CONFIDENCIAL

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

INSTITUTO SUPERIOR TÉCNICO

CALIBRATION OF THE COMPRIMETER FOR COMPACTION CONTROL

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Lisbon, July 2012

Resumo

A *Saint-Gobain Weber Portugal, S.A*. e o *Laboratório Nacional de Engenharia Civil (LNEC)* em colaboração com o *Instituto Superior Técnico* (*IST*), estabeleceram um protocolo, a 18 de Março de 2010, visando o estudo de um método de controlo da construção de aterros com agregados leves de argilas expandidas.

Foi definido um conjunto de ensaios de verificação e de calibração em laboratório com recurso ao *comprimeter* para avaliação das condições de compactação dos materiais em estudo.

O presente documento, apresenta as condições de preparação, os resultados e interpretação dos ensaios após a conclusão do programa experimental de laboratório.

Abstract

Saint-Gobain Weber Portugal, S.A. and the National Laboratory for Civil Engineering (*Laboratório Nacional de Engenharia Civil - LNEC)* in cooperation with the *Instituto Superior Técnico* (*IST*), signed a protocol, in 18th of March of 2010, aiming the study of a control method of the construction of embankments with light expanded clay aggregates.

A set of checking and calibration tests, at the laboratory, using the *comprimeter*, was defined for the evaluation of the compaction conditions of theses materials.

This document presents the preparations conditions, the results and interpretation of the tests after the conclusion of the experimental program at the laboratory.

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1. Introduction

The measurement of the compaction degree of light expanded clay aggregates during construction is a difficult and complex task due to the material nature. An attempt with the use of a comprimeter was carried out in the laboratory for different relative densities.

The present report presents a general description of the comprimeter and testing procedure, as well as the results obtained with two materials of different size grain distributions, identified as *#10-20* and *#0-32* materials.

2. General description of the equipment and testing procedures

The comprimeter was designed in the 70's to measure the state of compaction of sand more accurately and rapidly than was possible with other existent methods. This apparatus was tested on four different sands in laboratory and used in several compaction control activities. The results proved to be reliable the determination of the compactness of sand materials with this type of equipment (Eggestad, 1974).

This equipment was used by LNEC in the 80's for the compaction control of extensive protection levees in Mondego River, in Portugal.

The *comprimeter* is composed (Fig. 1) by three steel rings (two external and one interior), a Perspex plate, a rubber membrane and two valves (inlet and outlet valves) for driving in or out the water and an metallic rod with 25 mm of diameter and 50 mm^3 of volume. The external and internal diameters of the *comprimeter* are 300 and 30 mm, respectively

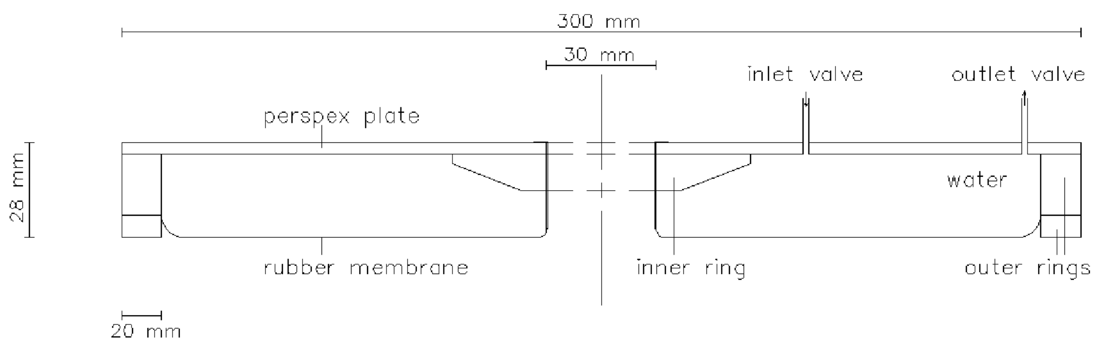

Fig. 1 – General scheme of the *comprimeter*

The basic principle use to measure the compaction is the following – when the rod is inserted in a dense soil, the material around will tend to heave according to its relative density. The *comprimeter* measures the heave volume at the surface, which can be related with the compactness level of the material.

The original membrane was deteriorated at the time, so new rubber membranes were fabricated at LNEC.

To simulate an embankment with different relative densities at the laboratory, the 500 mm oedometric chamber was used. Firstly, this chamber was filled with the material in loose state at the laboratory humidity, until 327 mm of height (Fig. 2). The surface was then smoothed and a metallic plate was placed at the specimen surface and connected to the pneumatic hammer (Fig. 2). A vibration was applied during the time need to achieve the selected relative density. Finally the hammer and the metallic plate were removed.

a) **b)**

Fig. 2 – Specimen preparation: a) oedometric chamber; b) vibrating hammer with metallic plate

To perform the tests, the *comprimeter* was placed above the specimen surface and filled with water (until the removal of all visible air bubbles – Fig. 3). After closing the inlet valve and opening the outlet valve, the metallic rod was then driven into the specimen through the inner ring until a standard penetration (marked in the rod) was attained. The water expelled, corresponding to the heave volume, was collected into a recipient (Fig. 3) and measured using a digital balance.

a) **b)**

Fig. 3 – a) Equipment with inlet valve closed and outlet valve opened; b) expelled water

3. Test results

For calibration purposes, two set of tests were performed with the two materials – #10-20 and #0-32 – previously subjected to an intensive mechanical behaviour study (Caldeira *et al*., 2012). Table 1 presents the initial preparation data of the specimens for the comprimeter calibration tests for both materials.

Table 1 - Data of specimen preparation of the *comprimeter* calibration tests of #10-20 and #0-32 materials

Material	Specimen diameter (mm)	Specimen height (mm)	Mass (kg)	Water content (%)	Dry unit weight (kN/m^3)	Voids ratio
#10-20 (1)	500	327	18.436	0.15	2.813	0.690
#10-20 (2)	500	327	17.046	0.15	2.601	0.827
#0-32 (1)	500	327	17.293	0.15	2.638	0.674
#0-32 (2)	500	327	16.969	0.15	2.589	0.706

The results obtained are presented in Fig. 4 and Fig. 5 for the #10-20 and #0-32 materials, respectively, in terms of $\Delta h/h_0$ as function of the ratio, HR, of the heave volume, V and rod penetration volume, V_t. These heave ratio is the mean value of the four determinations at the surface for each compaction conditions.

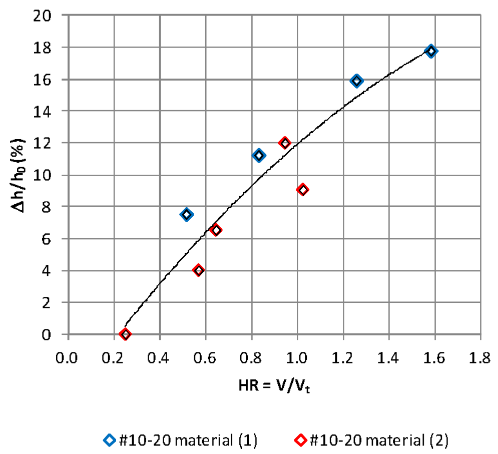

Fig. 4 - ***Comprimeter*** **calibration tests for #10-20 material**

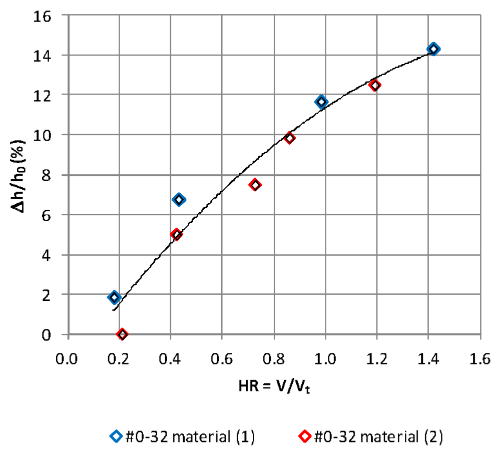

Fig. 5 - ***Comprimeter*** **calibration tests for #0-32 material**

The following calibration expressions were interpolated based on the presented test results and are represented in Fig. 6.

$$\Delta h/h_0 = -4.93\text{HR}^2 + 22.60\text{HR} - 4.81 \; (R^2 = 0.923) \qquad (1)$$

$$\Delta h/h_0 = -4.66\text{HR}^2 + 17.86\text{HR} - 1.85 \; (R^2 = 0.954) \qquad (2)$$

To test the calibration curve, a set of blind tests was carried out. Table 3 presents the preparation data of these tests" and Fig. 7 their test results compared with the calibration curves.

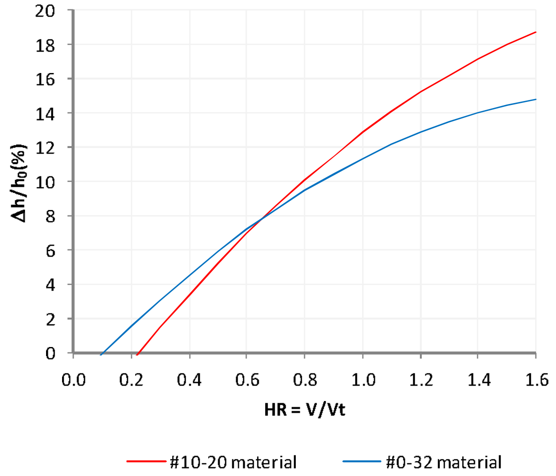

Fig. 6 - Calibration curves

Table 2 - Data of specimen preparation of the comprimeter blind tests for #10-20 and #0-32 materials

Material	Specimen diameter (mm)	Specimen height (mm)	Mass (kg)	Water content (%)	Dry unit weight (kN/m^3)	Voids ratio
#10-20 (1)	500	327	16.828	0.15	2.744	0.732
#10-20 (2)	500	327	16.894	0.15	2.792	0.582

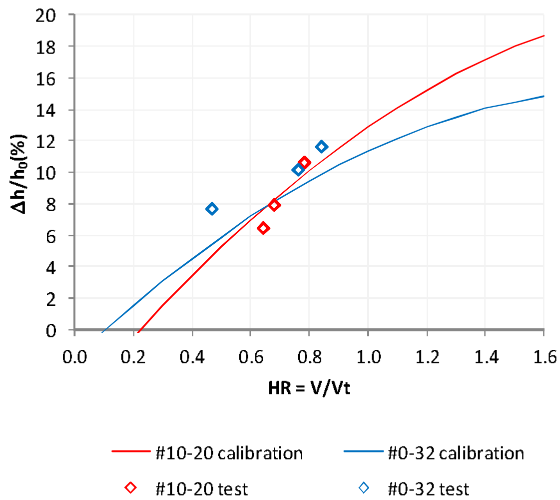

Fig. 7 - Comparison of the calibration curves with the values obtained in the blind tests

In the Table 3 a comparison between the estimated values, calculated with the calibration curves, and the blind test results is presented in terms of the variation of the $\Delta h/h_0$. The variation is larger for the material #0-32 and for small values of *HR* in both materials.

Table 3 - Blind test results and comparison with calibration curve

Test	#10-20 material			#0-32 material		
	$\Delta h/h_0$ (%)		Var. (%)	$\Delta h/h_0$ (%)		Var. (%)
	Estimated	Obtained		Estimated	Obtained	
First	7.69	6.45	1.24	5.50	7.68	2.18
Second	8.29	7.92	0.37	9.06	10.15	1.09
Third	9.87	10.61	0.75	9.89	11.62	1.73

The results were also represented (Fig. 8 and Fig. 9) in terms of the relative density, D_r, (4) as function of the heave ration, *HR*.

$$D_r = \frac{e_{max} - e}{e_{max} - e_{min}} \quad (3)$$

where e_{max} corresponds to the maximum value of void ratio and e_{min} the minimum value. The maximum value of the voids ratio was assumed as the maximum one obtained after preparation and the minimum the one corresponding to a maximum compaction produced by vibration.

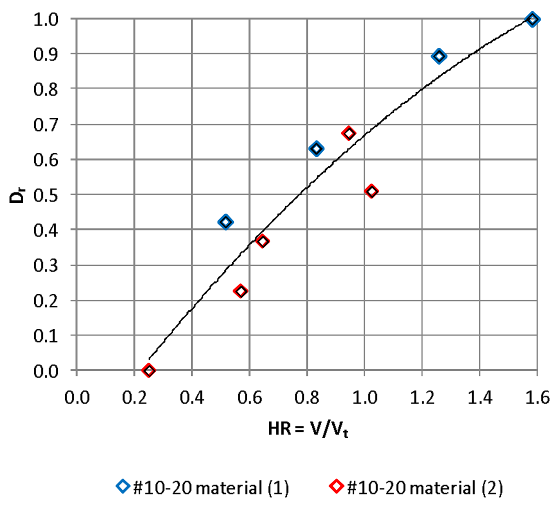

Fig. 8 – Results in terms of relative density for material #10-20

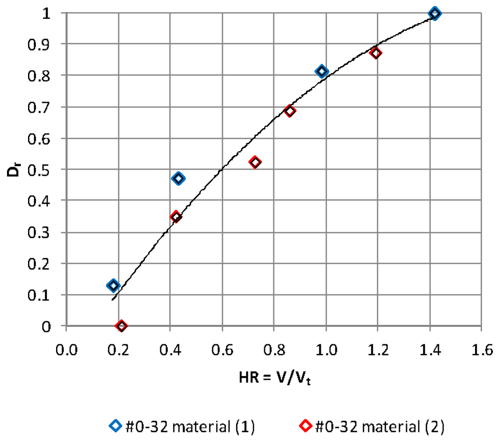

Fig. 9 – Results in terms of relative density for material #0-32

Fig. 10 presents the comparison between the results obtained with light expanded clay aggregates and four types of sand (Eggestad, 1974).

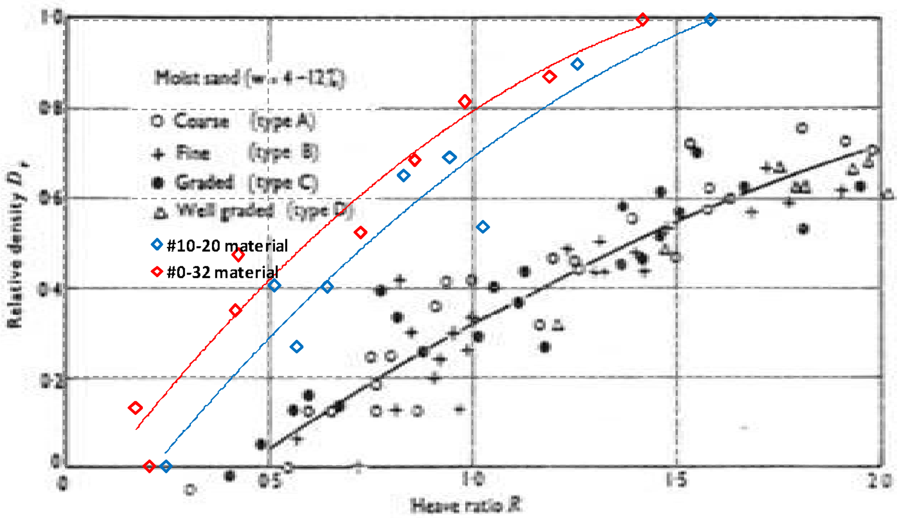

Fig. 10 - Comparison with the results obtained by Eggestad (1974) for four types of sand

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Acknowledgments

The authors acknowledge Amélia Reis, António Cardoso, Fernando Rodrigues and Joaquim Timóteo for their decisive contribution in the experimental work presented.

Lisbon, July 2012

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