Experimental investigation on the effect of thermal cycles on the strength properties of glass fibre SCC

P. Srinivasa Rao and Seshadri Sekhar T.

Concrete structures are exposed to temperature variations mainly due to solar radiation. As reported in literature, concrete containing 100 percent Ordinary Portland Cement (OPC) exhibited a steady decline in residual compressive concrete strength when subjected to thermal cycles. The elimination of vibration in compacting concrete during placing through the use of Self Compacting Concrete (SCC) leads to substantial advantages related to better homogeneity, enhancement of working environment and improvement in the productivity by increasing the speed of construction This paper presents an experimental investigation on the effect of thermal cycles on the strength properties of glass fibre self compacting concrete using alkaline glass fibres in various proportions of controlled mixes of grade M30 to M65.

INTRODUCTION

Concrete roof slabs, external columns and walls are exposed to solar radiation throughout their designed life span. The surface temperature of the exposed element increases gradually from sunrise and reaches maximum value between 12 noon to 3 pm. It is known that surface temperature of the structures reaches nearly two times greater than the ambient temperature. At many places in India, the ambient air temperature during summer goes beyond 40°C and in such places the surface temperature of the exposed elements such as roof slab, external column, beam and walls may reach somewhere between 80°C to 90°C. The degree of humidity also influences thermal gradient within the elements of structures exposed to solar radiation. Thus, all the structural elements that are exposed to solar radiation are said to experience one thermal cycle in a day, that is, a heating period to a peak value and then subsequent cooling period in a day. The extensive use of concrete as a structural material in all the above mentioned structures necessitates a study of the concrete subjected to thermal cycles.

RESEARCH SIGNIFICANCE

For a newly developing material like Self compacting concrete, studies on the effect of thermal cycles are of paramount importance for instilling confidence among the engineers and builders. The literature indicate that few studies are available on the effect of thermal cycles on plain self compacting concrete and fibre reinforced ordinary concrete. A comprehensive study which involves the studies on the effect of thermal cycles on strength properties of specimens of glass fibre self compacting concretes are not available. Hence, considering the gap in the existing literature, an attempt has been made to the study the effect of glass fibres when specimens of glass fibre self compacting concrete are subjected to thermal cycles.

LITERATURE REVIEW

Dr P. Srinivasa Rao et.al [1] in their investigation on concretes OPC and fly ash concretes of grade M20 and M30 exposed to various thermal cycles at different temperatures concluded that the resistance to adverse effect of thermal cycles is more for fly ash concrete when compared to ordinary concrete. Bairagi et.al [2] is significant step towards determination of variation in strength of concrete exposed to thermal cycles and concluded that thermal effects have an adverse effect on the compressive strength and dynamic modulus of elasticity. The reduction in compressive strength is because of formation of micro cracks at the interface between coarse aggregate and cement paste even prior to the application of the load on concrete. In case of concrete subjected to thermal cycles, the micro cracks further increase, probably due to the different coefficient of thermal expansion of cement matrix and aggregate .Internal stresses created due to unequal expansion or contraction of concrete constitutes might lead to an increase in the micro cracks. Okamura [3] proposed a mix design method for SCC based on paste and mortar studies for superplasticiser compatibility followed by trail mixes. However, it is emphasised that the need to test the final product for passing ability, filling ability, and flow and segregation resistance is more relevant. Manu santhanam et.al [4] discussed the existing research about various aspects of self compacting concrete, including materials and mixture design , test methods, construction-related issues, and properties. They summarised that self compacting concrete is a recent development that shows potential for future applications. It meets the demand placed by requirements of speed and quality in construction. Jagadish Vengala et. al [5] found that use of fine fly ash for obtaining self compacting concrete resulted in an increase of the 28 day compressive strength concrete by about 38%. Self compacting concrete was achieved when volume of paste was between 0.43 and 0.45 Dr. Seshadri Sekhar [6] has studied the effect of thermal cycles on concrete specimens of grade of concretes M30 to M65.

EXPERIMENTAL PROGRAMME

- To study the behavior of self compacting and glass fibre self compacting concrete specimens of M 30 to M 65 subjected to Zero, 28, 90 and 180 Thermal cycles .
- To study the effect of glass fibres on glass fibre self compacting concrete specimens when subjected to thermal cycles.

Materials

Cement

Ordinary Portland cement of 53 grade having specific gravity of 3.02 and fineness of 3200 cm^2/gm was used in the investigation. The cement used has been tested for various proportions as per IS 4031:1988 and found to be confirming to various specifications of are IS 12269:1987.

Coarse aggregate

Crushed angular granite metal of 10 mm size having the specific gravity of 2.65 and fineness modulus 6.05 was used.

Fine aggregate

River sand having the specific gravity of 2.55 and fineness modulus 2.77 was used.

Viscosity modifying agent

A viscosity modified admixture for rheodynamic concrete which is colourless free flowing liquid and having specific of gravity 1.01 ± 0.01 @ 25^oC and pH value as 8 ± 1 and Chloride Content nil was used .

Admixture

The modified polycarboxylated ether based super - plasticiser which is pale yellow colour and free flowing liquid and having Relative density 1.10 ± 0.01 at 25^oC, pH >6 and Chloride Ion content <0.2% was used .

Fly ash

Type-II fly ash confirming to IS 3812:1981 of Indian Standard Specification was used .

Glass fibres

The glass fibres were Anti Crack HD fibres of a reputed brand with Modulus of Elasticity 72 GPA, Filament diameter 14 microns, Specific Gravity 2.68, length 12 mm and having the aspect ratio of 857.1. The number of fibres per 1 kg is 212 million.

Table 1. Quantities of materials required per 1 cum of glass fibre self compacting concretes

Grade of concrete	Cement (kg/m^3)	Fly ash (kg/m^3)	Coarse aggregate (kg/m^3)	Fine aggregate (kg/m^3)	Water (kg/m^3)	SP (kg/m^3)	V.M.A (kg/m^3)	Glass fibres
M 30	225	225	865	898	179	4.50	0.315	0.03 % of concrete volume
M 35	231	231	862	864	175	4.62	0.370	
M 40	258	258	835	836	176	5.16	0.413	
M 45	330	220	826	827	176	5.50	0.440	
M 50	360	240	797	796	180	6.00	0.480	
M 55	360	240	812	813	168	6.00	0.480	
M 60	400	250	785	785	172	9.75	0.460	
M 65	450	250	760	760	174	11.20	0.490	

TEST SPECIMENS

Test specimens consisting of 100x100x100 mm cubes, 150 x 300 mm cylinders and 100x100x500 mm beams were cast using different concrete mixes as given in Table 1. These specimens were tested as per IS 516 and 1199.

DISCUSSION OF TEST RESULTS

Quantities of materials and fresh state properties of self compacting concrete and glass fibre self compacting concretes mixes

Table 1 gives the quantities of material required for self compacting concrete and Glass fibre self compacting concretes of grades M30 to M65. The casting was done by verifying the fresh state properties of high flow ability and segregation resistance as specified by guidelines by EFNARC.

Effect of glass fibre on bleeding

On the basis of the experimental study it was concluded that addition of glass fibres in concrete gives a reduction in bleeding. A reduction in bleeding improves the surface integrity of concrete, improves its homogeneity, and reduces the probability of cracks .

Table 2. Compressive strength, split tensile strength, flexural strength of self compacting concrete at 50°C at various thermal cycles

Grade of concrete	No. of days	50°C															
		M 30	M 35	M 40	M 45	M 50	M 55	M 60	M 65	M30 / GF	M35 / GF	M40 / GF	M45 / GF	M50 / GF	M55 / GF	M60 / GF	M65 / GF
Compressive strength (MPa)	0	33.94	38.90	41.20	45.95	53	56	61.64	66.29	39.37	44.74	47.80	53.30	61.00	66.88	70.89	76.24
	28	49.12	55.84	57.30	66.29	74.50	78.20	88.76	94.79	56.55	65.09	67.15	76.75	89.06	91.62	100.66	107.50
	90	53.62	61.50	64.50	70.75	82.41	88.35	95.54	103.41	61.02	70.54	72.02	83.15	96.77	99.65	109.18	115.88
	180	53.96	61.52	64.68	71.22	83.21	88.48	96.15	104.73	61.41	70.61	72.22	83.68	97.01	99.94	109.80	116.65
Split tensile strength (MPa)	0	3.01	3.25	3.68	4.08	4.44	4.67	5.21	6.44	3.50	3.84	4.23	4.69	5.06	5.37	5.88	7.27
	28	4.46	4.81	5.12	5.67	6.26	6.49	7.18	8.75	5.18	5.62	6.06	6.66	7.03	7.41	8.29	10.39
	90	4.90	5.29	5.74	6.41	6.92	7.14	7.97	10.04	5.45	6.20	6.62	7.41	7.69	8.00	9.18	11.19
	180	4.94	5.32	5.79	6.43	6.93	7.17	8.18	10.15	5.48	6.26	6.68	7.45	7.74	8.12	9.24	11.27
Flexural strength (MPa)	0	3.15	3.49	3.88	4.22	4.59	5.01	5.46	5.95	3.65	4.08	4.46	4.94	5.29	5.76	6.16	6.71
	28	4.41	4.89	5.59	5.86	6.20	7.11	7.75	8.39	5.04	5.40	6.48	6.97	7.30	8.46	8.56	9.46
	90	4.82	5.34	6.25	6.50	6.81	7.72	8.52	9.10	5.43	5.97	6.84	7.34	7.93	8.87	9.18	10.46
	180	4.85	5.37	6.28	6.58	6.87	7.78	8.58	9.14	5.48	6.11	7.00	7.38	8.01	8.98	9.30	10.51

Table 3. Compressive strength, split tensile strength, flexural strength of self compacting concrete at 100°C at various thermal cycles

Grade of concrete	No. of days	100°C															
		M 30	M 35	M 40	M 45	M 50	M 55	M 60	M 65	M30 / GF	M35 / GF	M40 / GF	M45 / GF	M50 / GF	M55 / GF	M60 / GF	M65 / GF
Compressive strength (MPa)	0	33.94	38.90	41.20	45.95	53	56	61.64	66.29	39.37	44.74	47.80	53.30	61.00	66.88	70.89	76.24
	28	41.41	47.88	50.08	56.06	64.92	67.88	75.20	81.54	48.43	55.52	58.38	64.50	75.03	81.59	86.49	93.01
	90	44.11	50.78	52.97	61.11	67.46	72.36	80.74	86.17	51.57	58.65	62.06	70.90	79.91	86.40	93.58	99.87
	180	44.46	51.35	53.36	61.57	67.84	72.80	81.36	86.38	51.96	58.91	62.42	71.42	80.52	86.42	94.29	101.02
Split tensile strength (MPa)	0	3.01	3.25	3.68	4.08	4.44	4.67	5.21	6.44	3.50	3.84	4.23	4.69	5.06	5.37	5.88	7.27
	28	3.67	3.93	4.45	5.01	5.37	5.74	6.41	7.98	4.23	4.71	5.25	5.72	6.17	6.55	7.05	8.8
	90	3.88	4.09	4.64	5.27	5.60	6.06	6.73	8.31	4.55	4.90	5.51	6.14	6.49	6.88	7.70	9.38
	180	3.95	4.11	4.68	5.30	5.62	6.08	6.80	8.35	4.62	4.96	5.57	6.18	6.58	6.93	7.78	9.47
Flexural strength (MPa)	0	3.15	3.49	3.88	4.22	4.59	5.01	5.46	5.95	3.65	4.08	4.46	4.94	5.29	5.76	6.16	6.71
	28	3.85	4.26	4.81	5.19	5.59	6.16	6.66	7.26	4.46	5.01	5.40	6.38	6.50	7.08	7.51	8.18
	90	4.06	4.47	5.09	5.44	5.97	6.53	7.05	7.68	4.78	5.30	5.87	6.48	6.85	7.51	8.00	8.86
	180	4.09	4.51	5.12	5.52	6.01	6.57	7.09	7.71	4.81	5.36	5.87	6.51	6.92	7.59	8.06	8.91

Behaviour of self compacting concrete and glass fibre self compacted concrete when subjected to zero, 28, 90 and 180 thermal cycles at 50°C and 100°C

Tables 2 and 3 gives the compressive , split tensile and flexural behaviour of self compacting and glass fibre self compacting concrete at zero, 90 and 180 thermal cycles at 50°C and 100°C. It is observed that 40 to 60% and 20 to 30 % variation in strength properties at 50°C and 100°C respectively. The behavior is shown in Figures 1 to 6.

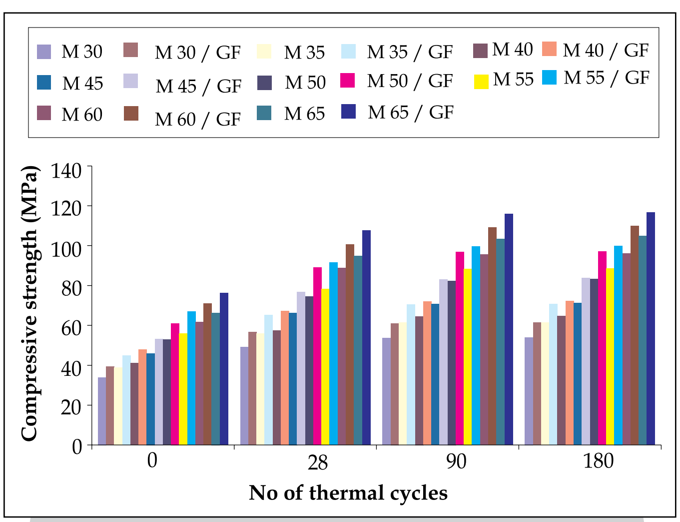

Figure 1. Variation of compressive strength at different thermal cycles of glass fibre self compacting concrete 50°C

The percentage increase in heated compressive strength of self compacting concrete and glass fibre self compacting concrete mixes was due to the dehydration C-S-H gel bond forms, leaving some amount of $Ca(OH)_2$ free. This free lime will be engaged by the SiO_2 available in low calcium fly ash and forms a strong C-S-H bond, which is responsible for higher strengths.

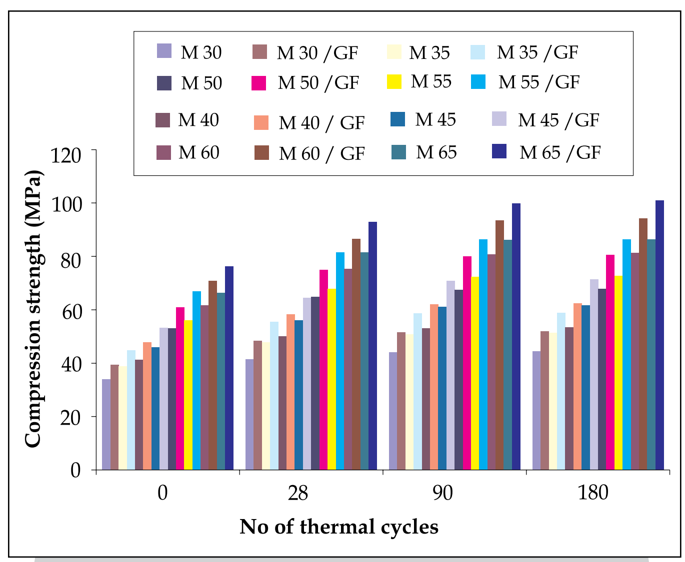

Figure 2. Variation of compressive strength at different thermal cycles of glass fibre self compacting concrete at 100°C

Effect of glass fibres on compressive, split tensile and flexural strength values of various grades of concrete specimens subjected to different thermal cycles at 50°C and 100°C.

The increase in compressive split tensile and flexural strength of various grades of glass fibre self compacting concrete mixes compared with self compacting concrete when subjected to different thermal cycles at 50°C and 100°C is observed to be 15% to 20%.

On the basis of the experimental study, it was observed that addition of glass fibres in concrete gives a reduction in bleeding. A reduction in bleeding improves the surface integrity of concrete, improves its homogeneity, and reduces the probability of cracks. The glass fibres suppress the localisation of micro cracks into macro cracks. The strength increased continuously for all mixes at all ages. The elastic modulus of Anti Crack HD fibre is significantly greater than that of hardened concrete. Therefore it is able to provide reinforcement not only during the setting process, but also to the hardened concrete.

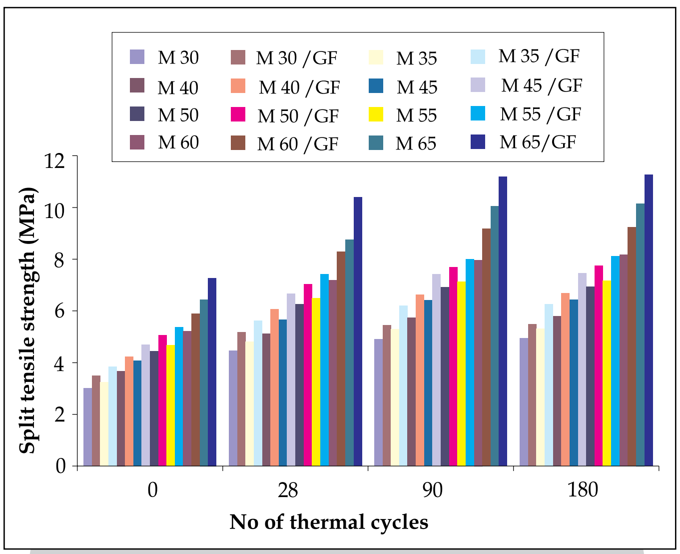

Figure 3. Variation of split tensile strength at different thermal cycles of glass fibre self compacting concrete at 50°C

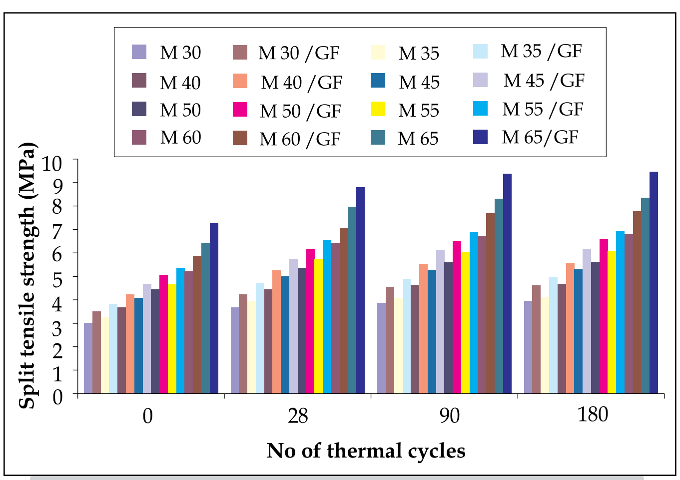

Figure 4. Variation of split tensile strength at different thermal cycles of glass fibre self compacting concrete at 100°C

CONCLUSIONS

1. The improvements in compressive, split tensile, flexural strength of self compacting concrete and glass fibre self compacting concrete mixes in comparison with zero thermal cycles for 50°C are

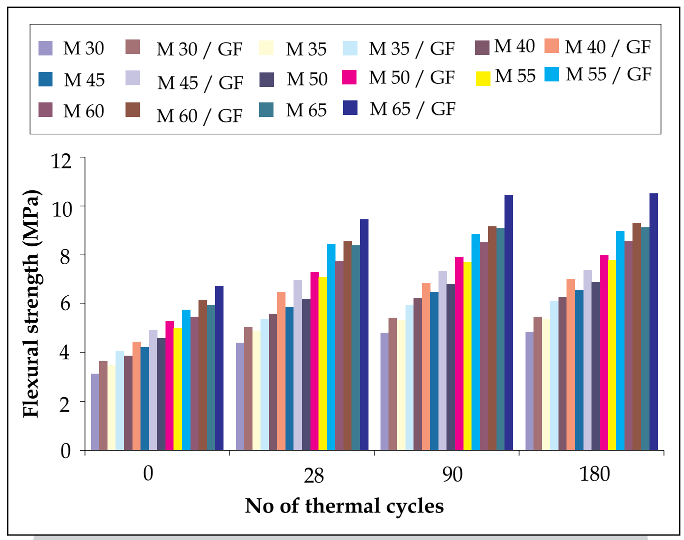

Figure 5. Variation of flexural strength of glass fibre self compacting concrete at different thermal cycles at 50°C

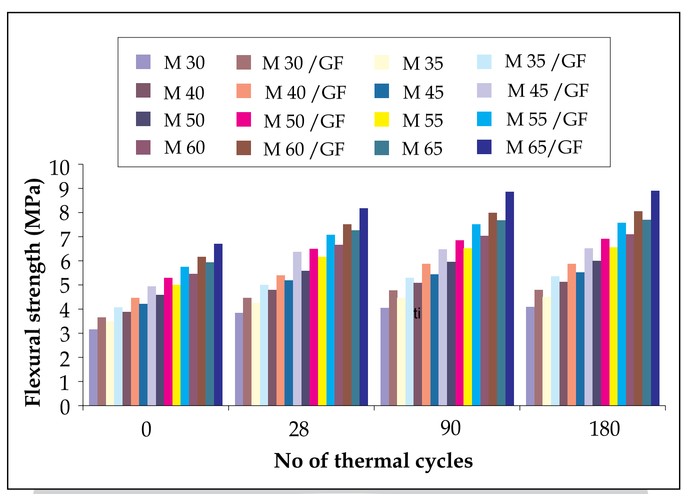

Figure 6. Variation of flexural strength of glass fibre self compacting concrete at different thermal cycles at 100°C

observed to be varied from 40 to 60 % for 28, 90, and 180 thermal cycles.

2. The improvements in compressive, split tensile, flexural strength of self compacting concrete and glass fibre self compacting concrete mixes in comparison with zero thermal cycles for 100°C are observed to be varied from 20 to 30 % for 28, 90, and 180 thermal cycles.

3. Glass fibre self compacting concrete mixes are observed to give higher strengths than self compacting concrete mixes when exposed to thermal cycles.

4. The variation in strengths of glass fibre self compacting concrete mixes is observed to be 15 to 20% when compared with self compacting concrete mixes subjected to various thermal cycles at 50°C and 100°C.

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Dr. P. Srinivasa Rao is a Professor in Civil Engineering, J.N.T University College of Engineering, Kukatpally Hyderabad. He is specialised in structural engineering and his research interests are concrete technology, structural design, high performance concrete, prefabricating structures, special concretes and use of micro silica, fly ash in building materials. He has been associates with a number of designs projects, for number of organisations and involved as a key person in quality control and mix designs. He has guided more than 20 PhD students and 100 M.Tech projects. He is a member of ISTE, ICI and Institution of Engineers and has delivered invited lectures in many organisations and institutions.

Dr. Seshadri Sekhar T. holds an M.Tech (Structural Engg) and PhD (Structural Engg) from JNTU, Hyderabad. He is Professor and Dean of NICMAR Hyderabad Campus, Telangana. He has published 110 research papers, guided four PhD candidates and presently five PhD candidates are working under his supervision. His research interests are concrete technology, high performance concrete and special concretes. He is Fellow member of ICI, Fellow of IE (I).