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An Innovative and Unconventional Modified Use of Geopolymer Based Fibre Reinforced Concrete

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ABSTRACT: Geopolymer based fibre reinforced concrete has excellent engineering properties which not only reduces the greenhouse gas emissions but also improves the strength parameters of the ordinary Portland concrete. Fibres in general and polypropylene (PP) fibres, in particular have gained popularity in recent years as it transmits tensile forces across a crack and also because they reduce the shrinkage. After experimentation, it was observed that, on replacing 20% quantity of cement by fly ash in OPC concrete and adding 0.85 kg fibres /cu.m of concrete, there was 50% increase in the compressive and 20% increase in the flexural strength of the OPC concrete. The introduction of polypropylene fibres in fly ash concrete improved the resistance to cracking as well as enhanced its durability. This research paper emphasizes the use of Geopolymer based fibre reinforced concrete in cast in situ construction of pavements and also highlights that it has high desirable structural engineering properties, which can lead to significant environmental and economic benefits as it reduces the consumption of cement by 25% as compared to OPC concrete.

KEYWORDS: Geopolymer, polypropylene fibres, flexural strength, pavements

I. INTRODUCTION

Concrete is the most extensively used material in civil engineering construction so considerable attention is taken for improving the properties of concrete with respect to strength and durability. India's total installed capacity of cement stood at 320 million tonnes per annum (mt/a). The cement industry produces about 5% of global man-made CO₂ emissions, of which 50% is from the chemical process, and 40% from burning fuel. The amount of CO₂ emitted by the cement industry is nearly 900 kg of CO₂ for every 1000 kg of cement produced.

Use of industry waste like fly ash to partly replace cementing material in concrete system addresses all the major sustainability issues. It is recommended over the ordinary concrete as it considerably saves cement and also prevents environmental pollution.

a) Advantages of Geopolymer based Fibre Reinforced Concrete:

- i. Reduced Permeability
- ii. Resistance to abrasion
- iii. Higher mix cohesion thus improving pump ability over long distances
- iv. Improved freeze-thaw resistance
- v. High resistance to explosive spalling in case of a severe fire
- vi. Improved impact resistance
- vii. Increased resistance to plastic shrinkage during curing
- viii. Increased durability

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- ix. Increased flexural strength
- x. Increased compressive strength

II. LITERATURE REVIEW

Hardjito.D and Rangan.B.V (2005), proposed in her paper that the development of fly ash-based geopolymer concrete is in response for the need of a 'greener' concrete in order to reduce the carbon dioxide emission from the cement production. Geopolymer concrete is manufactured from predominantly silica and alumina containing source material. It offers a significant opportunity to materialise 'green' concrete as it is possible to utilise an industrial by-product such as fly ash, to totally replace the use of ordinary Portland cement in concrete, and hence to reduce the emission of carbon dioxide to the atmosphere.

This paper presents the effect of some parameters on the engineering properties of fly ash-based geopolymer concrete. The measured stress-strain curves of geopolymer concrete in compression are also compared with those calculated using a model available for Portland cement concrete.

Suriya P. and Senthilkumar's paper presents results of an experimental program on the mechanical properties of Fibre Reinforced Geopolymer Concrete (FRGPC) such as compressive strength, split tensile strength, flexural strength. Alkaline liquid to fly ash ratio was fixed as 0.45 with 100% replacement of OPC. Steel fibre was added to the mix in volume fractions of 0.5%, 1.0%, and 1.5% by volume of concrete. Specimens were subjected to 24 hours of Heat curing at 80°C in heat curing chamber. Based on the test results, optimum % were formulated and compared it with conventional Concrete.

III. METHODOLOGY

This experiment was conducted on considering that the use of polypropylene fibres improves specific material properties of the concrete such as impact resistance, flexural strength, toughness, fatigue resistance and ductility. It is experimentally said that the addition of fly ash improves the workability of concrete, but polypropylene fibre decreases the workability of concrete. An attempt is made to study the mechanical properties of Fly ash concrete with addition of fibres at 0.5, 0.7, 0.9 and 1.1kg/cu.m. of concrete and with 15% fly ash replacement with cement.

By addition of fly ash in OPC concrete the 28 days compressive strength is increased; however; there is a possibility of initial cracking in fly ash concrete; i.e. between 3days to 21days; after casting. Therefore to overcome this defect fibres are added along with the fly ash in OPC concrete, which will result in a concrete of high strength (i.e. more than OPC) and also will produce a concrete having a good resistance against initial cracking.

A) Materials used.



Figure 1. Materials Used

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Table 1. Materials and their specifications

Sr. No.	Material	Specification
1	Cement	Ordinary Portland cement, 43 Grade conforming to IS 12269 – 1987
2	Fine aggregate	Locally available river sand conforming to Grading zone II of IS 383 –1970
3	Coarse aggregate	Locally available crushed basalt stones, graded aggregate of nominal size 20 mm
4	Fly Ash	Fly ash class C obtained from Cinarmass Plant in Indapur and Baramati which conforms as per IS 3812-2000
5	Fibres	Polypropylene Fibre 12mm long was used
6	Water	Potable water

B) Mix Design.

The compressive strength of hardened concrete which is generally considered to be an index of its other properties depends upon many factors like quality and quantity of cement, water and aggregates, batching and mixing, placing, compaction and curing. From technical point of view the rich mixes may lead to high shrinkage and cracking in the structural concrete and to evolution of high heat of hydration in mass concrete which may cause cracking. Thus, a good mix design using IS codes is very necessary.

Stipulations for Proportioning:-

- Grade designation- M25
- Type of cement- OPC 43grade
- Maximum nominal size of aggregate- 20mm
- Minimum cement content- 300kg/m³
- Maximum w/c ratio- 0.5
- Workability- 100mm (slump)
- Exposure condition- Moderate
- Type of aggregate- Crushed angular aggregate

IV. EXPERIMENTAL WORK

A) Testing equipment:

i) **Universal Testing Machine:** A universal testing machine (UTM) is used to test the tensile strength and compressive strength of materials. It is named after the fact that it can perform many standard tensile and compression tests on materials, components, and structures. Universal testing machines can be of different types based on output required like Computer operated Universal Testing Machine and digitally operated Universal Testing Machine

ii) **Compression testing machine:** This machine is used to test the compressive strength of the concrete cubes. Its rugged construction and simplicity makes it possible for even non-technical personnel to operate them with ease.

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B) Casting of cubes and beams with designed grade M25: Procedure



Figure 2. Dry mixing of all material

Step 1. Dry mixing of the materials and followed by wet mixing and preparing a homogenous mix. Shown in Figure 2.

Step 2. Fill the concrete in the mould having size 150mm ×150mm ×150mm for casting cubes and in mould of size 600mm×150mm ×150mm for casting beam and tamping by tamping rod.

Step 3. Demoulding of moulds after 24hours of casting and then place them into the curing tank for 28 days for curing.

Step 4. After curing, while testing weighing the concrete cubes on electric weighing machine, noting down its dimensions and testing on the compression testing machine for finding the compressive strength.



Figure 3. Testing of beam in universal testing machine

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Similarly weighing the casted beams, taking their weights, writing down their dimensions and testing them on the universal testing machine for finding the flexural strength as shown in Figure 3.

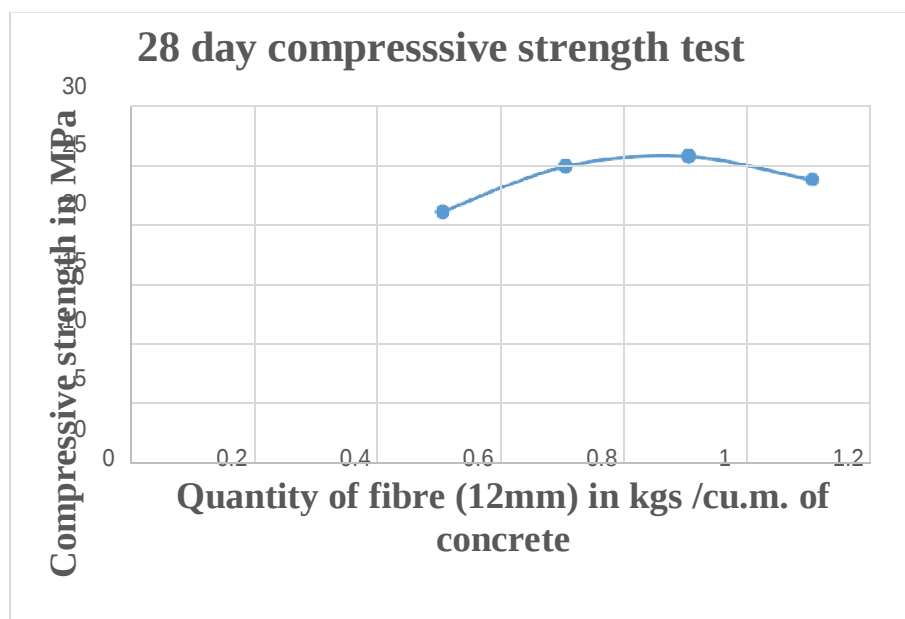
C) Experimental result and calculations:

i) **General.** We tested 48 cubes on the Compression Testing Machine for compressive strength and 7 beams for 3 point loading on U.T.M. for Flexural strength.

ii) Experimental Results.

Table 2. Compressive strength test on 28th day

Concrete description	28 days Compressive Strength
OPC	24.16 MPa
OPC+Fly ash	28.54 MPa
GPFRC -0.5kg/cu.m	22.07 MPa
GPFRC <u>-0.7kg/cu.m</u>	25.91 MPa
GPFRC-0.9kg/cu.m	26.74 MPa
GPFRC -1.1kg/cu.m	24.80 MPa



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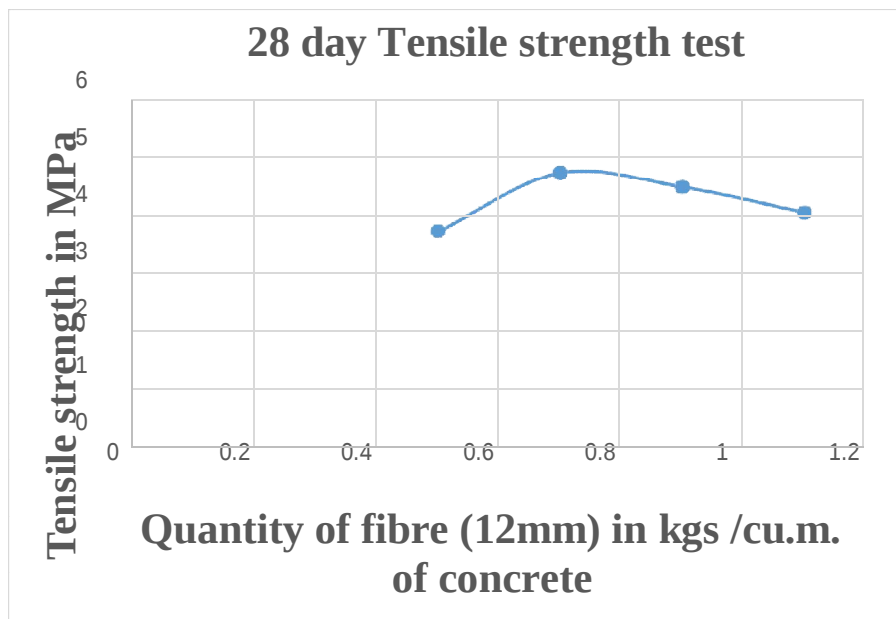
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Table 3. Flexural strength test on 28th day

Concrete Description	M.y/I (N/mm ²)
OPC	4.14
OPC+Fly ash	4.72
GPFRC-0.5kg/cu.m	3.84
GPFRC- <u>0.7kg/cu.m</u>	4.98
GPFRC-0.9kg/cu.m	4.83
GPFRC-1.1kg/cu.m	4.18



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V. INTERPRETATION

With increased quantity of fibres, the 28 days compressive strength of GPFRC is observed to be increased till the fibre content around 0.9 kg/cu.m., then after the 28 days strength is observed to be decreasing. The 28 days compressive strength of GPFRC can increase about 50 % above OPC concrete.

With increased quantity of fibres the 28 days Flexural Tensile Strength of GPFRC is observed to be increased till the fibre content around 0.8kg/cu.m., then after the 28 days strength is observed to be decreasing.

28 days Flexural Tensile Strength of GPFRC can increase about 20% above the OPC concrete.

VI. CONCLUSION

Variation in compressive strength

With addition of fibres, the 28 days compressive strength increases up to fibre content of around 0.9 kg/cu.m. then after it decreases.

The compressive strength at fibre content less than 0.8 kg/cu.m. and more than 1.2 kg/cu.m. is less than that of geopolymer concrete without fibres.

Thus we can conclude that the compressive strength remains low at too less or too more fibre content.

Variation in flexural strength

Similarly, with addition of fibres, the 28 days flexural tensile strength increases up to fibre content of around

1.1 kg/cu.m. then after it decreases.

The flexural tensile strength at fibre content less than 0.6 kg/cu.m. and more than 1.2 kg/cu.m. is less than that of geopolymer concrete without fibres.

Thus we can conclude that the flexural tensile strength remains low at too less or too more fibre content.

By interpreting the above variations in compressive and flexural strengths, we can in all conclude that by addition of fibres at 0.90 kg/cu.m. of concrete, we get the maximum compressive strength. Also we can conclude that at 0.80 kg of fibres/cu.m. of concrete, we get the maximum flexural strength. Thus, we may say that at 0.85 kg of fibres/cu.m. of concrete, we get the maximum compressive as well as flexural strength. Therefore, the proportion of fibres at 0.85 kg/cu.m. of concrete may be said as the optimum proportion for getting the maximum compressive and flexural strength. The increase in the flexural strength clearly indicates that there is an increase in the cracking resistance property of the fly ash concrete.

From this experiment we can conclude that, by replacing 20% of cement with fly ash and adding 0.85 kg/cu.m. of polypropylene fibres, the concrete so formed can be used for the construction of pavements and slabs.

We have verified performance of geopolymer based FRC using only fly ash as a geopolymer. There are so many other geopolymers such as opaline shales, diatomaceous earth, volcanic tuffs, pumicites, surkhi, etc., whose performances not verified by us. There is scope to evaluate the performance of geopolymer based FRC using these geopolymers.

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