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TO STUDY THE BEHAVIOR OF FIBER REINFORCED CONCRETE AGAINST FIRE BY USING SIKAFIBER®12

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Abstract- Concrete has not very much resistance against fire because of its brittle behavior therefore to check improvement in crack resistance and compression strength against fire, SikaFiber®12 with dosage (0, 0.4,0.8,1.5,2.5,3 % by weight of cement) was used as polypropylene fiber with addition of superplastisizer ("Sika Viscocrete 3110" used 0.70% by weight of water for workability) and w/c of 0.45 to cast 60 M25 Grade standard size cylinders (150 x 300 mm) of fiber reinforced concrete tested against fire under compression according to ASTM C39 (cured in water for 28 days) for duration of 0.5,1,1.5&2 hours in gas furnace using infrared thermometer to maintain a temperature of 200,400,600&700°C respectively to find optimum dosage of SikaFiber®12. Six series of concrete mixes (each with 10 cylinders) including five series of SikaFiber®12 and one series of plain concrete cylinders were tested at an age of 28 days after exposure to fire and cooled down. Reinforcement of SikaFiber®12 increased compressive strength of FRC cylinders after exposed to fire for 2 hours at 1.5% dosage and minimized splitting and crack width, delaying the appearance of concrete fragmenting. The addition of polypropylene beyond optimum value decreased the workability of concrete which results in rapid compression strength loss. At 1.5% dosage using SikaFiber®12 increase of 25.39% compressive strength was obtained and strength remained same at 0.4% dosage.

Keywords- Compression strength, cylinders, fire, SikaFiber®12.

1 Introduction

Safety against fire is an important part of the look of concrete structures, which avoid harm in fireplace [***1***]. To control cracks in concrete Polypropylene fiber are added. The addition of fibers within the matrix has several vital effects. One in all the first reasons for the intensive use of Polypropylene fiber in concrete is improving fatigue [***2***]. The behavior of concrete at elevated temperature is stricken by many factors like, most temperature and exposure time and cooling methodology [***3***].

Polypropylene fibers don't absorb water so mixed long enough to insure dispersion. To decrease shrinkage and cracks in concrete, length of the fiber should be double than the diameter of the coarse aggregate [***4***]. Addition of PPF in concrete prevents micro cracks making concrete ductile thus gradual failure will occur [***5***]. Many thousands of little Fibers are distributed in every direction and improve properties throughout the concrete cylinders [***6***]. SikaFiber®12 specimen showed nested behavior in reinforced concrete resulting in good ductility by decreasing number of cracks and crack length, enhancement of compression strength and resistance to fire.

2 Experimental Materials

2.1 Cement

The cement used was Fauji Ordinary Portland cement of Grade 53 satisfying ASTM C150-04 standards with 28 days strength of 10000 Psi and having specific gravity of 3.11. Initial and final setting times of the cement were 68 minutes and 210 minutes, respectively.

a) 

b) 

Figure 1: Concrete cylinders casting, a. SikaFiber®12 transparent & Sika Viscocrete 3110, and b. Casted concrete cylinders

2.2 Fine Aggregates

Good quality Lawrence Pur sand was used as fine aggregate. Specific gravity of 2.68 and its grading fell within ASTM.

2.3 Coarse Aggregates

The coarse aggregate used in this experimental work are of 3/4" size crushed angular in shape with specific gravity of 2.70.

2.4 SikaFiber®12

Addition of Polypropylene fibers to concrete increases life span of the structure by controlling micro cracks due to shrinkage when concrete is cured. SikaFiber®12 is chemical base 100 % polypropylene transparent of 12mm length & 32 µm diameter having 0.91 g/cm^3 density, 160 °C Melting Point and belongs to Class 1a: Mono filamented EN 14889-2 is shown in Figure 1a. SikaFiber®12 improves durability, impact resistance and reduces shrinkage, cracking and splintering of concrete at high temperatures.

Table 1-Design mix quantities for M25(1:1:2) concrete with SikaFiber®12

Cylinders	Percentage Dosage	SikaFiber®12(Grams)	Cement(Kg)	Sand(Kg)	Aggregate(Kg)
10	**0.4**	122	30.58	32	74
10	**0.8**	244	30.58	32	74
10	**1.5**	458	30.58	32	74
10	**2.5**	764	30.58	32	74
10	**3.0**	917	30.58	32	74

2.5 Superplastisizer

To maintain good workability of concrete Superplastisizer used is "Sika Viscocrete 3110" with dosage of 0.7% by weight of water is shown in Figure 1a.

3 Research Methodology

For preparation of M25 (1:1:2) concrete all concrete materials weighed on a weighing balance. The total cement content for six batches was 183.39 kg, fine aggregate taken 192 kg and coarse aggregate taken 444 kg. The water to cement ratio was kept constant as 0.45, Super plasticizer (Sika Viscocrete 3110) content was 0.7% by weight of water to maintain a slump of (60-95 mm) for all concrete mixes. Cement was replaced in percentages of 0%, 0.4%, 0.8%, 1.5%, 2.5%, 3% with SikaFiber®12.Cement, sand, coarse aggregates and SikaFiber®12 were first dry mixed then added with 11.2 liter of water containing 254 ml of dissolved liquid superplastisizer for each batch. After the materials were mixed, the slump test was performed on fresh concrete to find out the workability of the mixture as per ASTM C143. Right away after the completion of slump test, the fresh concrete was added into the oiled molds to form 60 standard 150 x 300 mm cylinders as per ASTM C 192. Casted concrete cylinders were demolded after 24 hours as shown in Figure 1b. Metal Cylinder molds were used for casting. Compression test was conducted at age of 28 days, cylinders were placed out of curing tank and placed in brick furnace using gas tank to burn concrete cylinders for maximum of 2 hours then cooled down to normal temperature by natural air. Two Sample cylinders from all dosages were tested for compression at different temperatures and from each batch two sample cylinder were tested without exposure to fire then the result obtained was compared, Optimum percentage dosage of fiber addition in concrete was determined.

3.1 Compression Strength Test

Compression strength test performed at 28 days concrete cylinders after burning in fire is shown in Figure 2b. Compressive test was performed by using the digital display pressure testing system which has a maximum load capacity of 2500 KN is shown in Figure 3a. The loading rate was 8 KN/Sec, and cylinders were loaded until failure. 60 Concrete cylinders of 150mm diameter and 300mm height, both heated and non-heated at the age of 28 days were tested in UTM according to ASTM C39 to obtain the compression strength. These tests were carried out 1 day after heating.

3.2 Heating

After the completion of 28 days curing, cylinders were dried in natural air for 24 hour before heating. A gas fire furnace with top cotton fiber blanket and refractory bricks wall was used for heating the concrete cylinders is shown in Figure 2a.Total seventeen kg of gas was used to burn cylinders in brick furnace for 2 hours. Four target temperatures of 200, 400, 600 and 700 °C were selected for heating period of 2 hours and then cylinders were left to cool down naturally. During heating process the temperature of burning cylinders was checked using an infrared thermometer.

a)

b)

Figure 2: Heating process, a. Brick furnace, and b. Cylinders under fire showing temperature

4 Results

Test results showed that SikaFiber®12 are of great use in long lasting structures as they have increased both strength of concrete and reduced cracking length and showed more ductile behavior than plain concrete in compression. By adding polypropylene fibers to the concrete, risk of explosive fracturing in fire is also reduced considerably.

4.1 Compression Strength Results

Compression strength result showed that as we increase SikaFiber®12 dosage compressive strength of FRC first increases and then decreases. Graphical comparison shows that strength of concrete cylinders with 2.5% and 3% fibers against fire is very lower than those of ordinary concrete as shown in Figure 5a. Maximum compression strength of concrete after fire with 1.5% dosage was obtained 38.427 Mpa which is 18.506% increase of 32.462 Mpa that is for same dosage without fire having difference 0f 6.001 Mpa.

Table 2-Compression strength results of concrete cylinders after failure

Dosages	**Control**		**0.4**		**0.8**	
Sample Strength	**Sample 1 Mpa**	**Sample 2 Mpa**	**Sample 1 Mpa**	**Sample 2 Mpa**	**Sample 1 Mpa**	**Sample 2 Mpa**
No Fire	25.408	26.484	26.823	27.106	26.88	28.351
0.5 Hr Fire 200°C	22.239	23.088	26.88	26.993	20.089	20.202
1 Hr Fire 400°C	23.711	22.353	23.541	23.145	22.635	21.221
1.5 Hr Fire 600°C	17.599	17.146	22.805	23.088	28.351	28.86
2 Hr Fire 700 °C	16.524	16.354	19.919	20.428	29.03	28.917

a)

b)

Figure 3: Lab testing, a. Cylinders under process in compression testing machine after fire, and b. Compression test results

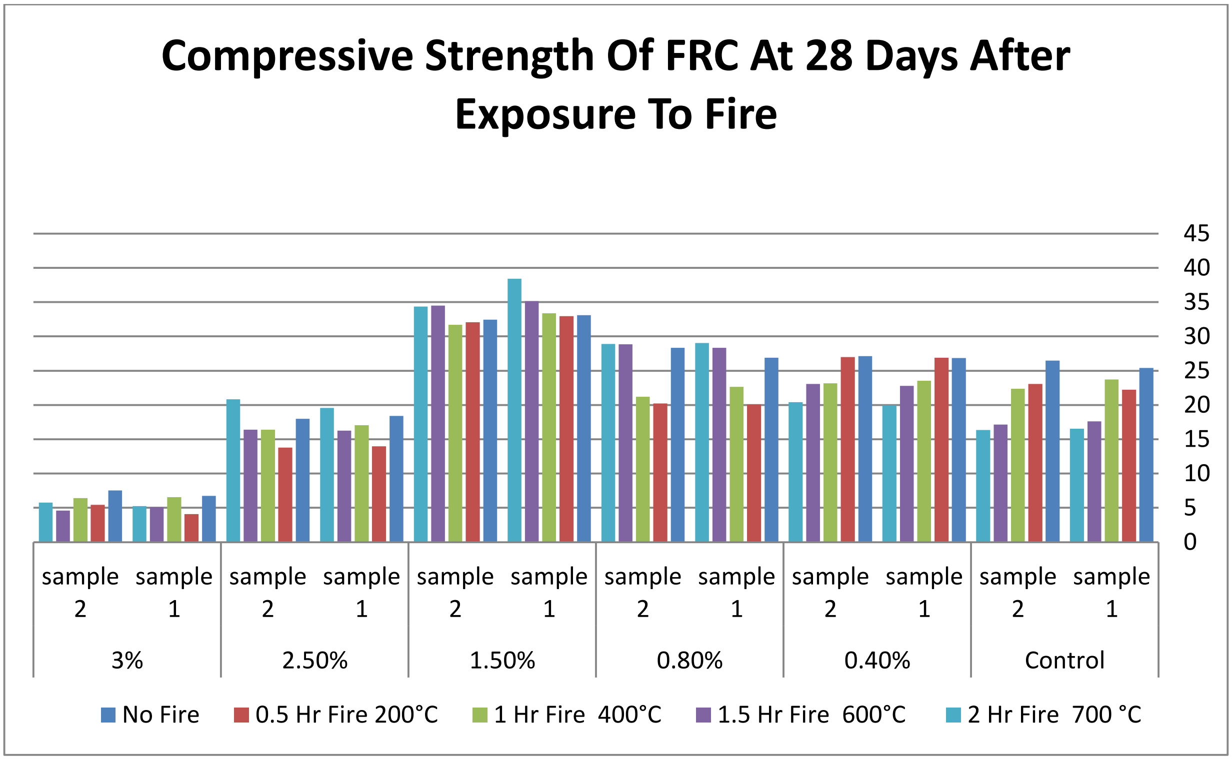
4.2 Visual Observation

In addition to partial splintering of concrete, plain concrete also bear harsh cracking after heating. Fiber reinforced cylinders showed less cracking and cracks were shallower and shorter than that of plain concrete. Increase of PPF dosage from 0.8 to 1.5 % showed extreme decrease in cracking as shown in Figure 4a. After undergoing compression test, SikaFiber®12 augmentation still holds together concrete components after failure like a fibers mesh showing ductile behavior. Thousands of SikaFiber®12 transparent fibers can be seen on casted concrete cylinders surface which is shown in Figure 4b. These fibers prevent concrete fragmenting during fire.

a)

b)

Figure 4: Concrete lab tested cylinders, a. Cylinders after failure, and b. View of SikaFiber®12 fibers reinforced in cylinder



a)

Figure 5: Graphical comparison of results, a. Compression results with and without fire

Table 3-Compression strength results of concrete cylinders after failure

Dosages	**1.5**		**2.5**		**3.0**	
Sample Strength	**Sample1 Mpa**	**Sample 2 Mpa**	**Sample 1 Mpa**	**Sample 2 Mpa**	**Sample 1 Mpa**	**Sample 2 Mpa**
No Fire	33.105	32.426	18.391	17.995	6.734	7.526
0.5 Hr Fire 200°C	32.933	32.087	13.977	13.807	4.074	5.432
1 Hr Fire 400°C	33.352	31.691	17.033	16.411	6.564	6.394
1.5 Hr Fire 600°C	35.163	34.502	16.241	16.411	5.093	4.583
2 Hr Fire 700 °C	38.427	34.37	19.58	20.825	5.262	5.772

Computer linked to compression testing machine gave the digital results of FRC cylinders after failure is shown in Figure 3b. This Compression test results also showed that SikaFiber®12 also enhances compression strength when tested without fire while increasing fibers dosage till 1.5%.

5 Implementation of SikaFiber®12 Results in Construction Industry

These test results of SikaFiber®12 are useful in implementation of this research in real field for engineers and designers to design structure safer and durable against fire hazards, saving more people lives and increasing structure lifespan. When Concrete is exposed to fire the vapor pressure in concrete is generated which is dangerous to structure causing concrete splintering. The reason behind implementation in field work is that these fibers have low melting point of 160°C and doesn't absorb H_2O, which means they will gradually melt and create a capillary system through which the evaporating water can escape, without any damage to concrete.

6 Conclusion

Following are the interpretations of work done on SikaFiber®12 FRC against fire.

- When SikaFiber®12 reinforced concrete cylinders were exposed to elevated temperature up to 700°C, strength of the fiber reinforced concrete cylinders increased with increasing fiber dosage and exceeded that of ordinary concrete till optimum dosage that is 1.5%.
- SikaFiber®12 reinforced concrete shows the highest compression strength and increase in bond strength at 1.5% than those of cylinders having more or less and no fiber content after heating to 700°C.
- The addition of SikaFiber®12 has increased the 28 days compressive strength of FRC by 25.39% than concrete without fibers.
- Compressive strength decreased with the increase of SikaFiber®12 content beyond 1.5% because the mix become fibrous which results in difficulty in handling and therefore compression strength of 2.5 and 3 % dosage is very poor near about 90-105 KN.
- Compressive strength of concrete cylinders without fibers at 28 days before fire was 26.484 Mpa which decreased rapidly to 16.524 Mpa as fire temperature was increased for duration of two hours.
- Concrete containing SikaFiber®12 with 0.4% dosage tried to resist compression strength against fire but could gain only 20.4 Mpa after exposure to 700 °C heating.
- Increase of 18.5% compression strength after fire exposure is obtained which is 32.462 Mpa.
- Dosage of 0.8% maintained compressive strength of 28.86 Mpa after fire exposure for 1 to 2 hours having strength of 28.35 Mpa without fire.

Further research work should be done on polypropylene fibers so that results obtained should be utilized in construction industry to improve construction methods and robustness of concrete against fire risk.

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