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Properties of Fly Ash Brick Prepared in Local Environment of Bangladesh

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Abstract**—**Coal fly ash, an industrial by product of coal combustion thermal power plants is considered as a hazardous material and its improper disposal has become an environmental issue. On the other hand, manufacturing conventional clay bricks involves on consumption of large amount of clay and leads substantial depletion of topsoil. This paper unveils the possibility of using fly ash as a partial replacement of clay for brick manufacturing considering the local technology practiced in Bangladesh. The effect of fly ash with different replacing ratio (0%, 20%, 30%, 40%, and 50% by volume) of clay on properties of bricks was studied. Bricks were made in the field parallel to ordinary bricks marked with specific number for different percentage to identify them at time of testing. No physical distortion is observed in fly ash brick after burning in the kiln. Results from laboratory test show that compressive strength of brick is decreased with the increase of fly ash and maximum compressive strength is found to be 19.6 MPa at 20% of fly ash. In addition, water absorption of fly ash brick is increased with the increase of fly ash. The abrasion value and Specific gravity of coarse aggregate prepared from brick with fly ash also studied and the results of this study suggests that 20% fly ash can be considered as the optimum fly ash content for producing good quality bricks utilizing present practiced technology.

Keywords**—**Bangladesh brick, fly ash, clay brick, physical properties, compressive strength.

I. Introduction

COAL has a large share of contribution towards worldwide electric power production. In recent years, coal consumption in power production sector has increased in a significant rate. In year 2011, 29.9% of the world's electricity was generated from coal fouled power plant and this rate is expected to be increased at about 46% at the end of year 2030 [1]. As a result, coal combustion waste, a part of which is basically fly ash is expected to grow in a colossal quantity which is hazardous in nature and its disposal method is now a great concern to engineers. Recent reports shows that the worldwide generation of fly ash is approximately 750 million tons and considering the estimated growth worldwide production of coal ashes will be around 13.33 billion tons by year 2030 (a considerable part of it would be the fly ash) [2]. Environmental impact of untreated coal fly ash has uncovered. At the present time, recycling coal fly ash is addressed as a good alternative to disposal. Some countries are promoting its use in different industries and sometimes regulating the process. Biggest neighbor of Bangladesh, India can be brought as an example in this case [3]. In the previous years, the global average utilization rate of fly ash was estimated nearly at about 25% and by the end of this year 2015, this rate is expected to at 70% of the total fly ash production.

Brick is one of the oldest construction material, which basically a shaped form of molded burned clay. Since clay is the core ingredient of brick, making fired brick is responsible for a top soil extraction and resulting the depletion of the virgin resources for farming [2]. Realizing the consequences Chinese government has banned the use of fired clay brick as a construction material [4]. Bangladesh is called upon the land of farmers as a major portion of the total population depends on the crop cultivation. To support its growing need and maintain the fool security it needs more cultivable lands. On the other side, population growth helps in increasing demand for housing and infrastructure also. Use of clay burned bricks as a construction material is very popular in Bangladesh and because of its emerging demand; brick manufacturing has become the fastest-growing industrial sector in Bangladesh [5]. Usually, clay for these factories is collected from the top soil of the cultivable lands and as result, pressure is increasing on the agricultural land. Accordingly, there is a need for an efficient sustainable alternative.

II. Research Significance

If in Bangladesh 2.41 % of the total energy is produced from coal burnet thermal power plants which are now the major source for production of fly ash. Current fly ash production of Bangladesh stands at 52000 metric tons per annum, which is expected to soar to 377000 metric tons per annum by the end of year 2018 [6]. Disposal system of this wastes is not abide by any law and practically the produced fly ash is transported and disposed into some dry embankments. Present problem with fly ash lies in the fact that not only does its disposal requires large quantities of land, water, and energy, its fine particles, if not managed well, by virtue of their weightlessness, can become airborne. When not properly disposed, fly ash is known to pollute air and water, and stands for the cause of respiratory diseases when inhaled.

Considering present scenario, Bangladesh should comply with the world's trend of recycling this waste (fly ash). A viable option for the bulk utilization of fly-ash could be in the production of structural bricks containing fly ash as a major ingredient. If it's possible two gigantic problems (reduction of

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using clay as for brick manufacturing and healthy disposal of fly ash) can be solved at a time. Though fly ash utilization as a partial and full replacement of clay for brick manufacturing is presented in several literatures [3], [4], [7]-[12]. Most of the cases the specimens are molded in the laboratory and then burnet in the furnace. However, in practical field that much attention is not paid. Therefore present study is concerned about to utilize the current brick making practice in Bangladesh by partially replacing the clay materials with fly ash. Thus, the specimens are prepared in a real operational factory with other ordinary bricks and burnt in the kiln. After burning, the samples were brought to the laboratory for property testing. From the experiment, it is further desired to compare the strength of fly ash brick by that of the conventional clay brick. The salient properties of bricks like compressive strength, water absorption, unit weight, shape and size, hardness and efflorescence are to be determined.

III. Specimen Preparation

In this research, total 125 brick samples were prepared to study different properties of fly ash bricks in compare to the normal clay bricks. These samples were grouped into 5 basic categories depending fly ash content. So each group owns 25 samples for property test program. Samples were prepared in a local brick plant were raw material (clay mineral) also supplies from a local source. For this particular experiment, fly ash was collected from source Barapukuria Power plant. A composition analysis result of the Barapukuria Power plant produced fly ash is presented in Table I.

TABLE I
Composition Analysis Result of the Barapukuria Power Plant Produced Fly Ash [6]

Oxides	Percentage
SiO_2	54.4
Al_2O_3	35.6
Fe_2O_3	2.9
TiO_2	3.2
Mn_3O_4	0.11
CaO	0.56
K_2O	0.66
Na_2O	0.06
MgO	0.18
P_2O_5	0.46
SO_3	0.13

Brick samples were molded to achieve a uniform size of 76 mm high, 230 mm long, and 110 mm wide brick. Fly ash was added with the clay sample at the time of preparing the raw materials for molding by volume basis at different parentages. An estimate of total brick sample specimens prepared is presented in Table II. The brick specimens were dried in open air for 4 days prior to fire in kiln. Burning process of these was fully traditional and took 14 days for completion. After 14 days of complete burning the kiln was allowed to cool for 4 days. Cooled bricks were brought to the laboratory for testing purpose. This whole process is summarized in Fig. 1 though a flow diagram.

TABLE II
An Estimate of the Total Brick Sample Specimens Prepared

Sample Group	Specimen Size (height x length x width)	Number of specimens	Volumetric Percentage of Fly Ash
T – 0	76 mm x 230 mm x 110 mm	25	0
T – 20		25	20
T – 30		25	30
T – 40		25	40
T – 50		25	50

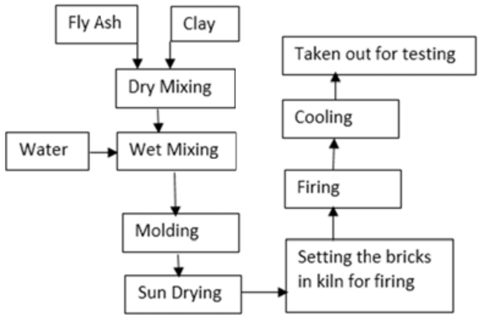

Fig. 1 Brick sample preparation process

IV. Testing Program and Results

A. Size and Shape Test

Size and Shape of the brick samples are checked from visual observation and brick size study data. Measurement is taken along the length, width, and height; then average length, width and height are taken for 5 bricks for each group. Size and shape test was performed according to ASTM C134-95 (2010) [13]. All experimental results of this test of brick samples are presented in Table III.

TABLE III
Experimental Results of Size and Shape of Bricks

Sample Group	Observed Size (height x length x width)
T – 0	227.4 mm × 95.0 mm × 51.6 mm
T – 20	223.6 mm × 97.8 mm × 50.6 mm
T – 30	227.8 mm × 99.6 mm × 54.0 mm
T – 40	230.8 mm × 99.8 mm × 53.2 mm
T – 50	230.6 mm × 100.4 mm × 53.4 mm

B. Compressive Strength Test

Brick specimens contained dry half brick (just along the length) for compressive strength test. Specimens were cured for 4 days (one day under damp jute bags and three days in clear water) and after lifting from water, their frogs were filled and flushed with the face of the brick with 1:2 cement sand mortar. Then compressive strength was determined by applying load on the specimen using a Universal Testing Machine. The average of five test results was taken to report the compressive strength value of each group of specimens. Total test method confirms ASTM C 67-14 [14]. Compressive strength test results are presented in Table IV.

C. Water Absorption Test

To know the water absorption value brick specimens were dried in a ventilated oven at (110-115) ˚C till it attains substantially constant mass. Then specimen was kept immersed in clean water at 27˚C for 24 hours. These were weighed again to determine the weight of water absorbed with the formula as

$$Absorption, \% = \frac{W_s - W_d}{W_d} \times 100 \qquad (1)$$

where, W_s = weight of saturated surface dry condition, W_d = weight of dry condition. The values were taken from 5 measured specimens. Here, test method confirms ASTM C 67-14 [14]. Results were reported on Table IV.

D. Efflorescence Test of Brick

In order to conduct efflorescence test of bricks, brick specimens were placed in end in a dish filled with water, the depth of immersion being 25 mm. The whole arrangement was placed in a warm (20-30) ˚C, well-ventilated room until all the water in the dish evaporated. When the water was absorbed and the bricks were appeared to dry then similar quantity of water is again filled in the dish and allowed to evaporate. The bricks were examined after second evaporation and the area of white patches on the specimen brick was measured. The liability of efflorescence was reported as 'nil', 'slight', 'moderate', 'heavy'. Indian standard was used in this particular case of experiment [15]. Results are reported in Table IV.

TABLE IV
PHYSICAL PROPERTY TEST RESULTS OF DIFFERENT GROUP OF BRICKS

Sample Group	Compressive Strength (MPa)	Water Absorption (%)	Efflorescence
T – 0	21.6	15.3	Nil
T – 20	19.6	20.1	Nil
T – 30	15.8	21.1	Nil
T – 40	14.8	23.2	Nil
T – 50	13.9	24.3	Nil

E. Specific Gravity of Brick made Coarse Aggregate

To determine the specific gravity of brick made coarse aggregate, brick specimens were crushed first to extract coarse aggregate from those. Then prepared aggregate samples were thoroughly agitated to remove dust or other coating from the surface of the particles and allowed to absorb water for 24 hours. Just after removing them from water saturated surface dry condition was confirmed. After that, samples were placed immediately in the air basket and weighted in water. Finally, the samples were dried to constant weight at a temperature of 100˚C-110˚C and then cooled to room temperature and weighted. The apparent specific gravity was calculated by the formula as

$$Apparent\ specific\ gravity = \frac{A}{(A-C)} \qquad (2)$$

where, A = Mass of oven dry specimen in air, C = Apparent mass of saturated test sample in water. Test method confirms ASTM C 127–15 [16]. Results of the specific gravity test of the brick made coarse aggregate are reported in Table V.

F. Los-Angeles Abrasion Test of Coarse Aggregate

To determine the Los-Angeles Abrasion (LAV) for the aggregate samples from different fly ash brick groups, instructions mentioned in ASTM C 131–14 [17] was followed. At the beginning, clean aggregate samples were dried in an oven at 105-110˚C to constant weight confirming the aggregate grading B was used for the test. Aggregate samples weighting 2.5 kg with a size in between 16 mm to 12.5 mm and another 2.5 kg with a size in between 12.5 mm to 9.5 mm for grading B were placed in the cylinder. The machine was completed about 500 revolutions with a speed of 30-33 rpm and sooner after the materials discharged from the machine. The portion of the material coarser than 1.7 mm size was washed and dried in an oven at 105-110 ˚C to constant weight. Washed samples' weights were compared with the original to find out the percent loss which can be reported as LAV. Table V summarizes the LAV for different groups of aggregate samples.

TABLE V
PROPERTY TEST RESULTS OF COURSE AGGREGATE EXTRACTED FROM FLY ASH BRICKS

Sample Group	Apparent Specific Gravity of Coarse Aggregate	LAV, (%)
T – 0	2.22	32
T – 20	2.16	34
T – 30	1.99	43
T – 40	1.85	47
T – 50	1.75	51

V. DISCUSSION ON RESULTS

A. Size and Shape Test of Brick with Fly Ash

The relative size of brick with using fly ash to the normal brick is the quite same. Both cases the soil sample was same. Thus, it is ensure that from the practical point of view the experimental bricks are uniform in size and shape. It has been found that the bricks are also uniform in color.

B. Compressive Strength Test of Brick

Fig. 2 shows compressive strength test result of bricks at different level of fly ash content and a relative comparison between a present research results and results from a previous research by [10] with the aid of bar chart is presented. Compressive strength results of present research program shows that maximum strength is obtained for normal clay brick. At 20% of fly ash, compressive strength is 19.6 MPa and it is observed that strength is decreased with the increase of percentage of fly ash. Patil and Dwivedi [10] revealed that the compressive strength of brick gradually increases till certain addition of fly ash and then it starts to decrease. However, present research result shows that compressive strength gradually decreases with the increase of fly ash. This may be a cause of improper mixing method which have practiced in the brickfield. In addition, compressive strength results reported in this research is more than that obtained by [10] in all cases.

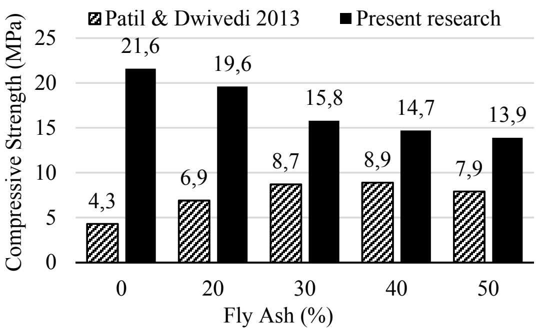

Fig. 2 Compressive strength (MPa) of brick as influenced by fly ash

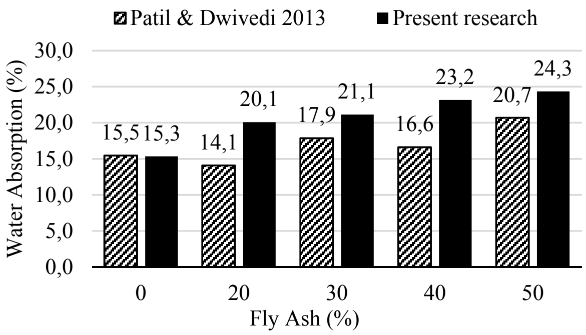

Fig. 3 Water absorption (%) of brick as influenced by percentage of Fly ash

C. Water Absorption Test of Brick

Water absorption influenced by percentage of fly ash is presented in Fig. 3 with a comparison of the data obtained by [10]. Illustration shows that water absorption of fly ash brick increases with increase of fly ash and all experimental value of water absorption of bricks with fly ash obtained is reported just more than 20%.The addition of fly ash speeds up the water absorption which is greater than normal brick. In their investigation, [10] found water absorption less than 20% up to 50% addition for fly ash bricks. However, present research indicates that water absorption is increased with increase of fly ash slightly more than 20%.

D.Efflorescence Test of Brick

Efflorescence test is an important one to identify good brick. It indicates soluble salt present in the brick. All the experimental results obtained is less than 10% so that efflorescence is said to be 'Nil'. Therefore, brick with 20% of fly ash can be used as building material.

E. Los-Angeles Abrasion Test of Coarse Aggregate

The LAV of normal brick is 32%, but LAV for fly ash brick made aggregate are just more than normal brick. The abrasion value is 51% (maximum) at 50% of fly ash. According to AASHTO for base course abrasion value of coarse aggregate should be less than 40% and for sub base course it should be less than 50%. Therefore, coarse aggregate obtained from fly ash brick can be used as in the base as well as in the sub base for road construction.

F. Specific Gravity Test of Coarse Aggregate

The specific gravity of coarse aggregate is decreased with the increase of fly ash; the specific gravity of coarse aggregate of normal brick is 2.22. The specific gravity is 1.75 (minimum) at 50% of fly ash. Therefore, the brick containing fly ash can be treated as lighter material compared to ordinary brick.

VI. CONCLUSION

Based on the experimental results the following conclusions are done from the present study:

- Size and shape of the fly ash bricks are found quite same as the normal clay brick and no distortion due to fly ash adding is observed. Fly Ash bricks are found to be sufficiently hard, as scratching by the finger nail on the surface left no impression on it as compared to normal bricks.
- The compressive strength of clay bricks are found to be 21.6 MPa and for fly ash bricks is found to be 19.6 MPa at 20% replacement. This is maximum for fly ash bricks.
- The average absorbed moisture content for clay brick is found to be 15.34% and for fly ash bricks, it is found more than 20%.
- The Efflorescence of all bricks tested are found to be nil and Los-Angeles Abrasion Value in all cases of fly ash bricks are greater than normal clay bricks and less than 50% except one case (50% fly ash content). That indicates the aggregate extracted from fly ash bricks can be used as a good building and road material.
- As the specific gravity of coarse aggregate decreased with the increase of fly ash, these fly ash bricks can fulfill the requirement where brick like light weight building materials are rewired (i.e. partition wall)
- Use of fly ash for brick production can be a potential source of raw material as well as the healthy disposal solution of produced fly ash in Bangladesh. As it is seen these goal can be achieved without altering the current brick manufacturing process practiced in Bangladesh.

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