Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 5, Issue 1; January-March, 2018, pp. 28-30

http://www.krishisanskriti.org/Publication.html

Fire Resistant Geopolymer Concrete

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Abstract—*Concrete provides low fire resistance and hence proves itself highly vulnerable in fire hazard situations. The fire resistance of concrete can be increased by replacing cement in concrete mix with different proportion's of fly ash. It will help in lowering the cost of concrete mix due to partial replacement of cement with Fly ash as fly ash is cheaper than cement. GGBS (Ground Granulated Blast-Furnace Slag) can be used as an admixture to provide high temperature resistance to concrete. It helps in decreasing cracking of concrete at higher temperatures and increasing itsstrength in Compression. A compound called Polypropylene Fiber can also be used as an additive so as to increase the fire resistivity of concrete mix.*

1. INTRODUCTION

Geopolymer are materials that are heat/fire resistant that could be mixed in concrete to make Fire-Resistant Concrete [1-3]. The fire resistance of concrete can be increased by replacing cement in concrete mix with different proportions of fly ash, GGBS and Polypropylene Fiber. It helps in decreasing cracking of concrete at higher temperatures and increasing its compressive strength [4-6].

Though Concrete is a fire resistant building material but at the time of fire hazards, the temperature is raised to a higher extent. At these temperatures, concrete loses its mechanical properties such as strength, stiffness etc. Also it undergoes spalling and shrinkage.

The production of OPC(Ordinary Portland Cement) liberates about 1 ton of CO2 to the atmosphere when 1 ton of OPC manufacture, which is a major contributor to the environmental pollution [7-8]

2. EXPERIMENTAL PROGRAM

A. Materials

a. Polypropylene Fiber: Polypropylene is a thermos-plastic polymer, made from monomer propylene and is being used in variety of applications. It is produced in various structures for various applications like textile, plastic parts, reusable containers, packaging and labeling.

Table 1: Properties of polypropylene fiber

Specific gravity (gr/cm3)	Tensile strength (MPa)	Elastic modulus (GN/m2)	Elongation at failure (%)
0.91	550-770	3.5-6.8	21

b. Ground Granulated Blast Furnace Slag (GGBS): GGBS is a waste product and it obtained from blast furnace in water or steam by quenching molten iron slag to produce a glassy, granular product which is then dried and grinded into a fine powder.

c. Fly-Ash: Fly ash is a residue produced after combustion of coal and it consists of fine particles which is hard to disposebecause it is obtain in huge amount. It is called fly-ash because after the complete combustion of coal and its generation, it rises above the ground.

3. MIX-DESIGN OF GEOPOLYMER CONCRETE

In the Mix design of Geopolymer Concrete of M25, coarse and fine aggregates together were taken as 77% of entire mixture by mass or the mix design of area basis. By assuming the ratio's of alkaline liquid to fly ash is taken as 0.4, mass of fly ash and mass of alkaline liquid was calculated. To obtain mass of sodium hydroxide and sodium silicate solutions, the ratio of sodium silicate solution to sodium hydroxide solution was taken as 2.5. For the present investigation, concentration of NaOH solution is taken as 8 M. TheW/C ratio of the mix preparation is taken as 0.45.Extra water and dosage of super plasticizer was added to the mix according to the workability desired.

4. PREPARATION OF GEOPOLYMER CONCRETE

For the preparation of Geopolymer Concrete mix, we replaced cement with different proportions of Fly-Ash, GGBS, Gypsum and Polypropylene Fiber as listed in table below.

Table 1 Mix proportioning ratios for geopolymer concrete

Component	Percentage by Weight (%)		
	K1	K2	K3
Fly-Ash	70	72.5	75
GGBS	25	22.5	20
Gypsum	3	3	3
Polypropylene Fiber	1.5	1.5	1.5

To preparation of sodium hydroxide solution of 8 molarity (8 M), 320 g (8 x 40 that is, molarity x molecular weight) of sodium hydroxide flakes was mixed in one liter of water. The mass of NaOH solids in a solution will vary depending on the concentration of the solution expressed in terms of molar, M. The mass of NaOH solids was measured as 248 g per kg of NaOH solution of 8 M concentration.

5. CURING OF GEOPOLYMER CONCRETE

After casting the specimens, they were kept in rest period for five day and then they were de-moulded. The term 'Rest Period' was coined to indicate the time taken from the completion of casting of test specimens to the start of curing at an elevated temperature. This may be important in certain practical applications. An adequate amount of time is required for fly-ash based geo-polymer concrete precast blocks between casting of products and sending them to the curing chamber. At the end of the Rest Period, 9 test specimens were kept under ambient conditions for curing at room temperature. Remaining 3 specimens were kept at 60^{o}C in hot oven for 24 hours.

6. EXPERIMENTAL STUDY

A. Slump Test

To determine the workability and consistency of concrete mix, Slump Test is performed. It could be carried out at the site where the mix is being used or at laboratory. It is carried out form batch to batch.

Fig. 1: Slump test apparatus along with slum measurement

B. Compressive Strength Test

To determine the maximum amount of compression load a concrete block can bear without fracturing, Compressive Strength Test is performed. The test is performed on cube specimens between two parallel metal plates and the amount of compression load is measured on a dial gauge. The load is gradually applied at rate of 140KN/m^{2}on Compression Testing Machine.

Fig. 2: Compressive strength test with machine setup

C. Fire Flame Test

In this test, the concrete cubes are exposed to controlled flames with the help of fire gun. The cubes are exposed to a temperature of 800^{0}C - 900^{0}C and the temperature and time duration after which cracks and spalling starts to develop in the cubes is noted to determine the fire resistance of concrete.

D. Pulse Velocity Test

It is a non-destructive test performed at site or laboratory to determine the strength and quality of concrete. This test is carried out by passing an ultrasonic pulse through the concrete block and measuring its velocity.

Fig. 3: Pulse velocity test on concrete cube

7. RESULT AND DISCUSSION

After performing various tests on Geopolymer Concrete Mix with different proportions of Polypropylene Fiber, Fly-Ash and GGBS, some results were obtained which when compared to standard proves the advantages of Geo-polymer Concrete.

The tests performed on standard concrete mix is denoted as K in the table below and the other mixes are denoted as K1, K2 and K3.

Table 2: Compressive strength of cubes at 7, 14, and 28 days interval after casting

No. of Days	Compressive Strength (MPa)			
	K	K1	K2	K3
7	18.525	18.8	19.2	17.6
14	24.2	23.8	25.6	21.9
28	28.5	28.8	29.6	26.4

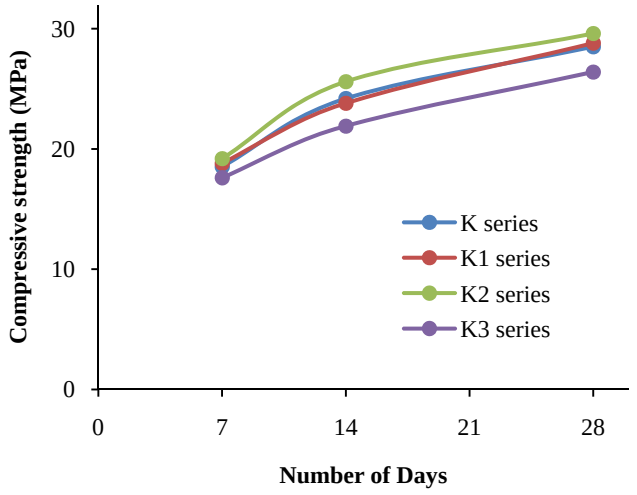

Fig. 3: Compressive strength of concrete

E. Slump Test

After performing slump test on various samples of mix prepared over different proportions of Geopolymer Concrete, the slump was resulting in the range of 80mm to 100mm.

F. Fire Flame Test

After exposing the geo-polymer concrete cubes to the controlled fire flame of temperature about 800^0C-1000^0C, there were no major cracking and spalling for about 60 minutes of exposure.

G. Pulse Velocity Test

For any good concrete structure, the standard reading for Non-Destructive Pulse Velocity Test is taken as greater than 4.5m/s.In case of our experimental program, the reading of pulse velocity test for geo-polymer concrete cubes is 4.6m/s.

8. CONCLUSION

The replacement of cement by Fly-Ash, GGBS and Polypropylene Fiber to the concrete has increased the workability of mix. Test Results has shown that Geopolymer Concrete gives more compressive strength than that of conventional concrete mix. Also, GGBS and Polypropylene Fiber has led to increase the fire resistance of Concrete Mix which is advantageous in case of Fire Hazards.

Geopolymer Concrete uses materials like Fly-Ash and GGBS which are treated as waste. Thus making it economical and environment friendly.

9. FUTURE ASPECTS

The following modifications done in the composition of Concrete will help in developing an advanced type of concrete which is highly fire resistant. It will also help in utilizing fly ash which is a waste product that is very problematic when it comes to its disposal. The use of fly ash will also help in decreasing the use of cement in concrete as manufacturing of cement leads to produce a large amount of carbon dioxide.

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