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Geopolymer Concrete: An Alternative of Conventional Concrete

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ABSTRACT
The rising cement demand is a direct result of the widespread usage of cement concrete in construction activities. Production of cement is causing greenhouse gas emission. This study investigated the compressive strength (28 days) of geopolymer concrete (GPC), a material that might one day replace cement concrete. Geopolymer concrete cube specimens were prepared for evaluating compressive strength after 28 days. Effect of binder content and effect of curing is studied. Total 6 cubes were prepared for each mix type. 3 cubes were provided ambient curing and 3 were provided temperature curing. Results showed that the compressive strength after 28 days was positively correlated with the amount of GGBS used as a binding agent. It was also observed that compressive strength (28 days) of GPC specimen having temperature curing are higher than ambient cured geopolymer concrete specimen

KEYWORDS
Geopolymer concrete, Compressive strength, GGBS, Ambient curing, Temperature curing.

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1. INTRODUCTION

Production of cement concrete is increasing with increasing infrastructure demand. Cement concrete is 2nd most used material after water on this planet (Awoyera & Adesina, 2020). Cement industry is contributing (5-9)% of manmade greenhouse gases which is 2nd after automobile industry (Adetona, Nhuchhen & Layzell, 2023; Mahasenan, Dahowski & Davidson, 2005; Ishak & Hashim (2015)). Limestone which is used to manufacture cement is a nonreversible source. Mining for raw materials of cement is also affecting the natural environment. Power is also required to run the cement industry (Gao et al., 2015). Looking the above constraint it is necessary to find some alternate of cement concrete.

Geopolymer concrete is one alternate of cement concrete which has comparable strength of cement concrete (Lloyd & Rangan, 2009). Geopolymer concrete is made of binding materials, fine aggregate, coarse aggregate and alkaline activator. Binding material may consists of industrial wastes which are aluminosilicate materials such as fly ash, silica fume, metakaoline and GGBS. Alkaline activator is a mixture of sodium hydroxide (NaOH) solution and sodium silicate (Na_2SiO_3) solution. Alkaline activator which reacts with aluminosilicate material and results in bond strength development. In case of conventional concrete hydration is responsible for bond strength but in case of geopolymer concrete polymerization is responsible for bond strength development. The binding material concentration, sodium hydroxide solution molarity, sodium hydroxide to sodium silicate solution ratio, and curing methods all influence the geopolymer concrete's properties.

Previous studies suggest that geopolymer concrete prepared with fly ash alone as binder has lower strength as compared to GPC prepared with fly ash and GGBS as binder. With rise of GGBS as binder strength of GPC increases. Molarity of sodium hydroxide solution also affect the strength and 12M is found optimum (Wardhono, 2018, Mermerdaş, Algın & Ekmen, 2020). NaOH to Na2SiO3solution ratio of 1:2.5 is determined for optimal performance (Mermerdaş, Algın & Ekmen, 2020). Curing of GPC also affects the strength of GPC (Patil, Chore & Dode, 2014; Zhang, Shi & Wang, 2018; Chouksey et al., 2022; Nurruddin et al., 2018). GPC may achieve strength even if cured at ambient condition but if temperature curing is provided to GPC then it has faster rate of strength development.

If geopolymer concrete is utilized in a large scale then it will results in reduced greenhouse gas emission from cement industry. Since GPC uses industrial waste as binding material it will result in reduced disposal problem of industrial waste. GPC does not need water curing which will reduce use of water in construction industry and also reduce the labour cost. Here compressive strength of GPC is evaluated for ambient cured GPC and temperature cured GPC. Effect of binder proportion on compressive strength is also studied.

2. MATERIALS

2.1 Binding materials.

2.1.1 Fly ash

Fly ash is a fine, powdery material produced when pulverised coal is burned in power stations to create electricity. Collecting it from the flue gases with electrostatic precipitators or other particle control systems yields one of the most useful industrial byproducts. Fine, glassy particles of a spherical form predominate in fly ash. SiO2, Al2O3, Fe2O3, CaO, and other elements are found. The type of coal being burnt and the combustion method both affect the chemical make-up of the fly ash that is produced. In this research fly ash used was obtained from NTPC, Kanti, Bihar.

2.1.2 GGBS

We use GGBS, or ground granulated blast furnace slag, in our industry. It is a byproduct of the blast furnace process, which involves heating limestone, coke, and iron ore to produce liquid iron. Pig iron is created by filtering impurities out of molten iron before pouring it into moulds. Non-metallic substances known as slag are produced during this procedure. Granulation occurs when slag is quickly cooled by water or air after being tapped from a blast furnace. GGBS is a glassy, granular substance formed during the quick cooling process. Silica and alumina make up the bulk of GGBS. In addition to other elements, it is rich in oxides of calcium, aluminium, silicon, and iron. Its chemical makeup might change depending on where the slag came from.

2.1.3 Alkaline activator and super plasticizer

Alkaline activator is made of NaOH solution and Na_2SiO_3 solution. An initial solution of 12 M sodium hydroxide was made, and then it was combined with solution of Na_2SiO_3. In a 1:2.5 ratio, sodium hydroxide and sodium silicate solutions were combined. Super plasticizer was also used along with alkaline activator for improving workability.

Figure 1: Sodium hydroxide

Figure 2: Sodium silicate solution

2.1.4 Fine and coarse aggregate

The sand utilised for the fine aggregate met the requirements for Zone II since it. 60% of the coarse aggregate used had a nominal size of 20 mm, whereas 40% was 10 mm.

3. METHODS

3.1 Mixing

According to Table 1, the proportions of binder, fine aggregate, and coarse aggregate were maintained at 1:1.5:3. The mixture was then well mixed. Alkaline activator was mixed in uniformly dry mixed mixture and mixed till all ingredients were mixed uniformly. Ratio of binding material to alkaline activator was kept as 0.55. Sample ID were assigned to each mix. F90_G10 means GPC sample is prepare with 90% fly ash and 10% GGBS as binder. Super plasticizer was utilized as 1% of total binder content.

Table 1: Mix proportion of geopolymer concrete mix

Sample ID	NaOH (kg/m^3)	Na_2SiO_3 (kg/m^3)	Binder (kg/m^3)		Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	
			FA	GGBS		20 mm	10 mm
FA90_G10	84	210	485	54	808	970	646
FA80_G20	84	210	431	108	808	970	646
FA70_G30	84	210	377	162	808	970	646

3.2 Casting and curing of GPC specimen

Freshly mixed geopolymer concrete was kept in cubes. Tamping is provided while filling the cube in three layer. Once cube is filled it is provided vibration in table vibrator. 6 cubes were prepared for each mix (Figure 3). Samples were kept for 24 hours. After 24 hours samples were demoulded and 3 cube samples were provided ambient curing and other 3 cubes were provided temperature curing at 150^{o}C for 4 hours in muffle furnace and then kept at ambient condition (Figure 4).

3.2 Testing of GPC specimen

As the curing period was over cube samples were subjected to compressive strength test. The material was subjected to a compression test according to IS 516:1959. Cubes were subjected to normal stress by being placed in digital testing equipment after ambient curing and temperature curing. It was administered such that a load of 140 kg/cm2/min would build up. Failure loads of samples were obtained as the cube sample began to fail.

Figure 3: Casting of GPC specimen

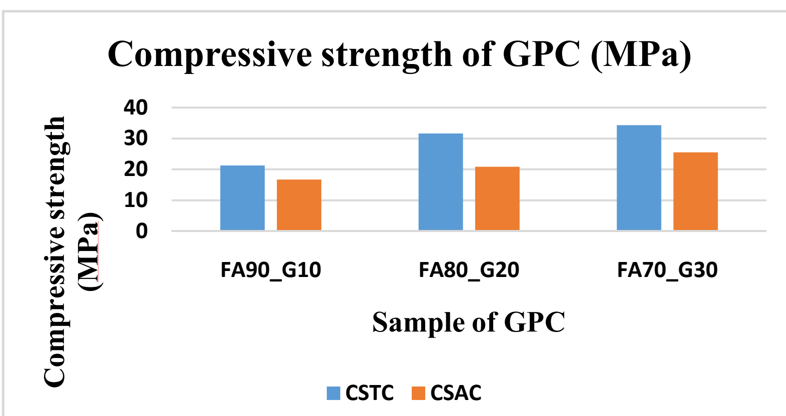
Figure 4: Ambient curing of GPC specimen

4. RESULTS AND DISCUSSION

Compressive strength test results for ambient cured specimen and temperature cured specimen are shown below (Table 2 and figure 5). This Research has shown that the compressive strength of GPC specimens is enhanced by increasing the GGBS. There was also a significant effect of curing condition on compressive strength i.e temperature curing increases the compressive strength as compared to ambient curing.

Table 2: Compressive strength of GPC specimen

Sample ID	Compressive strength (MPa)	
	TC	AC
FA90_G10	21.2	16.7
FA80_G20	31.6	20.85
FA70_G30	34.3	25.48



*CSTC: Compressive strength of temperature cured GP, *CSAC: Compressive strength of ambient cured GPC

Figure 5: Compressive strength of different GPC mix

5. CONCLUSION AND FUTURE SCOPE

Based on above study following conclusions can be drawn:

a. Geopolymer concrete can be used as replacement of conventional concrete.
b. GGBS can be used to improve strength of GPC.
c. Temperature curing will provide better strength than ambient curing.
d. Temperature curing might be a limitation for use of geopolymer concrete which may be removed by using higher GGBS content as binder. GPC having higher GGBS as binder will have higher strength even at ambient curing.

Future scope

a. Strength properties of GPC should be improved for ambient cured specimen.
b. Stress-block diagram should be established for GPC so that it can be used in structural design of Reinforced GPC design of structural members.

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