Water resistance of recycled cement compressed earth blocks

José Alexandre Bogas[1], Ricardo Cruz[1], Bruno Azevedo[1], Andrea Balboa[1], Vitor Sousa[1]

[1]CERIS, Instituto Superior Técnico, Universidade de Lisboa, Department Civil Engineering, Portugal

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Presenting author email: jose.bogas@tecnico.ulisboa.pt

The development of more sustainable materials is a major goal of the construction sector to meet the stringent targets of the European Union regarding the reduction of greenhouse gas (GHG) emissions and the economic growth decoupled from the extraction of natural resources (CEAP 2022, EGD 2022). Therefore, this new perspective for the construction sector has changed the research trends of the industry and scientific community, leading to the renewed interest of more eco-friendly traditional natural materials.

During this millennium, earth resurged as an affordable building material with low environmental impact and embodied energy, while providing aesthetic, hygrothermal and indoor environment benefits (Hall and Swaney 2012, Jayasinghe et al. 2016, Walker 2004). In this context, compressed stabilized earth blocks (CSEB) show to be one of the best approaches, reconciling the earth construction advantages with the technical improvement of some drawbacks related to the mechanical and durability performance, especially under wet environment (Bogas et al. 2018, Bogas 2020). This is attributed to the mechanical and chemical stabilization provided by the soil compaction and an appropriate binder, respectively. So far, the non-eco-friendly ordinary Portland cement (OPC) have been found to be the most efficient stabilizer, providing high mechanical strength and good water resistance to CSEB. However, OPC is responsible for the consumption of nearly 1.7 tonnes of natural resources per tonne of clinker production and circa 5-7% of the global anthropogenic CO_2 emissions (IEA 2018, Sousa and Bogas 2021). Therefore, more eco-efficient alternative stabilizers are needed to restore the ecological nature of earth construction, without significantly reducing its technical performance.

Low-carbon recycled cement (RC) has been explored in Instituto Superior Técnico, University of Lisbon (IST-UL), which simultaneously contributes to the significant reduction of CO_2 emissions, the lower consumption of natural resources and the direct reuse of construction and demolition waste (C&DW). This new binder is obtained from the cement fraction of concrete waste and its hydration capacity is recovered by thermoactivation at low temperature, around 600-700ºC (Yu and Shui 2013, Carriço et al 2020). Relevant researches carried out in IST-UL have demonstrated the high rehydration capacity of this binder, with its performance being comparable to that of low-grade OPC, with strength class 32.5 (Carriço et al. 2020b, Carriço et al. 2021, Bogas et al. 2022).

Bearing this in mind, this study aimed the development of CSEB with partial or total incorporation of RC and their characterization in terms of water resistance, comparing them with reference CSEB produced only with OPC. To this end, a comprehensive experimental work was carried out, involving different CSEB compositions subjected to various durability tests. CSEB were tested with different stabilizer contents (5%, 10%) and distinct percentage replacement of OPC with RC (0%, 20%, 50%, 100%). The water resistance was tested in terms of immersion and capillarity water absorption, low-pressure water absorption, water permeability and accelerated water erosion, which aims to simulate the effect of heavy rain (Figure 1).

In general, water resistance decreased with increasing amount of RC. The water resistance was affected by the compactness achieved in CSEB, which was lower in RC blocks due to their higher water demand. Therefore, CSEB with RC showed lower density and higher total porosity (up to 13% higher than that of OPC). In addition, the 28-day compressive strength of RC paste was about 65% of that with OPC of equal water/binder.

Nevertheless, the incorporation of RC significantly improved the CSEB performance compared to unstabilized blocks. Regardless of the environmental conditions, RC CSEB remained intact, even when subjected to high pressure water erosion.

As expected, a high correlation was found between the analysed physical properties, namely absorption, permeability and total porosity.

To sum up, more eco-efficient CSEB can be attained with the incorporation of 180 kg/m^3 RC, which in terms of CO_2 emissions can be potentially equivalent to the use of less than 40 kg/m^3 of OPC. Indeed, from a recent study by the authors (Real et al. 2022), it was estimated a 78% reduction in the global warming potential (kg CO_2 eq) from RC production compared to OPC. However, this assumes the same technical performance of cement-based materials with RC or OPC, which was not the case in this study.

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Figure 1 – Water resistance characterization of CSEB: capillary water absorption (left top); water absorption by immersion (center top); water permeability (right top); low-pressure water absorption (left bottom); spray test – accelerated water erosion (right bottom)

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