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Manufacturing, Physical and Chemical Characterization of Fire Clay Brick Value Added with Cow Dung Ash

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Abstract: Aim of this study was to introduce an eco-friendly, low cost and durable clay bricks with partial substitution of Cow Dung Ash (CDA). Five types of clay brick, consist CDA percentages 0, 5 10, 15 and 20% to the total weight of mixture, were manufactured by employing traditional method of dimension (18.5×8.5×6.5) cm^3. The clay and CDA were well mixed with the addition of sufficient amount of water to form a good workability. Green molded bricks were allowed to dry under sunlight for two days and then fired in the traditional brick kiln. Physical properties of the burned red bricks were then tested and analyzed with Sri Lankan and British Standard Specifications. The average density, water absorption, compressive strength and flexural strength for 10% Cow Dung Ash (CDA) are 1447 $kg.m^{-3}$, 17%, 150 $kg.cm^{-2}$ and 0.82 $kg.cm^{-2}$ respectively. These physical properties were compared with the standard brick purely manufactured from clay. From the results, clay-CDA bricks are obviously superior to the control brick; those are available in the Eastern region markets.

Keywords: Cow Dung, Cow Dung Ash, Fired Clay Bricks, Compressive Strength, Flexural Strength, Value Addition, Water Absorption, Eco-friendly

1. Introduction

Clay bricks are most important building materials, because of its eco-friendly nature. Since the ancient period these bricks are manufactured locally and have been emphasized all over the world because of their eco-friendly nature and low cost. However, the efficiency of the brick is an important factor for construction. This factor has been improved by utilizing the locally available sources such as agricultural and industrial waste. To overcome this, a challenge has been taken to increase the efficiency of clay brick by adding suitable waste materials along with clay in the manufacturing process [1-16]. Therefore, considering environmental impact and the efficiency, there is a need to select an alternative material to reduce the impact of brick manufacturing on the environment as well as increase the overall performance of the brick. Many research studied shows that some admixtures increase the bond between the particles and thus increase the efficiency of the brick. Such admixtures are lime, sawdust ash, rice husk ash, ground nut shell ash, coconut shell ash, bamboo leaf ash, tobacco leaf ash, rice husks, sawdust, etc., [1-12]. Therefore, the main aim of the research was to disseminate the knowledge of admixtures among the brick making community and to build a green environment by utilizing the natural agro waste materials. This research investigated the effect of clay brick with partial addition of Cow Dung Ash (CDA) on the efficiency of the brick.

2. Experimental Methodology

2.1. Materials

2.1.1. Brick Clay

Clay was collected from Verpavettuvan, which is located in Batticaloa District, Eastern Province of Sri Lanka. The chemical analyses shows that the major chemical compositions of the clay are silica, alumina, and ferric oxide, are tabulated in Table 1. The higher silica percentage in the clay increases the efficiency of the brick [9].

Table 1. *Chemical compositions of Verpavettuvan clay.*

Compounds (%)	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	TiO_2	P_2O_3	LIO
Present study [10, 11]	63.10	9.23	10.63	5.03	0.02	0.01	1.03	0.02	-	-	8.23
Badr El-Din *et al.* [12]	65.20	7.36	15.26	1.01	0.83	0.08	3.12	0.62	1.92	0.15	6.01

2.1.2. Cow Dung Ash (CDA)

The cow dung was collected from animal science farm, Eastern University, Sri Lanka. The CDA were cleaned and allowed to sun dried. Dried CDA was well ground and mixed with the clay. The chemical compositions of cow dung was tested and tabulated in Table 2, compared with the previous studies. The SiO_2 has a high binding property which enhances the efficiency of the brick.

Table 2. *Chemical Compositions of Cow Dung Ash (CDA).*

Compounds (%)	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	TiO_2	P_2O_3	Mn_2O_5
Present study	69.50	3.58	3.98	12.99	2.25	1.89	0.42	2.59	0.47	1.58	0.75
Omoniyi *et al.* [17]	69.95	2.99	4.27	12.55	2.22	1.36	0.57	2.94	0.33	1.48	0.63

2.2. Sample Preparation

Five types of brick were manufactured by applying traditional method, which consist CDA of 0, 5, 10, 15 and 20% to the total weight of mixture. Each type has nine bricks of dimension (18.5×8.5×6.5) cm^3 as shown in Table 3. The clay and CDA was mixed well with the addition of sufficient water to get a suitable plasticity and a good workability (water/clay ratio 0.5 to 0.6). Then green raw material was applied into a wooden mould to get green bricks. These green bricks were allowed to dry under sunlight of temperature around 35°C for one week. Then the dried green bricks were burned in a brick kiln of burning temperature range 600°C to 850°C, which is the industrial scale manufacturing process of fired clay bricks in the Eastern region of Sri Lanka. The burning process was continuously carried out for two days and allowed to cool in the environment. Finally, the properties of the fired bricks were analyzed.

Table 3. *Different Batching Proportions of Raw Materials.*

Brick Types	Brick Clay (wt. %)	Cow Dung Ash (CDA) (wt. %)
1	100	00
2	95	05
3	90	10
4	85	15
5	80	20

2.3. Analysis of Bricks

Density, compressive strength, flexural strength and water absorption analyses were carried out in accordance to Sri Lankan and British Standards.

2.3.1. Particle Size (PS) Analysis

Particle analysis was not done, because the aim of the research was to disseminate the knowledge to the local markets and improve the self-employment of the local community.

2.3.2. Water Absorption (WA) Analysis

Three bricks in each type were selected to analyze the water absorption property of the fired clay bricks. The analysis was done in accordance with Sri Lankan Standard [18] 855: Part 1: 1989 and British Standard [19] BS 5628: Part 1: 2005. Initially, the dry weight of the bricks was measured. Then the bricks were immersed in the water for 24 hours and the wet weights of the bricks were measured. Water absorption property is calculated in percentage using the equation 1, and the average value was calculated for each type.

$$\text{Water absorption} = \frac{W_2 - W_1}{W_1} \times 100\% \tag{1}$$

Where W_1– weight of the dry brick and W_2 – weight of the wet brick after 24 hours.

2.3.3. Compressive Strength (CS) Analysis

Compressive strength analysis was performed using Universal Testing Machine available in the Department of Physics, Eastern University, Sri Lanka. The testing was performed in accordance to Sri Lankan Standard [18] 855: Part 1: 1989 and British Standard [19] BS BS 5628: Part 1: 2005 similar to ASTM D1365-05 standard. Three bricks from each type were measured and the average compressive strength was determined using equation 2 and compared with the Sri Lankan standards.

$$CS = F_m / d \times l \tag{2}$$

Where; F_m is the maximum force applied to just break the bricks (or force failure), d is the width and l is the length of the brick.

2.3.4. Flexural Strength (FS) Analysis

Flexural strength analysis was done in accordance to the Sri Lankan Standard [18] 855: Part 1: 1989 and British Standard [19] BS 5628: Part 1: 2005 similar to ASTM D1365-05 standard. The applied force failed and the other physical parameters of the brick were recorded to determine the flexural strength using equation 3.

$$MR = FL / wh^2 = 3Fa / 2wh^2 \tag{3}$$

Where MR is flexural strength, (kPa), L is span length, (mm), w and h are width and height of the block, (mm) respectively, a is distance between line of fracture and the nearest support, (mm), and F is applied force failed (kN).

2.3.5. Thermal Conductivity (TC) Analysis

Thermal conductivity of the bricks was analyzed using Lee's Disc. Thermal conductivity is the ability to transfer heat through the material. It is a very important parameter to form a cooling effect inside the build. Using equation 4, the thermal conductivity and the specific heat were determined.

$$k = \frac{t_1}{(T_0 - T_1)}\left[\frac{V^2}{SR} - \frac{k_1}{t_2}(T_0 - T_2)\right] \text{ and } C_S = \frac{E^2}{k\,\rho} \qquad (4)$$

Where k and $k_1$are thermal conductivity of the brick and the insulating disc respectively, V is the voltage, R is the resistance of the coil, S is the surface area of the brick, ρ is the density of the brick, E is the thermal effusively, t_1 and t_2 are the thickness of the brick and insulating disc and T_0, T_1 and T_2 are the heated face temperature of brick, non-heated face temperature of brick and non-heated face temperature of insulating disc respectively.

3. Results and Discussion

3.1. Density Analysis

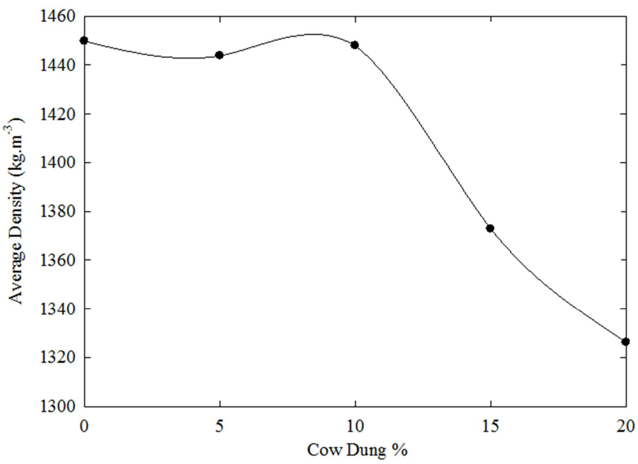

Figure 1. *Average density of brick as a function of CDA%.*

Figure 1 shows the average density of brick slight decreases and increases up to 10% of CDA, followed that, it shows a sharp decrease. This decreasing behavior is due to addition of clay with CDA which produces large particles with larger voids with a reduction of density [7]. The maximum average density 1447 kg.m^{-3} is obtained for brick contains 10% of CDA. Kiyohiko *et.al.* [20] investigation reveals that the density of the normal fired clay brick lies in the range between 1200 to 2200 kg.m^{-3}. In the present study, the 10% of CDA satisfied the Kiyohiko *et. al.* [20] results and the brick is most suitable for construction.

3.2. Water Absorption Analysis

Water absorption is one of the prime indicators to analyse the quality of the brick. Figure 2 shows that water absorption of brick as a function of CDA%. The water absorption increases sharply with increasing the CDA%. It shows a maximum absorption ≈ 17% at 20% CDA. This shows that CDA has a major role in clay-CDA mixture. The results clearly show that all the bricks, satisfy recommended value of 12% as per the Sri Lankan Standard [18] 855: Part 1: 1989 and British Standard [19] BS 5628: Part 1: 2005which lie within the standard values. The increasing behaviour depends on presence of porosity and the effect of soft nature of the CDA particles [20].

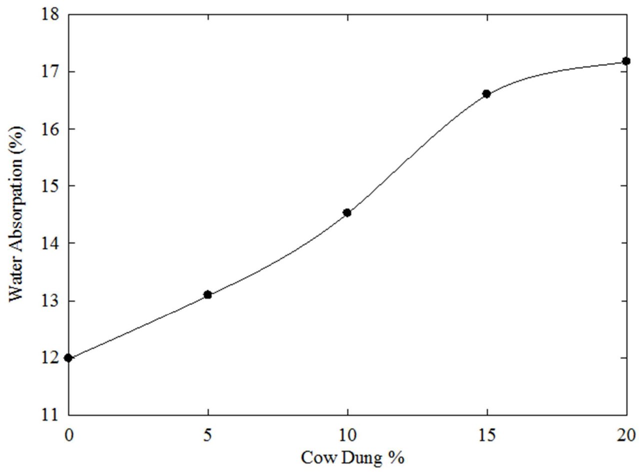

Figure 2. *Average water absorption of brick as a function of CDA%.*

3.3. Compressive Strength Analysis

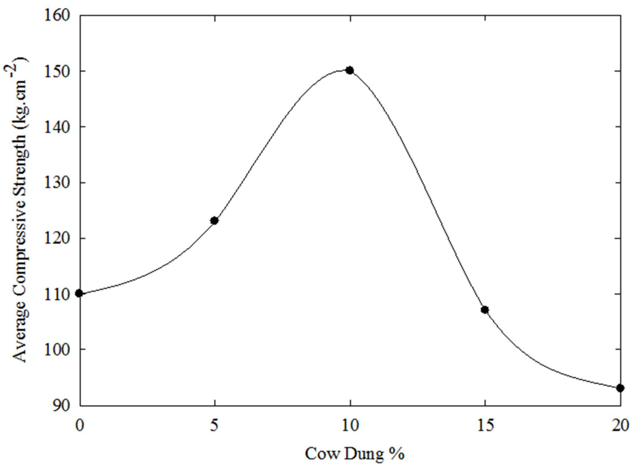

Figure 3. *Average compressive strength of brick as a function of CDA%.*

The compressive strength analysis is shown in Figure 3. The compressive strength strongly increases from 120 kg.cm^{-2} (0% CDA) to 150 kg.cm^{-2} (10% CDA) and strongly decreases to 93 kg.cm^{-2} (20% CDA). The increase behaviour is the effect of stabilisation of the clay material due to higher percentage of SiO_2 CDA. Therefore, 10% CDA is the maximum suitable percentage to form a good bonding to increase the strength of the brick. The CDA > 10%, the flabby nature of the CDA particles increase the open pores and decreases the compressive strength [21].

3.4. Flexural Strength Analysis

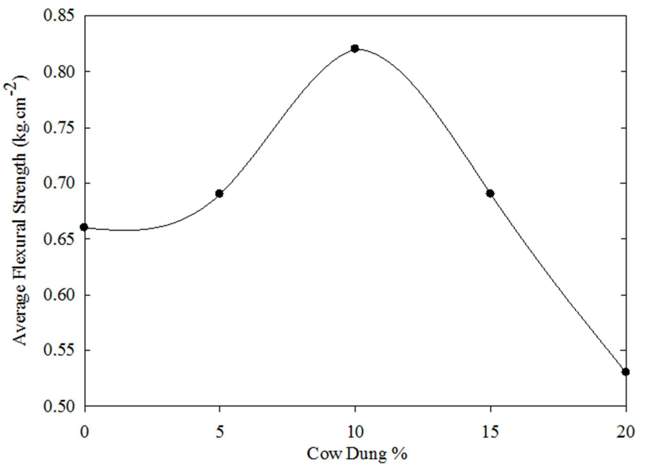

Figure 4. *Average flexural strength of brick as a function of CDA%.*

Figure 4 shows the change in flexural strength as a function of CDA. The flexural strength increases smoothly up to 0.82 kg.cm^{-2} from 0.66 kg.cm^{-2} and decreases to 0.53 kg.cm^{-2} with increasing the CDA percentage. A maximum flexural strength 0.82 kg.cm^{-2} is obtained for 10% CDA and satisfies the required conventional value 2.89 MN.m$^{-}{}_{2}$. The behaviour of flexural strength is similar to the behavior compressive strength.

3.5. Thermal Conductivity and Specific Heat Analysis

Thermal conductivity and specific heat decreases with increase of the CDA% is shown in Figure 5. This is due increase of CDA increases the porosity of the mixture. Thus these pores support to decrease the thermal conductivity and specific heat in the mixture. The thermal conductivity and specific heat varies in the same direction as the density (see Figure 1 and Figure 5), in this fact the mixture of clay with CDA provides thermal conductivities from 0.38 to 0.16 W.mK^{-1} and specific heats 720 to 650 J.kg.K^{-1}, lower than the thermal conductivity 0.82 W.mK^{-1} and specific heat 850 J.kg.K^{-1} for pure clay. This result confirms that the CDA is evidently favourable to the improvement of the thermal conductivity in the construction materials base on clay.

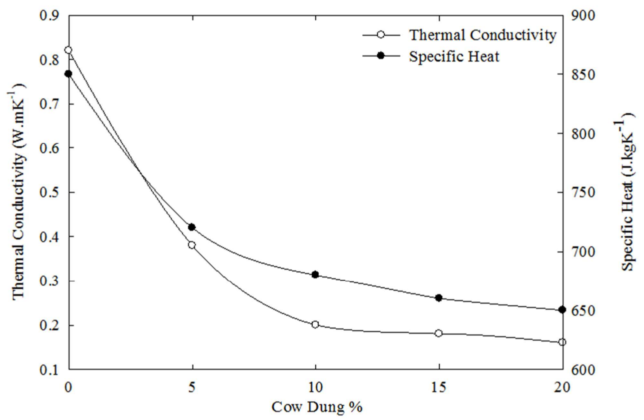

Figure 5. *Thermal conductivity and Specific heat of brick as a function of CDA%.*

4. Conclusions

From various physical properties studies performed by adding different percentage of CDA, it could be concluded that partial addition of CDA improves the physical properties of the fired clay bricks within the limit of experimental error.

The results obtained from this analysis exposed that addition of 10% CDA gives most favorable values in the physical properties are given as follows: The average density 1447 kg.m^{-3} was recorded and satisfy the requirements as per Sri Lankan Standard [18] 855: Part 1: 1989 and British Standard [19] BS 5628: Part 1: 2005 specifications for brick clay which stated the range in between 1200 to 2200 kg.m^{-3}. According to the results, all the brick, satisfy recommended water absorption value above 12% as per the Sri Lankan Standard [18] 855: Part 1: 1989 and British Standard [19] BS 5628: Part 1: 2005 which lie within the standard values. The maximum compressive and flexural strength 150 kg.cm^{-2} and 0.82 kg.cm^{-2} were recorded respectively. According to the BS 5628, compressive strength of the fired clay brick should be greater than 50.98 kg.cm^{-2}. For a single story building minimum compressive strength should be within the range 10 to 50.98 kg.cm^{-2} and recommended by the building authorities. The thermal cconductivities lay in the range 0.38 to 0.16 W.mK^{-1} and specific heats lay in the range 720 to 650 J.kg.K^{-1}, which are lower than the values of pure clay. Therefore, 10% CDA could be recommended for high strength external construction; as well as for interior wall partitions and decorations. Furthermore, this can be manufactured on site itself, low cost, semi labour skills and local economy will flourish. Not only has that by introducing the use of locally available natural agro waste materials directed to ecological structure.

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