Experimental Investigation on Mechanical Properties of Geopolymer Concrete When River Sand Replaced With Manufactured Sand As Fine Aggregate

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Abstract: Concrete is the world's most versatile, durable and reliable construction material. There are many ecological issues connected with the manufacture of OPC, at the same time availability of natural sand is also becoming costlier and scarcity due to illegal dredging of river sand. The geopolymer concrete with low calcium fly ash is best alternative material for conventional concrete and manufactured sand is an alternative for natural sand. The main objectives of the present work is to study the mechanical properties of geopolymer concrete of grades G30 and G50 when river sand is replaced with manufactured sand in different proportions as 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% and also compared the results of geopolymer concrete with controlled concrete of respective grades. It is observed that the mechanical properties are enhanced in geopolymer concrete when it is compared with the same grades of controlled concrete.

Key words: Geopolymer concrete, manufactured sand, river sand, controlled concrete
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1. INTRODUCTION

In present time, Construction is the one the fast growing fields worldwide. Concrete is the most used manmade material in the world. As per the world statistics, annual global production of OPC is over 4.1 Billion Metric tons. This quantity will be increased by more than 25% within next 10 years (ShiramMarathe et al. [2016]). The amount of carbon dioxide released during manufacturing of OPC due to the calcinations of lime stone and combustion of fossil fuels in the order of one ton for every ton of OPC produced, which is a major problem for the sustainable development. The global warming is caused by the emission of greenhouse gases, such as carbon dioxide, to the atmosphere by human activities. Among the green houses gases, CO_2 contributes about 65% of global warming. The cement industry is responsible for about 7% of all carbon dioxide emissions in to the atmosphere

On the other side, the abundance and availability of waste materials such as fly ash (FA), ground granulated blast furnace slag (GGBS), red mud and rice husk ash (RHA) worldwide create opportunity to utilize these by-product of different industries, as partial replacement for OPC in concrete. By considering all these factors there is a need for an alternative material for Ordinary Portland cement. The geopolymer concrete is such a promising material for this problem.

In 1972, Joseph Davidovits coined the name ''geopolymers'' to describe the zeolite like polymers. Geopolymers are the alumina-silicate polymers which consist of amorphous and three dimensional structures formed from the geopolymerisation of alumina-silicate monomers in alkaline solution.

However, little effort has been put on to find out mechanical properties such as compressive, split tensile and flexural strength of geopolymer concrete based on low calcium fly ash and slag in place of cement and manufactured sand as fine aggregate.

2. MATERIALS

2.1 Ordinary Portland Cement

In the experimental investigations, 53-grade of ordinary Portland cement is used. The cement thus procured was tested for physical properties in accordance with the IS: 4031-1968 and found to be conforming various specifications of IS 12629-1987.

2.2 Fine aggregate

The fine aggregate (River sand and manufactured sand used was locally available), river sand without any organic impurities and conforming to IS: 383 – 1970.

Table 1: Physical properties of Manufactured Sand

S.NO	Property	Method	Fine Aggregate
1	Specific gravity	Pycnometer IS:2386 part 3-1986	2.71
2	Bulk density(compact)	IS:2386 part 3-1986	1720Kg/cum

3	Bulk density(loose)	IS:2386 part 3-1986	1663.27Kg/cum
4	Fineness modulus	Sieve Analysis (IS:2386 Part 2-1963)	2.67
5	Bulking	IS:2386 Part 3-1986	4% wc
6	Grading		Zone –II

2.3 Coarse aggregate

The crushed angular aggregate of 20mm maximum size obtained from the local crushing plants is used as coarse aggregate in the present study. The physical properties of coarse aggregate such as specific gravity, bulk density, flakiness and elongation index are tested in accordance with IS: 2386-1963.

Water (by mass)	55.00%
Weight ratio (SiO_2 to Na_2O)	2.09
Molarity ratio	0.97

2.4 Fly Ash

In the present study of work, the Class F-fly ash is used, which is obtained from Vijayawada thermal power station in Andhra Pradesh.

2.5 Ground Granulated Blast Furnace Slag

Ground Granulated Blast Furnace Slag (GGBS) is a by product of the steel industry. Blast furnace slag is defined as "the non-metallic product consisting essentially of calcium silicates and other bases that is developed in a molten condition simultaneously with iron in a blast furnace". About 15% by mass of binders was replaced with GGBS.

2.6 Water

Water free from chemicals, oils and other forms of impurities is used for mixing of concrete as per IS: 456:2000.

2.7 Sodium Hydroxide

Sodium Hydroxide is one of the major ingredients of geopolymer concrete. The following are the specifications of Sodium hydroxide pellets and this material is procured from the local laboratory chemical vendors in Hyderabad. Specifications are tabulated in table 2 as given by the suppliers.

Table 2: The Physical properties of NaOH

Molar mass	40 gm/mol
Appearance	White solid
Density	2.1 gr/cc
Melting point	318^{o}C
Boiling point	1390^{o}C
Amount of heat liberated when dissolved in water	266 cal/gr

2.8 Sodium Silicate Solution

Sodium silicate solution is a type of alkaline liquid plays an important role in the polymerisation process. This material is procured from the local laboratory chemical vendors in Hyderabad. Specifications are tabulated in table 3 as given by the suppliers.

Table 3: Properties of Na_2SiO_3 Solution

Specific gravity	1.57
Molar mass	122.06 gm/mol
Na_2O (by mass)	14.35%
SiO_2 (by mass)	30.00%

2.9 Super Plasticizer

Super plasticizer GLENIUM B233 of Fosroc chemical India Ltd. was used as water reducing admixture, it increases workability.

3. EXPERIMENTAL INVESTIGATIONS

In the preparation of specimens, primarily alkaline activator solution was prepared by mixing the sodium hydroxide (NaOH) pellets and Sodium silicate (Na_2SiO_3) solution together according to the mix proportions. The alkaline solution is prepared 30 minutes before the casting. In this experimental work G30 and G50 grades of geopolymer concretes were prepared with 12 M and 16 M of NaOH respectively. The ratio of sodium silicate to sodium hydroxide used in this study is 2.5. The fly ash, GGBS, fine aggregates, coarse aggregates and alkaline activator solution are weighted according to the mix design and mixed by using a tilting drum type concrete mixer in the laboratory to produce geopolymer concrete.

3.1 Concrete Mix Design

The mix proportions for the present investigations are designed as per IS 10262-2009 and are given in table 4.

Table 4: Shows the Mix Proportions

Standard grade (M30) of Controlled Concrete	1:1.89:3.27:0.45
Standard grade (G30) of Geopolymer Concrete	1:1.89:3.27:0.45
Standard grade (M50) of Controlled Concrete	1:1.35:3.16:0.4
Standard grade (G50) of Geopolymer Concrete	1:1.35:3.16:0.4

4. TEST RESULTS

4.1 Compressive Strength

The cube specimens of size 150 mm X 150 mm X 150 mm are tested in accordance with IS Code : 516 – 1969 at 3, 7 & 28 days for the different composition of mix as shown in tables 5 and presented the results in table 6.

Table 5: Shows Type of Mix and Composition of Mix

Type of Mix	Composition of Mix	
	River Sand (%)	M- Sand (%)
Mix 1	100	0
Mix 2	90	10
Mix 3	80	20
Mix 4	70	30
Mix 5	60	40
Mix 6	50	50
Mix7	40	60
Mix 8	30	70
Mix 9	20	80
Mix 10	10	90
Mix 11	0	100

Table 6: Compressive strength of M30 and G30 grade Concrete

Type of Mix	Compressive Strength of M30 (MPa)			Compressive Strength of G30 (MPa)		
	3 days	7 days	28 days	3 days	7 days	28 days
Mix 1	19.45	27.68	38.39	33.45	35.29	38.53
Mix 2	19.87	27.82	38.72	33.86	35.37	38.60
Mix 3	20.28	28.12	38.97	34.12	35.92	38.73
Mix 4	20.94	28.53	39.38	34.79	36.54	39.35
Mix 5	21.36	28.97	39.89	35.04	36.79	39.87
Mix 6	21.98	29.31	40.03	35.56	37.16	40.29

Mix7	22.32	29.84	40.56	35.89	37.93	41.03
Mix 8	22.71	30.18	40.97	36.25	38.36	41.23
Mix 9	23.13	30.67	41.11	36.65	38.79	41.87
Mix 10	23.69	30.95	41.29	37.06	39.04	42.21
Mix 11	24.03	31.64	41.32	37.42	39.25	42.37

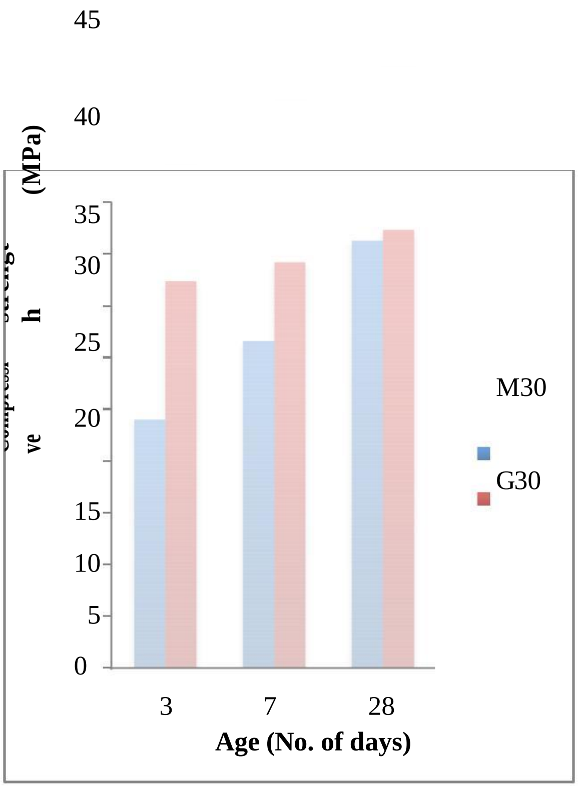

Figure 1: Shows the compressive strengths of M30 & G30 for Mix 11

Table 7: Compressive Strength of M50 and G50 grade Concrete

Type of Mix	Compressive Strength of M50 (MPa)			Compressive Strength of G50 (MPa)		
	3 days	7 days	28 days	3 days	7 days	28 days
Mix 1	28.92	41.07	58.33	54.19	55.63	58.33
Mix 2	29.31	41.36	59.21	54.49	55.97	59.92
Mix 3	29.84	41.82	59.56	54.86	56.28	60.34
Mix 4	30.23	42.21	59.97	55.12	56.93	60.79

Mix 5	30.64	42.64	60.24	55.36	57.36	61.06
Mix 6	30.89	42.95	60.75	55.97	57.89	61.49
Mix7	31.30	43.31	60.93	56.36	58.37	61.94
Mix 8	31.85	43.81	61.31	56.78	58.92	62.26
Mix 9	32.36	44.34	61.37	57.84	59.24	62.29
Mix 10	32.54	44.89	61.48	57.96	59.38	62.36
Mix 11	32.83	45.27	61.56	58.02	59.74	62.43

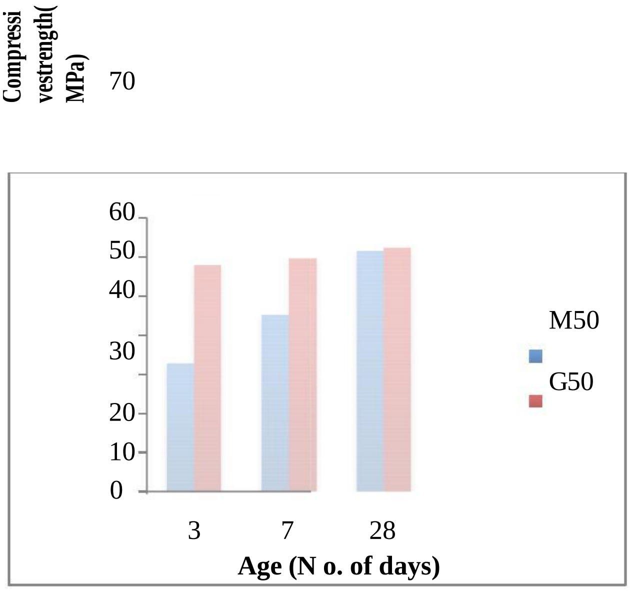

Figure 2: Shows the co mpressive strengths of M50 & G50 for Mix 11

4.2 Split Tensile Strengt h

A concrete cylinder of si ze 150 mm diameter and 300 mm height is casted and tested as per codal procedures and the result s are tabulated in table 8 & 9 and in figures 3 and 4.

Table 8: Shows Split Ten sile Strength of M30 & G30 (MPa)

Grade of Concrete	3 days	7 days	28 days
M30	1.99	2.79	3.98
G30	3.26	3.67	4.08

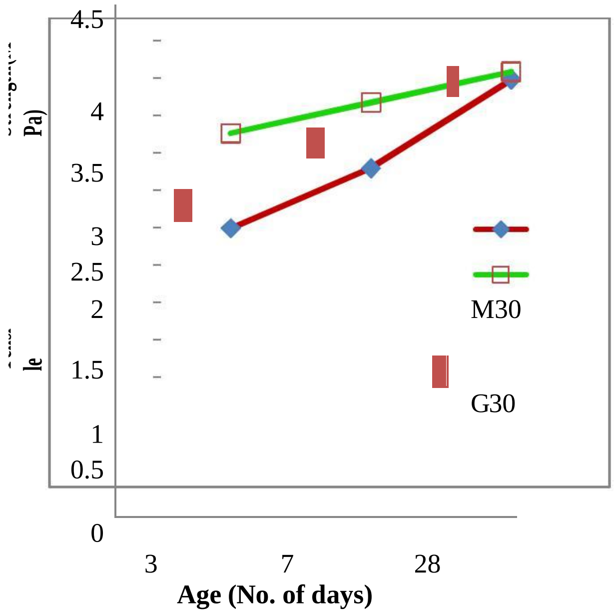

Figure 3: Shows Split Tensile Strengths of M30 & G30

Table 9: Shows Split Tensile Strength of M50 & G50 (MPa)

Grade of concrete	3 days	7 days	28 days
M50	2.64	3.69	5.27
G50	4.26	4.79	5.43

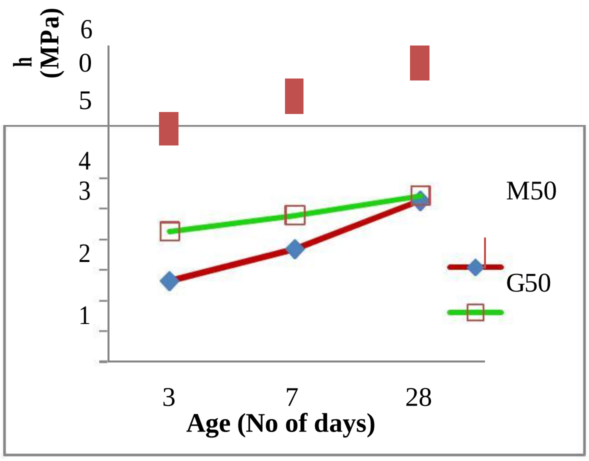

Figure 4: Shows Split Tensile Strengths of M50 & G50

4.3 Flexural Strength

Flexural strength is a measure of unreinforced concrete prisms of size 100 mm x 100 mm x 500 mm resist failure in bending. The flexural strength is expressed as Modulus of Rupture (MR) in (MPa) and is determined by standard test methods as per ASTM C 78 (third-point loading) or ASTM C 293 (centre-point loading). Flexural MR is about 10 to 20 percent of compressive strength depending on the type, size and volume of coarse aggregate used.

Table 10: Shows Flexural Strength of M30 & G30 (MPa)

Grade of concrete	3 days	7 days	28 days
M30	2.53	3.54	5.06
G30	4.15	4.67	5.19

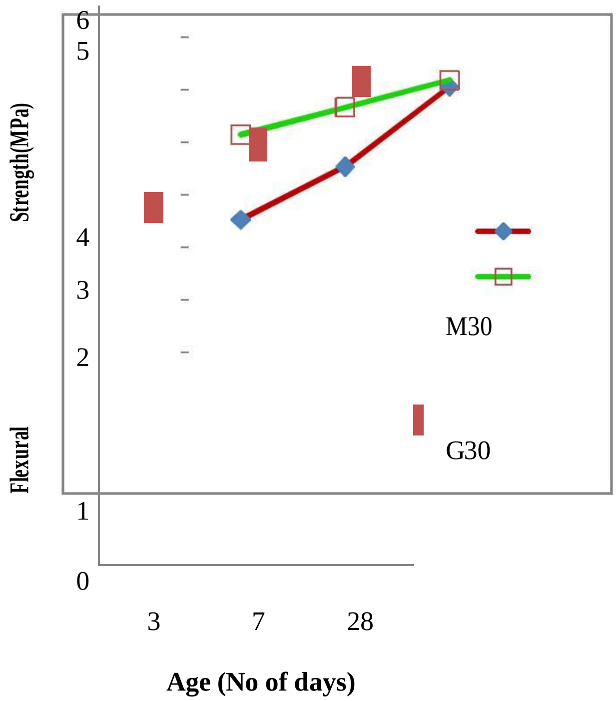

Figure 5: Shows Flexural Strength of M30 & G30

Table 11: Shows Flexural Strength of M50 & G50 (MPa)

Grade of concrete	3 days	7 days	28 days
M50	3.33	4.66	6.66
G50	5.38	6.05	6.74

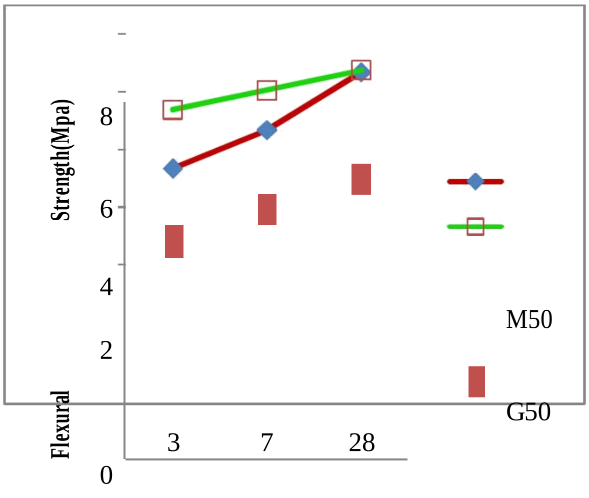

Figure 6: Shows Flexural Strength of M50 & G50

5. CONCLUSIONS

From the experimental investigations, the following conclusions are drawn:

1. It is observed that the maximum compressive strength of 42.37 N/mm^2 in G30 and it is found to be 2.47% more than that of M30 grade of controlled concrete which is 41.37 N/mm^2.
2. Similarly, it is observed that the maximum compressive strength of 62.43 N/mm^2 in G50 and it is also 1.39% more than that of M50 grade of controlled concrete which is 61.56 N/mm^2.
3. The split tensile strength of G30 increase by 2.45% and G50 increase by 2.94% when compared with conventional concrete of M30 and M50 respectively.
4. The flexural strength of G30 increase by 2.5% and G50 increase by 1.18% when compared with conventional concrete of M30 and M50 respectively.

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