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Earth of Datça: Development of pozzolanic activity with steam curing

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HIGHLIGHTS

- Earth of Datça-lime binder gained high strength in a short time with steam curing.
- Materials having low environmental impact were produced by steam curing.
- Steam curing provided more energy-efficiency and saving of time than the other methods.
- Earth of Datça-lime binder with steam curing may be used as 'bricks or blocks'.
- Earth of Datça-lime binder without steam curing may be used as 'mortar ingredient'.

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ABSTRACT

Environment friendly binders with relatively low energy consumption and low emissions may be an alternative to energy-intensive cement. To contribute to this knowledge, physical and mechanical characteristics of Earth of Datça-lime binder under steam curing conditions at atmospheric pressure was investigated. To evaluate the effects of the steam curing conditions, air, water, and heating curing were also examined. Tests results showed that Earth of Datça-lime binder through steam curing can be used for the production of materials similar to fired clay or calcium silicate bricks. Steam curing provided more strength, energy-efficiency and time saving compared to other curing conditions.

1. Introduction

As an industrial material, cement is manufactured intensively in building trade. Cement production significantly consumes natural resources and causes CO_2 emissions. CO_2 emissions represent approximately 5% of anthropogenic global CO_2 emissions [1]. Thus, there is an urgent need to produce alternative binders which are more environment friendly with lower energy consumption and lower CO_2 emissions instead of energy-intensive cement.

Lime-pozzolan is a binder with hydraulic properties mainly consisting of air lime with added pozzolanic material. Addition of a pozzolan to air lime enables the mortars to obtain hydraulic properties, resistance to water, higher compressive strength, but also durability and some resistance to weathering [2]. So, lime-pozzolan binder can be used as an alternative to the cement for both structural and non-structural purposes in modern and historical buildings. In addition, it is possible to use them in the production of alternative bricks to the cement-based or calcium silicate bricks.

Mechanical properties of lime-pozzolan binders increase slower than that of cement, depending on the type of the pozzolan used [2]. In order to obtain satisfactory strength in an acceptable time period heating curing is usually necessary [3]. The objective of curing is to provide appropriate temperature and humidity conditions to ensure the progress of hydration reactions causing the filling and segmentation of capillary voids by hydration products [4]. The progress of hydration reaction, which influences the binders' porosity, microstructure and strength, are directly connected to the curing conditions used [5]. Except for heating curing, diverse curing methods are used comprising steam curing at atmospheric pressure and high pressure steam curing. The primary objective of steam curing is to obtain a sufficiently high early strength so that the products may be handled soon after casting: the moulds can be removed, or the prestressing be vacated earlier than would be the case with ordinary moist curing, and less curing storage space is required; all these mean an economic advantage. When steam is at atmospheric pressure, i.e. the temperature is below 100 °C, the process can be regarded as a special case of moist

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Table 1
Chemical analysis of the main components of the hydrated lime, Earth of Datça, and Earth of Datça-lime binder.

Component	Hydrated Lime (%)	Earth of Datça (%)	Earth of Datça-lime binder (%)
SiO_2	1	72.07	49.20
Al_2O_3		13.06	7.90
Fe_2O_3		1.39	1.25
MgO	1	0.44	0.61
CaO	85	2.34	29.46
CO_2	5	–	–
Na_2O		3.27	1.66
SO_3	0.6	–	–
K_2O		4.60	3.04
TiO_2		0.20	0.25
P_2O_5		0.05	0.05
MnO		0.06	0.06
Cl		0.10	0.13
S		218PPM	503PPM
LOI		2.15	6.01
Total	92.6	99.73	99.63

curing in which the vapour saturated atmosphere ensures supply of water [6]. However, when the pressure is above atmospheric level, the curing method is called as high pressure steam curing or autoclaving, which is extensively used for the manufacturing of cement-based building products such as dense concretes, lightweight or aerated concretes and calcium silicate bricks. To obtain such products, high temperatures (170–210 °C) are necessary in order to impart to the silica the necessary reactivity towards lime [7]; it means higher consumptions of energy. But, there is no need high amounts of curing energy for lime-pozzolan products due to the fact that amorphous silica (and/or alumina) of pozzolan is more reactive than sand towards lime.

In a previous study [8], three types of curing methods (air curing, water curing and heating curing) was compared on the development of pozzolanic activity of volcanic tuff settled at the far west end of the Datça Peninsula in Turkey. It was determined that physical and mechanical characteristics of Earth of Datça-lime binder developed considerably with water and heating curing individually. However, the effects of both water and heating curing on this binder were not evaluated together. The purpose of the present study is to investigate the development of physical and mechanical characteristics of Earth of Datça-lime binder under steam curing conditions at atmospheric pressure which contains both of water and heating effects together. In this context, the objectives of the study can be summarized as:

- To produce a hydraulic binder as an alternative to cement;
- To obtain satisfactory strength in an acceptable period of time;
- To shorten the production time and consequently to minimize the energy consumption under the constant temperature;
- To investigate the possibility of preparing products with this binder similar to 'bricks'.

2. Materials and methods

Materials: The pozzolanic activity of Earth of Datça (ED) was examined according to the Turkish Standard 25 [9]. Quicklime was slaked in order to obtain calcium hydrated lime putty complying with TS EN 459-1 [10] and stored in the moist state by covering it for minimum 15 days until used. CEN standard sand based on TS EN 196-1 [11] was used. ED was put in an oven at 70 °C and dried until constant weight was determined. Afterwards, ED was milled by a tumbling ball mill. Maximum grain size (fineness) of the pozzolan was determined as 90 μm as per Turkish Standard 25 [9] and was measured by sieving it on standard sieves according to the TS EN 196-6 [12]. Table 1 reports the chemical characterization (XRF) and Fig. 1 presents mineralogical analysis (X-ray diffraction_XRD) of the hydrated lime, Earth of Datça, and Earth of Datça-lime binder (ED)B produced for the pozzolanic activity test. The mixture proportion of lime, pozzolan and sand is 1:2.3:9 by weight. XRF and

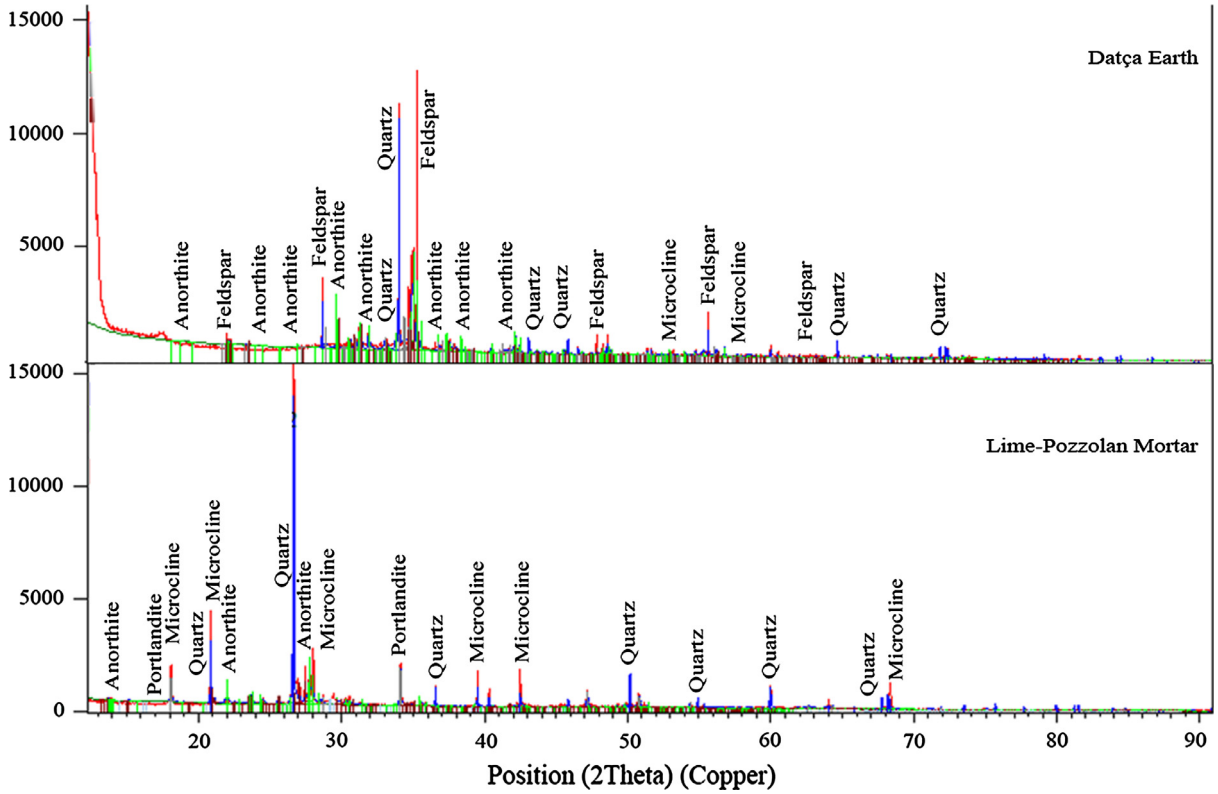

Fig. 1. Results of XRD in Earth of Datça, and Earth of Datça-lime binder.