Durability performance of non-stabilized Compressed Earth Blocks with optimized granular composition

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Abstract

Compressed Earth Blocks (CEBs) have been attracting increasing research interest recently, because of their sustainable nature. However, their poor performance against water-mediated weathering is still considered to be a major drawback for contemporary architecture. The aim of this study is to enhance the durability of non-stabilized CEBs produced in Cyprus by optimizing their granular composition. To that end, two locally sourced soils and a fine crushed aggregate were used to produce several CEBs. Spray erosion, drip and capillary absorption tests were carried out to test the performance of these CEBs against liquid ingress. The results suggest that the addition of sand can significantly improve the durability of non-stabilized CEBs against water action.

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Keywords: *Compressed Earth Block; Durability; Capillary absorption; Spray erosion test; Drip test*

1. Introduction/Background

Earth is one of the oldest building materials in the world. About 30% of the world's population still live in earthen structures, mainly located in developing countries [1]. Compressed Earth Blocks (CEBs) comprise a relatively new form of unfired earthen building material; they are produced by mixing soil at a low moisture content, under controlled pressure. Recently, CEBs have been gaining increasing research interest, mainly because of their low embodied energy and excellent recyclability potential [2]. However, the vulnerability of CEBs against water action is still considered to be a major drawback. Chemical stabilizers, such as cement or lime, have been used in order to improve the durability performance of CEBs [3]. However, this practice increases significantly the embodied energy of the end-product [4]. Guettala et al. [5] suggest that an increase in the sand content of the mix design can also improve the performance of CEBs against water attack. In this framework, the present study focuses on the enhancement of the durability of non-stabilized CEBs, by optimizing their granular composition.

2. Materials and Methods

Two different locally sourced soils, namely A-soil and T-soil, and a fine crushed calcarenite sand, were used in the mix design of the CEBs hereby presented. The granular composition of the four different mix designs produced was determined according to ASTM D422-63 [6] and is shown in Table 1. "A" and "T" mix designs refer to the CEBs produced without the addition of sand, whereas "AS" and "TS" mix designs refer to the CEBs produced after adding sand to the initial mix design.

Table 1. Granular composition (%) of mix designs.

Mix design	Gravel ($d \geq 2$ mm)	Sand (0.05 mm $\leq d < 2$ mm)	Silt (0.002 mm $\leq d < 0.05$ mm)	Clay ($d < 0.002$ mm)
A	3	26	48	23
T	-	29	46	25
AS	8	48	26	18
TS	7	55	26	12

In order to test the performance of the hardened CEBs against liquid action, capillary absorption, spray erosion and drip tests were carried out. Capillary absorption tests were conducted on six cubic specimens with edge 70 mm, using a non-reactive liquid, namely acetone, instead of water. The results were normalized at 20 °C. For the drip tests, six specimens with dimensions 50 mm x 100 mm x 100 mm were used, according to NZS 4298:2020 (Appendix E) [7]. The spray erosion tests were carried out using a customized setup developed according to the guidelines and recommendations found in NZS 4298:2020 (Appendix D) [7]. Six CEBs with dimensions 100 mm x 150 mm x 300 mm were sprayed with water at a specific rate for 1 h, simulating the effect of long-term rainfall; the maximum depth of erosion was measured after the test on each specimen.

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3. Results and Discussion

Table 2 summarizes the results of the capillary absorption, spray erosion and drip tests. All specimens tested under capillary absorption demonstrated a linear behaviour with respect to the $t^{1/2}$ law, as expected. CEBs made with A-soil had a lower coefficient of absorption, compared to those made with T-soil. After adding sand into the mix design, the coefficients of absorption for both optimised mix designs were significantly reduced. This is likely attributed to the denser structure produced after the addition of sand. The superior performance of “AS” mix design could be the result of better bonding between the sand used and A-soil, as both aforementioned materials were of calcareous nature, as opposed to T-soil, which had a more complex mineralogical composition, consisting of both silicates and carbonates.

In the drip tests, specimens obtained from CEBs made with A-soil experienced an average pit depth of 8.63 mm, whereas those made with T-soil experienced an average pit depth of 8.51 mm. Whilst the differences in the original mix designs were marginal, the two optimised mix designs again demonstrated better behaviour, with “AS” mix design showing superior performance; this is again attributed to the calcareous composition of both A-soil and the calcarenite sand hereby used.

The results of the spray erosion tests on the optimized mix designs were in line with those of the drip tests. CEBs made with A-soil recorded an average rate of erosion of 0.83 mm/min, whilst those made with T-soil recorded a much higher average rate of erosion (5.65 mm/min). With the addition of sand, the rate of erosion was reduced to 0.16 mm/min for the “AS” mix design and 0.78 mm/min for the “TS” mix design.

Table 2. Average values and coefficient of variation (COV) for the capillary absorption, drip and spray erosion tests.

Mix design	Capillary absorption test	Drip test	Spray erosion test
	Coefficient of absorption, $\text{gr/m}^2 \text{ sec}^{1/2}$ (COV)	Pit depth, mm (COV)	Rate of erosion, mm/min (COV)
A	144 (14%)	8.63 (10%)	0.83 (35%)
T	182 (11%)	8.51 (9%)	5.65 (52%)
AS	83 (10%)	2.45 (35%)	0.16 (26%)
TS	128 (20%)	4.53 (32%)	0.78 (33%)

4. Conclusions

The results suggest that granular composition optimization of CEBs through the addition of sand can indeed improve the durability performance of the hardened end-products. All the tests hereby performed have shown considerable improvement in the water-mediated behaviour of the hardened CEBs, following the addition of sand to the original mix designs. This confirms that sand may be used as a natural stabilizer to enhance the durability performance of CEBs, without negatively affecting their sustainable nature, as would have been the case with chemical stabilizers. The mineralogical composition of the sand additive used is also important, as it may affect the behavior of the primary raw material, i.e. soil.

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