EXPERIMENTAL INVESTIGATION ON STUDYING THE FLEXURAL BEHAVIOUR OF GEOPOLYMER CONCRETE SLABS UNDER FIXED BOUNDARY CONDITION

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Abstract

Geo polymer concrete is one of the emerging construction material as a substitute for conventional cement concrete, eliminating the usage of OPC. This work is aimed to cast and testing of geopolymer slab elements with restrained edge condition. The size of slab panel is 1m x 1m x 0.05 m. By using yield line theory, the moment of resistance and maximum deflection under flexural loading are calculated for the of GPC slabs. Reinforcement details of these slabs are calculated using ultimate load method as per IS code provisions. As the slab element is a composite material the experimental work is carried for determination of mechanical properties GPC matrix and casting and testing of slab elements under UDL. Test results are compared with the theoretical computations for bending moment and maximum deflections. The crack pattern of slabs in experimental work is also compared with yield line patterns (Developed for RCC).From the test results it is observed that the behaviour of GPC slabs under flexural loading is similar to conventional concrete slabs

KeyWords: *Geo Polymer Concrete, Slabs, Flexural Behavior, Yield Line Patterns , Load vs Deflections.*

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1. INTRODUCTION

Ordinary Portland cement is the primary binding material used in the preparation of concrete. The quantities ofCo_2 emitted during the manufacture of Ordinary Portland Cementis very high.1tonne of OPC emits 0.8-0.94 tonne of carbon dioxide.

1.1 Geopolymers

Davidovits is the first person who introduced the Geo polymer in 1978 into the research developments. Geopolymers are aluminosilicate inorganic polymers which are formed from polymerisation of alumina silicates with alkaline solutions.

Research works related to geopolymer concrete slabs are limited. So it is suggested that geopolymer concrete slabs need a lot of studies. 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 fixed boundary condition and compare with the conventional reinforced cement concrete.

2. METHODOLOGY

This paper is aimed at the investigation to prove the properties of Geopolymercement concrete which is nearly equal to the of Ordinary Portland Cement concrete. The objectives of this project are,

- This work is aimed to cast and testing of the GPC two way slabs with restrained end conditions and also to study behaviour of slabs under flexural loading
- To study the validity of yield line theory for Geopolymer concrete slab in computing MOR and Deflections
- To study the load-deflection behaviour of Geopolymer concrete slab.

3. MATERIALS

3.1 Flyash : Fly ash is a pulverized fuel ash which is divided into very fine particles releasedfrom the combustion of incineration of coal. Low calcium Class F flyash was selected for this work from VTPS Vijayawada , Andhra Pradesh.

Table : 1 Physical Properties of Flyash

S No	Physical Properties	VValue
11.	Specific Gravity (G_s)	22.67
22.	Fineness cm^2/gm	44069

Table 2: Chemical Compositions of Flyash

S.No	Chemical Compositions	% Compositions	As Per IS 3812 - 2003
1	SiO_2	66.80	>35%
2	Al_2O_3	24.50	>70%
3	Fe_2O_3	4	-
4	CaO	1.50	-
5	MgO	0.45	<5%
6	Na_2O	0.40	<1.5%
7	K_2O	0.22	<1.5%

3.2 Aggregate: The aggregates are classified as

(1) Fine aggregate
(2) Coarse aggregate

Table – 3 Properties of Coarse Aggregate

S.No.	Property	Test Result
1.	Bulk density (Kg/m^3)	1611
2.	Specific Gravity (G)	2.74
3.	Fineness Modulus	7.17

Table 4: Properties of Fine Aggregate

S.No.	Property	Test Result
1.	Specific Gravity	2.60
2.	Bulk density (Kg/m^3)	1543
3.	Fineness Modulus	2.74
4.	Zone	II

3.3 Alkaline Solution: The combination of sodium hydroxide (NaoH)and sodium silicate are used in the preparation of GPC mix. NaoH is readily available in pellets.

Sodium silicate is easily avalilable in the market of proportions is SiO_2= 30.24%, Na_2O = 15.7%, and H_2o – 54.06%by weight.

3.4 Water: Distilled water is used for mixing of GPC because it has high reaction capacity with alkaline solutions. The P_H value of distilled water is 7.5 to 8.2.

Table 5: Analysis of Water (Limitations As Per IS: 456-2000)

S. No.	Impurity	Max. Limit	Results
1	P^H Value	6 to 8.5	7
2	Suspended matter mg/lit	2000	220
3	Organic matter mg/lit	200	20
4	Inorganic matter mg/lit	3000	150
5	Sulphate (SO_4) mg/lit	500	30
6	Chlorides (Cl) mg/lit	2000 for P.C.C. 1000 for R.C.C.	60

3.5 Preparation the Alkaline solution: A8 MolarofNaoHand Sodium hydroxide is used in this work. The molecular weight of NaoH is 40 so, to prepare 8Molarity (40 x 8 = 320) of 320 gm of NaoH pellets are weighted and it can be dissolved into 1 litre of distilled water.

The sodium hydroxide solution is mixed with sodium silicate solution to get the desired alkaline solution one day before making the geopolymer concrete.

3.6 Super plasticizer: CONPLAST SP430 is used to improve the workability of fresh GPC mix.

4. MIX PROPORTIONS

From the literature survey it is understood that as there is no code available for Mix design of GPC. The density of GPC is 2400 Kg/m^3 adopted for calculations of ingredients of GPC mix. The total aggregates (FA and CA)istaken as 77% of entire concrete mix by mass. F A was taken as 30% of the total aggregates.The alkaline solution to fly ash and sodium silicate to sodium hydroxide ratios was taken as 0.4 and 2.5 respectively

5. MIXING, CASTING AND CURING

Initially, fine aggregates, coarse aggregates and fly ashwere mixed in dry statefor 4 to 5 minutes and then alkaline solutions are added. It was found that fresh GPC mix was grey in colour and was cohesive.

Distilled water is taken as 10 % of the cementious material. The super plasticizer is taken as 3% of the cementious material. The time taken for preparing GPC mix is about 6 to 8 minutes to attain a bonding nature between the materials.

Table 6. Mix design of GPC

Materials		Quantities
C.A	(20mm)	278.21 Kg/m^3
	(14mm)	368.79Kg/m^3
	(7mm)	647Kg/m^3
F.A		554.4Kg/m^3
Flyash		380.68.Kg/m^3
Na_2Sio_3		122.36Kg/m^3
NaoH		48.95Kg/m^3
Super Plasticizer		5.71 Lit/m^3
Extra Water		38.06 Lit/m^3
Molarity		8M
Na_2Sio_3/NaoH		2.5
Alkaline liquid / Flyash		0.45

6. TEST RESULTS OF GPC CUBES, CYLINDERS & PRISMS

The Geopolymer concrete slab is a composite material, so it is aimed to determine themechanical properties of GPC matrix

The specimens were testedas per IS 516:1959 and strengths were calculated for 14,28 days.

Compressive strength test is conducted on 1000 KN capacity compression testing machine.
GPC cubes (100x100x100mm) are cast by varying molarity and cured in ambientconditions. All specimens were tested for different ages (14 and 28days).

Flexural Test was conducted to obtain the modulus of rupture or first crack developed and full collapse of the beam.The flexural test was conducted on sunlight cured prism beams (500mm x 100mm x 100mm). The test was conducted after 14 & 28 days age of concrete.

Split Tensile Strength Thecylindricalspecimens(150mmDia and 300mm height) are tested on tensile testing machine 1000KN capacity**.**

Fig.1 : Testing of GPC cubes

Fig.2: Testing of GPC cylinder

Fig.3 : Testing of GPC Prism

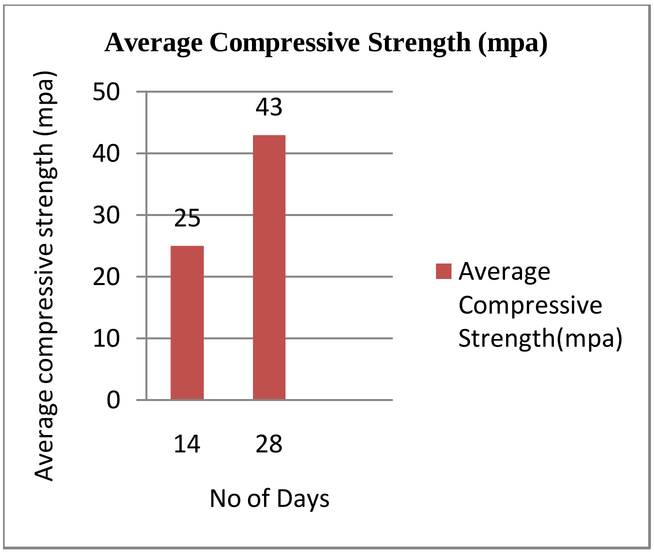

Fig 5 : Variation compressive strength of GPC (Oven curing)

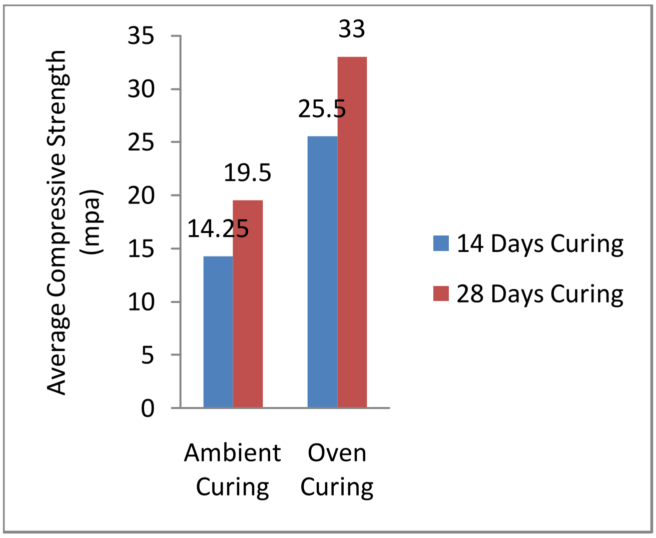

Fig 6 : Variations between the Compressive Strength with Different Types of Curing

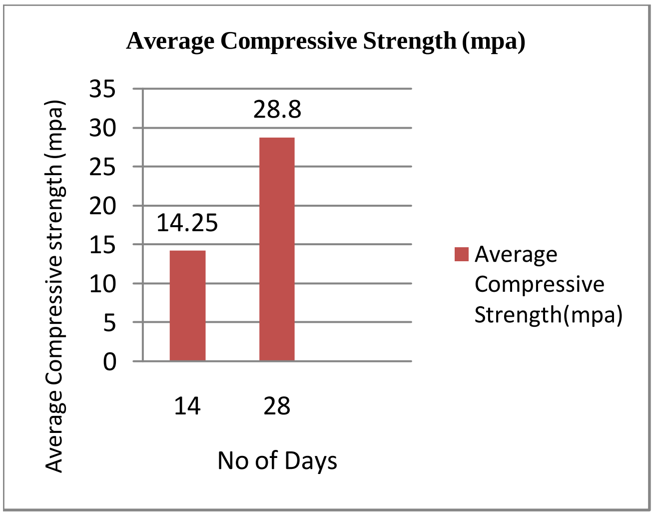

Fig.4 : Variation compressive strength of GPC (Ambient curing)

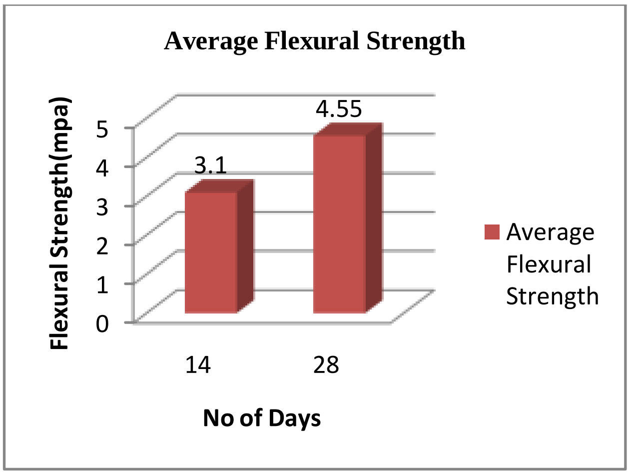

Fig.7 : Variation of Flexural Strength for Ambient Curing

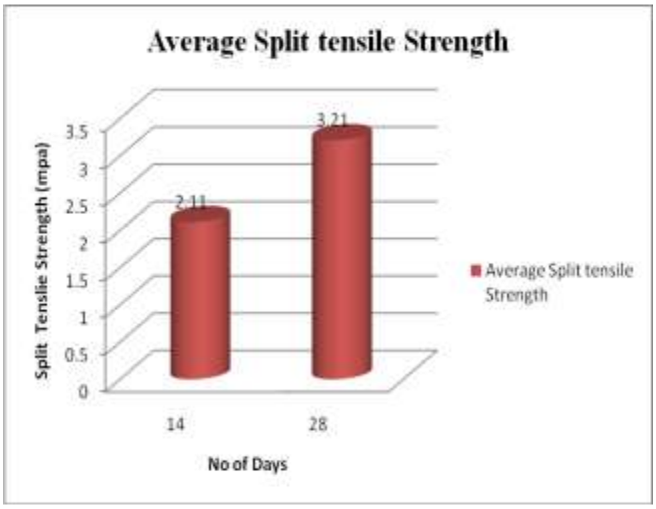

Fig.8: Variation split tensile strength of GPC (Oven curing)

Summary :

By this experimental results it is clearly known that the compressive strength of M20GPC mix is 28.1 N/mm^2.

7. SECONDPHASE OF INVESTIGATION STUDY ON SLABS

7.1 Yield Line Theory

It is defined as a line in which all the reinforcement bars are yielded. As the bar yield cracks develop in the slab along the yield line.

7.2 Methods of Yield Line Analysis:

There are two methods of yield line analysis of slabs, one is virtual and the other one is equilibrium method.
Two identical two-way slabs were fabricated and tested under fixed end condition, that is

1. Fixed ends (no rotation and no horizontal movement).
2. **Group (F):** Fixed supported slabs : (F_1& F_2)
3. The slabs had the dimensions of 1000mm x 1000mm x 50 mm.

7.3 Application of Yield Line Theory to Slabs:

The G.P.C. Slab was analysed by using ultimate load method and the moments were correlated with Yield line concept (virtual work and equilibrium method).

7.4 Ultimate Load Method

Data for Calculation:

1. Area of Reinforcement (φ6mm)
2. A_s = 28.27mm^2
3. Yield stress of reinforcement f_y = 220 N/mm^2 (from tension test of the reinforcement)
4. Compressive strength of concrete f_u = 28.1 N/mm^2 (from compression test of concrete)
5. Yield strain of concrete e_c = 0.003
6. Modulus of Elasticity E_s = 2x10^5 N/mm^2
7. Overall slab thickness h = 50mm

Table 7: Ultimate Moment of Resistance for Slabs (Ultimate Load Method)

Slab Type	M_y(KN-m)	M_x(KN-m)
F_1 & F_2	2.05	2.05

Table 8. Formulation of the Ultimate Loads By Yield Line Analysis

Slab Type	Virtual Work Method			Equilibrium Method
	W_{in}	W_{ex}	W_u	W_u
F_1	16M_u	W_u/3	48 M_u	48M_u
F2	16M_u	W_u/3	48 M_u	48M_u

Table 9: Theoretical Ultimate Load For All Slabs

Slab Type	Ultimate Load (kN/m)
F_1 &F_2	98

8. EXPERIMENTAL PROGRAM:

In this Phase, the work is to study the validity of the assumption made in the yield line theory in slabs under uniformly distributed load subjected to at the entire span under fixed end condition.

8.1 Preparation of Reinforced GPC slabs:-

It consists of two fixed support slab; (Referred to as F_1& F_2).

8.1.1 Slab Size

The size of slab specimen prepared is1mx1mx0.05mm.plywood form work is prepared with inside dimensions of 1mx1mx0.05mm.and cover blocks of size15mmx15mm is used.

8.1.2 Reinforcement for GPC Slabs

Fe250grade mild steel bar of 6mm diameter is used with a spacing of 120mm c/c and binded with ordinary binding wires. Thebottom and top cover of size10mm,side cover of 12mm is adopted.

8.1.3 Concreting for Slabs and Finishing;-

Mix design and preparation of alkaline solution is same as for first phase of investigation. But for restriction of slab depth, the maximum size of coarse aggregates is limited to 10mm.After mixing, the fresh GPC is cast into the slab mould in three equal layers and is compacted by ordinary rammer .after casting the slabs were left undisturbed in the form work for one day rest period. after that the slabs are kept for curing at room temperature.

Fig.9: Shows the arrangement of reinforcement and clear cover blocks in GPC Slab

Fig .10: Shows the Casting of GPC Slab

8.2 Loading Frame

Testing of slabs are done in 100 Tonnes capacity loading frame which electrically operated hydraulic jack.

Fig :11 Testing of slab on loading frame

8.3 Boundary Conditions:

The support condition for the tested slabs was fixed support. The Fixed support was achieved by fixed slabs to top of testing frame using 10mm bolts spaced 12mm center to center. To increase the fixing, steel plate was introduced at the top of slabs.

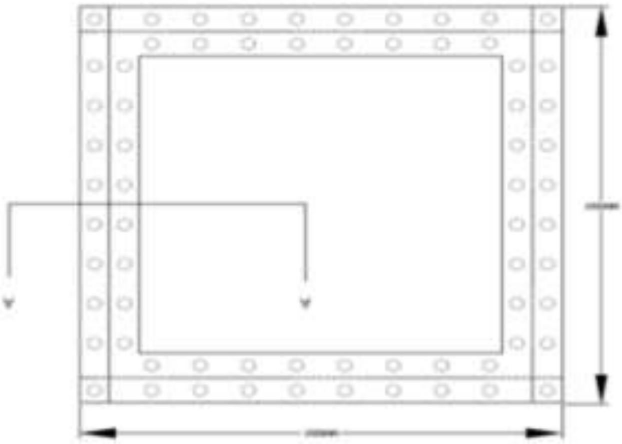

Fig :12 Shows the Frame of Fixed Slab

8.4 Application of Uniformly Distributed Load :

1. Uniformly Distributed Load is subjected at the centre of slabs by means of manual Jack its capacity was100 tons.

8.5 Procedure of Testing:

1. Zero reading of the dial gauges, a proving ring were noted down. The load was noted down.
2. The load was then applied gradually by manual jack and Load readings were taken from the proving ring.
3. The procedure was continued until cracks were visible and the load at which the cracks started was noted.

Fig 13: location of position of deflection for Fixed Slab

9. TEST RESULTS OF GPC SLAB ELEMENTS:-

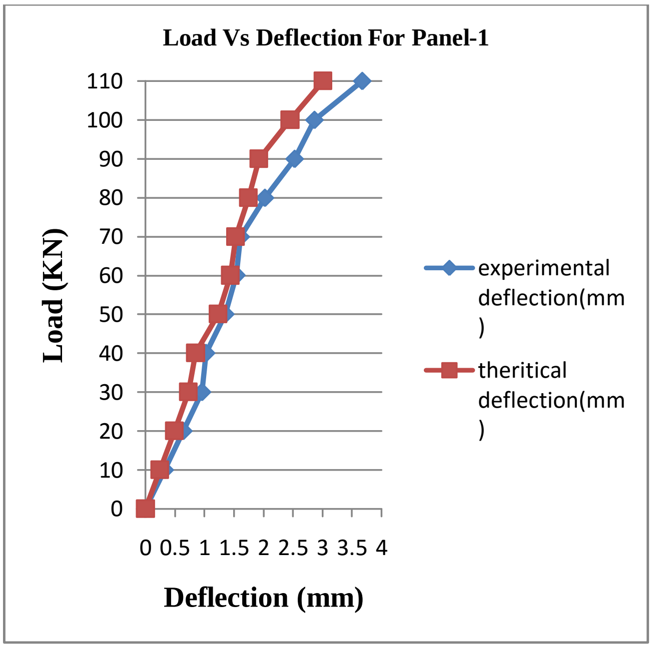

Fig 14: 6 Shows the Load Vs Deflection for Panel – 1 (F_1)

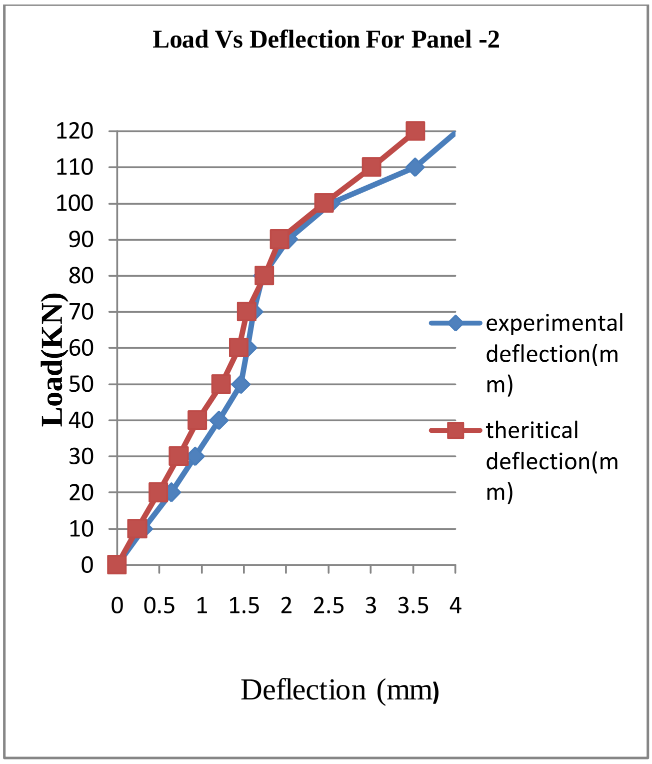

Fig 15 : Shows the Load Vs Deflection for Panel – 2 (F_2)

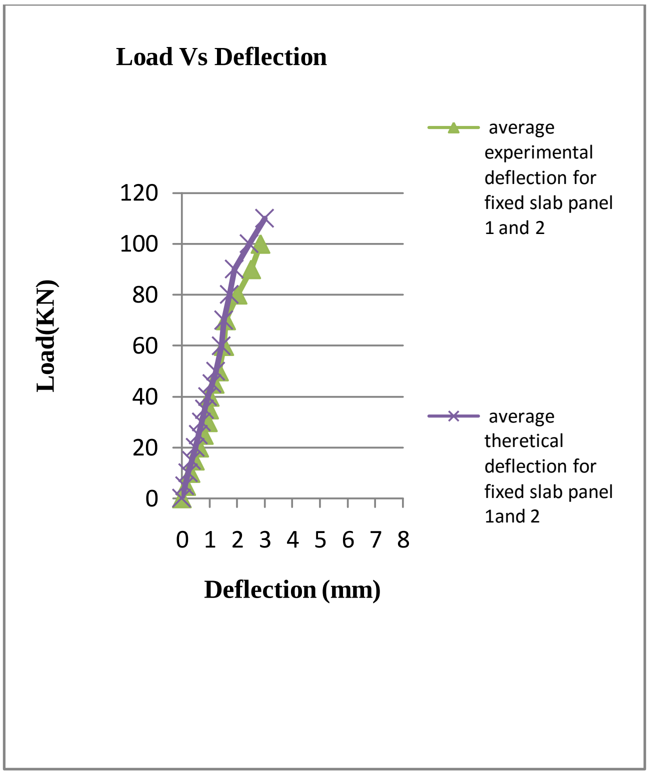

Fig 16 : Load Vs Deflections for the two slabs $F_1$and F_2

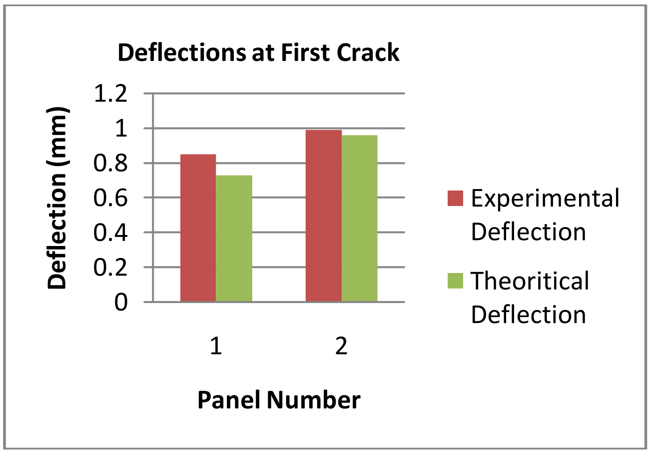

Fig 17 : Deflections of the First Cracks in different Panels

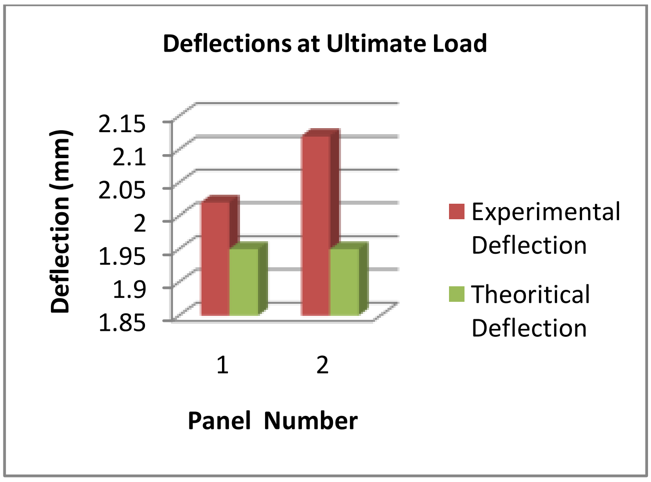

Fig 18 : Deflections of the Ultimate Load in different Panel

10. OBSERVATIONS& ANALYSIS OF RESULTS

The test slabs were analyzed based on the following information:

1. Observation of the cracks development.
2. Crack patterns, sketches of crack patterns which are assumed by yield line theory and compared with experimental crack patterns.
3. Deflection data, load-deflection curves.
4. Failure load, comparison between experimental and theoretical failure load for different slabs.
5. Modes of failure.

Observation of Crack Development:

1. For fixed supported reinforced slab (F_1) the first crack appeared at the bottom surface at the centre of the slab, under uniformly distributed load of 30 kN/m.
2. For fixed supported slab (F_2), thefirst crack appeared at a load of 40kN/m.

10. YIELD LINE PATTERNS

Fig 19 : Actual Crack on bottom surface for a Fixed Slab (Panel – 1) (F_1) Subjected to UDL

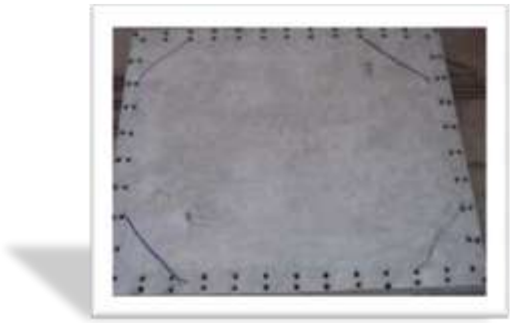

Fig 20 : Shows the Actual Crack on Top surface for a Fixed Slab (Panel – 1) (F_1) Subjected to UDL

Fig 21 : Actual Crack on bottom surface for a Fixed Slab (Panel – 2) (F_2) Subjected to UDL

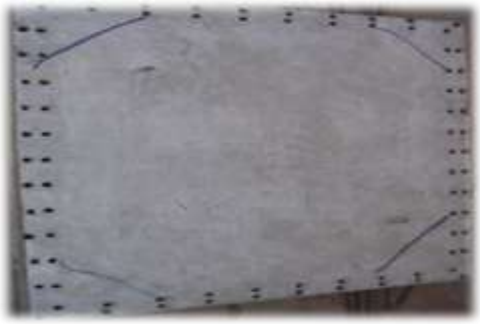

Fig 22: Actual Crack on Top surface for a Fixed Slab (Panel – 2) (F_2) Subjected to UDL

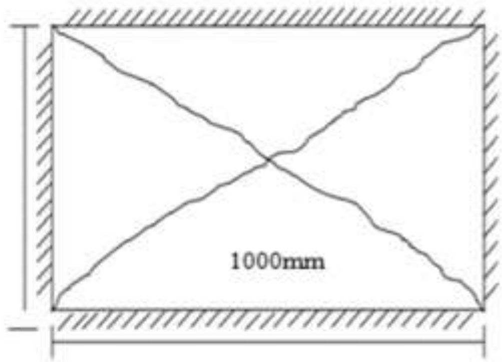

Fig 23: Theoretical yield line Crack pattern for a Fixed Slab (Panel – 1 and 2) Subjected to UDL

Table 10 : Shows the Test Variable and Comparison of Results

Panel No	Slab Mark	Dimension (m)	Type of Load	Support Condition	Type of Reinforcement	f_{ck} (mpa)	F_y(mpa)	W_u K/N m	W_{exp} kN/ m	W_{the} kN/ m	W_{the}/ W_{exp}	W_u W_{exp} /	Deflection at Failure load (mm)	Failure Mode
1	F_1	1 x 1 x 0.05	UDL	F/F	Iso	28.1	220	30	90	98	1.08	0.33	2.89	Steel Yielding
2	F_2	1 x 1 x 0.05	UDL	F/F	Iso	28.1	220	40	100	98	0.98	0.4	2.8	Steel Yielding

Notations

F/F = Fixed End

Iso = Isotropic Reinforcement

F_y = Tensile Stress of Reinforcement

f_{ck} = Compressive Strength of Concrete

W_u = Failure at First Crack

W_{exp}= Experimental Ultimate Load

W_{the}= Experimental Ultimate Load

11 CONCLUSIONS

1. Geopolymer concrete can be used for concreting works in a way to OPC concrete with slight change in mixing procedure i.e preparation of alkaline solution needs preparation 24hrs prior to mixing. Also little care is required while handling the solution as it is acidic.
2. Based on this experimental investigation and with reference to literature studies on physical and mechanical properties, the geopolymer concrete also used as a substitute in place of conventional reinforced cement concrete.
3. The ratio between theoretical and experimental ultimate load 1.08
4. The ratio between first cracking load (first yielding of steel) to the ultimate load was 0.36
5. GPC slabs satisfy the structural and theoretical behaviour on par with the conventional RCC slabs.
6. The formulations and concepts of ordinary reinforced cement concrete as per IS456-2000 can also be used forgeopolymer concrete with slight modifications.

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