Strength Behaviour of Geopolymer Concrete with Partial Replacement of Coarse Aggregate by Brick Bats

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Abstract - *Geopolymer concrete is an innovative, eco friendly construction material, and an alternative to portland cement concrete. Geopolymer concrete reduces the demand of portland cement which is responsible for CO_2 emission. This experimental study is based on strength behaviour of geopolymer concrete by partially replacing GGBS and brickbats. Light weight aggregate concrete reduces the density and increase thermal insulation. Brickbats are the type of artificial lightweight aggregate. The main objective of the project is to reduce the unit weight of geopolymer concrete by partially replacing brickbats in various percentages such as 0%, 5%, 10%, 15%, 20%, 25%, and 30% without affecting the environment. G 20 grade of concrete mix design with ratio 1: 1.5: 3 were used. The geopolymer is designed for 8M. The mechanical property test was done for geopolymer material such as Fly ash, GGBS, Fine aggregate, Coarse aggregate and brick bats. The test specimen of 150mm x 150mm x 150mm cubes were prepared for compression test and 100mm diameter 200mm length cylinder for spilt tensile were tested and compared with conventional geopolymer concrete.*

***Key Words*: Geopolymer concrete, Fly ash, GGBS, Brick Bats, Light weight aggregate**

1. INTRODUCTION

Geopolymer concrete is an innovative, eco friendly construction material, and an alternative to portland cement concrete. Geopolymer concrete reduces the demand of portland cement which is responsible for CO_2 emission. This experimental study is based on strength behaviour of geopolymer concrete by partially replacing GGBS and brickbats. Light weight aggregate concrete reduces the density and increase thermal insulation. Brickbats are the type of artificial lightweight aggregate. The main objective of the project is to reduce the unit weight of geopolymer concrete by partially replacing brickbats in various percentages such as 0%, 5%, 10%, 15%, 20%, 25%, and 30% without affecting the environment. G 20 grade of concrete mix design with ratio 1: 1.5: 3 were used. The geopolymer is designed for 8M. The mechanical property test was done for geopolymer material such as Fly ash, GGBS, Fine aggregate, Coarse aggregate and brick bats. The test specimen of 150mm x 150mm x 150mm cubes were prepared for compression test and 100mm diameter 200mm length cylinder for spilt tensile were tested and compared with conventional geopolymer concrete.

2. LITERATURE REVIEW

(Elizabeth 2016) In this project on Geopolymer concrete using GGBS which will react with sodium hydroxide and sodium silicate solutions. As coarse aggregate we are using a combination of gravels and broken tile (Mangalore tile) pieces and rock sand as fine aggregate.

(Shalini 2016) The use of RHA as partial replacement of cement in mortar and concrete has been extensively investigated in this paper. Due to high specific surface area of RHA the dosage of super plasticizers has increased and maintains desirable workability.

(Mohammed Areeb Qidwai, 2015) From this paper shows that the increase in the content of sodium hydroxide and sodium silicate increase both compressive as well as tensile strength. The setting time is very short so it is necessary to add super plasticizer to delay the setting time. The geopolymer concrete also shows excellent resistance to sulphate attack, good acid resistance, undergoes low creep, and suffers very little drying shrinkage. The geopolymer concrete is eco-friendly and cheaper than OPC concrete.

(Mohd mustafa al bakri abdullah, 2012) Investigation on the possibility of producing foam concrete by using a geopolymer system. Class C fly ash was mixed with an alkaline activator solution, and foam was added to the geopolymeric mixture to produce lightweight concrete. The NaOH solution was prepared by dilute NaOH pellets with distilled water

(Abdul aleem, 2012) This paper briefly reviews the constituents of geopolymer concrete, its strength and potential applications. This paper explains about the geopolymer schematic formation, necessity of geopolymer, constituents of geopolymer, properties of geopolymer, applications and limitation of geopolymer.

3. MATERIAL USED

Fly ash

Fly Ash is a by-product of the combustion of pulverized coal in electric power generation plants. The size of the Fly Ash particles varies but tends to be similar to slightly larger than Type I Portland cement. The Fly Ash is collected from the exhaust gases by electrostatic precipitators or bag filters. Chemical makeup of Fly Ash is primarily silicate glass containing silica, alumina, iron and calcium. Colour generally ranges from dark grey to yellowish tan for Fly Ash used for concrete.

Ground granular blast furnace slag

Ground granulated blast furnace slag (GGBS) is a by-product from the blast furnace used to make iron. These operate at a temperature of about 1,500 degrees centigrade and are fed with a carefully controlled mixture of iron-ore, coke and limestone. This 'granulated' slag is then dried and ground to a fine powder. GGBS cement is added to concrete in the concrete manufacturer's batching plant, along with Fly ash, aggregates and water. The normal ratios of aggregates and water to cementitious material in the mix remain unchanged.

Fine aggregate

Fine aggregate consists of natural sand, crushed stone sand or crushed gravel stone dust with most particles through a 9.5mm sieve. Fine aggregate is natural sand which has been washed and sieved to remove particles larger than 5mm.It should have finest modulus between 2.50 to 3.50.

Table -1: Properties of Fine aggregate

Specific gravity	2.42
Fineness modulus	2.7
Zone	II

Coarse aggregate

Aggregates are inert granular materials. Aggregates, which account for 60 to 75 per cent of the total volume of concrete, are divided into two distinct categories-fines and coarse.

Brick bats

Brickbats are Collected locally and then broken into pieces of 20mm size, mechanically sieved through 4.75mm sieve to remove the finer particles. These rejected bricks can also be a potential source of coarse aggregate.

Table -2: Properties of Coarse aggregate

Properties	Coarse aggregate	Brick bats
Specific gravity	2.85	2.56
Fineness modulus	6.6	-
Water absorption	1.3%	10.09%
Impact value	6.34	17.89

Sodium hydroxide solution:

Sodium hydroxides are available in solid state by means of pellets or flakes. The cost of the sodium hydroxide is mainly varied according to the purity of the substance. The role of sodium hydroxide in this study is to activate the Geopolymer concrete, which is a homogeneous material. Hence, it is recommended to use sodium hydroxide with cost effectiveness and purity.

Sodium silicate solution:

Sodium silicate is also known as water glass or liquid glass, available in liquid (gel) form. In the present investigation, sodium silicate 2.5 (ratio between Na_2O to SiO_2) is used.

4. MIX DESIGN

Alkaline solution preparation

Alkaline liquids are prepared by mixing of the sodium hydroxide solution and sodium silicate at the room temperature. When the solution mixed the both solution start to react i.e. (polymerization takes place) it liberate large amount of heat so it is recommended to leave it for about 24 hours thus the alkaline liquid is get ready as binding agent. In this paper, geopolymer concrete is prepared for 8 molarities of Sodium hydroxide. The molecular weight of sodium hydroxide is 40. To prepare 8M i.e. 8 molar sodium hydroxide solutions, 320g of sodium hydroxide flakes are weighed and they can be dissolved in dissolved in distilled water to form 1 litre solution. For this, pycnometre of 1 litre capacity is taken, sodium hydroxide flakes are added slowly to distilled water to prepare 1-liter solution.

Table -3: Constituents of Geopolymer concrete

S.NO	Mix design for 1 cubic meter	
	Material	Quantity(kg/m^3)
1	Fly ash	444.4
2	Fine aggregate	540
3	Coarse aggregate	1260
4	Water	129.7
5	Sodium hydroxide	44.5
6	Sodium silicate	111.5
7	Molarity	8M
8	NaOH and Na_2SiO_3	2.5

Mix design

In this design, G20 grade of concrete were used.8M of sodium hydroxide is used in alkaline preparation. The ratio between sodium hydroxide and sodium silicate is taken as 2.5. The aggregate volume is taken as 75% of total volume of cube. Alkaline liquid to fly ash ratio is 0.35. Water to geopolymer solid ratio is 0.35. Coarse aggregates are partially replaced with various percentages 0%, 5%, 10%, 15%, 20%, 25%, and 30%.

Table -4: Mix design of G-20 of concrete

Fly ash	Fine aggregate	Coarse aggregate	Sodium hydroxide	Sodium silicate
444.4	540	1260	44.5	104

Mix procedure

In the laboratory, the fly ash and the aggregates were first mixed together dry in pan mixer for about three minutes. The aggregates were prepared in saturated-surface-dry (SSD) condition. The alkaline liquid was mixed with the super plasticizer and water. The liquid component of the mixture was then added to the dry materials and the mixing continued usually for another four minutes. The workability of the fresh concrete was measured by means of the conventional slump test and compaction factor test. Heat curing of low-calcium fly ash-based geopolymer concrete is generally recommended. Heat curing substantially assists the chemical reaction that occurs in the geopolymer paste. Both curing time and curing temperature influence the strength of geopolymer concrete. The test specimens were heat-cured at 60°C in an oven. The curing time varied from 48 hours. Longer curing time improved the polymerization process resulting in higher strength.

Figure 1 Preparation of specimen

Figure 2 Casting of cubes

5. RESULTS AND DISICUSSION

SLUMP TEST

The slump test is most commonly used method of measuring consistency of concrete. The internal surface is thoroughly cleaned and placed in smooth surface. The mould is filled with four layers. The pattern of slump also represents the characteristics of concrete. The difference in height of the mould is measured and taken as slump of concrete.

Table -5: Slump values

GEOPOLYMER CONCRETE USING GGBS							
% of bricks added	0	5	10	15	20	25	30
slump value (mm)	72	76	79	82	85	80	75

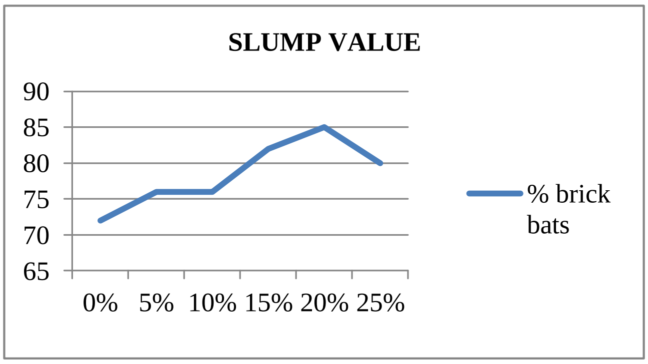

Chart 1 Slump values

Compaction factor test

Compaction factor test is more refined test than slump test. This test measures the degree of compaction and also measures the workability of concrete. The compaction factor test measures the quality of concrete. this test clearly depicts the workability of concrete.

Table -6: Compaction factor values

GEOPOLYMER CONCRETE USING GGBS							
brick bats %	0	5	10	15	20	25	30
compaction(mm)	0.85	0.88	0.92	0.94	0.98	0.93	0.90

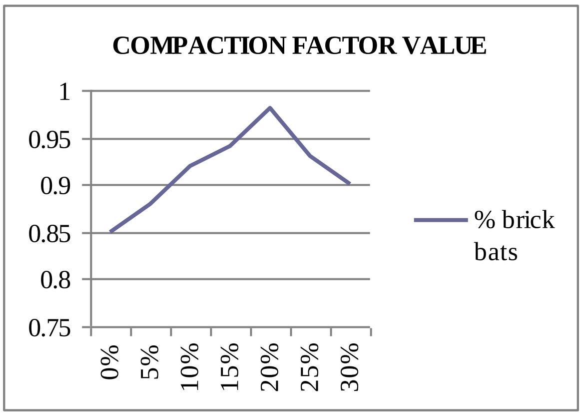

Chart 2 Compaction factor value

Compressive strength test

Compressive strength is most common test. The cube sizes of 150mm x150mm x 150mm.G 20 grade concrete were prepared. Each layer is compacted by tamping rod. After taping rod layer has been compacted, the top of the mould is levelled using trowel. The specimen is tested after 7 day and 28 days.

Table -7: Compressive strength

SI. NO	Coarse aggregate replaced with brick bats	Geopolymer concrete with 8M (N/mm²)	
		7 days	28 days
1	0%	20	28.52
2	5%	22.3	31.67
3	10%	23.7	35.10
4	15%	21.9	37.22
5	20%	23.4	34.61
6	25%	21.3	32
7	30%	20.5	28.6

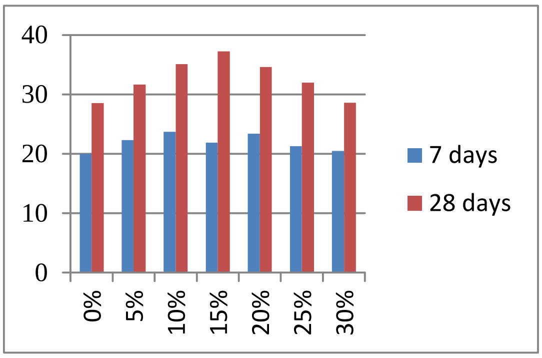

Chart 3 Comparison test on 7 and 28 days

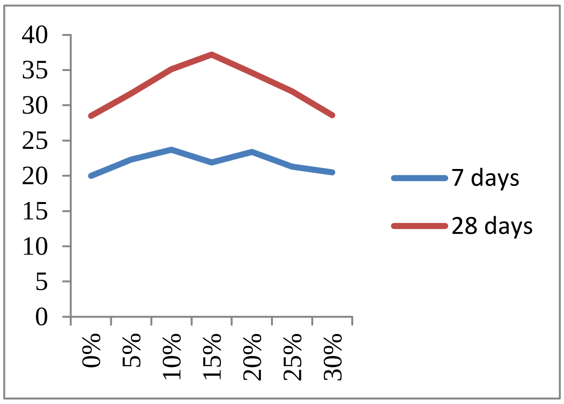

Chart 4 Comparison test on 7 and 28 days

Split tensile test

This is an indirect tension test. In this test a cylindrical specimen is placed horizontally between the loading surfaces of a compression testing machine. The load is applied until failure of cylinder along the vertical diameter. The main advantage of the test is the same compressive testing machine and the same cylindrical specimen used for compression test may be used. Narrow cracking strips of suitable material to reduce the high compressive stresses. The spilt tensile test is simple to perform and generally gives uniform results.

Table -8: Split tensile strength

SI.NO	Coarse aggregate replaced with brick bats	Geopolymer concrete with 8M (N/mm²)	
		7 days	28 days
1	0%	1.52	2.13
2	5%	1.57	3.13
3	10%	1.64	4.92
4	15%	1.66	5.0
5	20%	2.07	5.35
6	25%	1.60	3.20
7	30%	1.52	3.13

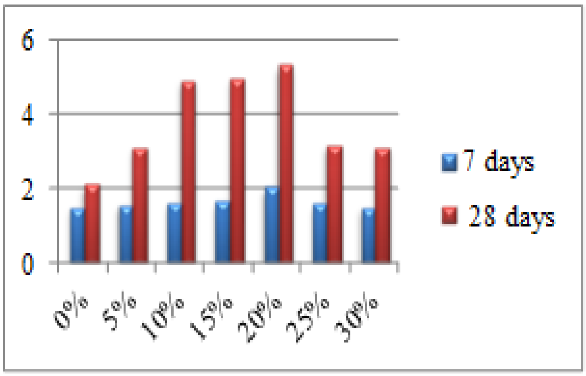

Chart 5 Comparison test on 7 and 28 days

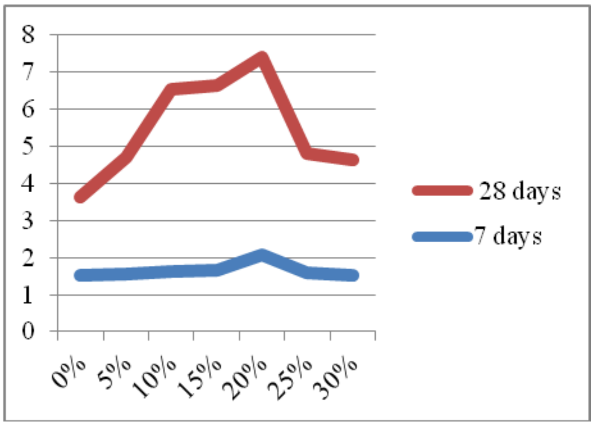

Chart 6 Comparison test on 7 and 28 days

6. CONCLUSION

The construction industry is in demand of eco-friendly & greener materials which are durable. As compared to the existing concrete materials, fly ash and GGBS is advantage than other material and main aim of the project is to reduce density of the geopolymer concrete by replacing coarse aggregate with brick bats 0%, 5%, 10%, 15% 20%, 25%, 30%. The strength of geopolymer concrete was increased with increase in percentage of brick bats in various percentages. During the mixing of concrete, the workability of the concrete is sufficiently attained less amount of water cement ratio itself. The strength of geopolymer concrete was increased with increase in percentage up to 20%. More than 20% replacement the strength of concrete is slightly decreases compare to nominal mix and its effects on the structure. The maximum strength obtained for brick bat at 20% in 28 days is 34.61 MPa. In split tensile test the maximum strength is obtained for 20% replacement of brick bats in concrete at 28 days. The unit weight also decreased a percentage of brick bat and decreased in comparison with the conventional geopolymer concrete. The compaction factor decreased the percentage of brickbat and decreased in comparison with conventional geopolymer concrete. When increasing the percentages of brick bats the unit weight decreases but the strength decreases. Geopolymer innovation is most progressive in precast applications because of the relative simplicity. Geopolymer concrete has many advantages over normal concrete. It is stronger, more resistant to chemicals and corrosion, and has more possible applications than concrete made with ordinary Portland cement. Overall geopolymer concrete is better and more reliable in extreme environments when compared to ordinary concrete.

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