

COMPRESSED EARTH BLOCKS USING METAKAOLIN AND LIME WITH ANTIFUNGICIDE ADDITIONS

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Keywords: Earth building research, metakaolin, lime

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 CO₂ 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

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.



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

3. MIX DESIGNS 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 materi-

al. 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. Furthermore, it is noted that mixtures using 75% Metakaolin and 25% lime is a much better option with respect to economic and environmental costs. Production of lime produces CO₂ as a result of calcium carbonate decomposition while metakaolin is free from this.

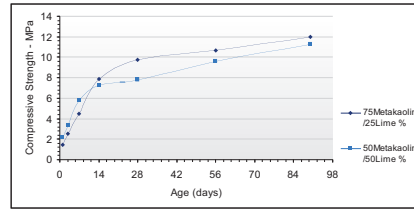


Figure 2. Compressive strength of metakaolin/lime mixtures (figure by authors).

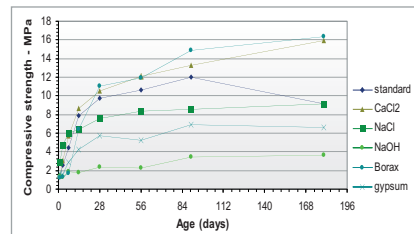


Figure 3. Activators effect on metakaolin/lime mixtures (until 90 days) (figure by authors).

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 (CaCl₂), sodium chloride (NaCl), sodium hydroxide (NaOH), borax or sodium borate (Na₂B₄O₇ · 10H₂O) [3] and gypsum (CaSO₄ · 1/2H₂O). 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 CaCl₂. 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).

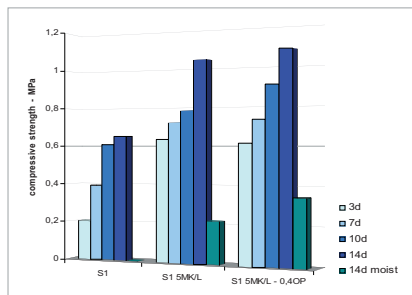


Figure 4. Compressive Strength Gain of mixtures using S1 (figure by authors).

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

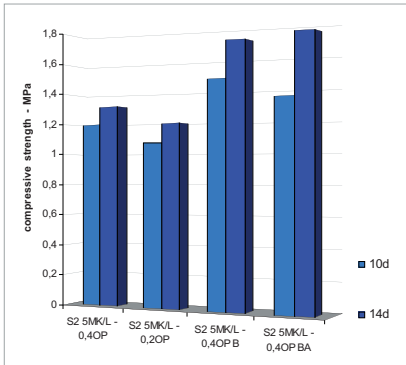


Figure 5. Compressive strength of mixtures using S2 (figure by authors).

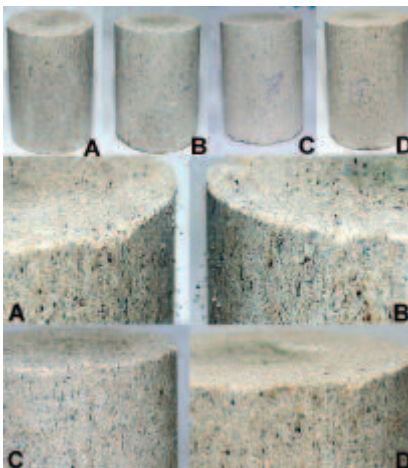


Figure 6. Specimens of fungus test: A and B without additives and C and D with borax and boric acid respectively (photo by Rute Eires).

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 additives 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 CO₂ liberation, harmful to the environment. Furthermore, it is a possible way of reusing industrial wastes.

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Curriculum

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a cura di Maddalena Achenza,
Mariana Correia, Hubert Guillaud

MEDITERRA 2009

1^a CONFERENZA MEDITERRANEA SULL'ARCHITETTURA IN TERRA CRUDA
1^{ère} CONFÉRENCE MÉDITERRANÉENNE SUR L'ARCHITECTURE DE TERRE
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EdicomEdizioni

INDICE / INDICE / CONTENTS

Prefazione / Préface / Preface	7
Atti - scheda tecnica / Actes - fiche technique / Proceedings - technical file	10
Scheda della conferenza / Fiche de la conférence / Conference file	12

**TEMA 1: ANTROPOLOGIA, CULTURE COSTRUTTIVE,
PAESAGGI CULTURALI**

**THÈME 1: ANTHROPOLOGIE, CULTURES CONSTRUCTIVES
ET PAYSAGE CULTUREL**

**THEME 1: ANTHROPOLOGY, BUILDING CULTURES
AND CULTURAL LANDSCAPE**

Introduzione al tema 1 / Introduction au thème 1 / Introduction to theme 1	20
L'architettura in terra nella pianura Padana (Italia settentrionale): gli edifici in mattoni crudi nella provincia di Cremona <i>Roberto Bugini, Danilo Biondelli e Luisa Folli</i>	23
Trasformazioni dei paesaggi culturali di terra in Calabria <i>Rosario Chimirri</i>	33
Les architectures en terre a coupoles dans la Syrie du nord <i>Emmanuelle Devaux, Letizia Dipasquale, Saverio Mecca, Silvia Onnis</i>	41
Églises en pisé mixte à Palencia <i>Juana Font Arellano</i>	53
Cultura del costruire: l'architettura di terra e l'equivoco "mediterraneo" <i>Eugenio Galdieri</i>	65
Earth architecture and Slovenia <i>Borut Juvanec</i>	71
Analyse constructive et structurales des coupoles «a encorbellement», en terre, dans la region d'Alep <i>Silvia Onnis, Mirta Paglini, Luisa Rovero, Ugo Tonietti</i>	85

- Reinforcement of rammed earth constructions with gypsum
in Aragon area, Spain 99
Fernando Vegas, Camilla Mileto, Valentina Cristini

OUTSIDE MEDITERRANEAN REGION

- The Mediterranean Portuguese influence in the Brazilian
earth-building tradition: a valuable heritage to research 109
Maria Isabel Kanan

TEMA 2: ARCHEOLOGIA, STORIA E LESSICOLOGIA
THÈME 2: ARCHÉOLOGIE, HISTOIRE ET LEXICOLOGIE
THEME 2: ARCHAEOLOGY, HISTORY AND LEXICOLOGY

- Introduzione al tema 2 / Introduction au thème 2 / Introduction to theme 2 122

- Earth-Stone symbiosis in archaeology and conservation 125
Cirillo Atzeni, Giorgio Pia, Ulrico Sanna, Nannina Spanu

- Mudbrick architectures in low Guadalquivir on orientalizing period.
Some reflections around carambolo settlement 131
Patrícia Bruno

- Stabilité, disparition et fluctuation des traditions constructives
en terre dans les pays méditerranéens 139
Claire-Anne de Chazelles

- Terra cruda nel patrimonio architettonico siciliano:
conoscenza e conservazione 151
Maria Luisa Germanà

- Les structures architecturales en terre crue de la Protohistoire
égéenne: de la fouille à l'identification 159
Raphaël Orgeolet

- Culture sismique locale en Crète (Grèce) à l'Âge du Bronze 169
Georgia Poursoulis

- Les débuts de l'architecture de terre au proche-orient 189
Martin Sauvage

TEMA 3: CONSERVAZIONE E GESTIONE DEL PATRIMONIO CULTURALE
THÈME 3: CONSERVATION ET GESTION DU PATRIMOINE CULTUREL
THEME 3: CONSERVATION AND MANAGEMENT OF CULTURAL HERITAGE

Introduzione al tema 3 / Introduction au thème 3 / Introduction to theme 3	200
Le patrimoine mondial en terre dans la Méditerranée	203
<i>Ana Paula Amendoeira, Maria Fernandes</i>	
Studies on the 18th Century mortars and plasters used in the housing construction from Balat-Fener District of Istanbul, Turkey	217
<i>Muhammed Aydın, Tülay Tulun</i>	
Dissesti e degrado a causa dell'uomo sull'architettura in terra cruda	223
<i>Stefano Bagliani</i>	
Il programma <i>Terre di Terra e il progetto colore</i>: una strategia per la conservazione e la valorizzazione del patrimonio in terra cruda	233
<i>Gaia Bollini, Isidoro Parodi</i>	
Guida al recupero dell'architettura in terra cruda nel Piemonte Sud-occidentale	249
<i>Daniela Bosia</i>	
Quel avenir pour les architectures de terre au Maroc?	259
<i>Mohamed Boussalh</i>	
Réflexion sur l'architecture en terre de Figuig et les enjeux de sa conservation	269
<i>Amar Abbou, Maurizio Cafarelli</i>	
<i>Tapia Valenciana</i>: caratteristiche di muri in terra cruda rinforzati con mattoni	285
<i>Valentina Cristini, José Ramon Rruiz Checa</i>	
Un avenir pour Nouveau Gourn	295
<i>El-Wakil Leïla</i>	
From catalogue to management: an experience of monitoring for the study and the conservation of local traditional building techniques	305
<i>Donatella Rita Fiorino</i>	

Il restauro dell'architettura in terra: una nuova metodologia per la valutazione dei trattamenti conservativi <i>Anna Maria Mecchi, Costantino Meucci, Ilaria Nicolini</i>	317
Characterization of the 4 th millennium mud-bricks of Arslantepe - Malatya (Turkey) <i>Giovanna Liberotti, Corrado Alvaro, Marcella Frangipane, Ciriaco Giampaolo, Sergio Lo Mastro, Paola Meloni, Raimondo Quaresima, Roberto Volpe</i>	327
OUTSIDE MEDITERRANEAN REGION	
A century of earthen architectural conservation in American Southwest National Parks <i>John M. Barrow</i>	337
Oltre il mediterraneo: dal dromedario al cammello. Architettura di terra e strategie di conservazione in un sito archeologico fortificato lungo la via della seta <i>Mauro Bertagnin, Désirée De Antoni, Anna Frangipane, Silvia Pozzi</i>	351
Combining traditional and innovative technologies in the conservation and development of Al Jahili Fort, a historic mud brick building in the oasis city of Al Ain, Abu Dhabi, UAE <i>Sami El-Masri, Peter Sheehan</i>	361
Preservation of Historic buildings in Earthen Architecture <i>Saleh Lamei</i>	369
Protecting earthen architecture from rainfall erosion in Arg-E-Bam (Iran) and Tayma (Saudi Arabia) <i>Guido Licciardi</i>	379
TEMA 4: RICERCA SU COSTRUZIONE, ARCHITETTURA, PIANIFICAZIONE URBANA, R & D	
THÈME 4: RECHERCHE EN CONSTRUCTION, ARCHITECTURE, URBANISME ET R & D	
THEME 4: RESEARCH IN CONSTRUCTION, ARCHITECTURE, TOWN PLANNING AND R & D	
Introduzione al tema 4 / Introduction au thème 4 / Introduction to theme 4	388

Influence de la teneur en sel et du Ph sur la plasticité du materiau terre	391
<i>Romain Anger, Laetitia Fontaine, Hugo Houben</i>	
An industrial experience on <i>ladiri</i> production in Sardinia	399
<i>Cirillo Atzeni, Mauro Coni, Maurizio Manias, Giorgio Pia, Ulrico Sanna</i>	
Static analysis of earthen corbelled domes in the Aleppo's region	405
<i>Giuseppe Berti, Mirta Paglini, Luisa Rovero, Ugo Tonietti</i>	
Weathering and multipollutants agents impact on earth architecture: damage processes and vulnerability	415
<i>Alessandra Bonazza, Gianfranco Carcangiu, Luigi Massidda, Paola Meloni, Cristina Sabbioni</i>	
Military topographies: earth fortresses between borders	425
<i>Gilberto Carlos, Mariana Correia</i>	
Le materiau pisé a Cherchell (Algérie): un autre type d'architecture en terre. Nature et filiation	437
<i>Yucef Chennaoui</i>	
Les portails de la Medina de Meknès, Maroc: etat des lieux	451
<i>Sanae Elkhanchoufi, Said Kamel, Rachida Mahjoubi, Jean Marc Vallet, Philippe Bromblet</i>	
Compressed earth blocks using metakaolin and lime with antifungicide additions	461
<i>Rute Eires, Aires Camões, Said Jalali</i>	
Influence of different reinforcing fibres on the mechanical properties of an earthen material	467
<i>Francesco Aymerich, Luigi Fenu, Paola Meloni</i>	
Quelques mécanismes de stabilisation du matériau terre de la terre stabilisée aux composites argiles - biopolymères	473
<i>Laetitia Fontaine, Romain Anger, Hugo Houben</i>	
The earth salt architecture of middle age in the Siwa oasis, Egypt	481
<i>Fabio Fratini, Silvia Rescic, Luisa Rovero, Ugo Tonietti</i>	

La costruzione in terra cruda della Sardegna meridionale: metodiche per la datazione delle strutture <i>Caterina Giannattasio</i>	493
Design and strengthening of earth construction in seismic areas <i>Maria Idália Gomes, Jorge de Brito, Mário Lopes</i>	505
Earthen architecture revival as brand building project in Cyprus; while investigating the seismic measures on historical structures <i>Bilge Isik</i>	517
Measurement of mechanical strength, thermal conductivity and moisture of earth samples from Crete, Greece, containing clay and straw for architectural applications <i>Theodoros Markopoulos, Paola Rotondo, Apostolos Pantinakis, Panagiotis Pantzekos, Apostolos Mousourakis, Georgia Chrysafaki</i>	527
Economy and common sense. Simple solutions from past for today and beyond <i>Domen Zupančič</i>	537
OUTSIDE MEDITERRANEAN REGION	
Mexican contemporary earthen architecture <i>Berenice Aguilar Prieto</i>	549
Kraftterra – the incorporation of recycled cement sacks to the soil for compressed earth block production <i>Márcio Albuquerque Buson, Rosa Maria Sposto</i>	561
Structural properties of adobe dwellings in Cusco (Peru) for seismic risk assessment <i>Nicola Tarque, Helen Crowley, Humberto Varum, Rui Pinho</i>	573
Using indigenous earthen architectural knowledge to build sustainable natural living environments <i>Lesley Freedman Townsend</i>	585

TEMA 5: DIDATTICA E SENSIBILIZZAZIONE PUBBLICA
THÈME 5: EDUCATION ET SENSIBILISATION PUBLIQUE
THEME 5: EDUCATION AND PUBLIC AWARENESS

Introduzione al tema 5 / Introduction au thème 5 / Introduction to theme 5	600
Restauero, nuova costruzione e didattica. Un'esperienza svolta a Treia, Italia <i>Anna Paola Conti</i>	603
Le terre del Mediterraneo <i>Gianfranco Conti</i>	615
Professional training in conservation of rammed earth constructions <i>Susana Sequeira, Maria Fernandes, Miguel Rocha</i>	623
«Exploraterra», un module d'enseignement innovant pour la didactique de l'architecture de terre <i>Hugo Houben</i>	631
Centre du patrimoine de terre de Marrakech: montage d'une structure de recherche, de formation et d'assistance <i>Tayyibi Abdelghani</i>	645
OUTSIDE MEDITERRANEAN REGION	
Professional training and academic teaching in earth architecture: the activities and experiences of the Dachverband Lehm E.V., Germany <i>Horst Schroeder, Ulrich Röhlen, Stephan Jörchel</i>	657
Makunaima – the adobe village and seasonal training camp for cultural heritage on earthbuilding, located in Berlin <i>Rainer Warzecha</i>	665