Evaluate properties of fly ash based Geopolymer Bricks

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Abstract-

In the recent tears, 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 studies the fresh and hardened properties of geopolymer. In this paper, we have studied the synthesis of high-strength geopolymer using fine high-calcium fly ash. The purpose of the present study is to evaluate the properties of fly ash based geopolymer brick and 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%). Minimum water/binder ratio of 0.35 is to be selected as per the previous research at room temperature. The compressive strength, water absorption test, efflorescence 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%, Quarry dust-25%.

Key words- *Evaluate, Properties, Fly ash, Lime, Gypsum, Quarry Dust, Geopolymer Bricks.*

I. INTRODUCTION

In the construction industries, bricks are widely used construction material, as it is mainly used for the construction of outer and inner walls in buildings. The brick industry is the most indicated technological activity sector to utilize solid waste due to the large quantity of raw material used by the sector as well as by the large volume of final products in construction. For manufacturing an eco-friendly building, it is important that the material using in such construction process should be atmosphere friendly. For wide production and application of bricks from waste materials, further research and development is needed, not only on the technical, economic and environmental aspects but also on standardization, government policy and public education related to waste recycling and sustainable development.

In recent years, there is a technology to research and study the utilization of by products and waste materials in the production of Fly Ash 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 in the production of fly ash-lime bricks to minimize the wastage and harmful effects of PET bottles as these products are non-biodegradable.

II. 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.

III. LITERATURE REVIEW

MM Abdullah et.al[1] has studied on production of fly ash-based geopolymer bricks. According to their study, bricks are the world's most versatile, durable and reliable construction material. The conventional bricks are manufactured from clay at a high temperature kiln firing and thus contain more consumption of energy and have excessive carbon footprint in surrounding environment. In many areas of all around the world, there is a shortage of natural source material for production of the conventional clay bricks. To reduce the depletion of environment and sustainable development, extensive research has been done by them on production of eco-friendly bricks from waste materials. They found that fly ash is a waste material of coal firing thermal plants and its accumulation near power plants causes severe pollution problems. Hence, the utilization of fly ash as a raw material for brick making will be a very beneficial solution in terms of economic as well as environmental aspects.

A. Sumathi et.al[2] makes the conclusion that the use of fly ash has many advantages, its low hydration at early stage causes the strength to be low. Hence, the experimental investigation was carried out by them to find the optimum mix percentage of fly ash brick. They have taken the brick specimen of size 230mm x 110mm x 90mm were cast for different mix percentage of Fly ash (15 to 50%), Gypsum (2%), Lime (5 to 30%) and Quarry dust (45 to 55%), compressive strength was studied for different mix proportions. The results show the variation of compressive strength for different mix proportions of materials mentioned earlier at different curing ages. From the test results they conclude that, the maximum compressive strength is obtained for mix proportion of Fly ash-15% Lime-30% Gypsum-2% Quarry dust-53%.

P. Sakthivel et.al[3] has purposely done a study to investigate the behaviour of Fly ash based Geopolymer eco Bricks and its Durability. 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. Visual inspection of Geopolymer mortar samples did not reveal any recognizable change in colour and remained structurally intact though the exposed surface turned slightly softer. By using Optical microscope, they have found the corroded surface could which increased with time of exposure. After exposure in the acid solution for 18 weeks, the Geopolymer samples almost lost its alkalinity and showed very low weight loss in the range from 0.54% to 0.28% of initial weight. Loss of weight was found higher for specimen with higher percent of Na_2SiO_3.As per their study, results indicate that Geopolymers are highly resistant to sulfuric acid.

M. Chester et. al[4] has done an experiment on the behaviour and the mechanical properties of light weight fly ash bricks. As per their study, results of an extensive testing program that used Class F fly-ash as a major constituent in the production of lightweight building bricks. The brick samples were made from varying proportions of fly-ash, sand, hydrated lime, sodium silicate and water. 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. During the study they mention that with proper proportioning, these bricks can produce with a good compressive strength and absorption characteristics comparable to those of clay bricks. The bricks produced using a combination of 70/30 for fly-ash/sand with 15% Na_2SiO_3 and 5% lime produced the best performing brick in terms of strength, its mould ability and water absorption. Apart from exhibiting characteristics comparable to those of normal fired clay bricks, the fly-ash bricks produced a significant weight reduction of approximately 50% making them a viable alternative.

Gurdarshan Singh Brar et.al[5] has studied to determine the effect of fly ash with a high replacing ratio of clay on the radiation shielding properties of bricks. They have measured some interaction parameters of clay fly ash bricks. For the investigation of shielding behaviour, fly ash bricks were moulded using an admixture to clay. A narrow beam transmission geometry condition was used for the measurements. The measured values of these parameters were found in good agreement with the theoretical calculations. At selected

energies the values of the effective atomic numbers and effective electron densities showed a very modest variation with the composition of the fly ash. This seems to be due to the similarity of their elemental compositions. The obtained results were also compared with concrete, in order to study the effect of fly ash content on the radiation shielding properties of clay fly ash bricks. After performing all test on test sample, they make a remark that the clay fly ash brick shows a good shielding property for moderate energy gamma rays. Therefore, these bricks are feasible and eco-friendly compared with traditional clay bricks used for construction.

IV. METHODOLOGY

A. Material

1.Fly ash

Fly ash is a fine, glass-like powder recovered from gases created by coal-fired at thermo- electric power generation. Fly ash material is solidified while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags. Fly ash particles are of spherical in shape and the size ranges from 0.5 μ to 100 μ. Fly ash consist mainly of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3).

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 is produced after burning lignite or sub-bituminous coal. Class C fly ash has CaO content more than 10%. In addition to pozzolanic properties, this possesses more Cementous properties and having a specific gravity is of 2.19.

For the casting of the geopolymer bricks, we have used the processed fly ash of P60 grade taken from the Dirk India Pvt. Ltd Nashik.

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 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. During reactions between hydrated lime and pulverized fuel ash, the calcium silicate hydrates get produced. This calcium silicate hydrates are responsible for the high strength of the compound.

Fig. 2 Lime

3.Gypsum

Gypsum is a binder occurring naturally as a soft crystalline rock. It has less bulk density, it is incombustibility and has a good sound absorbing capacity. It is good fire resistance with 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 cm. The density of gypsum powder is 2.8 to 3 grams per cubic cm.

Fig. 3 Gypsum

4. Sodium Hydroxides - NaOH

The sodium hydroxides are available in solid state. The purity of the substances causes variation in the cost of the sodium hydroxide. Since the geopolymer brick is homogenous material and its main process to activate the sodium silicate, so it is recommended to use the lowest cost i.e. up to 94% to 96% purity. In this investigation the sodium hydroxide flakes are used. The molecular weight of NaOH is 39.997 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

5.Sodium Silicate – Na_2SiO_3

The solid contain in sodium silicate which is taken from India Chemicals are

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.

6.M-sand

Getting good Quarry dust free from organic impurities and salts is very difficult in now a day. While adding the Quarry dust to the mix, the Quarry dust should be in uniform size i.e. all the Quarry dust particles should be fine. The Quarry Dust obtained from local resource was used in brick to cast test bricks. The physical properties and chemical properties of Quarry Dust are obtained by testing the samples as per IS Specification.

Fig. 5 M-sand

Table -1 Properties of M-sand

Property	M-sand
Specific Gravity	2.56-2.62
Bulk Density (kg/m^3)	1650-1800
Absorption (%)	1.18-1.45
Moisture Content (%)	0
Fine particles less than 0.075 mm (%)	12-16
Sieve Analysis	Zone-II

7. 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

- Coefficient of Thermal Expansion: 7 x 10-3/ºC
- Long Term Service Temperature: 115 - 170ºC
- Melting point 260ºC Specific Gravity: 1.3 – 1.4

7.Water

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. it is necessary that the water used in mixing shall be portable water.

B. Mixing of Materials

1. Alkaline solution preparation

The sodium hydroxide was prepared by dissolving NaOH flakes in water. The flakes are commercial grade with 97% purity; thus 13 molar solutions were made by dissolving 520 grams of sodium flakes in1 lit water. It is mandatory to prepare a sodium hydroxide solution one day prior to bricks batching to allow the exothermically heated liquid to cool to room temperature. The sodium silicate and sodium hydroxide solution were mixed just prior to bricks batching.

Quantity of alkaline solution

The Quantity of alkaline solution required for this mix design is calculated as follow

Solution/fly ash ratio by mass = 0.35

Mass of (Silica solution+ NaOH)/ 368 = 0.35

Mass of (Silica solution+ NaOH) = 128 kg/m^3

Take Sodium silicate to Sodium hydroxide ratio by mass of 1.

Mass of Sodium silicate = 64 kg/m^3

Mass of Sodium hydroxide = 64 kg /m^3

2. Quantity of Material

To find the mechanical properties of the fly ash bricks and also to calculate the quantity of the material required for casting, actual size of brick 230mm×110mm×70mm is to be taken.

Table-2 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-3 Quantity of material for Geopolymer Bricks

Proportions	Fly ash kg	Hydrated Lime kg	Gypsum kg	M-sand kg
I	64	5.65	3	56.25
II	64	7.10	3	56.25
III	68	7.10	3	53.1
IV	68	8.50	3	53.1
V	72	8.50	3	50

Table-4 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

Table-5 Quantity of material for PET Bricks

Proportions	Fly ash kg	OPC kg.	PET kg.	M-sand kg
I	64	13.33	0.00	59.89
II	64	13.33	0.80	59.89
III	68	13.33	1.60	56.25
IV	68	13.33	2.40	56.25
V	68	13.33	3.20	56.25

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 Test -

The Compressive Strength test procedure is adopted from IS 3495-1992 Part-I. The Compressive Strength test gives the load carrying capacity of brick under gradually applied load.

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

Table-5 Compressive Strength for fly ash Bricks

Proportions	7 Day Test	14 Day Test	28 Day Test
I	3.95	5.13	7.11
II	4.74	5.92	7.51
III	5.13	6.71	8.30
IV	6.32	9.09	10.28
V	5.53	7.90	9.09

Table-6 Compressive Strength for PET Bricks

Proportions	7 Day Test	14 Day Test	28 Day Test
I	7.39	8.69	9.88
II	7.79	9.18	10.11
III	9.88	10.27	11.85
IV	8.69	9.48	10.27
V	9.58	10.11	11.15

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 = $(M_2-M_1)/M_1\times100$ %

Table-7 Water absorption for fly ash Bricks

Proportions	M_1 kg	M_2 kg	$(M_2-M_1)/M_1\times100$ %
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

Table-8 Water absorption for PET Bricks

Proportions	M_1 kg	M_2 kg	$(M_2-M_1)/M_1\times100$ %
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

3.Efflorescence Test-

The Efflorescence test procedure is adopted from IS 3495:1992 Part-III. The Efflorescence test used to find out the percentage of white spots on the surface of brick.

Table-9 Efflorescence deposit

Description	Extent of Deposit
Nil	No percentile deposit of efflorescence.
Slight	10% Area covered with a thin salt deposit
Moderate	Up to 50% area covered, Heavy deposit, No powdering or flaking
Heavy	50% or more area covered, Heavy deposit, No powdering or flaking
Serious	Heavy deposit, Powdering or flaking observed

The Efflorescence test has done on clay brick and fly ash brick sample and the results were compared with reference to above table. 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 Ist mix proportion after 7 day curing, sample was broken as it doesn't contain PET fibres in it.

Table 10: Impact Test on Fly Ash bricks

Proportions	7 Day Test	14 Day Test	28 Day Test
I	3	2	2
II	3	2	2
III	2	2	0
IV	2	0	0
V	2	0	0

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 shape and size of moulded fly ash brick is of rectangular in shape and of the size 230mm×110mm×70mm and its edges are sharp and straight and uniform in shape.

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

1. Geopolymer bricks are suitable for main wall as well as partition walls.
2. Since, these bricks are relatively light weight and more flexible compared to normal brick, these bricks are potentially ideal material for earthquake prone areas.
3. The effect of pallets and flex 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. Geopolymer brick does not expand or contract, so sheets of glass or glass block can be embedded in and trimmed with geopolymer.
5. The geopolymer bricks are good sound absorbent, hence geopolymer is used in these bricks. So, these bricks can be used in auditoriums.

References

1. M.M. Abdhulla, 'A Review of Fly Ash-Based Geopolymer Lightweight Bricks', Applied Mechanics and Materials Vols. 754-755 (2015) pp 452-456.
2. A. Sumathi, 'Compressive Strength of Fly Ash Brick with Addition of Lime, Gypsum and Quarry Dust',Int.J. ChemTech Res.2014-15, 07(01),pp 28-36.
3. P. Sakthivel, 'Experimental Investigation On Flyash Based Geopolymer Bricks', International Journal of Application or Innovation in Engineering & Management (IJAIEM), Volume 5, Page 216-227.
3. M. Chester, 'Lightweight Bricks from Fly-Ash',
4. Gurdarshan Singh Brar, 'Experimental Investigation of Clay Fly Ash Bricks for Gamma-Ray Shielding', Nuclear Engineering and Technology (2016).
5. T.Subramani, K.S.Ramesh , " Experimental Study On Partial Replacement Of Cement With Fly Ash And Complete Replacement Of Sand With M sand", IJAIEM , Vol. 4, pp. 313-322 , 2015
6. Rai M., 'Fly ash Sand Lime Bricks in India, Technical Report, 4th CANMET/ACI International Conference on Pozzolans, Central Building Research Inst., Roorkee.
7. O.A. Abdulkareem, 'Effects of elevated temperatures on the thermal behaviour and mechanical performance of fly ash geopolymer paste, mortar and lightweight concrete', Construction and Building Materials 50, 377–387, (2014)
8. Tayfun Cicek, 'Use of fly ash in production of light-weight building bricks', Construction and Building Materials 94 (2015) 521–527
9. Tahmina Banu, 'Experimental Studies on Fly Ash-Sand-Lime Bricks with Gypsum Addition', American Journal of Materials Engineering and Technology, 2013, Vol. 1, Page 35-40
10. Tutunlu Faith, Atalay Umit, 'Utilization of Fly ash in Manufacturing of Building Brick', International Ash utilization Symposium, Center for applied Engineering Research; 2001, Paper 13.
11. Sloanaker, 'Production of Forty Percent Core Area Fly Ash Brick Using Selected Fly ashes'. Proc. 4th International Ash Utilization, American Coal Ash Association, Paper 76-231, pp.231-237.
12. IS 3812 (Part 1): 2013, Bureau of Indian Standard, Pulverized Fuel Ash-Specification Part 1, For Use as Pozzolana In Cement, Cement Mortar and Concrete.
13. IS 3495 (Parts 1 to 4):1992, Bureau of Indian Standard, Methods of tests of burnt clay Building bricks.
14. IS 12894:2002, Bureau of Indian Standard, Pulverized fuel ash-lime bricks-specification.
15. IS 2386 (Part-I)-1963, Methods of test for aggregates for concrete- Particle size and shape, Bureau of Indian Standards.

16. S. Alan, 'A Study on Mechanical Properties of fly ash Brick with Waste Plastic Strips', International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.53 (2015)

17. S. Premalatha, 'Utilization of waste pet bottles and industrial by-products as a construction material', International Research Journal of Engineering and Technology (IRJET), Volume: 03 Issue: 05 , May-2016

18. M. Shanmuga Priya, 'Modern Technique in Fly Ash Bricks', Volume-3, Issue-1, International Journal of Mathematical Sciences and Engineering (IJMSE), March 2014