AN EXPERIMENTAL INVESTIGATION ON BEHAVIOUR OF GEO-POLYMER CONCRETE SLAB WITH FLY-ASH & GGBS UNDER AMBIENT CURING

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Abstract

GeoPolymer Concrete (GPC) is an eco-friendly binding alternative material for an Ordinary Portland Concrete (OPC). Geo-polymer concrete is produced by mixing the GGBS, flyash, alkaline activator solution, fine aggregate, coarse aggregate. Alkaline solution is composed of Sodium Silicate (Na_2Sio_3) and Sodium hydroxide (NaOH). This research work deals with an experimental investigation on behavior of geopolymer concrete slab with flyash & GGBS under ambient curing. In this project work the behavior of the slab with normal conventional concrete and geopolymer concrete slabs has been studied in detail. The overall dimensions of the slabs are 1000mm X 1000mm X 60mm and reinforced with the 8mm HYSD bars at 230mm c/c are casted. For the geopolymer concrete slabs of 25% of GGBS 75% of flyash is used as a binding material for OPC. The 16M molarity of the NaOH solution used. The following tests conducted on GPC & M-20 concrete Compressive Strength, Split Tensile Strength, Flexural Strength. and The following analysis is conducted on the slab Cracks developed due to loading, Shear failure, Failure due to ultimate load, Cracks pattern due to ultimate load, Deflection due to loading, Load v/s deflection graph.

Keywords: *GeoPolymer, Molarity, Sodium hydroxide, Sodium Silicate, Flyash, GGBS.*

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1. INTRODUCTION

Concrete is a synonymous material with the longevity and strength. It has emerged as a one of the dominant construction material for the infrastructure development of the twenty – first century. Along with this, durable concrete can be easily manufactured and can be fabricated from readily available constituents. Hence it can be used for all types of structural systems. The challenge for the civil engineering community in the future is to analyze the project in the harmony with the concept of sustainable development of the community. This involves the use of the high performance materials and the materials can be manufactured at the low cost and lowest possible environmental impact.

In 1978 **"Davidovits"** of France first introduced the term "geo polymer" to the world; this became new field of research and developing technology. The use of the fly ash and the GGBS in the normal concrete has revolutionized the construction industry, by economizing the construction cost and decreasing the ash content. In this paper an experimental investigation conducted on behavior of geo polymer concrete slab with fly-ash & GGBS under ambient curing. In case of the geo polymer concrete cement is fully replaced by the fly-ash and GGBS in the proportion of 75% and 25% respectively as these both are actually containing silica – alumina containing materials. Hence these can be used as source materials for the generation of the geo polymer concrete. This will solves two problems simultaneously viz. saving the costly cement and the bulk utilization of the industrial waste fly-ash and GGBS. A Geo polymer concrete is an inorganic polymer composite, with ability to produce environmentally sustainable construction by supplementing or replacing the conventional ordinary portland cement concretes.

2. LITERATURE REVIEW

1. T Kiran et al. (2015) [1] studied **"Impact test on geo polymer concrete slabs"** This paper deals with the study of impact resistance capacity of geopolymer concrete slabs subjected to impact loading. For this study, ten specimens of size 0.6mX0.6mX0.06m were casted with 9 different combination of geopolymer concrete mix using different molar NaOH solutions and different percentages of mineral admixtures and normal concrete slab as control slab. The molarity of NaOH solution used was 8M, 12M and 16M. Fly ash and GGBS admixtures were used in three different ratios of 100:0, 75:25 and 50:50. These slabs were oven dried at 60˚C for about 24 hours. All these slabs were subjected to impact loading by the drop weight test method having a drop weight of 75.50 N from a height of 700mm. From this study they have concluded that with the increase in the concentrations of the molarity of the sodium hydroxide the strength characteristics and impact resistance capacity of the geo polymer concrete specimen increases.

2. Dr.Manjunatha N Hegde et al. (2014) [2] In this paper author studied the effects of flexural strength in between the uncarbonated and carbonated slabs of different durations and to determine the depth of carbonation among carbonated slabs. This experiment consisted of 16 slabs which included

4 series (each series having 2 specimens with 10 and 20mm cover to reinforcement). Each slab is of size 1000×500×75mm and reinforced with 6mm MS bars at 230mm c/c at bottom in Both directions First series consisted of control specimens and the other 3 series consisted of slabs subjected to 48, 96 and 144 hours of duration of carbonation. For casting of slabs M40 mix proportions of geo polymer concrete consisting of GGBS, flyash, alkaline solution i.e. sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3), manufactured sand, coarse aggregate, water and superplasticizer. Series of slabs were kept in the carbonation chamber for the specified time periods and tested for flexure over span/4 from supports with two sides are simply supported and the line loads is applied on it.

3. Madheswaran C K et al. (2014) [3] In this paper author studied **"Investigation on behaviour of reinforced geopolymer concrete slab under repeated low velocity impact loading",** the reinforced GPC slabs with and without steel fibers and compare with that of OPCC slabs. The overall dimensions of the GPC slab are 1mX1mX60mm Finite element modeling of slab was also carried out using ANSYS software. The Solid 65 element and link 8 elements were used to model the concrete slab and Reinforcement respectively. Displacement boundary conditions are applied at the supports. The measured impact load time history is used to excite the structure. Transient dynamic analysis was carried out. Results obtained in the form of the deflection time histories, the failure crack patterns for the fibre reinforced slabs and for the plain reinforced slabs predicted by the finite element analysis are compared with the results obtained from the experimental study.

4. Dr. Amarnath K. et al. (2015) [4] Study on **"Flexural Behavior of Fly Ash based Reinforced Rectangular Geopolymer Concrete Slabs",** In this experimental work the flexural behavior of the rectangular geo polymer concrete slabs is studied by using flyash and GGBS as a binder material. The proportion flyash and GGBS used is 70% and 30% respectively. And the molarity of the Sodium hydroxide solution used is of 8M. The ratio of the Sodium silicate to the sodium hydroxide solution is 2.5. Seven rectangular slabs were casted with the overall dimension of the slab as 1300mm X 650mm with the 75mm overall thickness with aspect ratio of 2.0. The reinforcement used for these slabs of Fe 500 High Yield Strength Deformed (HYSD) bars of 8mm diameter were placed parallel to 1300mm side and 8mm dia. bars were placed parallel to the shorter sides are placed. All these slabs were tested under the 50T loading frame. For testing of the slabs support condition provided on all the sides is simply supported and the uniformly distributed load (UDL) is applied on the slab panels. The study of the load v/s deflection is noted.

3. MATERIALS AND METHODOLOGY

3.1 Ingredients of geo polymer concrete

3.1.1 Fly-ash

Flyash is used a mineral admixture, The specific gravity of fly-ash is to be 2.25 and Fineness of the fly-ash which is determined from the Blaine's air permeability test is to be 325 m^2/kg. For this research work the "Class F" fly ash is used. This has been procured from the Ready Mix Concrete (RMC) - HIGH TECH plant Bangalore.

3.1.2. Ground Granulated Blast Furnace Slag (GGBS)

The specific gravity of is to be GGBS 2.85 and Fineness of the GGBS which is determined from the Blaine's air permeability test is to be 325 m^2/kg. For this research work the GGBS is also used as a source material. This has been procured from the Ready Mix Concrete (RMC) - INDIA plant Bangalore.

3.1.3 Preparation of alkaline activator solution

3.1.3.1. Sodium Hydroxide Solution (SHS)

Solid particles or pellets or granules of the sodium hydroxide flux will be mixed very slowly with water in several stages under fully ventilated conditions. Artificial cooling can be done by pre cooled water or by using fans.

3.1.3.2.Sodium Silicate Solution (SSS)

Sodium silicate solution (SSS) is measured by weight, because it is quite difficult to measure by volume. And this solution is highly viscous and specific gravity of the sodium silicate is of 1.6. This alkaline activator solution is a mixture of the sodium silicate solution and sodium hydroxide solution.

3.1.4 Cement

Type of cement used for this research work is OPC 43 Grade conforming to IS-8112, brand of cement is Zuari cement, specific gravity of the cement is 3.15, initial setting time of the cement is 30 min, and final setting time of the cement is 460 min.

3.1.5 Fine aggregate

Good quality of river sand is used as a fine aggregate for this research work. Specific gravity of the fine aggregate is 2.50. Water absorption of fine aggregate is 1.2 %. Sieve analysis of fine aggregate carried out as per IS-383:1970. & the fineness modulus of the fine aggregate is 2.81.

3.1.6 Coarse aggregate

Good quality of crushed angular coarse aggregates is used for this research work. Specific gravity of the coarse aggregate is 2.70. And water absorption of coarse aggregate is 0.6 %. Sieve analysis of the coarse aggregate as per IS – 383:1970. & the fineness modulus of the coarse aggregate is 3.90.

3.2 Design of geo polymer concrete mixes

The conventional mix design procedure such as water cement ratio and water binder ratio cannot be used directly. Proportioning of the basic ingredients of geo polymer concretes needs systematic detailed experimental investigations; The wet density of geo polymer concrete is approximately 2400 Kg/m^3. The ratio of Sodium Silicate (Na_2SiO_3) to Sodium Hydroxide (NaOH) is 2.5. Total water

Content 160 litre/m^3 (assumed) and aggregate content as 75% of total mix. Then assuming 62 % of Coarse aggregates and Fine aggregates of 38%. The water content in Sodium Silicate is 50 % it is obtained from the chemical manufacturer. From the earlier research study it is found that 1000gm of NaOH solution contains 443gm of NaOH Pallets & 557gms of water. Then 16 M of sodium hydroxide solution can be obtained. Conventional M-20 concrete designed as per IS:10262-2009.

3.3 Mixing

When fresh geo polymer concrete is mixed it was cohesive and grey in color. The amount of water added to the geo polymer concrete mix plays a very important role. All ingredients of the geo polymer concrete calculated as per the mix design are weighed and mixing is done by using tilting drum mixer. Initially all these ingredients were mixed for three minutes (Dry mixing), after few minutes alkaline activator solutions is added slowly, these solutions were prepared 24hours prior to mixing. Slump value for M-20 concrete is 90mm and that for the geo polymer concrete slump value is of 110mm.

3.4 EXPERIMENTAL PROGRAM

Table -1: Experimental program

Specimen	Dimension in mts	M-20 Concrete	GPC	Total
Slab	1X1X0.06	3	3	6
Cubes	0.15X0.15X0.15	9	9	18
Cylinders	0.15Dia.X0.3	6	6	12
Beam (Prism)	0.5 X 0.1 X 0.1	3	3	6

3.5 CASTING OF CONCRETE SPECIMENS

Cement, fine aggregate and coarse aggregate were taken in mix proportion 1: 2.25: 3.96 which correspond to M20 grade of concrete. In all the ingredients were dry mixed in a pan tilting drum mixer homogeneously. To this dry mix, required quantity of water is added of (W/C = 0.5) & the entire mix was again homogenously mixed. And filled in the moulds, then the specimens were given smooth surface and taken out of the vibrating table. After the compaction, the specimens were given smooth finish surface. After 24 hours the specimen were demoulded and transferred to curing tank were in they were allowed to cure for 7 and 28 days, then they were tested for respective strengths i.e. compressive strength, tensile strength, flexural strength.

3.5.1 Casting of Slabs

The wooden moulds of size 1mX1mX0.06m with these clear spacing's were prepared by using plywood boards. A non absorbent thin layer of polythene sheets is laid over the moulds. In order to provide the cover to the slabs cover blocks were used, these are provided at a spacing of 0.3m. These cover blocks laid in the bottom edges of the reinforcement is placed in required manner. Concrete is laid into the slab mould in 3 layers. Each layer is compacted by giving a manual stroke using rammer of weight 5 kg and it is compacted from a height of 0.5m with 25 blows on each layer of the slab. Fig. shows casting of slabs.

3.5.2 Curing

In this research work GPC mix specimens are subjected to the self curing i.e. the curing is done in ambient temperature or room temperature

Fig -1: Casting of GPC & M-20 concrete OPC Slabs

3.6 TESTING OF CONCRETE SPECIMENS

3.6.1 Compressive strength test

After 7, 28 and 56 days curing, the concrete cubes were tested on compression testing machine (CTM) as per I.S. 516-1959. The failure load was noted.

Table-2 Compressive strength results for 7, 28 & 56 days

Specimen	For 7 days MPa	For 28 days MPa	For 56 days MPa
M-20 concrete	**18.22**	**36.44**	**40.3**
GPC	**44.15**	**63.71**	**70.22**

Fig -2: Compressive strength test

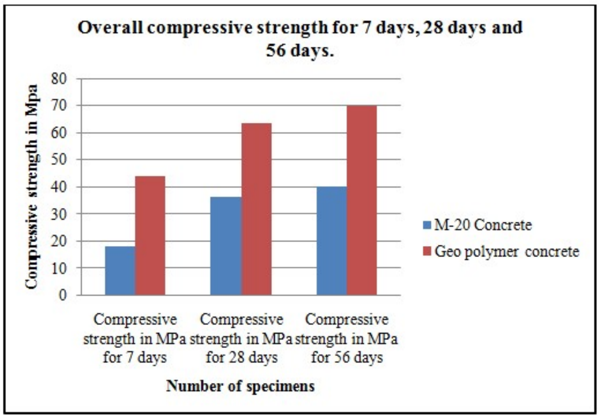

Chart -1: Overall compressive strength for 7 days, 28 days & 56 days.

3.6.2 Split tensile strength test

After 7 and 28 days of curing the concrete cylinder specimens were tested under compression testing machine. The failure load was noted.

Table-3 Split tensile strength results for 7, 28 days

Specimen	For 7 days MPa	For 28 days MPa
M-20 concrete	**1.24**	**2.36**
GPC	**1.97**	**3.41**

Fig -3: Split tensile strength test

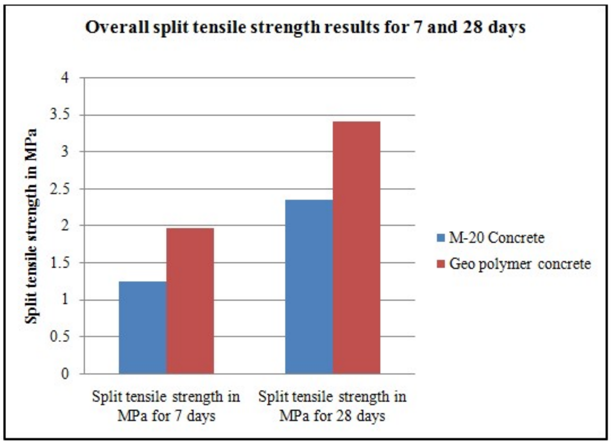

Chart -2: Split tensile strength results for 7 days, 28 days.

3.6.3 Flexural Strength test

After curing, the concrete prism specimens were tested according to IS: 516-1959. Modulus of rupture is measure of flexural strength and it can be calculated to the nearby 0.05 MPa. Flexural strength of M-20 concrete & GPC for 28 days in MPa.

Table-4 Flexural strength results for 28 days

Specimen	M-20 Conc. Strength in MPa	GPC Strength in MPa
1	**4.13**	**4.22**
2	**4.104**	**4.24**
3	**4.072**	**4.208**

Fig -4: Flexural strength test

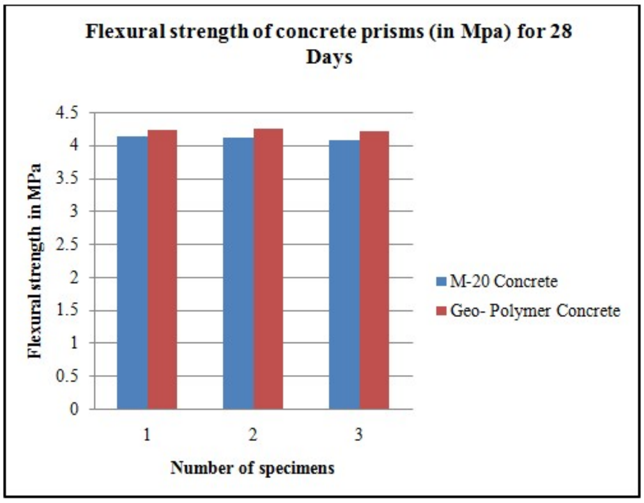

Chart -3: Flexural strength results for 7 days, 28 days.

3.6.4 Testing of slabs

Testing of M-20 slab and GPC slab is conducted on loading frame of 25T capacity. Slab is placed on the steel frame having dimensions of 900mmX900mm, so clear cover provided to the slab is 50mm on both sides. Then slab is placed on the steel frame and on this slab small I- Sections were kept, the arrangement is made as shown in the fig.

Then loading jack is placed on it and proving ring of 25 tonnes capacity is placed and set to zero. At the bottom surface of the slab dial gauges are placed at 5 points to know the deflection of the slab.

Fig -5: Testing of slabs for deflection and ultimate load

3.6.5 Crack pattern

Loading arrangements are as shown in the fig. then load is applied to the loading jack, deflection is measured at every 2KN interval. Then as the load is applied continuously the slab will goes on deflecting. At a certain load it will show crack on it that is referred as a "first crack load (P_{cr})". Then loading continued diagonal cracks will appear at the centre of the slab that load is referred as a "diagonal crack load (P_{dcr})". Further as loading increased the cracks get widened and the "ultimate load (P_u)" taken by the slab is noted down.

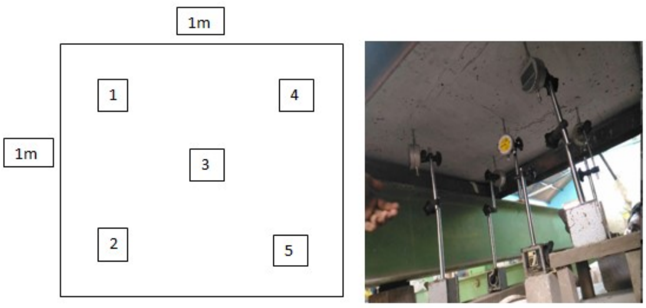

Fig -6: Deflection is measured at these 5 points and dial gauges.

3.6.6 Test results of slab

Table-5 Ex. of Load v/s/ deflection for OPC slab for 28 days

Sl. No.	Load (KN)	Deflection (mm)				
		1	2	3	4	5
1	0	0.04	0.05	0.02	0.06	0.05
2	2	0.10	0.10	0.09	0.09	0.09
3	4	0.15	0.21	0.12	0.16	0.12
4	6	0.33	0.36	0.36	0.21	0.19
5	8	0.68	0.42	0.47	0.30	0.21
6	10	0.92	0.50	0.51	0.37	0.25
7	12	1.03	0.70	0.66	0.55	0.65
8	14	1.24	0.88	0.85	0.69	0.81
9	16	1.32	0.98	1.04	0.78	0.94
10	18	1.53	1.12	1.18	0.91	1.11
11	20	1.76	1.27	1.39	1.05	1.31
12	22	2.01	1.42	1.54	1.20	1.52
13	24	2.29	1.59	1.65	1.37	1.75
14	26	2.47	1.70	1.85	1.49	1.92
15	28	2.74	1.88	2.02	1.66	2.16
16	30	2.93	2.02	2.37	1.80	2.34
17	32	3.09	2.35	2.68	1.88	2.48
18	34	3.42	2.51	2.85	2.16	2.74
19	36	3.73	2.96	3.24	2.39	3.10
20	38	4.29	3.48	3.46	2.78	3.21
21	40	4.94	3.70	3.64	3.27	3.61
22	42	5.30	4.00	4.10	3.57	4.29
23	44	5.63	4.20	4.90	3.94	4.55
24	46	6.03	4.40	5.40	4.00	5.02
25	48	6.37	4.55	5.61	4.70	5.29
26	50	6.54	4.60	6.11	4.73	5.43

Table-6 Ex. of Failure loads for slab OPC for 28 days

Type of load	Slab 1
First crack load (Pcr) in KN	44
Diagonal crack (Pdcr) in KN	70
Ultimate failure load (Pu) in KN	150

Similarly the load and deflection, first crack load, diagonal crack load & Ultimate loads are noted for 3-OPC & 3-GPC slabs are noted down.

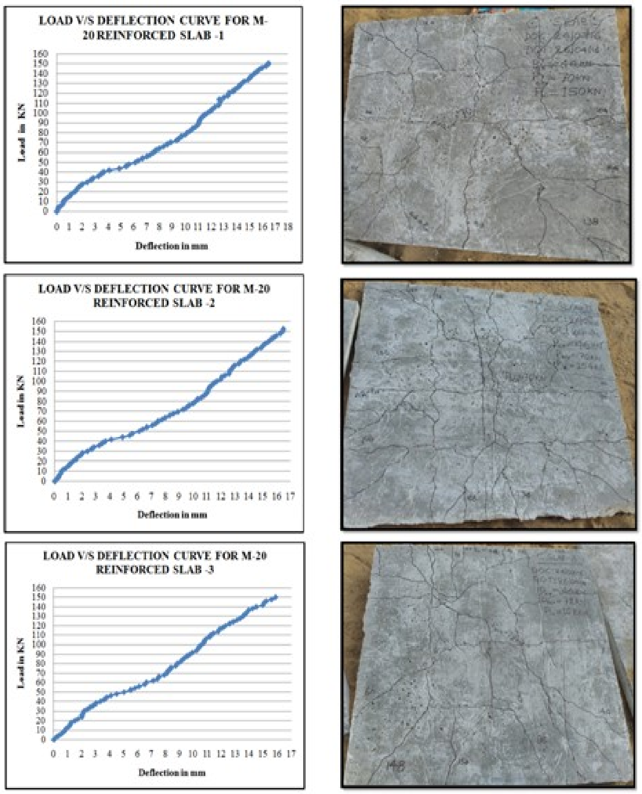

Fig -7: Load v/s deflection curve & Crack pattern for OPC Slabs is as shown in the above fig.

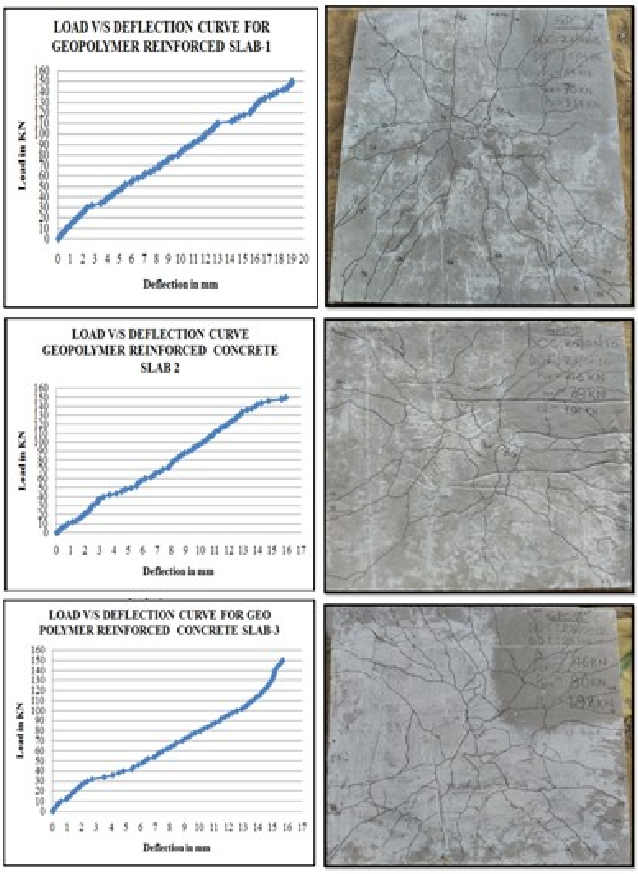

Fig -8: Load v/s deflection curve & Crack pattern for GPC Slabs is as shown in the above fig.

3.6.7 Overall slab test results

Table-7 Slab test results

Type of load	M-20 reinforced concrete slab			Geo polymer concrete slab		
	1	2	3	1	2	3
(P_{cr}) in KN	**44**	**46**	**44**	**46**	**46**	**46**
(P_{dcr}) in KN	**70**	**70**	**72**	**76**	**78**	**80**
(P_u) in KN	**150**	**154**	**152**	**214**	**190**	**192**

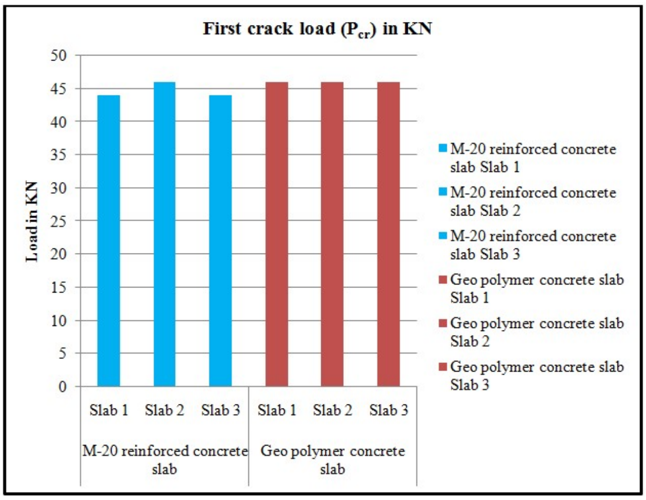

Chart -4: First crack load (Pcr) in KN

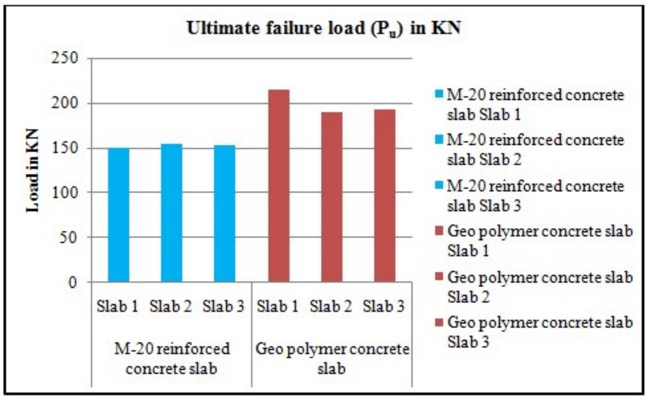

Chart -5: Ultimate failure load (Pu) in KN

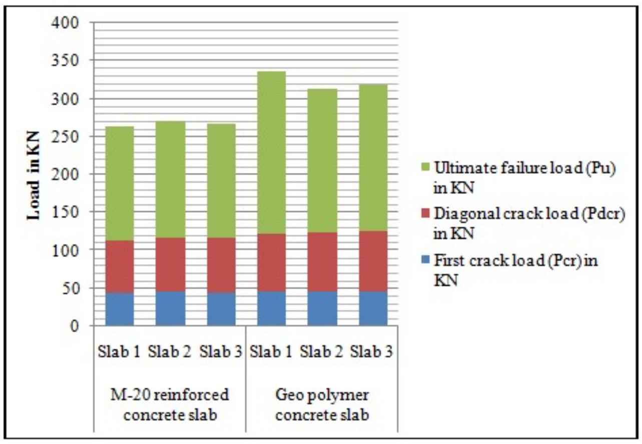

Chart -6: Graphical representation of the first crack, diagonal and ultimate failure loads for slabs.

4.0 CONCLUSIONS

1. Compressive strength of the geo polymer concrete (GPC) for 7 days is increased by 58.73% when compared with the M-20 concrete. And 7 day compressive strength of geo polymer concrete is of 44.15 N/mm^2. For 28 days the compressive strength of GPC obtained is of 63.71 N/mm^2 and the percentage increase in strength observed is 42.80%. Compressive strength of GPC for 56 days is found to 70.22 N/mm^2 and percentage increase in the strength is 42.80% when compared to M-20 concrete.
2. The split tensile strength of GPC for 7 days is 37.05% more than that of the M-20 concrete. And for 28 days it is 30.80% more than that of M-20 concrete.
3. Flexural strength of GPC for 28 days is 2.80% more than that of M-20 concrete.
4. The first crack load for the GPC is quite more than the M-20 reinforced ordinary portland cement slab. First crack load observed for GPC at 46KN
5. The diagonal cracks developed load in case of the GPC is higher than M-20 concrete i.e. for GPC it was 78KN and for concrete it was 70KN
6. The ultimate load carrying capacity for GPC slab is more than the M-20 OPC slabs. GPC slabs will resist higher loads up to 196KN and for M-20 OPC slabs it is of 152KN.
7. Failure patterns for GPC slabs shows localized failure i.e. failure of the slab at the centre, similar failure patterns were observed for M-20 OPC slabs.
8. It can be concluded that geo polymer concrete slabs can be used as a structural members.
9. From the above statements it can be concluded that the geo polymer concrete is more suitable for early strength gain development works. Ex: this is more suitable for road repair works or any other type of patch works.

SCOPE FOR FURTHER WORK

1. This research work can be extended for the varying thickness of the slab.
2. The experiment can be carried for varying percentage of the flyash and GGBS.
3. Shrinkage characteristics of the geo polymer concrete can be studied.
4. The study can be made for the different curing periods at various temperatures.
5. The behavior of geo polymer concrete at elevated temperature can be studied.

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BIOGRAPHIES

Ramesh Babu B.E., M.Tech, Assistant Professor, Bangalore Institute of Technology, has 29 years of experience in teaching & industry. His research areas include study on the properties of alkali activated flyash (geo polymer) concrete. He is actively involved in guiding M.Tech thesis & industry related consulties.

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