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EXPERIMENTAL STUDY ON FLY ASH AND GGBS BASED GEOPOLYMER CONCRETE USING M-SAND

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Abstract— This paper presents the results on mechanical properties of Fly Ash and GGBS based Geopolymer concrete utilizing M- sand as a replacement to Fine aggregate. M-sand is replaced in the ratio of 0%, 20%, 40%, 60%, 80% and 100% to natural sand. In this study, cement is fully reintegrated by fly ash together with GGBS as (FA100 -GGBS0, FA90-GGBS10, and FA80 -GGBS20). Sodium hydroxide (NaOH) and Sodium Silicate (Na_2SiO_3) solutions act as an alkaline activator. Molarity of sodium hydroxide used is 10M. Mechanical properties like compressive strength, split tensile strength and flexural strength of Geopolymer concrete at the age of 7 days, 28 days and 90 days are studied at ambient curing.

Keywords: Geopolymer, Fly ash, Alkaline liquids, GGBS, M-Sand, compressive strength, split tensile strength, flexural strength.

I. INTRODUCTION

Geopolymer concrete is considered as future concrete as it completely replaces the usage of cement which act as primary binding material for the construction of any structure. As the creation of cement is responsible for the huge volume of disposal of carbon dioxide within the atmosphere and also its production is highly energy intensive [1]. Emission of carbon dioxide within the atmosphere is the major reason for the consequence related to global warming. For every one ton of cement production during the manufacturing process, it releases one ton of co_2 into atmosphere[2].Based on this aspect it is essential to develop an alternative material which satisfies the properties of conventional concrete in addition to eco-friendly construction material. These include the materials which are obtained from industries as their by-products like fly ash, GGBS, Rice Husk Ash, metakaolin etc. In the present study, we use Fly ash along with GGBS as a complete replacement to cement. Fly ash blended GGBS based GPC mix enhances the strength properties of at ambient curing [4].

Fly ash is an industrial by-product which is formed during the process of ignition of coal at high temperatures whereas GGBS is the byproduct formed from the blast furnace during manufacture of iron. Among the various by products attained, Fly ash as well as GGBS considered as potential source materials in the manufacturing of Geopolymer concrete [5]. M-Sand is used as a substitute to river sand. It is used because of increase in the demand for sand leads to deficiency in normal sand in most parts of the world and by the usage of M-Sand,construction cost can be controlled easily [6]. Geopolymer Concrete was initiated by Davidovits (1978); represent an extensive variety of materials characterized by group or system of inorganic molecules. He recommended that an alkaline liquid is used to react with Silicon and Aluminium in source material like fly ash, GGBS, rice husk ash to form binders. This binder is termed as Geopolymer [3]. The chemical reaction that takes place between the source material and the alkaline liquid is known as polymerization process. Geopolymer has a chemical configuration identical to zeolites but they perhaps formed as an amorphous structure.

II. MATERIALS AND ITS PROPERTIES

A. Fly Ash

Fly ash used in the present investigation belongs to class-F fly ash and it is collected from Rayalaseema Thermal Power Plant (RTPP), Muddanur, Kadapa (Dist), Andhra Pradesh. The specific gravity of fly ash is 2.2.

TABLE 1
PROPERTIES OF FLY ASH

SI.No	Chemical composition	Fly ash (% wt.)
1	Silica	56.01
2	Aluminum oxide	28.10
3	Iron oxide	3.18
4	Calcium oxide	2.36
5	Magnesium oxide	0.38
6	Sulphur	1.64
7	Titanium oxide	1.75
8	Potassium oxide	0.73
9	Alkalies	0.61
10	Loss of ignition	0.40

B. Ground Granulated Blast Furnace Slag (GGBS):

GGBS is collected from JSW steel plant, Nandyal, Kurnool (Dist.), Andhra Pradesh. Specific gravity of GGBS is 2.9.

TABLE 2
PROPERTIES OF GGBS

SI.NO	Chemical composition	GGBS (% wt.)
1	Calcium oxide	40
2	Silica	34
4	Aluminium oxide	12
5	Manganese oxide	7
6	Iron oxide	1.0

C. M-Sand

M- Sand is used as an alternative to river sand. It is acquired from hard granite rock which is crushed into fine aggregate. M-sand is a superior quality manufactured sand conforming to international standards. The specific gravity of M- sand used in the present study is 2.65 and fineness modulus is 2.8.

D. Alkaline liquid

The alkaline liquid used in this investigation includes the solution of sodium hydroxide and solution 0of sodium silicate. Sodium hydroxide (NaOH) generally available in the form of pellets or flakes, in the present study sodium hydroxide is used in the pellets form with 98% purity. Sodium hydroxide of 10M (Molarity) is used. Specific gravity and pH value of sodium hydroxide are 1.8 and 14. Sodium silicate is available in the liquid form. The chemical composition of sodium silicate is Na_2O – 14.7, SiO_2 – 31.4 and water – 53.9 by mass. Specific gravity of sodium silicate is 1.7.

E. Coarse Aggregate

Coarse aggregates used in the present study are obtained from locally available crushed hard rocks passing through 20mm and retained on 10mm IS Sieve. The specific gravity of 20mm aggregate is 2. 7 and specific gravity of 10mm coarse aggregate is 2.54.

F.Fine Aggregate

Fine aggregate used in the present investigation is obtained from locally available sources. Sand which is passed through 4.75mm IS. Sieve is used. Specific gravity and fineness modulus of fine aggregate are 2.625 and 2.79.

G. Water

Potable fresh water is used if necessary.

III. METHODOLOGY

A. Mix design of Geopolymer concrete

The mix design of geopolymer is based on conventional concrete with some modifications. As the mix design of geopolymer concrete does not exist, we use trial and error method. In the design of geopolymer concrete mix combined mass of coarse aggregate and fine aggregate are taken as 75% of total mass of concrete. In the case of conventional concrete, it varies from 75% to 80% of the mass of concrete. Mass of concrete was taken as 2400kg/m^3. Mass of coarse aggregate was taken as 70% of total mass of aggregate and mass of fine aggregate was taken as 30% of total mass of aggregate. The combined mass of Geopolymer binder and Alkaline liquid can be obtained by assuming the ratio of alkaline liquid to flash as 0.45. Mass of geopolymer binder, the mass of fly ash and mass of alkaline liquid can be found. To obtain the mass of sodium hydroxide and sodium silicate solution, we take the ratio of sodium silicate solution to the sodium hydroxide solution as 2. If necessary extra water can be added to the mix to achieve workable concrete.

B. Preparation of alkaline solution

Alkaline solution was prepared by mixing of sodium hydroxide solution and sodium silicate solution. Sodium hydroxide solution was prepared before one day of the casting of geopolymer concrete. Sodium hydroxide solution was prepared by taking NaOH pellets of 10M consists of 10x40= 400gms and mixing with one liter of water, where 40 was the molecular weight of NaOH. On the day of the casting of geopolymer concrete mix, sodium silicate solution and sodium hydroxide solution are mixed thoroughly and then used.

C. Preparation of Geopolymer Concrete

Mixing: During the mixing process of geopolymer concrete, first the materials such as fly ash, GGBS, coarse aggregate, and fine aggregates are mixed in a dry condition about 3-4 minutes and then an alkaline solution of sodium hydroxide and solution of sodium silicate was added to the dry mix. The mixing process was continued for about 6-8 minutes for proper binding of all the materials.

Casting: After mixing, immediately geopolymer concrete mix was poured into moulds and tamping was done for proper compaction. The top surface of the mould was properly finished. Moulds used include cubes (150mmx150mmx150mm), cylinders (150mmx300mm) and beams (100mmx100mmx500mm).

Curing: After 2 days, moulds are demoulded and kept for ambient curing. Curing was done for 7 days, 28 days and 90 days and then tests are conducted.

IV. RESULTS AND DISCUSSIONS

In this study, the mechanical properties of Geopolymer concrete are investigated by using different ratios of M-sand. Mechanical properties such as compressive strength, split tensile strength and flexural strength of geopolymer concrete are studied.

A. Compressive Strength

Compressive strength of geopolymer concrete at different proportions of M-sand (0%, 20%, 40%, 60%, 80% and 100%) was shown in table. From the table mix id M4 that was 60% replacement of m-sand to fine aggregate has shown maximum compressive strength value.

TABLE 3
COMPRESSIVE STRENGTH

Mix id	% Replacement	Compressive Strength (N/mm^2)		
		7 Days	28 Days	90 Days
M1	0	27	38	43.13
M2	20	28.9	40.23	45.2
M3	40	31.3	42.26	48.17
M4	60	35	46	51.3
M5	80	33	44	48.5
M6	100	32	43	47.3

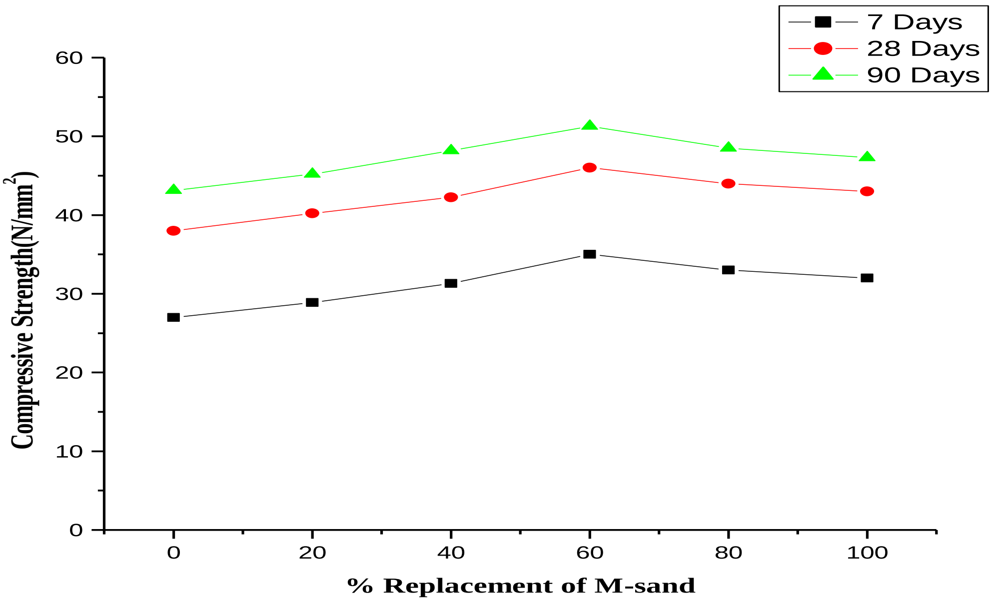

Figure 1: Compressive Strength Vs % Replacement of M-Sand

Figure 2: Compressive strength Test

B. Split Tensile Strength

The split tensile strength result of the geopolymer concrete at the age of 7 days,28 days and 90 days are shown in the table. From the table, Mix id M4 that was 60% replacement of M-sand to fine aggregate has attained maximum tensile strength value.

TABLE 6
SPLIT TENSILE STRENGTH

Mix id	**% Replacement**	**Split tensile strength (N/mm^2)**		
		7 Days	**28 Days**	**90 Days**
M1	0	2.07	2.8	3.28
M2	20	2.2	3.05	3.59
M3	40	2.35	3.27	3.86
M4	60	2.53	3.51	4.15
M5	80	2.41	3.4	3.9
M6	100	2.3	3.36	3.81

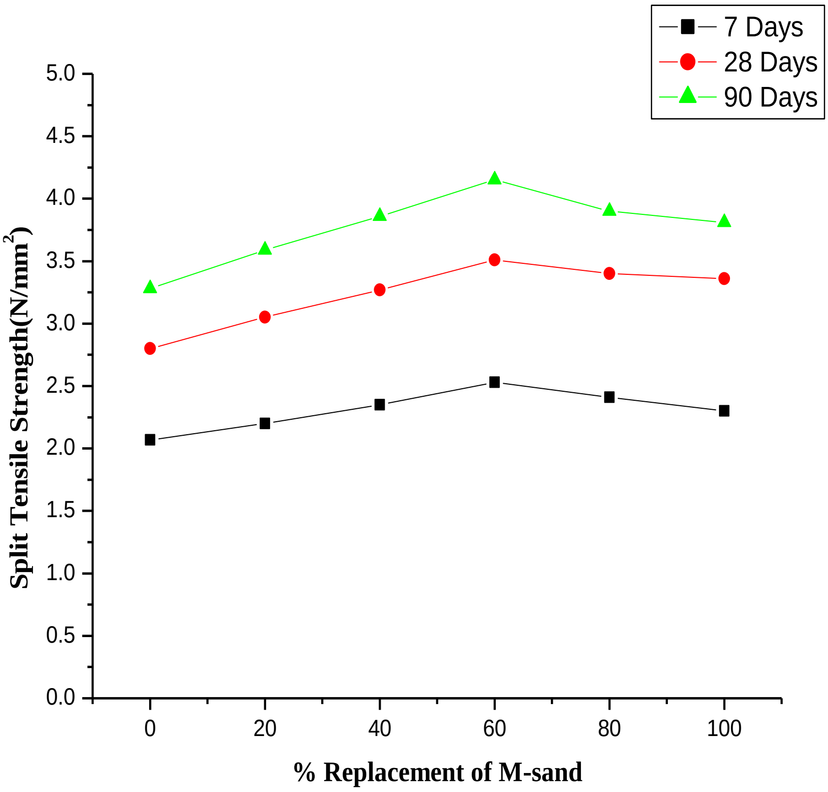

Figure 3: Split Tensile Strength vs. % Replacement of M-Sand

Figure 4 : Split Tensile Test

C. Flexural Strength

The flexural strength result of the geopolymer concrete at the age of 7 days, 28 days and 90 days are shown in the table. From the table mix id M4 that was 60% replacement of M-sand to fine aggregate has attained maximum flexural strength value.

TABLE 7
FLEXURAL STRENGTH

Mix id	% Replacement	Flexural strength (N/mm^2)		
		7 Days	28 Days	90 Days
M1	0	3.68	4.72	5.41
M2	20	3.96	5.01	5.73
M3	40	4.17	5.6	6.3
M4	60	4.45	6.1	6.8
M5	80	4.26	5.9	6.51
M6	100	4.05	5.7	6.27

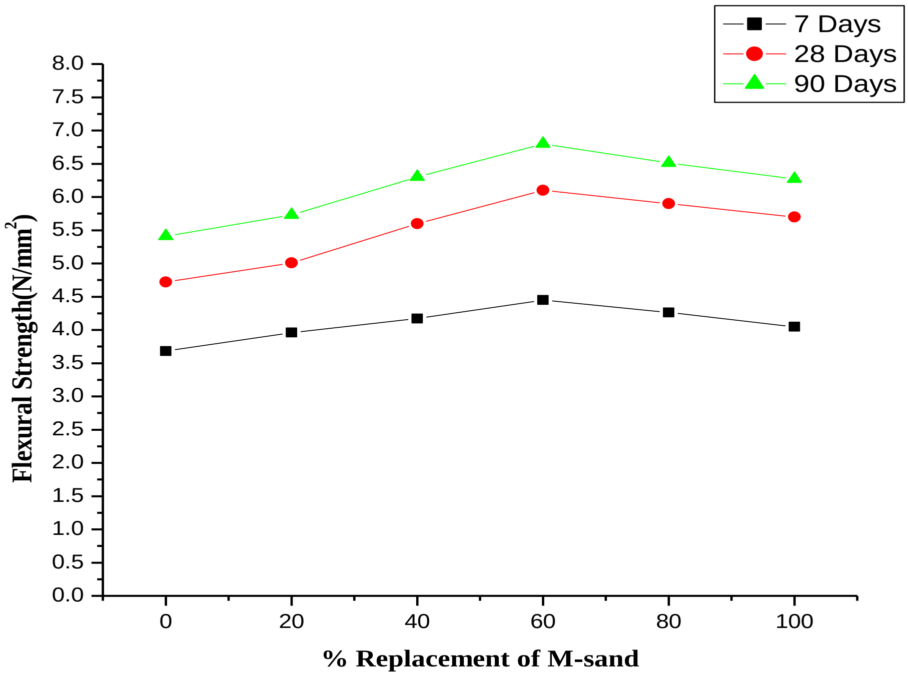

Figure 5: Flexural Strength vs % Replacement of M-Sand

Figure 6: Flexure Test

V. CONCLUSIONS

The use of industrial by-products like Fly ash, GGBS and M-sand has gained significant importance because of the requirement of environmental protection and sustainable construction in the future. Based on the experimental work reported in this study, the following conclusions are drawn.

1. Cement can be completely replaced by fly ash and GGBS to produce geopolymer concrete which will reduce the carbon dioxide emissions.
2. The usage of M-Sand in geopolymer concrete enhances the environmental benefits by reducing sand mining.
3. The compressive strength of Fly ash and GGBS based geopolymer concrete using M-Sand as fine aggregate was more than nominal geopolymer concrete.
4. The compressive strength of Mix M4 (60% replacement of M-sand) Geopolymer concrete shows maximum compressive strength.
5. Split tensile strength of Mix M4 (60% replacement of M-sand) Geopolymer concrete has shown maximum split tensile strength.
6. Flexural strength of Mix M4 (60% replacement) geopolymer concrete has shown maximum flexural strength.
7. Fly ash and GGBS shall be effectively used which reduces environmental pollution by dumping on landfills.

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