Thermal conductivity of compressed earth blocks produced with recycled cement

M. Glória Gomes[1*], J. Alexandre Bogas[1], S. Real[1], R. Cruz[1]

[1]CERIS, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisbon, Portugal

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Presenting author email*: maria.gloria.gomes@tecnico.ulisboa.pt

Earth building materials have been exploited in construction for centuries, due to its production simplicity, reduced embodied energy and carbon footprint as well as its good hygrothermal comfort (Walker, 2004). In particular, their thermal conductivity has been reported to be as low as 0.26 W/mK (Adam and Jones, 1995), proving to be a material with good insulation capacity. However, with the development of more robust building materials, such as concrete, it fell into disuse (Riza *et al.*, 2010).

In the last decades, the growing concern with sustainability and the emergence of new construction techniques, namely mechanical and chemical stabilisation, to improve their performance and address some of their main issues (reduced water resistance), has brought a new momentum to earth construction (Riza *et al.*, 2010). Chemical stabilisation of compressed earth blocks (CEB) is usually achieved with the incorporation of hydraulic binders, namely ordinary Portland cement (PC). Though it is effective in improving the overall performance of CEB (Walker, 2004; Riza *et al.*, 2010), PC is a carbon intensive building material, associated with the consumption of large quantities of natural resources and energy, as well as, with the emission of copious amounts of carbon dioxide and other harmful green-house gases (Real *et al.*, 2022).

Recently, a new promising binder has been developed as a more eco-efficient alternative to PC, thermoactivated recycled cement (RC), which is produced from recycled construction and demolition waste materials subjected to thermal activation at lower temperatures than PC (about 600-700ºC), thus, not only avoiding natural resource consumption and recycling waste, but also having reduced CO_2 emissions during production (Real *et al.*, 2022). RC has been successfully incorporated in other building materials, such as pastes, mortars and concrete (Real *et al.*, 2020; Carriço *et al.*, 2022; Real *et al.*, 2021; Carriço *et al.*, 2021). However, the effect of its use as a stabiliser on the performance of CEB has yet to have been assessed. Therefore, this study aims to analyse the influence of the incorporation of RC in the thermal conductivity of CEB. To this end, CEB were produced with different types of RC (recycled cement produced from cement paste waste treated at 650ºC) and PC and amounts of stabiliser (5-10%), as well as unstabilised CEB (UCEB), as presented in Table 1. The tests were performed using through a modified transient pulse method (ASTM D5334, 2014; ASTM D5930, 2009), resorting to an *ISOMET 2114* heat transfer analyser with a surface probe (Figure 1), from *Applied Precision Enterprise*. The CEB were tested under varying moisture conditions, namely in laboratory conditions and in the dry and saturated states.

Table 1 – Composition of CEB

Designation	Soil[a)] (%)	PC[b)] (%)	RC[b)] (%)	Water[c)] (%)
PC10	90	10	-	15.0
RC10	90	-	10	16.5
PC5	95	5	-	15.2
RC5	95	-	5	16.5
RC2PC8	90	8	2	15.0
RC5PC5	90	5	5	15.5
UCEB	100	-	-	14.4

[a)] Soil with 4% humidity; [b)] By weight of solids (soil+stabiliser); [c)] Total w/b (water/binder), including water absorbed by soil

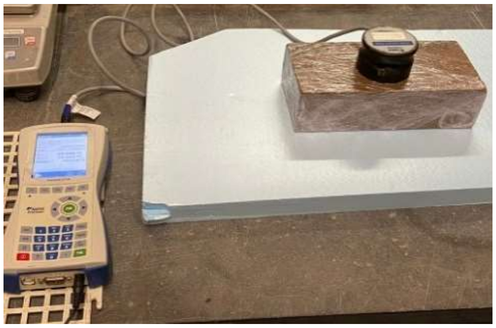

Figure 1 – Thermal conductivity test setup

Figure 2 presents the thermal conductivity of the tested CEB. As expected, the thermal conductivity tended to increase with the moisture content, given that the thermal conductivity of water is about 25 times higher than that of air (Ashworth and Ashworth, 1991). The thermal conductivity of the CEB in the saturated state was more than twice as high as those in the dry state, displaying a significant loss of thermal insulation capacity. Hall and Casey (2012) also pointed out this aspect. In fact, the effect of the moisture content was more relevant to the thermal conductivity than other parameters, such as the type and amount of stabiliser.

The CEB stabilised with RC displayed lower thermal conductivities than CEB stabilised with PC or UCEB. This should be due to the higher porosity associated to the CEB with RC, which were produced with a higher amount of water to account for the higher water demand and porosity of this stabiliser.

Figure 3 relates the thermal conductivity in the dry state with the total porosity of the CEB. A high correlation was found between these properties, demonstrating that the thermal conductivity is essentially influenced by the porosity of the CEB. This was expected, given that the thermal conductivity of building materials can be directly related to their porosity and density (Real *et al.,* 2016).

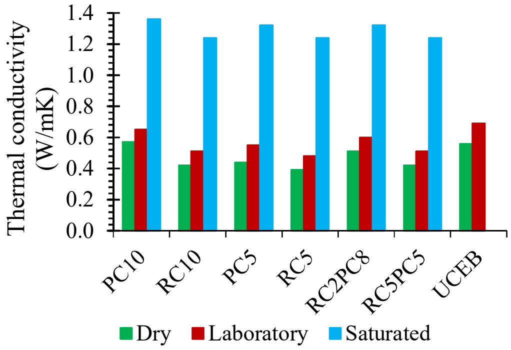

Figure 2 – Thermal conductivity of studied CEB

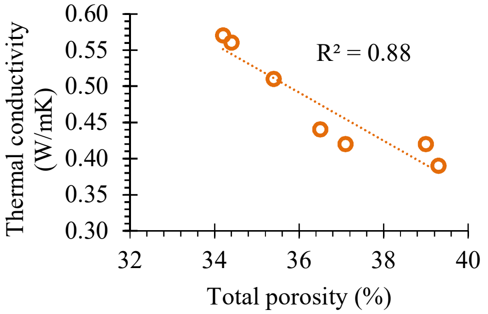

Figure 3 – Thermal conductivity in the dry state vs total porosity of CEB

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