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AN EXPERIMENTAL INVESTIGATION ON COST EFFECTIVE GEOPOLYMER BRICKS

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Abstract - *This investigation is mainly focused on the reuse of industrial wastes in the production of good quality bricks and also in the increment of low cost bricks towards the sustainable development of construction industry. In this study, experimental work has been performed on Geopolymer bricks made with fly ash, GGBS as source materials, quarry dust and river sand as fine aggregates and solution of sodium hydroxide (NaOH) and sodium silicate(Na_2SiO_3) as an activator. The molarity of sodium hydroxide was maintained at 1M for all the mixtures and the ratio of sodium silicate to sodium hydroxide solution varied as 0.25, 0.5 and 1. The brick specimens are taken for the dimensions 230mm*110mm*70mm. The brick properties such as compressive strength, water absorption and efflorescence tests were conducted on the test specimens. Compressive strength and weight of geopolymer bricks were determined after 3 and 7 days of ambient room temperature curing. It is observed that the increase of the ratio of SSS to SHS increased the weight and compressive strength of bricks at all ages and sodium silicate solution is imparting the increase in the strength of geopolymer bricks. It is also observed that the geopolymer bricks manufactured with quarry dust have attained less compressive strength when compared to geopolymer bricks prepared with sand.*

Key Words: Geopolymer brick, Fly ash, GGBS, Alkaline activator, Compressive strength, Cost analysis

1.INTRODUCTION

Brick is the most commonly used building material in India for more than 1000 years. India, a country over the total geographical area of 328.73 million hectares (MH), of which approximately 32% (105 MH) of it is facing land degradation. Currently, India produces over 360 billion bricks annually for which the net consumption is over 15,000 hectares of land with a serious adverse impact on soil erosion and unprocessed emissions. To produce conventional bricks, brick manufacturing industries nearly uses 2,200 m^3 soil per billion bricks per annum. But now-a-days fly ash bricks have been tremendously used due to the reduction in cost as well as its light weight. Due to the environmental pollution and its problems in the fly ash production, it is extremely important to rethink about the possibilities of alternative raw materials for brick manufacturing and sustainable development to protect the further land degradation. The cement manufacturing industries usually use fly ash as a partial and/or complete replacement to make Pozzolona cement. Ordinary Portland cement (OPC) typically produces a large amount of carbon dioxide (CO_2) in the nature that significantly contributes to greenhouse gas emissions. Geopolymer brick is an innovative building material, normally produced by the chemical reaction of inorganic particles which has a huge potential to deplete the greenhouse emission by 80%. This study is to present the technology behind the producing of geopolymer bricks using low calcium (Class-F) dry fly ash as its main source material and to discover and evaluate the physical and durable properties of it.

1.1 Need for Geopolymer brick

To produce environmental friendly brick, we have to replace the fly ash with some other binders which should not create any bad effect on environment. The use of thermal power plant by-products as binders can reduce this problem. In this aspect, the new technology geopolymer brick is a promising technique. In terms of reducing the global warming, the geopolymer technology could reduce the CO_2 emission to the atmosphere caused by fly ash and GGBS industries and also the proper usage of industrial wastes can reduce the problem of disposing the waste products into the atmosphere.

2.LITERATURE REVIEW

There is a wide range of research undergoing for the use of Geopolymer Brick. For our investigation, some important publications were reviewed to have a broad idea about Geopolymer Brick and they have been listed in the references at the end of the report.

However, the term Geopolymer was first introduced by Joseph Davidovits in 1978 and proposed that an alkaline liquid could be used to react with the silicon (Si) and the aluminium (Al) in a source material of geological origin or in by-product materials such as fly ash and rice husk ash to produce binders. Since the reaction is polymerization,he used the word Geopolymer in his study. After his study, so many scholars researched on geopolymer technology and proposed different methods on geopolymers. B.V.Rangan finally prepared proper mix design formulae for making of

geopolymer bricks and the same mix design is used in this study to evaluate the quantities of all ingredients so as to analyse the geopolymer bricks in terms of cost and quality.

3.EXPERIMENTAL STUDY

3.1 MATERIALS

Fly ash : Fly ash (FA) is a by-product of the combustion of pulverized coal in thermal power plants. It is a fine grained, powdery and glassy particulate material that is collected from the exhaust gases by electrostatic precipitators. Diameter of fly ash particles ranges from 1 µm–150 µm and surface area is typically 300 to 500 m^2/kg with specific gravity generally ranges between 1.9 and 2.8.

Fly ash is generally classified into classes C and F (ASTM C618) based on chemical composition. In this study, low calcium fly ash class F is used because of its high silica and alumina content. As fly ash is rich in silica and alumina, it replaces cement in concrete and also can be used as a binder. In presence of alkaline activator solution, it participates in polymerization and hence it plays a major role in the formation of geopolymers.

Ground granulated blast furnace slag(GGBS) : Ground granulated blast furnace slag (GGBS) is a by-product from the blast-furnaces used to make iron. These operate at a temperature of about 1,500^{0}C and are fed with a carefully controlled mixture of iron-ore, coke and limestone. The iron ore is reduced to iron and the remaining materials form a slag that floats on top of the iron. This slag is quenched which forms granules and this 'granulated' slag is then dried and ground to a fine powder called GGBS. GGBS is rich in lime and silica which has good cementitious properties and also imparts strength in concrete.

Fine aggregates : Natural river sand and quarry dust were used as fine aggregates in this study. The specific gravity in oven dry condition and water absorption of the sand as per IS 2386 (Part III, 1963) were 2.6 and 1% respectively. The specific gravity in oven dry condition and water absorption of the quarry dust as per IS 2386 (Part III, 1963) were 2.62 and 1.2% respectively.

Alkaline solution : The alkaline solution used was a combination of sodium silicate solution and sodium hydroxide solution. The sodium silicate solution has Na_2O= 13.7%, SiO_2=29.4%, and water=55.9% by mass. The sodium hydroxide (NaOH) solution was prepared by dissolving either the flakes or the pellets in water. The sodium silicate solution and the sodium hydroxide solution were mixed together one day before prior to use.

3.2 MAKING OF GEOPOLYMER BRICKS

As per Rangan's method, geopolymer bricks were manufactured using river sand and quarry dust as fine aggregates. The conventional method used in the making of normal brick is adopted to prepare geopolymer brick. First, the GGBS, fine aggregate and Fly ash are mixed in dry condition for 3-4 minutes and then the alkaline solution which is a combination of Sodium Hydroxide solution and Sodium Silicate solution is added to the dry mix. The sodium silicate solution and the sodium hydroxide solution were mixed together one day before prior to use. The mixing is done about 6-8 minutes for proper bonding of all the materials. After the mixing, the moulds are filled with the mixture by giving proper compaction. The sizes of the brick in the mould used here are 230mm x 110mm x 70mm.

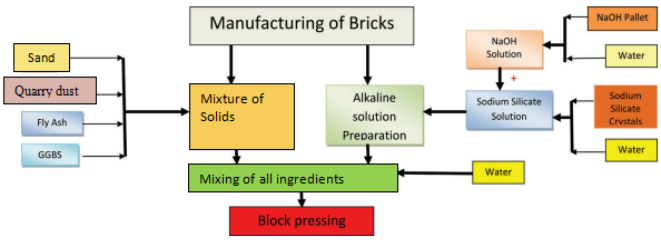

Fig 1 Manufacturing of Geopolymer bricks

3.3 MIX DESIGN OF GEOPOLYMER BRICK

Geopolymer bricks were manufactured as per Rangan's method. Mix design calculations for the ratio 1 (SSS/SHS) is explained below.

- Unit weight of brick =1200 Kg/m^3
- Percentage of fine aggregate = 30% =360 Kg/m^3
- (Fly ash + GGBS)+Alkaline liquid=70%=840 Kg/m^3
- Alkaline liquid/(Fly ash +GGBS)=0.3
- Fly ash+GGBS =646.15 Kg/m^3
- Alkaline liquid = 840-646.15 = 193.85 Kg/m^3
- Fly ash (90%) =582 Kg/m^3
- GGBS (10%) =64.15 Kg/m^3
- SSS/SHS =1
- SSS =193.85/2 =96.925 Lit/m^3
- SHS =193.85-96.925 =96.925 Lit/m^3
- SHP =96.925 x 40/1000 =3.877 Kg/m^3

- Water for SHS=96.925 - 3.877 =93.048 Lit/m^3

For SSS/SHS= 0.5 and 0.25, the values of SSS, SHS, SHP, water for SHS quantities also varies based on the SSS/SHS ratio.

Fig 2 Casted bricks and air dried bricks

3.4 Compressive strength of bricks

The compressive strength values of geopolymer bricks with varying SSS/SHS ratio made with different mixes of sand and quarry dust are drawn below.

Fig 3 Compressive strength testing on bricks

The compressive test of a brick is considered as an index of its durability and ability in a masonry wall to resist crushing loads. The dry compression test shall be carried out according to IS: 3495-Part 1(1992) specification. Three bricks per mix shall be taken for testing and their average value turns will be the "Dry Compressive Strength" of the brick.

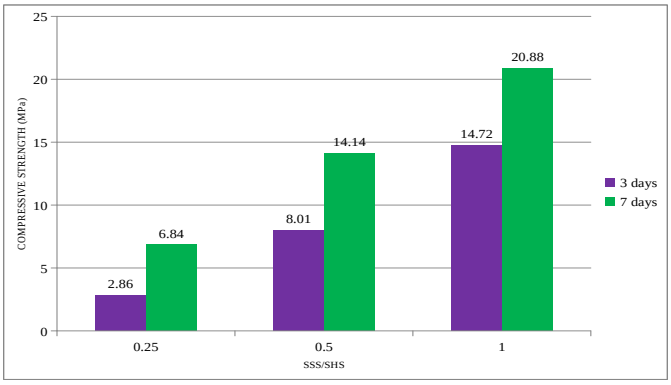

Fig 4 Average Dry ccompressive strength of Bricks using quarry dust for 3 and 7 days

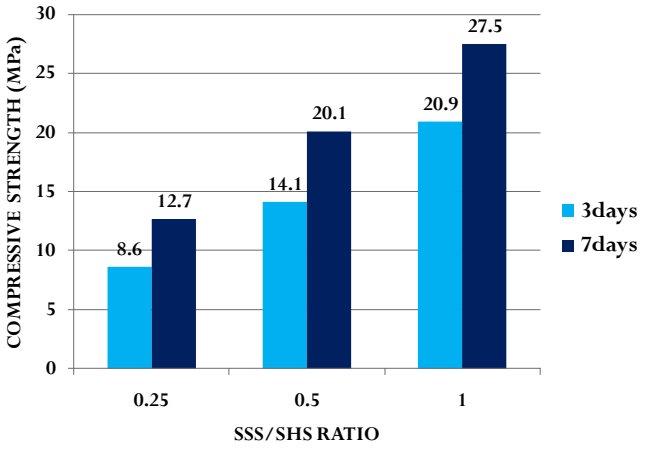

Fig 5 Average Dry ccompressive strength of Bricks using sand for 3 and 7 days

The above figures show the average dry compressive strength values of bricks for 3 and 7 days for different SSS/SHS ratios using both quarry dust and sand individually in different mixes. Both figures explains that the strength is maximum for SSS/SHS ratio 1.

4. CONCLUSION

Based on the test results, the following conclusions are drawn:

1) It is observed that the increase of the ratio of SSS to SHS increased the weight and compressive strength of bricks at all ages.

2) Sodium silicate solution is imparting the increase in the strength of geopolymer bricks.

3) It is also observed that the geopolymer bricks manufactured with quarry dust have attained less compressive strength when compared to geopolymer bricks prepared with sand.

4) It is observed that the increase of SSS/SHS ratio decreased the water absorption of bricks.

5) The bricks made with sand have less water absorption than the bricks made with quarry dust.

All other tested basic properties are meeting the acceptance criteria. It is recommended to use geopolymer bricks which has good strength and quality features and is eco friendly.

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