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Development of Geopolymer Bricks using Foundry Sand

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Abstract - *The study on production of geopolymer bricks using fly ash, mineral material, foundry sand and alkaline solution. Bricks widely belong to the category of construction materials since it's principally used for the development of boundary and partition walls in buildings. For eco-friendly building erection it's vital that the material use for such construction should be environment friendly. Bricks are world's most adaptable, reliable and durable material for construction. In Geopolymer bricks main ingredients of clay burnt or cement based brick is totally replace by the, waste of burnt coal known fly ash, foundry sand waste from metal casting industry. Materials rich in (Si) silica and (Al) alumina is the necessity for the geopolymer synthesis. The activated solution for geopolymerization is Sodium hydroxide (Na OH) mix with Sodium silicate (Na_2 SiO_3) solution in appropriate proportion. The key advantages are higher compressive strength as compare to clay burnt brick, eliminate the use of top most fertile soil and effective utilization of industry waste and production of eco-friendly product using waste. The practical work done casting a brick of 230×110×75mm size of geopolymer brick with replacement of sand by foundry sand and mineral material.*

Key Words: Geopolymer, Foundry sand, alkaline solution, Compressive strength.

1 INTRODUCTION

An increasing awareness towards ecological issues has focused industries to develop materials & products that will be additional environment responsive and results in structure development. The products from a country's natural and waste by-products are important as so much because the industrialization of a nation is bothered. Brick has space with wide family of construction materials since it's primarily utilized for the advancement of external and inward dividers in structures. For creating eco-friendly building it's vital, the structure exploitation in such construction method should be environment friendly. For ample manufacturing and use of bricks from waste materials, additional analysis and development is required, not only on the technical, economic and environmental aspects however conjointly on standardization, government policy and public education associated with waste use and property development. In India, mud bricks have been broadly utilized from long time and are the overwhelming development material even today. Current interest is more than 1000 billion bricks a year. The ordinary routine of terminating dirt bricks in conventional ovens (kilns) consumes extensive amounts of coal, kindling, and different Biomass fuels. The Indian brick industry, which is the second biggest maker on the planet, beside China, devours more than 150 million tons of coal yearly without including the power utilized in brick generation, the diesel for transporting the bricks alone create exactly 180 million tons of CO_2, approximately 33% of the aggregate CO_2 emission of the worldwide industry (550 million tons of CO_2).

1.1 GEOPOLYMER

Geopolymers are inorganic, typical ceramic materials forms long chain covalent bond amorphous network. The composition of the geo-polymer material is comparable to zeolitic materials however microstructure is of amorphous state rather than crystalline. In polymerization practice quick reaction of alkaline activated solution with Silica-Alumina minerals takes place and formation of a three-dimensional polymeric chain and ring structure made of -Si-O-Al-O bonds takes place.

1.2 GEOPOLYMER BRICK DEVELOPMENTS

In Geopolymer brick the (class F) fly ash having rich silica and alumina content reacts with alkali activated solution pre-mix of sodium silicate and sodium hydroxide results in formation of gel known as binder in geopolymer products. There is no use of cement in this brick production. Instead, the binder is formed by the reaction of an activated solution with a source material. Fly ash above 50%, foundry sand above 40% and (2 to 4) % of mineral

material is used for casting the brick of size (230×115×75) mm.

2. MATERIALS IN USE

Fly Ash: Fly Ash waste from thermal power plant units, which is composed of siliceous and aluminous material and many more other constituents. The main constituents of coal ash are Silicon dioxide (Si02), Aluminum oxide (Al203), Ferric oxide (Fe203) and calcium oxide (CaO). The prime constituents silicon dioxide (25- 60%), Aluminum oxide (10-30%) & ferric oxide (5-25%), when the total percentage of these three constituents is 70% or above 70% and reactive calcium oxide is less than 10% - theoretically the fly ash is considered as class F fly ash. Fly ash comes from bituminous coals. Where, CaO content is more than 20% is referred as high-calcium fly ash or (Class C) fly ash derived from the bituminous and hard shiny black coal is referred as (Class F) fly ash or low-calcium fly ash, it is known as source material as comparative to high-calcium (Class C) fly ash.

Alkaline solutions: The alkaline solution is combined mix of Sodium hydroxide (NaOH) or Potassium hydroxide (KOH) and Sodium silicate also known as water glass (Na2SiO3). The sodium hydroxide solution can be prepared by dissolving the solid flakes of NaOH in one liter of water for different molar concentrations by different mass. Both the solutions should be premixed of 24 hours before use.

Foundry sand: Foundry sand is high class silica sand with identical material characteristics. It is a by-product of ferrous and non-ferrous metal casting industries, where sand has been used for molding material because of its thermal conductivity. It is a by-product from metal castings industries. Approximately 100 million tons of sand is used for annually production of that 10 - 15 million tons are discarded.

Mineral material: The slag of high glass content with high reactivity obtained through the process of controlled granulation. The raw materials are composed of low calcium silicates. The slag is truly ultra fine. Due to its unique chemistry and ultra fine particle size, it can be used as a high range water reducer to improve the compressive strength.

Table -1: Characteristics and Properties:

Chemical Analysis	Mass %	Physical analysis	Range
CaO	32-34	Bulk Density	600-700kg/m^3
Al_2	18-20	Surface Area	12000 cm^2/gm
Fe_2O_3	1.8-2	Particle shape	Irregular
SO_3	0.3-0.7	Particle Size, d_{10}	< 2 µ
MgO	8-10	d_{50}	< 5 µ
SiO_2	33-35	d_{90}	< 9µ

As the chemical composition and physical characteristics listed above, mineral material has got the unique chemical composition mainly of CaO (31-33) % and SiO2 (33-35) %. The mineral material has property to impart strength where it is used.

3. EXPERIMENTAL WORK

Table 2: The detailed calculation of material per m^3 given in below table:

Mix	Fly ash (kg)	Foundry sand (kg)	Mineral material (kg)	NaOH (kg)	Na_2SiO_3 (kg)	Mass of alkaline solution (kg/m^3)	Na_2SiO_3/Na OH ratio	Alkali Solution/ Fly ash ratio
8M	884.5	720.72	32.76	128.8	322.2	451.10	2.5	0.51
8M	884.5	687.96	65.52	128.8	322.2	451.10	2.5	0.51
10M	884.5	720.72	32.76	128.8	322.2	451.10	2.5	0.51
10M	884.5	687.96	65.52	128.8	322.2	451.10	2.5	0.51
12M	884.5	720.72	32.76	128.8	322.2	451.10	2.5	0.51
12M	884.5	687.96	65.52	128.8	322.2	451.10	2.5	0.51

In experimental work the material used for casting brick is fly ash, foundry sand, alkaline solution & mineral material. The design mix calculations are done as per brick density 1638kg/m^3.Therefore, fly ash 54%, foundry sand (42 to 44) %, mineral material (2 to 4) % and variation of molarities 8M 10Mand 12M used for final experimental work. The ratio of alkaline solution to fly ash is 0.5, ratio of

Na_2SiO_3 to NaOH is 2.5.These ratios are referred from the research studies done by Dr. D.S.Ramachandra Murthy study on "Fly ash based Geopolymer Concrete Bricks for Building Construction". Fly ash & foundry sand is used along with alkaline solution for different molarities of (Na OH) solution 8M, 10M & 12M as refered from literature review of past research papers. The $Na_2SiO_3$and NaOH solution prepared of different molarity mixed before 24 hours so that chain reaction takes place. The dry mix of fly ash, foundry sand and mineral material is done manually after uniform mixing solution is added to the dry mix. Afterwards mix is poured into the moulds of non modular size (230 ×115×75) mm.

Fig:-1 Mixing of material

5. EXPERIMENTAL RESULTS & OBSERVATIONS

The final casting of bricks is done by using design mix varying the percentage of alccofine from (2 to 4) %. Use of 2% alccofine is optimum use to get desirable strength as brick tested in initial stage. The Compressive strength, water absorption, efflorescence test and shape & size of brick specimen is studied as per IS 3495-PART (1-4). The bar charts were plotted on results basis for different compressive strength of bricks at 7days and 28 days using alccofine (2 to 4) % at ambient temperatures. In this study for testing the compressive strength of Geopolymer bricks, bricks of (230mm×115 mm×75 mm) were casted and tested for each parameter specimens for 7 days simple air curing and other for 28 days simple air curing. Remaining bricks samples were used to perform water absorption and efflorescence test.

5.1 COMPRESSIVE STRENGTH

The compressive strength test was carried out as per specifications given in IS: 3495-(part 1)-1992. The surface of bricks is well dried before testing, mortar filled surface Kept facing upwards between two 3 mm plywood sheets, results are as below in table:

Table no-3: Compressive strength of Geopolymer Brick at 7 & 28 days using 2% (Alccofine)

Molarity	Compressive Strength (7 days) kg/cm²	Compressive Strength (28 days) kg/cm²	Temperature ˚C
8M	85.06	145.56	Ambient temp.
10M	103.9	160.68	Ambient temp.
12M	109.9	162.5	Ambient temp.

Observation:

The strength of bricks increases where the molarity of Sodium Hydroxide (NaOH) varies 8M, 10M, 12M. Compressive strength of first class brick achieved in 7 days, using 2% mineral material, the material has the cementitious property it imparts strength to the brick. At 28 day testing it gives the strength of first class brick.

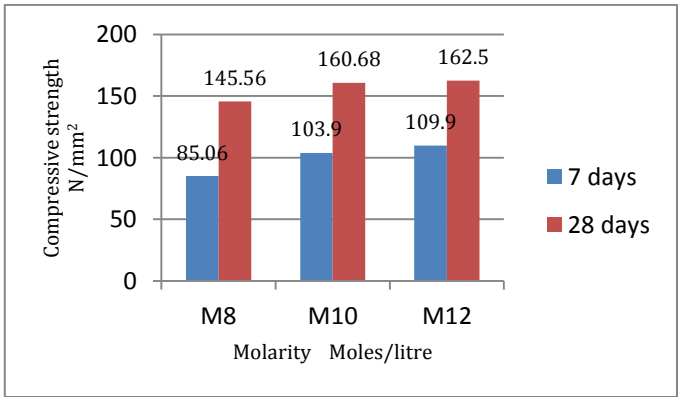

Chart 1

Table no-4: Compressive strength of Geopolymer Brick at 7 & 28 days using 4% (Alccofine)

Molar concentration	Compressive Strength (7 days) kg/cm²	Compressive strength (28 days) kg/cm²	Temperature ˚C
8M	96.4	158.79	Ambient temp.
10M	113.4	168.82	Ambient temp.
12M	119.09	172.02	Ambient temp.

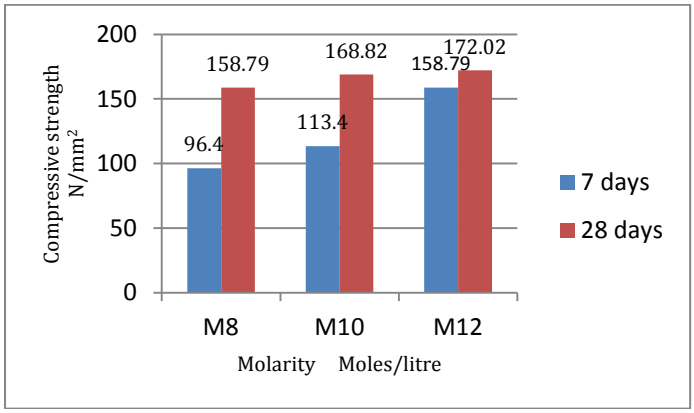

Chart 2

Observation:
As the percentage of alccofine varies from (2 to 4) % there is increase in compressive strength of brick. The study revealed that there is increase in strength of Geopolymer brick at ambient temperature both after 7 days and 28 days simple air curing for molarity of 12m when compared to 10M & 8M. The alccofine is ultra fine low calcium silicate based mineral material. It increases the packing density and improves the durability parameters.

5.2 Shape & Size:

As per specification given in IS: 1077 (1992) Size of brick is closely inspected to know the shape & size of brick. For this inspection work, 20 bricks of modular size (230mm x 115 mm x 75 mm) are first stacked along length, along width and along the height. The measurement with measuring tape is done along length wise, width wise and height wise:

Table no-5: Brick size

Brick size (mm)	Range (mm)	Measurement of 20 bricks(mm)	Tolerance as per IS:12894(2002) (mm)
Length=230	4520 to 4680	4560	±80
Width=115	2260 to 2340	2270	±40
Height=75	1500 to 1540	1532	±40

5.3 Water absorption test

As per given specifications in IS: 3495 (Part-2)-1992 bricks were weighed before placing in water tank or container full of water. The samples were kept for 24 hours and then placed out for 5 minute so that water wiped from surface and weighed and results given in below table.

$$\frac{W2 - W1}{W1} \times 100$$

W_2 = Weight of Brick after water absorption.

W_1 = Weight of Brick before immersing in water.

Table no- 6: Water absorption (fly ash+ foundry sand) based bricks

Molarity	Mineral material %	Water absorption %
8M	2	3
	4	3.8
10M	2	2.8
	4	3.64
12M	2	2.6
	4	3.24

Observation:
The results from above table shows water absorption decreases as the molar concentration of sodium hydroxide varies from 8M to12M where the 2 % of mineral material is used. The percentage of mineral material changes from 2 to 4 % there is increase in water absorption. Finally it observed that Na OH concentration affect the material.

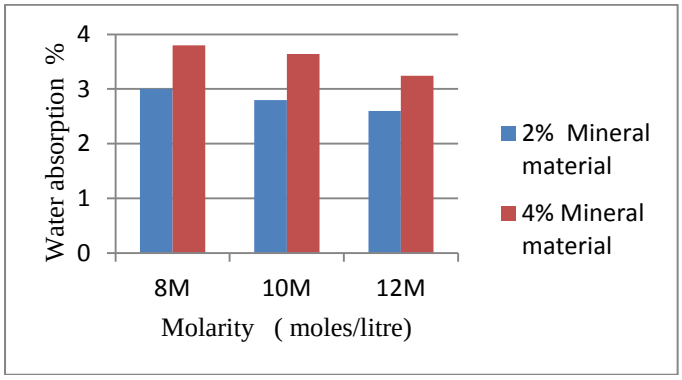

Chart 3

6. Advantages of Geopolymer Bricks

- No kiln burning is required.
- Bricks are uniform in shape and size as compare to clay burnt Bricks, therefore, require less mortar in brick work and finishing Work results in saving of cement mortar.
- Bricks are environment friendly as:

➢ Utilization of fly ash, which is a waste – product of thermal power plants having no value itself.
➢ Saves agricultural land where clay is used for manufacturing clay bricks.
➢ Less energy intensive compared to clay bricks and help in keeping clean environment.

- Utilization of by-products hence good solution to the disposal Problems.

7. CONCLUSIONS

In this research work experimental study is done on the newly developed Geopolymer brick using foundry sand by totally replacing the normal sand.

- Compressive strength is higher as compare to fly ash-cement based and burnt clay bricks.
- Water absorption is also low as compare to clay burnt bricks.
- Utilization of waste from foundry industry in making bricks for construction.
- Compressive strength increases as Na OH concentration varies from 8M to 12M.
- Size and shape is uniform throughout the length, width and height as per specification given in IS: 1077 (2002).
- Use of 2% ultra fine mineral material is optimum percentage which imparts strength to the bricks.
- No any kiln burning & water curing is required, simply bricks are harden by air curing and giving first class brick strength at 28 days.
- Slight efflorescence was visible on brick surface after performing efflorescence test.
- Its green material where utilization of waste by-product is done to develop brick.

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