Study on Flexural Behavior of Fly Ash based Reinforced Rectangular Geopolymer Concrete Slabs

Mr. Laxminarayan R Naik[1], Prof. Mahantesh N B [2], Dr. Amarnath .K[3]
[1]P.G Student ,
The Oxford College of Engg,
[2]Associate Professor – Alliance University,
[3]Prof & HOD,The Oxford College of Engg Bangalore

***Abstract*— Investigations on fly ash based geopolymer reinforced concrete structural elements are still in infant stage. The present investigation is aimed at study on flexural behavior of reinforced rectangular geopolymer slabs. Seven reinforced geopolymer concrete slabs were casted using *hand mixing and cured at room temperature*. All slabs were tested in 50MTon loading frame and load v/s deflection is noted. Comparison of measured deflections are done with calculated deflections as per IS 456-2000. The comparison indicates close relation between flexural behavior of conventional reinforced cement concrete and reinforced geopolymer concrete.**

***Keywords— Flyash, GGBS, Geopolymer slabs, Alkaline liquid, M-sand, workability, flexural strength, load vs. deflections*.**

1.0 INTRODUCTION.

With the ever increasing demand of urbanization utilization of Portland cement concrete has become second to water. Production of one ton of cement gives out one ton of Co_2 resulting into 6% of global Co_2 emanations and by the year 2020 this is expected increase by 50%. Investigations around the world are being continuously done to find an alternate binder replacing cement. The fly ash based investigations to replace cement are gaining momentum and are the promise of concrete structural elements.

Geopolymer concrete is the concrete for future. It has appreciable and better engineering properties compared to conventional Portland cement concrete. At present this concrete is still in laboratory quality control stage and needs careful study and formulation of manufacturing concepts and procedures to replace existing concreting practices.

The concrete produced from waste materials like fly ash and GGBS which are rich in alumina and silica content can replace cement in concrete by 100% .The chemical process involved is polymerization and hence this concrete is named as Geopolymer Concrete. The investigations on studying the behavior and applicability of fly ash/ GGBS based concrete to reinforced structural elements are still in infant stage.

Alkaline liquid used to activate silica and aluminum present in source materials governs the properties of geopolymer concrete.The early strength of geopolymer concrete prepared based on mixture of flyash and GGBS is mainly contributed by GGBS and this provides the scope for ambient curing of geopolymer concrete to suit Indian environment and construction industry. The industrial waste like GGBS is available in less quantity compared to fly ash.

2.0 CONSTITUENTS OF GEOPOLYMER CONCRETE

2.1 Fly Ash **:**Fly ash utilized for this investigation is collected from Raichur thermal power station Karnataka. This fly ash collected from the plant is an industrial waste and is of low calcium grade i.e., F class. This fly ash has sp.gravity of 2.15

2.2GGBS:Ground granulated blast furnace slag is the byproduct from blast furnace used to make iron. The GGBS procured is from Jindal steel factory Bellary ,has Sp.Gr 2.84, Fineness 321.

2.3 Alkaline Liquid

Alkaline activation in fly ash and GGBS is done by using sodium hydroxide (NaoH 97% purity) and sodium silicate (Na_2Sio_3) solution at a ratio of **2.5**. Sodium hydroxide flakes (262gms) are dissolved in potable clean drinking water (738gms) and kept undisturbed for 24 hours to produce 8Molar NaoH Solution.. The next day NaoH solution is mixed with Na_2Sio_3 solution of A53grade with $Si0_2$-to-Na_20 ratio ***2*** by mass, i.e., $Si0_2$ = 29.4%, Na_zO = 14.7%& water = 55.9%.


2.4.Coarse Aggregates

The sizes of coarse aggregates used are 20mm, 12.5mm and 4.75mm sizes of granite origin available from the local source confirming to having specific gravity 2.67 and fineness modulus 7.572 .Test on surface saturated dry condition reveal water absorption by dry coarse aggregate is significantly less (0.5%.after 24 hours) as the aggregates were stored in room temperature.


2.5. Fine Aggregates

Fine aggregates used consist of Manufactured sand and river sand at 25% and & 75% are used. M-sand used is brought from RMC plant, Kanakapura, Bangalore. Locally available river sand is washed and dried for one day and used. Specific gravity of river sand is 2.68, Fineness Modulus of M-sand and River sand is 2.901 and 4.637 respectively and Sp.Gravity of M-sand and River sand is 2.7 and 2.68 respectively.


2.6.Water

Clean potable water/commercial brand biseleri water is used for drinking purpose is used for preparing NaoH solution and concrete mixing concrete purposes.

2.7.Super plasticizer

Locally available sulphonated naphthalene based super plasticizer i.e., ***CONPLAST - SP430*** distributed by FOSROC chemicals is used to increase the workability of fresh geopolymer concrete.


3.0 MIX DESIGN OF GEOPOLYMER CONCRETE

The geopolymer concrete density is assumed as 2400 Kg/m^3 and other ingredients of mix are worked by selecting total percentage of Fine and Coarse aggregates as 77%. Trial mix designs done assuming 65 to 80% indicate 75 to 80 % gives more compressive strength and becomes more workable. Fly ash for the mix design is selected at 70% of total source material requirement and remaining 30% is filled with GGBS.A combination of 25% river sand and 75% M-sand is used to enhance the production of more workable geopolymer concrete. The proportioning of different sizes of coarse aggregates are of 20 to 12.5mm 35%, 12.5 to 4.75mm 35% and 4.75down size aggregates at 30% are used. Super plasticizers and extra waters are added to increase the workability of concrete.

Table 1: Ingredients for 1 m^3 of concrete

Sl NO	Material	Kg/m^3	Specifications
01	Fly Ash	288.00	70% of total FlyAsh
02	GGBS	123.429	30% of total Fly Ash
03	River sand	135.411	25% of total FA
04	M-Sand	406.234	75% of total FA
05	20mm to 12.5mm	442.344	35% of total CA
06	12.5mm to 4.75mm	442.344	35% of total CA
07	4.75mm to down sizes	379.152	30% of total CA
08	(NaoH) 8M	47.020	97%purity (26.20%)
09	(Na_2Sio_3)	117.551	
10	Super plasticizer	10.286	SP430 DIS (2.5%)
11	Extra water	8.229	Biseleri water

Notations: F.A-Fine aggregates, C.A-Coarse aggregates

4.0 PREPARATION AND MIXING OF GEOPOLYMER CONCRETE

4.1. Preparation of Alkaline liquids.

Alkaline liquid is prepared 24hours prior to mixing of concrete. This solution consists of ***NaoH/Na₂sio₃ ratio 2.50 with 8Molar NaoH solution.***

4.2. Mixing Procedure: Hand mixing of ingredients on non absorbent floor is used for all slab concreting. First calculated quantity of coarse aggregates of three sizes are are spread over one another on concrete floor and 1% of water is added to achieve S.S.D condition of coarse aggregates. Then over this river sand is spread and the mix is thoroughly done by turning mixture up and down in a traditional hand mixing procedure using ordinary Indian spades with wooden handle. On this M-sand is spread and remixing is continued. For the last coarse of mix containing alkaline solution, once again base coarse mixture is spread over freshly and alkaline liquid is spread over uniformly and mixing is once again carried out manually till a homogeneous and workable mix is produced .To achieve good workability superplasticizer and extra water are added to suit the desired slump (100 to 150mm). The total water to geopolymer solids is kept below 0.30.It is observed that the desired workability of concrete is achieved after rigorous and continuous mixing by turning the concrete up and down for nearly 15 to 17 minutes after the addition of alkaline solution.

4.3Preparation of Reinforced GPC slabs

4.31. Slab size

The size of the slab specimen prepared is **1300mm x 650mm x 75mm overall thickness,** having aspect ratio **2.0**. Ply wood form work is prepared with clear inside dimensions of 1300mm x650mm x75mm.Cover blocks of 50mm x 50mm are prepared using ordinary cement concrete are placed at 0.3 meter spacing inside the form work before placing the reinforcement mesh.

4.32 Reinforcement for GPC slabs

Fe500 grade HYSD steel bars of 8mm diameter 7 number parallel to 1300 mm side and 8mm diameter bars of 8 bars parallel to shorter sides are placed and joints are tied using ordinary binding wires.

4.33 Concreting for slabs and finishing

The geopolymer concrete is prepared as discussed in article 4.2 .First non absorbent polythene is laid over concrete floor. Then concrete cover blocks and reinforcement mesh is put inside the ply wood form work. Cover blocks are placed at 0.3meter spacing. After mixing, the fresh GPC is cast into the slab mould in three equal layers. Each layer is compacted by giving manual stroke by using by ordinary rammer of 5 kg weight and compacted from a height of 1.25 meter with 25 blows on each layer of slab. Compaction is ensured when a thin layer of film starts appearing on top surface of slab.

After casting, the slabs were left undisturbed in the form work

For one day as a rest period. On the second day, the ply wood form is removed manually and slabs were kept for curing at room temperature. The room temperature during the time of ambient curing was observed to **be 28.2ºc at day time and 26ºC at night**.

4.44. Compressive strength & split tensile strength of concrete used for slabs

Three cubes of 150mm x150mm x 150mm and three cylinders of 150mm dia and 300mm length are cast during slab concreting. These cubes and cylinders are tested on the day of testing of slabs to know the compressive strength and split tensile strength of slab concrete.

Table2:Test results for compressive strength of slabconcrete

S N.	Days curing	Weight Kg	Failue Load KN	Com Strength Mpa	DOC	DOT
1	7	8.035	1348.9	59.9	20-6-2015	26-7-2015
2	7	8.175	1102.7	52.5	20-6-2015	26-7-2015
3	7	7.950	1322.9	58.7	20-6-2015	26-7-2015

Table3:Test results for split tensile strength of slab concrete

Sl. No	Dia in mm	Length in -mm	Failure Load KN	Tensile Strength Mpa	DOC	DOT
1	150	300	259800	3.677	20-6-2015	26-7-2015
2	150	300	275500	3.899	20-6-2015	26-7-2015

5.0 LOAD TESTING OF SLABS

5.1 Loading Frame

Testing of slabs are done in 50Mton self straining loading frame with electrically operated hydraulic jack. One displacement transducer (LVDT) connected to multichannel digital automatic data logger is fixed at the center bottom of the slab to measure the maximum deflection. Digital load measuring system comprises of electronic load cell connected to automatic data logger. The automatic data logger is connected to computer interface system with advanced menu driven software enabling automatic measuring, recording and storing of load Vs displacement out puts in to computer.

5.2 End Conditions

For testing the slab specimen simply supported end conditions are created by resting the edges of slab on 50mm x 50mm solid steel sections provided along the periphery of slab. To create the free end condition the slab edges are left without solid section. The structural section arrangement for creating UDL on slab is arranged by using plates and channel sections as shown in fig.

5.3 Testing of Slabs:

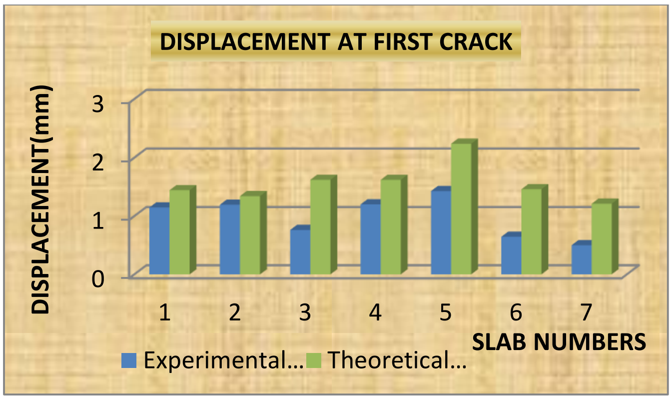
On the day of testing of slabs, specimen cubes and cylinders were tested to know the compressive strength and tensile strength of concrete used for casting the slabs .**Table 3** and **Table 5** indicate the average compressive strength of ***57.03 Mpa*** and Tensile strength of ***3.79 Mpa***.

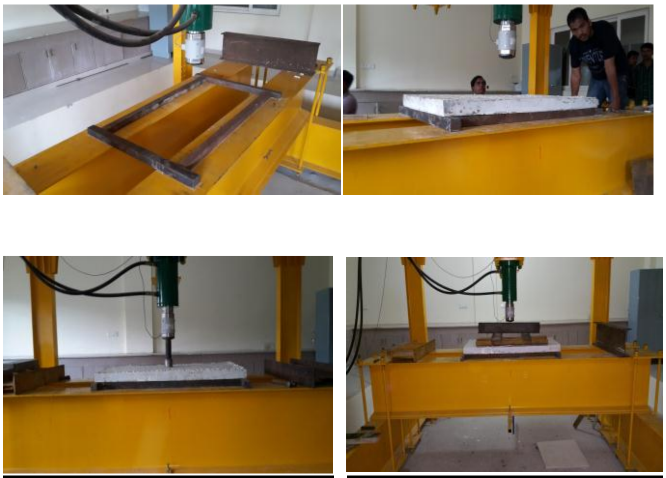
Load testing of slabs were conducted using different end conditions and loading.The test results of slab for load vs central deflections are noted in Table 4.Deflections at first crack are calculated based on ***IS456-2000*** provisions

Table 4: Test results of slabs at First crack

Slab	Slab Size mm×mm× mm	Loading	End cond.	Load Mton	Δex (mm)	Δcal mm
S1	1300 ×650 ×75	U D L	2LS, 2SS	6.7	1.148	1.444
S2	1300 ×650 × 75	U D L	2LS, 2SS	6.4	1.195	1.343
S3	1300 ×650 × 75	U D L	2SS, 2LF	1.3	0.762	1.621
S4	1300 ×650 × 75	U D L	2SS, 2LF	1.3	1.201	1.621
S5	1300 ×650 ×75	U D L	2SS, 2LF	1.5	1.429	2.237
S6	1300 ×650 × 75	C –Pt Load	2LS, 2SS	3.6	0.646	1.461
S7	1300 ×650 × 75	C –Pt Load	2SS, 2LF	1	0.5	1.213

Notations: SS: short sides simply supported,LS: Long sides simply supported,LF: Long side free, SF: Short sides free : C-pt central point load, UDL- uniformly distributed load



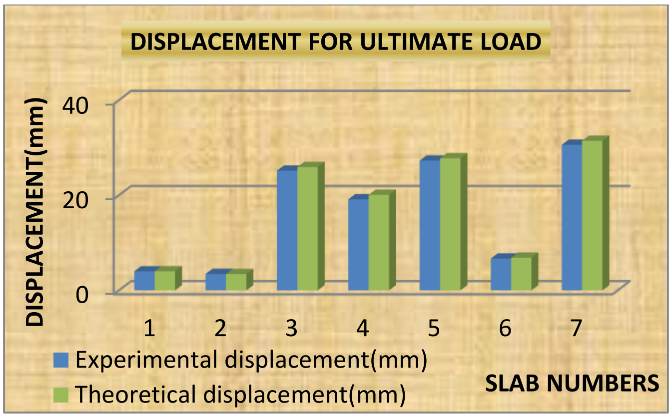


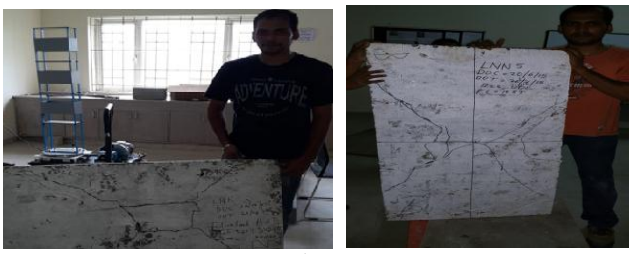
Test set up for four sides supported with point load & two sides supported with UDL.

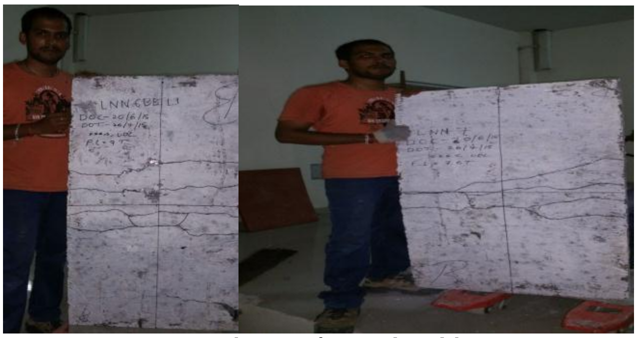
Further loading on slab continued and failure load Vs deflections are noted in ***Table 5***

Table 5 : Test results of slabs at Ultimate load

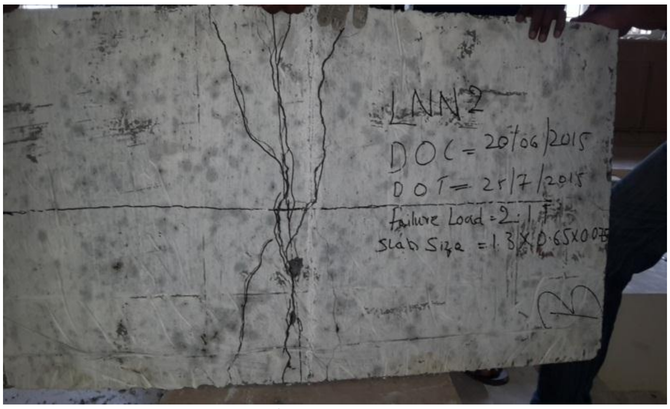
Slab	Slab Size mm×mm ×mm	Loading	End cond	Load Mton	Δex (mm)	Δcal mm
S1	1300× 650×75	UDL	2LS ,2SS	14.3	3.992	4.008
S2	1300× 650×75	UDL	2LS, 2SS	12.6	3.438	3.434
S3	1300× 650×75	UDL	2SS, 2LF	9.2	25.156	25.929
S4	1300 x 650 x 75	UDL	2SS, 2LF	7.6	19.131	20.083
S5	1300× 650×75	UDL	2SS, 2LF	9.8	27.291	27.776
S6	1300× 650×75	C –Pt Load	2LS, 2SS	6.2	6.693	6.867
S7	1300× 650×75	C –Pt Load	2SS, 2LF	2.1	30.6	31.45




Crack pattern for S1 and S2 slabs


Crack pattern for S3and S4 slabs


Crack pattern for S5 and S6 slabs


Crack pattern for slab S7

6.0 RESULTS AND DISCUSSIONS:

In these test results **NaoH** is of **8 Molar** concentration and **Na_2Sio_3/NaoH** ratio is **2.50**. It is observed that there is not much improvement in the compressive strength after **7 day** ambient curing. The tensile strength of geopolymer concrete is comparatively less than ordinary cement concrete by **20-25%**.Workability of concrete improves with rigorous hand mixing up to **20minutes**.For U.D.L first crack appears at 40-45% of failure load and for central point load first crack appears at 85-90% of failure load.

The reinforced geopolymer slabs undergo deformations as tabulated in Table 4 and Table 5. For all the slabs it is observed that the measured deflections at first crack formations are comparatively less than the calculated deformations based on RCC procedures. At failure point these deflections tend to converge.

7.0 CONCLUSIONS:

Here in this investigation geopolymer concrete is prepared by using NaoH solution of **08**Molarity with **Na_2Sio_3/NaoH ratio of 2.50**. The source materials being Fly ash and GGBS .Hand mixing is done by using wooden handled spades and curing is done at room temperature of 22 to 28 degrees. The Fly ash to GGBS ratio used is 70% to 30% for all slabs.

- Geopolymer concrete can be used for concreting works in a similar way to ordinary portland cement 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.
- Workability of concrete increases with increase in hand mixing time and preferably recommended up to 20 to 30 minutes.
- The reinforced geopolymer concrete slab behave in a similar way to reinforced cement concrete slab .Hence formulations and concepts of ordinary reinforced cement concrete as per IS456-2000 can be used for geopolymer concrete with slight modifications.
- The cost of production of GPC will become competitive for higher grade concrete.

8.0 REFERENCES

1. Pradip Nath, Prabir Kumar Sarker (2014), "Effect of GGBFS on setting, workability and early strength properties of fly ash geopolymer concrete cured in ambient condition."Department of Civil Engineering, Curtin University, GPO Box U1987, Perth, WA 6845, Australia.
2. BehzadNematollahi, Jay Sanjayan (2014), "Effect of different superplasticizers and activator combinations on workability and strength of fly ash based geopolymer."

Center for Sustainable Infrastructure, School of Engineering, Faculty of Science, Engineering and Technology, Swinburne University of Technology, Melbourne, Victoria 3122, Australia.

3. Flexural behavior of reinforced geopolymer concrete beams Rajamane et al (2011) International Journal of civil and structural engineering vol 2 ,No 1,2011
4. J.M. Srishaila, ParvezAhamed. P, K.N. Vishwanath, P. Prakash (2014), "Experimental Study on Workability and Strength Characteristics of Fly ash and GGBS based Self-Compacting Geo polymer Concrete," International Journal of Engineering Research and Development.
5. L.Krishnan, S.Karthikeyan, S.Nathiya, K. Suganya (2014), "Geopolymer concrete an eco-friendly construction material," IJRET: International Journal of Research in Engineering and Technology.
6. Janani R, Revathi A (2015)," Experimental Study of Geopolymer Concrete with Manufactured Sand," International Journal of Science, Engineering and Technology Research (IJSETR).
7. Partha sarathi Deb, Pradip Nath and Prabir kumar sarker (2013),"Properties of fly ash slag blended geopolymer concrete cured at ambient temperature.
8. Hardjito, Djwantoro. 2005. Studies of fly ash-based geopolymer concrete. Curtain University of technology, Dept. of civil engineering.

Dr Amarnath .K, Prof & HOD Civil Dept, The Oxford Engg college Bangalore , has 28 years of experience in Teaching & Industry. His research areas include concrete technology & tall buildings.He is actively involved in guiding PhD & M.Tech thesis, material testing and industry related consultancies

Prof Mahantesh,Associtae Professor, Alliance University Bangalore, (Formerly Associate professor TOCE) ,has 10 years of Industrial Experience & 18 years teaching experience.He is a research scholar working in concrete technology and tall building related research works.

Mr Laxminarayan R Naik is persuing his M.Tech at Oxford Engg college Bangalore