



Research paper

Magnesium oxide as alternative binder for unfired clay bricks manufacturing

Sandra Espuelas^a, Joshua Omer^b, Sara Marcelino^a, Angel Maria Echeverría^c, Andres Seco^{a,*}^a Dept. of Projects and Rural Engineering, Public University of Navarre, 31006 Pamplona, Spain^b Faculty of SEC, Penrhyn Road, KT1 2EE, Kingston University, London, UK^c Zabala Innovation Consulting S.A., 31192 Mutilva, Spain

ARTICLE INFO

Keywords:

Magnesium oxide

Lime

Unfired clay bricks

Pozzolanic reactions

Mechanical properties

Durability

ABSTRACT

Replacement of fired bricks by unfired ones could be an effective way to reduce the building industry environmental footprint: Their manufacture not only requires less energy and natural resources but also generates less waste. Bricks are based on the use of an additive cementitious material in the form of a binder, usually lime or cement. Such additives have a great environmental impact owing to the high energy consumption and CO₂ during in their manufacturing process. In this article experiments are carried out in order to investigate the applicability of a MgO rich industry by-product as a binder for the production of unfired clay bricks. From the experiments, the MgO was observed to show ability to enhance the mechanical properties of a clay brick in much the same way as lime does. Water absorption tests on bricks revealed the superiority of MgO over lime in enhancing the durability properties of unfired bricks. The laboratory results demonstrate the high potential of MgO based additives as alternative binders to the calcium based ones. Consequently, this offers opportunity for reducing the environmental impact associated with the use of fired clay bricks. In addition, it could allow an effective way for the valorization of MgO containing industry by-products that currently discarded to landfills.

1. Introduction

Fired clay bricks are used extensively for buildings construction around the world. The use of these bricks entails the consumption of large amounts of energy, with the manufacturing process requiring around 4186.8 MJ/tonne, mainly due to the firing process involved (BDA, 2010). The achievement of environmentally cleaner and a more sustainable building industry is an increasing concern, having become a major social and governmental goal for the sector (European Commission, 2014). Accordingly there is a challenge to develop more environmental friendly building materials such as unfired bricks. Such products can replace fired bricks in many applications, with considerable reductions in energy usage, natural resource consumption, and in the amount of wastes dumped in landfills (Oti et al., 2009). Unfired bricks are made up of t clay soil and a binder, which is usually lime or cement. Pozzolanic reactions between the clay and the binder result in transformation of the mechanical strength and durability properties of unfired bricks, making them suitable to be used as construction material (Seco et al., 2017).

From an environmental viewpoint, the use of calcium based additives like lime or cement inevitably leaves environmental footprint: because of the manufacturing necessitates de carbonation of natural

rocks to convert CaCO₃ into CaO. This process releases large amounts of CO₂ and requires a high energy consumption (Damtoft et al., 2008; Bellman and Stark, 2009; Habert et al., 2011).

From a chemical point of view certain attributes of MgO are similar to CaO. It has been stated (Xeidakis, 1996) that MgO has the ability to flocculate clay soils, leading to formation of cementitious gels. Additionally, Seco et al. (2011) reported that MgO reduced the natural swelling potential of expansive soils and other researchers (García et al., 2004; Navarro et al., 2006; del Valle-Zermeño et al., 2015) reported the ability of MgO to immobilize heavy metals in contaminated soils. These researches show the potential of Mg based binder as alternative to Ca based ones. Magnesite is an essential material for the manufacturing of refractory products. It is obtained by the calcination of raw MgCO₃ rocks at 1100 °C. Under these conditions the natural mineral decarbonates and turns into a MgO vitrified matrix. Industrially, this process is carried out in rotary kilns with crosscurrent air. As the air moves, it pulls dust from the whole length of the kiln containing three chemicals: (i) inert MgCO₃ particles, (ii) reactive, calcined MgO particles and (iii) inert vitrified MgO particles. In Spain, the production of calcined magnesite is approximately 150,000 tons per annum, generating 50,000 tons of kiln dust per year. The annual consumption of the product is however much less and the excess production ends up

* Corresponding author.

E-mail addresses: sandra.espuelas@unavarra.es (S. Espuelas), j.r.omer@kingston.ac.uk (J. Omer), sara.marcelino@unavarra.es (S. Marcelino), amecheverria@zabala.es (A.M. Echeverría), andres.seco@unavarra.es (A. Seco).<http://dx.doi.org/10.1016/j.clay.2017.05.034>Received 16 February 2017; Received in revised form 23 May 2017; Accepted 24 May 2017
0169-1317/ © 2017 Elsevier B.V. All rights reserved.

Table 1
XRD-based mineralogical composition of the Red Clay soil.

Mineral	Composition (%)
Quartz	31
Calcite	30
Muscovite	17
Dolomite	12
Chlorite	6
Gypsum	4

in landfills, thereby causing significant economic, social and environmental concerns.

This research continues the work of Miqueleiz et al. (2012) who studied the stabilization of a Spanish Clay soil with different binders. In this context, this investigation analyzes the ability of the magnesium-based additives to substitute for the calcium-based ones for a more sustainable building material. Thus it was imperative to how differently the additions of MgO rich dust and lime influence the properties of unfired clay bricks, in terms of mechanical strength and durability.

2. Materials

For this research a sample of a locally sourced clay soil was used. A detailed description of this soil can be read in Miqueleiz et al. (2012).

Table 1 shows the mineralogical composition of the clay sample as measured by XRD analysis, based on the chart proposed by Al-Rawas (1999). From a mechanical point of view, according to the Spanish Standards UNE 103104 and UNE 103103, this material showed a plastic limit (PL) of 24.9% and a liquid limit (LL) of 43.5%. Based on the Standard Proctor compaction Test (SP), as defined in the standard UNE 103500, the maximum dry density and the optimum moisture content were found to be 1.76 Mg/m³ and 15.4%, respectively. The swelling potential of the soil, based on the standard UNE 103601, was 3.88%.

Two different binders were used in this study: (1) a sample of a MgO rich kiln dust named PC-8, produced by Magnesitas de Navarra S.A. Company in its factory located in Zubiri (Navarra, Spain), and (2) a commercial calcareous hydrated lime (CL-90-S), complying with the Spanish Standard UNE-EN 459-1. Table 2 shows the composition of both additives, expressed as their most significant oxides, based on XRF analysis.

3. Methodology

To test the effectiveness of both additives, mechanical properties and durability were investigated for the 12 different dosages shown in Table 3.

The codes used for the different combinations are composed of the binder identification “PC-8/” in the case of the MgO waste and “CL-90/” in the case of the lime, followed by the percentage of additive. These applied dosages exceed the usual range of 4–10% but this was intended to enable analysis of the effects of the deficiency or overdose of the additives on the resulting properties of unfired bricks. A similar strategy was used successfully by Miqueleiz et al. (2012).

Table 2
Oxide composition of the additives.

Oxides (%)	PC-8	CL-90-S
Ca(OH) ₂	–	> 95
CaO	7.40	
MgO	61.85	
SO ₃	7.26	
Fe ₂ O ₃	2.42	
Al ₂ O ₃	0.56	
SiO ₂	3.41	

Table 3
Additive dosages tested.

Code	Dosage of PC-8 (%)	Dosage of CL-90-S (%)
SOIL	–	–
PC-8/3	3	
PC-8/6	6	
PC-8/9	9	
PC-8/12	12	
PC-8/15	15	
PC-8/18	18	
CL-90-S/3		3
CL-90-S/6		6
CL-90-S/9		9
CL-90-S/12		12
CL-90-S/15		15
CL-90-S/18		18

The mechanical properties of the unfired clay bricks were measured through unconfined compressive strength tests performed, in accordance with the Spanish standard UNE 103400. Durability properties were assessed through measuring the water absorbed by the bricks after 24 h of immersion in water, as stipulated by the European Standard EN 771-1. The unfired brick specimens were prepared as follows:

- For each combination clay soil and additive, Moisture/Density curves were calculated following the procedure showed in Seco et al. (2017), based on the Spanish Standard UNE 103500. This allowed determination of the Optimum Moisture Content (OMC) necessary to achieve the Maximum Dry Density (MDD) for the 13 N/mm² compaction pressure applied.
- For each clay-additive combination, enough quantities of the dry soil and additive were poured in a laboratory mixer and mixed thoroughly for 10 min to be as homogenous in state as possible.
- Then a calculated volume of water was added to the mix to achieve the OMC. The ingredients were then thoroughly mixed for a further 10 min to a uniform state.
- The wet mix was then compacted in a 65 mm diameter by 75 mm high cylindrical mold, using a 5 kN hydraulic press. After compaction the specimens were demolded and stacked in a wet chamber for curing, covered with polythene sheeting to prevent further moisture losses.
- The samples were cured for 1, 7, 28, 56 and 90 days to reach the intended testing age. In this research, a total of 360 cylindrical specimens corresponding to the 12 soil-additives combinations, were prepared.

4. Results and discussion

4.1. Maximum dry density and optimum moisture content determination

Figs. 1 and 2 show the MDD and the OMC variations for the different combinations. The addition of PC-8 to the soil from 3% to 18%, produced a slight increase of MDD from 1.98 g/cm³ to 2.00 g/cm³ and an increase of OMC from 12.6% to 15.7%. The addition of lime to the RC soil decreased the MDD, from 1.89 g/cm³ to 1.80 g/cm³. With this additive OMC rose from 13.1% to 18.3%.

4.2. Unconfined compressive strength

Figs. 3 and 4 show the unconfined compressive strength results of PC-8 and CL-90-S combinations, after 1, 7, 28, 56 and 90 days of curing time.

Generally, for all curing periods, specimen PC-8 showed clearer differences in unconfined compressive strength than those containing lime.

There compressive strength of PC-8 increased continuously for

Download English Version:

<https://daneshyari.com/en/article/5468823>

Download Persian Version:

<https://daneshyari.com/article/5468823>

[Daneshyari.com](https://daneshyari.com)