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EXPERIMENTAL INVESTIGATION ON ECO-FRIENDLY SUSTAINABLEGEOPOLYMER BRICKS

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ABSTRACT

Despite the extensive developments in the construction industry, bricks and blocks have still remained as the major building units. The traditional fired bricks still rule supreme since cost consideration is the prime influencing factor in the product choice. About 22 million tones of coal are consumed in the production of burnt bricks apart from 10 million tones of biomass. Clay bricks consume large amount of fertile top soil owing to fast depletion of soil. The alternative to these bricks is compressed cement bricks which have gained popularity recently. As an alternative to the above products a new technology is developed to manufacture fly ash based geopolymer bricks. There are several advantages of these bricks. Marginal materials can be used to develop these bricks. No traditional curing methods are adopted and no cement is being used. In the present investigation F-type fly ash is used as binder materials in the bricks at ambient and higher temperatures. The alkaline fluid-to-binder ratio (FBR) is optimized to get the maximum strength. The strength ratio used in the phenomenological model reflects the synergy between different ingredients in the microstructure of the geo-polymers. The results obtained are compared with red bricks, cement bricks and fly ash cement bricks.

***Keywords:* Fly ash, cement bricks, geopolymer bricks, F-type fly ash and fluid-to-binder ratio (FBR).**

I. INTRODUCTION

Geopolymer are inorganic polymeric binding materials, firstly developed by Joseph Davidov its in 1970s. Geopolymerisation involves a chemical reaction between solid alumino-silicate oxides and alkali metal silicate solutions under highly alkaline conditions yielding amorphous to semi-crystalline three-dimensional polymeric structures, which consist of Si-O-Al bonds [1].The geopolymerisation reaction is exothermic and takes place under atmospheric pressure at temperatures below100°C. The exact mechanism by which Geopolymer setting and hardening occurs is not yet fully understood. However, the most proposed mechanisms for the geopolymerisation includes the following four stages that proceed in parallel and thus, it is impossible to bedistinguished: (i) dissolution of Si and Al from the solid alumina silicate materials in the strongly alkaline aqueous solution, (ii) formation of oligomers species (Geopolymer precursors) consisting of polymeric bonds of Si-O-Siand/or Si-O-Al type, (iii) polycondensation of the oligomers to form a three-dimensional alumina silicate framework (geopolymeric framework) and (iv) bonding of the un-reacted solid particles and filler materials into the geopolymeric framework and hardening of the whole system into a final solid polymeric structure.

II. MATERIALS & METHODS

2.1 FLY ASH

Fly Ash is a by-product of the combustion of pulverized coal in electric power generation plants. When the pulverized coal is ignited in the combustion chamber, the carbon and volatile materials are burned off. However, some of the mineral impurities of clay, shale, feldspars, etc., are fused in suspension and carried out of the combustion chamber in the exhaust gases. As the exhaust gases cool, the fused materials solidify into spherical glassy particles called Fly Ash. Due to the fusion-in-suspension these Fly Ash particles are mostly minute solid spheres and hollow ecospheres with some particles even being plerospheres, which are spheres containing smaller spheres.

2.1.1 ADVANTAGES OF FLY ASH IN BRICK

Fly Ash is a pozzolan. A pozzolan is a siliceous or alumino siliceous material that, in finely divided form and in the presence of moisture, chemically reacts with the calcium hydroxide released by the hydration of Portland Cement to form additional calcium silicate hydrate and other cementious compounds. The hydration reactions are similar to the reactions occurring during the hydration of Portland cement. Thus, brick containing Fly Ash pozzolan becomes denser, stronger and generally more durable long term as compared to straight Portland cement brick mixtures.

2.1.2 FLY ASH, NTPC LIMITED (2007)

According to the paper presented by NTPC, In India, coal is the major source of fuel for power generation. About 60% power is produced using coal as fuel. Indian coal is having low calorific value (3000-3500 K cal.) & very high fly ash content (30-45%) resulting in huge quantity of ash is generated in the coal based thermal power stations. During 2005-2006 about 112 million tone of ash has been generated in 125 such power stations with the present growth in power sector, it is accepted that ash generation will reach to 175 million tonne per annum by 2012.

Fly ash is extracted from flue gases through Electrostatic precipitator in dry form. This ash is 2.5 fine material & possesses good pozzolanic property. Fly ash is produced in modern power stations of India is of good quality as it contains low sulphur & very low unburnt carbon i.e. less loss on ignition. In order to make fly ash available for various applications, most of the new thermal power stations have set up dry fly ash evacuation &storage system. In this system fly ash form Electrostatic precipitators (ESP) is evacuated through pneumatic system and stored in silos.

2.1.3 CHEMICAL COMPOSITION:

The major constituents of most of fly ashes are silica (SiO), alumina (AlO), ferric oxide (FeO) and calcium oxide (CaO). The other minor constituent of the flyash are MgO, principal constituent – Silica (25-60%), Alumina (10-30%), and Ferric oxide (5-25%). When the sum of this three principal constituent is 70%m or more and reactive calcium oxide is less than 10% -technically the fly ash is considered as or class F fly ash. Such type of fly ash is produced by burning of anthracite or bituminous coal and possess pozzolanic properties. If the sum of these three constituent is equal or more than 50% and reactive calcium oxide is not less than 10%, fly ash will be considered as also called as class C fly ash. This type of fly ash is commonly produced by burning of lignite or sub-bituminous coal and possesses both hydraulic and pozzolonic properties.

The fly ash particles are generally glassy, solid or hollow and spherical in shape. The hollow spherical particles are called as cenospheres. The fineness of individual fly ash particle range from 1 micron to 1mm size. The fineness of fly ash particles has a significant influence on its performance. The specific gravity of fly ash varies over a wide range of 1.9 to 2.55.

2.2 SODIUM HYDROXIDE

Generally the sodium hydroxides are available in solid state by means of pellets and flakes. The cost of the sodium hydroxide is mainly varied according to the purity of the substance. Since our 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 f lakes were used. Whose physical and chemical properties are given by the manufacturer is shown in Table 1.Sodium hydroxide is industrially produced as a 50% solution by variations of the electrolytic chloralkali process. Chlorine gas is also produced in this process. Solid sodium hydroxide is obtained from this solution by the evaporation of water. Solid sodium hydroxide is most commonly sold as flakes, prills, and cast blocks.(Figure.2 and Figure.3))

Table 1: Physical Properties.

Percentage	Specific Gravity
20%	1.22
30%	1.33
40%	1.43
50%	1.53


Fig. 1 : NaoH – Flakes **Fig 2 :** NaoH – Pellets

2.3 SODIUM SILICATE (Na_2sio_3)

Soluble silicates are one of the oldest and most benign industrial chemicals. The industrial beginnings of sodium silicate start in 1818 but references to making sodium silicate like products can be traced back as far as the ancient Phoenicians 2. One reason for the early development of soluble silicate was the relatively simple process for manufacturing it. Sodium (or potassium) silicates are manufactured by fusing sand (SiO2) with sodium or potassium carbonate (Na2CO3 or K2CO3) at 1100-1200°C. The resulting glass can be dissolved with high pressure steam to form a clear, slightly viscous liquid known as “water glass.” Sodium silicate is a white powder that is readily soluble in water, producing an alkaline solution. It is one of a number of related compounds like, sodium ortho silicate, sodium pyro silicate, etc. All are glassy, colorless and dissolve in water. Sodium silicate is stable in neutral and alkaline. In acidic solutions, the silicate ion reacts with hydrogen ions to form silicic acid, which when heated and roasted forms silica gel, a hard, glassy substance. Liquids and solids based on sodium silicate and produced by PQ Corporation have a density from 1.6g/cubic cm. to about 1.4 g/cubic cm.

2.3.1 CHEMICAL REACTIONS OF SILICATE

Sodium silicate is unique in that it can undergo four very distinct chemical reactions. These reactions have been defined as:

- Hydration/Dehydration
- Gelation
- Precipitation
- Surface Charge Modification.

These reactions allow silicate to act as a:

- Film Binder
- Matrix Binder
- Chemical Binder

Silicate can adhere an agglomerated material by one or more of its chemical reactions. Sometimes silicate-based formulations achieve their best performance by taking advantage of more than one of these adhesion mechanisms.

III. PROCEDURE

1. 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.

2.Thes Na2SiO3 solids were dissolved in water to make the solution. The mass of Na2SiO3 solids in a solution varies depending upon the concentration of the solution expressed in terms of Molar, M.

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 Na2SiO3, was prepared just before it was to be mixed with the dry materials

4. 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.

5. The fresh mortar was then casted into the moulds immediately after mixing and well compacted and the top surface is finished.

6. The size of the mould is taken as 19 cm x 9 cm x9 cm.

Fig 3:Mould of size19 cm x 9 cm x9 cm

TABLE NO. 1

Calculation of NaOH and Na2SiO3

Total wt. of fly ash (gm)	% of NaoH	NaoH by weight(gm)	% of Na_2SiO_3	Na_2SiO_3 by wt.
2056	3	61.68	2	41.12
2056	4	82.24	3	61.68
2056	6	123.36	4	82.24

3.1 CALCULATION 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 Na2SiO3 Solution

- Molecular Weight of Na2SiO3 powder = 212.14 gms
- For 1M, 212.14 gms of Na2SiO3 dissolved in 1000 ml of distilled water
- 21.2 gms of Na2SiO3 dissolved in 100 ml of distilled water
- For 1M, 2.12 gms of Na2SiO3 dissolved in 10 ml of distilled water

TABLE NO 2 Calculation of distilled water

NaoH by wt.(gm)	Distilled water in (ml)	Na2SiO3 by wt.	Distilled water in (ml)
61.68	154.2	41.12	194.08
82.24	205.6	61.68	291.12
123.36	308.4	82.24	388.17

IV. 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 60̊ 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

4.1 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

Fig.4: Geopolymer bricks place for curing

V. TESTS ON BRICKS

5.1 COMPRESSIVE TEST

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,

$$\text{Compressive strength}(N/mm^2) = \frac{\text{Maximum load at failure in N}}{\text{Avg. area of the bed faces in } mm^2}$$

Fig5:compressive testing machine

5.2 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 (M1). 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 (M2). Water absorption, percent by mass, after 24-hour immersion in cold water is given by the following formula:[(M2 – M1)/M1] * 100.

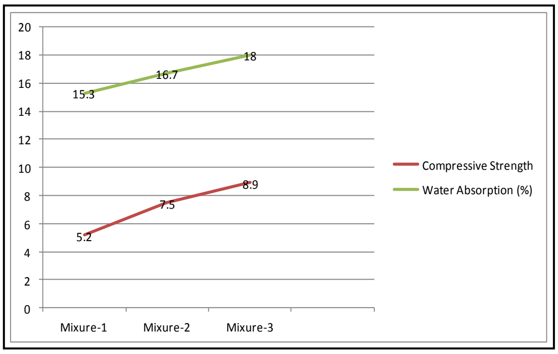
Fig.6:water absorption test

IV. TEST RESULT AND DISCUSSION

TABLE 3

Result of compressive strength and water Absorption.

Mixture	Compressive strength(Mpa)	Water absorption(%)
1	5.2	15.3
2	7.5	16.7
3	8.9	18



VII. CONCLUSION

From the experimental study presented in the project, the following conclusions can be made as follow,

1. If concentration of sodium hydroxide increase, higher compressive strength of fly ash-based geopolymer bricks.

2. Water Absorption and penetration is minimum

3. Higher curing temperature influences the compressive strength of the geopolymer bricks.

4. Reduces air pollution and CO2 emission greatly since there is no usage of cement in making geopolymer bricks.

5. Geopolmeric bricks required hot dry oven curing but in fly ash bricks wet curing is done.

6. Geopolymer fly ash bricks are eco-friendly as it protects the environment and utilization of waste products of Thermal Power Plants.

7. Production of commercial bricks need woods for burning in kilns which tendes to deforestation in other hand it can be avoided in geopolymer bricks.

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