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EXPERIMENTAL STUDIES ON THE MECHANICAL AND DURABILITY PROPERTIES OF GEOPOLYMER CONCRETE

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ABSTRACT

Construction activitiesare increasing tremendously due to economic developments worldwide. Cement consumption is on the raise due to the enormous construction activities. The production of cement adds approximately an equal weight of $CO_2$to the atmosphere which is a serious environmental problem. In order to avoid this scenario, usage of cement should be minimised. Geopolymer concrete is one kind of concrete in which cement is completely eliminated. Geopolymer concrete is a concrete produced using supplementary cementitious materials such as flyash, Ground Granulated Blast Furnace Slag (GGBS) and activator solution such as sodium hydroxide and sodium silicate. In this research, geopolymer concrete was developed using GGBS and sodium hydroxide and sodium silicate solutions at different molarities (4M, 6M, 8M, 10M and 12M). The ratio of NaOH to Na_2SiO_3 was fixed at 1:2.5 for all the mixes. The concrete specimens are cured at roomtemperature till the date of testing. Mechanical properties such as compressive strength, split-tensile strength and flexural strength were studied at the end of 7, 14 and 28 days. Water absorption test wasalso conducted at the end of 28 days. Results on compressive strengths revealed that at the end of 7 days, a compressive strength of 45MPa was obtained on 12M mix. Results also revealed that 12M mix is better than other mixes in all the aspects tested except water absorption.

Keywords: Geopolymer concrete, alkaline solutions, strength and durability characteristics.

I. INTRODUCTION

Construction activitiesare increasing day-by-day due to economic developments worldwide. Cement consumption is on the raise due to the enormous construction activities. The production of cement adds approximately an equal weight of $CO_2$to the atmosphere which is a serious environmental problem. In order to avoid this scenario, usage of cement should be minimised. Geopolymer concrete is one kind of concrete in which cement is completely eliminated. Geopolymer concrete is a concrete produced using supplementary cementitious materials such as flyash, GGBS and activator solution such as sodium hydroxide and sodium silicate.

The term Geopolymer was first used by Davidovitsin 1979 [1]. The chemical composition ofgeopolymeris very close to that of zeolites. Unlike hydration in cement based concrete, in geopolymer concrete polymerisation of Si-O-Al bond takes place which leads to the strength gain of the geopolymer concrete [2]. To increase the reactivity of supplementary cementitious material combination of sodium hydroxide/ potassium hydroxide and sodium silicate/ potassium silicate are used as activator. Geopolymer concrete provides high strength, less creep and shrinkage, resistance to heat and cold, and better chemical resistance [3, 4]. The main aim of this research is to produce geopolymer concrete using GGBS and to study its mechanical properties such as compressive strength, split-tensile strength and flexural strength as per IS516, 1959 [5]. In addition to these, water absorption of geopolymer concrete was also conducted as per ASTM C642, 2006 [6] to understand the durability.

II. MATERIALS AND METHODS

GGBSwas obtained from a local vendor and the characteristics of the material are tabulated in Table 1. Locally available coarse aggregate of size 20mm was used and manufactured sand (M-sand) has been used as fine aggregate. The specific gravity and water absorption of the fine and coarse aggregates are given in table 2. Sieve analysis of aggregates are tabulated in tables 3 and 4. The mix of sodium hydroxide and sodium silicate solutions were used as the alkaline solutions in this present study. The ratio of 1:2.5 was fixed based on the literature [7].

Table 1. Characteristics of GGBS

Particulars	Test results
Specific gravity	2.9
Fineness m^2/kg	389
Initial setting time(min)	175
Magnesia content(%)	7.7
Sulphide sulphur(%)	0.49
Sulphide content(%)	0.49
Loss of ignition(%)	0.25

Table 2. Specifications of Aggregates

Properties	Coarse aggregate	Manufactured sand (M-sand)
Specific gravity	2.77	2.65
Water absorption (%)	0.40	2.00

Table 3. Gradation of fine aggregate

Sieve Size	Weight retained(g)	Cumulative % Weight retained	Percentage passing
4.75 mm	49	4.9	95.1
2.36 mm	76	12.5	87.5
1.18 mm	397	52.2	47.8
600µm	284	80.6	19.4
300 µm	153	95.9	4.1
150 µm	35	99.4	0.6
Pan	6	100	0

Table 4. Gradation of coarse aggregates

IS sieve	Weight retained (g)	Cumulative % retained	Percentage passing
40	0	0	100
20	1406	46.17	53.13
10	1520	97.53	2.47
4.75	74	100	0

Preparation of Alkaline Solution

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Fig. 1. Preparation of alkaline solutions

The concentrations of NaOHwas taken as 4M, 6M, 8M, 10M and 12M. The alkaline solutions were prepared before 24hours of casting. For the preparation of alkaline solutions, required amount of sodium hydroxide pellets were diluted in the required amount of distilled water. The required amount of NaOH and $NaSiO_3$are mixed 24 hours before the day of casting of concrete specimen to enhance the reactivity of the GGBS [8]. Five different mixes with molarities 4M, 6M, 8M, 10M and 12M were studied. Table 5 shows the mix design of the Geopolymer concrete mixes used for all molarities.

In each category, 12cubes, 3cylinders and 3prisms were casted. For casting process, first coarse aggregate, M-sand, and GGBS was finely mixed in the concrete mix machine and then to bind together well the prepared alkaline solution was poured and mixed well. The specimens were casted and compacted well to avoid honeycombs and air voids. The specimens were demoulded after 24 hours of casting and stored under normal room temperature till the date of testing.

Table 5.MixProportions Used

Content	GGBS kg/m^3	Alkaline solution kg/m^3	Coarse aggregate kg/m^3	M-sand kg/m^3
Geopolymer mix proportion at SSD Condition	420	168	1150	767

Fig. 2.Preparation of specimen

III. RESULTS AND DISCUSSION

The compressive strength results are given in table 6. The results revealed that the strength increases with respect to the molarity of the NaOH solution. The split tensile strength test results are given in table 7. The split tensile results shows the similar trend to that of compressive strength results. The flexural strength test results are given table 8. The same trend was followed in case of flexural strength. The water absorption results are tabulated in table 9. The results indicates that the water absorption increases with molarity. It is to be noted that with the increase of molarity the compressive strength is increasing. Hence, it can be understood that the water absorption is increasing with increase in compressive strength, which generally not the case in ordinary concrete. This requires further detailed investigation.

Table 6 Compressive strength test values

Molarity	7 dayscompressive strength (MPa)
4M	27
6M	30
8M	35
10M	40
12M	45

Table 7 Split tensile strength test values

Molarity	7 days Split tensile strength (MPa)
4M	4.04
6M	4.36
8M	5.00
10M	5.40
12M	7.40

Fig.3.Testing of Flexural strength

Table 8 Flexural strength test values

Molarity	7 daysFlexural strength (MPa)
4M	7.025
6M	8.05
8M	8.505
10M	9.025
12M	9.525

Table 9. Water absoption results

Molarity	Water Absorption at 28 days (%)
4M	1.124
6M	1.427
8M	1.493
10M	1.560
12M	1.586

IV. CONCLUSIONS

- Geopolymer concrete made of GGBS and alkaline solutions produces higher early strength.
- There is an enhancement in the compressive strength with respect to molarity
- The water absorption also increases with the increase in the molarity.

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