STUDY OF STRENGTH CHARACTERISTICS OF GEOPOLYMER CONCRETE USING CERAMIC AGGREGATES AS COARSE AGGREGATES WITH ADDITION OF POLYPROPYLENE FIBERS

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Abstract
Geopolymer concrete is an innovative and eco-friendly construction material and replacement for Portland cement concrete. The geopolymer decreases the demand of Portland cement which is responsible for high carbon dioxide emission. Geopolymer concrete is made up of geological origin by-products or waste materials like fly ash, ground granulated blast furnace slag (GGBS). In this study by utilizing the fly ash, GGBS and glass powder for cement replacement, ceramic aggregates for replacement of coarse aggregates and sodium hydroxide solution used as binder. In this study molarity of sodium hydroxide is varied as 8M, 10M, 12M, 14M and 16M to obtain optimum molarity. The addition of polypropylene fibers to improve strength characteristics and this is added in percentages of 0%, 0.5% and 1%. The tests conducted were compressive strength, split tensile test and water absorption test. The casted specimens were tested for 7 and 28 days.

Keywords: Geopolymer concrete, Compressive strength, Split tensile strength, Polypropylene fibers (or PP fibres), Fly ash, Ground granulated blast furnace slag (GGBS), Sodium Hydroxide (NaOH), Molarity.

I. INTRODUCTION

Geopolymer concrete is an innovative and eco-friendly construction material and replacement for Portland cement concrete. The term geopolymer was initially introduced by Davidovits. The geopolymer decreases the demand of Portland cement which is responsible for high carbon dioxide emission. Geopolymer concrete is made up of geological origin by-products or waste materials like fly ash, ground granulated blast furnace slag (GGBS). Fly ash and ground granulated blast furnace slag (GGBS) are waste generated from thermal plant and steel plant respectively. Thus geopolymer concrete helps in waste management and decreasing the carbon emission by the use of Portland cement. The geopolymer's main constituent silicon and aluminum are provided by industrial waste products such as fly ash, GGBS, glass powder and alkaline solution i.e., NaOH solution which creates a binder and thus called as alkali-activated cement or inorganic polymer cement.

Waste glass in the form of glass powder. The glass is grinded to fine powder it exhibits pozzolanic properties due the presence of silica content. So the glass powder is used in partial replacement for cement and thus improving the strength characteristics and durability of the concrete.

The ceramic waste is a major contribute to construction and demolition waste, creating a serious environmental, technical and economical problem of now-a-days. In building construction, ceramic waste is produced on the transportation to the building site, on the execution of several works such as construction of facades and partition walls, roofs, and precast joint slabs and works on the opening of grooves. There is a broad range of possibilities to reuse this type of waste in landfilling, road pavement bases, recycling itself, in concrete production as aggregates, filling mortars and coating mortars.

Using of polypropylene fibers can improve spalling behavior of concrete. The compressive strength, tension strength and bending strength increased with higher fiber volume, while concrete liquefaction decreased. One of the most important reasons for using the fiber reinforced concrete is elevating the tension stabilization and elasticity of the concrete obtained properly by using such special concrete.

II. SCOPE AND OBJECTIVES

- The main objective is to determine the strength characteristics of geopolymer concrete using ceramic aggregates as coarse aggregates.
- Comparing the compressive strength of M-25 grade concrete using ceramic aggregates as coarse aggregates.
- To determine optimum molarity of sodium hydroxide i.e., NaOH by varying the molarity of NaOH to obtain maximum strength of geopolymer concrete.
- To determine the optimum strength by adding polypropylene fibers of varying percentages to optimum molarity geopolymer concrete.

III. EXPERIMENTAL WORK

In the present study M25 grade geopolymer concrete is used. In the study ceramic aggregate is used as coarse aggregate and the fibers were also used. The molarity of sodium hydroxide solution is varied by 8M, 10M, 12M, 14M and 16M. The addition polypropylene fiber content by 0%, 0.5% and 1% by volume of concrete. In this study cubes (150mm×150mm×150mm) and cylinders (150mm diameter × 300mm height) were casted. The casted moulds were kept for 7 and 28 days dry curing. The casted specimen were tested for compressive strength and split tensile strength. The water absorption test is conducted for the optimum compressive strength. The casted specimens were tested in 200T capacity compression testing machine. Preliminary test were conducted on the materials used.

Fly ash: The fly ash is collected from Udupi Power Corporation Limited (UPCL), Udupi is used for the study. In the present study, 150µm downsize is used.

Table1. Properties of Fly ash

Material	Specific Gravity
Fly ash	2.26

Ground granulated blast furnace slag (GGBS): The GGBS is collected from Quality Polytech, Baikampady Industrial Area, Mangalore.

Table2. Properties of GGBS

Material	Specific Gravity
GGBS	2.88

Glass Powder: The glass powder is collected from Enviro Safety Glasses, Mysore. In the present study, 600µm downsize is used.

Table3. Properties of Glass Powder

Material	Specific Gravity
Glass Powder	3.00

Polypropylene Fiber: In present study polypropylene fiber of 12mm length is used.

Table4. Properties of Fibers

Material	Specific Gravity
Polypropylene fiber	0.91

Sodium Hydroxide (NaOH): It is collected from Sri Durga Laboratory Equipment Supplies, Mangalore.

Fine Aggregates: In this study Fine Aggregates of 4.75mm down size is used.

Table5. Preliminary test results of Fine aggregates

SL.NO	Particulars	Test Results
1	Specific Gravity	2.56
2	Water absorption	0.8%
3	Fineness Modulus	2.806
4	Grading Zone	Zone-II

Ceramic Aggregates: In this study ceramic aggregate of 20mm down size is used.

Table6. Preliminary Test results of ceramic aggregates

SL.NO	Particulars	Test Results
1	Type of aggregate	Crushed angular
2	Specific Gravity	2.327
3	Water absorption	14.61%
4	Fineness Modulus	6.88

Mix Design:

Table7. Mix Proportion

Grade of concrete	M25
Cement content	450 kg/m^3
Water content	329.17 lit
Water cement ratio	0.4
Fine Aggregate	705.28 kg/m^3
Coarse Aggregate	751.44 kg/m^3

Table8. Mix Proportion

Cement	Fine agg	Coarse agg	Water
1	1.567	1.669	0.4

IV. RESULTS AND DISCUSSIONS

A. Compressive strength:

Compressive strength of moulds were tested in 200T capacity compression testing machine. The moulds were tested for 7 and 28 Days. The test result showed compressive strength of Geopolymer concrete was optimum at 12M of sodium hydroxide and 0.5% addition of Polypropylene fibers for 12M Geopolymer concrete. Further addition of fibers decreases the strength. Test were conducted as per IS 516-1959.

Table9. Compressive Strength (28 days) of different molarity.

Concrete with different molarity	Compressive strength (N/mm^2)
8M	7.85
10M	9.92
12M	11.70
14M	9.62
16M	7.40

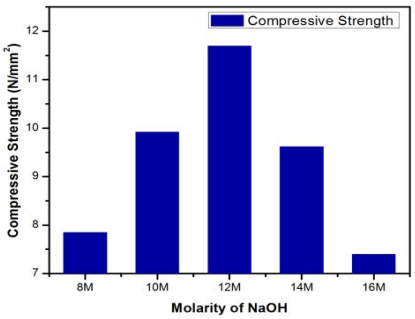

Figure 1. Compressive Strength (28 days) of different molarity

Table10. Compressive Strength (7 days) with addition of fibres

Concrete with different % fibres	Compressive strength (N/mm^2)
0%	6.219
0.5%	7.703
1%	5.036

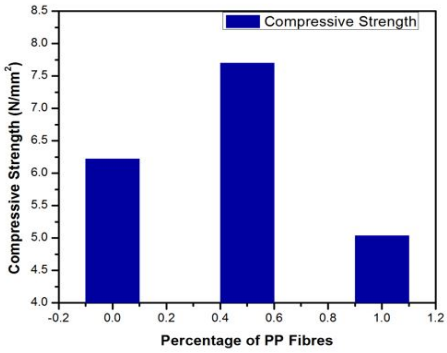

Figure 2. Compressive Strength (7 days) with fibres

Table11. Compressive Strength (28 days) with addition of fibres

Concrete with different % fibres	Compressive strength (N/mm^2)
0%	11.70
0.5%	15.70
1%	11.25

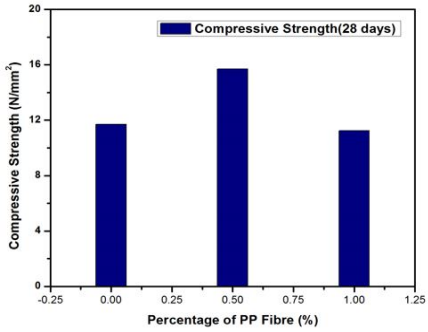

Figure 3. Compressive Strength (28 days) with fibres

The optimum compressive strength of Geopolymer concrete for different molarity of sodium hydroxide was 12M obtained for 28days.With 0.5% polypropylene fibres addition for 12M of Geopolymer concrete is optimum, obtained for 7 and 28 days. Further addition of polypropylene fibers decreases the strength.

A.1. Comparison of compressive strength of M25 normal cement concrete by replacing coarse aggregates with ceramic aggregates and which is kept in water curing.

Table12. Compressive Strength of M25 grade concrete.

Samples	Compressive strength (N/mm^2)
7 days	12.73
28 days	21.18

Figure 4. Compression Strength Test

B. Split Tensile test:

Split tensile strength of moulds were tested in 200T capacity compression testing machine. The moulds were tested for 7 and 28 Days. The test result showed split tensile strength of Geopolymer concrete was optimum at 0.5% addition of Polypropylene fibers for 12M Geopolymer concrete. Test were conducted as per IS 516- 1959.

Table13. Split Tensile Strength

Samples	Split Tensile Strength (N/mm^2)	
	7 Days	28 Days
12M	0.659	1.461
12M + 0.5% PF	1.320	2.065

Figure 5. Split Tension Test

C. Water Absorption test:

The cubes are casted for optimal values of Geopolymer concrete i.e. one with fibres and another without fibres (for 12M and 12M + 0.5% addition polypropylene fibres). These cubes are kept for dry curing for 28 days. The cubes are weighed after 28 days. The cubes are immersed in water for 24Hrs and weight of the cubes are taken i.e. W_1. The cubes again kept in the oven for 24Hrs and weighed again for complete dry weight i.e. W_2. Water absorption is calculated by below formula.

Water Absorption = $\{(W_1 \sim W_2) / W_2\} \times 100$

Table13. Water Absorption Test

Samples	Water Absorption (%)
12M	0.68
12M + 0.5% PF	0.52

V. CONCLUSIONS

- The optimum compressive strength of Geopolymer concrete for different molarity of sodium hydroxide was 12M.
- With 0.5% polypropylene fibres addition for 12M of Geopolymer concrete, compressive strength attained maximum value compared to no fiber Geopolymer concrete (12M).
- The optimum split tensile strength obtained for 12M Geopolymer concrete with 0.5% addition of polypropylene fibres.
- Addition of polypropylene fibres improves spalling behavior of concrete and ductility of concrete.
- With the addition of polypropylene fibres the water absorption is less compared to normal Geopolymer concrete.
- The compressive strength comparison of M25 grade concrete and Geopolymer concrete of above optimum values shows that the Geopolymer concrete which is obtained optimum can be used for road pavements, garden pavements etc.

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