Quality Assessment of SCGPC using Ultra-Sonic Pulse Velocity at High Temperature

C. Sashidhar, C. Yedukondalu

Abstract*: This paper presents the effect of high temperature on compressive strength and ultra-sonic pulse velocity of self compacting geopolymer concrete (SCGPC) mixes with varying molarities viz., 8M, 10M and 12M. At different ages, the specimens were kept at a high temperature (100, 200, 400, 600 and 800^{o}C) for 2 hours and then testing of the specimens was carried out. Prior to compressive strength of test specimens, ultra-sonic pulse velocity (UPV) test was performed after 7, 28 and 56 days of curing. From the results, it is revealed that the compressive strength and UPV results of SCGPC were decreased with the increase in temperature from 100^{0}C to 800^{0}C in all curing periods. Finally, it is concluded that the significant decrement in compressive strength and UPV 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 and pulse velocity of the concrete.

Keywords*: Self compacting geopolymer concrete; compressive strength; UPV; high temperature.

I. INTRODUCTION

Self compacting geopolymer concrete (SCGPC) is a special concrete, it does not require any compaction during the casting and it also an alternative concrete material to avoid the carbon dioxide (CO_2) in the environment [1]. The SCGPC have better filling, passing ability and segregation resistance as compare to ordinary Portland concrete (OPC). The reason for easy flowing and self-compacting of SCGPC is mainly due to its self-weight and the materials used in the concrete [2]. The utilization of superplasticizer (SP) also improves the filling and passing ability of the SCGPC. Generally, the byproducts like fly ash, ground granulated blast furnace slag (GGBS), glass powder, metakaolin, rice husk ash and silica fume were used as binder materials [1]. To activate the binder materials the combination of sodium silicate and sodium hydroxide solutions were used as alkaline activator solution (AAS) [3&4]. The binder materials were easily activated with high temperature other than ambient temperature and hence showed better strength results [5].

However, Samuel Demie et al. [6], studied the effect of super plasticizer various from 3 to 7% and different curing temperatures viz., 60°C, 70°C, 80°C and 90°C on the hardened properties and concluded that the strength characteristics of SCGPC showed higher results with SP dosage of 6% and cured at 70°C oven temperature compare to other mixes [6]. Yamini and Niraj Shah [5], reported that the macro and microstructure properties of SCGPC with varying percentage of rice husk ash from 0 to 25% and studied results reveals that the high strength and dense micro structure obtained at 70°C oven temperature with optimum replacement 15% RHA. The increase in sodium hydroxide concentration was directly influenced the compressive strength of SCGPC at 70°C for a period of 48 hours [7]. Based on several researchers [5-7], it is revealed that the increase in temperature up to 70°C enhances the strength characteristics of SCGPC as compared to ambient temperature.

A. Ultrasonic pulse velocity (UPV)

The UPV test is conducted to estimate the homogeneity and quality of the concrete. The cracks and voids present in the concrete structures can be easily estimated using UPV results. Sreenivasulu et al [3], stated that the compressive strength of concrete was directly correlated with UPV results. Although, the correlation was not unique and it mainly depends on the mix proportion, type of concrete and curing type [8&9]. Roja and Guru Jawahar [10], observed that the UPV and strength properties of SCGPC increases with increasing percentage of copper slag as fine aggregate up to 50% replacement at ambient room temperature. The compressive strength and UPV value of GPC decreases with increase in temperature especially under extreme heat condition [11]. While considering all observations, it is concluded that the UPV plays a prominent role to assess the uniformity, quality and strength of the concrete. But many researchers studied the effect of pulse velocity through the SCGPC at ambient temperature and limited research carried at the high temperature.

For that, in this study, it is aimed to investigate the effect of high temperature on hardened properties viz., compressive strength and UPV of fly ash and ground granulated blast furnace slag (GGBS) blended SCGPC. After 7, 28 and 56 days of ambient curing, the specimens were kept at a high temperature (100, 200, 400, 600 and 800^{o}C) for 2 hours and then testing of the specimens was carried out. In addition to this study, a new model has been proposed by considering UPV value as an independent variable to predict the compressive strength of SCGPC.

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II. EXPERIMENTAL STUDY

A. Materials

B. Fly ash and GGBS

In this study, low calcium fly ash (Class F) produced from Rayalaseema Thermal Power Plant (RTPP), Muddanur, A.P and GGBS collected from Astrra chemicals, Chennai were used as binders with a proportion of 50:50 by weight. The physical properties such as specific gravity and fineness of fly ash were found to be 2.25 and 360 (m^2/kg), whereas specific gravity and fineness of GGBS were determined as 2.83 and 400 (m^2/kg).

C. Coarse and fine aggregates

Crushed granite stones of size 12.5 mm conforming to IS 383-2016 [12] and locally available natural sand conforming to grading zone II of IS: 383-2016 [12] were used as coarse and fine aggregates respectively. The bulk specific gravity of coarse and fine aggregate was 2.76 and 2.64, and the water absorption of coarse and fine aggregate was 0.3 and 1% respectively [13]. The sieve analysis of 12.5 mm coarse aggregate and fine aggregate are presented in Table I & II. According to IS 383-2016 [12], the fineness modulus of fine aggregate was found to be 2.54.

Table I: 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

Table II: Sieve analysis of fine aggregate

Sieve Size	*Cumulative Percent Passing*	
	12.5 mm	*IS: 383-2016 – Zone II requirement*
10 mm	100	100
4.75 mm	98.8	90-100
2.36 mm	95.59	75-100
1.18 mm	83.15	55-90
600 μm	47.04	35-59
300 μm	17.85	8-30
150 μm	3.81	0-10

D. Alkaline Liquid

The combination of sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) solution were used as alkaline activator solution (AAS). The sodium silicate solution (Na_2O = 13.7%, SiO_2 = 29.4%, and water = 55.9% by mass) and sodium hydroxide (NaOH) in the form of flakes or pellets with 97%-98% purity were used. The Na_2SiO_3 solution and NaOH were purchased from Astrra chemicals, Chennai. In this study, the NaOH was used as an activator with varying molarity of 8M, 10M and 12M respectively. The sodium silicate and sodium hydroxide solution were prepared one day before prior to use [14].

E. Chemical admixtures

In this study, polycarboxylate ether was used as high range water reducer (HRWR) or superplasticizer (SP) to get better workability.

F. Water

Ordinary tap water was used in the preparation of SCGPC.

III. 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 [15&16]. 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 respectively.

IV. 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 a high temperature (100, 200, 400, 600 and 800^oC) for 2 hours and then testing of the specimens was carried out.

V. METHODOLOGY

The compressive strength of SCGPC was evaluated using the guidelines given by IS 516-1959 [17]. The UPV test (direct transmission) was conducted prior to the compressive strength based on the limitations given in IS 13311-1992 [18].

VI. RESULTS AND DISCUSSION

A. Compressive strength

In this study, the compressive strength of SCGPC mixes with different molarities (8M, 10M and 12M) were tested at different ages and the studied results are depicted in Fig 1, Fig 2 and Fig 3 respectively. From Fig 1, 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 2 and Fig 3. However, the increase of molarity increases strength of SCGPC at all ages. 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 concrete strength was reduced due to increase in the average pore size where amorphous structure was replaced by the crystalline Na-feldspars.

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B. Ultra-sonic pulse velocity

Table III shows the UPV of SCGPC mixes (8M, 10M and 12M) at different curing periods viz., 7, 28 and 56 days respectively. From Table 3, it was observed that the there was a significant decrease in UPV with the increase in temperature from 100°C to 800°C in all mixes after curing period of 7, 28 and 56 days, respectively. From the observation, the maximum pulse velocity attained at ambient temperature i.e., 4133 m/sec (12M) at 56 days and minimum pulse velocity attained at 800°C i.e., 1626 (8M) at 7 days. It is to be noted that the significant decrement in UPV is mainly due to increase in the average pore size and crack width, it results the pulse travelled through SCGPC takes more time (i.e., pulse travel from transducer to receiver) then the velocity should be decreases with increase in temperature from ambient to 800°C. The continuous moisture loss in SCGPC due to increase of temperature was also effect the pulse travelled time and resulted in pulse velocity degradation.

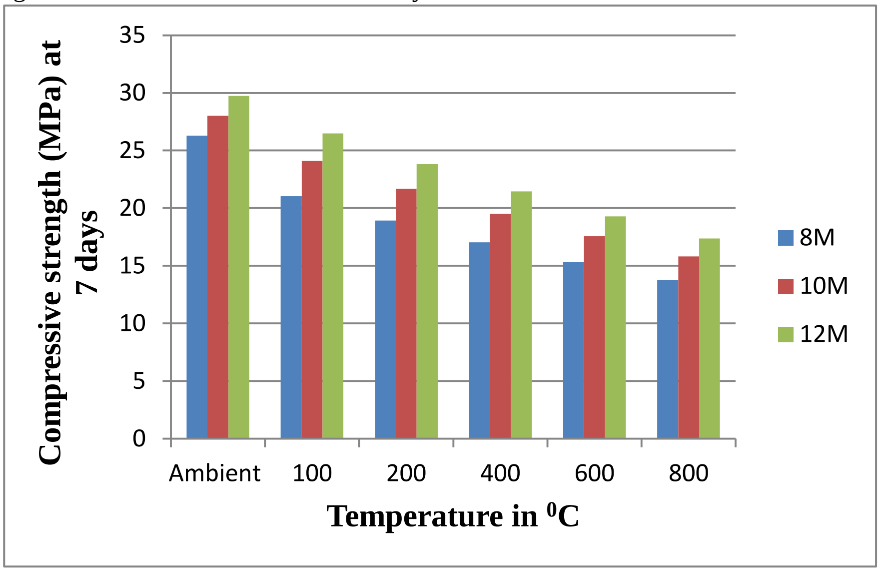

Fig 1. Compressive strength versus Temperature at 7 days

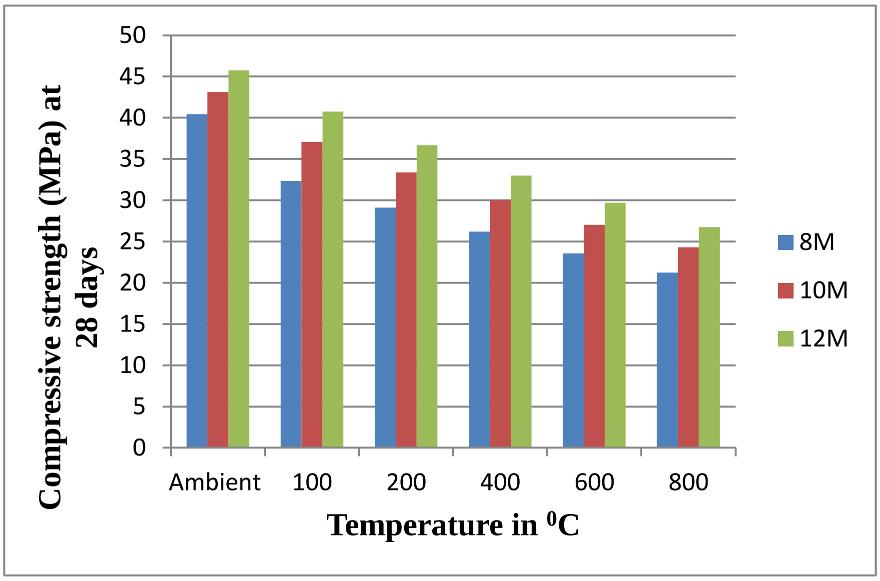

Fig 2. Compressive strength versus Temperature at 28 days

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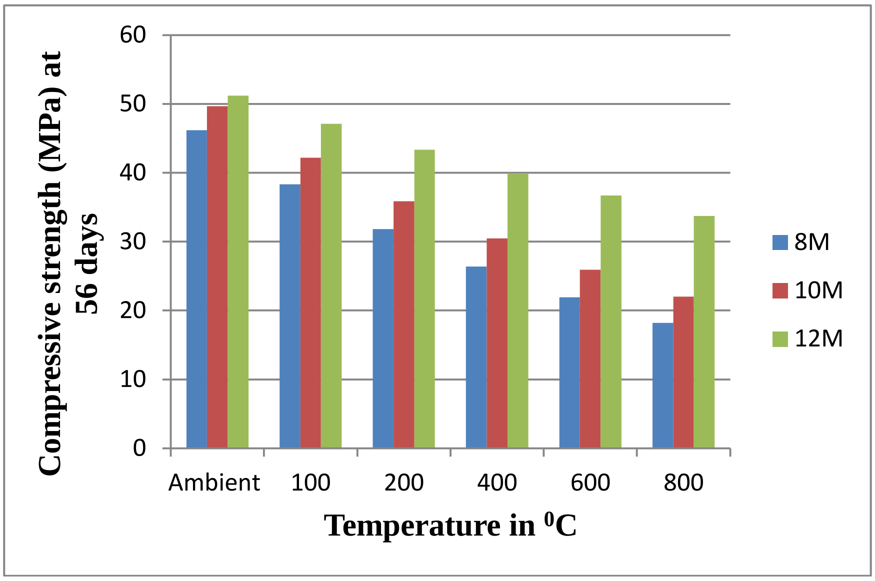

Fig 3. Compressive strength versus Temperature at 56 days

Table III: UPV of SCGPC

Mechanical property	***Age (days)***	***Temperature (^{0}C)***	***Molarity***		
			8M	***10M***	***12M***
Ultra-sonic pulse velocity (m/sec)	7	Ambient	2754	2805	2883
		100	2479	2581	2710
		200	2231	2374	2547
		400	2008	2184	2395
		600	1807	2009	2251
		800	1626	1849	2116
	28	Ambient	3084	3394	3690
		100	2899	3258	3616
		200	2725	3128	3544
		400	2562	3003	3473
		600	2408	2883	3404
		800	2264	2767	3336
	56	Ambient	3362	3733	4133
		100	3177	3569	4042
		200	3002	3412	3953
		400	2837	3262	3866
		600	2681	3118	3781
		800	2534	2981	3698

C. Compressive strength versus UPV

In order to predict the compressive strength of SCGPC, a new model has been proposed by considering UPV value as an independent variable. The calibration curve for compressive strength versus UPV of SCGPC is shown in Fig. 4 and the proposed equation as follows.

$$f'c = 6.98 \times e^{0.00047\ V}$$

Where, $f'c$ and V are compressive strength and UPV.

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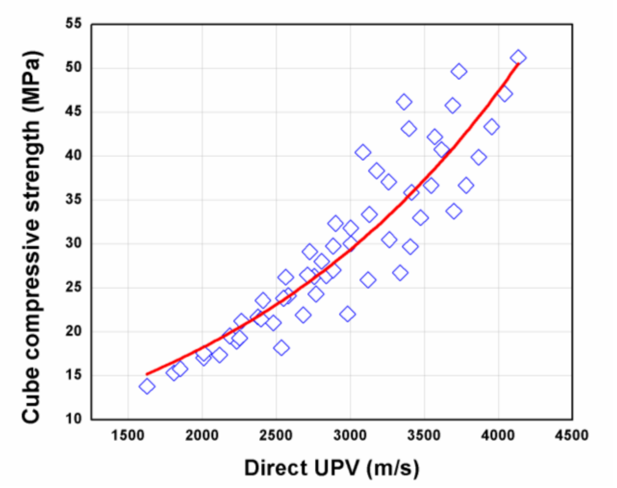

Fig 4. Compressive strength versus UPV of SCGPC

D. Effect of high temperature on compressive strength

The effect of high temperature on compressive strength of SCGPC mixes with different molarities (8M, 10M and 12M) are depicted in Fig 5. From Fig 5, it is observed that the there was a significant decrease in compressive strength with the increase in temperature from 100°C to 800°C in all mixes after ambient curing period of 7, 28 and 56 days respectively.

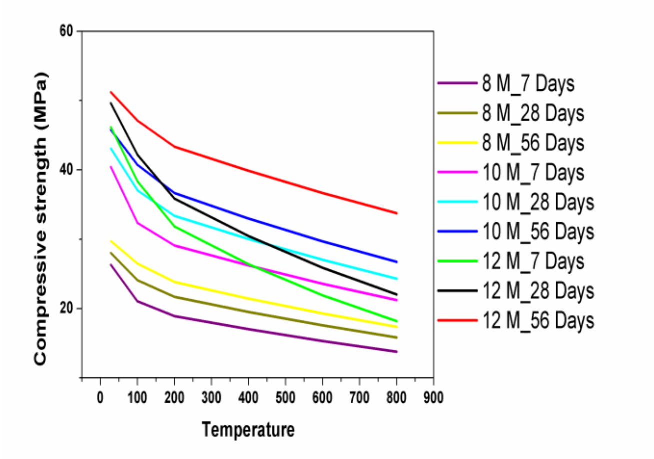

Fig 5. Effect of high temperature on compressive strength

From the observation, the maximum strength loss was attained for the 12 M mixes and the minimum strength loss was attained for the 8 M mixes due to effect of high temperature. The significant decrement in compressive strength is mainly due to reduction in the rate of degree of polymerization, increase in the total porosity and amount of smaller pores in the concrete matrix.

VII. CONCLUSIONS

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

1. The compressive strength of SCGPC was decreased with the increase in temperature from 100°C to 800°C in all curing periods.
2. The significant decrement in ultra-sonic pulse velocity was observed with the increase in temperature from 100°C to 800°C in all curing periods.
3. However, the increase of molarity increases the strength of SCGPC and pulse velocity of concrete at all ages.
4. The significant decrement in UPV is mainly due to increase in the average pore size and crack width, it results the pulse travelled through SCGPC takes more time (i.e., pulse travel from transducer to receiver) then the velocity has been decreased with increase in temperature from 100°C to 800°C.
5. The continuous moisture loss in SCGPC due to increase of temperature was also effect the pulse travelled time and resulted in pulse velocity degradation.

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