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MECHANICAL PROPERTIES OF SELF COMPACTING GEOPOLYMER CONCRETE AT ELEVATED TEMPERATURE

[1]C. Yedukondalu, [2]C. Sashidhar

[1] *M.S (Scholar), Department of Civil Engineering, Jawaharlal Nehru Technological University, Anantapur, India,* [2] *Professor, Department of Civil Engineering, Jawaharlal Nehru Technological University, Anantapur, India,*

ABSTRACT: The present investigation is mainly focused on finding the mechanical properties of self compacting geopolymer concrete (SCGPC) mixes with different molar concentration like 8M, 10M and 12M. The SCGPC mixes were cured at ambient temperature for different ages (7, 28 and 56 days). At different ages, the specimens were kept at an elevated temperature (100, 200, 400, 600 and 800^{o}C) for 2 hours and then testing of the specimens was carried out. Fly ash (class F) and ground granulated blast furnace slag (GGBS) were used at a ratio of 50:50 as geopolymer binders. Combination of sodium hydroxide (8M, 10M and 12M) and sodium silicate solution was used as an alkaline activator. Compressive strength and splitting tensile strength were studied after 7, 28 and 90 days of curing at ambient room temperature after the completion of oven temperature curing. From the results, it is revealed that the mechanical properties were decreased with the increase in temperature from 100^{0}C to 800^{0}C in all curing periods. It is concluded that the significant decrement in mechanical properties (compressive strength and split tensile strength) up to 800^{0}C is mainly due to continuous moisture loss from the specimens and increase in the average pore size, which produce the lower strength of the concrete.

Keywords: Self compacting geopolymer concrete; fly ash, GGBS; compressive strength; splitting tensile strength; elevated temperature.

I. INTRODUCTION

Conventional concrete (CC) is one of the most far used construction material in the world. In the CC, Ordinary Portland cement (OPC) plays an essential role in the concrete but it is not an environmentally friendly material. The production of OPC liberates a considerable amount of carbon dioxide (CO_2) and it leads to several environmental issues [1]. So, to reduce CO_2in the environment, the geopolymer technology was introduced by Davidovits in the 1978 [2-5].

On the other hand, placement of fresh concrete in the forms requires compaction efforts and also involves skilled labor for execution. This compaction primarily aims to minimize the entrapped air in fresh concrete in order to obtain homogeneous mix with no cavities or honey-comb [6]. While the concrete is placed and compacted at the construction site, normal vibrating concrete may unable to exhibit the required fresh and hardened properties [7]. To obtain adequate compaction in freshly mixed concrete, skilled labor is required. One solution to relieve this problem is the employment of self compacting concrete (SCC) [8].

So, while considering above issues, a new revolutionary concept was developed in the field of concrete technology i.e., self-compacting geopolymer concrete (SCGPC) [7]. It is an innovative type of concrete that does not require vibration for placing it and can be produced by complete elimination of ordinary Portland cement [8]. But many researchers studied the mechanical and durability properties of SCGPC at ambient temperature and limited research carried at the elevated temperature.

In this study, it is aimed to investigate the effect of fly ash and ground granulated blast furnace slag (GGBS) as binders on the hardened properties of SCGPC at elevated temperature. After 7, 28 and 56 days of ambient curing, the specimens were kept at an elevated temperature (100, 200, 400, 600 and 800^{o}C) for 2 hours and then testing of the specimens was carried out. Hardened concrete properties viz., compressive strength and split tensile strength were conducted.

II. EXPERIMENTAL STUDY

Materials

In this investigation, Class F (low calcium) fly ash produced from Rayalaseema Thermal Power Plant (RTPP), Muddanur. A.P and GGBS collected from Astra chemicals, Chennai were used at a ratio of 50:50 as geopolymer binders. The specific gravity of fly ash and GGBS are 2.25 and 2.83.The chemical properties of fly ash and GGBS are presented in Table 1. Combination of sodium hydroxide (8M, 10M and 12M) and sodium silicate solution is used as an alkaline activator. Locally available river sand conforming to grading zone II of IS: 383-2016 [9] and crushed granite stones of size 12.5 mm conforming to IS 383-2016[9] were used as fine and coarse aggregate respectively. The bulk specific gravity of the coarse aggregate and fine aggregate were 2.76 and 2.64,and the water absorption of coarse and fine aggregate were 3 and 1% respectively [10].The sieve analysis of 12.5 mm coarse aggregate are presented in Table 2 and fine aggregate gradation as shown in Fig.1, respectively [9]. Polycarboxylate ether based superplasticizer (SP) was used in SCGPC.

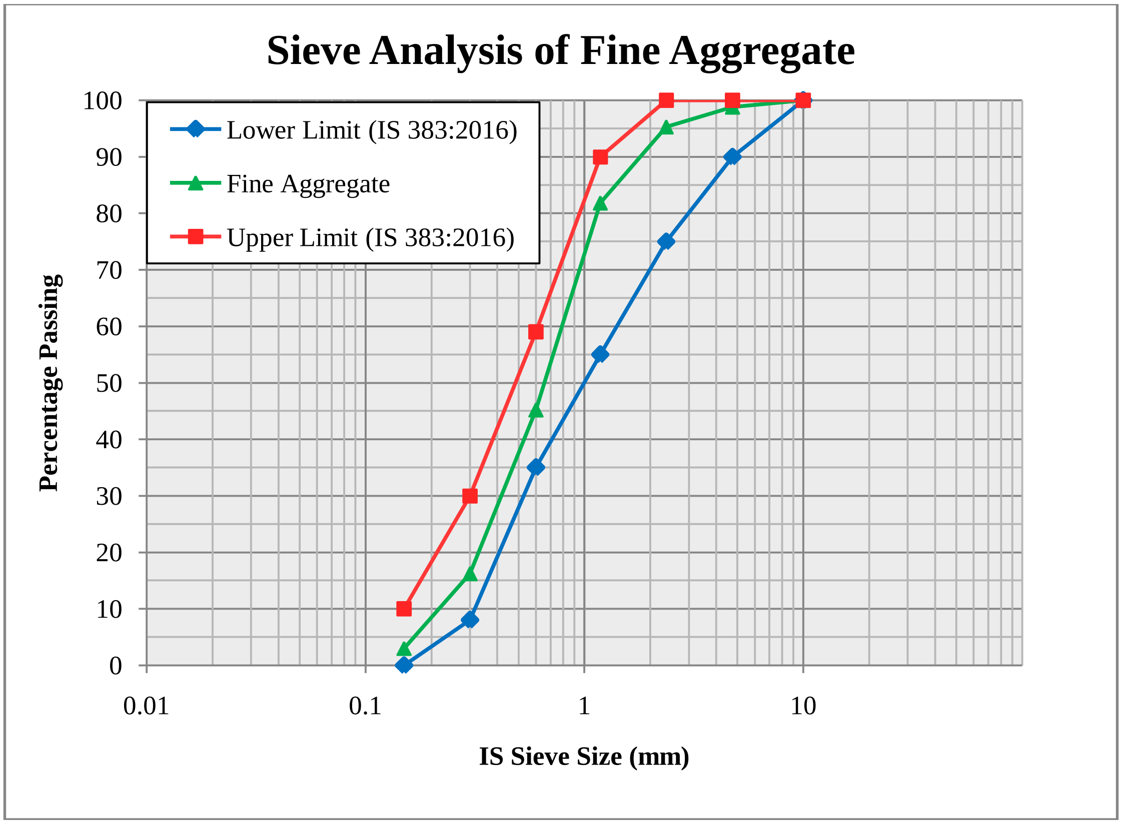

Fig 1. Sieve analysis of fine aggregate

Table 1: Chemical properties of fly ash and GGBS.

Particulars	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)	TiO_2 (%)	SO_3 (%)	LOI[a] (%)
Fly ash	65.4	28.2	3.0	1.0	1.0	0.5	0.2	0.29
GGBS	30.65	16.19	0.584	34.48	6.79	-	1.85	2.1

[a] LOI: loss of ignition

Table 2 : Sieve analysis of 12.5 mm coarse aggregate

Sieve Size	Cumulative Percent Passing	
	12.5 mm	IS: 383-2016 Limits
12.5 mm	99.64	85-100
10 mm	43.36	0-45
4.75 mm	6.67	0-10
2.36 mm	1.4	N/A

Mix proportions

The mix design in the case of self-compacting geopolymer concrete (SCGPC) is made by the help of EFNARC guidelines and Rangan's method [11 & 12]. The geopolymer binders like fly ash and GGBS are fixed at 50:50 proportion by mass. The water to geopolymer solids (W/G's) ratio by mass for all the mixes was maintained at 0.33 and the total powder content was fixed at 450 kg/m^3. To obtain the required workability characteristics of SCGPC, superplasticizer dosage of 2% by mass for the binder was used. For this study, the sodium hydroxide was taken different molarities like 8M, 10M and 12M.

Curing of Test Specimens

After demoulding the specimens, the test specimens were kept at ambient curing for different curing periods. At different ages, the specimens were kept at an elevated temperature (100, 200, 400, 600 and 800^{o}C) for 2 hours and then testing of the specimens was carried out.

III. RESULTS AND DISCUSSION

Compressive strength

In this study, the compressive strength of SCGPC mixes with different molarities (8M, 10M and 12M) were tested at different ages. The results are depicted in Fig 2, Fig3 and Fig 4 respectively. From Fig 2, it was observed that the there was a significant decrease in compressive strength with the increase in temperature from 100^oC to 800^oC in all mixes after curing period of 7 days. Similar type of trend was observed at 28 and 56 days also and depicted in Fig 3 and Fig 4. However, the increase of molarity increases the strength of SCGPC at all curing periods. From the observation, the maximum strength attained at ambient temperature i.e., 51.20 MPa (12M) at 56 days and minimum strength attained at 800^oC i.e., 13.80 MPa (8M) at 7 days. It is to be noted that the significant decrement in compressive strength is mainly due to continuous moisture loss from the specimens which produced voids and resulted in strength degradation and there was loss of moisture on the surface which may have developed surface cracks, hence strength of SCGPC decreased. At 800^oC, the strength of the concrete was reduced due to increase in the average pore size where amorphous structure was replaced by the crystalline Na-feldspars.

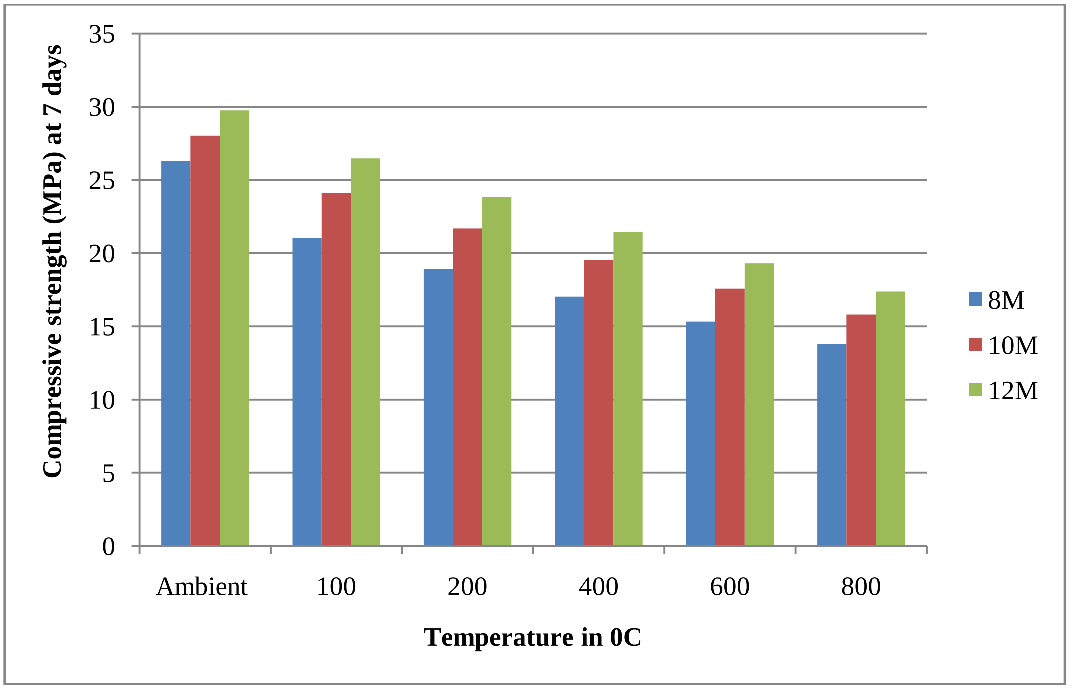

Fig 2. Compressive strength versus Temperature at 7 days

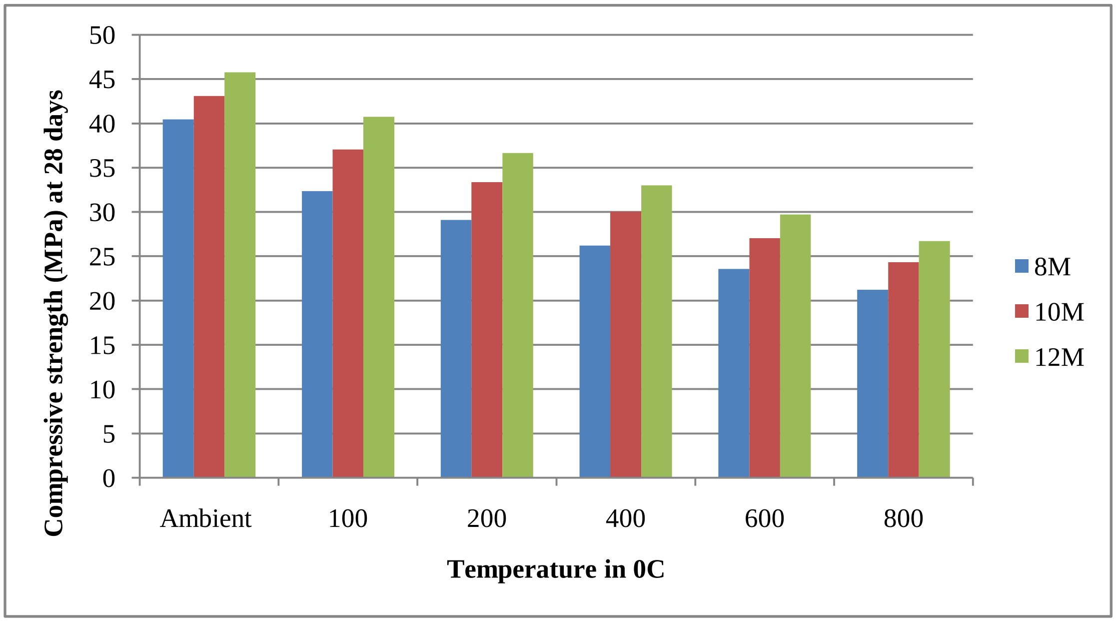

Fig 3. Compressive strength versus Temperature at 28 days

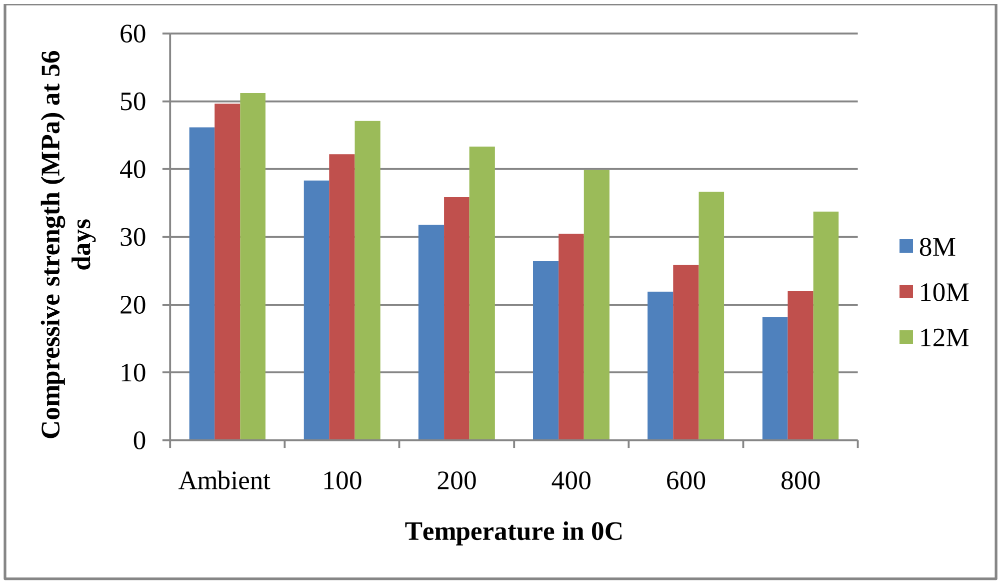

Fig 4. Compressive strength versus Temperature at 56 days

Split tensile strength

The split tensile strength of SCGPC mixes with different molarities (8M, 10M and 12M) were tested at different ages. The results are tabulated in Table 3. From the results, it was observed that the there was a significant decrease in split tensile strength with the increase in temperature from 100°C to 800°C in all mixes after curing period of 7 days. Similar type of trend was observed at 28 and 56 days also. From the observation, the maximum strength attained at ambient temperature i.e., 4.65 MPa (12M) at 56 days and minimum strength attained at 800°C i.e., 0.76 MPa (8M) at 7 days. It is to be noted that the significant decrement in split tensile strength is mainly due to increase in the average pore size, where amorphous structure was replaced by the crystalline Na-feldspars with increase in temperature from ambient to 800°C. There was continuous moisture loss from the specimens which produced voids and resulted in strength degradation.

Table 3: Split tensile strength of SCGPC

Mechanical property	**Age (days)**	**Temperature (⁰C)**	**Molarity**		
			8M	**10M**	**12M**
Split Tensile Strength (MPa)	7	Ambient	3.33	3.44	3.55
		100	2.47	2.68	2.91
		200	1.82	2.09	2.38
		400	1.35	1.63	1.95
		600	1.03	1.27	1.60
		800	0.76	0.99	1.31
	28	Ambient	4.13	4.27	4.40
		100	3.31	3.67	3.91
		200	2.98	3.30	3.52
		400	2.68	2.97	3.17
		600	2.41	2.68	2.79
		800	2.17	2.41	2.51
	56	Ambient	4.42	4.58	4.65
		100	3.67	3.89	4.28
		200	3.04	3.29	3.89
		400	2.54	2.80	3.58
		600	2.11	2.38	3.24
		800	1.75	2.02	2.98

IV. CONCLUSIONS

Based on the investigation, the following conclusions have been drawn.

1. The compressive strength and split tensile strength of SCGPC were decreased with the increase in temperature from 100^0C to 800^0C in all curing periods.
2. The significant decrement in split tensile strength was observed with the increase in temperature from 100^0C to 800^0C in all curing periods.
3. However, the increase of molarity increases the strength of SCGPC at all ages.
4. The significant decrement in mechanical properties (compressive strength and split tensile strength) up to 800^0C is mainly due to continuous moisture loss from the specimens and increase in the average pore size, which produce the lower strength of the concrete.

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