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The influence of burnt clay brick waste addition on recycled brick

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Abstract

Ceramic materials especially clay soil (CS) have been used in construction for decades now. This CS has been used either unmixed or mixed with several other constituent materials to produce materials with interesting engineering properties. The study in this paper is a contribution to the re-use of broken burnt clay bricks (BCB) by mixing it in various proportions and different grain sizes (0.08 mm to 0.1 mm and 0.25 mm to 0.5 mm) with the initial CS to produce useable bricks. Physical properties (density, porosity and water absorption) and mechanical properties (compressive strength and flexural strength) of the resulting brick are then analyzed. The formulations of these products are done using the following percentages of burnt clay powder (BCP): 0% (reference brick), 20%, 40% and 50%. Whatever the grain size of the samples, the results show a decrease in density (from 1.86 g/cm^3 to 1.2 g/cm^3) and in the water absorption rate with the burnt clay (BC) content. There is also a decrease in the compressive strength and flexural strength of the bricks with the amount of burnt clay. The loss of mechanical resistance in compression between the reference sample and the highly loaded one (50% burnt clay) is 37.86%, for the flexural strength it is 64.52%. Nevertheless, a small addition of BC (20%) reduces the loss in resistance to 17.4% for compression and 10.7% for flexural strength. Equally, there is an increase in the mechanical strength of the samples with decrease in grain size. The studies carried out shows that a small quantity of burnt clay waste (20 %) of the finer grain size can result in bricks with properties similar to those of the reference brick.

Keywords: Clay mixtures; gran size; Waste brick powder; Density; Mechanical property

1. Introduction

Burnt clay bricks (BCB) have been used in construction for more than 8000 years before Christ [1]. These bricks are obtained by extruding moist ground clay through various moulds and then sintered at different temperatures sometimes as high as 1350°C [2]. These bricks are of great importance in house construction, petroleum factories, ovens, ironfoundry etc.

Fired clay bricks mostly have better construction engineering properties than locally made sun dry bricks, though to an extend are lower in strength and life span than cement blocks [3]. To make up these strength and duration characteristics, many other materials (additives) are usually added to ameliorate, conserve or decrease the quality of these bricks [4-6].

Different studies have been done on the possibility of using different materials especially waste and natural fibers as stabilizers for clay soils, such as; sugar cane bagasse ash, rice husk, saw dust, palm kernel fibers, bamboo fibers etc. [7-10]. These studies revealed that stabilizers can aid the production of energy efficient and lighter structures [11-12]. Broken burnt clay bricks (BCB) are waste obtained from firing of clay bricks in ovens of brick factories. They have similar properties to that of clay. Djangang et al. [2] have studied the utilization of BCB mixed with clay in varied quantities and sintered at different temperatures to obtain usable bricks. It was observed that the final product has a reduced weight, reduced mechanical properties and a higher porosity. This makes the product a very good thermal insulator and view that air is a poor conductor of heat [2].

Murugesan et al. [7] have worked on evaluation of the characteristics of Burnt Clay bircks and fly Ash Unburnt bricks. The authors clearly show that the addition of fly ash considerably modifies the standard properties of a clay brick.

Mostly, broken fired bricks are used to fill pot holes on roads, some ground to use as mortar in building ovens and a large amount disposed as waste in fields causing environmental pollution. The purpose of this study is to access the possibility of reusing broken waste BCB to obtain useable bricks. The reuse of this waste will not only modify the strength performance of the resulting brick, but will also reduce environmental pollution and curb losses suffered by factories that sometimes incure up to 25% loss as broken bricks. The mixture of clay and burnt clay (BC) was used in different granulometry (from 0.08 to 0.1 mm and 0.25 mm to

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0.5 mm) and different quantities (0 %, 20 %, 40 % and 50 % by weight of broken burnt clay) to study its effect on the physical and mechanical properties of the resulting recycled brick.

2. Materials and methods

2.1. Materials used in this study

Samples used in this study consist of a mixture of clay from the same source, Etoa village (in the Centre Region of Cameroon, see Fig. 1): burnt brick powder and clay soil powder.

The location is chosen based on the fact that previous studies Ngon Ngon et al. [13]; have proven that clay from the source is sound for production of bricks and further, this site is an extraction zone for clay factories in Cameroon.

2.1.1. Burnt clay powder (BCP)

Burnt clay powder (BCP) is gotten by grinding waste BCB (obtained from the calcination of Etoa clay at 1150°C). After drying, the sample is ground to obtain powder using a drum grinding machine and later sieved to obtain the desired grain size. Fig. 2 shows the BCB and the BCP obtained from grinding these broken bricks. This powder is then sieved to obtain the , desired grain sizes of 0.08 to 0.1 mm and 0.25 to 0.5 mm.

Ngon Ngon et al. [13,14] have previously studied the characteristics of the Etoa village clay as a suitable building material and from a mineralogical point of view, X-ray diffraction analysis revealed that the clay contains mainly Kaolinite, Quartz, Goethite, Rutile and Brookite.

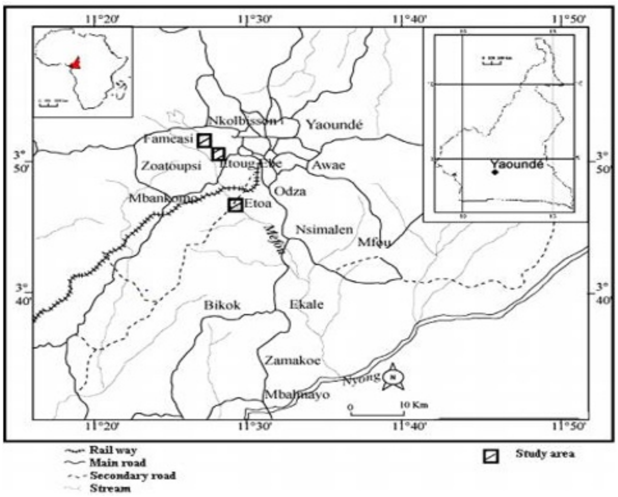

Fig. 1 Location of study area of clay samples in Yaounde, Center-Cameroon [14].

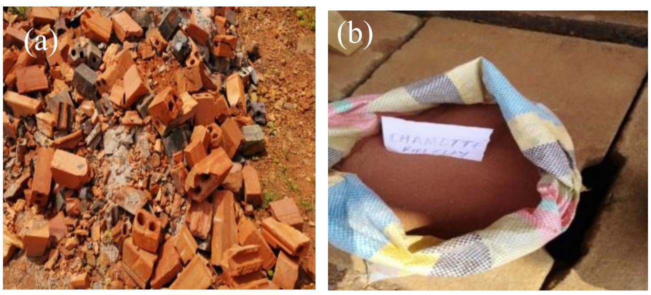

Fig. 2. (a) broken burnt bricks and (b) burnt brick powder.

2.1.2. Clay soil powder(CSP)

Natural clay soil is collected from Etoa village, some 40 km from Yaoundé (See Fig. 3). The sample is picked along the soil profile at the depth of 1.5 m. This soil is then ground to obtain the powdered form with the same granulometry 0.08 to 0.1 mm and 0.25 to 0.5 mm, the same as that obtained in the case of burnt clay.

2.1.3. Sample

Samples used in this study were a mixture of different proportions of these two soil material types with the same particle size and about 10 % of water. Table 1 presents the formulation of the different samples. Sampling in this paper is inspired by the studies in the literatures on the characterization of clay refractory bricks using local raw materials [4,15-16]. In the elaboration using local materials, some specific ratios and grain sizes were applied to obtain samples. The burnt brick powder and clay powder mixtures consist of two distinct granulomettry samples as shown on table 1 (a coarse sample [0.25 mm ≤ Φ <0.5 mm] and a fine sample [0.08 mm ≤ Φ < 0.1 mm]).

In this study, two types of samples were made; parallelepipede shaped (80 mm x 40 mm x11 mm) for flexural strength test and cubic shaped samples of sides 40 mm for compressive test (See Fig. 4). Shaping is performed by uni-axial compression using a hydraulic press. The supercharged samples are dried in the open air, fired at 110°C and prefired at 600°C for 1 hour with a heating rate of 1°C/min. Final firing is carried out at 1100°C for 2.5 hours, with a heating rate of 5°C/min.

2.2. Mechanical test machine

2.2.1. Compression test machine

The compression machine used to test samples is a Perrier 14570 press of 200 KN from the civil engineering laboratory of the

Table 1
Different granulometry and formulations of samples.

Granulometry	Formulation	% Burnt clay powder (BCP)	% Clay soil powder (CSP)
0.08mm -0.1 mm	100/0	100%	0%
	80/20	80%	20%
	60/40	60%	40%
	50/50	50%	50%
0.25mm – 0.5 mm	100/0	100%	0%
	80/20	80%	20%
	60/40	60%	40%
	50/50	50%	50%

Fig. 3. (a) Clay soil and (b) raw clay powder.

National Advanced School of Engineering Yaoundé. The machine was used to test cubic samples (See Figs. 4(a) and 4(c)).

2.2.2. Three point bending test

The three point bending test machine used to test samples is a CBR (Californian Bearing Ratio) press (CONTROLS T1004) with load characteristics: 9806 N Serial: 3558 belonging to the civil engineering laboratory of the National Advanced School of Engineering Yaoundé. This machine was used to test parallepipede samples. The distance between supports is 50mm. The deflection of the sample (bottom face) is read on the scale and the original value obtained by reading of tables of values supplied by the manufacturer of the machine (See Fig. 5).

3. Results and discussions

In this part, results and analyses of the various tests carried out on the different samples are presented.

3.1. Physical characterization of samples

3.1.1. Density

Fig. 6 presents the average density values for the different formulations and different granulometry.

The average density of fired material was determined using Eq. (1) by obtaining the mass of bricks fired at 1100°C ($M_{1100°C}$) and dividing it by volume (V).

$$\rho = \frac{M_{1100°C}}{V} \quad (1)$$

The values of the densities from Fig. 6 for granulometry varying from 0.08 mm to 0.1 mm show that the density decreases slightly with increase in burnt clay (BC) percentage showing that the density of BC is less than that of raw clay which is normal. For the case of granulometry varying from 0.25 mm to 0.5 mm, there was a weak influence on the density of the samples with increase in BC percentage. This might be due to the fact that the large grains

Fig. 4. Parallepipede and cubic samples before and after firing and sketch of the samples respectively according to the standard NF EN 771-1.

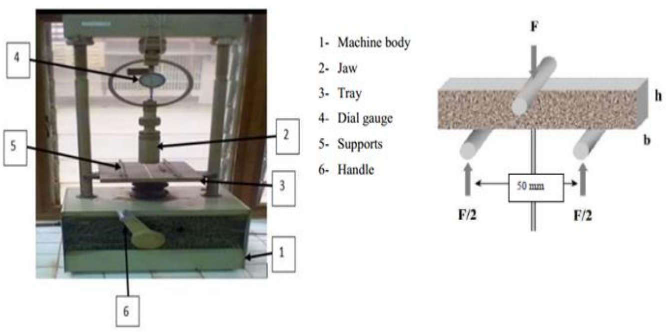

Fig. 5. Tensile/Three-point bending test machine.

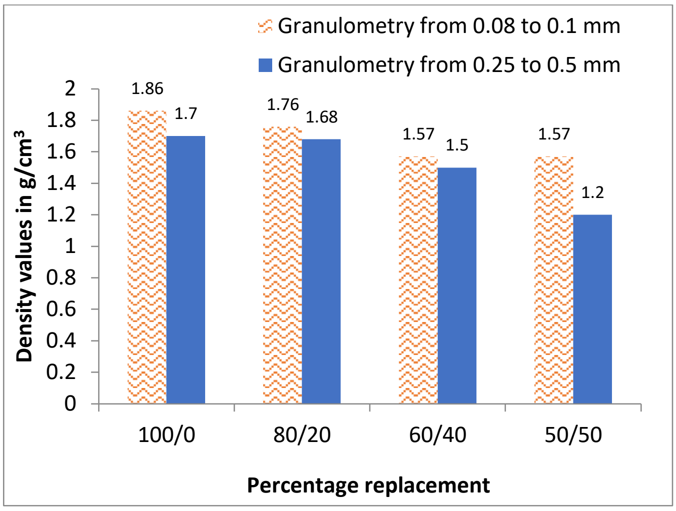

Fig. 6. Average density values of the samples.

covered some voids which increased the volume but reduced the weight. In a general aspect, it was observed that the density is higher with a lower granulometry. These values of density compared to the values obtained from normal BCB (100/0) show that these values are in the range for the smaller granulometry for the formulations from 80 /20 to 100 /0.

3.1.2. Porosity

Fig. 7 presents the average porosity values for the different formulations and different granulometry.

In the Fig. 7, it was generally observed that the value of porosity for 0.08mm to 0.1 mm granulometry increases with an increase in BC percentage. The same observation can be seen for the granulometriy from 0.25 to 0.5 mm, though slightly above the finer granulometry case. The high porosity values indicated that the product obtained can be a good thermal insulators and that air bubbles trapped in it is a poor conductor of heat, though the high porosity values can affect the mechanical properties of the product.

3.1.3. Water absorption

Fig. 8 presents the average % water absorption values for the different formulations and different grain sizes. It gives the

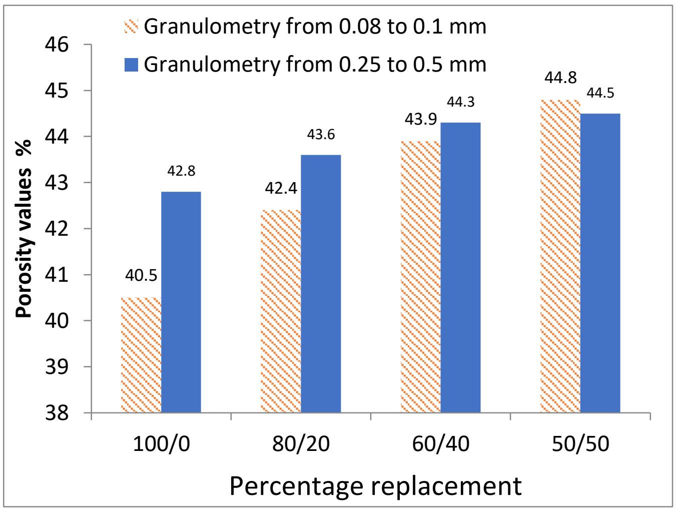

Fig. 7. Average % porosity values of the samples.

moisture intake by samples over a long period, expressed in %. It was measured according to the recommendations of EN 772-11 [17] by immersing the brick in water for 24 hours and then weighing the brick. Water absorption is achieved by dividing the weight of the wet brick by the initial weight of the dry brick.

In Fig. 8, the value for water absorption for the two granulometry follow that of porosity (see Fig. 7) which is evident since the more the pores, the greater the quantity of water absorbed.

3.2. *Mechanical characterization of samples*

3.2.1. *Compression test*

After studying the test conditions, simple compression tests imposed at a crosshead low speed of 0.1 mm/min were carried out at room temperature on samples, and the evolution of brick breaking force noted. Fig. 9 presents the average values of rupture stress for the samples.

It was observed from Fig. 9 that the value of rupture strength for each formulation reduces as the quantity of BC increases. Compressive strengths are higher for finer granulometry (0.08 mm to 0.1 mm). The strength loss between 100/0 and 50/50 samples is 37.8% for fine granulometry and 41.5% for coarse particle granulometry. Resistance losses are lower for a small proportion of BC (80/20 sample): 17.47% for fine granulometry and 10.76% for coarse particle granulometry. It can thus be concluded that the resistance of this material reduces with increase in BC percentage and can increase if the granulometry of the products is reduced (Fig. 9).

3.2.2. *Flexural strength test*

In this section, the results of flexural strength test performed on brick samples are presented in Fig. 10.

From Fig. 10, a decrease in the flexural strength is observed when the quantity of BC increases. The loss of flexural strength between 100/0 and 50/50 samples is 64.52% for fine granulometry and 59.3% for coarse granulometry. The losses of resistance are lower for a small quantity of BC (80/20 sample): 17.4% for the fine granulometry and 16.2% for the coarse granulometry. This shows that if the grain sizes of the formulation are reduced, and a considerable quantity of BC added, say 20 %, the bending strength of the material will be moderate. We can thus explain that the strength of the said material is a function of the granulometry and quantity of the BCP.

Fig. 11 indicates the correlation that exists between density and mechanical resistance. Mechanical properties (compression and

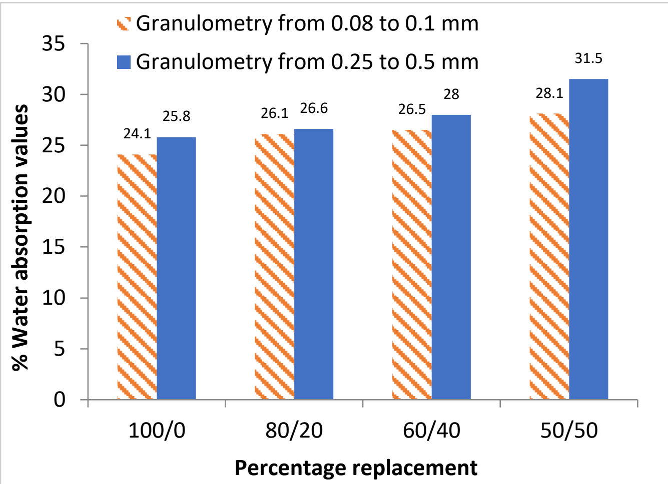

Fig. 8. Average % water absorption values of the samples.

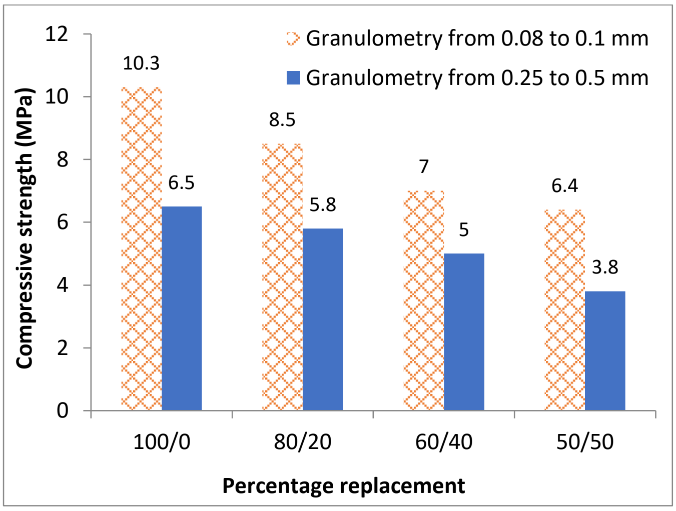

Fig. 9. Average compression strength values of the samples.

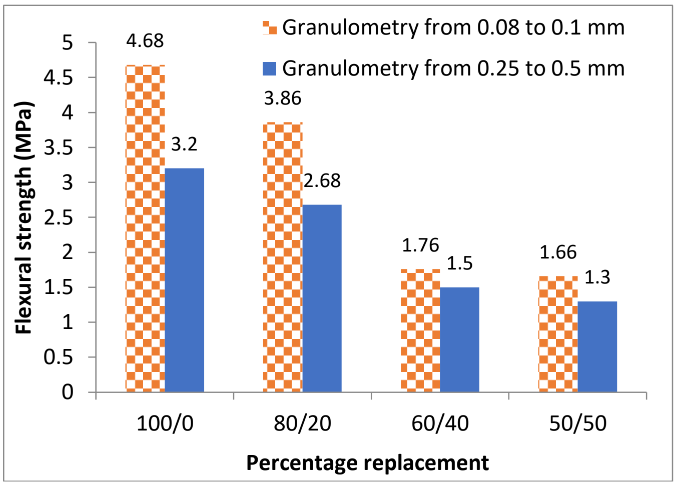

Fig. 10. Average rupture stress values of the samples.

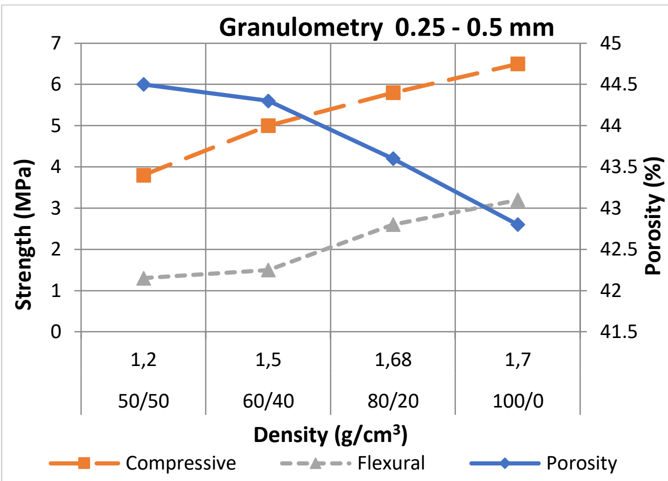

Fig. 11. Mechanical and physical properties as a function of porosity.

flexion) increase with the density obtained. Contrarily, a decrease in porosity is observed with increase in density.

4. Conclusion

This paper presents the influence on the properties of bricks produced from mixing raw clay and burnt clay waste using the following percentages of burnt clay waste : 0% (reference brick), 20%, 40% and 50% and two distinct grain sizes (from 0.08 mm to 0.1 mm and from 0.25 mm to 0.5 mm).

The ressults obtained from this study present some variation in physical properties (density, porosity and water absorption); whatever the grain size of the samples, the results show a decrease in density (from 1.86 g/cm^3 to 1.2 g/cm^3), an increases in porosity (from 40.5 % to 44.8 %), an increase in water absorption (from 24.1 % to 31.5 %). The results equally present variations in mechanical properties (compressive strength and flexural strength); whatever the grain size of the samples, the results present a loss of mechanical resistance in compression between the reference sample and the highly loaded one (from 10.3 MPa to 3.8 MPa) and a decrease in flexural strength (from 4.68 MPa to 1.3 MPa).

Nevertheless, the samples with the finer granulometry and waste brick content of 20 % present quasi similar properties (better compared to other formulations and grain sizes) to that of the reference samples. This information clearly shows that, if clay soils is mixed with burnt clay waste up to 20 % in content and grain size lower than 0.1 mm, effectively bricks having good construction engineering properties can be obtained..

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