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Manufacture of geopolymer fly ash bricks using class C fly ash

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Abstract
Fly ash is a thermal waste of coal firing thermal plants and its accumulation near power plants causes severe pollution problems. Therefore, its utilization as a raw material for brick making will be a very beneficial solution in terms of economical and environmental aspects which in case also reduces the use of clay brick that costs the nation heavily losing valuable top soil. Alonely usage of this thermal waste in brick production causes difficulties in early strength development, limiting their use to certain applications. Geopolymerization whereas makes full use of fly ash by using them as key reactants in synthesis of aluminosilicate gel binders in brick production. Geopolymers can be synthesized by mixing aluminosilicate reactive materials (Class C Fly ash) in strong alkaline solutions (Mixture of Sodium silicate and Sodium hydroxide). In this experimental investigation, fly ash geopolymeric bricks (230x110x75mm) were produced by dry hot oven curing at 60^{o}C for 24 hours. The compressive strength of these bricks were determined at the ages of one day. Test results have revealed that the compression strength values of these bricks ranged between 5 and 15Mpa with low water absorption. Since cement is hardly used, these bricks were produced at affordable cost with reduction in emission of carbon dioxide. Hence these bricks are ecofriendly and does not involve in global warming.

Keywords: Bottomash, Geopolymerisation, Poly condensation, pozzolanic cement

1. Introduction
Bricks which play the most vital role in terms of construction material are usually associated with Portland cement (cement bricks). It has been estimated that the production of cement will increase from about 1.5 billion tons in 1995 to 2.2 billion tons in 2010(Malhotra, 1999). The Global Warming which is also another rising issue recently due to cement and is becoming vast day by day. This is mostly due to man-made activities which results in the emission of CO_2. Among Green House Gases CO_2 contributes about 65% of Global Warming. The Cement industry emits 6% of CO_2 to atmosphere. The aggregates and cement industries together produces nearly 80% of CO_2 emissions.
The use of Portland cement is still unavoidable until the foreseeable future; many efforts are being made in order to reduce the use of Portland cement in brick. These efforts led to the utilization of supplementary cementing materials such as fly ash, silica fume, rice husk ash etc and finding alternative binders to Portland cement. In this respect, the Geopolymer technology proposed by Davidovits source considerable promise for application in brick industry as an alternative binder to the Portland cement. Inspired by the Geopolymer technology and the fact that fly ash is a waste material abundantly available, this project work is carried on "Manufacture of Geopolymer fly ash bricks using class C fly ash".

2. Materials and Methodology
2.1 Fly Ash
Fly ash consists of finely divided ashes produced by pulverized lignite in power stations. The chemical composition depends on the mineral composition of the lignite gangue (the Inorganic part of the coal). Silica usually varies from 40 to 60% and alumina from 20 to 30%. The iron content varies quite widely. Alkalies are present in an appreciable amount and potassium prevails over sodium. During the hydration process, fly ash chemically reacts with the calcium hydroxide forming calcium silicate hydrate and calcium aluminate, which reduces the risk of leaching calcium hydroxide and concrete's permeability.
Fly ash also improves the permeability of mortar by lowering the water content, which reduces the volume of capillary pores remaining in the mass. The spherical shape of fly ash improves the consolidation, which also reduces permeability. The colour of fly ash can be dark grey, depending upon the chemical and mineral constituents.

2.1.1 Types of Fly Ash
The chemical composition of various fly ash show a wide range, indicating that there is a wide variations in the coal used in power plants all over the world. There are generally two types: Class F and Class C.

i) Class F
Fly ash from the bituminous and anthracite coals is referred as ASTM class F fly ash or low calcium fly ash. It consists of mainly an alumino silicate glass and has less than 10 percent of CaO.

ii) Class C
Fly ash that results from burning sub-bituminous coals is referred as ASTM Class C fly ash or high-calcium fly ash, as it typically contains more than 20% of CaO. Class C fly ash can be used as a pozzolan in virtually any concrete applications.
When correctly proportioned Class C fly ash will add many benefits such as increased strength, increased durability and reduced permeability. Class C fly ash is particularly beneficial in high performance concrete applications where high compressive strengths are required or where severe exposure

conditions demand highly durable concrete.

3. Geopolymerization

3.1 Polymerization

The process in which many simple monomers (small molecules) join together to form a large complex macromolecule called polymer is called the "polymerization".

e.g. A + B + C +D ⟹ A-B-C-D
Monomers Polymer

3.2 Geopolymers

Geopolymers are a class of inorganic polymers formed by the reaction between an alkaline solution and an aluminosilicate source or feedstock. The hardened material has an amorphous 3-dimensional structure similar to that of an alumino silicate glass. Geopolymers are an example of the broader class of alkali-activated binders, which also includes alkali-activated metallurgical slags and other related materials.

3.2.1 Reactants

i) Sodium Hydroxide

The most common alkaline activator used in geopolymerization is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate. The type and concentration of alkali solution affect the dissolution of fly ash.

Leaching of Al^{3+} and Si^{4+} ions are generally high with sodium hydroxide solution compared to potassium hydroxide solution. Therefore, alkali concentration is a significant factoring controlling the leaching of alumina and silica from fly ash particles, subsequent geopolymerization and mechanical properties of hardened geopolymer. Duchesne *et al* (2010) confirmed that in presence of NaOH in the activating solution, the reaction proceeds more rapidly and the gel is less smooth. The gel composition analyzed in the sample activated with the mixture of sodium silicate and NaOH is enriched in Na and Al.

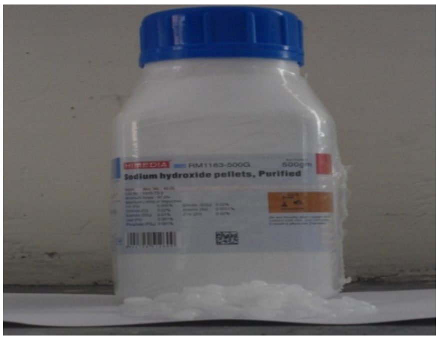


Fig 1: Sodium Hydroxide Pellets

ii) Sodium Silicate

Reactions occur at a high rate when the alkaline activator contains soluble silicate, either sodium or potassium silicate, compared to the use of only alkaline hydroxides. Tempest *et al* (2009) state that the sodium silicate activator dissolves rapidly and begins to bond fly ash particles. Open porosity can be observed and is rapidly filled with gel as soon as the liquid phase is able to reach the ash particles. The liquid phase is important as a fluid transport medium permitting the activator to reach and react with the fly ash particles.

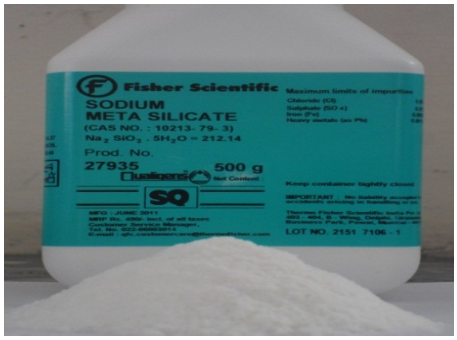


Fig 2: Sodium Silicate Powder

3.3 Alkali Activation

Figure 3 shows the dissolution process of the Si and Al occurs when the fly ashes are submitted to the alkaline solution. Then the higher molecules condense in a gel form and the alkali attack on the surface of particle, and then expand to larger hole, exposing smaller particles whether hollow or partially filled with other yet smaller ashes to bidirectional alkaline attack from the outside in and from the inside out. Consequently, reaction product is generated both inside and outside the shell of the sphere, until the ash particle is completely consumed.

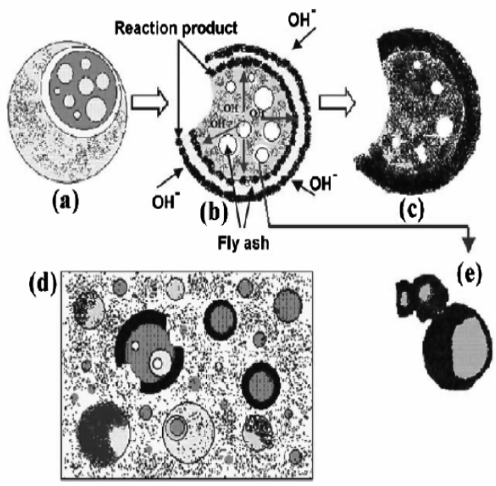
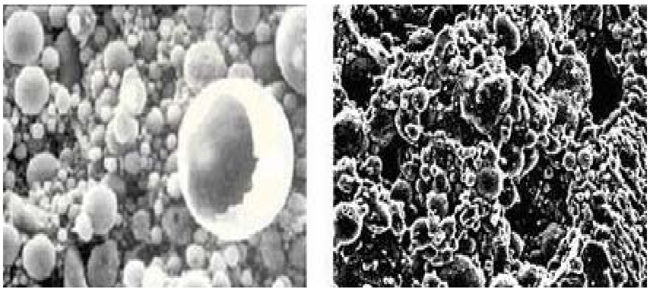


Fig 3: Descriptive Model of the Alkali Activation of Fly Ash.

The reaction of alumino-silicate materials in a strong alkaline environment results, first of all, in a breakdown of Si-O-Si bonds; later, new phases arise and the mechanism of their formation seems to be a process that includes a solution ("synthesis via solution"). The penetration of Al atoms into the original Si-O-Si structure represents a substantial feature of this reaction. Alumino-silicate gels (geopolymer precursors) are mostly formed. Their composition can be characterized by the formula Mn [-(Si-O) z - Al–O]n. wH_2O. The C-S-H and C-A-H phases may also be originated in dependence on the composition of the starting materials and the conditions of the reaction. Even secondary H_2O may be formed during these (poly-condensation) reactions. Amorphous (gel-like) or partially amorphous or crystalline substances may be originated in dependence on the character of starting raw materials and on the conditions of the reaction. The concentration of the solid matter plays a substantial role in the process of alkali activation.

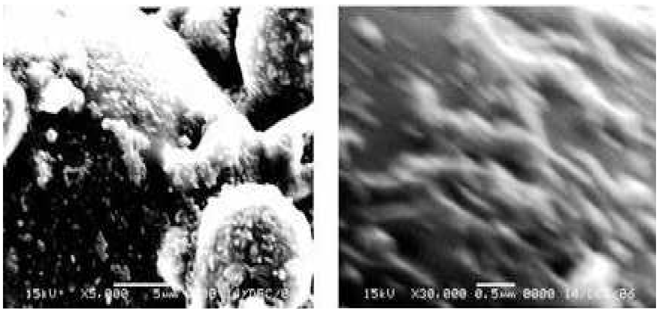
3.4 Microstructure of Geopolymer

Unlike ordinary Portland cement, geopolymer do not form calcium silicate-hydrates (CSHs) for matrix formation and strength, but utilize the polycondensation of silica and alumina precursors and a high alkali content to attain structural strength. Composition of the geopolymer is similar to natural zeolitic materials, but the microstructure is amorphous instead of crystalline. Fly ash particles: SEM was used to investigate the surface of fly ash, before and after reacting with NaOH. NaOH reacted with fly ash particles resulted in the roughness of surface as shown in Fig 4 and 5.



Before reacting **After reacting**

Fig 4: Fly Ash Before and After Reacting With NaOH



After reacting

Fig 5: Fly Ash after Reacting with NaOH

4. Experimental Work

4.1 Materials

The materials used for making fly ash-based geopolymer mortar specimens are

a) High-calcium dry fly ash as the source material
b) Sand
c) Bottom ash
d) Quarry dust
e) Pond ash
f) Alkaline liquids (NaOH and Na_2SiO_3)
g) Distilled water

4.1.1 Fly Ash

Fly ash used in this project is high-calcium (ASTM Class C) dry fly ash that possesses cementious (i.e., the fly ash reacts chemically with water in the same way that Portland cement does with water – self cementing property) in addition to pozzolanic properties due to free lime.

Fig 6: Fly Ash

4.1.2 Sand

The locally available sand which is used for concreting works can be used for making geopolymer bricks. IS 383: 1970 specifies the requirements for the sand to be used for the mortar work. In good quality sand the deleterious materials such as clay, silt particles shall not be more than 5%

Fig 7: Sand

4.1.3 Bottom Ash

Bottom ash is a by-product of coal or lignite combustion. Now-a-days the river sand, the main requisite in construction activity has become very scarce and hence bottom ash finds alternative to river sand. Use of Bottom ash in construction activities will eliminate the exploitation of natural resources (Sand).

Fig 8: Bottom Ash

4.1.4 Quarry Dust

Quarry dust can be used as a substitute for sand to improve the properties of lateritic soil. Quarry dust exhibits high shear strength which is highly beneficial for its use as a geotechnical material. It has a good permeability and variation in water content does not seriously affect its desirable properties.

Fig 9: Quarry Dust

Fig 10: Pond Ash

4.1.5 Pond Ash
Pond ash is a very fine, non-plastic and loose material dumped over the ground usually for a height of 10 to 30 m. Such types of materials are normally susceptible to liquefaction. The heavy particles are settled in the ash pond and the clear water is let out.

4.1.6 Alkaline Liquids
The alkaline liquid used was a combination of sodium silicate and sodium hydroxide solutions which is being prepared in the volumetric flask. The sodium hydroxide pellets and the sodium silicate powder was purchased from a local supplier. The NaOH and Na_2SiO_3 solids were dissolved in the distilled water to make the solution.

Fig 11: Alkaline Liquids in Volumetric Flask

4.2 Mixture Proportions of Geopolymers
- Molarities of Sodium hydroxide solution ranges between 8M to 14M
- Molarities of Sodium silicate solution ranges between 0.5M to 1M

4.3 Manufacture of Test Specimens
4.3.1 Preparation of Liquids
The sodium hydroxide (NaOH) solids were dissolved in water to make the solution. The mass of NaOH solids in a solution varies depending upon the concentration of the solution expressed in terms of Molar, M.
For instance, NaOH solution with a concentration of 8M consisted of 8x4 = 32 grams of NaOH solids (in flake or pellet form) is dissolved in 100 ml of the solution, where 40 is the molecular weight of NaOH. Note that the mass of NaOH solids was only a fraction of the mass of the NaOH solution and water was the major component.
Similarly the required amount of sodium silicate solution was made. Na_2SiO_3 solution with a concentration of 1M consisted of 1x2.12 = 2.12 grams of Na_2SiO_3 solids (in powder form) is dissolved in 100 ml of the solution, where 212.14 is the molecular weight of Na_2SiO_3.
The sodium silicate solution and the sodium hydroxide solution were mixed together with the extra water (if any) to prepare the liquid component of the mixture. The combination of NaOH and Na_2SiO_3, was prepared just before it was to be mixed with the dry materials.

4.3.2 Manufacture of Fresh Mortar and Casting
i) Test Specimens of Fly Ash with Sand
The fly ash and the fine sand were first mixed together for about 3 minutes. The liquid component of the mixture was then added to the dry materials and the mixing continued for further about 3 to 4 minutes to manufacture the fresh mortar. While casting the specimens, extra water can be added to the mixture along with the alkaline solutions upto the level of requirement. The fresh mortar was then casted into the moulds immediately after mixing and well compacted and the top surface is finished. The size of the mould is taken as 7cm × 7cm × 7cm.

Fig 12: Mortar Specimens

Table 1: Mortar with fly ash and sand Na_2SiO_3 (M) =1

Fly ash (gm)	Sand (gm)	NaOH (M)	NaOH (ml)	Na_2SiO_3 (ml)	Compressive Strength after One day (MPa)
200	400	8	80	20	2.75
100	500	14	70	30	1.80
100	500	14	30	70	1.50
150	450	14	70	30	1.26
200	400	12	80	20	1.10
200	400	10	80	20	7.08
200	400	8	60	10	4.50
200	400	10	40	10	2.42
200	400	10	50	10	4.36
200	400	10	70	10	6.38

ii) Test Specimen of Fly Ash with Bottom Ash
Now the sand is replaced by bottom ash in accordance with IS 1727 which possess the properties of sand and other procedures being the same

Table 2: Mortar with fly ash and bottom ash, Fly ash = 200 gm, Bottom ash = 400 gm

Na_2SiO_3 (M)	NaOH (M)	NaOH (ml)	Na_2SiO_3 (ml)	Compressive Strength after One day (MPa)
1M	10M	50	10	3.7
1M	10M	40	10	3.1
1M	8M	60	10	2.16
1M	8M	60	20	2.4

iii) Test Specimen of Fly Ash with Quarry Dust
Now the bottom ash is replaced by the quarry dust which possess the similar properties as that of the sand and the other procedure being the same.

Table 3: Mortar with fly ash and quarry dust, Fly ash = 200gm, Quarry dust = 400gm

Na_2SiO_3 (M	NaOH (M)	NaOH (ml)	Na_2SiO_3 (ml)	Compressive Strength after One day (MPa)
1	10	60	10	3.2
1	10	40	20	2.2
1	8	60	10	3.7
1	8	75	25	2.4

iv) Test Specimen of Fly Ash with Pond Ash
Now the quarry dust is replaced by the pond ash which is used as the replacement for sand and the other procedures being the same.

Table 4: Mortar with fly ash and pond ash, Na_2SiO_3 (M) =1

Fly ash	Pond ash	NaOH (M)	NaOH (M)	Na_2SiO_3 (ml)	Compressive strength after one day (Mpa)
200	400	10	60	10	0.7
200	400	10	40	20	1.0
300	300	10	60	10	2.4

The maximum strength is found only by the method of trial and error. Hence number of trials are attempted with various mix proportions and concentrations of the solutions.

4.3.3 Curing of Test Specimens
Generally heat curing is adopted for the geopolymer specimens. Due to heat being a reaction accelerator, curing of fresh geopolymer is performed mostly at an elevated temperature. When curing at elevated temperatures, loss of water should be taken care of. Two types of heat curing were used, i.e. dry curing and steam curing. For dry curing, the test specimens were cured in the oven and for steam curing, they were cured in the steam curing chamber. For this experimental project, dry curing is adopted and the test specimens were placed in the oven at an optimum temperature of 60°C.

After the curing period, the test specimens were left in the moulds for at least six hours in order to avoid a drastic change in the environmental conditions. After demoulding, the specimens were left to air-dry in the laboratory until the day of test.

Fig 13: Dry Hot Oven Curing

4.3.4 Curing Time
The test specimens were cured for 24 hours in the dry oven and were found that prolonged curing time was not found to alter the compressive strength of the mortar.

4.3.5 Compression Strength Test
The compression strength of the specimens were tested using ACTM (Automatic Compression Testing Machine). The specimens were tested in compression in accordance with the test procedures given in the Bureau of Indian Standards, IS 3495 (Part I), Methods Of Tests Of Burnt Clay Bricks – Determination of Compressive Strength (1992).

Using this compressive strength was determined using the formula,

Compressive strength (KN/cm^2)

$$= \frac{\text{Maximum load at failure in KN}}{\text{Average net area of the two faces under compression in cm}^2}$$

Here the compressive strength is expressed in the terms of Mega Pascal as

1 KN/cm^2 = 10 MPa

Fig 14: Compression Test in ACTM

4.3.6 Water Absorption Test

The specimens were tested for water absorption in accordance with the test procedures given in Bureau of Indian Standards, IS 3495 (Part 2), methods of tests of burnt clay bricks–24-hour immersion cold water test.

First, Cool the specimen to room temperature and obtain its weight (M_1). Then immerse completely the dried specimen in clean water for 24 hours. Remove the specimen and wipe out any traces of water with a damp cloth and weigh the specimen. Complete the weighing 3 minutes after the specimen has been removed from water (M_2).

Water absorption, percent by mass, after 24-hour immersion in cold water is given by the following formula:

$$[(M_2 – M_1)/M_1] * 100$$

4.4 Manufacture of Brick

Geopolymer fly ash brick is manufactured by mixing sand and fly ash in the ratio of 1:2 and the concentration of sodium hydroxide solution and sodium silicate solution is taken in the ratio of 10M:1M as the maximum compressive strength is obtained in this case of the mortar.

Fig 15: Manufacture Of Bricks Using Semi-Automatic Fly ash Making Machine

4.5 Calculation

For Casting a Cube

Size of the mould = 7 cm × 7 cm × 7 cm

Initial weight of the sand in the empty mould = 600 gm

Thus total quantity of dry materials to be taken in one mould (approx) = 600 gm

Weight of Fly ash taken = 200 gm

Weight of Bottom ash taken = 400 gm

Molarity of NaOH = 10M

Molarity of Na_2SiO_3 = 1M

Ratio of alkaline solution = 50 ml: 10 ml (NaOH: Na_2SiO_3)

1M = Molecular Weight of a substance dissolved in 1lit of distilled water

For NaOH Solution

Molecular Weight of NaOH pellets = 40 gms

- For 1M, 40 gms of NaOH dissolved in 1000 ml of distilled water
- 4 gms of NaOH dissolved in 100 ml of distilled water
- For 10M, 40 gms of NaOH dissolved in 100 ml of distilled water
- For 10M, 20 gms of NaOH dissolved in 50 ml of distilled water

For Na_2SiO_3 Solution

- Molecular Weight of Na_2SiO_3 powder = 212.14 gms
- For 1M, 212.14 gms of Na_2SiO_3 dissolved in 1000 ml of distilled water
- 21.2 gms of Na_2SiO_3 dissolved in 100 ml of distilled water
- For 1M, 2.12 gms of Na_2SiO_3 dissolved in 10 ml of distilled water

For Casting A Brick

- Size of the brick = 23 cm × 11 cm × 7.5 cm
- Wt.of fly ash Brick (approx) = 3.3 kg
- Fly ash: Bottom ash = 1: 2
- Weight of Fly ash taken = 1.1 kg
- Weight of Bottom ash taken = 2.2 kg
- Ratio of alkaline solution = 50 ml: 10 ml (NaOH: Na_2SiO_3)
- Weight of a brick = (3300/600) = 5.5 times the Weight of a cube
- For 10M, 110 gms of NaOH dissolved in 275 ml of distilled water
- For 1M, 11.16 gms of Na_2SiO_3 dissolved in 55 ml of distilled water

For Making 100 Bricks,

- Quantity of NaOH pellets required = 11 kg
- Quantity of Na_2SiO_3 powder required = 1.166 kg
- Amount of Distilled water required = 33 litres

Finally while casting the specimen extra water can be added if required.

Table 5: Brick with fly ash and sand

Fly ash (kg)	sand (kg)	Na_2SiO_3 (M)	NaOH (M)	NaOH (ml)	Na_2SiO_3 (ml)
1.1	2.2	1	10	40	10
1.1	2.2	1	10	50	10
1.1	2.2	1	10	80	20
1.1	2.2	1	10	80	20

Table 6: Brick with fly ash and Bottom ash

Fly ash (kg)	Bottom ash (kg)	Na_2SiO_3 (M)	NaOH (M)	NaOH (ml)	Na_2SiO_3 (ml)
1.1	2.2	1	10	50	10
1.1	2.2	1	10	40	10
1.1	2.2	1	10	80	20

The test specimens are cured and they are done the compressive and water absorption tests similar to that of the mortar specimens.

5. Results and Discussion

- The experimental results are presented and discussed. The parameters are considered as follows;
- The mass of sodium hydroxide solution taken is much higher than the mass of sodium silicate solution.
- Sodium hydroxide (NaOH) is more preferable to Potassium hydroxide since leaching of Al^{3+} and Si^{4+} ions are generally high with NaOH solution.

- Addition of Sodium silicate (Na_2SiO_3) enhances the reaction between the source material and the solution.
- Curing of bricks can be done at a temperature from 60°C to 90°C. Here, curing is done at a temperature of 60°C.
- Geopolymer gain 70% of the final strength in first 3–4 h of curing.

Table 7: Brick Specimens with Fly Ash and Sand

Mixture	Compressive strength (MPa)	Water Absorption (%)
1	4.3	14.9
2	6.2	15.2
3	14.73	14.6
4	14.03	14.3

Table 8: Brick Specimens with Fly ash and Bottomash

Mixture	Compressive Strength (Mpa)	Water Absorption (%)
1	7.4	14.1
2	5.8	15.3
3	14.8	14.7

5.1 Comparison between Conventional Clay Bricks and Geopolymer Fly ash Bricks

Number of Conventional Clay Bricks Required

Considering a house patio of 1500 square feet

1 square feet = 12 × 12 inches = 144 inches
1500 square feet = 1500×144= 216000 square inches
Size of the brick = 19 cm × 9 cm × 9 cm
1 inch = 2.54 cm
19 cm = 7.48”
9 cm = 3.54”
Brick cover area = (7.48” ×3.54”) = 2s6.48 inches
Number of bricks required = Area of house patio/Brick cover area
= (216000/26.48)
= 8155 bricks

Number of Geopolymer Fly ash Bricks Required

Size of the brick = 23cm × 11cm × 7.5 cm
Brick cover area = (9.05” × 4.33”)
= 39.18 inches
Number of bricks required = Area of house patio/Brick cover area = (216000/39.18) = 5515 bricks

5.2 Cost Analysis

Cost for the Conveyance of Fly ash

Size of the brick = 23 cm × 11 cm × 7.5 cm
Volume of one brick = (23 × 11 × 7.5)
= 1897.7 cm^3
= 0.0018975 m^3
Ratio of Fly ash: Bottom ash = 1: 2
100 m^3 of brick = ((1.1/3.3)×100)
= 33.33 m^3 of fly ash
0.0018975 m^3 of brick = ((0.0018975 × 33.33)/100) m^3 of fly ash
100 bricks = 0.0018975 × 33.33 m^3 of fly ash
= 0.00632m^3 of fly ash
Density of fly ash = 1600 kg/m^3
0.00632 m^3 of fly ash = 0.00632×1600
= 101.19 kg for 100 bricks

Conveyance of fly ash per MT from Neyveli Power station
= Rs.75
Conveyance = ((101.19 × 75)/10^3 = Rs.7.5

Cost for the Conveyance of Bottom Ash

100 m^3 of brick = ((2.2/3.3)×100) = 66.67 m^3 of bottom ash
0.0018975 m^3 of brick = ((0.0018975 × 66.67)/100) m^3 of bottom ash
100 bricks = 0.0018975 × 66.67 m^3 of bottom ash
= 0.12650 m^3 of bottom ash
Density of bottom ash = 1900 kg/m^3
0.12650 m^3 of fly ash = 0.12650×1900
= 240.36 kg for 100 bricks

Conveyance of Bottom ash per MT from Neyveli power station = Rs.75
Conveyance = ((240.36 × 150)/10^3 = Rs.36

From the Manufacturer

50 kgs of Sodium hydroxide pellets = Rs.2200
50 kgs of Sodium Silicate powder = Rs.5000
1 litre of distilled water = Rs.7

For manufacturing 100 bricks

11 kgs of Sodium hydroxide pellets = Rs.528
1.166 kgs of Sodium Silicate powder = Rs.116.6
33 litres of distilled water = Rs.231

Table 9: Cost analysis for 100 machine pressed Geopolymer bricks

Qty	Description	Rate	Per	Amount
101.9Kg	Convy. of fly ash	75.00	1 MT	7.64
240.4 Kg	Convy. of bottom ash	75.00	1 MT	18.03
33 litres	Distilled water	350	50 litres	231.00
11 Kg	Sodium Hydroxide	2200.00	50Kg	440.00
1.1 Kg	Sodium silicate	5000.00	50Kg	111.6
100 nos	Labour charge for 4500 Nos.	4227.70	4500 nos	93.95
LS	Electric charges			9.82
LS	Depreciation of machine			1.40
LS	Machine maintenance, spares, etc.			1.00

Cost for 100 bricks = Rs.914.44
Cost per unit volume of geopolymer fly ash brick
= Rs. 9.14
Cost per unit volume of conventional chamber brick
= Rs 7
Cost of conventional clay bricks per 1500 sq.ft
= Rs. 57085.62
Cost of Geopolymer fly ash bricks per 1500 sq ft
= Rs. 50131.35

6. Conclusion

From the exhaustive experimental study presented in the project, the following conclusions can be made:

- Higher concentration of sodium hydroxide results in higher compressive strength of fly ash-based geopolymer bricks.

- The compressive strength of heat cured fly ash-based geopolymer brick does not depend upon the age.
- Water Absorption and penetration is less.
- Higher curing temperature greatly influences the compressive strength of the bricks.
- Reduces air pollution and CO_2 emission greatly since there is no usage of cement in making geopolymer bricks.
- Geopolmeric bricks required hot dry oven curing but in fly ash bricks wet curing is done.
- Geopolymer fly ash bricks are eco-friendly as it protects the environment though conservation of top soil and utilization of waste products of Thermal Power Plants.
- Production of commercial bricks need woods for burning in kilns which leads to deforestation whereas it can be avoided in geopolymer bricks.
- Wet curing in not needed as that of fly ash bricks so substantial amount of water usage is reduced.

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