Study on Premixed Geopolymer Concrete as a Repair Material

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***Abstract*:** Geopolymer concrete as an environmentally sustainable repair material with reduced carbon footprint is widely studied area. Different types of the pozzolanic materials like Fly Ash (FA), Ground Granulated Blast Furnace Slag (GGBFS), Rice Husk Ash (RHA), Metal Slags, etc are generally used in the geopolymer concrete as a binder after being activated by alkali. The premixed concrete using cement as a binder has shown limited use in general mainly due to the short life of cement. So, this study has been conducted to investigate the use of the fly ash based premixed geopolymer concrete as a repair material. The internal reactivity of materials will be checked and after that the test results of the compressive strength, shear strength, flexural strength and bonding strength of the premixed geopolymer concrete will be obtained.

Keywords: **Fly ash, Ground granulated blast furnace slag, Sodium silicate, Sodium hydroxide, Geopolymer concrete.**

1. INTRODUCTION

Since the era when Portland cement was invented the cement manufacturing industries are contributing in large emission of greenhouse gas in atmosphere and energy intensive issues. About 2.80T of raw materials along with fuel and other materials are required to produce 1.0T of Portland cement and as a consequence, decarbonation of lime releases about 1.30 billion tons of greenhouse gas. From past 3-4 decades, remarkable evolution have been accomplished in concrete technology to partially or completely eradicate the various ill effects on environment from the aftermath of Portland cement production, one such advancement is Geopolymer Concrete (GPC) which is complete replacement of Portland cement by waste products of industries

Geopolymerization is the process of combining small molecules known as oligomers into a covalently bonded network. They are classified based on the ratio of Si/Al in their structures: a) Poly (sialite) (-Si-O-AL-O-) b) Poly (sialate-siloxo) (-Si-O Al-O-Si-O-) c) Poly (sialite - disiloxo) (-Si-O-Al-O-Si-O-Si-O-). The distribution and relative amounts of Al and Si building blocks influence the chemical and physical properties of the final product. Geopolymerization takes place at ambient or slightly elevated temperature, where the leaching of solid aluminosilicate raw materials in alkaline solutions leads to the transfer of leached species from the solid surfaces into a growing gel phase, followed by nucleation and condensation of the gel phase to form a solid binder.

Geopolymer concrete is developing as an environmentally friendly alternative to Portland Cement Concrete (PCC). The geopolymer concrete is synthesised by mixing a geopolymer binder (aluminosilicate material and alkaline activator) with aggregate. In general, the geopolymer binder is prepared by mixing an aluminosilicate material (i.e. fly ash and blast furnace slag) with an alkaline activator, i.e. sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). The chemical reaction (geopolymerization) between the aluminosilicate material and the alkaline activator forms a three-dimensional inorganic polymer with coherent and adhesive properties.

Geopolymer concrete is a high strength and lightweight inorganic polymer that can be used in place of normal concrete. It is made by mixing different combinations of cementing materials such as silica fume, rice husk ash, metakaolin, Ground granulated blast furnace slag(GGBS) and Fly ash along with fine aggregate, coarse aggregates and alkaline solution. Geopolymer concrete is increasing its popularity as the demand for a green and sustainable building material increases each year. Around 75%-80% of the mass is made of coarse and fine aggregates.

Premixed Geopolymer concrete is a dry mix of the ingredients of geopolymer concrete packed in a bag. This concrete can be used by adding liquid in the dry mix, then apply it on the surface where repair is needed. When the area of repair or amount of needed repair material is very small then the premixed geopolymer concrete can be economical. Premixed or prepacked cement concrete is commercially available but use of it is very limited due to the short life of the cement. Premixed geopolymer concrete bags can be available in the market in the package of 5kg, 20kg or 50kg.

2. Experimental Program

2.1. Materials

The materials used for the geopolymer concrete mixture consisted of the normal Type I Portland cement, Fly ash, Ground granulated blast furnace slag, Sodium silicate powder, Sodium hydroxide powder, the gravel having a maximum size 10 mm, and the river sand having a fineness modulus of 2.184.

Fig. 1: Fly ash and Ggbs

Table 1: Chemical composition of Fly ash

Sr. No.	Type of Test	Results obtained
1	SiO2 (%) by mass	48.10
2	Fe2O3 (%) by mass	11.56
3	Al2O3 (%) by mass	12.81
4	CaO (%)	5.32
5	K2O (%)	0.12
6	MgO (%)	1.28
7	Total Chloride (%) by mass	0.038
8	Loss on Ignition (%) by mass	2.84

Table 2: Chemical composition of Ggbs

Sr. No.	Type of Test	Results obtained
1	SiO2 (%) by mass	81.55
2	Fe2O3 (%) by mass	0.37
3	Al2O3 (%) by mass	1.86
4	CaO (%)	14.12
5	K2O (%)	0.04
6	MgO (%)	0.97
7	Total Chloride (%) by mass	0.026
8	Loss on Ignition (%) by mass	4.50

Table 3: Properties of Sodium Silicate powder

Sr.No.	Properties	Values
1	Na2O	25.00% ± 0.5%
2	SiO2	71.40% ± 0.5%
3	Total Active Content	96.40%
4	Ratio of Na2O : SiO2	1:2.85 ± 0.1%
5	PH	11.5 or More
6	Moisture	5% to 6%

Table 4: Properties of Sodium Hydroxide powder

Sr. No.	Properties	Values
1	Molecular Weight	40 g/mol
2	Absolute Density	2.13 g/cm3
3	Melting Point	318.4℃
4	Boiling Point	1390℃
5	Solubility in Water	42@0℃, 114@25℃, 347@100℃ (g/100g H2O)

2.2. Mixing and Curing

The material of dry mixed should be active after around 3 months from manufacturing. Our first goal was to check the activity of dry mixed materials 12M (NaOH) GPC at the different interval of time from 0 to 90 days after dry mixing. The dry mixed materials were packed in the 8 bags as proportioning for M20 grade of concrete. First 2 bags were opened after 7 days and casted the specimens for compressive strength & split tensile strength test. Those specimens were tested after 7 days of casting. The same procedure will be repeated after 28, 56 and 90 days and results will be marked.

The mixing process started with the dry mixing of the ingredients of the geopolymer concrete for 1 min, then added water and the mixture was mixed for 5min to ensure that the Alkaline activator can evenly disperse throughout the concrete. The fresh concrete was filled in 150mm×300mm cylinder moulds and 150mm×150mmx150mm Cube molds. The former is for the tests of spilt tensile strengths, and the latter is for compressive strength. Both molds were removed after 24 h, and the specimens were put in the open at ambient temperature until the testing. Property tests were performed after the 7 and 28 days of casting.

2.3. Mix Design

Since no codal provisions are available for the mix design of geo-polymer concrete, the mix design has been taken from the research paper based on mix design of geopolymer concrete.

From the literature it was found that at an AAS content of 200 kg/m3 GPC can be developed effectively with better strength, workability and economy. AAS/FA ratio is taken as 0.5, For all the mixes the ratio of Na2SiO3 solution to NaOH solution is taken as 1.5. GGBFS, Cement and FA are taken as 30%, 20% and 50% respectively.

Table 5: Mix Proportion

Sr.no.	Mix	M1 (8M)	M2 (10M)	M3 (12M)
1	Coarse aggregate (kg/m3)	1303.3	1303.3	1303.3
2	Fine Aggregate (kg/m3)	531.5	531.5	531.5
3	NaOH powder (kg/m3)	20.9	24.96	28.70
4	Na2SiO3 powder (kg/m3)	41.4	41.4	41.4
5	Fly ash (kg/m3)	200	200	200
6	GGBFS (kg/m3)	120	120	120
7	Cement	80	80	80

3. RESULTS AND DISCUSSION

3.1. Compressive strength

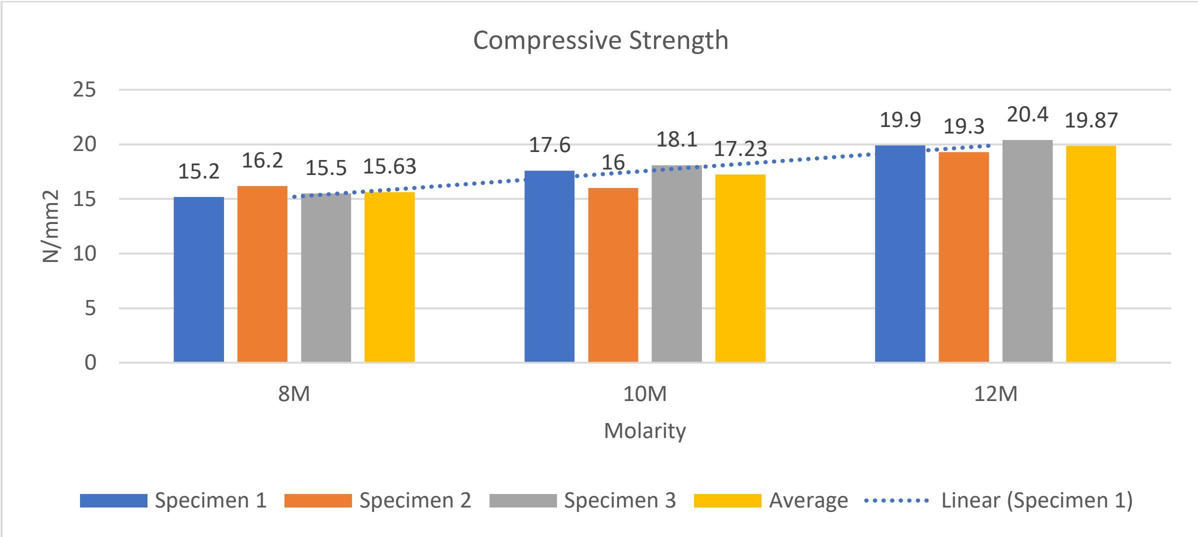

Fig. 2: 7-Days Compressive Strength

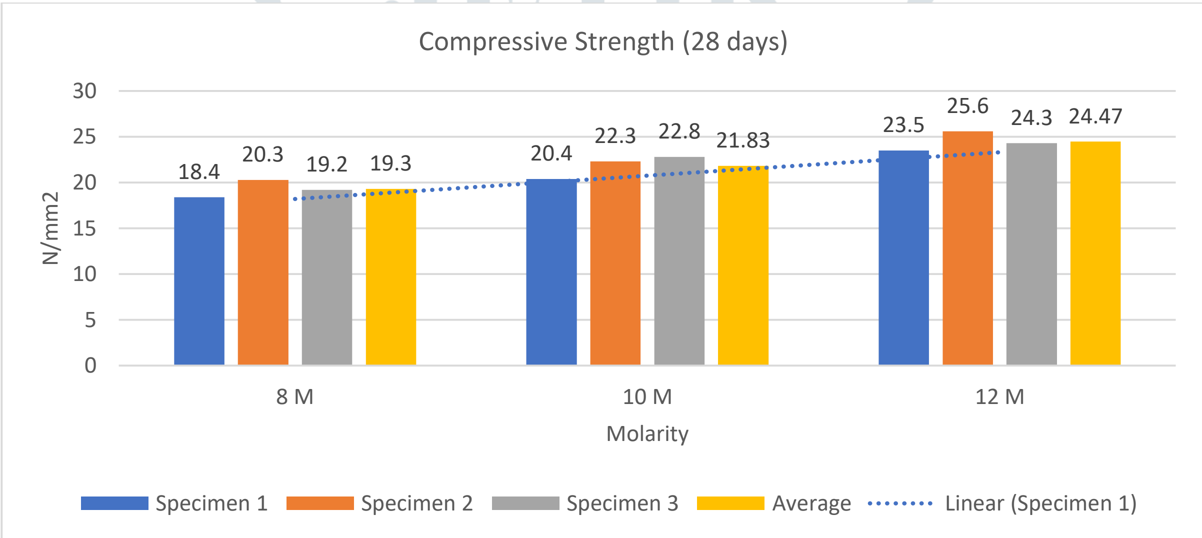

Fig. 3: 28-Days Compressive Strength

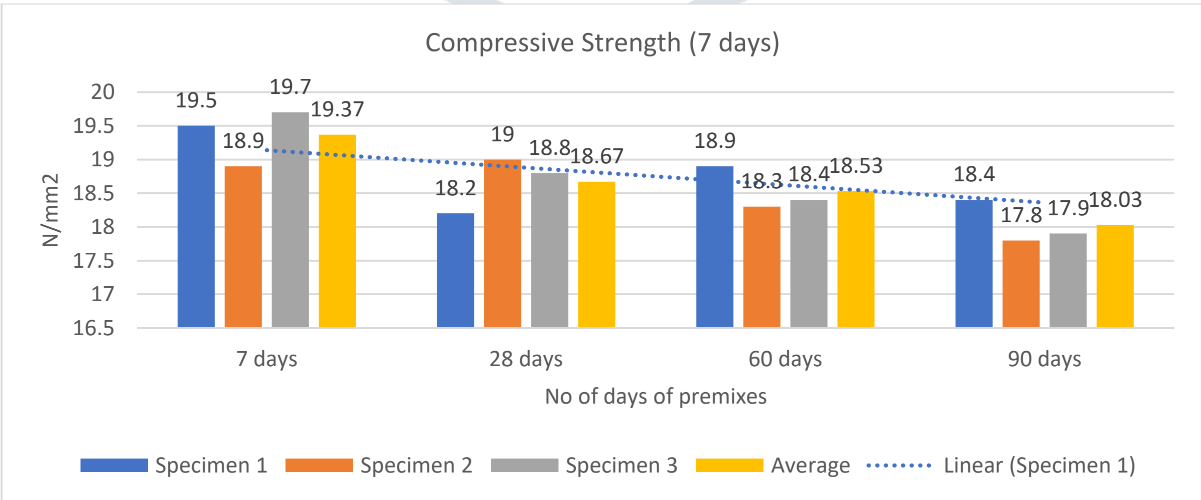

Fig. 4: 7-Days compressive strength for different duration of premixes

The Compressive Strength of the pre mixed geopolymer concrete keeps on increasing as the molarity of sodium hydroxide increases. The maximum Compressive strength was for 12 M NaOH powder with 19.87 N/mm2 after 7 days and 24.47 N/mm2 after 28 days. The compressive strength of the 12 M NaOH mix decreases by the 2.5%, 6.04%, 6.74% & 9.26% after 7, 28, 60 & 90 days of premixes respectively.

3.2. Split-tensile strength

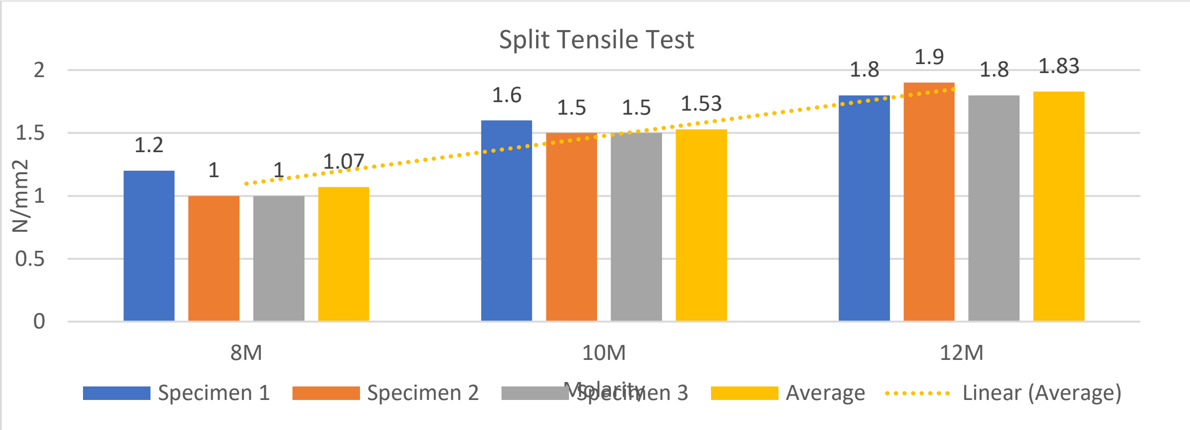

Fig. 5: 7-Days Split-Tensile Strength

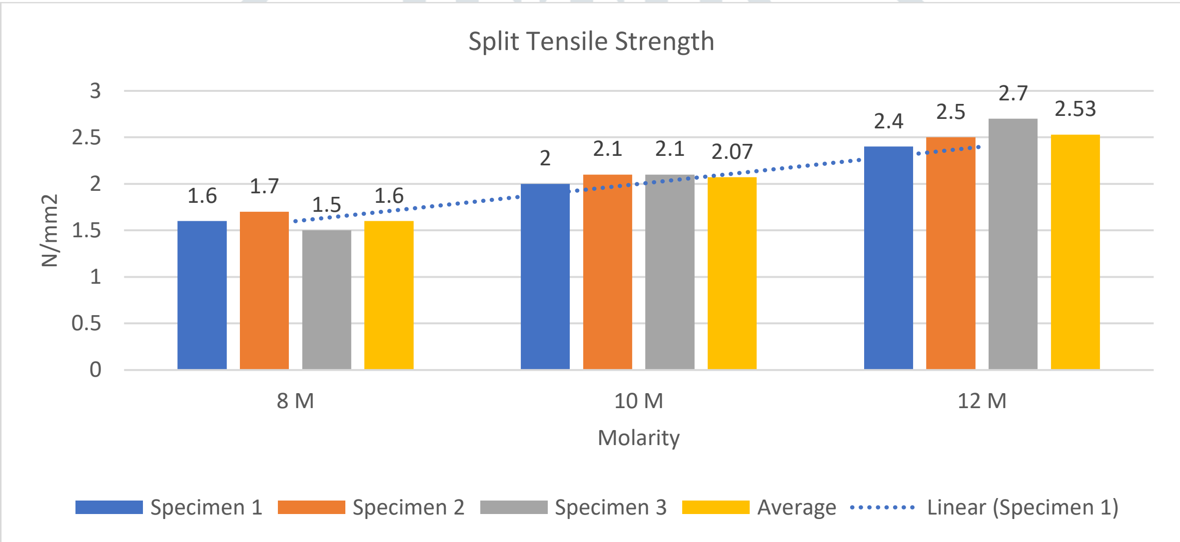

Fig. 6: 28-Days Split-Tensile Strength

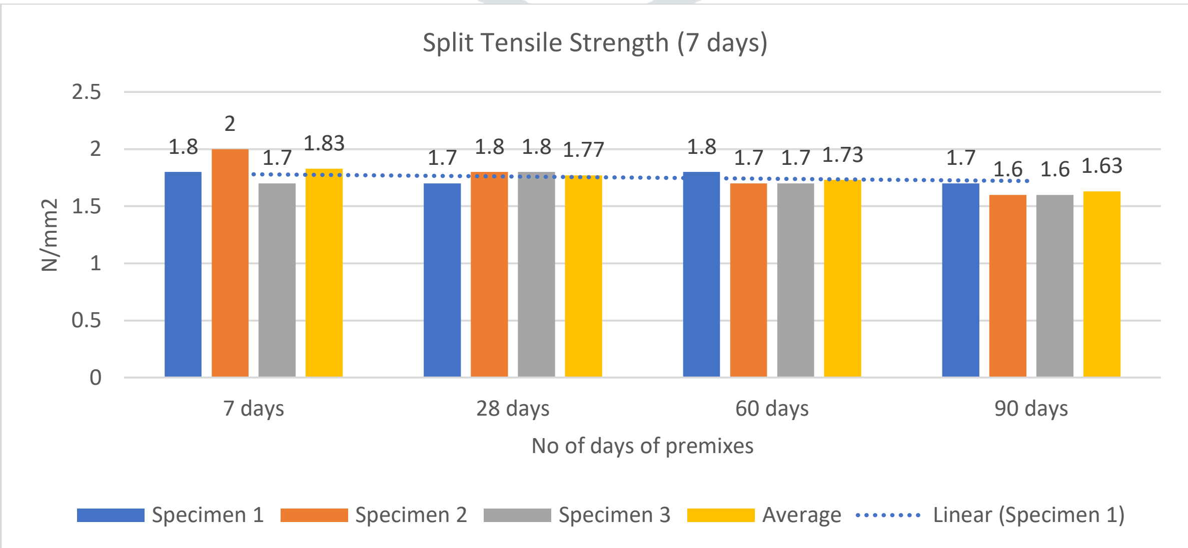

Fig. 7: 7-Days Split Tensile Strength for different duration of premixes

The split tensile Strength of the pre mixed geopolymer concrete keeps on increasing as the molarity of sodium hydroxide increases. The maximum split tensile strength was for 12 M NaOH powder with 1.83 N/mm2 after 7 days and 2.53 N/mm2 after 28 days. The compressive strength of the 12 M NaOH mix decreases by the 2.5%, 6.04%, 6.74% & 9.26% after 7, 28, 60 & 90 days of premixes respectively.

4. CONCLUSION

Following conclusions are drawn from the experimental investigations conducted to assess the influence of fibers on the mechanical response of the concrete

- The mix with the 12 M of NaOH gives 21.33% & 13.28% more compressive strength and 41.53% & 16.4% more split tensile strength than 8 M and 10 M of NaOH respectively after 7 days of casting.
- After 28 days of casting the mix with 12 M of NaOH gives 21.12% & 10.79% more compressive strength and 36.75% & 18.18% more split tensile strength than 8 M and 10 M of NaOH respectively.
- The compressive strength of the 12 M NaOH mix decreases by the 9.26% after 90 days of premix.
- The split tensile strength of the 12 M NaOH mix decreases by the 12.57% after 90 days of premix.

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