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FLEXURAL BEHAVIOR OF HIGH STRENGTH GEO-POLYMER CONCRETE BEAMS

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The demand for concrete is increasing day by day. As the consumption of cement is increased, environmental issues arise due to the release of CO_2 during the manufacturing of cement. The objective of this research work is to produce a pollution free concrete with a combination of fly ash and GGBS (Ground granulated blast furnace slag) and without the use of cement. In this paper an attempt was made to study the mechanical properties of high strength geo-polymer concrete of grade M60 using GGBS, fly ash and micro silica. The testing program was planned for the mechanical properties of geo-polymer concrete and flexural behavior of corresponding beams. The experimental results indicated that the geo-polymer concrete M60 grade has a compressive strength of 70.45 MPa at the age of 28 days cured at ambient condition. Further, flexural strength and split tensile strengths for M60 grade high strength geo-polymer concrete at 28 days were observed to be 5.45 MPa and 3.63 MPa respectively. The modulus of elasticity was higher than the theoretical value proposed by IS 456-2000. It was also observed that the load carrying capacity of M60 grade high strength geo-polymer concrete found to be more than corresponding grade conventional concrete. The load-deflection, moment-curvature relationships were studied. The experimental results were encouraging to continue for further research in the area high strength geo-polymer concrete.

Keywords: GGBS, Fly ash, Micro silica, Compressive strength, Splitting tensile strength, Flexural strength, Modulus of elasticity, Mechanical properties.

1 INTRODUCTION

Concrete is the second most used material after water. Ordinary Portland Cement (OPC) becomes an important material in the production of concrete which acts as a binder for the ingredients of concrete. Utilization of cement causes pollution to the environment and reduction of natural resources. The current contribution of greenhouse gas emission from Portland cement production is about 1.5 billion tons annually.

The purpose of this study to produce environmental friendly concrete, replacing cement with the industrial by products such as fly ash, GGBS (Ground granulated blast furnace slag) etc. and to develop cost-efficient and eco-friendly concrete. To produce high strength concrete using geo-polymers and without ordinary Portland cement.

The objective is to determine the mechanical properties of geo-polymer concrete of M60 grade. To investigate the flexural behavior of geo-polymer concrete beams and comparing with conventional reinforced concrete beams.

2 SCOPE OF THE WORK

Three Cubes (150mm x 150mm x 150mm) each for 7 days and 28 days were tested for compressive strength. Three cylinders (150mm diameter x 300mm length) for splitting tensile strength and three cylinders of the same size were used for determination young's modulus of elasticity at 28 days. Six prisms (100mm x 100mm x 500mm) were tested for flexural strength at 28 days. Two numbers geo-polymer concrete reinforced concrete beams (150mm x 230mm x 1500mm) were cast and another two beams of the same size of conventional concrete were cast for flexure behavior.

3 LITERATURE REVIEW

Naidu *et al*. (2012) with 28.57% replacement of fly ash with slag, achieved compressive strength of 57MPa for 28 days. For the same mix strength obtained was 43.56 MPa after exposure to 500°C for 2 hours. Vignesh and Vivek (2015) made an attempt to study strength properties of geo-polymer concrete using low calcium fly ash replacing with slag in five different percentages. Ramujee and Potharaju (2014) aimed at making eco-friendly concrete and increasing the strength of the concrete. Sagawa *et al*. (2013) investigated the chloride diffusion coefficient of the concrete mixed with ground granulated blast-furnace slag (GGBS). Islam *et al*. (2014) concluded that experimental study on the development of compressive strength of ground granulated blast furnace slag-palm oil fuel ash-fly ash based geo-polymer mortar.

4 EXPERIMENTAL PROGRAM

After several trial mixes, mix proportions for M60 grade geo-polymer concrete are determined. Materials fly ash, GGBS), alkaline liquids, sodium hydroxide (NaOH), sodium silicate (Na_2SiO_3), fine aggregates, coarse aggregates, micro silica, super plasticizers are used. Physical and chemical properties of fly ash and GGBS are presented in Table 1 to Table 4.

Table 1. Physical properties of fly ash.

S.No	Description	Value	As per IS 3812-2007
1	Specific gravity	2.2	---
2	Fineness (m^2/kg)	369	Minimum - 320
3	Lime Reactivity	4.9	Minimum - 4.5
4	Soundness(Autoclave Test)	0.034	Maximum - 0.8

Table 2. Chemical composition of fly ash.

S.No	Description	Mass (%)	Requirement as per IS 3812-2007
1	Loss of Ignition	1.90	12.0 (Max)
2	Silica, SiO_2	52.16	($SiO_2+Al_2O_3+Fe_2O_3$) 70 (Max)
3	Alumina,Al_2O_3	31.97	
4	Iron, Fe_2O_3	9.32	
5	Magnesium MgO	0.71	5.0 (Max)
6	Sodium Na_2O	0.89	1.5 (Max)
7	Sulphur SO_3	0.5	2.75 (Max)

Table 3. Physical properties of GGBS.

S.No	Description	Value
1	Colour	Off white
2	Specific gravity	3.15
3	Fineness (m^2/kg)	420
4	Glass Content (%)	75

Table 4. Chemical composition of GGBS.

S.No	Description	Mass (%)
1	Loss of Ignition	2.6
2	Calcium, CaO	42.5
3	Silica, SiO_2	34.4
4	Alumina,Al_2O_3	12.9
5	Iron, Fe_2O_3	1.12
6	Magnesium MgO	4.87
7	Sodium Na_2O	0.45
8	Sulphur SO_3	3.10
9	Potassium K_2O	0.66

4.1 Alkaline Liquid

The most common alkaline liquid in geo-polymerization is a combination of a sodium silicate solution and sodium hydroxide. Sodium based solutions were chosen because it is a low cost than potassium based solutions. The solution is prepared 24 hours prior to testing.

4.2 Sodium Hydroxide (NaOH)

In the present investigation for the preparation of alkaline solution sodium hydroxide of 12M molarity was considered. The Sodium Hydroxide solids of a laboratory grade in pellets form with 99 percent purity. The sodium hydroxide (NaOH) solution was prepared by dissolving the pellets in water.

4.3 Sodium Silicate (Na_2SiO_3)

Sodium silicate solution obtained from local chemical suppliers was used. The chemical composition of the Sodium silicate solution was Na2O =14.7%, SiO2 = 29.4% and water 55.9% by mass. The PH value of the liquid was 11.7. The mix proportions for mix design for M60 grade geo-polymer concrete are shown in Table 5.

4.4 Specification of Reinforced Concrete Beam

An under reinforced concrete beam was designed to determine the flexure strength of the geo-polymer concrete beam. Also two conventional under reinforced RC beams were cast with same grade i.e., M60 and compared the flexural strength. Main reinforcement was formed by 4 no's of 16mm diameter in tension zone (bottom) and 2 no's of 12mm diameter in compression zone (top). Further, the stirrups of 8mm diameter at 125mm center to center are proposed.

Table 5. Mix proportions of geo-polymer concrete for M60 grade.

S.No	Description	Qty (kg/Cum)
1	Fly ash	274
2	GGBS	206
3	Fine aggregate	767
4	Coarse aggregate	948
5	Na2 SiO3	171
6	NaOH	18
7	Water	51

5 TEST SPECIMENS AND RESULTS

Mechanical test results are tabulated in Table 6 to Table 9.

Table 6. Test results of the Compressive strength of geo-polymer concrete (GPC).

S.No.	Compressive strength at 7 days for GPC (N/mm^2)	Compressive strength at 28 days for GPC (N/mm^2)	Compressive strength at 28days for conventional concrete (N/mm^2)
1	41.86	69.51	73.00
2	44.00	71.74	72.45
3	42.40	70.11	69.67
Average Strength	42.75	70.45	70.70

Table 7. Splitting tensile strength of M60 grade geo-polymer concrete.

S No	Sample	Splitting tensile strength (N/mm^2)
1	M-60-A	3.60
2	M-60-B	3.50
3	M-60-C	3.78
Average value		

Table 8. Flexural strength of geo-polymer concrete.

S.No.	Sample	Flexure strength (N/mm^2)
1	M60-A	5.18
2	M60-B	5.58
3	M60-C	4.78
4	M60-D	5.18
5	M60-E	5.98
6	M60-F	5.98
Average value		5.45

Table 9. Test results of modulus of elasticity.

S.No	Sample	Modulus of Elasticity (GPa)
1	1	41.00
2	2	42.00
3	3	47.00
Average value		43.00

Crack patterns and failure mode were observed for tested beams. The load carrying capacity of the geo-polymer concrete beam is little higher than convention concrete. The load and corresponding deflections were recorded for both geo-polymer concrete beam and convention concrete beams. The results are presented in Figure 1. Also, the moment-curvature relationship is shown in Figure 2.

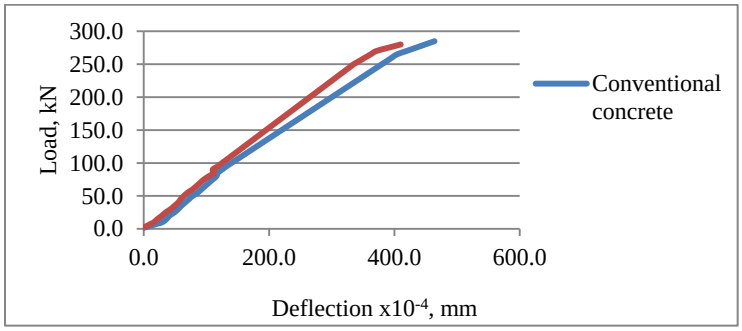

Figure 1. Comparisons of Load vs Deflection for M60 grade between Geo-polymer concrete beam and a conventional concrete beam.

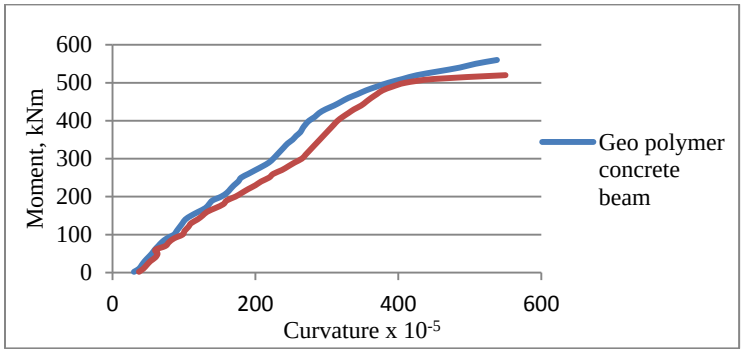

Figure 2. Comparisons of Moment vs Curvature for M60 grade between Geo-polymer concrete beam and a conventional concrete beam.

6 CONCLUSIONS

An attempt was made for the development of high strength geo-polymer concrete beams. Based on the investigation reported in this paper the following conclusions were drawn:

- The average density of fly ash based geo-polymer concrete is observed to be similar to that of conventional concrete.

- The compressive strength of fly ash-GGBS-Micro silica-based high strength geo-polymer concrete of grade M60 under the ambient temperature at 28 days is almost equal to the compressive strength of conventional concrete.
- The modulus of elasticity and load carrying capacity of high strength geo-polymer concrete of grade M60 are observed to be slightly higher side when compared with conventional concrete of the same grade.
- Hence, geo-polymer concrete mix with 47.5 % fly ash and GGBS, 20% of Micro Silica and 12M give required compressive strength in terms of M60 grade of concrete.
- Geo-polymer concrete can be used to replace high strength normal concrete since it does not only satisfy all the properties but also eco-friendly.

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