COMPRESSED EARTH BLOCKS USING METAKAOLIN AND LIME WITH ANTIFUNGICIDE ADDITIONS

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Abstract: Earth building with compressed earth block (CEB) incorporating cement addition in order to stabilize the soil and to improve its mechanical properties is a technique that has been used widely. However, Portlan cement can be replaced successfully by eco-efficient materials such as metakaolin and lime.

Metakaolin is an artificial pozzolan that contains a much lower embodied energy and hence with much lower CO_2 emissions.

The lime used reacts with metakaolin to produce cementitious material with good mechanical and durability properties.

This research work is developed with the aim of achieving an optimal mix proportion of metakaolin and lime and presents an evaluation of the mechanical properties and durability of such compressed earth blocks (CEB).

Furthermore, in order to improve the mechanical behaviour, the durability, the resistance to bacterium and fungicide attack and reducing the curing time a small percentage of mineral activators was also used in the mixtures studied.

1. INTRODUCTION

This research work is divided in two different phases: the first one developed in order to achieve the optimal percentages of metakaolin and lime in the pozzolanic mixture, as well to study the effect of activators added to reduce the curing time and to improve the strength; in the second phase, the use of an organic polymer to prevent the fungus and bacterium attack is evaluated.

2. MATERIALS USED AND TESTS PERFORMED

Figure 1. Manufacture of specimens using metakaolin and lime mixture and tested specimens (photo by Rute Eires).

The selected metakaolin resulted from treated waste of an aggregate extraction mine. These wastes were heat treated that transforms it into a pozzolanic amorphous material that reacts with calcium hydroxide originating a cementitious material [1].
The lime used is a Portuguese one with a high purity: over 90% of calcium hydroxide.
Two artificial soils were produced in the laboratory, soil S1 using 85% sand and 15% kaolin, while S2 used 80% sand and 20% kaolin (percentages by weight). The amount of water added in both cases was 10% of the total mass.

Specimens were moulded using a static compaction (see Fig. 1). The specimens were cylindrical 30 mm diameter and 37 mm height. The specimens were cured in closed recipients keeping the relative humidity around 100% with minimal interference of carbon dioxide [5].

To evaluate the compressive strength of the produced mixtures, three specimens were tested at any given age and the results showed here are the average values of these three tests.

In order to evaluate the efficiency of the activators applied for decreasing the fungus attack, specimens of the different soil mixtures with and without activators were exposed to fungus attack collected from the exterior land of the university and placed in a hermetically closed container for five months.

3. MIX DESGINS TESTED AND RESULTS OBTAINED

3.1. Pozzolanic mixtures

Two compositions incorporating metakaolin and lime were tested, one with 25% lime and the other with 50% lime by weight. The water/powder ratio was maintained constant and equal to 0,6.

The compressive strength behaviour of these mixes results are presented in Figure 2. The specimens failed with a conical shape, indicating a high cohesion of the material. Figure 2 indicates that the mixture using 75% Metakaolin and 25% lime has a better mechanical behaviour with higher compressive strengths after 14 days curing.

Results obtained indicate that a higher amount of lime is beneficial in the first two weeks, while after two weeks the excess of lime does not increase the formation of cementitious products.
Furhtermore, it is noted that mixtures using 75% Metakaolin and 25% lime is a much better option with respect to economic an environmental costs. Production of lime produces CO_2 as a result of calcium carbonate decomposition while metakaolin is free from this.

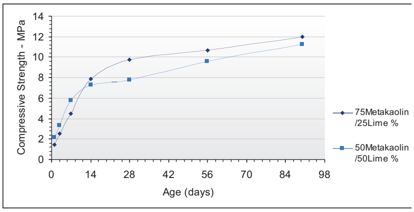

Figure 2. Compressive strength of metakaolin/ lime mixtures (figure by authors).

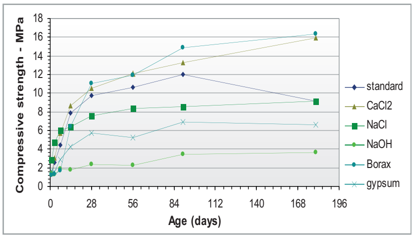

Figure 3. Activators effect on metakaolin/lime mixtures (until 90 days) (figure by authors).

For an evaluation of the potential effects of different mineral activators new mixes were prepared using small amount of activators, i.e. 2% by weight of lime. The activators used were calcium chloride ($CaCl_2$), sodium chloride (NaCl), sodium hydroxide (NaOH), borax or sodium borate ($Na_2B_4O_7$, $10H_2O$) [3] and gypsum ($CaSO_4$, $1/2H_2O$). Results obtained are presented in Figure 3.

Figure 3 indicates that borax composition has a slow strength gain in the early days but exceeds the values of the specimens without activators, i.e. standard mix. The addition of sodium chloride accelerated the strength upto 7 days but showing a lower strength gain there after. The other activators used showed lower strength gain than reference mix except mixture with $CaCl_2$. The mix with calcium chloride not only showed a higher early strength gain but also maintained its higher strength gain even after 28 days curing.

3.2. Compressed Earth Blocks Using Sandy Soils and Metakaolin and Lime Mixtures

Seven different mixes were tested using different activators as shown in Table 1. The abbreviations used are: MK for metakaolin, L for lime, OP for organic polymer, B for borax and BA for boric acid. In all cases the amount of activator used was by weight percent of MK+Lime.

	Soil - S1 85% sand +15% kaolin	Soil - S2 80% sand +20% kaolin	MK+lime (%)	OP (%)	Borax (%)	Boric Acid %
S1	100%	-	-	-	-	-
S1 5MK/L	95%	-	5%	-	-	-
S1 5MK/L - 0,4OP	94,6%	-	5%	0,40%	-	-
S2 5MK/L - 0,4OP	-	95%	5%	0,40%	-	-
S2 5MK/L - 0,2OP	-	95%	5%	0,20%	-	-
S2 5MK/L - 0,4OP B	-	95%	5%	0,40%	2%	
S2 5MK/L - 0,4OP BA	-	95%	5%	0,40%	-	2%

Table 1. Mixtures Studied (table by authors).

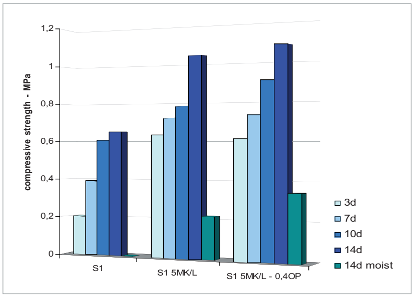

Figure 4. Compressive Stength Gain of mixtures using S1 (figure by authors).

Figure 4 shows the strength gain of the different mixes studied. It can be observed that the addition of pozzolanic mixture (S 5MK/L) increase the compressive strength when compare to the soil (S). The addition of 0,4% of organic polymer (S 5MK/L - 0,4OP) increase once more the resistances. The sandy soil mixtures have a mechanical behaviour more ductile than the pozzolanic ones. Moist specimens, humidified by immersion in water, were also tested. The test of these specimens shows a high decrease on resistances face to the dry mixtures and the simple soil (S) crumbled inside the water and was not possible to make the compressive test.

The graphic of Figure 5 shows a decrease on the compressive strength when a smaller addition of the organic polymer is used and an increase with addition of borax or boric acid.

3.3. Fungus test

The mixtures S2 5MK/L - 0,4OP (named as A) and S2 5MK/L - 0,2OP (named as B), made without additives, and mixtures S2 5MK/L - 0,4OP B (named as C) and

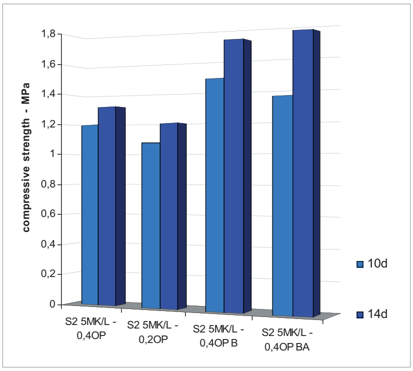

Figure 5. Compressive strength of mixtures using S2 (figure by authors).

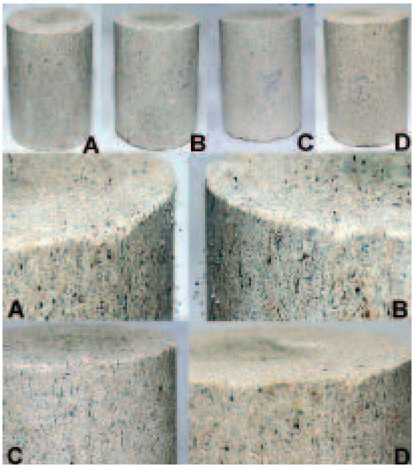

Figure 6. Specimens of fungus test: A and B without additives and C and D with borax and boric acid respectively (photo by Rute Eires).

S2 5MK/L - 0,4OP BA (named as D), with borax and boric acid respectively, were tested, against fungus according to the referred methodology using three specimens of each soil mixture.

Figure 6 shows one specimen of the different produced mixtures after the test. By visual evaluation it can be seen two types of fungus in the mixtures without additives, a small black fungus with base on the surface of the specimen and a white fungus as small spots (A and B specimens).
This white fungus appears also in one of the S2 5MK/L - 0,4OP BA (boric acid) specimens.
The black fungus was not present in any specimen with additives (C and D). And any other kind of visible fungus appears in the mixtures.

4. CONCLUSIONS

The study shows that the pozzolanic mixtures can be improved by adding mineral activators that increase the compressive strength in the first days of cure, as the calcium chloride, or during a long period of time as the borax.

In the CEB mixtures, the study reveals that it seems possible to improve the mechanical and durability behaviour of the sandy soils joining pozzolanic mixtures of metakaolin and lime. Also, the addition of organic polymer enhances the compressive strength of the soil mixtures as well the additions of borax or boric acid.

The anti-fungi effect of the addictives was also verified in one type of fungus (black fungus), but the study can not be considered conclusive concerning the white fungus. It will be necessary to continue the preliminary study and to extend the analysis to other type of fungus and verifying these with biological professionals that can give more knowledge about fungus and bacterium species. So we can identify with strictness the species.

The main benefits of the utilization of this kind of mixture that can be used also as mortars for earth construction may be divided as functional, economic and environmental. In functional terms, they provide an increase of mechanical strength, enhanced waterproofing and durability to chemical attacks. Economically, the pozzolanic materials used consume less energy during their production than cement. Also a lower cost can be obtained as industrial by-products were used. Environmentally, it contributes to a reduction of energy consumption and decrease the CO_2 liberation, harmful to the environment. Furthermore, it is a possible way of reusing industrial wastes.

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Curriculum

Rute Eires has a Master's from University of Minho on Materials and Rehabilitation of Construction in Portugal. She is doing a PhD at the University of Minho, on the topic of Earth Building Materials.
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