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An Experimental Investigation of Geopolymer Concrete at High Temperature

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Abstract- The production of material results in the emission of a similar amount of carbon dioxide, a greenhouse gas that alters the climate unnaturally. To combat environmental problems, fly debris and ground granulated impact heater slag (GGBS) can be used as concrete substitutes due to their cementitious material qualities. Large amounts of fly debris are produced during the power age in warm plants as a side effect, and their removal is problematic. In contrast, GGBS supports lower fly debris in steel plants. Due to illegal digging, access to stream sand is also becoming more expensive and limited; as a result, manufactured sand is used as a substitute for waterway sand. Thus, the goal of this inquiry is to consider the compressive strength and flexural strength of geo-polymer concrete formed of M sand exposed to warm relieving at 500C and 600C with various activator arrangement proportions and molarity presentations at elevated temperature. In different blend extents, sodium hydroxide and sodium silicate combinations were used as antacid activators. Inorganic aluminohydride polymer, also known as geopolymer, is frequently made from silicon and aluminium particles found in fly ash and GGBS.

Keywords: Geo-polymer, Green Concrete, Mechanical Properties, Temperature Variation

1. Introduction

OPC is the most frequently used material in the field of development to meet the demands of framework advancement, despite the fact that its use has been criticised for a long time due to its contribution to the arrival of just under 1500 million tonnes of CO2 per year, which causes natural problems and accounts for 36% of global energy consumption [1]. For this reason, it is necessary to reduce the use of concrete. Two methods could be used, such as the production of concrete without clinker and Portland concrete that can be mostly replaced by cementitious materials. By enacting aluminum-silicate based salt compounds like GGBFS, fly debris (FA), metakaolin (MK), and others, soluble base actuated receptaculitids are formed. In 1978, Davidovits suggested that intriguing coverings may incorporate silicon and aluminium from kaolin clay and antacid liquids, which are natural sources of silicon and aluminium. When [AlO4]-5 and [Si04]-4 tetrahedra are combined, semi-translucent three-dimensional outline works known as geo-polymers are produced. Fire may cause serious damage to buildings, so it's crucial to safeguard people and property wherever it occurs. Due to the dehydration and disintegration of crystalline hydrates and C- S-H gel[2][3], traditional concrete is not structurally robust when exposed to high temperatures. Nematollahi Behzad et al. investigated how different superplasticizers and activator combinations affected the strength and workability characteristics of GPC, and they discovered that these characteristics improved when the activator combination ratio (Na2SiO3/NaOH) was 2.5[4]. Contrary to organic polymers, geo-polymeric materials have an inorganic structure that shields them from fire. They are also quite heat resistant. It is important to note that the mix design[5, chemical composition, and synthesis method are frequently what define the mechanical qualities and effectiveness of a geopolymer exposed to high temperatures. Fly ash's compressive force is unaffected when a naphthalene-based superplasticizer is used with it [6]. Geo polymer-based binders [9] exhibit better spalling resistance than cement base binders [7, 8]. Various cure techniques, including membrane cure, heat gun cure, ambient cure, steam cure, and oven therapy, were tried in numerous investigations. However, overtreatment, which is exclusively used in precast applications, is the most practical and effective method. The strength often declines at high temperatures, leading in a thermal resistance [10]–[12] when the activator concentration is increased.

2. Material Used

Coarse aggregates: The ground aggregates are made from natural granite stones with a maxi mum size of 20mm as shown in Fig. 1. (a). Table 1 describes the properties.

Table 1 Physical properties of aggregate

S.no.	Name	Coarse sand	M sand
1.	Specific Gravity	2.8	2.67
2.	Max size	20mm	4.75
3.	Water absorption	0.65%	3.54%
4.	Fineness modulus	6.3	2.8

Fly ash: Fly ash is primarily used since it is less expensive. The majority of coal's qualities are decided by the burning and quenching processes because coal is a changeable material. [8 granular aggregates: The ground aggregates, as shown in Fig. 1, are made from natural granite stones with a maximum size of 20mm (a). Table 1 provides a description of the features. Because it contains silicon dioxide, calcium oxide, and aluminium oxide, it is utilised as a binding substance. The cementitious capabilities of the substance are enhanced by the tendency of the aluminosilicate components to react with calcium hydroxide. The physical characteristics are listed in Table 2. and Fig. 2 provides an instance of it.

Sodium Silicate: Silicate is being purchased as a solution from a local store.

Sodium Hydroxide: Sodium hydroxide pellets with a purity of about 97-98 percent are bought from a nearby store to make the necessary concentration solution.

GGBS: GGBS is a byproduct of steam or water furnaces that is created by pressing molten iron ore to create a granular, glassy stuff that is then dried and powdered into a fine powder, as seen in figure 1. (b). Calcium oxide, silica, alumina, and magnesia are made up of calcium oxide, silica, alumina, and magnesia, which are all displayed in Table 1[13].

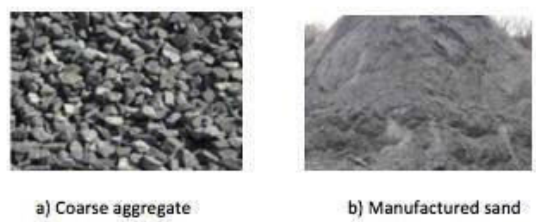

Fig. 1 Coarse aggregate and M sand

Fig. 2 Fly ash and GGBS

Manufactured Sand: Locally available M-sand is used as shown in Fig. 2(b), due to unavailability of river sand. M-sand conforming to zone II as per IS 383:2016 and other properties are described in Table 1.

Table 2 Physical properties of binding material

S.no.	Name	GGBS	Flyash
1.	Specific Gravity	2.8	2.1
2.	Shape	Spherical	Spherical
3.	Avg particle size	Less than 4.75mm	o.5 □
4.	Colour	White	Light grey
5.	Fineness(m^2/kg)	400	350

3. Experimental Procedure

Mixing Procedure : The main difference is that fly ash and GGBS are used to bind GPC instead of OPC. It is thought that the GPC density with M-sand is 2,550 kg/m3. Using the IS: 10262–2019 guidelines, the ratios in Table 3 are calculated, and sample specimens are made using three different NaOH molarities, two different activator ratios, and two different curing temperatures of 500C and 600C. The amounts of NaOH used were 12, 16, and 20 mol per litre. Fine and coarse aggregates are mixed well in a dry pan mixer, then binders are added, followed by alkaline solutions and superplasticizer [14].

Preparation of alkaline solution : In this analysis, the most common combination of alkaline activators, NaOH and NA2SiO3, are used. To make the alkali solution, potable water is added to pellets of sodium hydroxide. The molarity of NaOH is found by dissolving the right number of moles of solute (weight divided by molecular weight) in the right amount of water [10]. After the pellets are mixed with water and dissolved, they need to cool for at least a day before they can be used again within 36 hours. Sodium silicate is used because it is easy to get in the area. For about 10 minutes, the alkaline activators (NaOH and Na2SiO3) are thoroughly mixed with the alkaline solutions in a ratio of 1:2 or 1:2.5, depending on how much of each is in each solution.

Table 3: Mix proportions

S.No.	Materials	Specifications	Mix 1	Mix 2
1.	Binding aids	GGBS	0.5	0.5
		MK	0.5	0.5
2.	FA	------	1.60	1.60
3.	CA	-------	3.03	3.03
4	Alkaline activator solution	Sodium hydroxide	0.12	0.14
		Sodium silicate	0.28	0.30
5.	Superplasticizer	-----------	0.015	0.015

Curing: Most of the time, GPC is cured at room temperature, which is called "ambient curing." For the best strength, however, heat or steam curing must be used. Previous research has shown that the longer the curing time, the stronger the material is up to 24 hours, but that after 24 hours, the increase in strength isn't as big, which leads to tiny cracks. The samples are then dried in ovens for 24 hours at either 60 livres or 70 centimetres[15]. Putting samples in high temperatures: After the desired age, the sample must be heated to 200°C in the oven for 1 hour, since NBC says the minimum time must be 1 hour and the maximum time must be 3 hours [16].

4. Tests for specimens

Compressive strength: In accordance with IS: 516-1959, size 150 X 150 X 150 mm metal cube moulds are used to cast cubes and can easily be separated without specimen disruption. For each parameter a specimen of three cubes is obtained and is subject to an average of 200^0c high temperature after 28 days. Compaction is performed by 35 S per layer during casting so that it does not include excess laitance or separation. Bending Stress: For casting, standard samples of 100x100x500 mm dimensions are used. The mould parts are rigidly assembled to make sure the mould is filled and processed. Every criterion is de-moulded and casted at least three sample prisms after 24 hours following the target time span, which expose the specimens to elevated temperature of 200^0C for 1 hour. Then, in accordance with the IS: 516-1969guidelines, the specimens are permitted to repress at room temperature and test in the beam test machine.

5. Results and Discussion

Compressive Strength

When compared to heat-cured GPC cubes at 500°C, those exposed to 2000 and cured at 600°C have a lower compressive strength by about 3.2 percent, 1.15 percent, and 4.5 percent for 1:2.5 ratio of activator solution with molarities at 12, 16, and 20 molarity and about 1.35 percent, 11.9 percent, and 9.55 percent for 1:2 ratio of alkaline activator combination with concentrations at 12, 16, and 20 M of sodium hydroxide. At 16 molarity, cubes with a ratio of 1:2 and a curing temperature of 500°C are the strongest, while cubes with a ratio of 1:2.5 and a curing temperature of 600°C are the weakest.

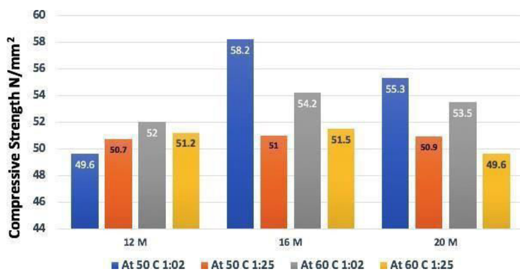

Fig 3. Compressive Strength N/mm^2

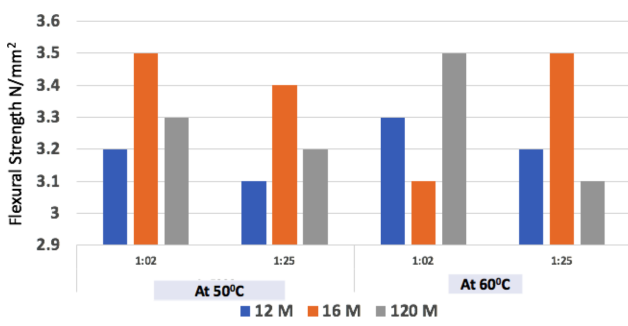

Fig 4. Flexural Strength N/mm^2

Bending Strength: Bending capacity goes up at a ratio of 2.5 of sodium hydroxide for about 4 percent, 5 percent, and 7.8 percent heat-cured prisms at 70 C with 12, 16, and 20 molarity and about 11.1 percent, 8.5 percent, and 11.1 percent heat-cured prisms at 500C with 12, 16, and 20 molarity and about 3.2 percent, 5.5 percent, and 8.8 percent heat-cured prisms at 600C with 12, 16, and 20 molarity. It is only slightly affected by the amount of sodium hydroxide, and it is often the same. Even after being heated to 200 C, prisms that were cured at 500 C are stronger than those that were cured at 600 C. In Fig. 4, intensity of bending is used a lot.Bending capacity goes up at a ratio of 2.5 of sodium hydroxide for about 4 percent, 5 percent, and 7.8 percent heat-cured prisms at 70 C with 12, 16, and 20 molarity and about 11.1 percent, 8.5 percent, and 11.1 percent heat-cured prisms at 500C with 12, 16, and 20 molarity and about 3.2 percent, 5.5 percent, and 8.8 percent heat-cured prisms at 600C with 12, 16, and 20 molarity. It is only slightly affected by the amount of sodium hydroxide, and it is often the same. Even after being heated to 200 C, prisms that were cured at 500 C are stronger than those that were cured at 600 C. In Fig. 4, intensity of bending is used a lot.

5. Conclusion

Based on the investigations following conclusions can be drawn;

- After being heated to a high temperature to test thermal resistance, the compressive strength of GPC that had been heated at 500C for 24 hours was better than that of specimens that had been heated at 600C.
- When GPC samples are heated to 200 C, 16 molarity of NaOH has a higher compression strength than 20 molarity of NaOH. This shows that GPC's thermal resistance does not increase with molarity.
- Even though the curing temperatures and sodium hydroxide concentrations were different, the flexural strength of geopolymer concrete mixes with more sodium silicate was always better.
- As the results showed, as the sodium silicate content went up, the flexural strength of GPC went up, but the compressive strength went down.

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