Compaction Management: Results of a Demonstration Project

Manuel Parente[1,a], António Gomes Correia[1,b]

[1]C-TAC – Centre for Territory Environment and Construction, School of Civil Engineering, University of Minho, 4800-058 Guimarães, Portugal

[a]map@civil.uminho.pt, [b]agc@civil.uminho.pt

Keywords: Compaction, intelligent compaction, compactors, soil, stiffness

Abstract. Compaction management, also referred to as intelligent compaction (IC), is a real time automatic operation adjustment and continuous compaction control technology of soils or asphalt layers. It is essentially a technology for optimization and evaluation of the compaction process, being capable of adjusting the compaction energy applied to the material, increasing or decreasing compaction efficiency in the necessary areas according to an acceptance target value, thus attaining maximum stiffness, while preventing overcompaction and minimizing the total number of passes. This study seeks to assess in a case study the IC performance, in comparison with conventional compaction methods in terms of efficiency in compaction of a sandy soil. For this purpose, a specific experimental section was carried out in which the performance of an IC compactor was compared with a conventional heavier class compactor. Data was obtained and analysed by the IC continuous information, as well as by the application of several different conventional compaction control tests and methods. Results show that the IC technology presents a superior performance, as well as various advantages when compared to conventional compactors.

Introduction

Intelligent compaction (IC) initially appeared in Europe around 1980 [1], although it has recently been subject of significant study and development in the U.S. by the FHWA (Federal Highway Administration) [2], [3]. This technology combines continuous measurement of the material degree of compaction with feedback from the vibratory drum, which enhances the equipment with the capability to adjust the applied compaction energy depending on the measured material conditions. Based on a roller integrated system, including components such as accelerometers that measure drum vibration, onboard electronics that record and process sensor output and material stiffness, associated with linkage elements to the machine controls that allow for compaction effort adjustment according to measured stiffness, GPS system to record machine location and local storage or wireless communication system for data transfer [4–6]. The equipment has the ability to increase compaction effort in areas that have not yet reached the specified target value, while preventing overcompaction of areas that have achieved or exceeded this value. This leads not only to an increase in the foundation quality, but also to the subsequent improvement of the pavement long-term performance, as a direct consequence of superior compaction uniformity and quality on the foundation. Furthermore, both an increase in productivity and a reduction of costs during the compaction process are associated with the advantages of this technology [7].

With the aim of assessing the advantages and disadvantages of this IC technology compared with the conventional compaction, this paper begins with the description of a demonstration project carried out for that purpose, including geomaterial description, available compaction equipments and construction planning. Compaction efficiency of the compactors on the soil layer is analyzed through different monitoring devices and the conclusions are presented.

Demonstration Project

The current demonstration project was prepared at a road construction site in Alijó, Portugal. The test section area was 9x40 metres and consisted of three lanes, 3 meters each, built using a sandy soil, as depicted in Fig. 1. The soil section was prepared with 0,45m thickness, as suggested by the Guide to Earthwork Construction (GTR) [8].

The foundation material is characterized by a residual soil of granite where singularity zones of low and high stiffness were constructed (Fig. 1) using uncompacted soil and concrete, respectively. These singularities aim to evaluate how IC technology is able to detect them and change vibration parameters to achieve an efficient compaction for each of the layer thicknesses. As far as the layer material is concerned, it falls under a B1 material, designated as a fines-poor sand soil according to the GTR standards, and its maximum dry density and optimum moisture content are 1,947 g/cm3 and 9,6%, respectively, as obtained from the Modified Proctor test results.

The available compaction equipment for the demonstration project was a BOMAG BW 213 DH-4 BVC (equipped with IC technology), with a load per unit of length (W/L) of 44,1 kg/cm and a maximum amplitude (A0) of 2,5 mm, and a regular Caterpillar model CS 683E, with a W/L of 62,3 kg/cm and A0 of 1,8 mm. Considering those characteristics, these rollers were classified as compactor classes V4 and V5, respectively, according to the GTR.

The test section area included three different lanes which would be compacted by three different technologies (Conventional Compaction – CC; Intelligent Compaction – IC; and Continuous Compaction Control – CCC), as shown in Fig. 1. Note that rollers equipped with IC technology have the option of turning the automatic adjustment of the vibratory parameters off, thus working as a regular roller equipped with continuous measurement of material stiffness (CCC) technology. The compaction process included FWD measurements, as well as nuclear moisture density gauge tests, every 2 roller passes, for each lane. The process was accomplished carrying out FWD measurements throughout the length of the test section.

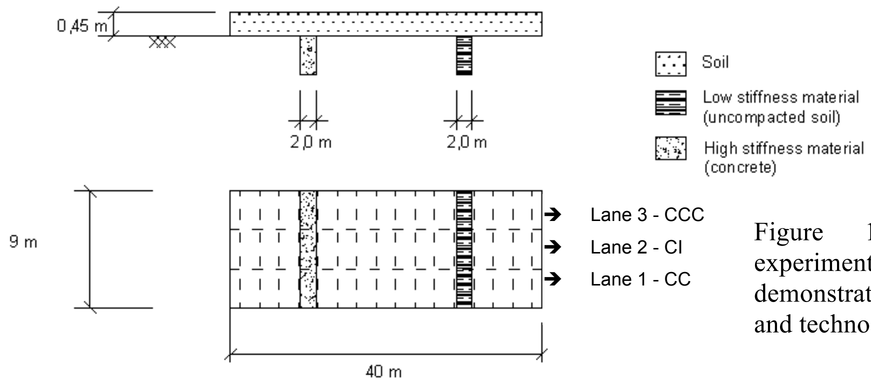

Figure 1: Schema of the experimental section used in the demonstration project for soil layer and technologies used in each lane

Results and Discussion

In this section, the outcome obtained from the demonstration project measurements and tests, as well as a discussion of the results, are presented. The first analysis corresponds to the evolution of the degree of compaction measured with the nuclear density gauge (using the maximum density obtained by the Modified Proctor test as a reference) as a function of the number of roller passes, followed by the analysis of the deflection values obtained by the FWD measurements. Finally, the verified in-situ effectiveness of the equipment capability to detect the foundation singularities (both lower and higher stiffness singularities) in each case is also discussed. Note that these measurement passes with the IC roller are performed using the technology in "manual" mode (CCC), so as to guarantee constant vibration parameters, thus resulting in an effective measurement at constant depths.

In terms of degree of compaction measurements (Fig. 2), it is clear that the IC roller equipped with automatic adjustment technology achieves the best results when compared to CC and CCC technologies, also confirmed by analyzing the FWD results in (Fig. 3), discussed ahead. It is to be emphasized that IC technology (lane 2) has a continuous effective compaction without overcompaction risks. In fact, the layer degree of compaction is either rising or constant throughout all the 6 passes, having significantly increased mainly in the first 2 passes, followed by a gradual increase in the remaining passes. Note that the compaction of the soil layer was carried out by 4 passes on high amplitudes (low frequencies) and 2 passes on low amplitudes, which may explain the significant increase on the degree of compaction detected on the last 2 passes in lane 3, especially considering these results correspond to nuclear density gauge measurements (0,30 m depth). Regarding the water content, evidence is provided that, on average, its value is approximately 1% below the optimum water content (9.6%).

When analysing the evolution of the inverse of the deflection (1/D2) with the number of passages (Fig. 3), results indicate that CC and CCC technologies appear to only reach a maximum value of material stiffness after all 6 passes. The stiffness increase measured by the FWD is significant in the 2 final passes of these technologies, which correspond to low amplitude (thus high frequency) compaction with the aim of completing the surface layers compaction process. Considering the previously discussed results regarding the nuclear density gauge measurements, IC technology was referred as having achieved better final results, reaching the maximum degree of compaction in the second passage and increasing gradually in the following passes, which is consistent with these FWD results

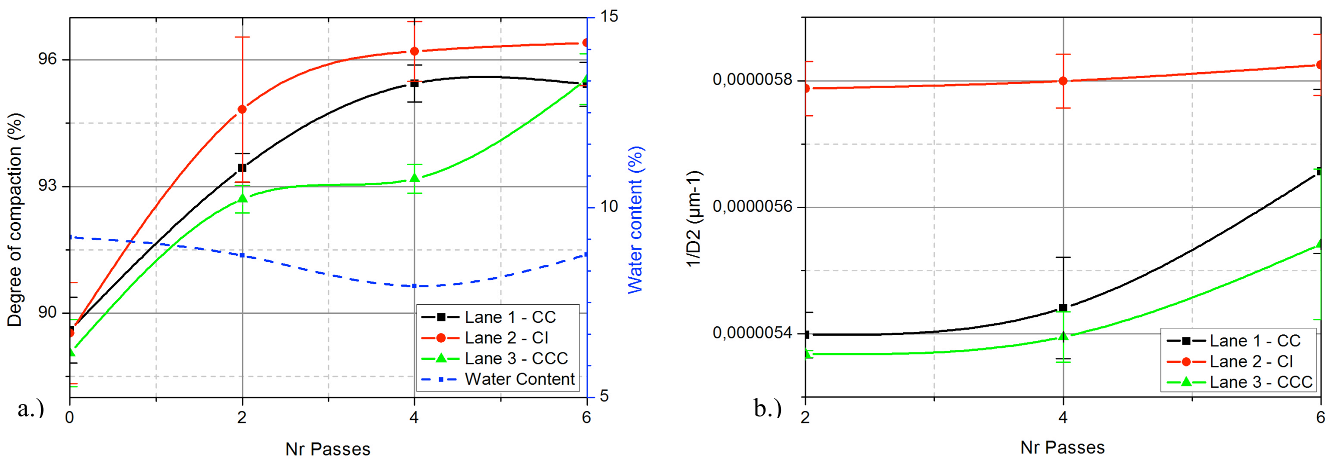

Figure 2: Example of the evolution of measurements as a function of number of passes on the on the 0,45 m thickness soil layer: a.) material degree of compaction determined from the nuclear density gauge; b.) deflection values from the FWD tests

Finally, regarding the IC technology's capability of detecting the foundation singularities, one can infer that on the early passes both singularities are easily identifiable by the IC roller. However, by the end of the compaction process, only the singularity corresponding to the concrete material is visible in the roller output. This indicates that, in the case of the soil layer, the roller was able to compact the lower stiffness singularity which consisted of uncompacted soil present on the layer foundation. As a consequence, the final results show a good uniformity of the compaction achieved throughout the test section area, as depicted in Figure 4, in which the original position of the high and low stiffness singularities is also shown at 10 and 30 m, respectively.

Conclusions

The study concerning the Compaction Management technology provides evidence that it offers technical and economic advantages in the optimization of the compaction process when compared to the conventional compaction method.

It appears that in terms of achieving maximum stiffness with minimum number of passes the IC technology can accomplish equivalent or even higher results to conventional compactors, particularly with regards to the compaction efficiency related to the low number of passes needed to achieve the highest possible stiffness. In fact, the IC roller was found to achieve better results, both regarding the maximum compaction obtained and compaction efficiency. Furthermore, it is evident that the IC roller had the ability to compact and resolve the problematic area consisting of low stiffness material (uncompacted soil) existent on the layer foundation, achieving a significant homogeneity in terms of degree of compaction and stiffness at the end of the compaction process.

In addition, during the demonstration project it was found that the IC roller is a very effective measuring instrument in the context of quality control, having not only the ability to assess the stiffness conditions of large areas in a very short time, but also the capability to identify and pinpoint potential problematic areas in both the soil layer and its foundation.

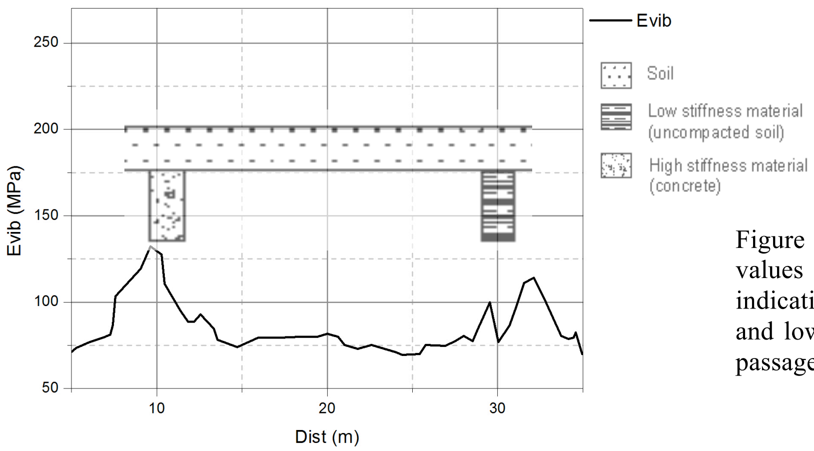

Figure 3: Example of the measurement values from the IC technology, with indication of the original position of the high and low stiffness singularities on the second passage of the 0,45 m thickness soil layer

Acknowledgment

The authors wish to thank FCT (PEst-OE/ECI/UI4047/2011; SFRH/BD/71501/2010), as well Mota Engil, S.A. and particularly to Eng. Luís Gomes for providing all the field facilities.

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