IJSRD - International Journal for Scientific Research & Development| Vol. 6, Issue 02, 2018 | ISSN (online): 2321-0613

A Study of Geopolymer Concrete Slabs with Silica Sand as Partial Replacement of Natural Sand

K. Niranjankumar[1] C. Sreenivasulu[2] K. Sai Abhinav[3] MM. Premchand[4] J. Guru Jawahar[5]
[1]M.Tech Student [2,3]Assistant Professor [4]Research Scholar [5]Professor
[1,2,3,4,5]Department of Civil Engineering
[1,2,3,5]Annamacharya Institute of Technology & Sciences, India [4]S.V.University, Tirupati, India

Abstract— Many efforts are put on the advances in construction technology. Study on the Geopolymer concrete, which is produced by developing a binder named geopolymer are rich in silica and alumina as source materials by an alkaline reaction, it replaces Ordinary Portland Cement. This study mainly focused on the Flexural behaviour of geopolymer concrete One-way slab with partial replacement of silica sand as natural sand at different proportions like 100:0, 90:10, 80:20, and 70:30 (natural sand: silica sand). The grade of conventional concrete M40, which is equivalent to grade of geopolymer concrete. The Slabs were cured for 28 days at ambient room temperature and tested for two point loading. The flexural parameters under two point loading like Load characteristics, first crack load, Ultimate load, service load, yield load, Ultimate deflection, bending stresses, Moment characteristics are presented. The study final concludes that at 20% replacement level of silica sand as partial replacement of natural sand gives better results at 8M, hence the silica sand used as a filler material for well graded geopolymer concrete.

Key words: Geopolymer Concrete, Silica Sand, Two-Point Loading, Flexural Parameters

I. INTRODUCTION

Slabs are plane structural members whose thickness is small as compared to its length and breadth. One way slab is made with geopolymer concrete, which was introduced by Davidovits1978, rich in silica and aluminium. In the process of polymerization of materials, alkaline substances are to be added [1]. The source material for silica and aluminium are Fly ash (FA), which is produced from thermal power plants as a waste and ground granulated blast furnace slag (GGBS), which is produced from AASTRA Chemicals, Chennai. Alkaline substances used for obtaining Polymerization reaction are alkaline grade sodium silicate solution (Na2Sio3) and sodium hydroxide solution (NaOH) as an alkaline activator, were taken as 8M. Geopolymer concrete made with only flyash as a source material for silica and aluminium has shown poor results [2]. Geopolymer concrete require curing under ambient room temperature itself. Results are already concluded that GGBS and FA blended GPC mixes attained enhanced mechanical properties at ambient room temperature itself [3-6]. Comparative effect of earth quake on flat slab and grid floor system consisting of beam spaced at regular intervals in perpendicular direction, monolithic with slab [7]. Flat slab building structures which are more significantly flexible than traditional concrete, thus becoming more vulnerable to seismic loading. Comparing the behaviour of multistory building having flat slabs with drops to two way slabs with beams and to study the effect of part shear walls on performance under seismic forces [8]. Flat slab RC buildings exhibit several advantages over conventional moment resisting frames. Derivation of fragility curves using medium-rise flat slab buildings with masonry infill walls [9]. The flat slab is preferred as a floor system because of its architectural appearance, flexibility of flat slab RC structure, easy to construct and economic structure. The seismic response of flat slab structure with different heights as well as variation in plan [10]. The seismic behaviour of multi-story flat slab and conventional reinforced concrete framed structures for different heights and changes occured, if height of traditional and flat slab changes [11]. Flat slab buildings in which slab is directly rested on columns, constructed recently due to the advantage of reduced floor to floor heights to meet economical and architectural demands [12]. Punching shear strength of high performance concrete (HPC) two way slabs under simply supported edge condition and tested under a central patch load, possess higher energy absorption, higher punching shear strength than central specimens [13].

The present study aimed to find the flexural parameters viz. Load characteristics, moment characteristics, cracking load, ultimate load, service load, maximum moment resistance capacity and ultimate deflection under the flexural behaviour of geopolymer concrete slabs at different replacement levels of silica sand after 28 days ambient room temperature curing.

II. EXPERIMENTAL STUDY

A. Materials

In this present study, FA, GGBS and silica sand were used as binders who’s chemical and physical properties are tabulated in Table1. According to ASTM C 618 (2003) [14], class F fly ash produced from Lanco Industry, sri kalahasti, A.P and GGBS produced from AASTRA chemicals, Chennai, A.P were used in the manufacturing of GPC.

Particulars	Class F fly ash	GGBS	Silica sand
Chemical composition			
% Silica(Sio2)	65.6	30.61	81.5
% Alumina(Al2O3)	28.0	16.24	0.64
%Iron Oxide(Fe2O3)	3.0	0.584	0.76
% Lime(Cao)	1.0	34.48	0.14
% Magnesium(Mgo)	1.0	6.79	0.99
%Titanium Oxide(TiO2)	0.5	-	-
%Sulphur Trioxide(So2)	0.2	1.85	-
Loss on Ignition	0.29	2.1	-
Physical properties			
Specific gravity	2.12	2.94	2.60
Fineness(m2/kg)	360	400	-

Table 1: Chemical & Physical Properties of Class F Flyash, GGBS & Silica Sand

The alkaline liquid used was a combination of sodium silicate solution (Na2O = 13.7%, SiO2 = 29.4% and water = 55.9%) and sodium hydroxide (NaOH) in pellets form with 97% - 98% purity was purchased from local suppliers. The sodium hydroxide (NaOH) solution was prepared with a concentration of 8M. The sodium silicate solution and sodium hydroxide solution were mixed together one day before prior to use. Crushed granite stones of size 20mm and 10mm used as coarse aggregate, river sand used as fine aggregate and silica sand used as replacement of natural sand at different levels 100:0, 90:10, 80:20 and 70:30. The bulk specific gravity in oven dry condition and water absorption of the coarse aggregate 20mm and 10mm were 2.66 and 0.3% respectively. The bulk specific gravity in oven dry condition and water absorption of the fine aggregate were 2.62 and 1% respectively. The bulk specific gravity in oven dry condition and water absorption of silica sand were 2.60 and 0.4% respectively.

B. Mix Design

Based on the past research on GPC, the mix proportions were selected based on Rangan's method. Geopolymer concrete mix proportions of constituent materials are shown in Table 2.

Materials		Mass(Kg/m^3)			
		100:0	90:10	80:20	70:30
Coarse aggregate	20mm	774	774	774	774
	10mm	516	516	516	516
Fine aggregate		549	494.1	439.2	384.3
silica sand		0	54.9	109.8	164.7
Flyash(Class F)		204.5	204.5	204.5	204.5
GGBS		204.5	204.5	204.5	204.5
Sodium silicate solution		102	102	102	102
Sodium hydroxide solution		41	41	41	41
Extra water		55	55	55	55
Super plasticizer		2.86	2.86	2.86	2.86

Table 2: GPC Mix Proportions of Constituent Materials

C. Experimental Setup

Compressive strength test was conducted on the cubical specimens for all the mixes viz., silica sand as replacement at 100:0, 90:10, 80:20 and 70:30 after 7, 28 and 90days of curing as per IS516:1991 [12]. Three cubical specimens of each proportion of size 150mmx150mmx150mm were casted and tested for each age and each mix.

The dimensions of one way slab for flexural test were chosen as 1200mm in length, 40mm in breadth, 70mm thick. The reinforcement bars of diameter 8mm (Fe415) were used longitudinally at spacing of 150mm and 120mm laterally. A clear cover of 20mm was provided. Stirrups having 6mm diameter were placed at a spacing of 150mm center-to-center(c/c). The slabs were white washed so that the cracks can be easily identified. The effective span of the slab was taken as 1000mm. The slabs were tested in manually operated loading frame. The slabs were subjected to a two point loading at a distance of L/3 (where L is effective span). Linear variable displacement transducers (LVDT's) was set up at L/2 and at L/3 in order to calculate the deflections. The DATA LOGGER was used in order to collect the data as First crack load, Ultimate load and deflections at L/2 and L/3. The load was applied manually by using a hydraulic jack as shown in Figure 1. The flexural failure of the slab after loading is as shown in Figure 2.

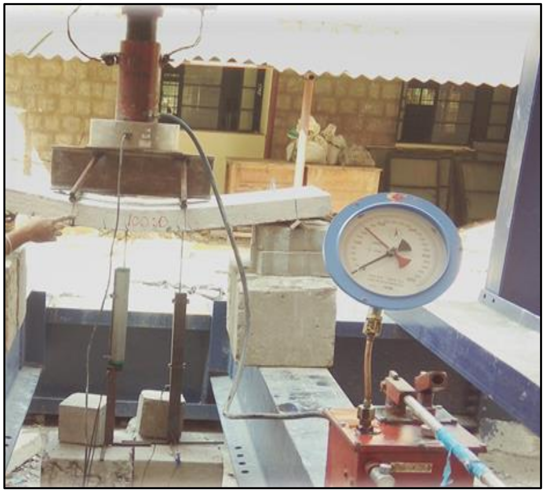

Fig. 1: Set up of a GPC Slab under Two-Point

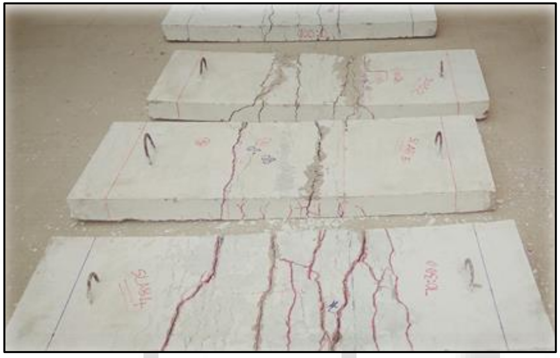

Fig. 2: Flexural failure of a Slab under Two-Point Loading

III. RESULTS & DISCUSSION

A. Mechanical Properties

From Table 3, we can clearly see that there is an increase in the compressive strength of cubes from 31.2 MPa of 100:0 S to 31.3 MPa of 90:10 to 32.9 MPa of 80:20 and decreases at 30.5 MPa of 70:30 for 7days and an increase in compressive strength from 42.3 MPa of 100:0 to 44.97 MPa of 90:10 to 48.2 MPa of 80:20 and decreases at 41.6 MPa of 70:30 for 28days and an increase in compressive strength from 45.42 MPa of 100:0 to 45.91 MPa of 90:10 to 56.53 MPa of 80:20 and decreases at 44.66 MPa of 70:30 for 90days. This increase in performance at 80%S+20%SS is due to increase in silica content present in silica sand but 70:30 , results were poor because there is no reactivity due to increasing silica sand content at 8M.The performance has also been increased from 28days to 90days. The comparison at different replacement levels has been shown in figure 3.

Mix Type	Compressive strength (MPa)		
	7 days	28 days	90 days
100:0	31.2	42.3	45.42
90:10	31.3	44.97	45.91
80:20	32.9	48.2	56.53
70:30	30.5	41.6	44.66

Table 3: Compressive Strength of Cubes At 7, 28 & 90days Curing

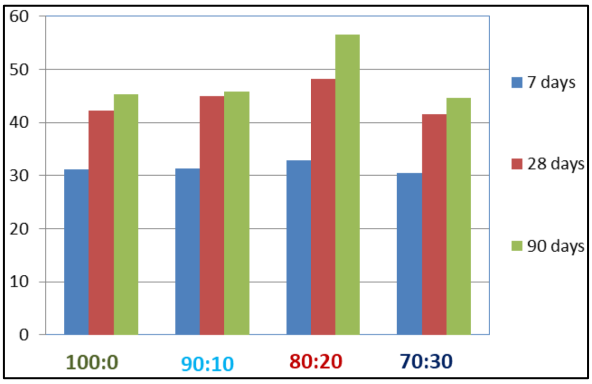

Fig. 3: Comparison of Compressive strength of cubes at 7, 28 and 90days curing

B. *Load Characteristics*

The load characteristics like First crack load, Ultimate load, Service load and yield load as shown in Table 4. The serviceable load has been calculated by using factor of safety 1.5, taken from IS 456:2000. From the below table, it can be easily noticed that the first crack load increases from 40.862 kN of 100:0 to 54.328kN of 90:10 to 54.898 kN of 80:20 and decrease at 54.624 kN of 70:30 for 28 days. Ultimate Load increases from 94.504 kN of 100:0 to 96.162 kN of 90:10 to 98.808 kN of 80:20 and decreases at 88.654 kN of 70:30 for 28days. Serviceable load increases from 63.00 kN of 100:0 to 64.11 kN of 90:10 to 65.87 kN of 80:20 and decreases at 59.10 kN of 70:30 for 28 days. Yield load increases from 73.852 kN of 100:0 to 74.878 kN of 90:10 to 82.291 kN of 80:20 and 80.21 kN of 70:30.

Mix Type	First crack load (KN)	Ultimate load (KN)	Serviceable load (KN)	Yield load (KN)
100:0	40.862	94.504	63.00	73.852
90:10	54.328	96.162	64.11	74.878
80:20	54.898	98.808	65.87	82.291
70:30	54.624	88.654	59.10	80.21

Table 4: Load Characteristics at 28 Days of Curing

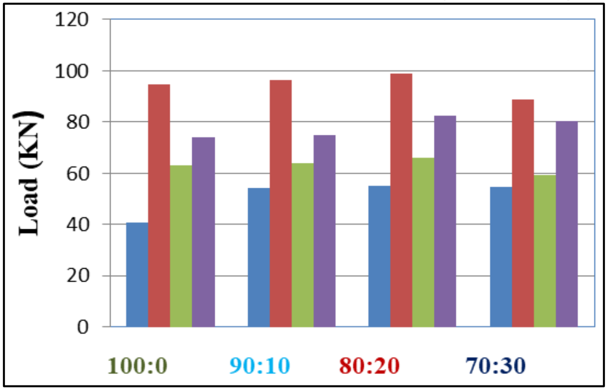

Fig. 4: Comparison of Load Characteristics at Various Proportions

C. *Moment Characteristics*

The below table 5, shows that predicted cracking moment increases from 6.81 kN-m of 100:0 to 9.05 kN-m of 90:10 to 9.15 kN-m of 80:20 and decreases at 9.10 kN-m of 70:30 for 28 days. The experimental cracking moment increases from 6.91 kN-m of 100:0 to 9.16 k N-m of 90:10to 9.25 kN-m of 80:20 and decreases at 9.21 kN-m of 70:30 for 28days. The predicted ultimate moment increases from 8.46 kN-m of 100:0 to 8.53 kN-m of 90:10 to 8.6 kN-m of 80:20 and decreases at 8.44 kN-m of 70:30 for 28days. The experimental ultimate moment increases from 15.86 kN-m of 100:0 to 16.13 kN-m of 90:10to 16.57 kN-m of 80:20 and decreases at 14.88 kN-m of 70:30 for 28 days.

Mix Type	Predicted Cracking moment (KN-m)	Experimental Cracking moment (KN-m)	Predicted Ultimate moment(KN-m)	Experimental Ultimate moment (KN-m)
100:0	6.81	6.91	8.46	15.86
90:10	9.05	9.16	8.53	16.13
80:20	9.15	9.25	8.6	16.57
70:30	9.10	9.21	8.44	14.88

Table 5: Moment Characteristics at 28 Days of Curing

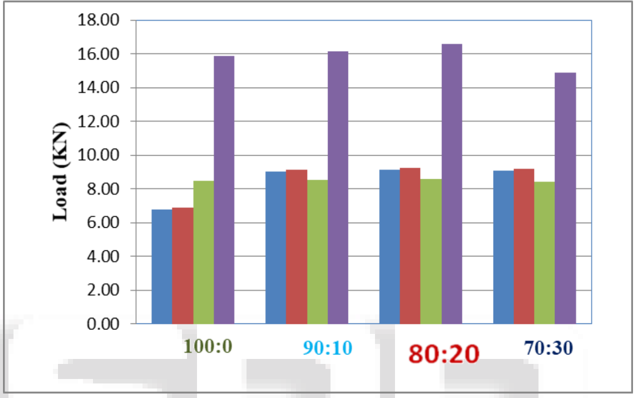

Fig. 9: Comparison of Moment Characteristics at 28 Days Curing

D. *Ultimate Load*

The below table 6, shows the predicted ultimate load increases from the 47.58 kN of 100:0 to 48.39 kN of 90:10 to 49.71 kN of 80:20 and decreases at 44.64 kN of 70:30 for 28 days. Experimental ultimate load varies from 94.504 kN of 100:0 to 96.162 kN of 90:10 to 98.808 kN of 80:20 and decreases at 88.654 kN of 70:30 for 28 day.

Mix type	Predicted Ultimate load (KN) at 28days	Experimental Ultimate load (KN) at 28days
100:0	47.58	94.504
90:10	48.39	96.162
80:20	49.71	98.808
70:30	44.64	88.654

Table 6: Ultimate Load at 28 Days of Curing

E. *Serviceable Load*

From the below table 7, it can be clearly noticed that the predicted serviceable load increases from 31.72 kN of 100:0 to 32.26 kN of 90:10 to 33.14 kN of 80:20 and decreases at 29.76 kN of 70:30 for 28 days. Experimental serviceable load varies from 63.00 kN of 100:0 to 64.11 kN of 90:10 to 65.87 kN of 80:20 and decreases at 59.10 kN of 70:30 for 28 days.

Mix type	Predicted serviceable load (KN) at 28days	Experimental serviceable load(KN) at 28days
100:0	31.72	63.00
90:10	32.26	64.11
80:20	33.14	65.87

70:30	29.76	59.10

Table 7: Serviceable Load at 28 Days of Curing

F. Cracking Load

From the below table 8, it can be clearly noticed that the predicted cracking load increases from 20.43 kN of 100:0 to 27.15 kN of 90:10 to 27.45 kN of 80:20 and decreases at 27.3 kN of 70:30 for 28 days. Experimental serviceable load varies from 20.73 kN of 100:0 to 27.48 kN of 90:10 to 27.75 kN of 80:20 and decreases at 27.63 kN of 70:30 for 28 days.

Mix type	Predicted Cracking load (KN) at 28days	Experimental Cracking load(KN) at 28days
100:0	20.43	20.73
90:10	27.15	27.48
80:20	27.45	27.75
70:30	27.3	27.63

Table 8: Cracking Load at 28 Days of Curing

G. Ultimate Deflection

The below table 9, shows the Ultimate deflection varies as 63.3 mm of 100:0 to 93.42 mm of 90:10 to 89.22 mm of 80:20 and decreases at 106.8 mm of 70:30 for 28 days.

Mix Type	Ultimate deflection (mm)
100:0	63.3
90:10	93.42
80:20	89.22
70:30	106.8

Table 9: Ultimate Deflection at 28 Days of Curing

IV. CONCLUSIONS

1) At 80:20 replacement level of silica sand as natural sand of 8M gives the better results.
2) Though the results were good at 70:30, the workability of concrete with this proportion is poor because of there is no reactivity, of increasing silica sand content.
3) The First cracking load of the slab at 80:20 is 54.898 KN, which is higher of other replacement levels.
4) The Ultimate load and ultimate moment of slab at 80:20 is 98.808 KN and 16.57 Kn-m for 28 days curing.
5) The cracking load and cracking moment of slab at 80:20 is 27.75 KN and 9.265 Kn-m for 28 days curing.
6) The serviceable load and yield load of beam at 80:20 is of 65.87 KN and 82.291 KN of 28 days curing.
7) The bending stress of the slab at 80:20 is 29.46 Mpa at 28 days curing.
8) The ultimate deflection of the slab at 80:20 is 89.22mm of 28 days curing

REFERENCES

[1] Davidovits J. Geo polymers: man-made geosynthesis and the resulting development of very early high strength cement, Journal of materials education, 16(1994)91-139

[2] J. Guru Jawahar, D. Lavanya, C. Sashidar. "Performance of flyash and ggbs geopolymer concrete in acid environment", International Journal of Research and scientific Innovation (IJRSI), 3(2016), 101-104.

[3] Guru Jawahar J, Mounika G. strength properties of flyash and GGBs based geopolymer concrete, Asian journal of Civil Engineering, 17(2016)127-135.

[4] C.Sreenivasulu, J.Gurujawahar, M.Vijayasekhar Reddy and D. Pavankumar, "Effect of Fine aggregate belnding on short-term mechanical properties of geopolymer concrete, Asian journal of Civil Engineering(BHRC), volume-17, issue-5(2016),PP-537-550.

[5] C.Sreenivasulu, A. Ramakrishnaih, and J.Guru Jawahar, mechanical properties of geopolymer concrete using granite slurry as sand replacement, International journal of advances in Engineering and Technology, April2015 , volume-8, issue-2, PP-83-91.

[6] C.Sreenivasulu, J. Guru Jawahar, C.Sashidar, Study and predicting the stress strain characteristics of geopolymer concrete under compression , case studies in construction materials, 8(2018) 172-192.

[7] S.D. Bothara. Varghese. "Dynamic analysis of special moment resisting frame building with flat slab and grid slab", International journal of engineering research and applications. Vol.2, Issue 4, Aug 2012.

[8] U. Gupta .Ratnaparkhe, s. Gome, p., "Seismic behaviour of building having flat slabs with drops" , International journal of engineering technology and advanced engineering, vol 2, issue 10,oct 2012.

[9] M.K. Eebrik., Elnashai, S.A. "Vulnerability analysis of falt slab structures" 13th world conference of earth quake engineering, vencouver, B.C. Canada, Aug-1-6, 2004.

[10] Abhishek Lakshman Dhangar., S.B. Walke "A Comparative study of flat slab structure and conventional structure" International journal of latest trends in engineering and technology7., vol 5., Issue 3, May 2015.

[11] k.S. Sable. Ghodechor, V.A, B, Kandekar, S.B. "Comparative study of seismic behaviour of multi-story flat slab and conventional reinforced concrete framed structures" International journal of computer technology and electronic engineering, vol2, issue 3, june 2012.

[12] R.K. Makode., k.R. Akhtar, S.Bathan. G., "Dynamic analysis of multi storied RCC building frame with flat slab and grid slab". International journal of engineering research and applications, vol 4. Issue 2(version1)feb 2014.

[13] S. Rao., chundapale, S. Ghorpade, V.G.Reddy ,v.k, "Behaviuor of simply supported high performance concrete two way slabs in Punching shear ", International journal of engineering trends in engineering and development, issue-4, vol 2(march 2014).

[14] ASTM C 618:2003, standard specification for coal flyash and raw or calcined natural pozzolana for use in concrete.