Investigates the properties of geopolymer concrete based on fly ash and examines how varying curing conditions affect its performance.

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ABSTRACT

OPC is employed as a binding material in the building industry all over the world, especially in the CO2-emitting process of producing OPC. One ton (T) of cement is produced in the same way as one ton of CO2. CO2 is produced as a result of the calcination of limestone, fuel ignition, and power generation. The cement producing sector contributes between 5% and 8% of the world's CO2 emissions. in order to lower CO2 emissions. French The name "geopolymers" was first used by Prof. Joseph Davidovits in 1978. These inorganic polymers are obtained by alkali activation of aluminosilicate materials, such as fly ash. Prof. Davidovits suggested, following more investigation, that an alkaline solution reacts with rich silica and alumina materials, including fly ash, GGBS, rice husk, and others, to generate an aluminosilicate gel, which functions as the binding agent for the concrete.

This study focused the workability and compressive strength of fly ash-based geopolymer concrete, comparing it to OPC concrete. Fly ash is used as a substitute to cement in geopolymer concrete with sodium hydroxide concentrations of 6M, 9M, 12M, and 14M. For geopolymer concrete, 150 mm x 150 mm x 150 mm molds were cast, and the cubes were heat cured in an oven for 24 hours at 30 °C, 60 °C, and 90 °C. They were then tested after seven, fourteen, and twenty-eight days of repose. The findings indicate that workability increases as NaOH concentration rises. When comparing the compressive strengths of geopolymer concrete at 12M at 60OC and OPC concrete, the latter has a lower compressive strength.

Keywords: Fly ash, GGBS, Rice-husk, NaOH & Na2SiO3, Workability, Compressive strength and Heat Curing, Molarity

1.INTRODUCTION

The geopolymer, a revolutionary inorganic polymeric binding substance, was first introduced by French professor Joseph Davidovits in 1978. This innovative material is formed through a polymerization process, which involves a reaction between an alkaline solution or liquid and a chemical containing silicon and alumina. This reaction yields an aluminosilicate gel, which provides the aggregates with their strength and bonds them together, thereby imparting the geopolymer its unique bonding property. Unlike traditional Portland/Pozzolanic cement, geopolymer concrete does not form Calcium silicate- hydrates (CSHs) gel for matrix formation and strength. Instead, it forms an aluminosilicate gel, which contains silico-aluminate (-Si-O-Al-O-) bonds created through a polymerization process. These bonds are responsible for providing strength to the concrete. Geopolymer source materials can be derived from natural minerals or by-products, which are rich in amorphous silicon (Si) and aluminium (Al). Natural minerals such as kaolinite and clays, as well as by-product elements like fly ash, silica fume, slag, rice-husk ash, and red mud, can be utilized. The availability and pricing of these raw materials are crucial factors to consider in the manufacturing process of geopolymers.

2.LITERATURE REVIEW

Balram Singh Rajput at. el (2023): The research focused on investigating the effects of various variables on the workability and compressive strength of GPC. Specifically, the molarity of sodium hydroxide (NaOH) solutions (6 M, 9 M, 12 M, and 14 M), curing temperatures (30 °C, 60 °C, and 90 °C), and curing periods (7, 14, and 28 days) were examined. The performance of GPC was compared to that of OPC-based control concrete.

Praveen Gupta, Vishal Gajghate (2022): In this research, they investigate the compressive strength of geopolymer concrete at various curing temperatures, employing fly ash as a replacement to cement in an alkaline solution. They discovered the compressive strength of GPC for alkaline solution to fly ash ratios of 0.35 and 0.40 at 60oC and 100oC for 7 days, 14 days, and 28 days using a combination of 8M NaOH solution.

Ajay Xavier, Sanket Bhagat at el. (2021): In this research, they investigate the effect of alkaline/fly-ash ratio on 10M and 14M. The compressive strength test was performed on a 15cm X 15cm X 15cm cube at 33oC and 75oC for 7 days, 14 days, and 28 days using 10M and 14M NaOH solutions, respectively. The alkaline solution to fly ash ratio was 0.35.

Pallavi Vivek Dongre, et.al (2020): In this study, they work on different alkaline/fly ratios of 0.30, 0.35, and 0.40 at different curing temperatures of 30oC, 60oC, and 90oC at a curing time of 27 days for compressive strength test. The results obtained show that the compressive strength of GPC was greatest at 60oC of 0.40 ratio.

Amer Hassan, Mohammed Arif, M. Shariq (2019): In this article, they investigated the curing influence on the mechanical characteristics of fly ash-based geopolymer concrete. In a 10M NaOH solution, the alkaline to fly ash ratio was 0.4, with a NaOH/Na2SiO3 ratio of 1.75. Mechanical characteristics were determined in two curing regimes.

Piyush Soni, Vijayant Panday (2018): In this article, fly ash is employed as a substitute to OPC, while NaOH and Na2SiO3 are used as alkaline solutions. The slump cone and compressive strength tests were performed on 8M, 10M, 12M, and 14M of alkaline solution at various curing temperatures. The results reveal that increasing the molarity of GPC enhanced its workability, and the maximum compressive strength was attained after 28 days at 12M and 60oC.

3. MATERIAL USED IN STUDY

Ordinary Portland Cement

OPC has cohesive and adhesive properties, which are utilised to bond the concrete ingredients. The cement is made up of calcareous and argillaceous components. The calcareous component contains limestone, chalk, marl, and so on, while the argillaceous component contains sand stone, blast furnace slag, fly ash, clay, and so on. During the grinding process, gypsum is added to control the setting time of cement. This addition, approximately 3% of the clinker weight, plays a crucial role in regulating the hydration process and preventing flash setting. The resulting cement is a fine powder that, when mixed with water, forms a paste that hardens over time.

Fly ash -

Fly ash is a fine grey powder produced as a byproduct of coal burring in power plants. Fly ash contains alumina, silica, ferric oxide, and calcium oxide. It possesses binding properties. Fly ash particles in spherical form. In one experiment, fly was employed as a replacement to OPC in geo-polymer concrete, reacting with an alkaline solution to generate aluminosilicate gel. Fly is a byproduct that may be obtained at little cost. Which helps to reduce the cost of concrete. Fly ash increases the strength of concrete.

Alkaline activators -

A mixture of NaOH & Na2SiO3 was taken as an alkaline activator and is used to activate the fly ash. The Na-based activators were taken because they are cheaper than the Ka-based activators. The Na-OH was taken in pellets form, sodium silicate in powder form and is obtained from locally available supplier.

Aggregates -

According to Indian standard (IS: 383-1970), The aggregate may be natural and artificial aggregates. The natural aggregate such as, crushed rock, gravel & sand are used for reinforced concrete. The artificial aggregate such as, saw dust & foamed slag.

4.METHODOLOGY

Design of OPC concrete for M-20 grade of concrete

Design stipulations -

a) Concrete grade = M-20
b) Cement grade = OPC 43
c) aggregate size = 20 mm
d) Exposure condition = Mild (IS 456:2000 from Table 3)
e) Min. cement content = 300 kg/m3 (IS 456:2000 from Table 5)
f) Workability in term of slum = 75 mm
g) S= 4.0 N/mm2
h) Max. cement content = 450 kg/m3 (IS 10262-2019, cl. 7.1)
i) w/c ratio = 0.55 (IS 456:2000 from Table 5)
j) Fine aggregate = Zone II
k) Sp. Gravity of cement = 3.15
l) Sp. Gravity of fine aggregate = 2.46
m) Sp. Gravity of coarse aggregate = 2.73
n) Sp. Gravity of water = 1.0

Step-1: Target mean strength and standard deviation

1. The Target mean strength,

$$f'_{ck} = f_{ck} + kS \text{ (IS 10262: 2019)}$$

or

$$f'_{ck} = f_{ck} + X \qquad \text{whichever is max.}$$

where, S = Standard deviation
k = A constant which is as per IS code is 1.65
X= factor based on grade of concrete (IS 10262:2019)

The Target mean strength

$$\mathbf{f`_{ck} = f_{ck} + 1.65S}$$

The Target mean strength for M-20 grade of concrete

$$\mathbf{f`_{ck} = f_{ck} + 1.65S}$$

f_{ck} = 20 N/mm^2
S= 4.0 N/mm^2 (IS:456-2000 from Table 2)

$$f`_{ck} = 20 + 1.65x4 = 26.6\ N/mm^2$$

and,

$$\mathbf{f`_{ck} = f_{ck} + X}$$

X= 5.5 N/mm^2 (IS 10262:2019 from Table 1)

$$f`_{ck} = 20+ 5.5 = 25.5\ N/mm^2$$

Therefore, designing for a Target-mean strength of **26.6 N/mm^2**

Step-2: Selection of w/c ratio:
w/c ratio = 0.55, **(IS:456-2000 from Table 5)**
Step-3: Selection of water content
Max. water content for 20mm coarse aggregate = 186 kg, for 50mm slum **(IS 10262:2019 from Table 4)**

1. For slump of than 25-50 mm, increase the water content by 3% for each additional of 25 mm slump as per **(IS 10262: 2019, cl. 5.3)**

In this case slum was consider 75 mm
Max. water content for 20mm coarse aggregate = 186 kg + (3% of 186kg)
Max. water content for 20mm aggregate= 191.4 kg

Step-4: Calculation of cement content

$$\text{Cement content} = \frac{\text{water content}}{\text{water cement ratio}}$$

$$\text{Cement content} = \frac{191.4}{0.55}$$

Cement content= 348 kg/m^3

348 kg/cu.m > 300 kg/cu.m (minimum cementitious content)

Step-5: Aggregate proportion between CA & FA

Vol. of CA, for zone II = 0.62 **as per (IS 10262:2019 from Table 5)**

Vol. of CA = 0.62 m^3

Vol. of FA = 1 – 0.62 = 0.38 m^3

Step-6: ***Mix calculation***

For 1 cu. m,

(a) Vol. of cement = $\frac{\text{mass}}{\text{specific gravity}}$ X $\frac{1}{1000}$

Volume of cement = $\frac{348}{3.15}$ X $\frac{1}{1000}$ = 0.1105 m^3

Vol. of cement = 0.1105 m^3

(b) Vol. of water = $\frac{\text{mass}}{\text{specific gravity}}$ X $\frac{1}{1000}$

Volume of water = $\frac{191.4}{1.0}$ X $\frac{1}{1000}$ = 0.1914 m^3

Vol. of water = 0.1914 m^3

(c) Vol. of all in aggregate = 1 – (a + b)

Vol. of all in aggregate= 1 - 0.1105 - 0.1914 = 0.6981 m^3

Vol. of all in aggregate = 0.6981m^3

(d) Mass of CA = volume of all in aggregate*vol. of CA*specific gravity*1000

Mass of CA = 0.6981*0.62*2.73*1000

Mass of CA = 1181.60 ≈ 1182 kg

***Mass of CA* = 1182 kg**

(a) Mass of FA = vol. of all in aggregate*volume of FA*specific gravity*1000

Mass of FA = 0.6981*0.38*2.46*1000

Mass of FA = 652.58 ≈ 653 kg

Mass of FA = 653 kg

The mix pro-portion of OPC concrete, for M-20 for 1 m^3

Cement	**FA**	**CA**	**Water content**
348 kg/m^3	653 kg	1182 kg	191.4 kg
1	1.88	3.36	0.55

Mix-proportion of OPC concrete

Mix-design for Geo polymer concrete with flyash

As we know that the percentage of CA & FA together lies in the range 75-80% of the whole mixture by mass for OPC concrete Therefore, in the present research work we have taken 80% for total aggregates and FA was taken as 30% of total aggregate because it is clear from the various research on geopolymer concrete. The density of GPC assumes to be 2400 kg/m3. In the present work alkaline solution by fly ash ratio was used is 0.35.

The mix design calculation are as follows: -

Let density of Geopolymer Concrete = 2400 kg/m3

Total Aggregate = 80% of 2400 kg/m3 = **1920 kg/m3**

FA = 30% of Total Aggregate

= (30/100) x 1920 = **576 kg/m3**

Coarse Aggregate = 70% of Total Aggregate

= (70/100) x 1920 = **1344kg/m3**

Fly Ash + Alkaline solution = 20% of 2400 kg/m3

= (20/100) x 2400 = **480kg/m3**

Ratio of Alkaline Activator Solution to Fly Ash = 0.35

Alkaline Activator Solution = 0.35 x Fly Ash

Alkaline Activator Solution + Fly Ash = 480kg/m3

(0.35 x Fly Ash) + Fly Ash = 480kg/m3

1.35 x Fly Ash = 480 kg/m3

Fly Ash = 480/1.35

= **355.56 kg/m3**

Alkaline Solution = 480-355.56

= **124.44 kg/m3**

Description	Quantity (kg/m^3)	Proportion
Fly ash	355.56	1
Alkaline solution	124.44	0.35
FA	480	1.34
CA	1344	3.78

Mix-proportion of GPC

5.EXPERIMENTS AND RESULTS

Com-pressive strength for geopolymer concrete

COMPRESSIVE STRENGTH IN (N/mm2)

For Geopolymer concrete

Molarity	**7days**			**14days**			**28days**		
Temperature	*30ºC*	*60ºC*	*90ºC*	*30ºC*	*60ºC*	*90ºC*	*30ºC*	*60ºC*	*90ºC*
6M	1.81	1.96	3.56	1.85	3.54	2.87	3.99	7.81	5.36
9M	2.24	6.33	3.11	4.69	8.12	8.28	13.9	17.2	8.78
12M	5.67	10.7	8.67	6.44	12.27	9.1	10.2	27.9	22.03
14M	3.02	4.88	4.17	3.15	6.07	5.77	13.8	18.56	17.16

Com-pressive strength of GPC

After the com-pressive strength test on geo-polymer concrete cubes, it was seen that the strength of 12M cube at 60º C were maximum in 7days, 14days & 28days of results was 10.7 N/mm2, 12.27 N/mm2 & 27.9 N/mm2 in comparison of other molarity 6M,9M,12M & 14M. It is also notice that the com-pressive strength of cubes after 60º C to 90ºC was drop.

Com-pressive strength for OPC concrete

COM-PRESSIVE STRENGTH IN (N/mm2)

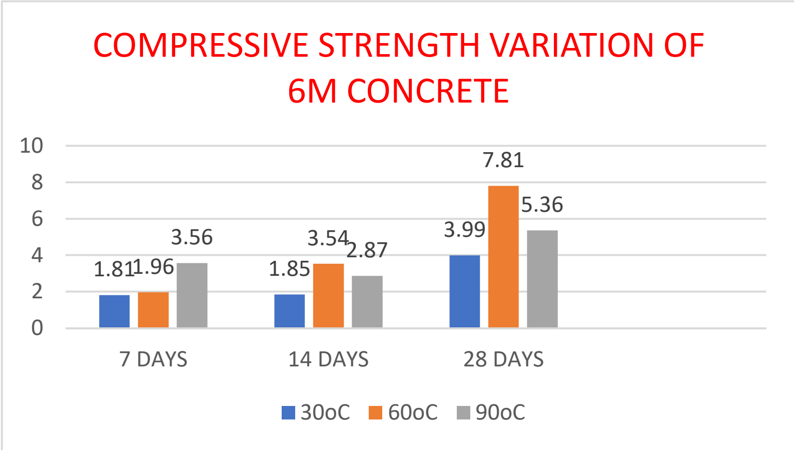
For OPC concrete

S. No.	Cube age	Load (KN)	Compressive strength (N/mm^2)	Avg. Com pressive strength (N/mm^2)
1	**7days**	312.75	13.9	**14.23**
2		319.50	14.2	
3		328.50	14.6	
4	**14days**	437.85	19.46	**19.16**
5		425.70	18.92	
6		429.75	19.1	
7	**28days**	559.57	24.87	**25.11**
8		569.47	25.31	
9		566.10	25.16	

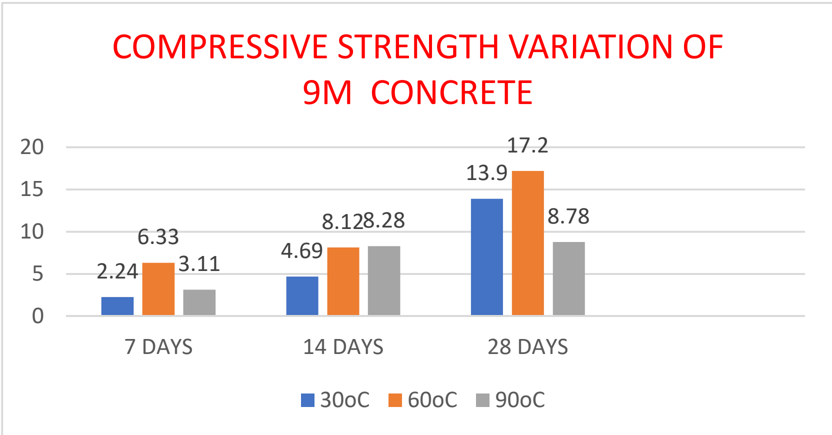
Com-pressive strength of OPC concrete

After the com-pressive strength test in OPC concrete cubes, it was notice, the strength of cubes 25.11 N/mm^2 at 28 days but in comparison of geopolymer concrete cube of 12M at 60ºC was less because the strength of GPC cube was 27.9 N/mm^2

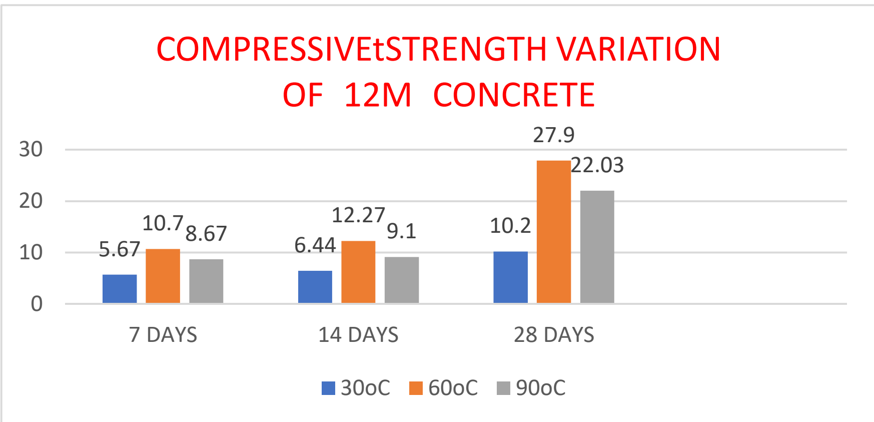
Graph of Compressive strength variation for 6M,9M,12M & 14M



Com-pressive strength variation of 6M concrete



Compressive strength variation of 9M concrete



Com-pressive strength variation of 12M concrete

6.CONCLUSION

An experimental study was conducted to investigate the properties of Geopolymer Concrete (GPC) and Ordinary Portland Cement (OPC) concrete. The research focused on the effect of the molarity of Na-OH solution on the properties of GPC, including slump and flexural strength. The study aimed to explore the potential of GPC as a sustainable alternative to traditional OPC concrete.

The experimental results led to several conclusions:

- Geopolymer concrete helps reduce carbon dioxide emissions, making it an environmentally friendly option.
- Geopolymer concrete is considered "green concrete" due to its eco-friendly properties.
- Increasing the concentration of Na-OH solution enhances the workability of geopolymer concrete.
- The alkaline solution prepared for the experiment was found suitable for geopolymer concrete production.
- The strength parameters of geopolymer concrete depend on the mixture of alkaline solution and fly ash.
- It was observed that increasing the temperature beyond 60°C decreases the strength of concrete.
- The 12M molarity concrete cubes, cured at 60°C, achieved the highest strength of 27.9 N/mm2, surpassing the strength of OPC concrete.

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