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Compressive Strength of Fly Ash Brick with Addition of Lime, Gypsum and Quarry Dust

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Abstract: Although the use of fly ash has many advantages, its low hydration at early stage causes the strength to be low. In this study, the experimental investigation was carried out to find the optimum mix percentage of flyash brick. However the brick specimen of size 230mm x 110mm x 90mm were cast for different mix percentage of Flyash (15 to 50%), Gypsum (2%), Lime (5 to 30%) and Quarry dust (45 to 55%), compressive strength were studied for different mix proportions. The results shows the variation of compressive strength for different mix proportions of materials mentioned earlier at different curing ages. From the results it was inferred that, the maximum optimized compressive strength is obtained for optimal mix percentage of Flyash-15% Lime-30% Gypsum-2% Quarry dust-53%.
Key words : Fly ash, Lime, Gypsum, Quarry dust, Compressive strength and Water absorption.

Introduction

In the present scenario in the construction industry, use of economic and environmental friendly material is of a great concern. One of the main ingredients used is cement. It is observed from various studies that the heat emitted from cement accounts to a greater percentage in global warming. Cement industries account to a greater emission of CO_2 and they also use high levels of energy resources in the production of cement. In order to minimize these effects, replacement of cement with some pozzolanic materials such as fly ash, can have an improving effect against these harmful factors. In this work, identified the optimum mix of fly ash (major ingredients) generated at Barapukuria Thermal Power Plant, sand, hydrated lime and gypsum and also optimized the brick forming pressure. Fly ash- 55%, sand- 30% and hydrated lime – 15% with gypsum-14% was found to be the optimum mix. For the optimum mix studied the compressive strength, microstructure, shrinkage property, unit volume weight, Initial rate of absorption, absorption capacity, apparent porosity, open pore and impervious pore of the fly ash–sand–lime-gypsum bricks produced with optimized composition under various brick forming pressures, Efflorescence and radio activity of the bricks formed under optimized conditions were also investigated[1]. In this paper, experimentally investigated the fly ash brick mix proportions by Taguchi method. Least quantity of cement and fly ash has been used as binding materials and considered the control factor as water binder ratio. Both. So the effects of water/binder ratio, fly ash, coarse sand, and stone dust on the performance characteristics are analyzed using signal-to-noise ratios and mean response data. Furthermore, the estimated optimum values of the process parameters are corresponding to water/binder ratio of 0.4, fly ash of 39%, coarse sand of 24%, and stone dust of 30%[2]. The addition of flyash up to 60% at a fixing temperature as 950ºc has no siginificant harmful effects on the brick quality.It seems that the fly ash added building bricks show reasonably good properties and may become competitive with the conventional building bricks. Use of fly ash as a raw material for the production of building bricks is not only viable alternative to clay but also a solution to difficult and expensive waste disposal problem[3]. In the present work the attempt has made to find the optimum mix percentage of to obtain maximum compressive strength of flyash brick admixed with lime, gypsum and quarry dust at various proportions.

Need for the Study

1. To improve the engineering properties such as workability, plasticity, water tightness, etc.
2. To improve the compressive strength to estimate the stability and durability of the brick
3. To maintain the uniform size and shape of flyash bricks and to reduce the plastering thickness.

Objective

To find out the optimum mix design for making brick so as to achieve the maximum compressive strength

Methodology

Materials and methods

The details regarding the methods and properties of materials used in this study.

Materials used

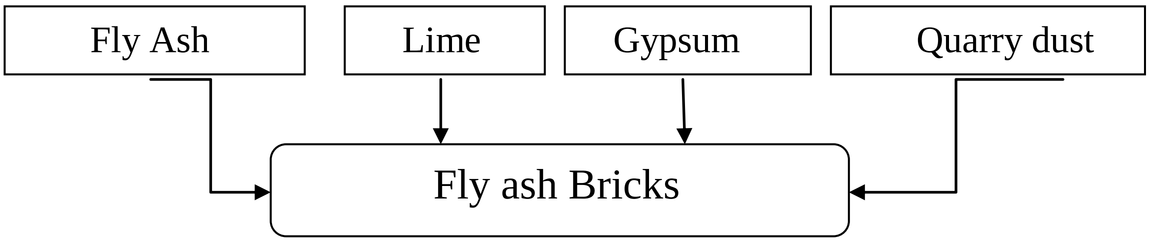

Fig. 1 Flowchart shows the materials used.

Properties of Materials

Fly ash

Fly ash is finely divided residue resulting from the combustion of powdered coal and transported by the flue gases and collected by electrostatic precipitator.

ASTM broadly classify fly ash into two classes

Class F: Fly ash normally produced by burning anthracite or bituminous coal, usually has less than 5% CaO. Class F fly ash has pozzolanic properties only.

Class C: Fly ash normally produced by burning lignite or sub-bituminous coal. Some class C fly ash may have CaO content in excess of 10%. In addition to pozzolanic properties, class C fly ash also possesses cementious properties. Fly ash used is of type class C with a specific gravity of 2.19**.**

Lime

Lime is an important binding material in building construction. It is basically Calcium oxide (CaO) in natural association with magnesium oxide (MgO).Lime reacts with fly ash at ordinary temperature and forms a compound possessing cementitious properties. After reactions between lime and fly ash, calcium silicate hydrates are produced which are responsible for the high strength of the compound.

Gypsum

Gypsum is a non- hydraulic binder occurring naturally as a soft crystalline rock or sand. Gypsum have a valuable properties like small bulk density, incombustibility, good sound absorbing capacity, good fire resistance, rapid drying and hardening with negligible shrinkage, superior surface finish, etc. In addition it can strengthen material or increase viscosity. It has a specific gravity of 2.31 grams per cubic centimeter. The density of gypsum powder is 2.8 to 3 grams per cubic centimeter.

Quarry dust

It is residue taken from granite quarry. Due to excessive cost of transportation from natural sources locally available river sand is expensive. Also creates environmental problems of large-scale depletion of these sources. Use of river sand in construction becomes less attractive, a substitute or replacement product for concrete industry needs to be found. Whose continued use has started posing serious problems with respect to its availability, cost and environmental impact. In such a case the Quarry rock dust can be an economic alternative to the river sand. Usually, Quarry Rock Dust is used in large scale in the highways as a surface finishing material and also used for manufacturing of hollow blocks and lightweight concrete prefabricated Elements. After processing fine particles of size less than 4.75 mm is used in this work.

First Arriving mix percentage of flyash bricks for Flyash (15 to 50%), Lime (5 to 30%), Gypsum (2%) and Quarry dust (45 to 55%).Standard flyash brick size of 230 mm x 110mm x 90 mm are used to cast the bricks. For each proportion 12 number of bricks are casting in that nine bricks are used to determine the compressive strength of brick in N/mm² at 7days,14days,21days curing time and three bricks are used to determine the water absorption. Compressive Stress is determined using Compression Testing Machine (CTM) of 3000 kN capacity. The following Flow chart describes the methodology of this study.

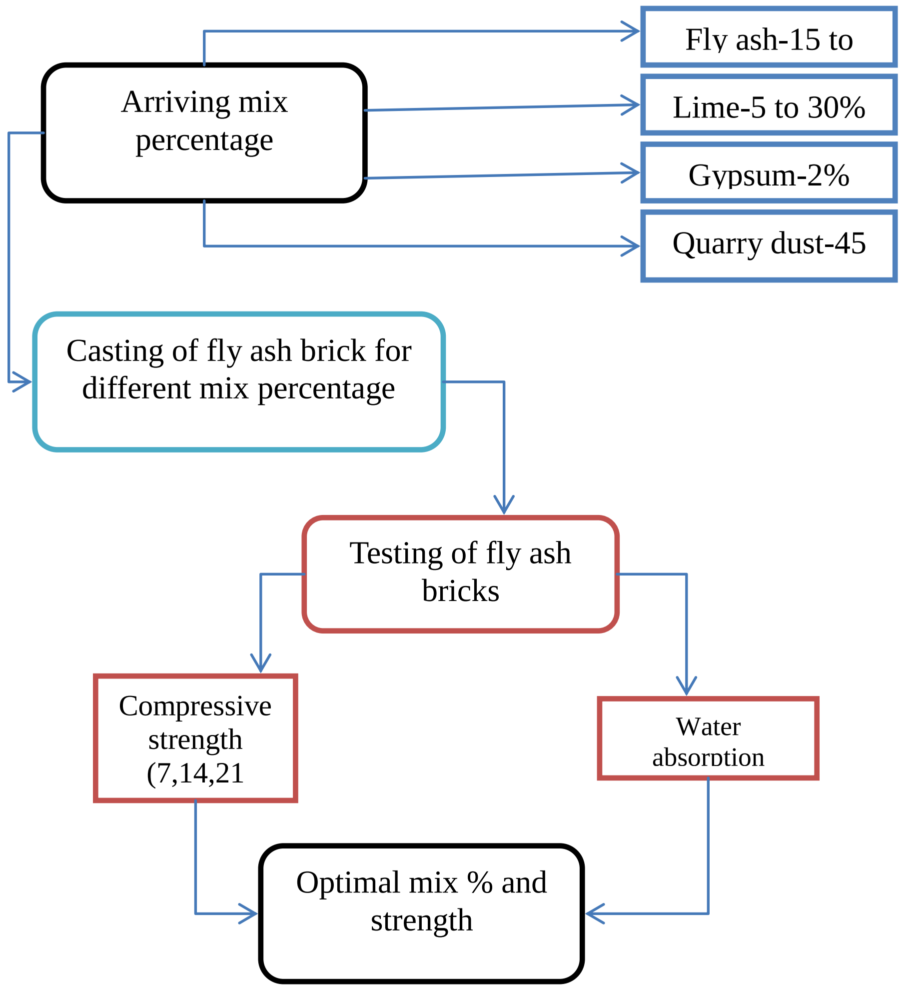

Fig. 2 Flowchart shows the Methodology

Mix Proportion

To make the flyash brick following mix proportions are arrived by trial and error method. The Table.1shows the various mix proportions.

Table. 1 Various Mix Proportions

Proportions	Fly ash (%)	Lime (%)	Gypsum (%)	Quarry dust (%)
I	15	30	02	53
II	20	25	02	53
III	20	30	02	48
IV	25	20	02	53
V	30	15	02	53
VI	35	10	02	53
VII	40	05	02	53
VIII	40	10	02	48
IX	50	25	02	23

The quantity of materials required to cast a single brick is arrived by taking a brick weight of 3.5kg is given in the Table.2.

Table 2 Quantity of Materials used

Proportions	Fly ash (kg)	Lime (kg)	Gypsum (kg)	Quarry dust (kg)
I	0.525	1.050	0.2	1.855
II	0.700	0.875	0.2	1.855
III	0.700	1.050	0.2	1.855
IV	0.875	0.700	0.2	1.855
V	1.050	0.525	0.2	1.855
VI	1.225	0.350	0.2	1.855
VII	1.400	0.175	0.2	1.855
VIII	1.400	0.350	0.2	1.680
IX	1.750	0.875	0.2	0.805

Water-binder ratio

Water- binder ratio is calculated based on weight of fly ash and weight of lime to total weight of the brick. It also plays the significant role on the compressive strength of the brick. Considering the water content or water to binder ratio is an indirect approach to sizing the volume, thus ensuring greater durability in the mixture proportions for bricks made. Then water-binder ratio used for various proportions is given in the Table.3

Table 3 Water-Binder ratio (%)

Proportions	Water- Binder ratio (%)
I	0.45
II	0.43
III	0.50
IV	0.45
V	0.45
VI	0.45
VII	0.45
VIII	0.50
IX	0.75

Preparation and Testing of Specimens

Casting of bricks

The normal hand mould is used to cast the bricks with the standard size of 230mm x 110mm x90mm.They were cast according to the standard procedure with various mix proportions arrived.

The required quantity of Fly ash, Lime, Gypsum, Quarry dust is calculated previously, according to that the materials mixed properly. Then required quantity of water was added. Then they mixed thoroughly.

Then the prepared mix was poured in to the mould and it is compacted. After compacting gets over then the mould is removed. Then the wet brick was kept under air curing for 2 days and then bricks were water cured for a period of 7,14,21 days.

The Fig. 3 -11 shows the materials used and mixing of materials to cast the brick.

Fig. 3 Brick Hand Mould

Fig. 4 Fly ash

Fig. 5 Quarry dust

Fig. 6 Gypsum

Fig. 7 Lime

Fig.8 Mixing of Materials

Fig. 9 Casted Brick Kept for Air Curing


Fig 10 Casting of Brick **Fig. 11 Curing of Bricks**

Results and Discussions

The investigation was carried out to determine the optimal mix percentage of fly ash brick admixed with lime, gypsum, and quarry dust and also to determine the water absorption.

Arriving proportions

Mix proportions are arrived by referring the articles and data collecting from local manufacturing companies. For the various proportions arrived bricks are casted and the following tests were conducted.

Tests are applied to bricks

Compressive Strength test
Water Absorption test
Efflorescence

Compressive strength test

The compressive strength of flyash brick is three times greater than the normal clay brick. The minimum compressive strength of clay brick is 3.5 N/mm².So as the flyash brick has compressive strength of 10-12 N/mm². Bricks to be used for different works should not have compressive strength less than as mentioned above. The universal testing machine is used for testing the compressive strength of bricks.

After the curing period gets over bricks are kept for testing. To test the specimens the bricks are placed in the calibrated Compression testing machine of capacity 3000 kN applied a load uniform at the rate of 2.9 kN/min. The load at failure is the maximum load at which specimen fails to produce any further increase in the indicator reading on the testing machine. In that three numbers of bricks were tested for each mix proportion. Each brick may give different strength. Hence, average of three bricks was taken.

Water absorption

Fly ash Bricks should not absorb water more than 12%. The bricks to be tested should be dried in an oven at a temperature of 105 to 115^{o} C till attains constant weight cool the bricks to room temperature and weight (W1). Immerse completely dried and weighed W1 brick in clean water for 24 hrs at a temperature of 27±20 Degree Celsius. Remove the bricks and wipe out any traces of water and weigh immediately (W2).

Water absorption in % by weight = (W2 – W1/W1) x 100

The average of three bricks should be taken. Our bricks absorb 09.114 % of water only; it has less water absorption property.

Efflorescence

For this test, brick was placed vertically in water with one end immersed. The depth of immersion in water being 2.5 cm, then this whole arrangement should be kept in a warm-well-ventilated room temperature of 20-30 ^{0}C until all evaporates. When the water in the dish is absorbed by the brick and surplus water evaporates. When the water is completely absorbed and evaporated place similar quantity of water in dish and allows it to absorb and evaporate as before. Examine the brick after this and find out the percentage of white spots to the surface area of brick. If any difference is observed because of presence of any salt deposit then the rating is reported as 'effloresced'. If no difference is noted, the rating is reported as 'not effloresced'.Percentage of white spot in the brick = Nil

Optimal Mix Percentage

Table. 4 Mean values of Compressive Strength (N/mm^2)

Proportions	7 days (N/mm^2)	14days (N/mm^2)	21days (N/mm^2)
I	1.98	3.95	7.91
II	1.68	3.36	6.78
III	1.81	3.43	6.97
IV	1.44	3.08	5.98
V	1.22	2.43	5.34
VI	1.03	1.97	5.04
VII	1.12	2.23	5.14
VIII	1.21	2.67	5.28
IX	1.34	2.62	5.45

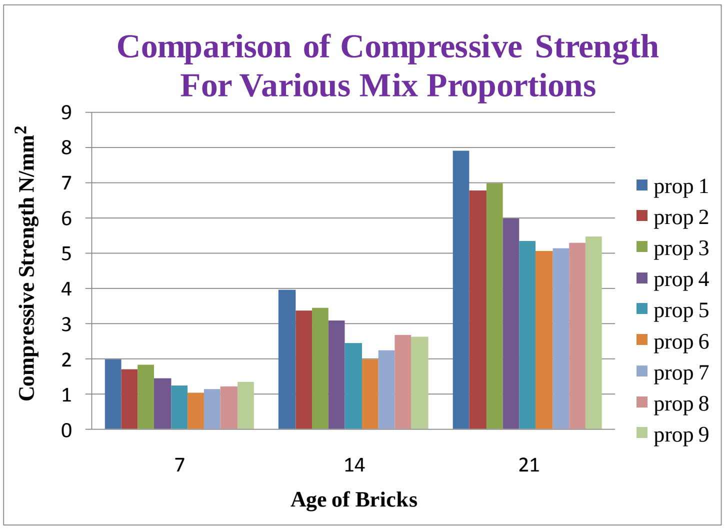

Fig.12 Compressive strength for various proportions at 7, 14, 21 days curing

From the experimental results proportion-1 shows the maximum compressive strength value. So that proportion-1 was taken as a optimal mix percentage of fly ash brick (Fly ash-15% Lime-30% Gypsum-2% Quarry dust-53%).The compressive strength decreases with increases of fly ash content. The Fig. 13 shows the compressive strength decreases with increases of flyash.

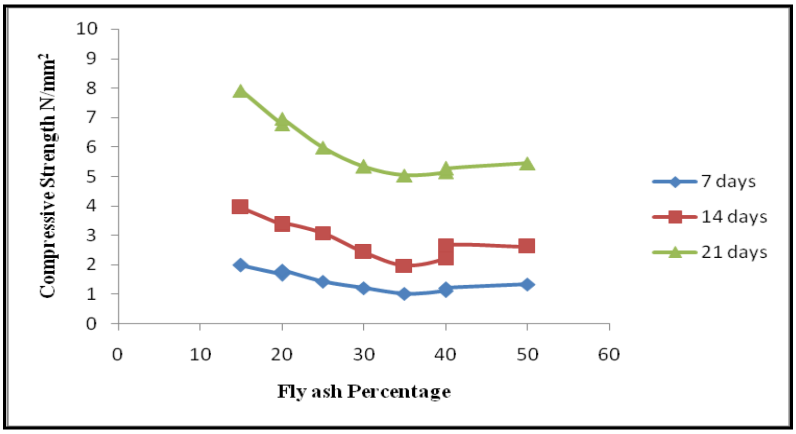

Fig.13 Variation of compressive strength with increase of Flyash

Calculation of water absorption for various proportion are given in the Table. 5

Table 5 Calculation of Water Absorption value (%)

Proportions	W1 (kg)	W2 (kg)	(W2-W1)	(W2-W1)/W1	(W2-W1)/W1X100 %
I	3.75	4.16	0.41	0.109	10.9
II	3.69	4.15	0.46	0.124	12.4
III	3.71	4.18	0.47	0.126	12.6
IV	3.75	4.25	0.50	0.133	13.3
V	3.69	4.25	0.56	0.151	15.1
VI	3.71	4.29	0.58	0.156	15.6
VII	3.75	4.34	0.59	0.157	15.7
VIII	3.69	4.29	0.60	0.162	16.2
IX	3.73	4.36	0.63	0.168	16.8

Water absorption= (W2-W1)/W1x100
= [(4.16-3.75)/3.75]x100
= 0.109x100
= 10.9%

From the results obtained water absorption for optimal mix percentage is 10.9%.It is lesser then the standard value of 12%.And also observed that for maximum strength only a good water absorption obtained. The following figure shows the variation of water absorption with compressive strength of brick.

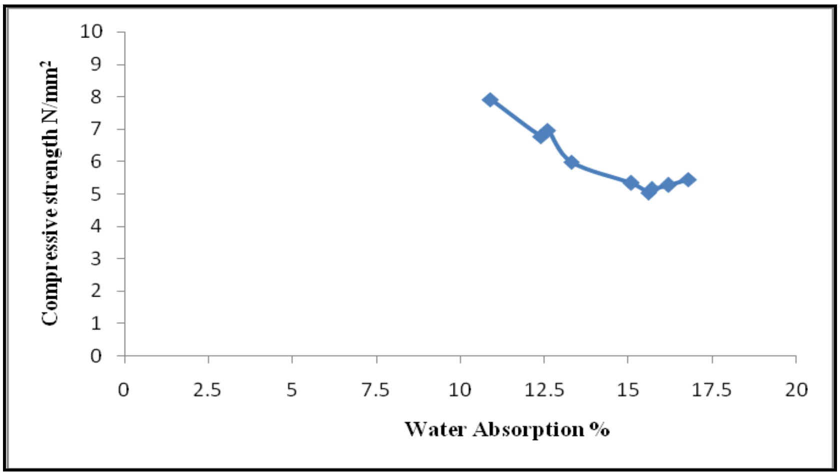

Fig. 14 Comparison between strength Vs water absorption

Conclusion

Based on the experimental study, following conclusions can be drawn regarding the strength behavior of flyash brick;

The study was conducted to find the optimum mix percentage of flyash brick. However the brick specimen of size 230mm x 110mm x 90mm were cast for different mix percentage of Flyash (15 to 50%), Gypsum (2%), Lime (5 to 30%) and Quarry dust (45 to 55%). However the specimens have been tested for seven mix proportions. The mechanical properties such as compressive strength were studied for different mix proportions, at different curing ages. From the results it was inferred that, among the seven proportions the maximum optimized compressive strength is obtained for optimal mix percentage of Flyash-15% Lime-30% Gypsum-2% Quarry dust-53% as 7.91 N/mm².

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