Studies on Utilization of Coffee Waste

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Abstract

The agro-industrial activities are responsible for the production of large amounts of solid wastes, and used as alternatives. In solid wastes, coffee bean beneficiation generates an equal amount of coffee husks whose highest reuse potential is as fuel. Recently, the production of bricks from waste materials was increased. Firing methods were indicated to consume significant amount of energy and release large quantities of greenhouse gases. In order to investigate utilize the coffee spent ash in brick manufacturing; the present investigation was carried out. Different ratios of spent ash (4-10%) were added to clay, while the applied firing temperature was kept at 950^{0}C. The result shows that the bricks prepared from coffee spent having light weight and more firing shrinkage, while decreasing compressive strength and volume mass. However, all the samples with 4% coffee waste and the samples with 6% fired at 950^{0}c, are in the highest grade of standards.

Key Words: *Brick, Coffee Spent*

INTRODUCTION

The coffee pulp, coffee spent and husk are large amounts of by-products obtained during industrial processing of coffee bean had found only limited application as livestock feed, fertilizers etc. These applications utilized only a fraction of available quantity and were not technically very efficient. Nearly one tone of green coffee produces 650kg of spent. So, recent attempts have focused on their application as substrates in bricks preparation. The increase in the popularity of using environmental friendly, low cost and lightweight construction materials in building industry has brought the need to investigate how this can be achieved by benefiting the environment as well as maintaining the material requirements affirmed in the standard. Recycling of waste generated from industrial and agricultural activities as building materials appears to be viable solution not only to such pollution problem but also to the problem of economic design of buildings (Perez JA et al, 1996). Brick belongs to the wide family of construction materials since it is mainly used for the construction of outer and inner walls in buildings. The brick industry is the most indicated technological activity sector to absorb solid waste due to the large quantity of raw material used by the sector as well as by the large volume of final products in construction (Andreola et. al, 2005) Various attempts were made to incorporate various waste material in bricks production such as natural fibers, textile laundry wastewater sludge, foundry sand, granite sawing waste, municipal solid incineration fly ash slag (Chee-Ming, 2011- Raut et al, 2011). This review highlights the effects of use of coffee spent on the bricks property like physical and mechanical properties as well as thermal insulation.

Brick is one of the most important materials for the construction industry. The conventional method of bricks production has brought undeniable shortcomings. The consumption of earth-based materials as clay, shale and sand in brick production resulted in resource depletion, environmental degradation, and energy consumption. The brick was anciently produced by mixing the virgin resources, forming the bricks, drying them and then firing them. The current trend in bricks manufacturing has major emphasis on the use of post-consumer wastes and industrial by-products in the production process. Most of the researches went through enhancing the clay brick quality and properties by mixing the clay with various recycled wastes as foundry sand, granite sawing waste, harbor sediments, sugarcane baggase ash, clay waste and fine waste of boron, sewage sludge, waste glass from structural wall and other different wastes. Researches were held in developing bricks from wholly waste materials without exploiting any sort of natural resources, in order to achieve sustainability.

Also within the ceramic field, the spent coffee grounds could be used as an additive to brick production, as Eliche-Quesada et al. have proven. After brick and steel, clay brick is the most used construction material; in the last decade, worldwide clay brick production was 256 billion units per year. In an attempt to reduce the consumption of non- renewable natural resources and reduce the final costs, a few authors have evaluated the suitability of reusing different residues in clay mixtures to sintering clay ceramics for construction. The incorporation of used green and core sand from the foundry industry, waste bricks, sewage sludge, rock sawing waste, muscovite granite waste, red mud, processed tea waste and recycled paper mill waste are some examples of this practice.
As shown in a review by Raut et al., the discussion of material properties has focused on water absorption and compressive strength in all investigations. However, some types of waste like coffee spent could provide bricks with some

attractive properties, namely low thermal conductivity. Eliche-Quesada et al. used different amounts of glycerine and spent, and the results showed that the use of waste decreased mechanical strength; nevertheless, the values were higher than those required by the standards. It was also noticed that thermal conductivity decreased by 20% when spent was incorporated and up to 40% when glycerine was added, when compared to reference clay bricks.

Owing to widespread concern about the energy consumption of buildings, these results are quite promising in the reduction of building energy demands. The International Energy Agency estimates that buildings are responsible for 30–40% of the world's energy consumption and 50% is energy used for controlling the interior climate. Thus, most countries have initiated policies to reduce energy consumption in buildings with regulatory requirements. Within this context, the improvement of the thermal insulation properties of the materials used in building construction is crucial. As mentioned above, Eliche-Quesada et al. reused coffee grounds in brick manufacture; the researchers used coffee grounds up to 5 % in clay and fired the green bodies at a temperature of 950^0C. The reduced changes in mechanical strength and the decrease in thermal conductivity make the incorporation of larger percentages of coffee grounds attractive. Their use could also be considered in the manufacture of ceramic tiles; therefore, it is important to know the reaction of such mixtures at other firing temperatures and with other types of clay raw materials. One of the most important properties that make these mixtures suitable for industrial manufacture is the plastic behaviour, which reflects the workability and extrudability of the paste, overlooked in research by Eliche-Quesada et al.10.

The present project aims at providing further knowledge on the influence of different clay/coffee waste mixtures in structural ceramics by incorporating different amounts of spent coffee grounds as an additive. The purpose of this research is the assessment of physical and mechanical proprieties as well as the technological viability of such manufacture. In attempting to evaluate their suitability in the industrial shaping processes, the plastic behaviour of the different mixtures was studied. To understand the effect of firing temperature in the ceramics, three different maximum temperatures were used. The physical, mechanical, aesthetic and thermal characteristics of the fired samples were evaluated and compared with other formulations of clay/waste. This approach could give an alternative solution to waste management, reduce the utilisation of non-renewable natural resources, reduce the costs of ceramic fabrication and contribute to the improvement of thermal performance in buildings.

The present investigation was carried out by keeping the following objectives. The increase in the popularity of using environmental friendly, low cost and lightweight construction materials in building industry has brought the need to investigate how this can be achieved by benefiting the environment as well as maintaining the material requirements affirmed in the standard. Recycling of waste generated from industrial and agricultural activities as building materials appears to be viable solution not only to such pollution problem but also to the problem of economic design of buildings

1. To incorporate coffee spent in brick production
2. To analyse the physical and mechanical properties of bricks prepared by using coffee spent.

MATERIALS AND METHODS

The following raw materials are used for the present study with specific quantities.
a) Silica (sand) – 42% by weight
b) Alumina (clay) – 35- 45% by weight
c) Coffee spent- 0% to 10% by weight
d) Iron oxide – 7% by weight
e) Lime – 5% by weight
f) Magnesium – less than 1% by weight
i) Water

Preparation of Samples

Prepare four different samples of bricks that is A, B, C and D and one control sample. Each 1000 gm. of sample contain different amount of coffee spent and clay. We changed only in the proportion of clay and coffee spent, other ingredients proportion remained same in every sample.
In samples, the following proportions of material were taken. In sample A 42% sand, 41% clay, 4% coffee spent, 7% iron oxide, 5% lime and 1% magnesium. In sample B 39% clay and 6% coffee spent and other ingredients are in same proportion. In sample C 37% clay and 8% coffee spent and other ingredients are in same proportion. In sample D 35% clay and 10% coffee spent and other ingredients are in same proportion. Make control sample for comparative results. In control sample all ingredients are in standard proportion and did not add coffee spent. Different proportions of samples content are shown below.

Table 1 Sample proportion

Sample	Sand (Wt.in gm.)	Clay (Wt.in gm.)	Coffee spent (Wt.in gm.)	Iron oxide (Wt.in gm.)	Lime (Wt.in gm.)	Magnesium (Wt.in gm.)
Control sample	420	450	0	70	50	10
A	420	410	40	70	50	10
B	420	390	60	70	50	10
C	420	370	80	70	50	10
D	420	350	100	70	50	10

Manufacturing Process

The initial preparation consists of shredding clay in a hammer mill in order to obtain particles with a suitable size to be sifted through a 150 µm sieve.

In order to determine the effect on the clay matrix caused by the pore formation of different amounts of coffee spent ash (0-10%) with a humidity level of 49% in clay were added. Coffee spent ash prepared by burning the coffee spent at 950^{0}C. After weighing the suitable amounts of clay and coffee spent, raw material and lighting additive were mixed in a mortar to obtain good homogenization. In order to obtain comparative result a series of 5 samples, each containing 0-10% of coffee spent, were prepared for the tests. The necessary amounts of water (2-5% of moisture) were added to obtain adequate plasticity and absence of defects, mainly cracks, during the semidry compression moulding stage. At this stage, uniaxial pressure of 54.5 MPa was applied. Conformed bricks with 75×100 mm cross-sections and a length of 230 mm were obtained. After moulding, the bricks were dried for 48 h at 110^{0}C to reduce the moisture content, so that no cracks would appear on samples at later stage.

Eventually, the dried bricks were fired in a laboratory type electrically heated furnace at a rate of 10^{0}C per min up to 950^{0}C for 24 hr. This temperature is usually used in the fabrication of clay bricks. The bricks were then cooled to room temperature by natural convection inside the furnace after being turned off. The conformed bricks will be use for physical and mechanical testing.

Properties of Fired Bricks

Clay bricks exhibit a set of properties that are important in the evaluation of strength and durability. The properties are closely related to the raw material used and directly associated with the conditions of manufacture. The physical, mechanical, chemical and mineralogical parameters are relevant to the evaluation of the durability and resistance of bricks.

Physical Properties

A) Density

Apparent density is described as the ratio between the dry brick weight and the volume of the clay brick, measuring the proportion of matter (clay) found in the volume. It is evident from this description that the higher this value is, the denser the brick is and obviously the better it's mechanical and durability properties. Typical values for the apparent density range from 1.253 to 1.693 g/cm^3.

Calculation

1. Exterior Volume, V: Obtain the volume, V, of the test specimens in cubic centimetres by subtracting the suspended weight from the saturated weight, both in grams, as follows:

$$V,\ cm^3 = W - S$$

2. Bulk Density, B: The bulk density, B, of a specimen in grams per cubic centimetre is the quotient of its dry weight divided by the exterior volume, including pores. Calculate B as follows:
B, g/cm^3= D/ V

B) Water Absorption

Pores constitute a large part of the brick's volume, and when the bricks are exposed to rainfall or rising damp, water generally penetrates into the pores. Water absorption then determines the capacity of the fluid to be stored and to circulate within the brick, favouring deterioration and reduction of mechanical strength. In countries where temperatures fall below 0°C, the water inside the pores can freeze leading to surface de-laminations, disintegration or cracking. Moreover, in the presence of soluble salts, water tends to react with them and to cause efflorescence. Though this is mostly an aesthetic deterioration of the surface of the brick, the volume increase caused by the crystallization of the salts can cause severe damage.

The values found in the literature are significantly scattered, with a large quantity of bricks with higher than average water absorption rates. Binda et al. (2000) reported different absorption rates with respect to the colour exhibited by brown and red bricks were found to have a water absorption of about 20.1 and 24.9 wt.%. Another relevant parameter is the velocity of water absorption, measured by suction rate. The water is sucked by the pores as a result of capillary tension along the walls of the pores.

Calculation

1. Water Absorption, A: The water absorption, A, expresses as a percentage the relationship of the weight of water absorbed to the weight of the dry specimen. Calculate A as follows:

$$A,\ \% = [(W-D)/D] \times 100$$

Mechanical Properties

Masonry is a heterogeneous material, and therefore its compressive strength depends on the strength of the components: brick, mortar and brick-mortar interface. Nevertheless, experimental results indicate that masonry compressive strength is mostly influenced by the strength of the brick units. Therefore, brick mechanics is very relevant to the safety assessment of existing brick masonry structures. In traditional masonry shapes, such as columns, walls, arches and vaults, bricks are mostly subjected to compressive stresses. The adopted structural shapes for these elements make full use of properties of clay bricks, namely reasonable strength in compression and low strength in tension.

C) Compressive Strength

Compressive strength is strongly influenced by the raw material and by the production process. It is known that the raw clay of old bricks were often of low quality and the manufacturing process was relatively primitive and inefficient. Other characteristics of existing old bricks can provide an indication about compressive strength, such as mineral composition, texture, crack pattern and porosity level, by revealing the conditions of drying and firing. The range of values is quite wide (about 1.5–32 MPa), meaning that in situ testing or destructive testing of samples must be carried out when the compressive strength of the brick is required. An average compressive strength 13.39 N/mm^2 was found. The pressure required to crush them is noted and the average compressive strength of the brick is stated as Newton's per mm square of surface area required to ultimately crush the brick. The crushing resistance varies from about 3.5 N/mm^2 for soft facing bricks up to 140 N/mm^2 for engineering bricks. We use compression testing machine (2000 KN) for measurement of compressive strength.

- **Calculation**

Compressive strength is calculated using the following formula:

Compressive strength (N/mm^2) = W_f / A_p
Where,
W_f = Maximum applied load just before load, (N)
A_p = Plan area of cube mould, (mm^2)

RESULTS AND DISSCUSSIONS

The present investigation was conducted to studies on utilization of coffee waste. The physical, mechanical properties for all the brick samples are represented below.

Physical Properties

1. Density-The densities of brick for the entire sample are represented in Table. The highest density was obtained for Control sample with 1693 $kg/m^3$and lowest was 1253 kg/m^3 respectively.

Table 2 Density

Sample	**Density (kg/m^3)**
Control	1693±58.42
A	1684±55.65
B	1441±10.11
C	1352±21.64
D	1253±30.15

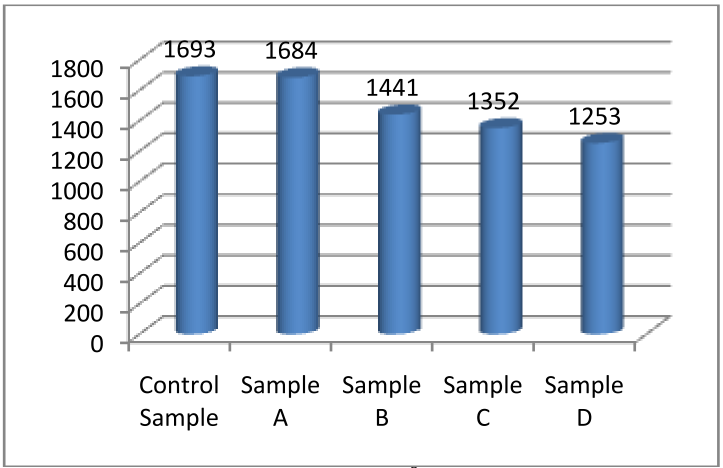

Figure 1 Density (kg/m^3)

2. Water absorption- The obtained value of water absorption percentage of all samples are shown below in table-

Table 3 Water absorption

Sample	**Water absorption %**
Control	21.16±0.89
A	15.6±1.38
B	26.53±2.32
C	29.85±2.71
D	36.24±4.05

Sample A absorbs lesser amount of water that is 15.60% than other samples due to higher amount of clay. As shown in result, coffee spent ash increases the water absorption capacity. Hence, sample D absorbs 36.24% water that is higher than other samples.

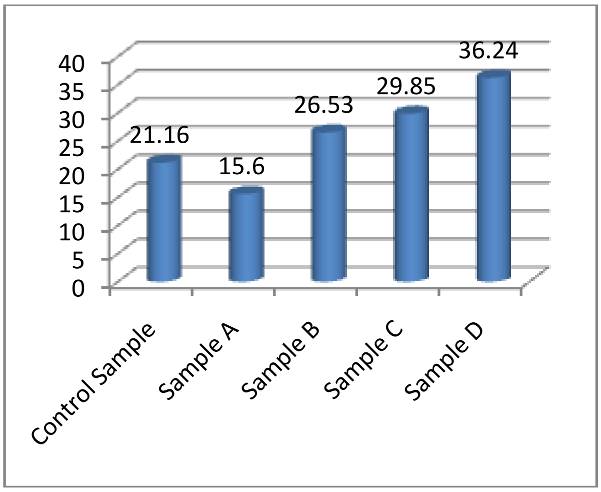

Figure 2 Water absorption (%)

Mechanical Properties

3. Compressive Strength- The obtained value of compressive strength of all samples are shown below in table-

Table 4 Compressive strength

Sample	C.S(N/m^2)
Control	13.08±0.73
A	17.19±0.56
B	14.56±0.44
C	11.46±0.65
D	10.67±0.31

The compressive strength of brick for all samples are represented in the table. The highest compressive strength was obtained for A Sample with 17.19 (N/m^2)and lowest sample D was 10.67(N/m^2). Sample A result shows that 4% of coffee spent increases the compressive strength of bricks.

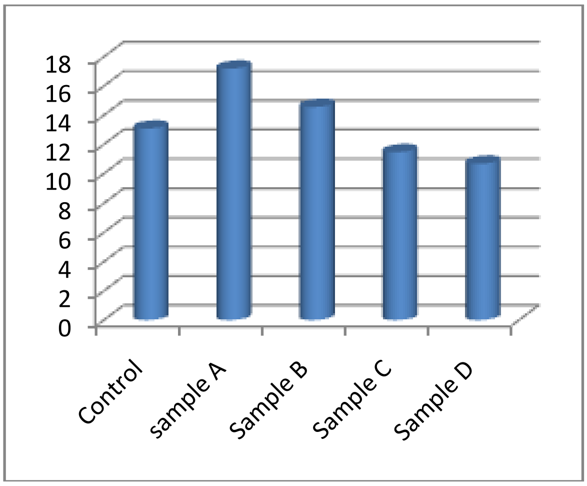

Figure 3 Compressive Strength (N/m^2)

Other Properties

4. Efflorescence: We found the efflorescence in all five samples is nil.

CONCLUSION

The present study was proved that feasibility of the use of significant amounts of coffee waste as an additive and lightening raw material in ceramic manufacturing for construction purposes. The mixtures in the right proportions give to the pastes proper workability features and are capable of industrial processing. Coffee grounds have been chosen since, being organic residue, and easily combusted during the firing stage and incorporated into the clay body without causing defects like cracks. In some cases, the incorporation of such waste could improve the plastic characteristics. The results show that the use of coffee waste increases water absorption and apparent porosity while the bulk density decreases. The increasing firing temperature causes a decrease in pore size. The incorporation of coffee waste produces a mechanical strength reduction. However, all the samples with 4% coffee waste and the samples with 6% fired at 950^{0}c, are in the highest grade of standards. The technological properties are more promising than those obtained in the literature for other types of waste. An excellent improvement in porosity properties was obtained.

According to the results obtained, incorporating coffee ground amounts of up to 4% causes an increase in compressive strength of the brick that means right amount of proportions gives workability. Total porosity of the clay body, as shown by bulk density values (a decrease of 6.63%). As a consequence, the residue causes an increase in total porosity of the sample, in open and closed porosity and in absorption and suction values. However, the kind of porosity produced by this residue depends on its concentration. Bricks with mainly closed porosity (coffee grounds >4 %) barely show changes in mechanical properties, compared with bricks consisting only of clay. The proportion of added coffee grounds is, therefore, a key factor affecting brick quality. Optimal results are achieved by incorporating 4% coffee grounds into the clay, since mechanical resistance is then higher than that of the clay, resulting in a decrease bulk density and an increased total porosity.

Based on these preliminary results, it can be concluded that coffee waste can be used as an addition for the production of ceramic bricks with acceptable physical and mechanical performance. Depending on firing temperatures, the use of mixtures containing 4–6% of coffee waste produces bricks with the best compromise between physical and mechanical characteristics. As a way of reducing the use of non-renewable natural resources, coffee waste could be reutilised as a secondary clay raw material to form adequate clay construction ceramics which could reduce the energy consumption of a building.

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