AN EXPERIMENTAL STUDY ON FLY-ASH BRICKS

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Abstract : Fly-ash is produced in vast quantities as a by-product of the burning of fossil fuels for the thermal generation of electricity. Nowadays the utilization of fly-ash in brick manufacture is increased day by day. These materials are used for making bricks in different proportions. By using fly-ash in the preparation of bricks the CO_2 emission may be reduced due to reduction in use of cement. These bricks are useful for various constructional activities. Our aim to improve the engineering properties such as workability, water tightness. To develop cost effective eco-friendly bricks. Fly-ash brick is one of the most innovative and eco- friendly materials to the environment. Fly-ash bricks comprises of various low-cost materials such as fly-ash, fine aggregate, sodium silicate, and hydrated lime. These materials are used for making bricks in different proportions. By using fly-ash in the preparation of bricks the CO_2 emission may be reduced due to reduction in use of cement. This presents the results of an extensive testing program that used fly-ash as a major constituent in the production of lightweight building bricks. Scaled down, pressed bricks were made from varying proportions of fly-ash, sand, hydrated lime, sodium silicate and water. Bricks of three distinct sand to fly-ash ratios were used, namely 50/50, 60/40,70/30 with varying amounts of sodium silicate (5, 10, 15% by total mass) and a 20% hydrated lime content.The materials of different proportions are mixed and then water is added to that mix based on w/c ratio. The mix can be placed into moulds of standard size 190mm×90mm× 90mm. After these moulds have been dried up to 24-48 hours and also oven drying, curing is required for these bricks.

***IndexTerms* - Fly-ash, sand, hydrated lime, sodium silicate, mix proportions, compressive strength.**

I. INTRODUCTION

Approximately 80-90% of the ash formed from burnt coal is carried out of the furnace, then extracted from the flue gas and is known as fly-ash. The remaining coarser fraction fall to the bottom of the furnace where it sinters together to become bottom ash. The structure, composition and properties of the ash particles depend upon the structure and composition of the coal and the combustion processes by which the ashes are formed. In the last 15 years or so the effective utilization of fly-ash has been a major area of concentration for scientists and engineers. Large quantities of fly-ash produced as by-product of coal-based power stations have been viewed as a serious environmental problem. This is due to its constituents being the oxides of silica, alumina, and iron, calcium magnesium along with traces of some toxic elements such as arsenic, selenium and boron. Therefore, no simple disposal method has been considered safe from an environment-protection point of view. Australia alone produces in excess of 8 million tonnes of fly-ash each year. At present10-15% of the fly-ash produced is utilized in the manufacture of cement and concrete. In Queensland there is annually, some ten million tonnes of bituminous (black) coal burnt, producing about two and a half million tonnes of ash residue. Therefore, an effective utilization of fly-ash can be regarded as economically fruitful and environmentally beneficial. It is not surprising that with growing environmental awareness, there has been considerable interest in the use of fly-ash in the brick manufacturing industries. The use of fly-ash in brick manufacturing is not new. Use of fly-ash as a raw material to produce building bricks is not only viable alternative to clay but also a solution to difficult and expensive waste disposal problem. In the present work the attempt has made to find the optimum mix percentage of to obtain maximum compressive strength of fly-ash brick admixed with hydrated lime, sodium silicate and at various proportions.

1.2. Classification of bricks

There are different types of bricks available on the market used for various kinds of purposes. These bricks can be categorized under various headings and subheadings on different basis. The various classifications of types of bricks are briefly discussed below.

A. Classification based on method of manufacturing:

Bricks can broadly be categorized into two types as follows based on how its manufactured:

1. Un-burnt or sun-dried bricks
2. Burnt bricks

B. Classification based on shape:

The ordinary bricks are rectangular solids. But sometimes the bricks are given different shapes to make them suitable for construction. Here we have enlisted different types of bricks available with various shapes.

1. Bull-nose brick
2. Channel bricks
3. Coping bricks
4. Cow-nose bricks
5. Curved sector bricks
6. Hollow bricks

1.3. Need for the Study

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

1.4. Objective:

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

1.5. Scope of Fly-ash:

- Fly-ash is the pozzolana material it can be represented by silica because non-crystalline silica glass is the principal constituent of fly-ash. Slowly and gradually it forms additional sodium silicate hydrate which is a binder, and which fills up the space, and gives us impermeability and more and more strength. We are using fly ash as used in manufacturing of fly ash bricks.
- Fly-ash can be used as prime material in brick manufacturing process. One of the most common uses of fly ash provides significant economic benefits. For various constructional activities such as for medium and low size structures. And also used for non load bearing structures. It is an eco-friendly developed product.

2.LITERATURE REVIEW

1. Lishman (1973):

He had suggested that fly-ash can be moisturized, mixed with coarser aggregate and binding agents, pressed and fired in kilns to produce bricks, similar to clay bricks but having certain distinct advantages. The bricks are said to be approximately 30% lighter than normal bricks, can be produced with much greater compressive and tensile strengths, and can be glazed to improve their water absorption characteristics.

2. Sloanaker (1976):

He had studied class F-fly ash from West Virginia and Pennsylvania to produce fired bricks for construction. He indicated that fired bricks made from feeds of 72% fly-ash, 25% bottom ash, and 3%sodium silicate met commercial specifications. It is also worth noting that recently India has been leading the way in fly-ash brick manufacturing. Rai (1992) indicated that calcium silicate type bricks using fly-ash, sand and lime mixtures can be moulded at high pressures (>19MPa).

3. ObadaKayali (2005):

He investigated that the high performance of bricks from fly-ash. He concluded that the fly-ash brick had 24 % better compressive strength and 44% higher bond strength than the good quality clay brick. Also, he reported that the tensile strength of the fly-ash brick was three times greater than the value for standard clay bricks.

4. Henry Liu et al (2009):

Probed the environmental properties of fly-ash bricks and reported that the fly-ash brick passed the Toxicity Characteristic Leaching Procedure (TCLP) test recommended by Environmental Production Agency (EPA) with large margins. Also it can absorb carbon-dioxide from the atmosphere causing carbon sequestration. Consequently, it reduces the CO_2 in the atmosphere which helps to mitigate global warming.

3.MATERIALS

The materials which are used in the preparation of fly-ash bricks are

1. Hydrated lime
2. Fly-ash
3. Sand
4. Sodium silicate

3.1. Hydrated 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, sodium silicate solution is added to it and which is responsible for the high strength of the compound.

Table3.1. Chemical Composition of lime

Chemical name	Cao	Mgo	Fe_20_3	Al_20_3	Co_2	$Si0_2$
Lime Dry white powder	>83.3	<0.5	<2	<1.5	<5	<2.5

3.2. Fly-ash:

Fly-ashes are heterogeneous fine powders consisting of mostly rounded or sphericalparticles ranging in diameter from < 1 am to 150 µ m. The Australian Standards require a fine-grained" fly-ash to have ≥ 75% passing a 45 µm sieve and a maximum Loss on Ignition (LOI) of 4.0%.

Table 3.2. Main Constituents and Properties of Fly ash

CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3	Na_2O	K_2O	TiO_2	Mn_2O_3
0.1%	70%	25%	1%	0.1%	0.01%	0.1%	0.5%	1.6%	0.03%
Note: pH=4	Particle density= 2.14	Loss on ignition =1.5							

Table 3.3. Physical properties and chemical properties of the fly -ash

Color	Bulk density (g/cm3)	Specific gravity	Moisture (%)	Average particle size
Whitish grey	0.994	2.288	3.14	6.92

Compound	SiO2	Al2O3	Fe2O3	CaO	MgO	SO3	K2O	LOI
Content, % wt	59.00	21.00	3.70	6.90	1.40	1.00	0.90	4.62

Benefits of Fly-ash Bricks for Environment

The increase in greenhouse gases, out of which CO_2 is one of the major constituents, increases the global warming year after year, causing drought and floods. The total CO_2 Emissions globally account for 24,960 million tons at 1990 levels. Cement and building materials industry is one of the major contributors.

Fly-ash bricks uses

The CO_2 emission is about ninety million tons out of cement and forty-nine million tons out of clay bricks production in India. As per the ongoing practices in India, each million clay bricks consume about 200 tons of coal (or any other fuel with equal quantity of thermal values) and emit around 270 tons of CO_2.

Fly-ash bricks production in energy-free route saves the emissions totally, befitting the project to qualify under Clean Development Mechanism (CDM), as envisaged by Kyoto Protocol Uses of Fly-ash.

3.3. Sand:

Two types of sand were used in this study, namely:

1. Fine aggregate
2. Coarse aggregate

3.3.1. Fine aggregate:

Fine aggregate means the sand which is passing through 4.75 mm IS sieve. There are two types of sand like river sand & M sand. River sand means which is available at the shore places. M sand (manufactured sand) which is crushed from coarse aggregates through crushing machines, nowadays M sand is rocking in the city because its eco-friendly & low in cost.

Uses of fine aggregate:

- To provide a mass of particles which are suitable to resist the action of applied loads and show better durability than cement paste alone.
- To provide a relatively cheap filler for the cementing material.
- To reduce volume changes resulting from setting and hardening process and from moisture changes during drying

Table 3.4.Chemical properties and physical properties of fine aggregate

Constituents	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	TiO_2
Natural Sand (%)	80.78	10.52	1.75	3.21	0.77	1.37	1.23	NIL
Physical property	Specific gravity		Water absorption		Fineness modulus			
Fine aggregate	2.49		1.5%		2.93			

3.3.2. Coarse aggregate:

Coarse aggregate means which is breaked from rocks using explosives & crushed into pieces using machines & coarse aggregate sizes 6mm,12mm,20mm,40mm,60mm are divided using big sieves in machines & coarse aggregate like 6,12,20mm is used to mix in concrete for construction purposes & 40mm is used for railroads.

3.3.3. Properties of sand:

- **Porosity (or) permeability:**

It is the property of sand which permits the steam and other gases to pass through the sand. The porosity of sand depends upon its grain size, grain shape, moisture and clay components are the sand. If the sand is too fine, the porosity will be low.

- **Plasticity:** The sand must have sufficient plasticity.
- **Cohesiveness:** It is the property of sand due to which the sand grains stick together during ramming. It is defined as the strength of the sand.

3.4. Sodium Silicate

3.4.1. Properties

Table3.5. chemical and physical composition of sodium silicate

Chemical formulae	SiO_2	Na_20	H_20	Appearance	Specific gravity
Sodium silicate	22-24%	11-12%	64-67%	Crystals (white colour)	1.38

4.TESTS ON MATERIALS

The tests conducted on sand are

1. Sieve Analysis
2. Specific gravity
3. Bulk density

4.1. SIEVE ANALYSIS

Table 3.6. Tabulation and testing results for Sieve Analysis:

IS sieve designation	Weight of retained	% weight retained	Cumulative weight retained	%passing through
4.75mm	32	3.2	3.2	100
2.36mm	70	7	10.2	96.8
2.00mm	36	3.6	13.8	89.8
1.18mm	178	17.8	31.6	86.2
600 microns	226	22.6	54.2	68.4
425 microns	208	20.8	75	45.8
300 microns	102	10.2	85.2	25
150 microns	64	6.4	91.6	14.8
75 microns	62	6.2	97.8	8.4
pan	22	2.2	100	2.2

Coefficient of uniformity, (Cu)

$=(D_{60})/(D_{10})$

$= (0.9)/ (0.6)$

$= 1.5$

Coefficient of curvature, (C_c)

$= (D_{30}^2)/(D_{10})\times(D_{60})$

$= (0.46)^2/ (0.9 \times 0.6)$

$= 0.39$

Result:

1. Coefficient of uniformity, (Cu) = 1.5
2. Coefficient of curvature, (C_c) = 0.39

4.2. SPECIFIC GRAVITY OF SOIL PARTICLES BY USING PYCNOMETER METHOD

Description	Trail 1	Trail 2	Trail 3
Weight of empty bottle (w_1)	640	640	640
Weight of bottle + sand (w_2)	1392	1402	1416
Weight of bottle +sand+ water (w_3)	1790	1794	1804
Weight of bottle + water (w_4)	1340	1340	1340
Specific gravity $=\frac{\omega_2-\omega_1}{(w_2-\omega_1)-(\omega_3-\omega_4)}$	2.49	2.47	2.48

Result : Specific gravity of sand should be 2.48

4.3. BULK DENSITY

%water added to sand	0	2	4	6	8	10	12	14	16	18
Bulking of sand	500	570	600	610	620	660	590	570	520	500

5.ESTIMATION

Estimation procedure for mix proportions

1) Mix proportion (50/50)
2) Mix proportion (60/40)
3) Mix proportion (70/30)

5.1. Mix proportion (50/50):

- Sand -50%
- Fly-ash-50%
- Hydrated lime -20% (by total mass)
- Sodium silicate-5% (by total mass)

Procedure:

1) Take standard size of brick mould of having size 190mm*90mm*90mm
2) Volume of brick mould = (190mm)*(90mm)*(90mm)
   $=1.539*10^{-3}$ m^3
3) Additional 50% of material will be added to the considered amount of material
   =1.54
   Total volume required = $(1.54)*(1.539*10^{-3)}$
   $= 2.308*10^{-3}$ m^3
4) Materials required are in kilograms
   Fly- ash = $(1)*(2.308*10^{-3})*(1440)$
   =3.32 kg
   Sand = $(1)*(2.308*10^{-3})*(1580)$
   = 3.64 kg
   Hydrated lime = 20% (by total mass)
   = (3.32+3.64) *(20/100)
   = 1.392 kg
   Sodium silicate = 5% (by total mass)
   = (3.32+3.64) *(5/100)
   =0.348kg
5) Sodium silicate solution will be prepared with the hot water when heated at a temperature about 175^{o}c.
6) The above estimation details are for the preparation of 3 bricks.

6.METHODOLOGY

Fly-ash bricks are hi-tech well-improved quality bricks used for construction of brick masonry structures. They are used as replacement for normal clay bricks and has better properties than it. Fly-ash bricks competitive in comparison to the conventional clay bricks and provide enormous indirect benefits. The utilization of fly-ash bricks results in conservation of natural resources as well as protection of environment.

The important compositions of fly-ash bricks are:

1. Fly-ash
2. Sand
3. Sodium silicate
4. Hydrated lime
5. Water

6.2. Manufacture of Fly-ash Bricks:

There were four major steps involved in producing the test specimens. These included, proportioning of constituents, mixing, molding/pressing of fly-ash bricks and finally drying. The process of manufacturing of bricks from fly-ash involves preparation of fly-ash with lime and, sodium silicate molding and then drying and burning of bricks. The bricks are building materials which are generally available as rectangular blocks. The bricks do not require any dressing and brick laying is very simple compared to stone masonry.

6.2.1. Composition:

Three different sand to fly-ashes ratios (by mass) were used, namely, 50/50, 60/40, 70/30. Sodium silicate (5, 10, 15%) and hydrated lime (20%) contents were added to the mix with proportions calculated by multiplying the percentages in parenthesis by the total mass of primary raw materials.

6.2.2. Mixing:

The mixing of raw materials was performed in two stages. First, the dry materials (ash, sand, hydrated lime) were mixed thoroughly using hand mixing. This created uniform mixture and was thus performed in a sample preparation. The second stage involved the addition of water (as required) as based on w/c ratio. This was done gradually until the mixture was of a uniform and moldable consistency.

Fig 6.1. Mixing

Fig 6.2. Moulding

6.2.3. Moulding:

A special steel mould (or) with moveable top and bottom platens was used to produce the fly ash bricks. It was found by trial and error method we are produce a test brick of size approximately {190 mm x 110 mm x 70mm} the ratio of these dimensions are similar to those of a standard size building brick {190mm x 90mm x 90mm}.

6.2.4. Demoulding:

Demoulding is a process which is used to remove the brick from the mould safely without any damage to it. Demoulding is done by hitting the sides of the mould for depleting the bond between the walls of mould and the material present in it. After certain strikes to it the material loses its stickiness and easily come out of the mould without any damage to it.

Fig 6.3. After demoulding

Fig: 6.4. Oven drying

6.2.5. Drying:

The starting temperature of the bricks are exposed to atmosphere was 25°C approximately. This was increased to 50°C Over 30 minutes and held at that temperature for one hour, before raising the temperature again, to 105°Cover 30 minutes and holding it at that temperature for one hour. Note that the gradual increase to 105°C was to minimize shrinkage/cracking. Subsequently, temperature was increased to 250°C over 40 minutes and remained at 250°C for 100 minutes.

6.2.6 Curing:

Curing is a process which converts the brick into tough or hard surface. Water sprinkling is one type of curing process. The required quantity of water is sprinkle on all sides of the brick and is exposure to the sun light. The water is absorbed by the pores present in the brick and increase its weight. To reduce the moisture content it is exposed to the sun light and the water content is evaporated by the heat produced by the sun. This curing gives internal strength to the brick for bearing load which act upon it. Curing is most important for any RCC structures.

7.TESTS ON FLY-ASH BRICK

Types of Tests on Bricks for Construction Purpose:

Following tests are conducted on bricks to determine its suitability for construction work

1. Water Absorption test
2. Compressive strength test
3. Hardness test
4. Shape and size
5. Sound ness test

7.1. Water Absorption Test on Bricks

Weight of brick before absorption of water(w_1) = 2.59 Kg

Weight of brick after absorption of water(w_2) = 2.98 Kg

Amount of water absorbed = $(\mathbf{W_2} - \mathbf{W_1}) / \mathbf{W_1}$ **X 100**

= ((2.98-2.59)/2.59) X 100

= 15%

The water absorption of brick should not absorb 20% of the total weight of brick.

7.2. COMPRESSIVE STRENGTH TEST

Table 7.1. Tabulation results for mix proportion 50/50 (sand- fly-ash)

50/50 mix proportion			
Days	Failure Load (KN)	Cross-sectional Area M^2	Compressive strength N/mm^2
3 days	18	0.0171	1.05
7 days	22	0.0171	1.28
14 days	24	0.0171	1.41

Table 7.2. Tabulation results for mix proportion 60/40 (sand- fly-ash)

60/40 mix proportion			
Days	Failure Load (KN)	Cross-sectional Area M^2	Compressive strength N/mm^2
3 days	24	0.0171	1.41
7 days	28	0.0171	1.63
14 days	32	0.0171	1.87

Table 7.3. Tabulation results for mix proportion 70/30 (sand- fly-ash)

70/30 mix proportion			
Days	Failure Load (KN)	Cross-sectional Area M^2	Compressive strength N/mm^2
3 days	30	0.0171	1.75
7 days	35	0.0171	2.04
14 days	50	0.0171	2.92

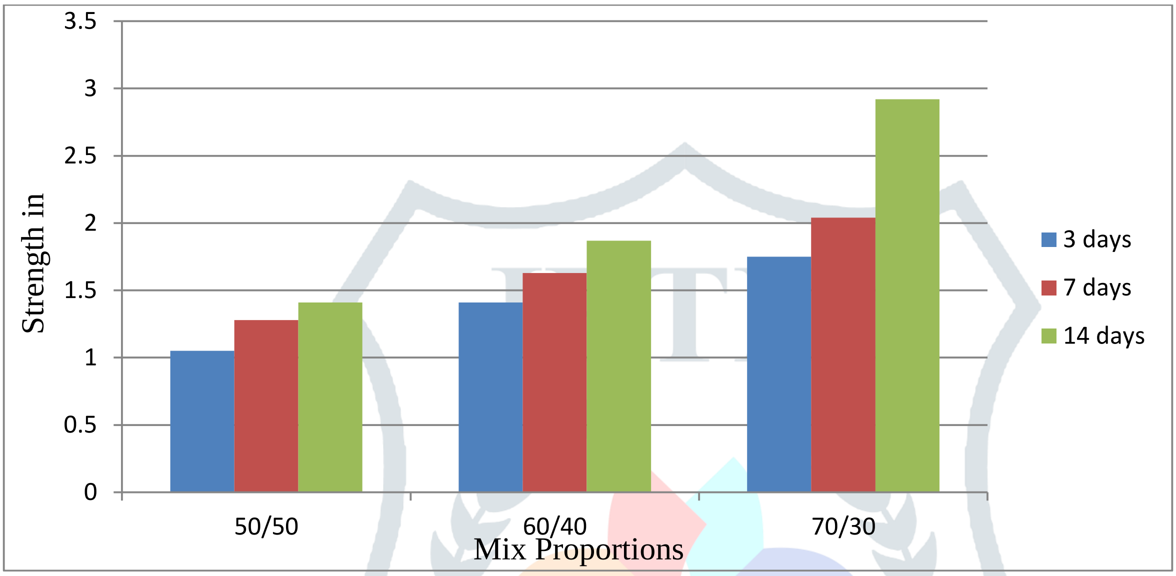

Fig: 7.1. Bar chart for compressive strength test

7.3. HARDNESS TEST

A good brick should resist scratches against sharp things. So, for this test a sharp tool or finger nail is used to make scratch on brick. If there is no scratch impression on brick then it is said to be hard brick.

7.4. SHAPE AND SIZE TEST

Shape and size of bricks are very important consideration. All bricks used for construction should be of same size. The shape of bricks should be purely rectangular with sharp edges. Standard brick size consists length x breadth x height as 19cm x 9cm x 9cm. To perform this test, select 20 bricks randomly from brick group and stack them along its length, breadth and height and compare. So, if all bricks similar size then they are qualified for construction work.

Fig 7.1. Shape and size of brick

Fig 7.2. Soundness test

7.5. SOUNDNESS TEST

Soundness test of bricks shows the nature of bricks against sudden impact. In this test, 2 bricks are chosen randomly and struck with one another. Then sound produced should be clear bell ringing sound and brick should not break. Then it is said to be good brick.

Advantages of Fly-ash:

1. It is highly economical.
2. Use of Fly-ash is environmentally friendly as the waste materials from industries are effectively being used to create quality building materials.
3. Fly Ash has very small particles which makes the bricks are highly dense and reduces the permeability of bricks. It can add greater strength to the building.
4. The brick mixture generates a very low heat of hydration which prevents thermal cracking.
5. Fly Ash concrete is resistant to acid and sulphate attacks.
6. The shrinkage of fly ash concrete is very less.
7. The use of fly ash gives concrete good work ability, durability and finish.

8.CONCLUSION

1. The results of this investigation suggest that it is possible to produce lightweight bricks from fly-ash which could satisfy engineering requirements. In particular, with proper proportioning, these bricks can produce compressive strengths comparable to those of common clay bricks.
2. A combination of 70/30 for common sand/fly-ash with 15% sodium silicate and 20% lime would produce the best performing brick in terms of strength, mouldability and water absorption. As compared with fly-ash bricks containing silica sand, it was found that fly-ash bricks containing common sand performed better in terms of water absorption while their strength characteristics were not significantly different.
3. The strength of the fly-ash brick increases day by day. The compressive strength of fly-ash brick is three times more than the normal clay brick.
4. If the curing time of fly-ash bricks is done for 91 days it gains the strength up to 10-12 N/mm^2.
5. Sodium silicate place a key role in increasing the strength of the fly-ash brick.
6. Our aim to reduce the industrial waste which is coming from the industries.to develop Eco- friendly products used in various constructional activities

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