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Fly Ash Brick: An Environmental Pollutant Converts into Eco-friendly Building Material

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Abstract

In Bangladesh, bricks are one of the most important building materials. Hoffman Kiln's clay brick production is directly related to air pollution, the loss of fertile top soil, the cutting down of trees, and so on. Again, fly ash is also considered an environmental pollutant and is generally a by-product from coal-based power plants. It typically dumped and resulted in water pollution from heavy metal intrusion, loss of land fertility, and breathing problems that caused respiratory diseases. This study evaluates the experimental approach of using fly ash in brick making, which eliminates the need for soil and results in a lower carbon footprint. Fly ash brick was created using locally available construction materials such as sand and cement, as well as fly ash that met Bangladesh Standard (BDS). Five number of trail mix were done, and the outcome shows fly ash brick as low water absorbent (9%), with a compressive strength of 14.3 MPa (comparable to Class B as per BDS). Other properties like efflorescence, hardness, and soundness were also evaluated, and these showed satisfactory results as per BDS. In heavy metal leaching tests, it showed negligible water pollution. While evaluating the carbon footprint value, it showed a value 6.5 times lower than clay brick. The goal of this study is closely related to the Government of Bangladesh's current idea of replacing clay bricks phase by phase and also converting a coal power-based waste material known as fly ash into an important raw material for brick making.

Keywords: *Brick, Fly -Ash, Carbon- footprint, heavy -metal, leaching*

1 Introduction

Burnt clay bricks are an essential component of construction materials and are widely used in our nation. Since this clay brick uses clay that comes from agricultural land, it is detrimental to the environment. Additionally, a significant amount of fossil fuel is utilized to burn clay brick in kilns. Such fossil fuel combustion results in air pollution and greenhouse gas production that contributes to global warming. Therefore, it is imperative that innovative, sustainable building components take the place of conventional building materials. Given that waste creation has increased as a result of growing industrialization, this building material will be able to use industrial waste. Developing nations employ a variety of techniques to create construction materials that are both affordable and environmentally beneficial. Additionally, because there is a shortage of energy and raw materials, people are looking for products that use the fewest resources possible. Therefore, a different approach is needed that uses industrial waste, such as fly ash, to substitute clay brick. Thermal power plant burnt residue called coal fly ash is dangerous, and getting rid of it is a major issue. About 0.6 million tons of this trash are produced grossly annually in Bangladesh(Banu, Billah, Gulshan, & Kurny, 2013). The government plans to build 6 additional thermal power plants, of which two are already moving forward. The Rampal Power Plant (1300 MW) is now in the building phase, while the 250 MW power plant is mostly in the tendering stage(Tamim, Dhar, & Hossain, 2013). Fly ash generation from thermal power plants will increase significantly in the near future, and its disposal as a byproduct will cause a serious ecological imbalance(Ugurlu, 2004). Thousands of hectares of storage area are needed for the fly ash disposal process. Fly ash may occasionally be combined with water to create an aqueous slurry, which is subsequently disposed of close to a thermal power plant or ash pond(Sati, 2020). This kind of wet disposal harms the surface water system, while dry ash disposal turns the land into waste, endangering the environment. Additionally, continuing to store fly ash in an ash pond may cause heavy metals to leak, ultimately contaminating the soil and groundwater system(Singh, Gupt, & Guha, 2012). Additionally, fly ash pollutes the environment by sending hazardous substances directly from power plants into the atmosphere(Thomas, Ph, Eng, Engineering, & Brunswick, n.d.). Consequently, because fly ash pollutes the environment, its use has drawn greater attention recently(Liu, Banerji, Burkett, & Vanengelenhoven, 2009).Fly ash is already utilized in the production of cement, concrete, mortar, as a binder, and other cementitious materials(Thomas et al., n.d.).Different approaches had been made to make FAL-G bricks, Barapukuria fly ash is combined with sand, gypsum, and lime. They changed the fly ash (10%–15%), lime (5–15%), and gypsum (2%–14%)(Banu et al., 2013).Another attempt was done to manufacture fly ash bricks with addition of lime, gypsum and quarry dust by varying fly ash proportion 15% to 50%,Lime 5% to 30%,Gypsum 2%,quarry dust 23% to 53% and the water binder ratio 0.45 to 0.75(Thomas et al., n.d.). Fly ash is used in the plastic industry, the elimination of metal toxicity from soil, waste water treatment, and other processes as a potential element or agent(Ashikuzzaman, 2018). However, the usage up to this point has fallen short. By serving as an alternative to traditional clay brick, fly ash bricks or blocks could be a smart choice because they will lessen environmental degradation and safeguard natural resources. There is no combustion of fossil fuels involved in the production of fly ash brick. As a result, the fly ash brick produced using this method won't cause a burning problem or environmental carbon dioxide emissions. The study's two main goals are to determine whether fly ash is suitable for creating brick in place of clay brick and to compare how environmentally friendly fly ash brick is to clay brick in order to satisfy that previously mentioned demand.

2 Materials and Methods

2.1 Material Collection

This includes the collection of cement, sand, and fly ash. Sand was obtained from TSC construction site, CUET, and fly ash and cement were obtained from Confidence Cement Ltd. (Chattogram). Class F fly ash was utilized in the production of brick. The wooden mold that was used to create the fly ash bricks was manufactured in line with Bangladesh Standard, measuring 9.5" X 4.5" X 2.75".

Sand:

Sylhet sand was used as fine aggregate. The properties of sand were determined by conducting tests as per IS; 2386 (Part-1). The results obtained are shown in test data of materials.

Fly Ash:

Class F fly Ash was taken from local cement company and test result adopted from the company.

Table 1. Chemical Composition of Fly ash

Description	Local Cement Company Standard	Found result
Physical appearance	-	Ash
Loss on ignition (%)	<5	3.71
Fineness, (cm^2/gm)	1500 minimum	2325
F (CaO) (%)	<1	0.82
(CaO) (%)	<10	2.2
SiO_2 (%)	>45	54.2
Moisture (%)	<2	0.23

Cement:

The cement used for making fly ash brick was Ordinary Portland Cement (OPC)

2.2 Methodology:

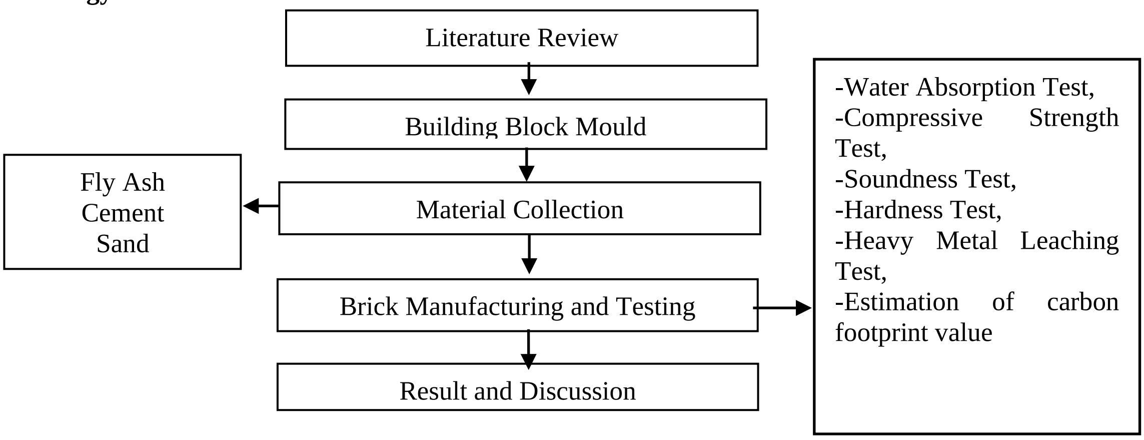

Figure 1. Road map of study

The study began with literature review of previous relevant works. Then preparing a wooden BDS standard mould to manufacture PWD Standard size 9.5" X 4.5" X 2.75"size brick.

The three basic components were taken into a bowl after mixing and manually combined. The material must be blended twice: once while dry and once while adding water. Therefore, in brick work, the water to binder ratio (W/B) of each combination is taken into consideration to be 0.45. After being put into a brick mold, the mixture is crushed with a wooden tamper bat. The trowel is used to polish the surface. The sides of the mold were greased before the slurry was placed inside of them for simple brick removal. After two or three minutes, the mold was eliminated. The bricks are then prepared for air curing for 24 hours before being submerged in water for 7, 14, and 21 days of water curing.

Fly ash brick Preparation:

In the present study fly ash brick had been made with different composition of fly ash varying from 50% to 60% Five mix design were selected where the sand, cement and fly ash were varied as per the mix ratio. The batching proportion of raw material required to produce the brick are shown in table.

Table 2. Different Batching Proportion of Raw Material

Sample	Percentage by Weight		
	Fly Ash %	Sand%	Cement %
S1	60	30	10
S2	60	25	15
S3	50	40	10
S4	50	30	20
S5	55	30	15


Figure 2. Mixing


Figure 3. Tamping


Figure 4. Demolding


Figure 5. Curing

2.3 Method for carbon footprint calculation:

The most commonly used tool for evaluating the environmental effects of the manufacturing and use of building materials is the carbon footprint calculation method. The components that are derived from it mostly reflect the amount of CO_2 and other greenhouse gases that are connected to this product, generally expressed as CO_2 equivalents. It is mainly done by LCA (Life Cycle Assessment) analysis of every component of a product's manufacturing and use. The LCA technique was used to calculate the CF values(Habert, 2015). Fly ash bricks are made with cement and sand, which adds to their respective carbon footprint values. Sand production results in GHG emissions of 0.25 CO_2-e per ton as opposed to cement manufacture's 162.5 kg CO_2-e per ton (F. Ma, 2016).

3 Results and Discussions

3.1 Sand Properties Test

The properties of sand were determined by conducting tests as per IS: 2386 (Part-I)

Table 3. Properties of sand used to prepare brick sample

Serial Number	Tests	Results
1	Specific Gravity	1.79 kg/m^3
2	Fineness Modulus	2.85
3	Apparent Specific Gravity	1.82
4	Absorption Capacity	1.03%
5	Field Moisture Content	0.17%

3.2 Fly Ash Properties Test

Fly Ash bricks are put through the following tests to check out it appropriateness as a building block and then compare with the conventional clay brick.

3.3 Absorption Test

This test is conducted to check the durability of brick and determine the percentage of water absorbed by brick. For any brick the average water absorption should not be more than 20% of dry weight of brick (BDS: 208)

3.4 Hardness Test: This test is conducted by making a scratch on the surface of the brick by finger nail or sharp tool. The brick will be recognized as sufficiently hard if there is no effect after scratching (BDS: 208)

3.5 Efflorescence Test:

Efflorescence results in the surface of brick due to the presence of water-soluble salts. When no salt is present on the surface of brick, then there is no appearance of grey or white deposits. In this case the report will be considered as nil (BDS: 208)

3.6 Soundness Test:

This sound test is conducted to check out if clear ringing sound is produced or not when two bricks are struck with each other without breaking any portion of the two bricks. A good quality brick produces a clear ringing sound and does not break (BDS: 208)

Table 4. Test Results of Fly Ash Bricks

Test Name	Different Mix Proportion	Results
Water Absorption Test	S1	12%
Water Absorption Test	S2	10%
Water Absorption Test	S3	11%
Water Absorption Test	S4	09%
Water Absorption Test	S5	10.3%
Soundness Test	All Mix Proportions	A Clear ringing sound
Efflorescence Test	All Mix Proportions	Nil
Hardness Test	All Mix Proportions	No impression after scratching on the surface of brick

The analysis of test results shows that for mix design S4 the water absorption is 9%. This value meets the criteria of a standard brick since the water absorption shall not exceed 20%.

3.7 Compressive Strength Test:

The compressive strength test of a brick is conducted with the help of a compressive testing machine. It helps to find out material behavior under load, and its suitability as a construction material. The compressive strength is conducted for all the five specimens. For making fly ash brick, amount of fly ash is varied between 50% and 60%.

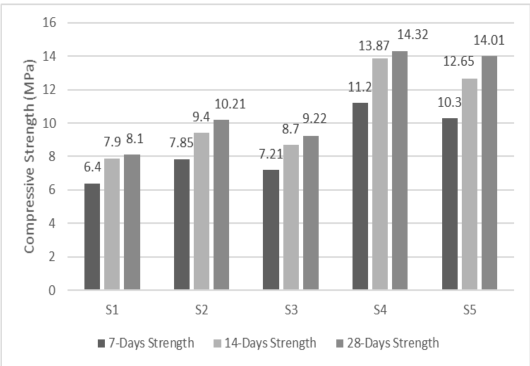

Figure 6. Compressive Strength test results of Fly Ash bricks

Figure 7. Fly Ash brick in compression

From the graph, the compressive strength increases with the decrease in fly ash and increase in cement in the brick composition. Our main objective was to utilize maximum amount of fly ash. But at mix design S5 the crushing strength declines. Moreover, it can be stated that if the amount of fly ash decreases there will be less bonding, and strength will gradually decrease. And it is also cost effective if the amount of fly ash is kept within 60%. Hence, based on these scenario S4 is taken as the cut off line. Mix design S4 has is the optimum one as it delivers better compressive strength alongside with less water absorption.

3.8 Test Results of Heavy Metal Leaching Test:

Since fly ash is composed of heavy metals like Cu, Mn, Zn and others so it is important to find out while subjected to rain whether these toxic metals will leach out from fly ash when it is used as a brick. The heavy metal leaching test (Table 5) shows that the fly ash brick does not exceed the WHO drinking water standard when it is immersed in rain water(Aryal, Gautam, & Sapkota, 2012). And the percentage of leaching is very negligible. Thus the rain water will not any serious leaching of heavy metals from fly ash brick.

Table 5. Test Results of Heavy Metal Leaching Tests of Fly Ash Bricks

Heavy metal	Fly ash (mg/l)	rainwater(mg/l)	Fly ash brick immersed in rainwater(mg/l)	WHO drinking water standard 1993 (mg/l)	Leaching (%)
Cu	1.55	0.15	0.19	2	2.58
Mn	8.2	0.125	0.180	0.5	0.67
Zn	0.99	0.53	0.53	3	0

3.9 Test Results of Carbon Footprint Value

We are calculating carbon footprint value for our design mix-04 fly ash bricks as it shows maximum strength. For design 04 cement is 20%, sand is 30%. The weight of our brick is 2.9kg.
Carbon footprint value for cement = (162.5 x 0.58)/1000=0.094 kg CO_2-e
Carbon footprint value for sand = (0.25 x 0.87)/1000=0.0008 kg CO_2-e

Table 6. Calculation of Carbon Footprint Value

LCA (Life cycle assessment)	Carbon footprint of Fly Ash brick (kg)	Carbon footprint of Clay brick(kg)
Producing gas	0.009	0.281
Raw material transportation	0.004	0.018
Electricity used	0.045	0.070
CO_2 emission from cement	0.094	0.0
Sand	0.0008	0.0
Total	0.152	0.999

So, the carbon footprint value of clay brick is 0.999/0.152=6.5 times of fly ash brick. It indicates higher emission of CO_2 from clay brick. Burning of wood in brick kiln results in huge amount of GHG in the atmosphere. It creates problem in respiration as well as deadly diseases. This proves that the fly ash brick will cause less environment pollution in compare to clay brick.

3.10 Comparison between Clay Brick & Fly Ash Brick

The standard value of clay brick is taken from ASTM C62-17.

Table 7. Properties of Fly ash brick and Clay Brick

Properties	Fly Ash brick	Clay brick
Basic Raw material	Fly Ash, cement, sand	Clay
Burning	Not required	Required
Excavation of top fertile soil	Not required	Required
Lowest Water absorption(S4)	9%	According to BDS Grade A<10% Grade B<12% Grade C<16%
Highest Compressive strength(S4)	14.3 MPa (2070 psi)	According to BDS Grade A > 20.7 MPa(3000 psi) Grade B > 13.80 MPa(2000 psi) Grade C > 8.30 MPa(1200 psi)
Carbon footprint value (Kg)	0.152	0.999
Brick kiln	Not needed	Needed

4 Conclusion and recommendation

All the test results show that-

1. Fly ash has low water absorption of about 9% which is less than Grade A & Grade B clay brick as per BDS. Highest Compressive Strength of clay brick is like Grade B clay brick as per BDS. Efflorescence, hardness, soundness test it acts same as clay brick.
2. Fly ash brick is more suitable for the environment than the clay brick in the sense that the total carbon footprint of fly ash brick is 6.5 times less than conventional burnt clay brick. Fly Ash bricks are ecofriendly as it protects environment through conservation of top soil and side by side utilizes the waste product of thermal power plant. The manufacturing process of fly ash brick does not require any burning and hence saving wood and fossil fuel. In short, fly ash brick is cost effective, energy efficient & environment friendly.
3. We exerted little pressure on the material since we were manually compacting it. The material may be completely compacted and achieve the required compressive strength to be categorized as a Class A brick by the BDS if a high pressure machine were utilized.

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