Shear Behaviour of M- Sand Based Geoploymer Concrete

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Abstract

This paper presenting an experimental investigation has conducted on shear behavior of M-sand based geopolymer concrete, in this study low calcium flyash is used to make geopolymer concrete along with sodium hydroxide, sodium silicate solutions. The experimental study included a total of 5 beams and 12 cube specimens are casted, beam of size 100 x 150 x 1200mm and cube of size 150 x 150 x 150mm. All the Beams were provided with same amount of flexural and shear reinforcement and the beams were tested for various replacement of river sand by M-sand under two point loading.This research study focuses on complete elimination of Portland cement for production of concrete that can be achieve 28 days strength in the range of 40-44Mpa only under the sunlight curing. From this result geopolymer with M-sand beam shows higher compressive strength alsothebehavior of reinforced geopolymer concrete beams and M-sand based geopolymer concrete beams failing in shear, including the failure modes and crack patterns are found to be similar to those observed in reinforced Portland cement concrete beams including M-sand beams. It has found that the methods of calculation including code provisions, used in the case of reinforced Portland cement concrete beams are applicable for predicting the shear strength of reinforced geopolymer concrete beams. Being the fact that flyash and M-sand is considered as a waste material, so flyash and M-sand based geopolymer concrete is 30% cheaper than Portland cement concrete.

Keywords — *Geopolymer concrete, OPC, Shear behavior, M-sand, Deflection.*

I. INTRODUCTION

Concrete is second only to water as the most consumed material on earth. Portland cement has been used as a binder to combine the coarse and fine aggregates to make concrete since the 19th century. The demand for concrete is increasing with the growing demands of infrastructure, energy and resources. However, there are some issues associated with cement production, for not only it is one of the most energy intensive materials used in construction, but it is also responsible for some carbon dioxide (CO2) emissions, the gas most implicated in global warming. Several efforts are in progress to address the global warming issue. These include the utilization of Supplementary materials such as fly ash, granulated blast furnace slag, silica fume and rice-husk ash, and also the development of alternative binders to Portland cement.

In view of sustainable development in the construction industry, geo-polymer technology shows considerable promise as an alternative binder to Portland cement. Geo-polymer is emerging materials which, since being proposed by Davidovits in 1979, have been used in applications ranging from waste management to the building industry.

II. LITERATURE REVIEW

Ambily P.S, Madheswaran C.K, [1] Conducted an experimental investigations on Shear behavior of reinforcedGeopolymer concrete thin webbed T-beams. Therefore in this study the results of a series of tests were conducted on reinforced geopolymer concrete with different spacing of shear reinforcement as well as with and without steel fibers. This experimental work has done for the percentage of steel fibers was 0.75%. In this paper also discussed about mix proportion of GPC mixes, preparation of RGPC beams and evaluated the structural behavior with respect to cracking, service load, deflection at various stages and failure modes. By the comparison with different text data finally identified the failure mechanism has been transformed from brittle to ductile mode by the help of steel fibers.

M.K. ThangamaniBindhu and Dr.D.S.Ramachandra Murthy, [2], discussed about the materials and mix proportions of fly ash based geopolymer concrete. They mainly analyzed the performance of RGPC beams such as load carrying capacity, moments, deflection and crack width at different stages. Conducted investigations on 7 beams having different mix proportions of fly ash and GGBS for different percentage of steel, concluded GGBS was increased the compressive strength of geopolymer concrete.

Nagajothi. S and Elavenil. S, [3], an experimental study on concrete mix design of G30 was done based on Indian Standard code (IS10262) with fully replacement of river sand by M-sand. Tested were conducted for evaluating compressive strength and split tensile test by varying the percentage of M-sand. It was concluded that compressive strength, tensile strength and flexural strength was increased when M-sand was fully replaced by river sand.

T. G. Ushaa, R. Anuradha, [4], had proposed the study on flexural response of self-compacting geopolymer concrete beams by partial replacement of flyash by GGBFS and various replacement of river sand by M-sand under two point loading. Mixtures were prepared with alkaline liquid to binder ratio by mass value was 0.33 for mix M1, M2, M3, M4, M5. The ratio between sodium hydroxide to sodium silicate solution was 1:2:5. They mainly analyzed the properties of fresh and hardened self-compacting geopolymer concrete, mechanical properties such as compressive strength, split tensile strength and flexural strength at the period of 28 days ambient curing and 24 hours heat curing. Super Plasticizer was added to achieve the good workability. It was found that the SCGC beams have higher flexural strength.

Saranya.C.S, Ajith.J, [5], This paper presents an experimental investigation on steel fibregeopolymer reinforced concrete using fully replacement of river sand by M-sand. This study was continued to investigate the behavior of hardened properties of such steel fibre reinforced geopolymer concrete under compressive strength, split tensile strength and flexural strength of the concrete with an Ambient temperature curing of 60˚ C was required for 24 hours. Concluded from this experimental results are the maximum strength at all age of testing was obtained at GPC 2 of 80 aspect ratio steel fiber.

Shiva Kumar K.K.V and M. Prakash, [6], proposed that geopolymer concrete was prepared by the combination of flyash, GGBS were used along with sodium hydroxide and sodium silicate solutions. This researcher has evolved the performance of reinforced geopolymer concrete columns with different percentage of steels under axial and eccentric loading conditions. Also this study was continued to investigate the mechanical properties of geopolymer concrete through the compressive and split tensile tests. Finally results were concluded thatgeopolymer concrete with reinforcement percentage of 3.21% given more load carring capacity of 392kN, minimum deflection of 4.35mm and higher stiffness of 90.1kN/m.

K. Suseela and T. Baskaran, [7], had proposed the studies on high performance concrete with glass fibre, glenium, M-sand and fly ash. The specimens were tested under compression, split tension and flexure. Flexural tests were conducted on 8 beams, 2 with control mix, 2 with M-sand, 2 with glass fibre and finally 2 with optimized mix. It was concluded from the studies that the beam had 0.4% glass fibre and 60% of M-sand accomplished better results.

III. EXPERIMENTAL INVESTIGATION

A. Material Testing

1) Sieve Analysis Test for Fine Aggregate

Table 1: Sieve Analysis Test for Fine Aggregate

S.no	IS Sieve	Weight retained			Cumulative weight retained (grams)	Cumulative % retained	% finer
		Empty weight of sieve	Retained weight of sieve	Retained weight of sand			
1	4.75mm	400	410	10	10	1	99
2	2.36mm	360	455	95	105	10.5	89.5
3	1.70mm	340	540	200	305	30.5	69.5
4	1.18mm	390	645	255	560	56	44
5	600µ	360	710	350	910	91	9
6	425 µ	385	415	30	940	94	6
7	300 µ	400	430	30	970	97	3
8	150 µ	335	355	20	990	99	1
9	75 µ	330	335	5	995	99.5	0.5
10	Pan	450	455	5	1000	100	0

From IS: 383-1970, Fine aggGrading zone=II

Specific Gravity Test&Flyash

For Fine Aggregate = 2.64, Coarse Aggregate = 2.7

Low calcium flyash used for this experimental work, the specific gravity of flyash is 2.2

2) Alkaline Liquid Preparation

Fig 1: Preparation of Alkaline solution

B. Design of Rectangular Beam

Breadth, b= 100mm, Depth, D = 150mm
Provide 2 nos of 12mm dia bars at top and bottom of the beam (Ast = 226.08mm^2)
Provide 8mm dia 2 legged vertical stirrups at 120mm c/c spacing

C. Mix Proportion of Geopolymer Concrete

Design compressive strength is approximately 40Mpa.Hence, the Mix Proportion is 1:1.456:4.85:0.106: 0.264

Table 2: Mix Proportion

Materials	Mass (kg/m^3)	Materials	Mass (kg/m^3)
Coarse aggregate	3439.8	Coarse aggregate	1024
Fine aggregate	1031.4	Fine aggregate	676.6
Fly ash	708.3	Cement	444.4
Sodium silicate solution	187	Water	200
Sodium Hydroxide solution	74.8	W/C	0.45

D. Preparation ofOPC & GPC Concrete and Casting

Fig 3: Casting of Cubes, Beam, Curing and remolding of beam

IV. TESTS AND RESULTS WITH TABULATIONS

A. Compressive Strength

The compressive strength variation for the cube specimen shown in Fig 4. Specimens of size 150mm x 150mm x 150mm were casted under sunlight curing. The cubes are tested at the age of 7 & 28 days curing.

Table 3: Compressive strength for OPC &Geo-polymer cubes (7 & 28 days)

S.No	Cubes	Compressive Strength N/mm^2	
		7Days	28Days
1	Conventional Cube	30	44
2	OPC with M-Sand	31	46
3	GPC	27	42
4	GPC with M-Sand	29	43

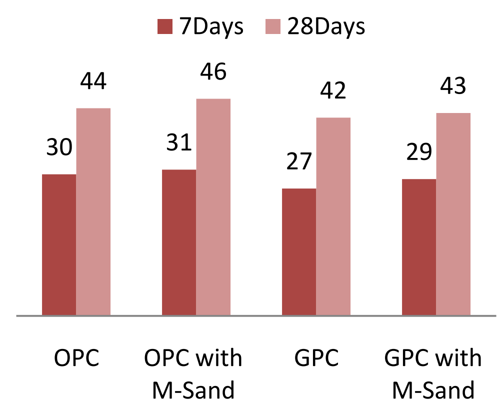

Fig 4: Bar chart showing variation of compressive strengths for various blended cements

V. EXPERIMENTAL TEST SETUP OF BEAM

VI.

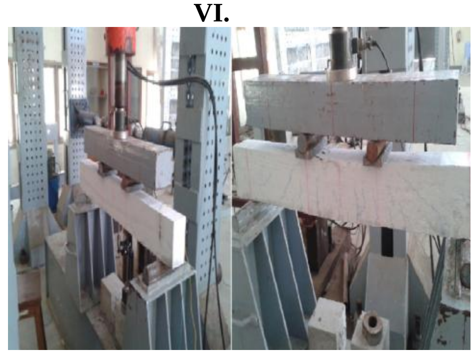

Fig 5: Two-Point Loading Setup& Crack Pattern identification

The beam specimen test setup and Crack pattern as shown in fig 5. The beams are subjected to two points loading at 0.33mm from each end. Deflection in the test specimen under loading points & at mid span were measured using deflectometers during testing. The beams were loaded using hydraulic actuator. The load was measured by means of a load cell. The load is applied gradually up to failure. Strain Gauge is placed at the support on the tension and compression zone to identify the strain value. The crack pattern identification was done by visual analysis.

VII. EXPERIMENTAL RESULTS

Table 4:Deflection, Stiffness and Strain for Each Load Increment for Control Beam

Load in KN	Deflection in mm			Stiffness	Strain Comp	Strain Tension
0	0	0	0	0	0	0
5	0.16	0.2	0.17	25	0.0001	0.0003
10	0.41	0.45	0.42	22.22	0.0003	0.0004
15	0.7	0.76	0.73	19.74	0.0004	0.0006
20	1.01	1.06	1.02	18.87	0.0005	0.0008
25	1.47	1.53	1.5	16.34	0.0007	0.001
30	1.88	1.92	1.92	15.63	0.0009	0.0011
35	2.36	2.41	2.38	14.52	0.001	0.0015
40	2.68	2.75	2.71	14.55	0.0013	0.0016
45	3.11	3.16	3.13	14.24	0.0014	0.0018
50	3.5	3.54	3.51	14.12	0.0017	0.002
55	3.85	3.92	3.88	14.03	0.0019	0.0022
60	4.18	4.28	4.23	14.02	0.0021	0.0025
65	4.64	4.71	4.65	`13.80	0.0025	0.0028
70	5.15	5.21	5.16	13.44	0.0027	0.0032
75	5.61	5.72	5.62	13.11	0.0029	0.0033
80	6.21	6.3	6.23	12.69	0.003	0.0035

Table 5:Deflection, Stiffness and Strain for Each Load Increment for OPC with M-Sand Beam

Load KN	Deflection inn mm			Stiffness	Strain Comp	Strain Tension
0	0	0	0	0	0	0
5	0.24	0.27	0.25	18.52	0.00015	0.00017
10	0.58	0.61	0.59	16.39	0.00017	0.0003
15	0.76	0.81	0.78	18.52	0.00027	0.0005
20	1.11	1.17	1.13	17.09	0.00032	0.0007
25	1.51	1.57	1.5	15.92	0.00046	0.00085
30	1.88	1.99	1.9	15.08	0.00063	0.0009
35	2.22	2.31	2.25	15.15	0.0084	0.0012
40	2.5	2.62	2.56	15.27	0.001	0.0014
45	2.88	2.97	2.9	15.15	0.0015	0.0019
50	3.3	3.38	3.32	14.79	0.0017	0.0022
55	3.52	3.69	3.55	14.9	0.0019	0.0023
60	4.08	4.15	4.1	14.46	0.0023	0.0027
65	4.39	4.47	4.42	14.54	0.0024	0.0028
70	4.87	4.99	4.89	14.03	0.0026	0.003
75	5.3	5.45	5.34	13.76	0.0028	0.0032
80	5.78	5.82	5.79	13.74	0.0029	0.0033
85	6.46	6.62	6.48	12.84	0.0031	0.00034
90	7.54	7.7	7.55	11.68	0.0033	0.0036

Table 6:Deflection, Stiffness and Strain for Each Load Increment for Geopolymer Beam

Load KN	Deflection inn mm			Stiffness	Strain Comp	Strain Tension
0	0	0	0	0	0	0
5	0.3	0.32	0.3	15.63	0.00018	0.0002
10	0.53	0.55	0.54	18.18	0.00027	0.0003
15	0.85	0.9	0.88	16.67	0.0003	0.0005
20	1.2	1.25	1.25	15.63	0.0004	0.00062
25	1.6	1.65	1.61	15.15	0.00047	0.00072
30	2.15	2.2	2.17	13.64	0.0006	0.00078
35	2.4	2.45	2.41	14.29	0.0008	0.001
40	2.89	2.95	2.91	13.56	0.0013	0.0013
45	3.5	3.55	3.51	12.68	0.0014	0.0015
50	3.93	4	3.95	12.5	0.0016	0.0019
55	4.54	4.6	4.55	11.96	0.0019	0.0022
60	5.14	5.2	5.16	11.54	0.0022	0.0025
65	5.55	5.6	5.57	11.64	0.0025	0.0028
70	5.87	5.92	5.89	11.82	0.0029	0.0031
75	6.44	6.5	6.46	11.54	0.0031	0.0033

Table 7:Deflection, Stiffness&Strain for Each Load Increment forGeopolymerwithM-Sand beam

Load KN	Deflection inn mm			Stiffness	Strain Comp	Strain Tension
0	0	0	0	0	0	0
5	0.27	0.3	0.28	16.67	0.00016	0.0002
10	0.61	0.65	0.63	15.38	0.00022	0.0003
15	1.07	1.11	1.09	13.51	0.00029	0.00036
20	1.43	1.47	1.43	13.6	0.00036	0.0005

25	1.87	1.9	1.88	13.16	0.00044	0.0006
30	2.24	2.3	2.25	13.04	0.00055	0.00075
35	2.7	2.78	2.72	12.59	0.00065	0.0009
40	3.26	3.3	3.28	12.12	0.0008	0.001
45	3.68	3.75	3.7	12	0.001	0.0012
50	4.21	4.28	4.22	11.68	0.0012	0.0015
55	4.56	4.6	4.58	11.96	0.0013	0.0018
60	5.08	5.12	5.1	11.72	0.0016	0.002
65	5.51	5.55	5.53	11.71	0.0018	0.0023
70	5.85	5.9	5.88	11.86	0.002	0.0025
75	6.37	6.42	6.4	11.68	0.0023	0.0029
78	6.93	7	6.95	11.14	0.0026	0.0031

Table 8:Deflection, Stiffness and Strain for Each Load Increment for Geopolymer with Partially Replaced M-Sand Beam

Load KN	Deflection inn mm			Stiffness	Strain Comp	Strain Tension
0	0	0	0	0	0	0
5	0.29	0.32	0.3	15.63	0.00012	0.0002
10	0.71	0.74	0.72	13.51	0.00016	0.00025
15	1.08	1.2	1.1	12.5	0.00023	0.00035
20	1.62	1.65	1.61	12.12	0.00028	0.00045
25	1.92	1.95	1.92	12.82	0.00033	0.0005
30	2.2	2.25	2.21	13.33	0.0004	0.00065
35	2.68	2.75	2.7	12.87	0.00045	0.0007
40	3.21	3.25	2.23	12.31	0.00051	0.0008
45	3.66	3.7	3.68	12.16	0.00062	0.0009
50	4.3	4.35	4.31	11.49	0.00075	0.0015
55	4.8	4.85	4.82	11.34	0.0009	0.002
60	5	5.06	5	11.85	0.001	0.0025
65	5.48	5.55	5.51	11.71	0.0015	0.0028
70	6	6.2	6.1	11.29	0.002	0.003
75	6.72	6.8	6.75	11.03	0.0024	0.0032
79	7.17	7.2	7.18	11.11	0.0028	0.0034

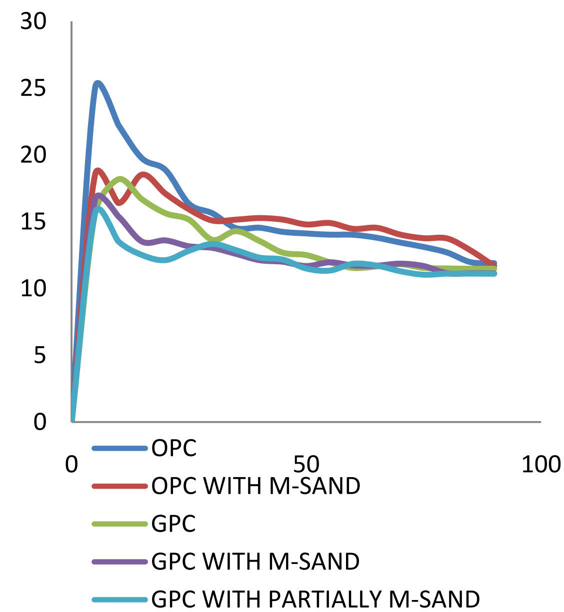

Fig 6: Load vs Deflection curve

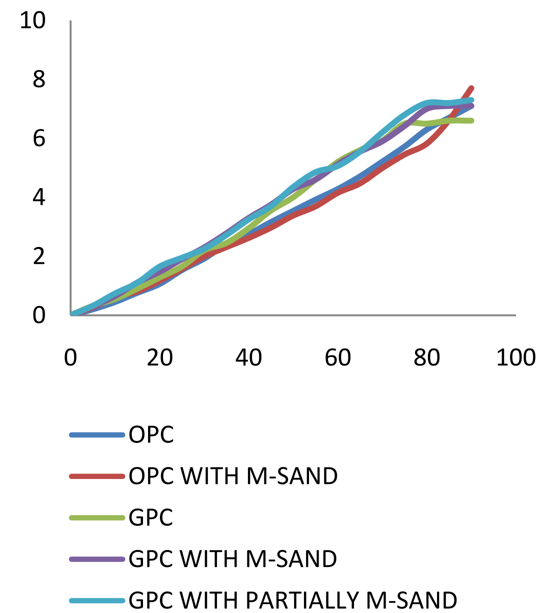

Fig 7: Load vs Stiffness curve

From table 4 to table 8 and table 9 summarized the ultimate load, corresponding deflection and strain value for the different types of beams. The deflection at failure ranges from 6.3mm to 7.7mm for OPC and OPC with M-sand. For GPC & GPC with M-sand the deflections range between 6.5mm to 7.2mm. In corporation of M-sand improves the load carrying capacity as well as stiffness of the OPC and GPC beams.

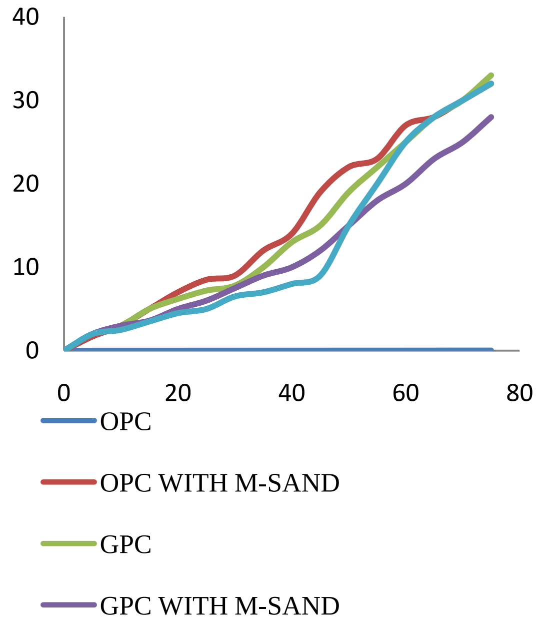

Fig 8: Load vs Strain for Tension

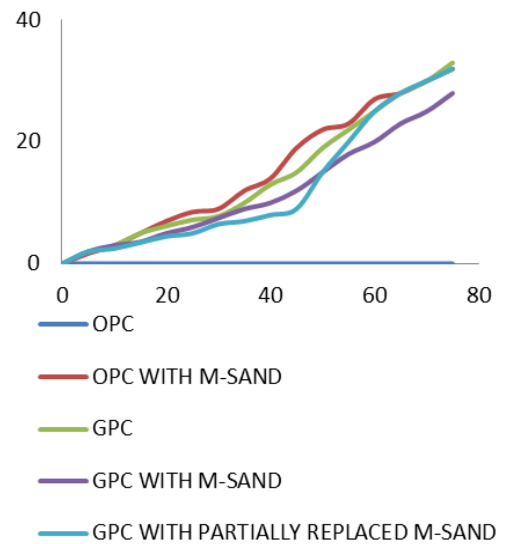

Fig 9: Load vs Strain for Compression

Fig 6(Load vs Deflection curve) Fig 7 (Load vs Stiffness curve) have shown the variation of Deflection and stiffness for OPC, GPC with M-sand under different loading stages. From this graph GPC, OPC with M-sand Gives a better results. Strain variation determined on the compression zone and tension zone by strain gauge under different load condition. Fig 8 and Fig 9 showed the typical variation near to the support section.

Table 9: Ultimate load and corresponding deflection

Specimen	Load (kN)	Deflection (mm)
OPC	85	8.2
OPC With M-SAND	90	7.7
GPC	75	6.5
GPC With M-SAND	78	7.0
GPC with partially replaced M-SAND	79	7.2

Table 10: Ultimate Load and Shear Crack Load in KN

Specimen	Shear CrackLoad(kN)	Ultimate load in(kN)
OPC	80	85
OPC With M-SAND	75	90
GPC	65	75
GPC With M-SAND	70	78
GPC with partially replaced M-SAND	72	79

VIII. CONCLUSION

From the various observations made by testing of different specimens, the following conclusions are made:

- The blended cement concrete showed properties similar to that of normal concrete made of OPC. The failure pattern of the entire beam was almost similar, initially a crack was found at the Centre, when the load reached as ultimate then flexural cracks developed around the supports.
- The load carrying capacity of Geo-polymer concrete mixed with M-sand is marginally lower with that of OPC concrete. OPC concrete blended with M-sand is slightly higher than conventional OPC concrete , OPC with M-sand found which indicates that M-sand is a better replacement for conventional river sand.
- Load by deflection ratio gives stiffness of the beam. It was found that OPC with M-sand beam had greater stiffness compared with other beams. Finally concluded that GPC beam with partial replacement of M-sand is better than GPC and GPC with M-sand beams.

- Comparing workability ordinary conventional concrete is better thangeopolymer concrete and M-sand based concrete. (240 to 260 mm slump). Therefore super plasticizer is required.
- When we consider the economical aspect, the geo-polymer concrete replacing M-sand is economical than conventional concrete by about 25 to 30%, as sand is replaced by M-sand and cement by Fly ash.

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