THEORETICAL AND EXPERIMENTAL INVESTIGATION OF ONE WAY SLAB USING CONVENTIONAL CONCRETE AND GEOPOLYMER CONCRETE

[1]T.S.Kalaivani, [2]C. Rubesh Babu
[1]PG Research Scholar- Structural Engineering, [2]Assistant Professor,
[1,2]DepartmentofCivilEngineering, Bharathidasan Engineering College,
Natrampalli,TamilNadu.Email ID:kalailive1516@gmail.com[1], rihan.rubesh@gmail.com[2]

1. INTRODUCTION

Concrete is an essential and widely used building material in the construction of vital infrastructure applications such as road, bridges, dam, and highway, our entire society is very dependent on concrete as a basic building product, with the rise of developing countries such as china and India future demand for concrete is predicted to dramatically in to the foreseeable future. The most common ingredient used as the binder in the concrete is ordinary Portland cement and this will continue to be the primary binder used in the future. However the production of ordinary Portland cement consumes large amount of co2 in to the atmosphere the cement industry is one of the largest carbon emitting industries. So, to overcome the disadvantages in cement regarding an environmental effect, the geopolymer has introduced as a binder in the concrete.

1.1 GEOPOLYMER CONCRETE

The name geopolymer was formed by a French professor Davidovids in 1978. The geopolymer depend on thermally activated natural‟s materials like Meta kaolinite or industrial by products like fly ash or slag to provide a source of silicon (si) and aluminum (Al). These silicon and aluminum is dissolved in an alkaline activating solution and subsequently polymerizes into molecular chain and become the binder. Professor B. vijayaRangan (2008), curtin University, Australia, stated that the polymerization process involves a substantially fast chemical reaction under alkaline conditions on silicon – aluminum minerals that result in a material with three dimensional polymeric ring and chain structure.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 and ring structure consisting of Si-O-Al-O bonds. Water is not involved in the chemical reaction of geopolymer concrete and instead water is expelled during curing and subsequent drying. This is in contrast to the hydration reactions that occur when Portland cement is mixed with water, which produce the primary hydration products calcium silicate and hydrate and calcium hydroxide.

1.2.1 Constituents of Geopolymer Concrete

The following are the constituents of geopolymer concrete

☐ Fly Ash- rich in silica and aluminum
☐ Sodium hydroxide and potassium hydroxide
☐ Sodium silicate or potassium silicate

1.2.2 Properties of Geopolymer Concrete

The superior properties of geopolymer concrete based on prof. B. Vijaya Rangan and Hardijit are

☐ Set as room temperature
☐ Nontoxic bleed free
☐ Long working life before stiffening
☐ Impermeable
☐ Higher resistant to heat and resist all inorganic solvents
☐ Higher compressive strength

1.2.3 Limitations

☐ alkaline solution Bringing the base materials fly ash to the required location
☐ High cost for the

☐ Safety risk associated with the high alkalinity of the activating solution

☐ Practical difficulties in applying steam curing/high temperature curing process considerable researchis ongoing to develop geopolymer systems that address these technical hurdles

2. Objectives

• To design the mix proportion for geopolymer concrete and ordinary concrete

• To determine the properties of geopolymer concrete.

• To determine the properties of GFRP and steel reinforcement.

• Flexure behavior of cement concrete one way slabs reinforced with steel reinforcement.

• Flexure behavior of cement concrete one way slabs reinforced with GFRP reinforcement.

• Flexure behavior of geopolymer concrete one way slab reinforced with steel reinforcement.

• Flexure behavior of geopolymer concrete one way slab reinforced with GFRP reinforcement.

• Theoretical analysis of the above 4 types of slabs.

• Comparison of theoretical and experimental results for the validation.

3. MOMENT-CURVATURE RELATIONSHIP

The analytical moment-curvature relationship for a reinforced concrete section can be easily determined under the following assumption.

1. Perfect bond between concrete and reinforcement.

2. A plane section remains plane under the loading.

3. Simplification of the stress- strain relationship for the constituent materials.

3.1MOMENT-CRACKWIDTH RELATIONSHIP

The theoretical Moment-Crack width relationship for a reinforced concrete section can be determined by the following procedure. The theoretical procedure developed for the design of concrete structure reinforced with steel bar is not necessarily applicable to structures reinforced with GFRP. The ductility, modulus of elasticity, bond characteristics of FRP bars are likely to be different from those of steel bars, the calculation of crack width of reinforced concrete one way slab is

$$W_{cr} = \frac{3\, a_{cr}\varepsilon_m}{1+\frac{2(a_{cr}-C_{min})}{D-K_d}}$$

4. MIX DESIGN RATIO

The concrete grade used for the specimens are M 20. The conventional concrete design has been designed as per Indian standard mix design procedure and Geopolymer concrete mix design has been designed as per available literatures. The design mix ratio for conventional concrete and geopolymer concrete are shown in tables 1 and 2. For the proposed mix design slump is measured as 60 mm and as shown in fig.1

Fig.1. Typical Slump

Table 1 Mix Ratio for Conventional Concrete

S.no	Grade of concrete	W/c	Cement	Fine aggregate	Coarse aggregate
1	M 20	0.5	1	1.81	2.989

Table 2 Mix Ratio for Geopolymer Concrete

S.no	Grade of concrete	Flyash	Fine aggregate	coarse aggregate	Sodium silicate	Sodium hydroxide
1	M 20	1	1.55	3.62	0.357	0.142

5. TEST SPECIMENS

Conventional slabs were designed after that to provided same reinforcing detail for all slabs to comparison purpose, it is provided 4 numbers of 12 mm diameter bar at 187mm c/c spacing and 8numbers 8 mm diameter bar at 393mm c/c spacing here the slabs were designed by under reinforcement failure mode fig 2 and 3 shows the reinforcement details of the specimens both for steel and GFRP.

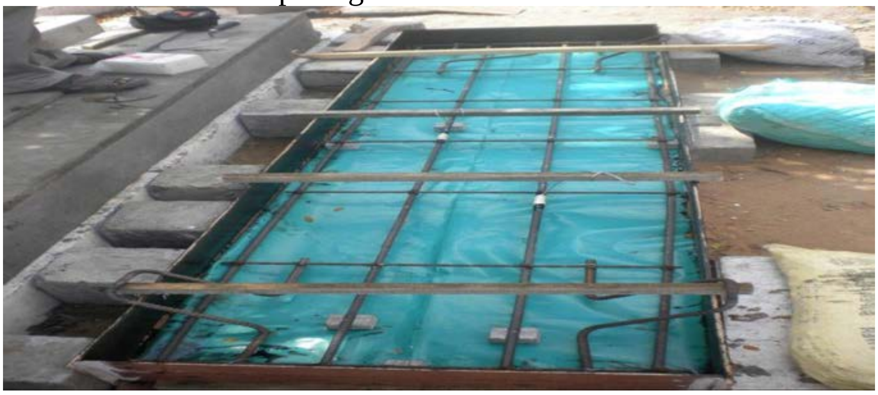

Fig 2 Slab Reinforced with Steel

Fig 3 Slab Reinforced with GFRP Reinforcement

Fig 4 Crack Pattern for Conventional Concrete with GFRP

Fig 5 Crack Pattern for Geopolymer Concrete Slab with Steel Reinforcement

6. ANALYSIS OF TEST RESULTS

Slabs are subjected to two point loading system and properly loaded at equal intervals up to failure. The corresponding deflections are measured at mid-point for all slabs. From the load-deflection and moment-curvature relationship, flexural behaviors of the slabs are compared. The experimental moment-curvature is arrived from the measured deflection and the theoretical moment-curvature is calculated from the stress distribution up to failure in the designed section. The theoretical values of load and deflection are obtained from the theoretical values of moment and curvature.

6.1 EXPERIMENTAL TEST RESULTS

The readings observed during the experimentation for all the slabs are noted down and are presented in the tables 5. Then the test results are presented in the form of graphs as shown in figures 5.

Table 3 Experimental Moment Curvature for Geopolymer Concrete Slab with GFRP Reinforcement

SL.NO	LOAD	DEFLECTION			MECHANICAL GAUGE READING
		LEFT	CENTRE	RIGHT	
	Newton	in mm	in mm	in mm	
1	0	0	0	0	0
2	2500	0.3	0.5	0.29	0.3
3	5000	0.48	0.59	0.46	0.9
4	7500	0.61	0.8	0.63	1.2
5	10000	0.84	1.1	0.84	3
6	12500	1.6	1.9	1.54	5.2
7	15000	2.3	3.08	2.31	5.9
8	17500	3.24	5.09	3.25	6.4
9	20000	4.18	7	4.21	8.2
10	22500	6.01	8.99	6.05	9.2
11	25000	7.89	10.09	7.87	10
12	27500	10.08	13.08	10.07	14

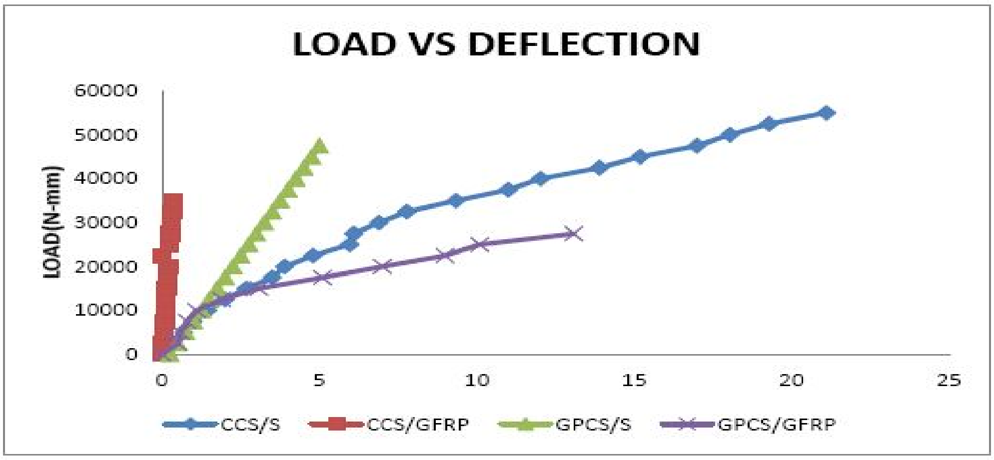

Fig 6Experimental Load-Deflection for Slabs

Table 4 Experimental Moment Crack Width for Geopolymer Concrete Slab with GFRP Reinforcement

SL.NO	MOMENT (N-mm)	CRACK WIDTH (mm)
1	3665000	0.02
2	4581250	0.06
3	5497500	0.09
4	6413750	0.2
5	7330000	0.9
6	8246250	1.6
7	9162500	5.6

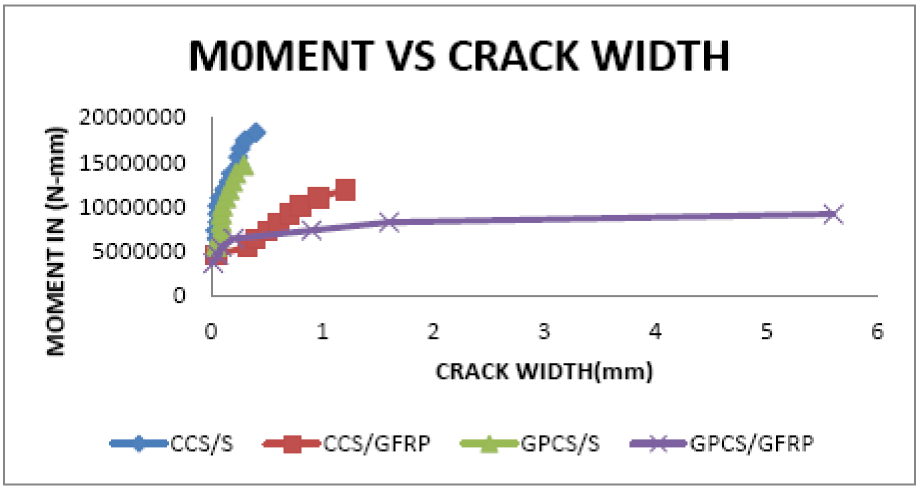

Fig 7 Experimental Moment Crack Width for Slabs

6.2 Discussion on Results

The theoretical and experimental variation in moment and curvature for each slab is represented in the fig 5. The theoretical and experimental variation in load and deflection for each slab is shown in fig 6. The theoretical and experimental variation in moment and crack width for each slab is represented in the fig 7. From the results

1) The load/moment carrying capacity of the conventional concrete with steel reinforcements shows better performance than the other slabs specimens.

2) The load/moment carrying capacity is lesser than CCS/S by 2 to 50 % for all other slabs.

3) The maximum deflection of CCS/S is lesser than CCS/GFRP by 50 %.

4) The maximum deflection of CCS/S is almost equal to GPCS/S.

5) It is observed very less deflection for GPC/GFRP slab.

6) When compare to GPC the conventionally reinforced specimens shows symmetrical behaviour than the GFRP reinforced specimen.

7) When compare the experimental results with theoretical results the moment- curvature relationship closely agreed with CCS/S tan the other slabs.

8) When compare the experimental results with theoretical results the load – deflection behaviour hold good agreement expect GPC/GFRP

9) When compare the experimental results with theoretical results the moment- Crack width relationship closely agreed with CCS/S than the other slabs.

Table 5 Maximum Values of Loads and Deflections

SLAB SPECIMENS	MAXIMUM LOAD (N)	MAXIMUM DEFLECTION AT MIDDLE (mm)	MAXIMUM DEFLECTION AT LOADING POINT (mm)	CRACK WIDTH AT ULTIMATE STAGE (mm)
CCS/S	55000	21.1	13.1	0.4
CCS/GFRP	35000	43.7	33.1	1.2
GPCS/S	50000	21.9	18.5	0.43
GPCS/GFRP	27500	13.8	10.8	5.6

7. CONCLUSIONS

In the investigation, the effect of GFRP and steel in the cement concrete and the effect of GFRP and steel in the geopolymer concrete have been studied. Three one-way reinforced concrete slabs, were tested under static monotonic loading conditions. Behaviour of the specimens prior to and after cracking was monitored, including mid span deflections and crack width. Based on these experimental results the following conclusions may be made.

1. Behaviour of the GFRP reinforced with both cement concrete and geopolymer concrete slabs throughout the testing was bilinear elastic until failure. Stiffness of the slabs reinforced by GFRP reinforcement is significantly reduced after initiation of cracks in comparison to slabs reinforced by steel.
2. The slab behaviour exhibited adequate warning prior to failure through large and deep cracks, accompanied by large deformations for slabs reinforced by GFRP slabs. Crack widths and deflections of slabs reinforced by GFRP reinforcements are significantly larger than slab reinforced with conventional steel with the same percentage of reinforcement. This is due to the low elastic modulus of GFRP bars in comparison of steel rebar.
3. The ultimate load carrying capacity of geopolymer with GFRP reinforcement slab is very low due to poor bond between the GFRP and geopolymer concrete.
4. The combination of geopolymer concrete with steel reinforcement flexure behavior is almost same as the conventional slab with steel reinforcement.
5. It is observed from the experiment the crack width is lesser for GPC specimens than the CCS/S

8. RECOMMENDATIONS FOR FUTURE RESEARCH

1. Slab size can be changed and tried for the flexural response.
2. Reinforcement ratio of GFRP can be increased and tried for the load carrying capacity.
3. Point load or uniformly distributed load or repeated load can be applied.
4. End conditions can be changed and tried for the flexural response.
5. Texture of GFRP can be changed such as deformed and threaded texture were studied for improvement in flexural response. That means to improve the bond strength between the concrete and GFRP
6. By varying different concrete mix, the variation in response can be studied.

REFERENCES

1. Hardjito,D. and Rangan, B.V., “Developments And Properties Of Low Calcium Fly Ash Based Geo Polymer Concrete”, Research Report GCI, Faculty Of Engineering , Curtin University Of Technoledge, 2005.
2. Lioyd,N. and Rangan,V., “Geo Polymer Concrete Sustainable Cement Less Concrete” Proceeding Of The 10th ACI International Conference On Recent Advances In Concrete Technology And Sustainability Issues, Sevile, ACI SP-261,2009,33-54.
3.Rangan, B.V., “Mix Design And Production Of Fly Ash Based Geopolymer Concrete”, Indian Concrete Journal, V . 82 (5), 2008 , pp. 7- 15.
4. Nawy , E.G. &Neuwerth, G. E., Fiberglass Reinforced Concrete Slabs And Beams. Journal of the Structural Engineering Divition. ASCE, 104 ST2 (1977) 421 – 440.
5. Nann, A. (1993). “Flexure Behavior And Design Of RC Members Using FRP

Reinforcement". J structEngg., ASCE, 119 (11). 3344 – 3350.
6. Recent Research Geopolymer Concrete – Nguyen Van Chanh Bui Dang Tuan, Dang Van Tuan during the 3rd ACF international conference – ACF/VCA 2008.
7. Mehta. P .K. 20021 " reducing the environmental impact of concrete ", ACI concrete international 23(10): pp. 61 -66
8. K. Vijai, R. Kumutha and B. G Vishnuram" effect of types of curing on strength of geopolymer concrete." department of civil engineering, sethu institute of technology, India 2010.
9. M. Pecce, G. Manfredi, R. REalfonzo, E. Cosenza" experimental and analytical evaluation of bond properties of GFRP bars", journal of materials in civil engineering 2001.