Towards fully-recycled high sustainable compressed stabilised earth blocks

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Despite its ecological nature, low cost and hygrothermal benefits, Unstabilised earth has poor performance in outdoor building elements (Jayasinghe et al. 2016, Bogas 2020). Therefore, even in compacted earth solutions, such as rammed earth and compressed earth blocks (CEB), chemical stabilization is necessary. However, although ordinary Portland cement (PC) has shown to be the most effective earth stabiliser in compressed stabilized earth blocks (CSEB), improving their mechanical and durability performance, it has serious consequences on the embodied energy and carbon footprint of earth construction (Bogas et al. 2019, 2023). As just a reference, about 800 kg of CO^2 are released per ton of clinker (Prakasan et al. 2020). This means that for usual amounts of PC in CSEB, of around 80-200 kg/m^3 (4-10%, Morel et. 2007), it is estimated that 60-150 kg/m^3 of CO_2 are emitted.

The exploration of natural stabilisers, like agricultural wastes (Villamizar et al. 2012), or industrial by-products, such as slag and fly ash (Sekhar et al. 2018; Elahi et al. 2021), of lower environmental impact, have been attempted. However, for different reasons, such as poor stabilisation efficiency, low availability, difficult industrial scalability, and biological vulnerability, these approaches have shown only some scientific interest. Alkali-activated geopolymers have been also considered as stabilisers, but their cost-effectiveness and eco-efficiency are still are still far from being demonstrated (Narayanaswamy et al. 2020).

Extensive research aiming the development of new low-carbon binders from the reuse of cement waste has been conducted in Instituto Superior Técnico, University of Lisbon (IST-UL) since 2018. The aim is to recover the hydration capacity and binding properties of old cement waste through a low temperature thermoactivation process (Carriço et al. 2020). The production of this recycled cement (RC) not only saves relevant carbon emissions and depletion of natural resources, but also contributes to the effective reuse of construction and demolition waste (CDW). In fact, a major current problem in the construction industry is the large generation of low-value CDW, whose destination is mainly landfill. Therefore, new solutions are needed for the ambitious target of 70% CDW reuse in EU countries (EU 2028). Recent researches have shown the great binding capacity of RC in concretes (Real et al. 2021, Carriço et al. 2021). In fact, in these works it is reported that mechanical strength and durability performance of concrete is little affected for up to 40% PC replacement with RC. In addition, the environmental impact of RC production was compared with that of clinker production, leading to a reduction of more than 60% in CO_2 emissions (Real et al. 2022). However, the production of RC from cement waste initially involves the difficult task of concrete waste separation, to individualise the cementitious fraction from remaining constituents, namely aggregates. In this regard, a new method for concrete waste separation was developed and patented in IST (Carriço et al. 2021). With this method, high-quality recycled sand of less than 3 wt% adhered paste and cement waste with over 75 wt% purity can be obtained, allowing the production of RC.

In this study the partial to fully substitution of PC with RC was explored in the production of water resistant CSEB. CSEB with 4-8% stabiliser composed by 20-100% RC was tested for mechanical strength, water absorption capillary and water erosion properties. In parallel, Unstabilised CEB (UCEB) and reference CEB produced with PC were considered for comparison purposes. Moreover, for the very first time, compositions with RC directly retrieved from concrete (RCC), using the above-mentioned separation method, were also studied.

As found in previous studies on concrete, RC showed high rehydration and binding capacity, similar to that of PC. The mechanical strength was well related with total porosity, regardless the type of binder (Figure 1). However, due to the higher water requirement of RC, blocks were produced with higher porosity than PC CSEB, affecting the mechanical and durability performance (Figure 2). Nevertheless, RC CSEB showed high water resistance, with equivalent mechanical strength sensitivity to different moisture contents as PC CSEB. Moreover, compared to unstabilised earth blocks (UCEB), RC CSEB was able to increase more than twice the compressive strength and to maintain their integrity after contact with water, even under severe erosion conditions (Figures 1,3). The UCEB were completely eroded at 3-4 mm/min under 0.5 bar pressure, whereas CSEB showed no significant erosion, regardless of the type of stabiliser, even at 2.5 bar pressure (much higher than heavy rain falls, Figure 3). Only some surface erosion, with detachment of few particles was detected for 4% RC (Figure 3). Therefore, contrary to UCEB, water-resistant blocks were achieved, even considering the incorporation of only 4% RC, by weight of earth. This is environmentally comparable to the production of CSEB with less than 30 kg/m^3 of cement, which means only about 20 kg/m^3 of CO_2 emissions. RCC, retrieved from concrete debris, showed to be as effective as artificial pure RC in improving the mechanical strength and durability of UCEB (Figures 1,2).

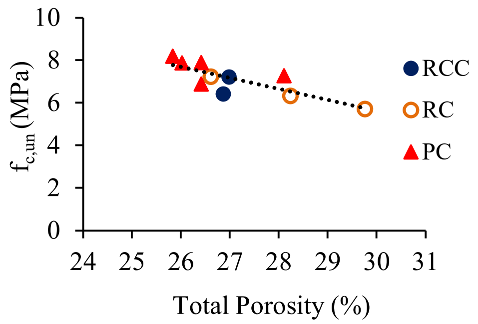

Figure 1 – Compressive strength versus total porosity for 8% stabiliser

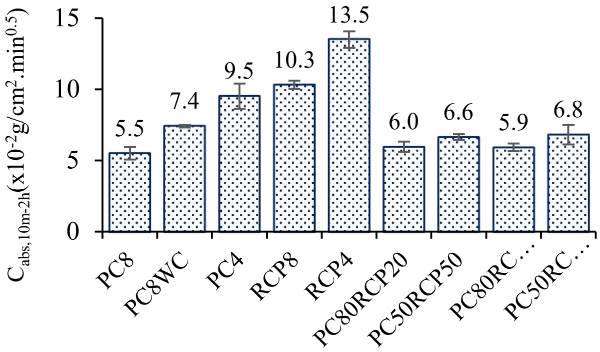

Figure 2 – Coeficient of absorption between 10 min and 2 hours in CSEB with different content of PC, RC and RCC

Figure 3 – Accelerated erosion test (left); erosion surface on blocks with 8%PC 8%RC and 4%RC (right).

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