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

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Abstract

Applications of polymer based binder material can be an ideal choice in civil infrastructural applications since the conventional cement production is highly energy intensive. Moreover, it also consumes significant amount of natural resources for the large-scale production in order to meet the global infrastructure developments. On the other hand the usage of cement concrete is on the increase and necessitates looking for an alternative binder to make concrete. Geo-polymer based cementitious binder was one of the recent research findings in the emerging technologies. More studies in the recent past showed a major thrust for wider applications of geopolymer binder towards a cost economic construction practice. This also envisages the reduction of global warming due to carbon dioxide emissions from cement plants. The present study is aimed at providing a comprehensive review on the various production processes involved in the development of a geopolymer binder.

Keywords: *Geopolymer concrete, compressive strength split tensile strength, workability*

INTRODUCTION

In present time, Construction is the one the fast growing fields worldwide. Concrete is the most used man-made material in the world after water. As per the statistics every year on an average 3 tons of concrete is consumed by each person. As per the world statistics, total global annual production of OPC is more than 4.1 Billion Metric tons. This quantity will be increased by more than 25% within next 10 years. Shortage for lime stone, so the availability of which might end within next 40 years. Cement industry is responsible for about 7% of all carbon dioxide emissions in to the atmosphere.

Amount of CO2 released during preparing of OPC due to the calcinations of the lime stone and combustion of fossil fuels in the equal to 1 ton for every 1 of OPC produced, which is a major problem for the sustainable development. The term Geo-polymer was first coined and invented by Davidovits [1] which was obtained from fly ash as a result of geo-polymerization reaction.

Many other scientists done works on this concrete by considering the requirements with their used materials at different proportions. Hardjito and Rangan demonstrated in their extensive studies that geopolymer based concrete showed good mechanical properties as compared to conventional cement concrete. The results from the studies exhibited an excellent formation of geopolymer with rapid setting properties. It can be noted that the presence of calcium content in fly ash played a significant role in compressive strength development. The presence of calcium ions provides a faster reactivity and thus yields good hardening of geopolymer in shorter curing time.

EXPERIMENTAL STUDY

A. General

Low calcium (class F) dry fly ash collected from Vijayawada thermal power station was used as the source material to make Geopolymer Concrete in the laboratory. For the alkaline activator, a combination of sodium silicate (Na2SiO3) to sodium hydroxide (NaOH) solution was used. The NaOH solution of required molarity is prepared by dissolving the sodium hydroxide solids, either in the shape of pellets or flakes, in water. In order to improve work-ability of fresh fly ash and slag based Geopolymer Concrete we have added masterglenium sky B233-based superplasticizer and some extra water as per the mix design.

The sodium silicate solution used contained Na2O-14.35%, SiO2=30.00%, and 55% of water, by mass. All the liquids are mixed jointly before adding to the solids.

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B. Materials

Sodium Hydroxide NAOH pillets, Sodium silicate Na_2SiO_3 solution, G30 grade of concrete, Ordinary Portland Cement (53 grade), Fly Ash (class-F), Coarse aggregate, River sand, Manufactured sand, GGBS, Silicon Dioxide (SiO2) to Sodium Oxide (Na2O) ratio as2, Alkaline liquid to fly ash ratio, One day rest period, The ratio of Na2SiO3 to Sodium hydroxide (NaOH) as 2.5,Oven Curing temperature of 60°C for 24 hours, Effect of super plasticizer on compressive strength, Effect of replacement of fine aggregate on mechanical properties of Geopolymer Concrete. In the present study river sand is replaced with manufactured sand up-to 100%..

C. Mix Design and Methodology Proportion of Vol. of Coarse Aggregate and Fine Aggregate Content

From Table 3(IS 10262: 2009), volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for water-cement ratio of 0.50 =0.62. Here water-cement ratio is 0.45. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water to cement ratio is lower by 0.10, the proportion of volume of coarse aggregate is increased by 0.02 (at the rate of -/+ 0.01 for every + 0.05 change in water to cement ratio). Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.45 = 0.62. Therefore, Volume of coarse aggregate = 0.62 Volume of coarse aggregate = 1-0.62 Volume of fine aggregate = 0.38

MIX DESIGN FOR CONTROLLED CONCRETE (M30)

The procedure for designing concrete mix of M30 concrete is adopted as per IS\10262: 2009 and IS: 456-2000.

Table No.1 Test data of materials of M30 Concrete

Test Data of Materials		
1	Cement Used	OPC of 53 grade
2	Specific gravity of cement	3.15
3	Specific gravity of coarse aggregate	2.672
4	Specific gravity of fine aggregate	2.84
5	Specific gravity of water	1
6	Water absorption of the coarse aggregate	1.12%
7	Water absorption of the fine aggregate	1%
8	Free (surface) moisture content of coarse aggregate	NIL
9	Free (surface) moisture content of fine aggregate	NIL
10	Sieve Analysis of Fine Aggregate	Separate Analysis Done

Table No.2 Stipulations for Proportioning M30 Concrete Mix Design

M30 CONCRETE MIX DSIGN		
AS per IS 10262-2009		
Stipulations for Proportioning		
1	Grade Designation	M30
2	Type of cement	OPC of 53 grade
3	Maximum Nominal Aggregate Size	20 mm
4	Minimum Cement Content	320 kg/m^3
5	Maximum Water Cement Ratio	0.45
6	Workability	50-75mm(slump)
7	Exposure Condition	Normal
8	Degree of Supervision	Good

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Table No.3 Mix Proportions of M30 Concrete

Mix Proportion		
1	Cement	1
2	Fine Aggregate	1.88
3	Coarse Aggregate	3.26

Table No.4. Details of G30 GPC Mix Design

Geopolymer Concrete (G30)		
1	Unit weight of concrete	2400 Kg/m^3
2	Mass of combined aggregate 78.14% of 2400	1875.36 Kg/m^3
3	Mass of flyash and alkaline liquid	524.64 Kg/m^3
4	Considering Alkaline liquid to flyash as	0.45
4(a)	Mass of flyash	361.82 Kg/m^3
4(b)	Mass of Alkaline liquid	162.819 Kg/m^3
5	Considering Na2SiO3 to NaOH ratio	2.5
5(a)	Mass of NaOH	46.51 Kg/m^3
	For 12 Molarity(NaOH solids)	16.79 Kg/m^3
5(b)	Mass of Na2SiO3	116.3 Kg/m^3
6	Mass of water	29.72 Kg/m^3
7	From Na2SiO3	162.81 Kg/m^3

Table No.5. Mix proportions of G30 Concrete

Mix Proportion		
1	Flyash	1
2	GGBS	0.17
3	Fine Aggregate	2.21
4	Coarse Aggregate	3.85

D. Preparation of Specimens

In the preparation of specimens primarily alkaline activator solution was prepared by together mixing the sodium hydroxide (NaOH) pellets and Sodium silicate (Na2SiO3) solution according to the mix proportions. The NaOH and Na2SiO3 solution is prepared before 2 hours. In this experimental work, G30grade of Geopolymer Concrete was prepared with NaOH solutions. The mass of NaOH varied depending on the concentration of solution. The ratio 2.5 of sodium hydroxide to sodium silicate is used in experimental study. The fly ash, GGBS, fine aggregates, coarse aggregates and alkaline activator solution are weighted according to the mix design and together mixed by using a tilting drum type concrete mixer in the laboratory to produce Geopolymer Concrete. A Tiltingdrum type concrete mixer used for obtaininguniform mixture of concrete with less effort. The fresh Geopolymer Concrete was used to cast cubes of size 100mm X 100mm X 100mm to determine its compressive strength, 150mm X 300mmsize cylinders to determine its split tensile strength, 100mm x 100mm X 500mm size prism to determine Flexural strength. Each specimen was casted and compacted by using table vibrator. This is the most commonly used vibrator for concrete. The period of vibration is 30 sec to 2min.

E. Curing

The specimens are cured in oven at a temperature of 60°C after one day rest period for 24 hours and the specimens are kept in atmosphere until testing. Controlled Concrete specimens were cured in water.

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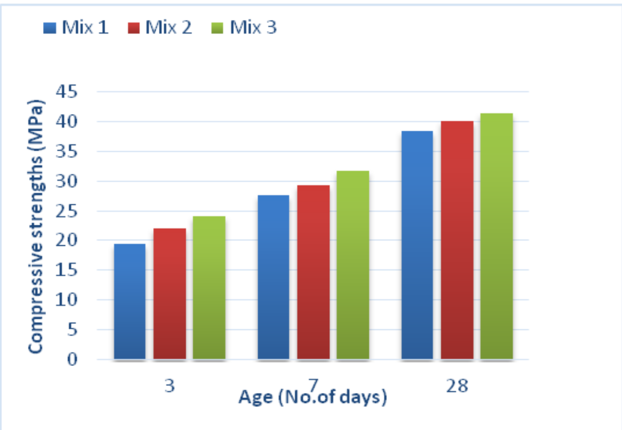
TESTS ON GEOPOLYMER CONCRETE AND CONVENTIONAL CONCRETE

A. Compressive Strength Test:

The concrete is more strong compression and weak in tension. In this present study the cube specimens of size 100 X 100 X 100mm are tested in accordance with IS Code: 516-1969. The testing was done on a CTM of 200 tons capacity. The machine has been to the required standards. The plates are cleaned and checked for oil level.After 3, 7 & 28 days of curing, cube specimens were removed from the curing. The smooth surfaces of the specimen are placed on the bearing surfaces. The test was repeated for the 3 cubes and the average value is taken as the mean strength of concrete. The Mix proportion of GPC of G30 grade of concrete obtained like OPC. From experimental investigation it was seen that higher compressive strength obtained when river sand is completely replaced with M- Sand. There is 2.47% increase of compressive strength for Geopolymer concrete(G30) when compared to normal concrete (M30) after 28 days of curing time.

Compressive strength of M30 grade concrete

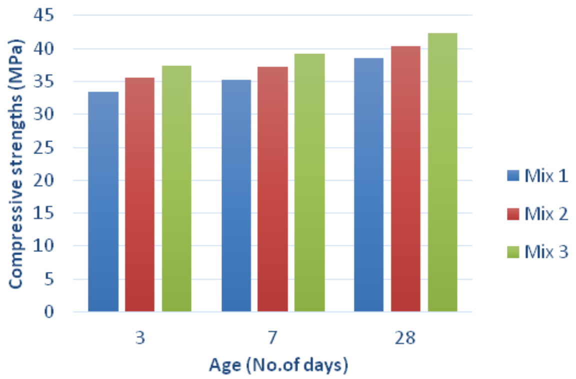
Type of mix	3 days (N/mm^2)	7 days (N/mm^2)	28 days (N/mm^2)
Mix 1	19.45	27.68	38.39
Mix 2	21.98	29.31	40.03
Mix 3	24.03	31.64	41.32



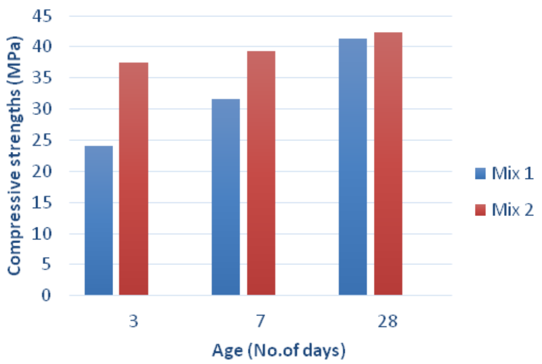
Compressive strengths of M30 concrete

Compressive strength of G30 grade concrete:

Type of mix	3 days (N/mm^2)	7 days (N/mm^2)	28 days (N/mm^2)
Mix 1	33.45	35.29	38.53
Mix 2	35.56	37.16	40.29
Mix 3	37.42	39.25	42.37



Compressive strengths of G30 concrete



Compressive strengths of M30 & G30 concrete

B. SplitTensileTest

Tensile strength tests are used to know the cracking resistance of concrete and bond strength to reinforcing bars. However direct tests for knowing tensile strength of the concrete is very difficult to conduct. The most commonly adopted tests for determining the indirect tensile strengths are the flexural strength and the splitting test.A concrete cylinder of size 150 mm diameter and 300 mm height is subjected to the action of a compressive force along two opposite edges, by applying the force in this manner. The cylinder is subjected to a uniform (constant) tensile stress.

Horizontal tensile stress (fs) =2P/NDL

Where

(fs) = splitting strength (MPa),

P = failure load (kN),

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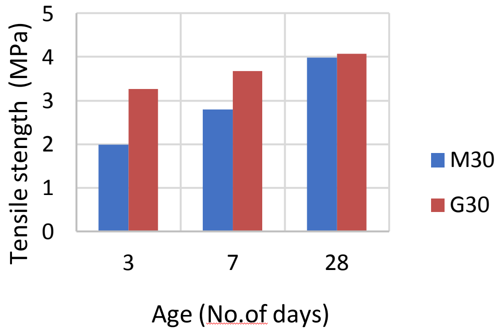
L = length of cylinder (mm) and

D = diameter of cylinder (mm)

The Mix proportion of GPC of G30 grade of concrete obtained like OPC. The specimens are casted using manufactured sand. From experimental results the maximum value it was noted that, 2.45% increase of tensile strength for GPC when compared to Normal Concrete for 28 days of curing time.

Tensile strength of M30 and G30 concrete

Grade of concrete	3 days (N/mm^2)	7 days (N/mm^2)	28 days (N/mm^2)
M30	1.99	2.79	3.98
G30	3.26	3.67	4.08



% Increase in Tensile strengths of…

C. Flexural Strength Test

Flexural strength is used to know the bending strength of concrete prisms. It is used to measure of unreinforced concrete prisms to resist failure load in bending. It is measured by giving loading 150 mm x 150mm concrete prisms with a span length at least 3 times the depth. To determine by MR the three-point loading (ASTM C 78) or by centre-point loading(ASTM C 293) used. MR is nearly 10 to 20% of compressive strengthdepending on the size, type and vol. of coarse aggregate used.

For a sample under a load in a 3-point bending

$0 = 3FL/2bd^2$

F= load (force) at the fracture point (N)

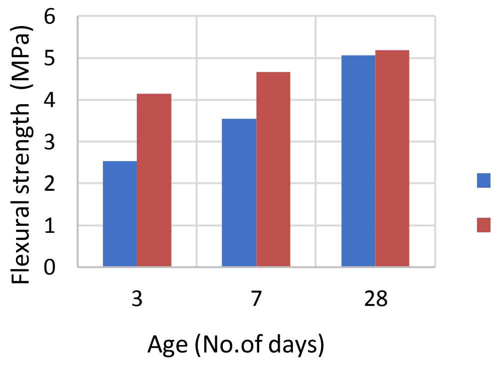
L = length of the support span

b = width

d = thickness

FLEXURAL STRENGTH OF M30 AND G30

Grade of concrete	3 days (N/mm^2)	7 days (N/mm^2)	28 days (N/mm^2)
M30	2.53	3.54	5.06
G30	4.15	4.67	5.19



% Increase in Flexural strengths of…

CONCLUSION

From the experimental investigation, the following conclusions are made:

- The maximum compressive strength 42.37 N/mm2 was observed after 28 days of curing period (G30).
- The maximum compressive strength 41.37 N/mm2 was observed for M30 Conventional Concrete.
- The compressive strength of G30 increase by 2.47% whencompared with Conventional Concrete of M30 respectively.
- The split tensile strength of G30 increase by 2.45% when compared with Conventional concrete of M30 respectively.
- The flexural strength of G30 increase by 2.5% when compared with Conventional Concrete of M30 respectively.
- The early strengths are possible in Oven cured Geopolymer concrete compared to conventional concrete
- The cost of G30 grade concrete is decreased when it is compared to Normal concrete M30.

REFERENCES

1. Ajay Takekar and Prof.G.R. Patil; "Experimental Study on Mechanical Properties of Fly ash and GGBS based Geopolymer Concrete", International Journal of Engineering Research & Technology (IJERT), volume 04, Issue 08, Aug 2017, 18-23.
2. B. Pradeep Kumar et al.; "Study of Strength Development of Geopolymer Concrete using M-Sand as Fine Aggregate", International Journal of Engineering Science and Computing(IJESC), volume 07, Issue 04, April 2017, 10468-10473.
3. B. Rajini and A.V. Narasimha Rao; "Mechanical Properties of Geopolymer Concrete with Fly Ash and GGBS as Source Materials", International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET), Vol. 3, Issue 9, Sep 2014, 15944-15953
4. Cheng, T. W. & J. P. Chiu "Fire-resistant Geopolymer Produced by Granulated Blast Furnace Slag." Minerals Engineering16(3), 2003, 205-210.
5. Ganapati Naidu. P et al.; "A Study on Strength Properties of Geopolymer Concrete with Addition of GGBS", International Journal of Engineering Research

and Development (IJERD), Vol. 02, Issue 04, July 2012, 19-28

6. Hardjito, D., S. E. Wallah, D. M. J. Sumajouw & B. V. Rangan (2004). "On the Development of Fly Ash-Based Geopolymer Concrete." ACI Materials Journal, Vol. 101, No. 6, pp 467-472.

7. K. Arul Priya; "Strength and Durability Studies of M-Sand and Fly Ash Based Geopolymer Concrete", International Journal of Trend in Research and Development (IJTRD), Volume 3(3), May-Jun 2016, 90-97.

