EFFECT OF BINDER TYPE ON FREEZE THAW DURABILITY OF SIFCON

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Abstract— In the places which have high number of annual freeze thaw effects causes cracks in structural elements such as concrete. These cracks cause cement-based composites to lose its bearing capacity under mechanical loads as well as thermal effects like freeze-thaw. Different cement-based composites were researched in past years to resist these effects. But composites such as slurry infiltrated fiber concrete (SIFCON), homogeneous cement paste phase, causes cracks to occur, expand and disintegrate more easily. To prevent the spread and distribution of cracks in such composites, fiber elements and cement type should select very carefully. In this experimental study different type of cements were used in SIFCON production with steel fibers. As a result of cracks steel fibers with two different dimensions were used to investigate the effect of fiber length. In the binder phase Portland, puzzolonic and fly ash added cements were used. Produced prismatic specimens were exposed to 50, 75 and 100 cycles of freezing-thawing effects. As a result the effect of fiber length and binder type on SIFCON performance under freezing-thawing cycles were determined with examining the changes in unit weight, ultrasonic pulse velocity, bending strength, compressive strength.

Index Terms— SIFCON, cement type, fly ash, freeze-thaw effect.

I. INTRODUCTION

Concrete is a widely used structural material which can be used in many areas such as substructure, superstructure, transportation, dams ... etc. The need for concrete will continue for a long time because ease of manufacture, practicality, affordability and technical specifications makes the concrete preferable. Metal, polymeric, mineral and natural raw materials added with specific length/diameter ratio in numerous ways and different amounts to improve the properties of fresh concrete. One of these additives is called fiber. Industrial fibers are producing from steel, plastic and glass type raw material with different dimensions. Fiber length/diameter aspect ratio has accepted as the best numeric parameter to define fiber by ACI (American Concrete Institute) committee. Geometric shape of fiber and tensile strength are the other parameters to define fiber [1]. Fibers have begun to use in reinforced concretes as additives in concrete roads and overlays, highway pavement and overlays, bridge slab pavements, slabs of airport, taxiways and aprons at 1970's. Since 1984, fibers were used as additives in 1 million m3 reinforced concrete road in Europe [2]. In spite of their relatively high cost, high performance fiber reinforced cement-based composites are used more widely all overthe world especially in seismic retrofit design and in the structures under explosive and impact effects. High or ultrahigh strength concrete with very high compressive strength values remains basically a brittle material. The inclusion of adequate fibers improves tensile strength and provides ductility. The fiber volume fraction of conventional fiber reinforced concrete and ultra-high performance fiber reinforced concrete is generally limited to 1–3%. On the other hand, some special composites are produced with fiber volume fraction values between 5% and 30%. These composites can be classified as slurry infiltrated fiber concrete (SIFCON) which have high ductility and tensile strength properties [3]. In a study which SIFCON behavior produced with steel fibers under triaxial compression have researched, the governing failure patterns and failure criterions of HSC, HPFRC and SIFCON samples were discussed by the obtained stress-strain curves. As a result SIFCON specimens have shown unique triaxial compression characteristics such as high ductility, high triaxial compressive strength and hardening behavior [4]. In SIFCON, the bond between fiber and concrete gains importance. Tuyan et al. investigated the fiber type and length effect on SIFCON performance and bond between fiber and concrete. Their results indicated that the pull-out peak load increased with the increase in embedded length of steel fiber, peak load of hooked-end steel fibers was higher than those of smooth steel fibers and debonding toughness of hooked-end fibers increased much more than those of smooth steel fibers [5]. Mineral additives were used in SIFCON production in past studies to investigate the effects on SIFCONs performance. Beglarigale et al. investigated physical, chemical and mechanical characteristics SIFCON specimens which produced with Portland cement (CEM I 42.5 R) and ground granulated blast-furnace slag (GGBFS). In the experimental study they were replaced 50% (by weight) of cement with GGBFS. Their results indicated that GGBFS replacement and decrease in Water/Binder ratio caused an increase in the pull-out peak load values and tensile strength of SIFCON composites [6].

II. EXPERIMENTAL STUDY

2.1. Materials

Fly Ash (FA): The fly ash, chemical and mechanical properties are given in Table I. Fly ash was used in

our experiments as additive material which has come from Seyitömer.

Table I. Properties of fly ash

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	SO_3	Cl	LOI
54,5	20,6	9,27	4,26	4,48	2,01	0,65	0,52	0,006	3,01
Spec. Gravity g/cm^3		2,13		Blaine, cm^2/g				2800	

Cement: CEM I 42,5R type Portland cement from Cimsa Company Cement Mill used as binder and CEM IV/B (P) 32.5 N type puzzolonic cement was used as additive. The properties of cements were provided from the company and chemical, physical and mechanical properties are shown in Table II.

Table II. Properties of cements

	CEM IV	CEM I		CEM IV	CEM I
SiO_2	38,0	19,2	Spec.Grav., g/cm^3	2,87	3,09
Al_2O_3	9,68	4,56	Blaine., cm^2/g	4450	3590
Fe_2O_3	2,91	3,09	Initial Set.., dk	190	163
CaO	32,2	62,9	Final Set., dk	270	228
MgO	1,64	1,88	Expansion, mm	1	1
K_2O	1,14	0,63	Compressive Strength, MPa		
Na_2O	1,00	0,31	7 day	20,1	
LOI	4,0	3,8	28 day	38,1	52,1

Superplasticizer: A new generation superplasticizer was used in experiments which is a product of Gunerca Chemical Industry. The properties of superplasticizer are given in Table III.

Table III. Properties of superplasticizer

Composition	Appearance	Specific Gravity	Cl-, %	Alkali, %
polycarboxylic ether	Amber (colored liquid)	1.02-1.06	< 0,1	< 2
Solids,%	Point of boil	Flash point	pH	Dissolution in Water
16,1-16,8	min. 100°C	>61 °C	4-6	Soluble

Water: Eskisehir tap water was used. The chemical analysis of the drinkable water is given in Table IV.

Table IV. Chemical analysis of the water (mg/lt)

pH	NH_4	SO_4	Al	SO_4	NO_3	Hardness, Fd°	Turbidity, NTU
7.35	0.06	80	0.04	80	11.1	30.11	0.25
Zn	As	K	Ni	P	Mn	Fe	Cu
5.06	1.10	6.8	5.07	0.06	0.015	0.007	0.016

Fiber: Two lenght of hooked-end steel fibers used in experiments. The properties of fibers are given in Table V. Types of fibers are shown in Fig.1.

Table V: Properties of fibers

	SSF	LSF
Brand	Dramix	Dramix
Type	65/35	65/60
Lenght, mm	35	60
Diameter, mm	0.55	0.9
l/d	65	65
Tensile Str., MPa	1345	1160
E, GPa	210	210

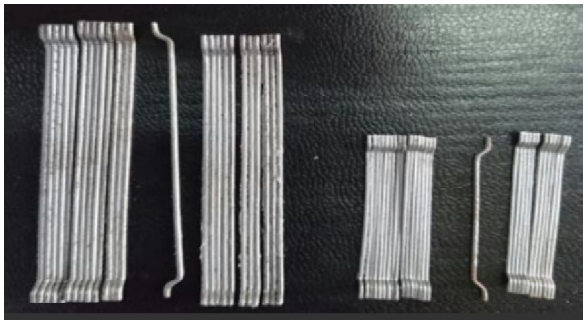


Fig. 1. Macrosteel and microsteel fiber

2.2. Method and Tests

In SIFCON production fly ash was used with CEM I and CEM IV cements. Water/binder ratio was used as 0.5 in specimen production. Viscometer was used to measure the viscosity in production and superplasticizer was used for constant viscosity. Additive ratio was 0.2% in SIFCON specimens produced with CEM I cement, 0.29% with CEM IV cement and 0.1% with 50% CEM I + 50% Fly Ash. Microsteel fibers (SSF) and macrosteel fibers (LSF) were used to produce SIFCON specimens. As seen in Fig. 2 fibers have imbedded into the molds freely then the binder slurry which has stable viscosity poured into molds. The fiber weight was different due to fiber type and length which embedded into mold without compacting Standard compaction and surface finishing has applied to specimens. Binder/fiber ratio which was used in specimens are shown in Table VI.

Table VI: Fiber/binder ratio (%).

CEM I, CEM IV, 50%CEMI+50%FA	SSF	LSF
	16.36	24.55



Fig. 2. Production of SIFCON

Specimens produced in 4x4x16 cm dimensions and cured in standard conditions. After 28 day from production of specimens, freeze-thaw effect have applied to specimens by 2 hours at +20°C degree and

2 hours at -20°C degree with 50, 75, and 100 cycles. Losses because of freeze-thaw cycles have determined by examining the changes in unit weight, ultrasonic pulse velocity, bending and compression strengths. The cracks are shown at the end of freeze-thaw cycles on SIFCON specimens shown in Fig. 3.



Fig. 3. Cracks of SIFCON specimens.

III. RESULTS AND DISCUSSION

The changes in unit weight after freeze-thaw cycles are shown in Fig.4. In Fig. 4 it is examined that unit weights were decreased when freeze-thaw cycles increased. With additives and fly ash added specimens, puzzolonic additives have low densities. So, SIFCON specimens produced with these additives were observed to have less unit weight. It is seen in Fig. 5 that ultrasonic pulse velocity was decreased by the increase in freeze-thaw cycles. Fiber length was shown no significant effect on this loss. Especially after 75th cycle unit weight was rapidly falled down due to increase in crack quantity and length. Fly ash, which filled in the voids in SIFCON specimens due to having smaller dimensions than cement, was provided a positive impact on ultrasonic pulse velocity. But cracks have growed because the specimens couldn't reach the compressive strenght need to resist the stresses occured by freeze-thaw cycles in specimens and due to slow reaction properties. By reasson of this ultrasonic pulse velocity was decreased.

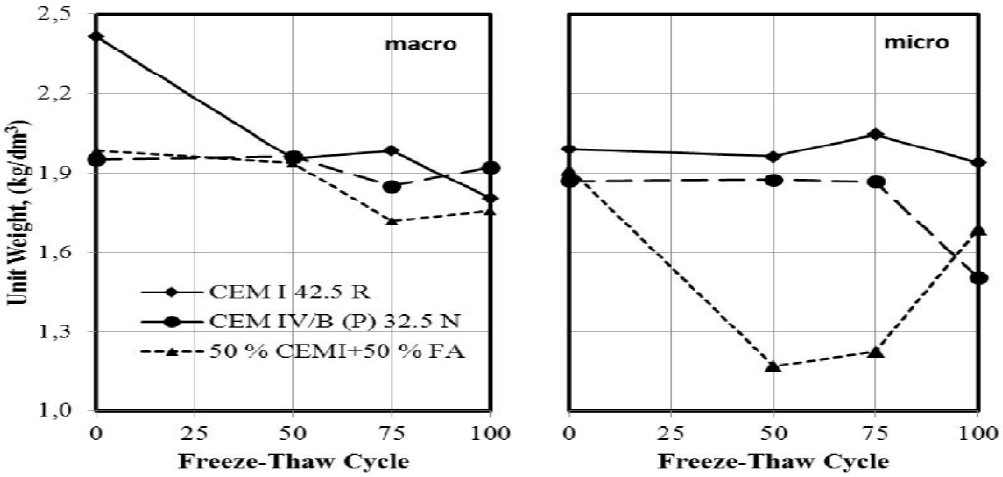


Fig. 4. The variations of unit weights of SIFCON with freeze-thaw cycle

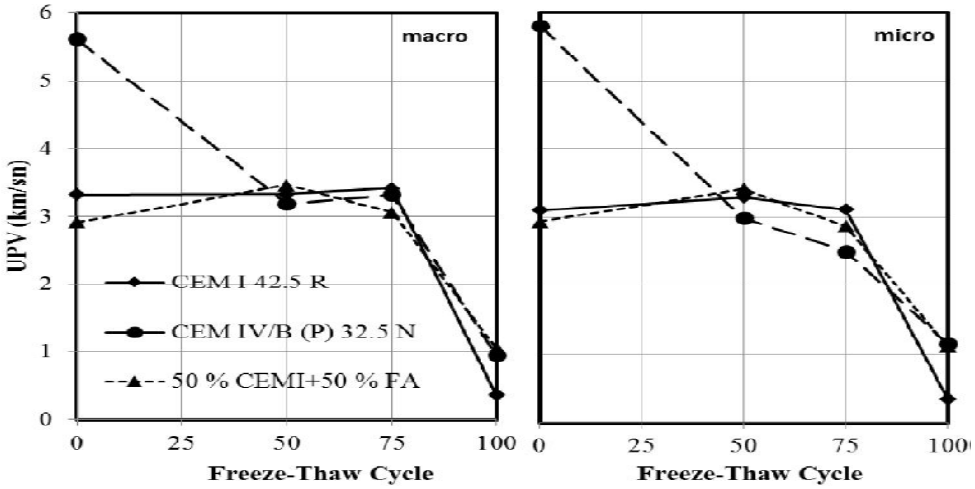


Fig. 5. The variations of ultrasonic pulse velocity of SIFCON with freeze-thaw cycle

The changes in bending strengths due to fiber type under freeze-thaw effects are shown in Fig.6. It is examined in Fig. 6 that bending strength was slightly increased up to 50th cycle than decreased by following cycles in SIFCON specimens without fly ash. This increase was caused by fibers which have taken the load at crack zones. The losses were increased after 50th cycle because adherences in

fibers and concrete have decreased. SIFCON specimens were indicated different behavior under bending loads due to adherence problems in fibers at crack zones. Because mineral additives were acted on resistant performance later than expected.

The changes in compressive strengths due to fiber type under freeze-thaw effects are shown in Fig.7. It is examined in Fig. 7 that compressive strength of SIFCON specimens without mineral additive was decreased due to increase in freeze-thaw cycles. SIFCON specimens with high mineral additive were lost their compressive strengths after 50th cycle. The effects of fly ash additive in SIFCON specimens were became significant at 60th day and after. In early ages, SIFCON specimens, which couldn't get enough strength, could easily lose their compressive strengths under freeze-thaw effects. Compressive strength caused different behavior in lower mineral additive is used specimens due to fibers which were effective at microcracks which occurred under compressive strength.

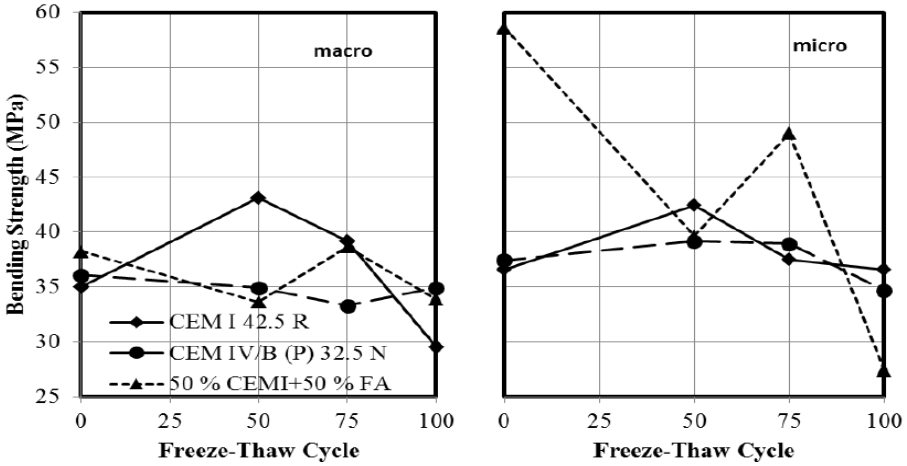


Fig. 6. The variations of bending strengths of SIFCON with freeze-thaw cycle

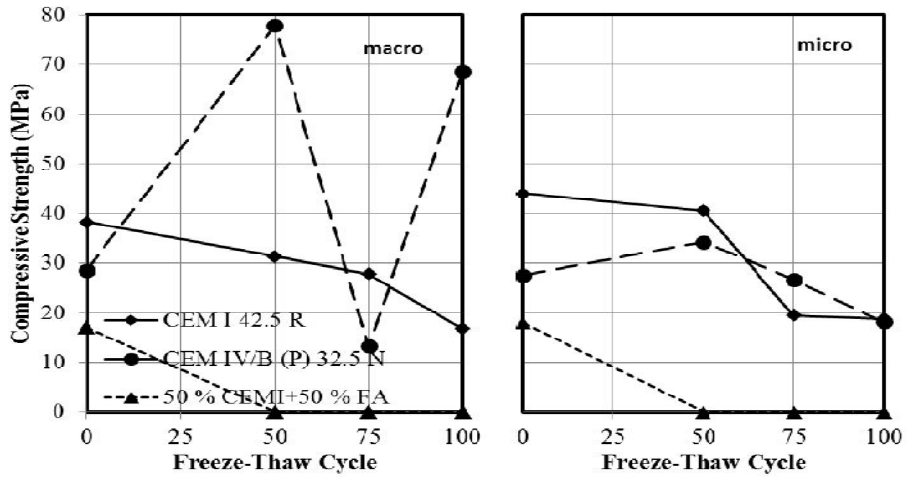


Fig. 7. The variations of compressive strengths of SIFCON with freeze-thaw cycle

CONCLUSION

In the case of binder type effect on SIFCON's freeze-thaw resistance, the following results obtained by experiments:

•The use of mineral additives with binder was decreased unit weight of SIFCON specimens. Cracks due to freeze-thaw effects were caused unit weights to decrease.

• It is examined that ultrasonic pulse velocity os specimens were decreased rapidly after 75th cycle. Also high fly ash usage was decreased ultrasonic pulse velocity up to 80% under freeze-thaw effects.

•SIFCON specimens couldn't reach expected early age strength due to mineral additive usage with cement as binder caused fibers to compensate bending loads at crack zones. At a result of adherence problems occurred between fibers and binder, variable bending treatments have indicated.

•At high freeze-thaw cycles, highly mineral additive used SIFCON specimens couldn't reach expected strengths. So that specimens couldn't resist the internal stresses, especially in the concrete which produced to resist compressive strengths, these specimens weren't resisted to mechanical effects such as compressive strengths.

Highly mineral additive usage in SIFCON production as structural element in the places which have high number of annual freeze thaw cycles doesn't suggested due to losses in bearing capacity. In places

which early age freeze-thaw durability needed, cements without mineral admixtures can be recommended in SIFCON production.

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