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Research Article
Use of Recycled Fireclay to Improving the Mechanical Strength of Ain Nouissy Brick

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Abstract

Background: Kaolin fireclay is a waste product of brick production. The estimated 150,000 t of fireclay produced annually represents nearly 30% of the total amount of bricks produced by weight. This study explored the reuse of fireclay in brick production at the Ain Nouissy Mostaganem brick factory in Algeria. The need to recycle the fireclay is an environmental as well as a financial concern because of the exhaustion of clayey natural resources and constraints related to its storage and future use. The physico-chemical and mechanical characteristics of bricks made from the reuse of fireclay can be affected by the particle size distribution and percentage added of this latter. **Materials and Methods:** In this study, several different amounts of fireclay that had different particle sizes were included in the brick manufacturing process. The effect of the fireclay on the quality of the resulting bricks was assessed in terms of liquidity limits, plasticity, bulk density and mechanical compressive strength and bending. **Results:** We found that fireclay particle size and amount for optimal brick production was 0.2 mm average diameter and 4% dry weight of the raw material, respectively. In this case, the brick records an increase resilience of 20%. **Conclusion:** This study suggested that reinjection of fireclay in manufacturing process, not only improves the resilience quality of brick but also, contributes to reduce the financial and spatial constraints of handling and storage of fireclay.

Key words: Kaolinite, brick, fireclay, recycling, physico-chemical, mechanical properties

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The ceramics industry is continuously evolving to take multi-disciplinary and integrated approaches to the manufacture of complex materials that are composed of heterogeneous materials[1,2] such as clay brick[3]. One avenue of investigation to improve the properties of bricks is the reuse of fireclay wastes that are produced during manufacturing.

Brick fireclay is most commonly used for road development[4-6], building facings and concrete consolidation[7] but its use in the brick industry itself is rare. Therefore, studying whether fireclay can be used to improve the mechanical performance of brick is of interest.

Discharges to fireclay in the clay brick industry are an economic burden and present storage challenges. Indeed, previous findings noted that fireclay represents by weight on average 20-30% of output[8]. Thus, the use of fireclay in brick manufacture requires the implementation of an optimal method to address both storage issues and to reduce brick manufacturing costs.

MATERIALS AND METHODS

Material

Ain Nouissy brick factory: The brick factory for this study is located in Ain Nouissy 17 km West of Mostaganem and is in the public sector. Including all annexes, the factory occupies an area of 20,000 m^2. The factory has an average annual production of 150,000 t.

Clay: The kaolinite used in the brick factory originates from the Ain Nouissy deposit located near the factory site. The deposit capacity has an estimated a lifetime of 120 years based on current production rates. The chemical structure of kaolinite shows that 15.05% is lost to fire[9] (Table 1).

A mineralogical analysis of the clay showed several peaks for kaolinite, illite and calcite (Fig. 1). The clay also contained gypsum, quartz and feldspar.

Fireclay: The fireclay derives from waste arising from breakage that occurs during handling of the finished bricks. Fireclay is estimated to represent nearly 30% of the total production amount by weight[10]. In terms of chemical structure, 4.08% are fire losses (Table 2). The mineralogical composition of the fireclay is very similar to that of clay, which supports its incorporation into the brick manufacturing process (Fig. 2)[11].

Brick crusher: The factory crusher is from Deltalab and is used to crush the brick waste to obtain reusable fireclay in the form of clay paste[12].

Mixer: The mixer is also from Deltalab and has an agitator used to prepare a homogeneous mixture of clay-fireclay.

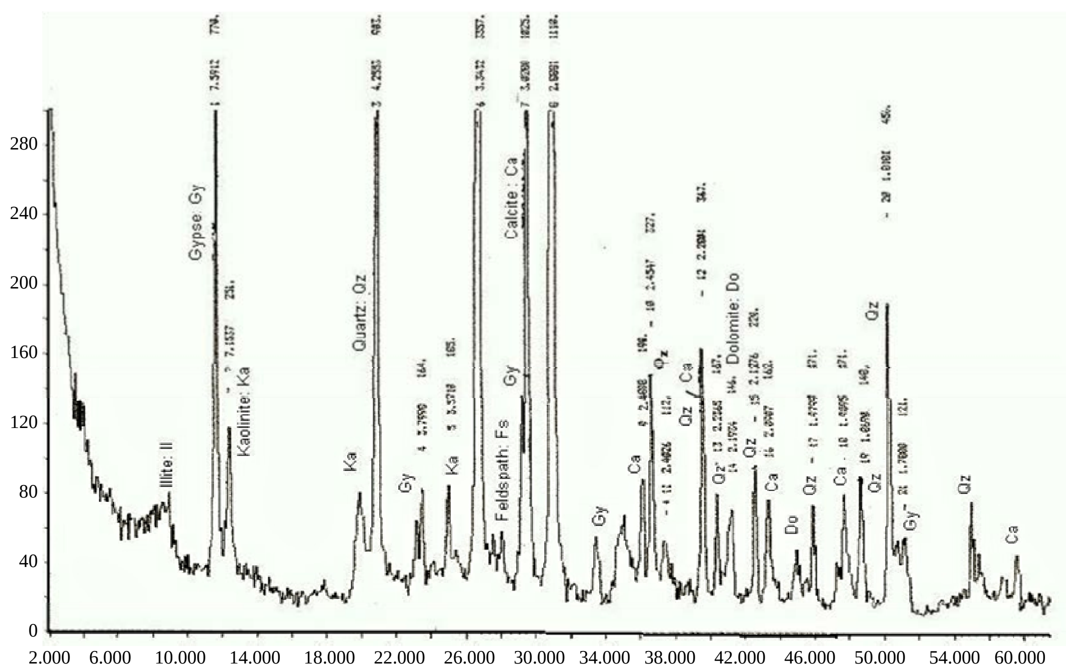

Fig. 1: Spectroscopic analysis of clay by x-ray diffraction

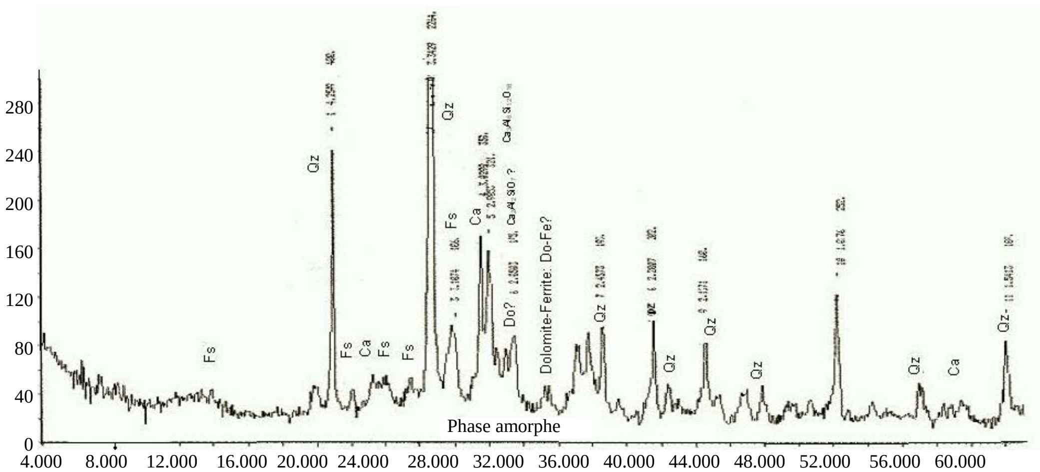

Fig. 2: Spectroscopic analysis of fireclay by x-ray diffraction

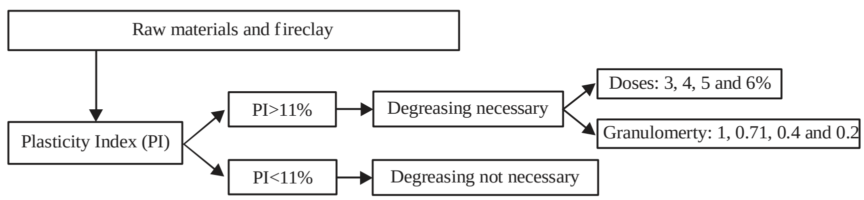

Fig. 3: Diagram of working methodology

Table 1: Chemical composition of raw material

	Element (%)													
	S_iO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3T	K_2O	Na_2O	TiO_2	MnO	P_2O_5	Cr_2O_3	Fire losses	Total
Clay (matrix)	49.57	11.99	5.26	11.53	2.51	0.14	1.97	0.57	0.614	0.04	0.162	0.028	15.05	99.43

Table 2: Chemical composition of fireclay

	Element (%)													
	S_iO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3T	K_2O	Na_2O	TiO_2	MnO	P_2O_5	Cr_2O_3	Fire losses	Total
Fireclay	54.97	13.89	5.81	13.98	2.97	0.21	2.29	0.63	0.664	0.049	0.187	0.028	4.08	99.76

Methods

Methodology: The adopted methodology (Fig. 3) was used to determine the Plasticity Index (PI) of the raw material-fireclay mixture. Degreasing was only necessary for PI>1%. In this study, we determined the fireclay doses for use and their particle sizes.

Raw material and fireclay preparation: The previously ground clay was sieved to 4 µm and treated with sodium hexametaphosphate as a dispersant. The paste was then placed in an oven at 110°C for 24 h. The crushed brick waste after production was subjected to a series of six sieves of decreasing pore diameters: 2, 1, 0.71, 0.5, 0.4 and 0.2 mm.

Clay-fireclay mixture and sample preparation: Moisture from the mixtures was evaporated and mixtures with three amounts of fireclay were prepared that had 5, 10 and 15% of prepared clay weight. The control contained only clay. After an average agitation time of 40 min, the mixer produced homogeneous mixtures[13]. After preparation the blends were mixed at the liquidity limit[14,15].

Drying and cooking: The mixtures were dried for 24 h in a 110°C oven[16]. The firing of the ceramic material took place in a furnace where the sample was in a fixed state and subjected to a temperature change from 100-1350°C[17].

Measurement methods: The liquidity limit (W_L, %), plasticity limit (W_P, %) and Plasticity Index (PI%) were determined according to the method described by O'kelly[14].

The bulk density (ρ_{ap}, g cm^{-3}) and absolute density (ρ_{ab}, g cm^{-3}) were determined by hydrostatic balance and with a pycnometer, respectively.

The mechanical strength expressed as compression R_C and flexion R_F were determined by a hydraulic press method and 3-dots flexion, respectively.

Microscopic analysis of raw material and fireclay was carried out using an x-ray diffractometer (DX 09/04 series).

RESULTS AND DISCUSSION

Atterberg limits: To determine the amount of fireclay to be added to the raw material, the plasticity index should be determined as an indicator of the need for treatment degreasing[18]. Previous studies indicated that for clays with a plasticity index <11% degreasing is not needed[8,9]. However, in this study only the 5% dose of fireclay had an PI>11% (Table 3) and thus we used a final amount of fireclay that was at or around 5%, e.g., 3, 4, 5 and 6%. The control sample contained fireclay sifted to 1 mm and contained all particle sizes.

Compression and flexion: Assays of brick resistance to compression[13,19] and flexion showed that 4% was the optimal amount of fireclay for inclusion during brick manufacture (Fig. 4).

However, the effect of fireclay particle size is dependent on compression and flexion and characterize product quality wherein finer fireclay particles contribute to enhanced resistance to compression and bending. Notably, the effect of a broad grain size distribution appears to have unfavorable effects on both compression and flexion properties (control).

Bulk density: Assays of brick bulk density as a function of fireclay content and granularity further confirm that these two parameters are linked to brick quality (Fig. 5). The optimum bulk density in terms of brick quality was seen for 4% fireclay and a particle size of 0.2 mm.

This density phenomenon as a function of particle size persists for 4% fireclay (Fig. 6). The pink color in the figure represents highly aggregated areas in the finished material (shard). This color is characteristic of the fritting phenomenon and is even more dense than with finer particle sizes due to the formation of mullite[16,17].

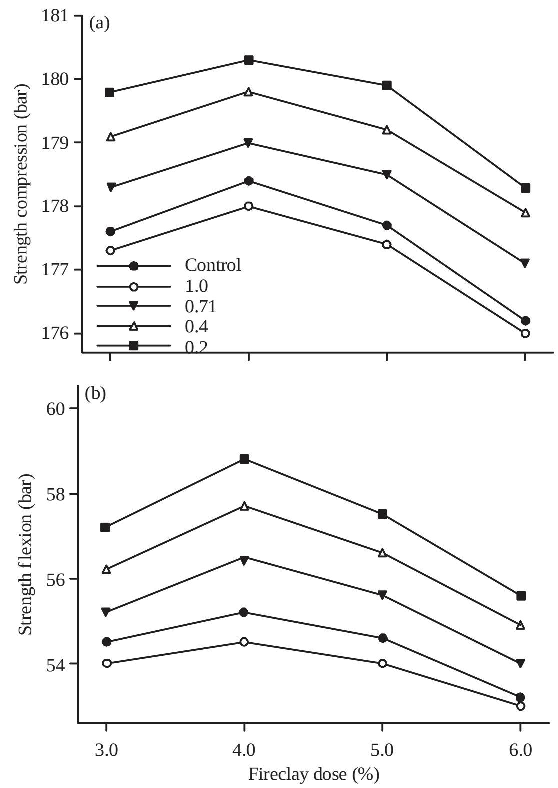

Fig. 4(a-b): Resistance of brick to (a) Compression (bar) and (b) Flexion (bar) as a function of fireclay dose (3, 4, 5 and 6% dry weight) and granularity (1, 0.71, 0.4 and 0.2 mm grinding), Control: Raw material without fireclay

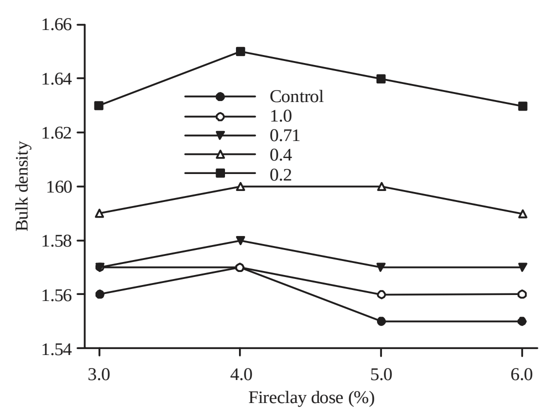

Fig. 5: Brick bulk density as a function of fireclay dose (3, 4, 5 and 6% dry weight) and granularity (1, 0.71, 0.4 and 0.2 mm grinding), Control: Raw material without fireclay

Table 3: Averages of Atterberg limits

Fireclay (%)	W_L (%)	W_P (%)	IP (%)
5	21.3	9.3	12.0
10	20.6	9.8	10.8
15	20.5	9.7	10.8

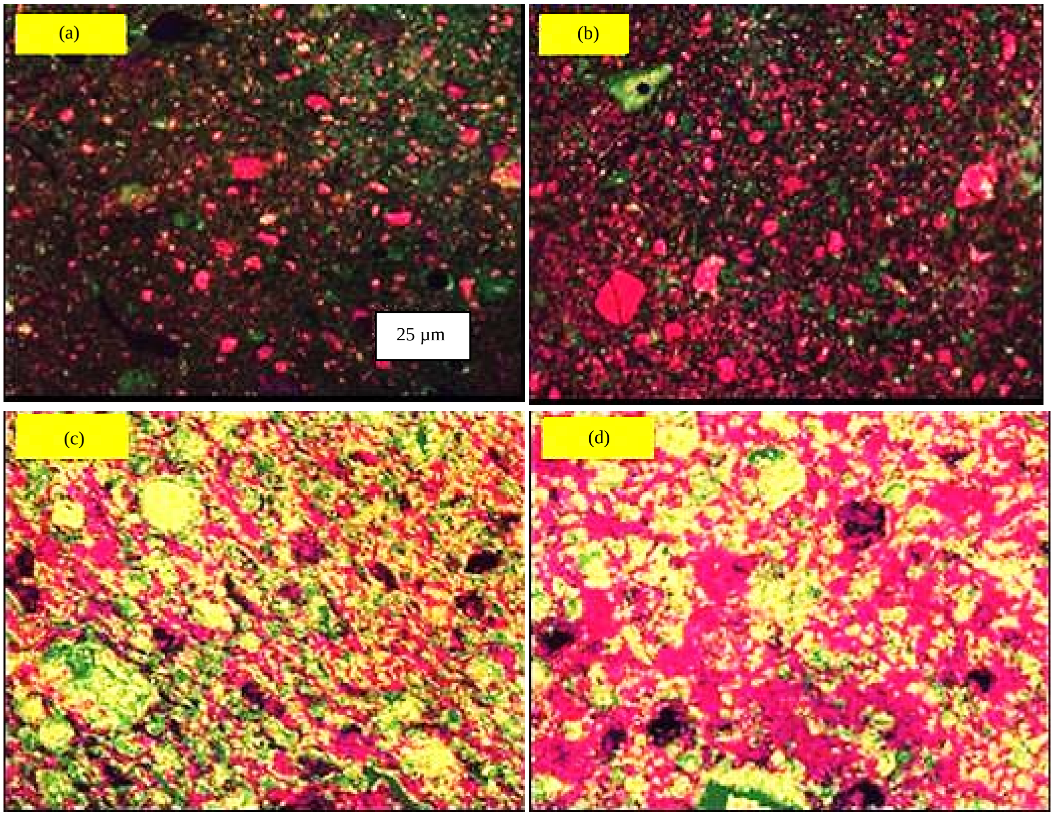

Fig. 6(a-d): Brick crystallization as a function of particle size (a) Control, (b) 1 mm, (c) 0.4 mm and (d) 0.2 mm grinding at 4% fireclay, Control: Raw material without fireclay

CONCLUSION

One of global important results of this study is the highlighting of a recycling method of the fireclay for improving the brick resilience to compression and flexion.

With the new brick properties obtained after fireclay addition at Ain Nouissy factory, the annual volume of rejections must decrease 21% on average. Which will allow increasing 9% in weight, the brick production. In this case, 45,000 t of fireclay can be recycled annually. Although, these results relate to the brick production factory of Ain Nouissy, this method of fireclay recycling is itself applicable to other factories with taking in account the differences in raw materials properties.

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