Research Article

Investigation on Properties of Geopolymer Concrete using Fly Ash & GGBS

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Abstract
The major problem the world is facing today is the environmental pollution. Mainly in the construction industry the production of Portland cement causes the emission of pollutants that causes serious threat to the environment .The pollution effects on environment can be reduced by increasing the usage of industrial by-products in our construction industry. Geo-polymer concrete is such a one and in the present study, to produce the geo-polymer concrete the Portland cement is fully replaced by fly ash and GGBS (Ground granulated blast furnace slag). The alkaline liquids are used for the activation of these materials. The alkaline liquids used in this study for the polymerization are the solutions of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). Different molarities of sodium hydroxide solution i.e. 8 M , 12 M &16 M are considered to prepare geopolymer concrete mixes. Different combinations of fly ash and GGBS were used in this study such as 90% fly ash and 10% GGBS (F90 G10), 80% fly ash and 20% GGBS (F80 G20), 70% fly ash and 30% GGBS (F70 G30) and 60% fly ash and 40% GGBS (F60 G40). The geopolymer concrete prepared using the above combinations of fly ash and GGBS were tested for its compressive, split tensile and flexural strength. The test results indicate that a good quality geopolymer concrete can be produced with fly ash and GGBS with appropriate parameterisation and mix design. The geo-polymer concrete specimens were tested for their compressive strength at the age of 1, 3, 7, and 28 days and the split tensile & flexural strengths were evaluated at the age of 28days. The result shows that the strength of geopolymer concrete is increasing with the increase of the molarity of sodium hydroxide. Also it was noted that with the increase in content of GGBS, the strength increases.

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Introduction

Nowadays, there is a big concern about the development of alternative materials to Portland cement concrete. The invention of geopolymer concrete provides an alternative solution for production of conventional concrete. Geopolymer concrete is environmental friendly and substantially reduces emissions of CO_2. The geopolymer concrete is manufactured by the activation of source materials using alkaline liquids. The industrial waste material which has pozzolanic properties could be used as the source material. Fly ash and Ground Granulated Blast Furnace Slag (GGBS) are the general source materials used to produce the geopolymer concrete.To produce 1 ton of cement, about 1.6 tons of raw materials are required and the time taken to form the lime stone is much longer than the rate at which humans use it. On the other side the demand of concrete is increasing day by day for its ease of preparing and fabricating in all sorts of convenient shapes. So to overcome this problem, the concrete to be used should be environmental friendly. To produce environmental friendly concrete, we have to replace the cement with the industrial by products such as fly-ash, GGBS (Ground granulated blast furnace slag) etc. In this respect, the new technology geo-polymer concrete is a promising technique.

Experimental

Materials Preparation [1-3]

Following are the basic materials used for the preparation of Geopolymer concrete:

a) Fly ash (source material), b) GGBS (source material) c) Aggregates (Coarse and Fine aggregate) d) Alkaline Activators, e) Water and f) Superplasticizer.

Fly ash

In the present experimental work, low calcium Class F fly ash is used and it is obtained from the Mettur thermal power station from Southern India.

Aggregates

Locally available clean river sand was used as fine aggregate in the study. The fineness modulus of the fine aggregate is 2.73 and the specific gravity is 2.67. The fine aggregate used conforms to Zone-II as per IS: 383-1970.The locally available crushed granite of maximum size 20 mm was used as the coarse aggregate. Specific gravity of coarse aggregate is 2.62.

Alkaline Solution

Sodium silicate and sodium hydroxide were used as activators to react with the aluminum and the silica in the fly ash and GGBS. Commercially available sodium silicate was used for this experimental work. Sodium hydroxide solution of 8 M and 12 M concentration was prepared by dissolving sodium hydroxide flakes with 97% purity in the water. The ratio of sodium silicate to sodium hydroxide solution was fixed as 2.5. The alkaline solution was prepared by mixing both sodium silicate solution and sodium hydroxide solution together at least one day prior to use.

Water & Plasticizers

Distilled water is used for preparation of alkaline solution.To improve the workability of the fresh geopolymer concrete, high-performance super plasticizer (Conplast -SP 430) was used throughout the experimental work.

Mixing and Casting of Geopolymer Concrete Specimens [4-7]

Mixing

The solids constituents of the fly ash-based Geopolymer concrete, i.e., the aggregates, fly ash and GGBS were dry mixed manually for about 3 min. Then the alkaline solution mixed with super plasticizer is added to the dry mix. The mixing is continued for another 5 minutes. The fresh fly ash-based geopolymer concrete was dark in color with shiny appearance and the mixtures were usually cohesive.

Casting & Curing

The fresh concrete was cast into moulds immediately after mixing. The fresh concrete is cast into 100 x 100 x 100 mm cubes, 150 x 300 mm cylinders, and 100 x 100 x 500 mm prisms, to find the compressive strength, split tensile strength andb flexural strength respectively. The specimens for compressive and flexural strength were prepared and tested in accordance with IS-516:1959. Test for split tensile strength was done as per the procedure laid down in IS 5816:1999. After casting, all the specimens were kept at room temperature till the date of testing.

Results and Discussion

Compressive Strength

The compressive strength test results at different ages of concrete are given in Table 4.1. From the test results it was found that, the compressive strength increases when the age of concrete increases. Similarly as the molarity increases the compressive strength also increases from 8M to 12M and the increase in compressive strength of 12M was about 24%, 8%, 8% and 20% for F90G10, F80G20, F70G30, and F60G40 with respect to 8M. The compressive strength also increases from 8M to 16M and the increase in `compressive strength of 16M was about 39%,23%,13 and 23% for F90G10, F80G20, F70G30, and F60G40 with respect to 8M. For a molarity of 8M, specimens with 10% GGBS produces a compressive strength of 41.78 MPa whereas for the same molarity specimens with 40% GGBS produces a compressive strength of 67.07 MPa. Similarly For a molarity of 12 M, specimens with 10% GGBS produces a compressive strength of 51.88 MPa whereas for the same molarity specimens with 40% GGBS produces a compressive strength of 80.73 MPa. This clearly reveals that as the content of GGBS increases, the compressive strength also increases. For a molarity of 16 M, specimens with 10% GGBS produces a compressive strength of 58.11 MPa whereas for the same molarity specimens with 40% GGBS produces a compressive strength of 82.28 MPa. This clearly reveals that as the content of GGBS increases, the compressive strength also increases.

Figure 1 Cube Test on Compression Testing Machine

Table 1 Average Compressive strength (MPa)

Mix ID	1 Day			3 Days			7 Days			28 Days		
	8M	**12M**	**16M**	**8M**	**12M**	**16M**	**8M**	**12M**	**16M**	**8M**	**12M**	**16M**
$F_{90}G_{10}$	3.80	4.89	5.06	15.15	15.53	16.75	24.20	24.13	42.30	41.78	51.88	58.11
$F_{80}G_{20}$	8.47	9.16	10.35	19.65	21.56	23.95	25.93	27.33	48.99	50.22	54.30	61.58
$F_{70}G_{30}$	13.8	15.60	17.85	35.51	36.07	37.89	35.28	37.07	51.56	63.78	68.70	72.30
$F_{60}G_{40}$	15.1	18.30	19.45	41.59	43.35	46.88	51.73	54.36	62.02	67.07	80.73	82.28

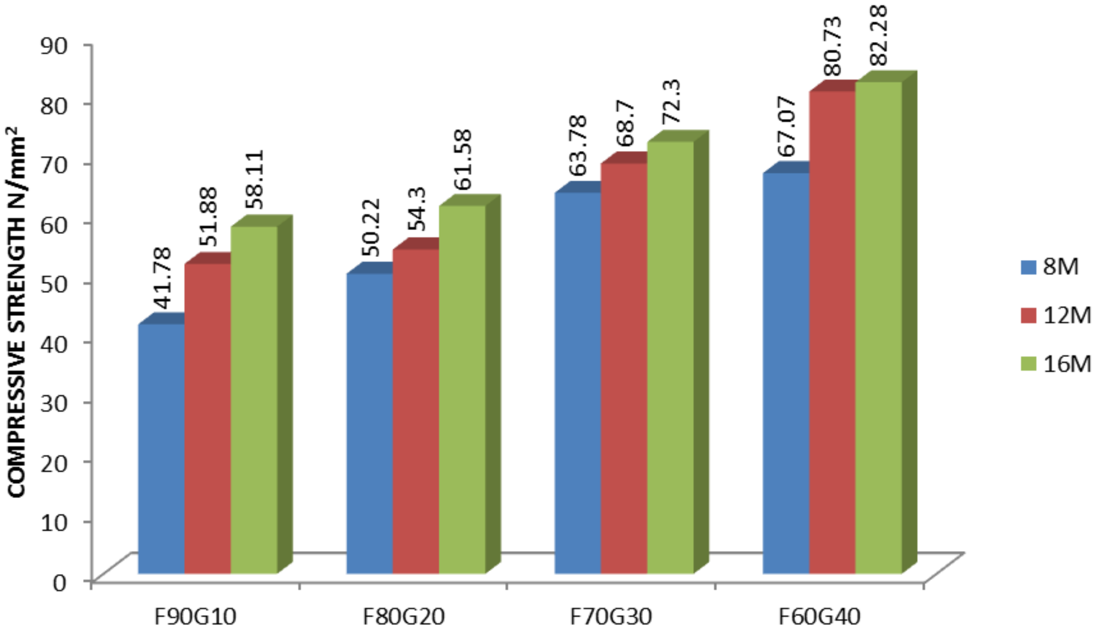

Figure 2 Effect of Concentration of NaOH on Compressive strength at 28days.

Split Tensile Strength

The spilt tensile test was conducted using 150 X 300 mm cylindrical specimens according to IS: 516-1959 and the tests results are shown in Table 4.2. From the test results it was found that, strength increases when the concentration of NaOH increases. Similarly as the molarity increases the Split tensile strength also increases from 8M to 12M and the increase in split tensile strength of 12M was about 5%, 6%, 14% and 7% for $F_{90}G_{10}$, $F_{80}G_{20}$, $F_{70}G_{30}$, and $F_{60}G_{40}$ with respect to 8M. The split tensile strength also increases from 8M to 16M and the increase in split tensile strength of 16M was about 9%,7%,18% and 10% for $F_{90}G_{10}$, $F_{80}G_{20}$, $F_{70}G_{30}$, and $F_{60}G_{40}$ with respect to 8M. For a molarity of 8M, specimens with 10% GGBS produces a split tensile strength of 2.25 MPa whereas for the same molarity specimens with 40% GGBS produces a split tensile strength of 3.81MPa. Similarly For a molarity of 12 M, specimens with 10% GGBS produces a compressive strength of 2.35MPa whereas for the same molarity specimens with 40% GGBS produces a compressive strength of 4.05 MPa. For a molarity of 16 M, specimens with 10% GGBS produces a split tensile strength of 2.46 MPa whereas for the same molarity specimens with 40% GGBS produces a compressive strength of 4.20 MPa. This clearly reveals that as the content of GGBS increases, the split tensile strength also increases.

Figure 3 Split Tensile Test on Compression Testing Machine

Table 2 Average Split tensile strength (MPa)

Mix Id	8M	12M	16M
$F_{90}G_{10}$	2.25	2.35	2.46
$F_{80}G_{20}$	2.62	2.78	2.81
$F_{70}G_{30}$	3.23	3.66	3.80
$F_{60}G_{40}$	3.81	4.05	4.20

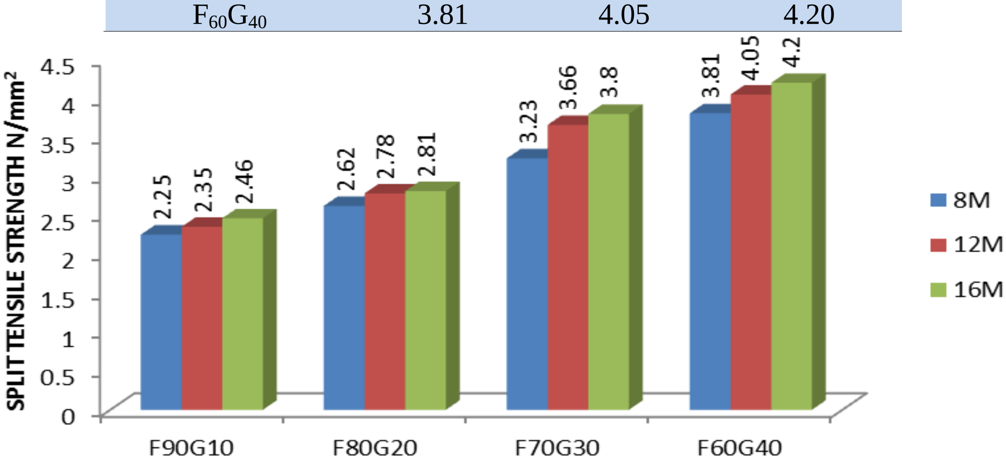

Figure 4 Effect of concentration of NaOH on Split tensile strength

Flexural Strength

Tests were carried out on 100 X 100 X 500 mm prism specimens according to IS: 516-1959 and the tests results are shown in Table 4.3. From the test results it was found that, strength increases when the concentration of sodium hydroxide increases.Similarly as the molarity increases the flexural strength also increases from 8M to 12M and the increase in split tensile strength of 12M was about 5%, 3%, 3% and 4% for $F_{90}G_{10}$, $F_{80}G_{20}$, $F_{70}G_{30}$, and $F_{60}G_{40}$ with respect to 8M. The flexural strength also increases from 8M to 16M and the increase in flexural strength of 16M was about 17.6%,17.75%,17.27% and 12.75% for $F_{90}G_{10}$, $F_{80}G_{20}$, $F_{70}G_{30}$, and $F_{60}G_{40}$ with respect to 8M. For a molarity of 8M, specimens with 10% GGBS produces a flexural strength of 8.86 MPa whereas for the same molarity specimens with 40% GGBS produces a flexural strength of 9.83MPa. Similarly For a molarity of 12 M, specimens with 10% GGBS produces a compressive strength of 9.22MPa whereas for the same molarity specimens with 40% GGBS produces a flexural strength of 10.17 MPa. For a molarity of 16 M, specimens with 10% GGBS produces a split tensile strength of 10.42 MPa whereas for the same molarity specimens with 40% GGBS produces a flexural strength of 11.08 MPa. This clearly reveals that as the content of GGBS increases, the flexural strength also increases.

Figure 5 Testing of flexure Beam

Table 3 Average Flexural strength (MPa)

Mix Id	8M	12M	16M
$F_{90}G_{10}$	8.86	9.22	10.42
$F_{80}G_{20}$	9.06	9.31	10.67
$F_{70}G_{30}$	9.26	9.53	10.86
$F_{60}G_{40}$	9.83	10.17	11.08

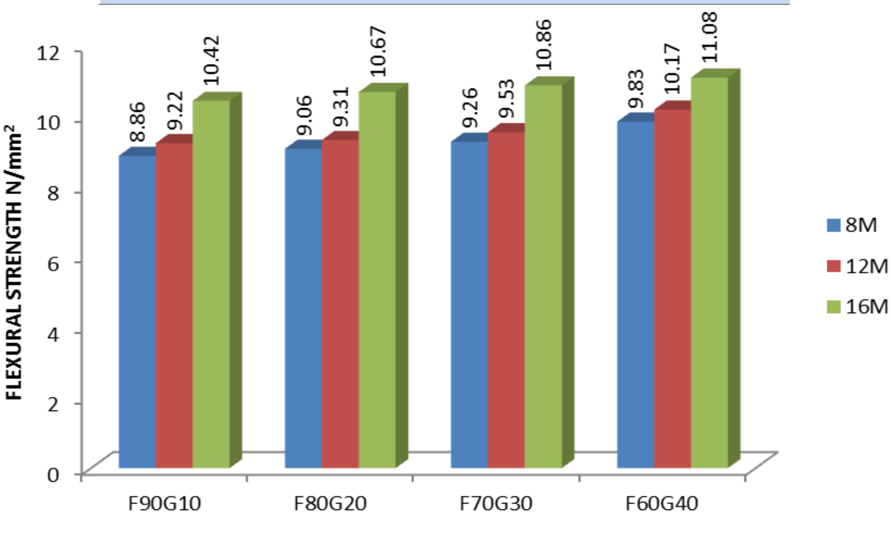

Figure 6 Effect of concentration of NaOH on Flexural strength

Conclusions

From the experimental investigations carried out, the following conclusions were drawn:

1. The mechanical properties of geopolymer concrete such as compressive strength, flexural strength, split tensile strength increases with the increase in GGBS content.
2. As the concentration of NaOH solution increases, the strength increases. The compressive strength of geopolymer concrete increases with an increase of age of concrete.
3. It is possible to produce a concrete of grade M80 using 40% GGBS and 60% fly ash.
4. By proper proportioning of GGBS and fly ash and by selecting appropriate parameters, desired strength of geopolymer concrete can be achieved.
5. The Geopolymer Concrete shall be effectively used for the beam column junction of a reinforced concrete structure.
6. Due to the high early strength Geopolymer Concrete shall be effectively used in the precast industries.
7. The government can make necessary steps to extract sodium hydroxide and sodium silicate solution from the waste materials of chemical industries, so that the cost of alkaline solutions required for the geopolymer concrete shall be reduced.

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