International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 08 | Aug 2021 www.irjet.net p-ISSN: 2395-0072

COMPARATIVE STUDY ON COST EFFECTIVE GEOPOLYMER BRICKS USING SAND AND QUARRY DUST

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Abstract - This study is mainly dealt with *Geopolymer bricks comprising of ingredients such as fly ash, GGBS as source materials, quarry dust and river sand both used as fine aggregates for different compositions and solution of sodium hydroxide(NaOH) and sodium silicate(Na_2SiO_3) as an alkaline activator. The molarity of sodium hydroxide was taken as 1M for all the compositions and the ratio of sodium silicate to sodium hydroxide solution varies as 0.25, 0.5 and 1. The dimensions of the brick specimens are taken as 230mm*110mm*70mm. Compressive strength, water absorption and Efflorescence tests were conducted on the test specimens to find out the brick properties. Compressive strength and dry and wet weights of geopolymer bricks were determined after 3 and 7 days of ambient curing at room temperature. It is observed that the increase of the ratio of SSS to SHS increased the dry and wet weights and compressive strength of bricks at all ages and sodium silicate solution is the main agent that is playing a major role in the increase in the strength of geopolymer bricks. It is also observed that the geopolymer bricks made with quarry dust have attained less compressive strength when compared to geopolymer bricks made with sand.*

Key Words: Geopolymer, Fly ash, GGBS, Quarry dust, Sand, Compressive strength, Cost analysis

1.INTRODUCTION

Bricks have been used in India for more than 1000 years. Due to the cost reduction as well as their less weight properties, fly ash bricks have been tremendously used. Due to the environmental pollution and its problems in the production of fly ash, it is highly important to rethink about the possibilities of alternative methods to control pollution and sustainable development. The cement manufacturing industries generally 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 increase greenhouse effect. Geopolymer brick is an innovative building material 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 production of geopolymer bricks using non-pollutant industrial waste materials and to discover and evaluate the physical and durable properties of it.

1.1 Introduction to Geopolymer

Generally, geopolymers are typically inorganic and alumino-silicate (Si-O-Al) based ceramic materials similar to zeolites. The formation of geopolymers is a quick reaction of the alkaline activated solution with silica, alumina minerals which further forms a three-dimensional polymeric long chain of an amorphous covalent bond network. The name geopolymer derived from the rock forming raw materials which are of geological origin and used in the synthesis process for silicon-based polymers.

1.2 Development of Geopolymer Bricks

Generally, fly ash of class F is rich with silica and alumina content. When fly ash (class-F) is used in the brick manufacturing, the high amount of silica and alumina reacts with alkali activated pre-mixed solution of sodium hydroxide and sodium silicate. This reaction activity results in gel formation which is known as the binder hence there is no requirement of cement in this brick production.

1.3 Objectives

This investigation is mainly focused on the basic properties of geopolymer bricks manufactured with class F fly ash and ground granulated blast furnace slag (GGBS), river sand and quarry dust used as fine aggregates,sodium hydroxide and sodium silicate used as an alkali activator. The molarity of sodium hydroxide fixed at 1M for all the mixtures and the ratio of sodium silicate solution (SSS) to sodium hydroxide solution (SHS) was varied at different ratios (0.25, 0.5 and 1). Based on the background of this project, the research comprises of the following stages:

1. To determine the weight and compressive strength of Geopolymer bricks using quarry dust and river sand as fine aggregate after 3 and 7 days of ambient room temperature curing.

2. To determine the effect of the ratio of SSS and SHS on the weight and compressive strength of geopolymer bricks.

3. To determine the basic properties of geopolymer bricks.

2. LITERATURE REVIEW

There is a wide range of research work undergoing on Geopolymer Brick. In this study, past literature was reviewed in order to have a brief knowledge on Geopolymer Bricks.
However, the term **Geopolymer** was first introduced by Joseph Davidovits in 1978 and proposed that an alkaline liquid can react with the silicon (Si) and the aluminium (Al) source materials like fly ash and GGBS to produce binders. Since the reaction is polymerization, he used the word Geopolymer in his study. B.V. Rangan introduced 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.

3. EXPERIMENTAL STUDY

3.1 MATERIALS

Fly ash : Class F Fly ash (FA) was being used in this study. Specific gravity of fly ash (FA) is 2.12.

Ground granulated blast furnace slag(GGBS) : GGBS was being used in this study. Specific gravity of GGBS is 2.7.

Fine aggregates : In this study, Natural sand and quarry dust were used as fine aggregates. The specific gravity of sand and quarry dust are 2.6 and 2.62 respectively.

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

3.2 MAKING OF GEOPOLYMER BRICKS

As per Rangan's methodology, geopolymer bricks were prepared using sand and quarry dust (QD) as fine aggregates. 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 (SHS) and Sodium Silicate solution (SSS) was added to the dry mix. The SSS and SHS were mixed properly together one day prior to cast. The mixing was done around 6 to 8 minutes for proper bonding of all the ingredients. Upon the mixing the ingredients, the brick moulds were filled with the mix and gave proper compaction through vibration. The sizes of the brick in the mould used here are 230mm x 110mm x 70mm.

Fig 1 Making of geopolymer bricks

3.3 MIX DESIGN OF GEOPOLYMER BRICK

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

To produce light weight geopolymer bricks, mix design is being proceeded assuming the unit weight of each brick as 1200-1500 Kg/m^3. The composition of a geopolymer brick comprises 70% of the main ingredients (fly ash, GGBS, Alkaline liquid) and the remaining 30% is the filler material(Fine aggregates..either sand or quarry dust). Again the main ingredient batch (70%) comprises of 20% of Alkaline liquid solution which is a mixture of Sodium Silicate and Sodium Hydroxide, 8-10% of GGBS and remaining 70% is fly ash. Based on this, quantities of SSS, SHS, SHP and extra water are calculated.

For SSS/SHS= 0.5 and 0.25, the values of sodium silicate solution (SSS), sodium hydroxide solution (SHS), sodium hydroxide pellets (SHP), water for SHS quantities also varied based on the SSS/SHS ratio.

Fig 2 Casted bricks and air dried bricks

3.4 Compressive strength of bricks

The compressive strength of geopolymer bricks with varying SSS/SHS ratio made with various mixes of sand and quarry dust are calculated as below.

Fig 3 Compressive strength test on bricks

The compressive strength test was carried out as per IS: 3495-Part 1(1992). Three number of bricks per each mix have been taken for testing and their average value was calculated as compressive strength of the brick.

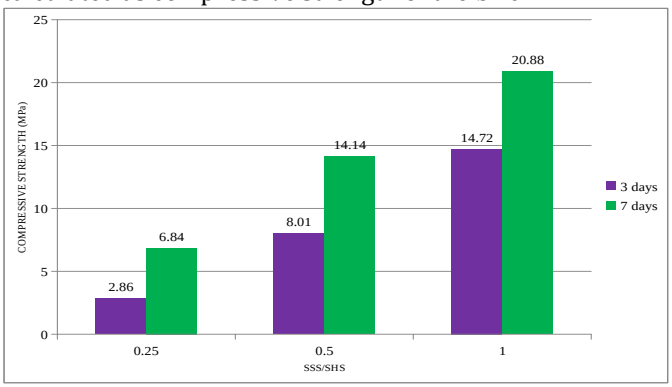

Fig 4 Average ccompressive strength of Bricks using quarry dust at 3 and 7 days

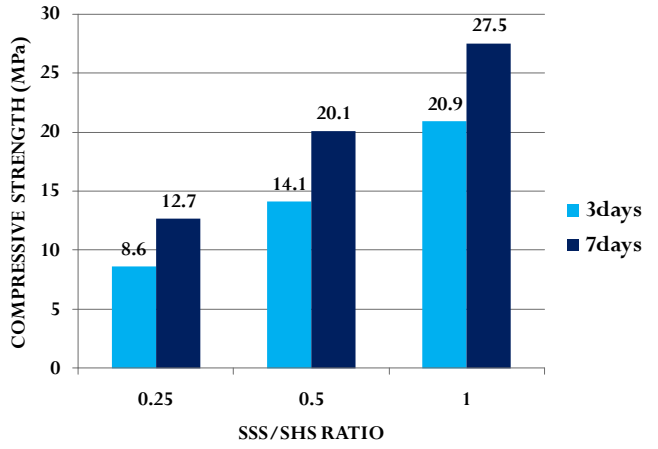

Fig 5 Average ccompressive strength of Bricks using sand at 3 and 7 days

The compressive strength of geopolymer bricks after 3 and 7 days of ambient curing were shown in the figures above for different SSS/SHS ratios using sand and quarry dust separately in different geopolymer mixes. The results explained that the strength is maximum at SSS/SHS ratio.

3.5 Water absorption of bricks

Water absorption of a geopolymer brick is the percentage of water absorbed by the brick itself which can be calculated by the difference between dry and wet weights of a brick.Water absorption test can be done by taking the dry weight of air-dried brick specimens of all compositions and noted as W1, and then those bricks are immersed in water for 24 hours. After 24 hours, the bricks are removed from the water and wiped with cloth to remove water on the surface. Then the weights of all specimens of bricks are taken nearest to grams and noted as Wet Weight W2. The ratio of difference between these weights to the wet weight gives the water absorption of the brick.

W1 = dry weight of brick ;W2 = wet weight of brick

Water Absorption %={ (W2 -W1)/ W2 } x 100

Table 1 Water absorption of bricks using quarry dust

SSS/SHS ratio	Dry Weight W1 (Kg)	Wet Weight W2 (Kg)	Water Absorption %
0.25	2.74	2.87	4.74
0.5	2.82	2.94	4.25
1	2.93	3.04	3.75

Table 2 Water absorption of bricks using sand

SSS/SHS ratio	Dry Weight W1 (Kg)	Wet Weight W2 (Kg)	Water Absorption %
0.25	2.78	2.89	3.96
0.5	2.82	2.92	3.55
1	2.96	3.05	3.04

The water absorption for dry bricks should not exceed 20% of the weight of the brick. It is noticed that the increase of sodium silicate solution and sodium hydroxide (SSS/SHS) ratio decreased the water absorption of bricks. The bricks were made with sand had less water absorption than the bricks made with quarry dust.

Some other properties were observed as follows:

1. All the samples tested showed very slight efflorescence which is acceptable.
2. All the samples tested for soundness showed that they are heavy and good causing a metallic ringing sound when struck against each other.
3. All the samples tested showed very slight indentation, which is acceptable. The bricks are compact, homogeneous and free from
4. any imperfections such as lumps, holes, etc.
5. The overall lengths of the arranged bricks shall be measured with the help of a steel tape. Similarly the width and depth of the arranged bricks are measured along straight line.
6. All the samples tested show moderate edge failure which is acceptable.

3.6 Cost Analysis of geopolymer bricks

Cost analysis of geopolymer bricks made with quarry dust and sand is discussed here. As per standard rates at present, the material cost per kg is tabulated below.

Table 3 Material cost per kg

Material	Cost per kg (Rs)
Class F Fly ash	1/-
GGBS	3/-
Quarry dust	0.5/-
Sand	1.2/-
Sodium silicate solution	23/-
Sodium hydroxide pellets	78/-

Cost analysis of geopolymer bricks made with quarry dust and sand for different SSS/SHS ratios is tabulated below.

Table 4 Cost analysis of geopolymer brick

SSS/SHS ratio	Cost per brick (Quarry dust) Rs.	Cost per brick (Sand dust) Rs.
0.25	5.87/-	6.50/-
0.5	7.08/-	7.14/-
1	8.67/-	9.30/-

It is observed from the cost analysis, it is recommended to use geopolymer bricks which save the environment.

4. CONCLUSIONS

Based on the results, the conclusions are given below.

1) Weight and compressive strength of bricks gets increased with the increase of SSS/SHS ratio.

2) Sodium silicate solution is the main ingredient that gives strength property to the geopolymer brick.

3) When made a comparision of compressive strength between bricks made of quarry dust and sand, sand made bricks has higher strength than quarry dust made bricks.

4) Water absorption gets decreased with increase in SSS/SHS ratio and sand made bricks has less absorption than bricks 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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