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Experimental Studies on Polypropylene Fibre Reinforced Geopolymer Concrete Slabs

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***Abstract*— Geopolymer Concrete is one of the emerging construction materials as a substitute for conventional cement concrete, eliminating the usage of Ordinary Portland Cement. This paper aims to provide the failure pattern and yield line behaviour of Geopolymer concrete two way slabs with polypropylene fibres and compare with the conventional reinforced cement concrete. The Slab model used is of 1000mmx1000mmx30mm reinforced with 4mm diameter steel mesh. The failure pattern was studied experimentally for slab subjected to uniformly distributed load with fixed condition all-round. The results obtained agree with behaviour of conventional concrete. The results were validated using finite element model.**

***Keywords*-Geopoolymer concrete,Polypropylene fibre,Yield line pattern,Finite element model.**

I. Introduction

Geopolymers are aluminosilicate inorganic polymers which are formed from polymerisation of aluminosilicates with alkaline solutions. Geopolymers have several desirable attributes which include good mechanical properties and durability [1]. In addition, they are environmentally friendly, being derived from natural materials and because they can be prepared at room temperature they do not emit high levels of carbon dioxide that is associated with the preparation of Portland cement [2,3].

Research works related to geopolymer concrete slabs are limited. So it is suggested that geopolymer concrete slabs need a lot of studies. Due to lack of knowledge in geopolymer concrete slabs, the investigation of geopolymer concrete slabs is needed.

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Many research works are taking place in this connection in order to prove its properties are similar to that of conventional concrete, out of them many focus on their physical and mechanical properties but fail to provide its yield line behaviour pattern. This project aims to provide the failure pattern and yield line behaviour of Geopolymer concrete two way slabs with polypropylene fibres and compare with the conventional reinforced cement concrete.

This paper also presents the physical and mechanical properties of polypropylene fibre reinforced geopolymer composites. The motivation of this work was to investigate the structural behaviour of polypropylene fibre reinforced geopolymer concrete slabs and also to validate its results using ANSYS.

II. Methodology

This research is aimed at the investigation to prove the properties of Fibre Geopolymer concrete is similar to that of Ordinary Portland Cement concrete The objectives of this project are,

A comparative study will be carried for three types of slabs

- Geo polymer concrete slab(GPC)
- Fibre Reinforced Geo polymer concrete slab(FGPC)
- Conventional Ordinary Portland Cement (OPC) concrete slab(RCC)

III. Material Properties

A. Fly ash:

The low calcium class F fly ash was obtained from Tuticorin Thermal Power Station, Tamil Nadu, India. The reaction of fly ash with an aqueous solution containing Sodium Hydroxide and Sodium Silicate in their mass ratio, results in a material with three dimensional polymeric chain.

B. Alkaline solutions:

A combination of sodium silicate solution and sodium hydroxide (NaOH) solution can be used as the alkaline liquid.

Commercially available sodium silicate solution with Si-toNa_2O ratio by mass of approximately 2 i.e., SiO_2 – 29.4%, Na_2O – 14.7%, and water – 55.9% by mass, is used. Commercially available sodium hydroxide salt dissolved in water(8 molar) is used.

C. Aggregate:

River sand with specific gravity 2.64 is used as fine aggregate and granite stone jelly with specific gravity 2.56 is used as coarse aggregate.

D. Fibres:

The Fibres are polymeric synthetic Fibres (Recron 3S) obtained from Reliance Industries within the following range of specifications were used:

Effective diameter : 10 micron – 1.0 mm.

Length : 6-48 mm.

Specific gravity : more than 1.0.

Suggested dosage: 0.6-2.0 kg/cumec (0.23-0.6 % by Weight of cement in mix). Usage will be regulated as stipulated in IRC: 44/456 or any other specialist literature.

Water absorption : less than 0.45 percent.

Melting point of this Fibre shall not be less than 160˚C

The aspect ratio generally varies from 200 to 2000.

These synthetic Fibres have good alkali and UV light resistance.

Figure 1. Polypropylene Fibre (Recron 3s)

D. Mix Proportion:

TABLE I MIX PROPORTION OF POLYPROPYLENE FIBRE GEOPOLYMER CONCRETE

MATERIAL	MASS(Kg/m$^{3)}$
Coarse Aggregate	1294
Fine Aggregate	554
Fly ash (class F)	408
Sodium silicate solution	103
Sodium hydroxide solution	41(8M)
Fibre(Polypropylene)	0.9
Super plasticizer	6

The ordinary Portland cement concrete mix proportion is 0.37: 1: 1.17:2.16

IV. Experimental Program

A. Material preparation

Geopolymer concrete was manufactured by adopting the conventional techniques used in the manufacture of Portland cement concrete.The alkaline solution was prepared 24 hours before casting. The fly ash and the aggregates were first mixed together dry for about three minutes.The alkaline liquid was mixed with the super plasticiser and the extra water. The liquid component of the mixture was then added to the dry materials and the mixing continued for another four minutes .

Cylinder specimens of 150x300 mm and Cube specimens of 150x150x150 mm were casted and vibrated for 10 seconds on a vibrating table.

Figure 2. Casting of Geopolymer concrete cubes and cylinders

Slab specimens of 1000x1000x30 mm reinforced with steel mesh of 4 mm diameter and 30 mm c/c were casted. Compaction was made by manual strokes and vibrated on a vibrating table.

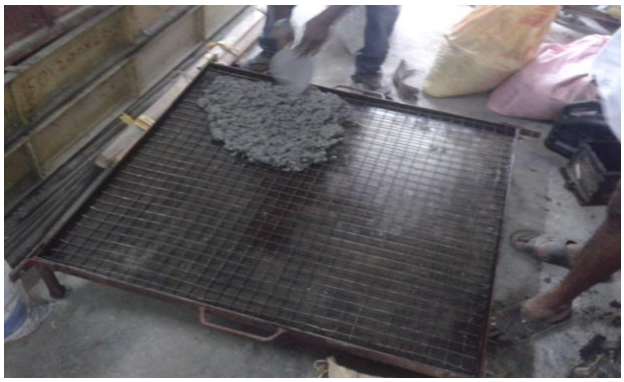

Figure 3. Casting of Reinforced Geopolymer concrete slab and conventional RCC slab

B. Curing:

The geopolymer test specimens and slabs were cured at an elevated temperature in the heat curing chamber for 36 hours.

Figure 4. Heat Curing of Reinforced Geopolymer concrete Slabs.

After curing, the geopolymer concrete specimens were allowed to cool down in the moulds to avoid drastic change in the environment for at least six hours. After releasing from the moulds, the test specimens were left to air dry in the ambient conditions in the laboratory until the day for testing.

C. Testing of Specimens

The cubes were tested for compressive strength and the cylinders for Split tensile strength.

The experimental setup for two way slab is shown in Figure 6 . The four edges of slab is fixed by providing 2 ISA 30X30X3mm.50T capacity Hydraulic jack is placed centrally to transfer uniformly distributed load to the slab through channels spaced at appropriate spacing. One Dial gauge is placed centrally below the slab to measure the deflection. The load is applied gradually at an interval of 0.1T corresponding deflection measured till failure.

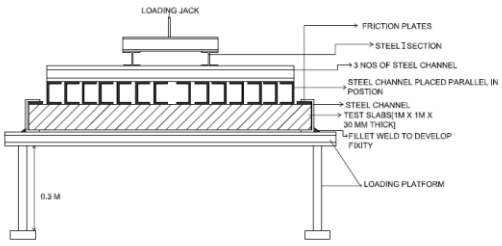

Figure 5. Slab fixing and loading arrangements

Figure 6. Experimental Set up

D. Results And Discussion

The main parameters such as load carrying capacity, load vs deflection, failure pattern were discussed in this chapter. Influence of fibres with increase in load and control of deformation were also noted. For better prediction of results, FGPC specimens were compared with the RCC control specimen.

1) Parameter Study

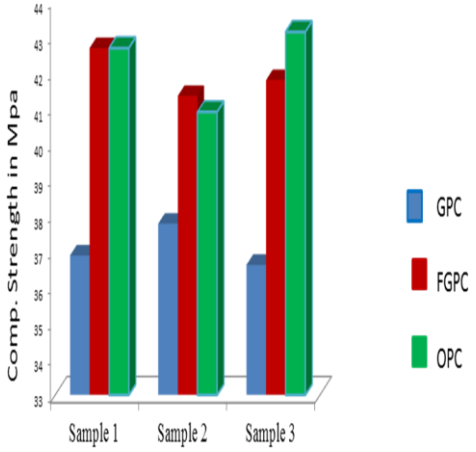

Figure 7. Comparison of compressive strength of cubes

The compressive strength results has shown that GPC is 12.65 % less than OPC,whereas FGPC is 0.71% less than OPC.

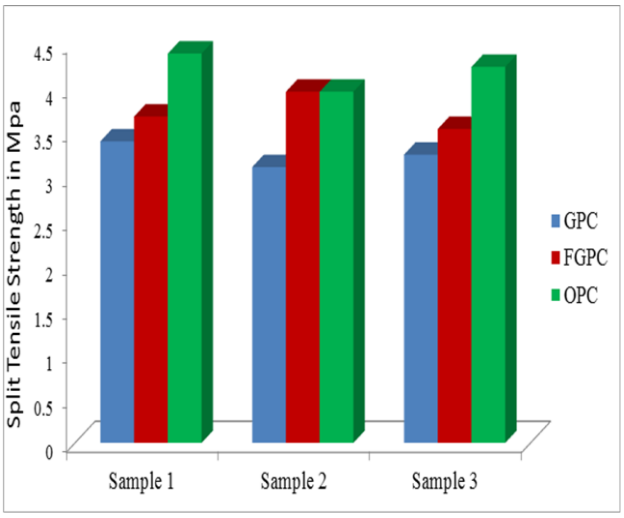

Figure 8. Comparison of Tensile Strength of cylinders

The split tensile strength results has shown that GPC is 22.62 % less than OPC,whereas FGPC is 11.19 % less than OPC.

The compressive strength of FGPC and OPC are comparable whereas the split tensile strength shows GPC and FGPC are lesser compared to OPC.

2) *Study On Slabs*

a)Load Deflection Study:

The observations were taken from the slab testing is tabulated below.

TABLE II. TEST RESULTS OF SLAB

LOAD (KN)	DEFLECTION IN mm		
	RCC SLAB	GPC SLAB	FGPC SLAB
1	0	0.22	0.18
2	0	0.26	0.34
3	0.06	2.72	0.48
4	0.18	4.65	0.56
5	0.3	5.52	0.72
6	0.35	6.52	0.84
7	0.48	7.04	0.96
8	0.57	7.58	1.04
9	0.7	7.98	1.2
10	0.81	8.35	1.68
11	0.93	8.66	1.84
12	1.08	9.08	2.03
13	1.23	9.4	2.28
14	1.4	10.22	2.58
15	1.6	10.71	2.74
16	2.02	11.08	3
17	2.28	11.42	3.31
18	2.56	11.8	3.56
19	2.78	12.22	3.84
20	3.1	12.58	4.1
21	3.62	12.92	4.42
22	4.1		4.64
23	4.46		5.03
24	4.7		5.24
25	4.92		

Deflection of GPC Slab is higher compared to RCC Slab. By adding polypropylene fibres in the geopolymer concrete, reduction in deflection is achieved. With the mixture of fibre in geopolymer, the concrete behaviour can be brought similar to the conventional concrete.

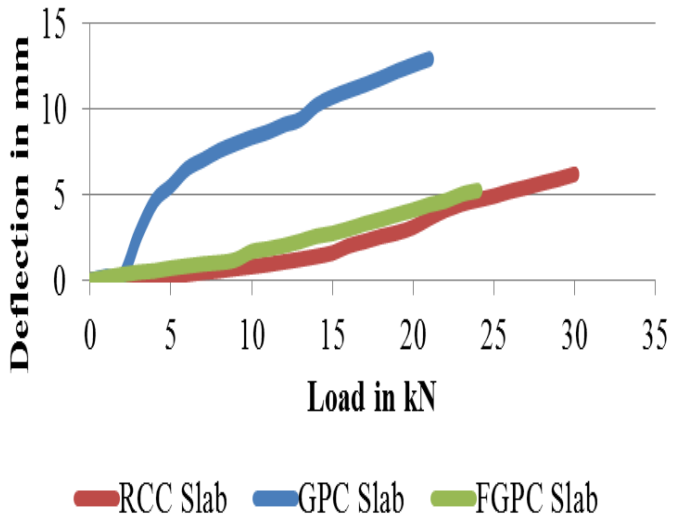

Figure 9. Load Vs Deflection of Slabs

b) Failure Pattern Of Slabs:

The failure pattern of FGPC slabs were in accordance with the conventional yield line behaviour of RCC slabs.

- Negative yield lines similar to conventinal RCC slabs are noticed at the top face at failure load.
- Positive yield lines similar to conventinal RCC slabs are noticed at the bottom face at failure load.
- Corner forging also noticed at top surface similar to conventional RCC slabs and Yield line theory.
- The failure load was found matching with Hillerbergs strip method of analysis.

Figure 10. Negative yield line pattern

Figure 11. Positive yield line pattern

Figure 12. Corner forging of slab

E. Validation In Ansys

Extensive finite element analysis using the ANSYS CIVIL FEM program was carried out to study the behaviour of the tested slabs.3D elastic beam type of element is used to model the concrete slab. For slabs reinforced, it is worthwhile to notice that the meshing was created according to the locations of reinforcing bars, either the longitudinal or transverse reinforcement, as well as the slab specimen cross-sectional perimeter.The load was applied as pressure on the entire slab.Slabs were fixed on all four sides.

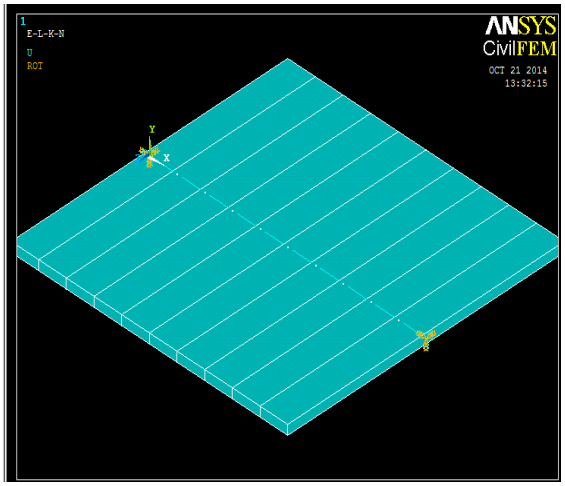

Figure 13. FEM Modelling of Slabs.

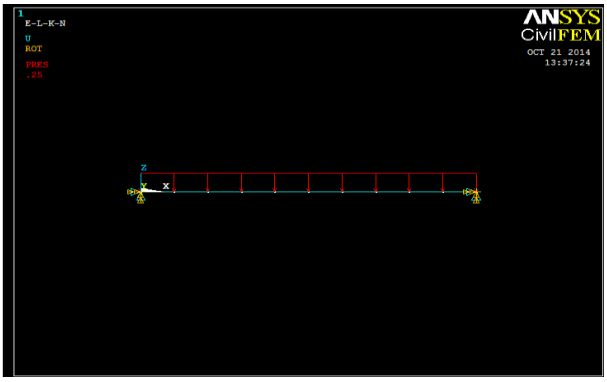

Figure 14. Loading on Slabs.

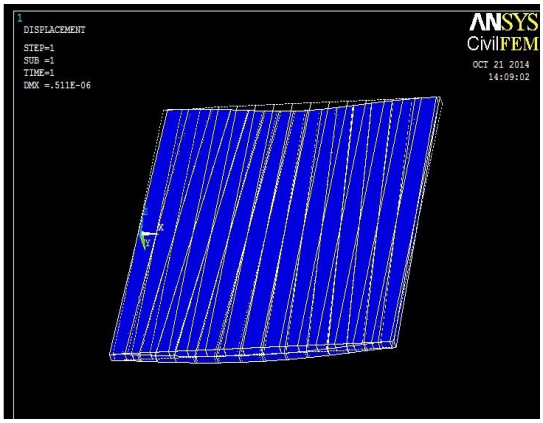

Figure 15. Deflection of Slabs.

The deflected pattern obtained in ANSYS was similar to that of experimental values.

V. Conclusion

Based on this experimental investigation and with reference to literature studies on physical and mechanical properties, the fibre reinforced geopolymer concrete can be used as a substitute in place of conventional reinforced cement concrete. From the test results its observed that deflection of GPC Slab is higher compared to RCC and the GPC slabs exhibited brittle failure.By adding polypropylene fibres in the geopolymer concrete, reduction in deflection was achieved and the nature of failure of FGPC slabs were ductile which is inaccordance with conventional RCC slabs. The behaviour of slabs were also validated in ANSYS and it was similar to that of experimental results.With the incorporation of polypropylene fibre in geopolymer, the geopolymer concrete behaviour can be made ductile.

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The author is a Phd scholar doing research on Geopolymer concrete.He is doing experimental studies on polypropylene fibre reinforced Geopolymer concrete slabs.