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Split Tensile Strength of Steel Fibre Reinforced Concrete with Fly Ash and Silica Fume as Binary and Ternary Blends under Chloride Curing

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Abstract

Test results of investigation on split tensile strength of steel fibre reinforced concrete with fly ash and silica fume as binary and ternary blend, cured up to 150 days under normal water and 5% sodium chloride solutions are presented. Mix proportions of 1:1.90:2.89 with 0.45 water-cement ratio were adopted. 0.75% volume fraction of crimped steel fibres having 0.5mm diameter and 36mm long were used. Seven combinations of mixes with replacement levels of fly ash (0, 20, 30 and 40%) as binary blend and silica fume (10%) as ternary blend were adopted. Naphthalene-formaldehyde-sulphonate-based super plasticizer was used during mixing. Split tensile strengths of all the mix combinations at different curing periods were obtained. All ternary blended mixes showed higher strengths than that of corresponding binary blended mixes at all ages under both normal and chloride curing conditions. Blended specimens showed increased values of strength ratio than control specimens under chloride curing, at all ages, indicating the effect of continued process of strength gaining whereas unblended specimens showed the process of reduction in strength.

Keywords: Steel fibre reinforced concrete, Fly ash, Silica fume, Binary blend, Ternary blend.

1. Introduction

Steel fibre reinforced concrete (SFRC) is a composite material consisting of plain concrete and randomly oriented discontinuous, discrete fibres. SFRC finds its application in tunnel lining, highway and airfield pavements and overlays, industrial floors and repair of hydraulic structures. It can also be used for castable linings, which are subjected to high temperatures and impulsive loads (Kunio Nishioka et.al., 1975). Plain concrete, being brittle in nature, has lower tensile strength and lower resistance to crack propagation. Due to inherent volumetric and micro structural changes, micro cracks develop during the manufacture of concrete. These micro cracks widen under loading (Ghosh, S. et.al, 1989). The fibres help to bridge and arrest the cracks and restrict the growth of flaws in the matrix, controlling them from enlarging under stresses into cracks which eventually cause failure (Kukreja C.B, et.al., 1980). The addition of these fibres improves significantly many other engineering properties of concrete such as flexural strength, shear strength, fracture toughness, post-cracking ductility, resistance to fatigue, impact, thermal variations, wear and spalling. These property improvements can be used to reduce the section and to enhance performance or both. Although, SFRC enhances many properties, it should be durable without deterioration over a longer period of exposure, especially when subjected to physical or chemical attacks, either external or internal, caused under aggressive environments (Krishnamoorthy T.S, et.al. 2000).

Mineral admixtures such as fly ash, silica fume, blast furnace slag, rice husk ash, are finely divided siliceous materials and are added to concrete as a partial replacement for cement. These admixtures improve the performance characteristics of concrete due to its pozzolanic and/or cementitious property, that too when exposed to aggressive environments. The addition of these admixtures also results in significant savings in energy and cost.

As steel fibres have almost zero cover near the surface of SFRC structural elements, their durability aspects under aggressive environments are of much importance and use of mineral admixtures may help in such situations. Many investigators have studied the mechanical properties and durability characteristics of SFRC with and/or without binary blending of mineral admixtures. However, a few studies have been reported on influence of binary and ternary blends on strength and durability aspects of SFRC under chloride environment. The combination of fly ash and silica fume as binary and ternary blends should result in a number of synergistic effects (Thomas M.D.A, et.al 1999). Hence an effort has been made to study the effect of fly ash and silica fume as binary and ternary blend on the split tensile strength of SFRC under chloride storage. This paper discusses the test results of the experimental investigation of the study.

2. Experimental Programme

2.1 Materials

Fly ash was obtained from Raichur Thermal Power Station, Raichur, Karnataka and was of Class F category. Samples of fly ash were collected directly from all six hoppers of the electrostatic precipitator (ESP) system starting from closest to farthest hoppers from the boiler. After preliminary studies for its effect on compressive strength, fly ash with higher fineness of 5601 cm^2/gm and specific gravity of 2.247 was used as partial replacement for cement during preparation of SFRC.

Ordinary Portland cement satisfying the requirements of IS 8112-1989 (43 grade) with a 28 day strength of 44.2 MPa was used. Locally available river sand with a fineness modulus of 2.19 and a specific gravity of 2.62, and crushed granite aggregate of maximum size 20mm and specific gravity of 2.72 were used. Potable tap water available in the laboratory was used for mixing and curing of the concrete. Crimped type of steel fibres available in market with an average length of 36 mm and diameter of 0.5mm were used. The superplasticizer used was naphthalene-formaldehyde-sulphonate-based, which is capable of maintaining effectiveness over the period usually needed for manufacturing and placing of SFRC.

2.2 Mix Proportions

Concrete mix proportions of 1:1.90:2.89 with water-binder ratio 0.45, fibre volume fraction 0.75 % and seven levels of partial replacement by fly ash and silica fume as binary and ternary blend were used. The details of the mix proportions are presented in Table 1. For all mixes workability was kept constant with slump values ranges between 15-25mm by controlling the dosage of superplasicizer. The mixes were designated as SA, SB, SC, and SD for 0, 20, 30 and 40% fly ash replacement respectively and, SE, SF, and SG for (10+10, 20+10 and 30+10%) fly ash + silica fume replacement respectively.

Table 1: Proportioning of mixes by absolute volume method.

Mix	Cement (kg/m3)	Fly ash (kg/m3)	Silica fume (kg/m3)	Sand (kg/m3)	Coarse Agg. (kg/m3)	Water (kg/m3)	Fibre (kg/m3)	SP(%) by wt. of cement
SA	385.0	0.0	0.0	731.5	1112.6	173.3	58.0	0.5
SB	308.0	77.0	0.0	731.5	1112.6	173.3	58.0	0.5
SC	269.5	115.5	0.0	731.5	1112.6	173.3	58.0	0.5
SD	231.0	154.0	0.0	731.5	1112.6	173.3	58.0	0.5
SE	308.0	38.5	38.5	731.5	1112.6	173.3	58.0	0.8
SF	269.5	77.0	38.5	731.5	1112.6	173.3	58.0	0.8
SG	231.0	115.5	38.5	731.5	1112.6	173.3	58.0	0.8

2.3 Mixing, Casting and Curing

First the dry mixtures of binders (cement, fly ash and silica fume), sand and coarse aggregates were charged and mixed in the laboratory concrete mixer of rotary drum type. About two-thirds of total quantity of required water-superplasticizer mixture was added to the dry mixture and mixed for 2-3 minutes continuously. Then the clump-free steel fibres were fed into the concrete mixer by uniform sprinkling. While feeding the fibres, the drum was kept rotating to ensure uniform mixing of fibres with the concrete. Addition of fibres usually takes about 2-3 minutes. Finally the remaining water-superplasticizer mixture was added and mixed for another 2 minutes (approximately 30-40 revolutions) so as to get a homogeneous mix. This procedure was adopted, as per the guidelines of ACI 544.3R-84 report, in order to avoid the 'balling' phenomena. Workability tests - slump, compacting factor and vee-bee time - were conducted on all mixes in order to check uniformity in concrete workability. Mix cohesiveness, stickiness, fibre balling, handling ease or difficulty and finishability were observed among all mixes as a comprehensive measure of subjective assessment of workability to obtain uniform workable concrete.

Thirty cylinders of diameter 100mm and height 200mm along with companion cubes of 100mm size were cast in steel moulds for each combination of mix proportions and compacted using 25mm diameter needle vibrator. The specimens were de-moulded after 24 hours of casting and kept under water for curing in a tank in the laboratory for different periods. After 28 days, each set of fifteen cylinders and cubes were stored in 5% NaCl solutions for different periods up to 150 days until testing.

2.4 Testing

The cylinders were weighed and tested for their split tensile strength in a load controlled universal testing machine at different ages under normal curing and different storage periods under NaCl solutions up to 150 days.

3. Results and Conclusions

Test results of average of three specimens of SFRC at different ages up to 150 days for all combinations of mixes cured under normal water and NaCl solutions are presented in Table 2. From Table 2, under normal curing, all ternary blended mixes of SFRC showed higher strengths than that of corresponding binary blended mixes at all ages. However, binary blended mixes showed increased trend of higher strengths than that of control mix at later ages. Similarly, in case of NaCl curing, same trend was observed as that of normal curing with slightly lower strength values in all the mixes at corresponding ages.

Table 2: Spilt tensile strength (MPa) of SFRC mixes at different ages under Normal and NaCl curing.

Mix	Normal curing					NaCl curing				
	28d	**60d**	**90d**	**120d**	**150d**	**28d**	**60d**	**90d**	**120d**	**150d**
SA	5.16	5.21	5.24	5.39	5.48	5.16	5.32	5.14	4.95	4.65
SB	4.63	4.94	5.19	5.50	5.69	4.63	5.12	5.23	5.33	5.47
SC	4.51	4.81	5.08	5.37	5.55	4.51	4.93	5.08	5.21	5.35
SD	4.16	4.49	4.84	5.25	5.43	4.16	4.76	4.89	5.14	5.28
SE	5.34	5.56	5.72	5.98	6.32	5.34	5.63	5.69	5.74	6.23
SF	5.13	5.42	5.64	5.82	6.21	5.13	5.51	5.58	5.67	6.00
SG	4.75	5.17	5.29	5.45	6.04	4.75	5.35	5.40	5.51	5.92

Table 3 shows strength ratio values for SFRC mixes under NaCl curing compared to normally cured specimens at corresponding ages as well as compared to 28day strength of normally cured specimens. From Table 3, under NaCl curing, higher strength ratio values at corresponding ages were observed for blended (both binary and ternary) specimens than control specimens. This indicates better performance of blended specimens than unblended specimens under chloride environment. Similarly, compared to 28 day strength of normally cured specimens, blended specimens under NaCl curing showed increased values of strength ratio than control specimens at all ages. This indicates that even under NaCl solution, blended specimens showed the effect of continued process of strength gaining whereas unblended specimens showed the process of deterioration after 90 days.

Table 3: Spilt tensile strength ratio values of SFRC mixes under NaCl curing.

Mix	compared to normally cured specimens at corresponding ages					compared to 28 day strength of corresponding normally cured specimens				
	28d	60d	90d	120d	150d	28d	60d	90d	120d	150d
A	1.000	1.022	0.981	0.930	0.860	1.000	1.031	0.996	0.959	0.901
B	1.000	1.037	0.978	0.969	0.961	1.000	1.105	1.129	1.150	1.181
C	1.000	1.026	0.975	0.971	0.964	1.000	1.093	1.126	1.155	1.186
D	1.000	1.015	0.948	0.979	0.972	1.000	1.144	1.175	1.235	1.268
E	1.000	1.013	0.995	0.960	0.986	1.000	1.054	1.065	1.074	1.166
F	1.000	1.017	0.990	0.974	0.966	1.000	1.074	1.088	1.105	1.169
G	1.000	1.019	0.984	0.975	0.980	1.000	1.127	1.137	1.160	1.247

References

[1] ACI Committee 226.3R-87 (1987), Use of Fly ash in Concrete, ACI Materials Journal, Sept-Oct, pp.381-409.

[2] ACI Committee 544.2R-88 (1988), Measurement of Properties of Fibre Reinforced Concrete, ACI Materials Journal, Nov-Dec, pp.583-593.

[3] ACI Committee 544.3R-84 (1984), Guide for Specifying, Mixing, Placing and Finishing Steel Fibre Reinforced Concrete, ACI Materials Journal, Mar-April, pp.140-147.

[4] Ghosh, S., Bhattacharya, C., and Ray, S.P.,(1989), Tensile Strength of Steel Fibre Reinforced Concrete, *Institution of Engineers (India) Journal*, Vol.69, Jan., pp.222-227.

[5] IS:4031-1988, Methods of Physical Tests for Hydraulic Cement, Bureau of Indian Standards, New Delhi, India.

[6] IS:8112 -1989, Specification for 43 grade Ordinary Portland Cement, Bureau of Indian Standards, New Delhi, India.

[7] Krishnamoorthy T.S, Bharatkumar, B.H, Balasubramanian, K and Gopalakrishnan S.,(2000), Investigations on Durability Characteristics of SFRC, *Indian Concrete Journal,* Feb., pp.94-98.

[8] Kukreja C.B, Kaushik S.K, Kanchi M.B, and Jain O.P.,(1980), Tensile Strength of Steel Fibre Reinforced Concrete, *Indian Concrete Journal*, July, pp.184-188.

[9] Kunio Nishioka, Noboru Kakimi, Sumio Yamakawa and Kiyoshi Shirakawa,(1975), Effective applications of Steel Fibre Reinforced concrete, *Fibre Reinforced Cement and Concrete, RILEM symposium,* Construction Press, London, pp. 425-433.

[10] Thomas M.D.A., Shehata, M.H., Shashiprakash, S.G.,Hopkin, D.S., and Cail, K., (1999), Use of Ternary Cementitious Systems Containing Silica Fume and Fly Ash in Concrete, *Cement and Concrete Research*, 29, pp.1207-1214.