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Evaluate properties of fly ash based Geopolymer Bricks

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Abstract- *In the recent years, study focus on the sustainable construction development. As the effect of greenhouse gases is increased more due to high range of CO_2 emissions associated with manufacturing process of OPC. Hence, research studies the possibility of geopolymer manufacturing from fine fly ash (Class F) and Alkaline solution, then studied the hardened properties of fly ash bricks with addition of lime and gypsum. In this paper, we have studied the composition of high-strength fly ash-lime bricks using a fine pulverized fuel ash class-F. The purpose of this research is to evaluate properties of pulverized fuel ash based geopolymer brick along with its durability, the size of the brick is adopted as 230mm×110mm×70mm. The brick is casted with different percentages of Fly ash (55-65%), M-sand (25-35%), Hydrated lime (5-15%) and Gypsum (3%). According to the various research, the optimum w/b ratio is to be taken as 0.35 and the temperature for curing is to be selected as normal room temperature. The tests on specimen to be conducted are a compressive strength, water absorption test, efflorescence test, impact test for various mixing proportions on respective curing period of 7 days,14 days and 28 days. From the results, the maximum optimized results are obtained for optimum mixing proportion of Fly ash-65%, Hydrated lime-12%, Gypsum-3%, M-sand -25%.*

Key words- Evaluate, Properties, pulverized fuel ash, hydrated lime, gypsum, M-sand, geopolymer Bricks.

1. INTRODUCTION

In the construction industries, bricks are widely used construction material, as it may be used for the outer portion or the inner portion i.e. for the partition of a building. Making of brick is more important technological processing sector to use a solid waste just because of that the construction industry uses a large quantity of raw materials. For the manufacturing of a green buildings, it becomes essential to utilise waste material in such a way that the process of construction must be eco-friendly. For an excessively large quantity of production along with the application of these type bricks by using waste materials, further investigation and improvement is essential according to the technical aspects, economical aspects & environmental aspects.

In the recent years, there is a technology to research and study the utilization of by products and waste in the manufacturing of fly ash-lime bricks. Successful utilization of waste materials that will result in the reduction of hazardous effect on environment and waste management. Efforts in this area is focus in identifying and optimizing the benefits of adding waste materials to Quarry Dust. The Pulverized fuel ash is a very useful by-product from thermal power plants using pulverized coal as fuel and it has a good pozzolanic activity. This resource has been utilized for manufacture of pulverized fuel ash-lime bricks as a replacement to common burnt clay buildings bricks which leads to conserving the depletion of natural resources like clay and improving the quality of environment. Pulverized fuel ash i.e. Fly ash-lime bricks are mainly consisting of pulverized fuel ash in major quantity (55-65%), quarry sand (25-35%), lime (8-15%) and gypsum (3%). Generally, Pulverized fuel ash-lime brick is to be manufactured by intergrading blending various raw materials which are then moulded into bricks. These bricks are subjected to curing period at different temperatures. PET fibres are also used for the manufacturing of fly ash-lime bricks to minimize the wastage and harmful effects of PET bottles as these products are non-biodegradable.

2. OBJECTIVE OF INVESTIGATION

1. To utilize the waste material fly ash produced at thermal power plant.
2. To obtain the optimum mix proportion having good compressive strength.
3. To evaluate properties of fly ash bricks at different curing period and at varying temperature.

4. To minimize the excessive use of earth-based material as clay for the manufacturing of brick that resulted in resource depletion, environmental degradation.
5. To optimize fly ash based geopolymer bricks with addition of foaming agent.

3. LITERATURE REVIEW

MM Abdullah et.al [1] has done an experimental work on the manufacturing of alkaline activated fly ash-based geopolymer bricks. According to their study, bricks are mostly useable construction material. Generally, such conventional bricks have been made up of clay at relatively high temperature into the kiln firing. This conventional process requires more energy and emits more CO_2 in the environment. This causes harmful effects on surrounding environment. Because of this conventional production process, inadequacy of natural ingredients is going to a big issue in all over the world. To minimize the depletion of environment, more research work has been done by them on production of eco-friendly bricks from waste materials. They suggest that a waste material i.e. fly ash which is produced after coal firing at the thermal plants causes dangerous pollution in surrounding area. To reduce environmental depletion due to excessive use of clay and to utilise fly ash, it can be used as a raw material for production of the brick. This will be an alternate solution in terms of economic and environmental parameters.

A. Sumathi et.al [2] has done experiments on the useful properties fly ash and its actual use in construction industry. Various experiments were conducted by A. Sumathi to find appropriate mix proportion of fly ash bricks. The specimen size of dimensions 230mm x 110mm x 90mm was selected. For the sampling, Various mix proportions was taken as follow-fly ash (15 to 50%), gypsum (2%), lime (5 to 30%) and quarry dust (45 to 55%). The test for finding a compressive strength was conducted on various mixing proportions. The compressive strength varies with the change in mix proportions which was cured at different curing period. From various test conducted on sample, for mix design of fly ash-15%, quarry dust-53%, lime-30% and gypsum-2% obtained a maximum compressive strength.

P. Sakthivel et.al [3] has purposely done an experiment to investigate the behaviour of alkali activated fly ash bricks and its sustainability in various environmental condition. The size of the bricks was adopted during the study as 190mmx90mmx90mm. The brick was cast with fly ash to river sand and m-sand (silica sand) with the different ratios of 1:1.6, 1:1.8, 1:2 by weight. The minimum water/ binder ratio of 0.416 was selected by them. Bricks was casted in this study under ambient curing. This is very difficult to predict any change in properties of such alkali activated fly ash-mortar samples by optically. Under the Optical microscope, they observed that the corrosion may increases with increase in time of exposure. During the experiment, they put geopolymer samples in the acid solution for 18 weeks, almost lost its alkalinity and showed very low weight loss in the range from 0.54% to 0.28% of initial weight. More weight loss was observed in mix proportion contain more percent of Na_2SiO_3. Also, the geopolymers shows good resistance properties when put into a sulfuric acid.

M. Chester et.al [4] has done various experiments on the characteristics and the mechanical properties of light weight pulverised fuel ash i.e. fly ash bricks. As per their study, results of an extensive testing program that used Class F fly-ash as a major constituent in making of lightweight bricks. They take varying proportions of fly-ash, M-sand, lime, Na_2SiO_3 and potable water during the production of brick sample. They have used three distinct fly-ash to sand ratios of 50/50, 70/30 and 90/10, with varying amounts of sodium silicate (5, 10, 15, 20% by mass) and a 5% hydrated lime content in mix. Also, they have used two different types of sand, silica sand and common sand. Thus, resulting in twenty-four different types of fly-ash brick. The results of their study suggest the possibility to produce lightweight fired bricks from fly-ash to satisfy engineering requirements. They mention that by maintaining proper mix proportions, bricks having maximum strength in compression and absorption characteristics can be produced. They found that bricks containing fly-ash/sand in the ratio of 70/30 with addition of 5% lime and 15% Na_2SiO_3 are good in compression, easy to mould and less water absorption properties. Apart from this, the weight of such brick is less as compare with the clay bricks fired in kiln.

Gurdarshan Singh Brar et.al [5] has studied the effect of fly ash instead of clay taking a maximum replacing ratio. Also, they have check properties of fly ash bricks against the radiation. The brick sample was prepared using fly ash as an admixture to clay. The Shielding behaviour was measured by transmuting a narrow beam. By using the theoretical

calculations, they mention that the recorded values are match with the theoretical. During the test, the value of effective atomic number and effective electron density vary with the variation in mixing of fly ash in brick sample. Also, the comparison was done with concrete to study the effect of radiation on property of shield. At the time of moderate energy gamma radiation, such brick shows better shielding property. They make a remark that such bricks are eco-friendlier compared with conventional clay brick and can be used for construction.

4. METHODOLOGY

A. Material

1.Fly ash

Fly ash is a waste material produced by burning a coal at thermo-electric power plant. A waste material is collected in electrostatic precipitators or filter bags. The particle size may vary from 0.5 μ to 100 μ and it consist of spherical shape. Main constituents present in fly ash are silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3).

According to the ASTM, the fly ash is divided into F-class fly ash and C-class fly ash. Generally, a class-F fly ash contains CaO less than 5% and produced by burning anthracite or bituminous coal during the production of energy. It has a good pozzolanic property. While a C-Class fly ash consists of more than 10% CaO compared with F-class fly ash. C-class fly ash posse's good cementitious properties as well as pozzolanic properties. It may produce after burning lignite or sub-bituminous coal.

For the casting of the geopolymer bricks, we have used the processed fly ash of P60 grade.

Properties of Fly ash (As per IS 3812 Part-1-2013)

Physical Properties

1. Fineness= 368 m^2/kg
2. Lime Reactivity = 6.09 N/mm^2
3. Moisture content = 0.30%

Chemical Properties

1. Loss on Ignition Max.= 1.13%
2. $SiO_2+Al_2O_3+Fe_2O_3SiO_2$=92.73 %
3. SiO_2 = 59.57 %
4. MgO= 2.17 %
5. SO_3= 0.8 %
6. Na_2O= 0.55 %
7. Total Chlorides = 0.03 %

Fig.1 Fly ash

2.Hydrated Lime

Lime has a good binding property. So that it is used as a building material in geopolymer brick. In a Lime, calcium oxide (CaO) is associated with magnesium oxide (MgO). During the reaction, lime conglomerates with fly ash at normal temperature which produce cementations composition. During the fusion process the calcium silicate hydrates get produced. The strength of the composition is depending upon formation of calcium silicate hydrates.

Fig. 2 Lime

3.Gypsum

Gypsum is a naturally occurring soft crystalline rock having binding properties. It has low bulk density; it is incombustible. It is good sound absorbent. It has fire resisting capacity. It dried rapidly and gives superior surface finish. The specific gravity is observed of about 2.3 gm/cc. While the density is about 2.7 to 3.1 gm/cc.

Fig. 3 Gypsum

4. Alkaline Solution- Sodium Hydroxides – NaOH

The NaOH is omnipresent in solid state. It may be in Flake form or in Pellet form. The cost of NaOH varies with its purity. NaOH is used to activate the Na_2Sio_3 during the polymerization. In this investigation the sodium hydroxide flakes are used. The molecular weight of NaOH is 40 gm/mol. Sodium hydroxide appears as white, waxy, opaque crystals. It is an odourless. Pure sodium hydroxide is a colourless, crystalline solid that melts at 318 °C without decomposition.

Fig.4 NaOH-Flake

Sodium Silicate – Na_2SiO_3

The solid contain in sodium silicate consists of

Na_2O=14.53 %

SiO_2= 23.72%

Water= 61.75%

Appearance of the Sodium Silicate is notice as white to greenish opaque crystals. The density of Sodium Silicate is 2.61 gm/cm^3.

5 .M-sand

M-sand i.e. quarry dust is a by-product collected after the crushing of stone in crusher. It should free from organic impurities. The quarry dust of uniform size must be used for mixing the sample. All particles should be fine. The physical properties of quarry dust are taken from test results. The on sample is carried as per IS Specification.

Specific Gravity 2.56-2.62

Bulk Density (kg/m^3) 1650-1800

Absorption (%) 1.18-1.45

Fine particles less than 0.075 mm (%) 12-16

Zone-II

Fig. 5 M-sand

6. PET

PET is basically being a thermo plastic resin composed of phthalates.

Basic Properties of Recycled Pet

- Density: 1380 kg/m3
- Elastic Modulus: 3100 N/mm^2
- Tensile strength: Around 450 MPa
- Ultimate elongation: 11.2%

Physical Properties of Poly Ethylene Terephthalate

- Melting point >250ºC
- Specific Gravity: 1.32 – 1.43

7.Water

Water is very important parameter for preparation of alkaline solution. It is necessary that water used in mixing shall be portable water.

B. Mixing of Materials

1. Alkaline solution preparation

By dissolving flakes of sodium hydroxide into portable water, an alkaline solution is prepared. Flakes used in an alkaline solution are of commercial grade having a purity about 97%. We have maintained the molarity of solution about 13. It is mandatory to prepare a sodium hydroxide solution one day prior to bricks batching. The Na_2SiO_3 and NaOH solution is mix before actual casing of geopolymer bricks.

Quantity of alkaline solution

To calculate quantity of material, we have taken the solution to fly ash ratio of about 0.35 by mass (as per the references).

[(Na_2SiO_3 + NaOH)/fineness of fly ash] ratio by mass = 0.35

(Na_2SiO_3 + NaOH)/ 368 by mass = 0.35

(Na_2SiO_3 + NaOH) by mass = 128 kg/m^3

Now, select the ratio of Na_2SiO_3 to NaOH is 1.

Therefore,

Mass of Na_2SiO_3 = 64 kg/m^3

Mass of NaOH = 64 kg /m^3

2. Quantity of Material

The actual size of brick is to be taken as 230mm×110mm×70mm as per the IS for the non-modular bricks [14].

Table-1 Mix Percentage for Geopolymer Bricks

Proportions	Fly ash %	Hydrated Lime %	Gypsum %	M-sand %
I	55	8	3	32
II	55	10	3	32
III	60	10	3	30
IV	60	12	3	30
V	65	12	3	25

Table-2 Mix Percentage for PET Bricks

Proportions	Fly ash %	OPC %	PET %	M-sand %
I	55	8	0	37
II	55	8	0.5	37
III	60	8	1.0	32
IV	60	8	1.5	32
V	60	8	2.0	32

C. Testing of Materials

The various tests have been done to find the mechanical properties of the bricks as per the IS 3495-1992.

1.Compressive Strength of geopolymer brick -

The test procedure for finding a compressive Strength of geopolymer brick is adopted from IS 3495-1992 Part-I. The Compressive Strength test gives the load carrying capacity of brick under gradually applied load under a rate of 14 N/mm^2.

Compressive strength (f_c) = Load/Area (N/mm^2)

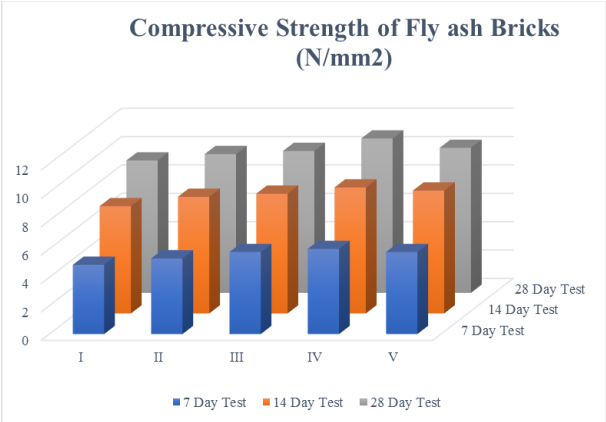

Chart 1: Compressive strength of Fly ash bricks

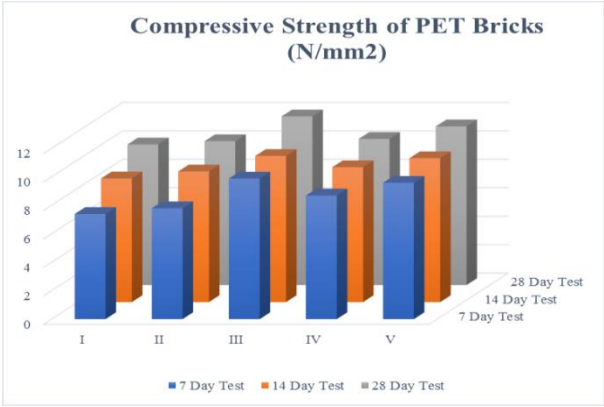

Chart 2: Compressive strength of PET Bricks

2. Water Absorption Test

The ware absorption test procedure is adopted from IS 3495-1992 Part-II. The water absorption gives the quantity of water being absorbed by bricks in time.

Water Absorption = $(M_2-M_1)/M_1 \times 100$ %

Table-3 Water absorption for fly ash Bricks

Proportions	M_1 kg	M_2 kg	$(M_2-M_1)/M_1 \times 100$ %
I	2.814	3.103	10.16
II	2.859	3.114	10.51
III	3.100	3.419	10.29
IV	3.105	3.427	10.37
V	3.125	3.448	10.33

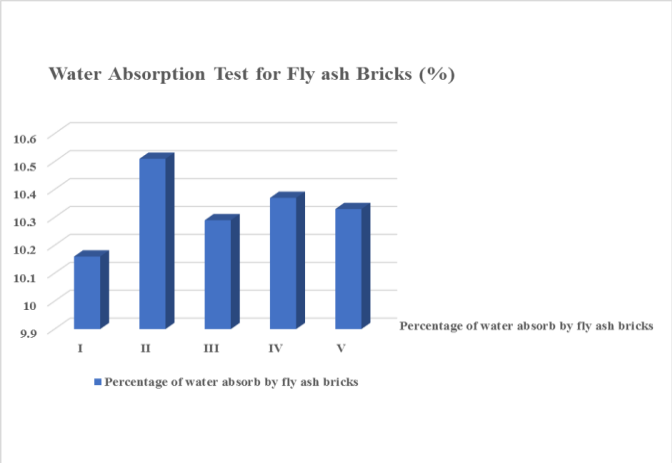

Chart 3: Water absorption of fly ash Bricks

Table-4 Water absorption for PET Bricks

Proportions	M_1 kg	M_2 kg	$(M_2-M_1)/M_1 \times 100$ %
I	2.714	2.973	9.54
II	2.765	3.023	9.51
III	2.918	3.196	9.53
IV	2.944	3.227	9.61
V	3.125	3.423	9.54

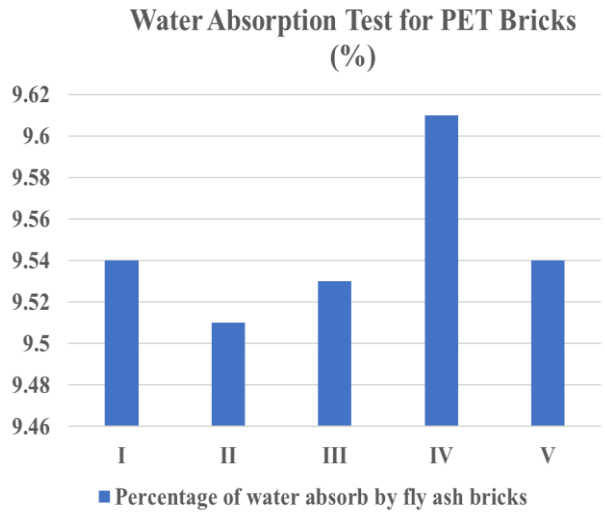

Chart 4: Water absorption of PET Bricks

3. Efflorescence Test-

The Efflorescence test procedure is adopted from IS 3495:1992 Part-III. The Efflorescence test results indicate that the percentage of white spots on the surface of brick.

i. Nil- No percentile deposit of efflorescence.
ii. Slight- Up to 10% Area covered with a thin salt deposit
iii. Moderate- Up to 50% area covered, Heavy deposit, No powdering or flaking
iv. Heavy- Covered area of 50% or more, deposit is said to be Heavy, No powdering or flaking
v. Serious- It consist of heavy deposit on surface, Powdering or flaking can observe.

The Efflorescence test has done on clay brick, fly ash brick sample and PET bricks. The results are compared with reference to above. The visual observation shows that grey or white deposits are slight to moderate in normal clay brick and less than 10% on the surface area in fly ash brick. No efflorescence is found on test samples of PET bricks.

4. Impact Test-

The test on bricks was taken after 7, 14,28 days of curing. Minimum 5 brick sample of each mix proportion have been taken for different curing day. Then allow the sample to freely fall from height of 1m from the ground level. Note the pieces how much it was broken.

As we have used OPC in PET bricks, negligible effect is observed for all mix proportion. Except for I st mix proportion after 7day curing, sample was broken as it doesn't contain PET fibres in it.

5. Dimension Test-

As per the IS 12894:2002, the standard Modular Size of Pulverized fuel ash-Lime is 190mm×90mm×40mm & 190mm×90mm×90mm, whereas the Non-Modular Size of the brick is 230mm×110mm×30mm&230mm×110mm×70mm.

The moulded geopolymer brick is having a rectangular shape, the size of a sample is of 230mm×110mm×70mm.The edges of sample bricks are sharp and straight.

6.Colour Test-

Fly ash brick has uniform grey colour throughout. Fly ash brick does not contain any cracks and fissures on the brick. When a brick is struck against another brick, it gives a clear metallic ringing sound. It is observed that a freshly fractured brick has a homogeneous compact structure without any lumps.

V. CONCLUSION

Based on investigation, the following conclusions have been drawn for various mix proportion of geopolymer bricks-

1. Geopolymer brick shows good compressive strength at mix proportion of Fly ash 60%, lime 12%, M-sand 30% and PET bricks for mix proportion of 60% fly ash, 8% OPC, 1% PET fibres, 32% quarry dust.

2. Geopolymer bricks absorb water below 15% whereas PET bricks absorb water below 10%.

3. The effect of flake form of sodium hydroxide activator on processed and unprocessed fly ash were analysed and seen that the activators play important role for achieving the strength of geopolymer bricks.

4. There is less impact effect on geopolymer bricks and PET bricks.

5. Uniformity observed in colour and having a good compacted mass with a perfect rectangular shape.

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