Effects of compaction stress on the physical, hygroscopic and mechanical properties of an earthen construction material

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1 Introduction

The use of raw earth blocks for masonry construction has gained interest in recent years due to the limited carbon footprint and the potentially advantageous hygro-thermal properties of this material. The present work investigates the effect of compaction effort during manufacturing of raw earth materials on the resulting physical, mechanical and hygroscopic properties. Three compaction pressures, i.e. 25, 50 and 100 MPa, are applied to a soil mix composed by 0.4% gravel, 40.4% sand, 42.9% silt and 16.3% illitic clay. As a term of comparison, the most powerful presses available on the market for the production of earth blocks can apply a maximum compaction stress of 15 MPa.

Firstly, we analyse the effect of the compaction stress on the pore size distribution by means of two different experimental techniques: mercury intrusion porosimetry and liquid nitrogen adsorption. Then, we assess the mechanical properties of the material by means of unconfined compression tests and, finally, we measure the moisture buffering capacity when the material is subjected to cyclic variations of relative humidity.

2 Results

2.1 *Pore size distribution*

Mercury intrusion porosimetry (MIP) tests and nitrogen adsorption (NA) tests were performed on compressed earth samples. Fig. 1 shows the pore size distribution (i.e. the derivative of pore volume respect to the logarithm of pore diameter) for the samples compacted to the lowest and highest pressures investigated in this study (i.e. 25 MPa and 100 MPa). For the particular soil mix considered here, the increase of compaction pressure from 25 MPa to 100 MPa only modifies the distribution of macropores (i.e. pores with diameter larger than 50 nm) while mesopores and micropores (i.e. pores with diameter smaller than 50 nm) remain virtually unchanged as compaction pressure increases. The overall porosity reduces from 0.24 to 0.14 when compaction stress increases from 25 to 100 MPa.

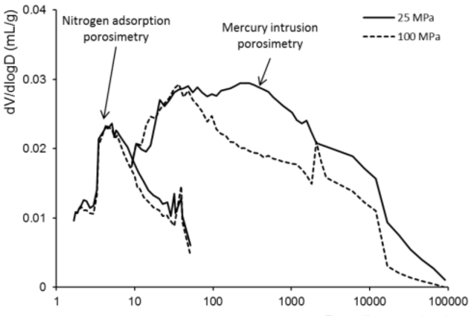

Figure 1: Pore size distribution (comparison of compaction pressures of 25 MPa and 100 MPa)

2.2 *Compressive strength*

Cylindrical samples (diameter of 50 mm, height of 100 mm) were axially loaded at a constant displacement rate of 0.001 mm/s to measure the unconfined compressive strength of the material. Fig. 2 shows the measured values of strength against dry density for all samples compacted at 25, 50 and 100 MPa, together with additional values of strength obtained from samples compacted according to the standard Proctor method. All data are fitted by an unique trendline (thick line) with a relatively narrow standard deviation band (dashed lines). Compressive strength increases more than linearly with increasing dry density, with an average gain in strength of about 50% when compaction pressure grows from 25 to 100 MPa.

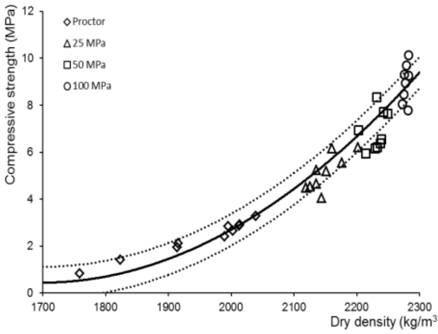

Figure 2: Variation of compressive strength with dry density

2.3 *Moisture buffering capacity*

Tests to measure the moisture buffering capacity of the earthen material were performed in accordance to the norm ISO 24353. Samples were exposed to subsequent step changes of relative humidity between 75% (for 12 hours) and 53% (for another 12 hours) at a constant temperature of 25 °C. Hydraulic hysteresis was observed at the beginning of the test but tended to reduce over subsequent cycles and eventually disappeared. Fig. 3 shows the last stable cycle, i.e. a cycle with negligible hysteresis, from which the moisture buffer value (MBV) has been calculated as prescribed by the norm ISO 24353. By using Kelvin equation (to relate humidity with capillary pressure) and Young-Laplace equation (to relate capillary pressure with pore size), it can be shown that exchanges of water vapour under the imposed conditions of temperature and relative humidity take place prevalently within pores with diameters from 3 to 7 nm. Given that the compaction pressures investigated in this work do not affect this class of pores (Fig. 1), samples compacted at different stress levels show very similar moisture buffering behaviour (Fig. 3). The measured moisture buffer value (MBV) is about 4.2, which is well above that of traditional building materials such as cement blocks or cooked bricks [1].

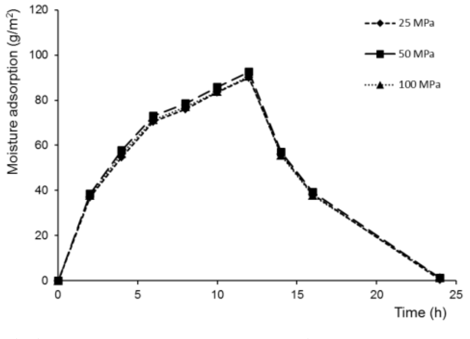

Figure 3: Adsorption and desorption of moisture during the final relative humidity cycle (comparison of compaction pressures of 25, 50 and 100 MPa)

References

[1] C. Rode, R. Peuhkuri, B. Time, K. Svennberg and T. Ojanen, Moisture buffer value of building materials, *ASTM Symposium on Heat-Air- Moisture Transport: Measurements on Building Materials, Toronto* (2006).