics, TU Wien, Austria, <johannes.pistol@tuwien.ac.at> <dietmar.adam@tuwien.ac.at>

² FCP - Fritsch Chiari & Partner ZT GmbH, Vienna, Austria, <kopf@fcp.at>

³ HAMM AG, Tirschenreuth, Germany, <Werner.Voelkel@hamm.eu>

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1 INTRODUCTION

1.1 Dynamic roller compaction

Dynamic roller compaction has become the commonly used method for near-surface compaction, because dynamic rollers are much more efficient compared to static rollers. However, the continuously improved compaction techniques in earthworks and geotechnical engineering also require the use of adequate test equipment to assess the achieved compaction success. The sole use of conventional spot like compaction testing methods, especially at large construction sites, is inefficient and does not represent the state of the art anymore. Continuous Compaction Control (CCC) is a suitable method to overcome the drawbacks of spot like compaction testing methods.

1.2 Oscillating rollers

Two types of excitation are mainly used for dynamic roller compaction, the vibratory drum and the oscillatory drum.

The eccentric masses of a vibratory drum are shafted concentrically to the drum axis, resulting in a significantly higher vertical loading, but also increased ambient vibration.

The torsional motion of an oscillatory drum is caused by two opposed, rotating eccentric masses, which shafts are mounted eccentrically but point symmetric to the drum axis (see Fig. 1). Soil is loaded horizontally by the drum motion and vertically by the dead load of the drum and the roller.

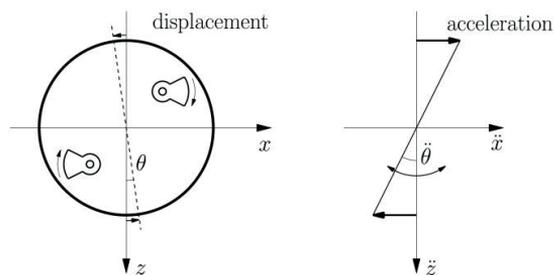


Figure 1. Excitation of an oscillatory drum.

While CCC systems have become the state of the art in compaction control for vibratory rollers during the last decades, the lack of a CCC system for oscillating rollers has been a major disadvantage for these rollers.

2 DEVELOPMENT OF A CCC VALUE FOR OSCILLATING ROLLERS

A comprehensive research project on oscillatory rollers was launched by the German roller manufacturer HAMM AG in 2011 in cooperation with the Institute of Geotechnics at TU Wien. The aim of the project has been the development of a better understanding for the motion behaviour of an oscillatory drum and its impact on the compacted soil as well as the development of a CCC system for oscillatory rollers. Within this project, large-scale in situ tests were performed with a tandem roller in a gravel pit near Vienna Airport. Details on the test setup and measurements can be found in (Pistor 2016).

2.1 Motion behaviour of oscillating drums

The interaction of oscillatory drum and soil does not only cause accelerations in the soil, but also has an influence on the motion behaviour of the drum itself. The interaction results in a distortion of the signal and a formation of a secondary vibration with double frequency in the vertical accelerations measured in the bearing of the drum (see Fig. 2).

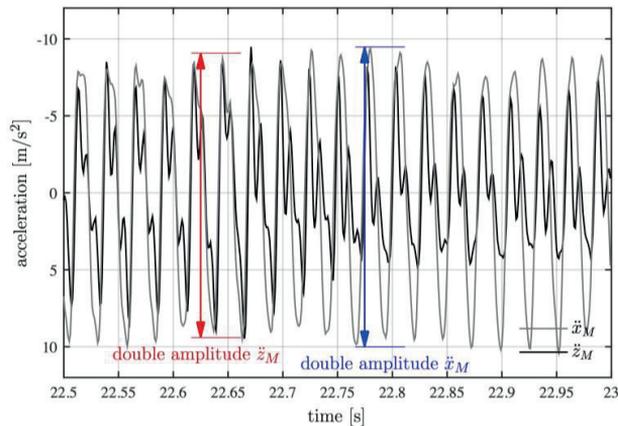


Figure 2. Horizontal and vertical accelerations in the bearing of the oscillatory drum for the eleventh pass on lane 2 of the test field (Pistor 2016).

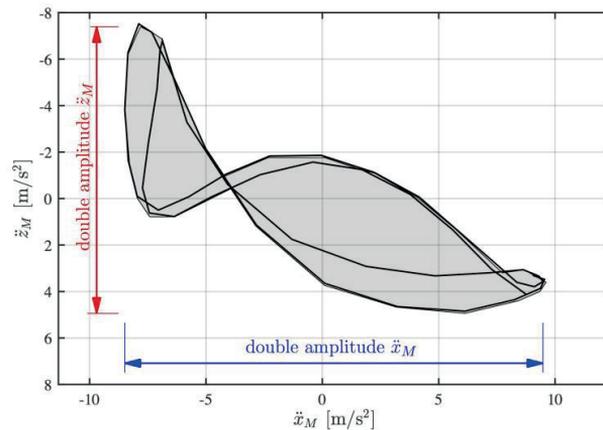


Figure 3. Horizontal and vertical accelerations in the bearing of the oscillatory drum for two periods of excitation during the eleventh pass on lane 2 of the test field (Pistor 2016).

In Fig. 3 the same accelerations in the bearing of the drum are plotted for two consecutive periods of excitation as in Fig. 2. However, the accelerations are not plotted in the time-domain, but in a diagram with horizontal accelerations on the abscissa and vertical accelerations on the ordinate. The chronologically connected pairs of accelerations $(\ddot{x}_M | \ddot{z}_M)$ form a reproducible shape, similar to a recumbent eight in this type of representation. The superposition of oscillatory motion and roller travel causes an asymmetry of the settlement trough and subsequently an asymmetry of the recumbent eight-shape of accelerations. A comparison of test runs at different states of compaction showed an expansion of the recumbent eight-shape with increasing soil stiffness.

2.2 Definition of the CCC value for oscillating rollers

The centrifugal forces of the two eccentric masses of an oscillatory drum cancel each other out. Therefore, the horizontal and vertical soil forces are the dynamic impact, which dominates the motion behaviour of the drum. The accelerations in the bearing of an oscillatory drum are proportional to the soil forces as shown in the results of the experimental investigations and can therefore be used for an assessment of the force path.

The formation of the recumbent eight-shape of drum accelerations changes depending on the soil stiffness. Various characteristics of the described shape can be used for assessing the soil stiffness. These include the extent in horizontal and vertical direction, gradient and curvature of various regressions, or the area circumscribed by the eight-shape. The described area showed the greatest significance of all characteristics, tested on measurement data. However, the calculation of this area cannot be done easily, especially when real measurement data shall be processed. The shape changes continuously and if one period of excitation is considered the last measurement point of the shape does not necessarily equal the first measurement point. Therefore, an algorithm has been developed to approximate the area of the eight-shape with sufficient accuracy (Pistol 2016).

The calculated area is defined as novel CCC value for oscillatory rollers and adopts the theoretical unit of m^2/s^4 . A factorisation of the presented CCC value with process parameters or machine parameters, e.g. drum diameter, static line load, vibrating mass or unbalance torque, can be used to obtain more practical CCC readings.

3 CCC IN EXPERIMENTAL FIELD TESTS

3.1 The CCC algorithm tested on real measurement data

The CCC value for oscillating rollers was evaluated in experimental field tests discussed in (Pistol 2016). For the calculation of the CCC values a time frame of 1,024 sampling points was considered, which equals approximately one CCC value for each second.

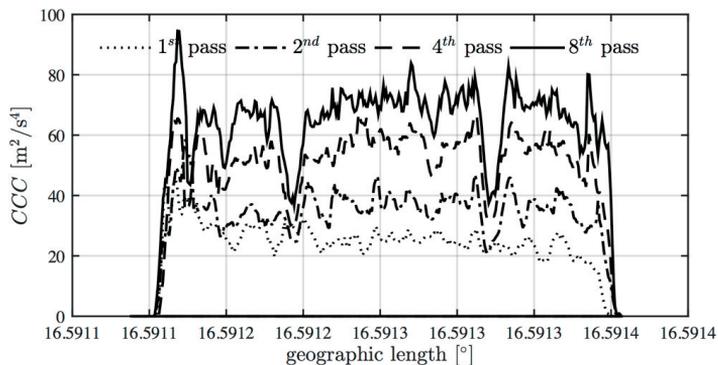


Figure 4. Progress of the measured CCC values of the passes 1, 2, 4 and 8 on lane 2 of layer 2 of the test field (Pistol 2016).

The progress of the measured CCC values is shown in Fig. 4 for the passes 1, 2, 4 and 8 on layer 2 of lane 2 of the test field. When the CCC curves for various passes are compared to each other, an increase of the level of CCC values can be observed. Fig. 4 shows a significant increase within the first four passes on lane 2 and another smaller increase during the passes 5 to 8. This is in accordance with the common experience, that the first passes of a roller on less compacted soil gain the largest increase in soil stiffness. When the soil gets closer to its state of maximum compaction, the increase in soil stiffness becomes asymptotically smaller with each pass of the roller.

Two artificial weak spots under lane 2 (mattresses buried in 15 cm and 55 cm below ground level) cannot be located in the measurement curve of the first pass on the less compacted soil. However, their location becomes clearer with every pass of the roller. Weak spot 2 was buried in a depth of only 15 cm below ground level and shows a linear elastic behaviour. The soil above this weak spot can hardly be compacted and the CCC values of the eighth pass are only slightly larger than the CCC values after the first pass. Although weak spot 1 was buried in a depth of 55 cm below ground level of lane 2, it is still clearly visible in the CCC curves in Fig 4.

The presented CCC value for oscillating rollers is properly reflecting the increase in soil stiffness with an increasing number of roller passes and capable of detecting poorly compacted areas. Further results and a comparison to results of dynamic plate load tests can be found in (Pistrol 2016).

3.2 Validation of the CCC system for oscillating rollers

The company HAMM AG used the results of the research project and the algorithm for calculating the CCC value for oscillating rollers to produce a CCC system for oscillating rollers. Two single-drum rollers and a tandem roller were equipped with the novel CCC system to test the systems functionality in another round of experimental field tests. The tests proved that the calculation of the CCC value for oscillating rollers can also be done online in real time and under site conditions. The CCC systems of all tested rollers showed a reproducibility of their results (see Fig. 5). However, the tests also showed the dependence of the CCC value on machine parameters like the weight of the roller compared to the excitation and the ratio between mass of the drum and mass of the roller, which results in different sensitivities of the CCC system for oscillating rollers.

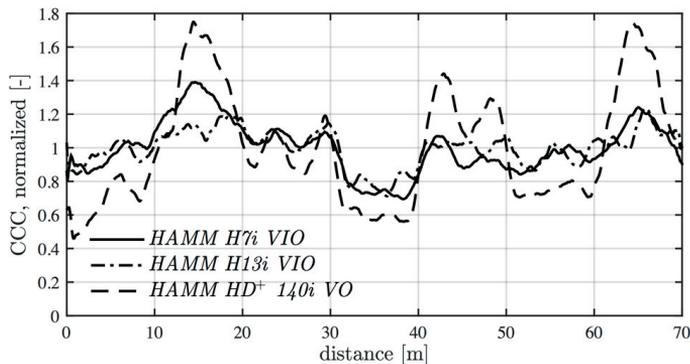


Figure 5. Validation of the CCC system exemplary for three oscillating rollers (Pistrol 2016).

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REFERENCES

Pistrol, J. (2016). *Compaction with Oscillating Rollers*. Doctoral Thesis, TU Wien, Vienna, Austria.