Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 14th International Scientific and Practical Conference. Volume 3, 124-128

Ingredients Degradation in Steel Fiber Reinforced Concrete after Thermal Loading

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Abstract. **The steel fiber reinforced concrete in structures provides good mechanical and physical characteristics and such material applications are increasing. At the same time, if structure is subjected to thermal load it is affecting both properties of reinforcement and matrix as well. The aim of the present research is to investigate the degradation of the characteristics of fibers, randomly distributed in the body of concrete block. A short steel fiber reinforced concrete slabs (400x300x18cm)** [1], [2] **with homogeneously distributed fibers was undergone to calefaction process from one side. dimension of 16.5x14.5x15 cm) Fiber fracture process was performed based on the single fiber pull-out test by preparing the specimens with fiber from calefacted SFRC block. Experimental curves from each layer were compared with different layer of fibers and investigation had shown that higher load-bearing capacity is there over the thermal loaded fiber. The conclusion were made with the microscopic results and the experimental data.**

Keywords: concrete, pull out, Thermal loading, reinforced concrete, material degradation.

I.INTRODUCTION

Concrete is a frequently utilized construction material across the world. It is brittle under tension and compression. When combined with brittleness, a high strength-to-weight ratio results leads to catastrophic tensile failure, requiring some form of tensile reinforcement. Steel rebars and cages long time have been used for that. Randomly distributed short fibers, in some situations, less efficient, in comparison to conventional rebars, at the same time, the closely spaced fibers improve the hardness and tensile qualities of concrete and aid in fracture control. Combining fiber reinforcement with conventional steel reinforcement optimizes performance. Fiber reinforced concrete (FRC) research and development has been renewed in the last three decades because of the improved quality of fiber reinforced concrete products [3] [4] [5] [6].

Fiber reinforced concrete is made up of short, discontinuous fibers that are randomly placed throughout the concrete. Fibers made of steel, glass, polymer, or natural resources are used in cement-based composites [7] [8] [9]. Because of their close spacing, fibers can withstand breaking better than traditional reinforcing steel bars. Fiber-reinforced concrete in many situations can be replacement for standard steel bars [10]. Several applications in advanced concrete technology need the use of both fibers and continuous reinforcing steel bars. Steel fiber is the most common type of reinforcement used in FRC [11] [12] [13].

The fiber reinforced concrete is used in order to enhance the life of the concrete but that steel fiber reinforced concrete exposed to the high temperature it started to get weak, so in this research the fibers from the concrete block is treated up to the temperature of 800 degrees and are studied detailly how the mechanical properties of the steel material is changed by doing microscopic analysis. Knowledge about structure deformation and analysis of pull - out test results, performed in laboratory, will allow to know the strength factors of the fiber, studying the material under normal temperature and high temperature in situation with degrading fiber mechanical properties [14] [15].

Print ISSN 1691-5402
Online ISSN 2256-070X
https://doi.org/10.17770/etr2023vol3.7228

II. MATERIALS AND METHODS

Steel fiber reinforced concrete (SFRC) slabs after exposure to open flame from one side [1], [2] were catted to samples with the size of 16.5×14.5×15cm. Short steel fibers were randomly distributed in the volume of each slab.

2.1 Properties of Steel Fibers

SFRC specimen was made up of the commercially available hooked-ended steel fibers Dramix 3D 80/60BG. Fiber properties (supplier's data) are:

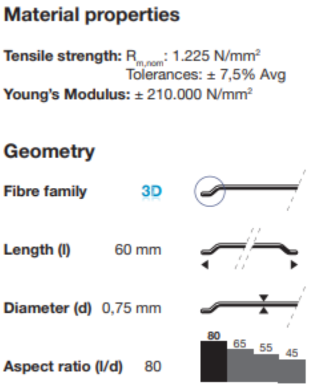

Fig.1. Fiber properties.

2.2 Concrete Mix Design and Materials

The concrete mix was designed using the tables and calculations provided in the standard EN-206 [1], [2].Concrete mix design: Portland cement, sand, quartz, admixture silica fume, plasticizer, and water [16] [17] [18].

Table. 1 Mix proportion

Concrete Mixture		
S.No	**Name of Ingredients**	**Quantity**
1	Portland Cement (CEM II / 42,5 N)	2.8 kg
2	Micro silica 940-U	200 g
3	Sand (0-1 mm)	9.33 kg
4	Quartz QS 0-0.5 mm	1.67 kg
5	Plasticizer Sika D190	20 g
6	Water	2000 g

2.3 Collecting of fibers

In this portion of the investigation, we began by collecting every single fiber from the thermally treated concrete block (with dimensions 16.5×14.5×15cm). The block was shattered to obtain as much fiber as possible for each band width of one centimeter. To separate the fiber samples for further analysis, we shattered the block while holding the samples, and they came out in various bits. We were especially concerned about preserving virgin fiber [19] [20] (see figure 2). For every fiber was fixed fibers central point distance from the surface subjected to open flame (heated surface).

Fig. 2. Collecting of fibers.

2.4 Examine of collected fiber

An Optical Microscope was used for fibers outer surface analysis. For more detail fiber surface analysis is possible to use Electron microscope facilities [21].

Fig. 3.1 Fiber from the non-heated end.

Fig. 3.2 Fiber from the heated end.

At figures 3.1 and 3.2 is possible to see two fibers. One was located in the layer with thickness 1cm from the surface subjected to the flame (figure 3.2). Second were removed from the l cm thick layer located at the surface of the block opposite to subjected to the flame (figure 3.1). Take a new sample of steel fiber with a cleanly cut edge and a smooth surface; the sample must be at least 6 cm in size. This sample is put under the microscope's lens, just below the view finder when viewed through the eye piece. Some analytical calculations are made to study the exact condition of fiber. After getting the clear inspection of the fiber, we can move for the next one [22].

2.5 Preparation of Specimens

Each block was divided into slices with thickness one and half cm. Were obtained 12 slices. 7 specimens (fibers, with central point located within the slice) for each band were obtained. Fibers removed from the concrete block were used in pull-out experiments. Were fabricated samples consisting of two concrete prisms separated by plastic film. Two prisms were connected by fiber immersed into concrete of both prisms. Initially all the concrete is mixed for the required amount no more concrete is prepared. Now the mold is ready for concreting, then concrete is poured inside the mold without steel fiber for the compression at the base for 100 mm initially, now the first frame is placed over the concrete mixture and tampered to adjust its levelling.

Fig. 4. Making of mixture.

For making the samples with fiber, fibers should be placed in the middle of the mold. So, every fiber is marked 3cm at the center and should be placed in the exact position. At first concrete is filled in each side of the specimen to check the placement fiber. Small amount of vibration is produced to remove the air molecules in the mixture. Now the opposite side of each sample is filled with the concrete and the same procedure will be followed as we did earlier. Now the cube mold is immediately covered with plastic wrapper and maintained in the laboratory where the relative humidity must be 90% but the inside temperature must be between 27, + or -2 degrees. The test samples are taken out from mold after 48 hours and are transferred to the laboratory for further curing process. The specimens must be protected from heavy temperature changes and shaking during the conveyance. Samples to be tested at one time and the average test results. The samples without fibers are considered for the compression test strength. Immerse the samples (without fiber) in the curing tank containing clean water until it is suitable for testing. The sample must be completely submerged, and more than the required water must be put down because the concrete specimen absorbs water during hydration.

2.6 Mechanical Testing Methods

After 28 days from the fabrication, the specimens were tested for fiber pull-out from the concrete matrix and compression test were performed. Test machine Zwick Roell Z150 was used to determine the fiber pull-out force and compression tests were done to measure the strength of the concrete which we used to make the specimens. [23] [24]

Fig.5. Tensile strength machine setup.

III. Experimental Results and Discussion

3.1 Compression Test

The cube should be positioned into the compression testing machine so that, its smooth faces land on the steel plate on the bottom side. The top surface of the finished cube must never be met with the machine's platens, as this generates unbalanced loading over the cube due to the uneven, rough surface, as opposed to the faces along the smoother side of the mold [25] [23] [26].

For cube test, standard dimensions (are commonly recommended for cube testing), 10 x 10 x 10 cm were fabricated. The loading was performed without pausing and loads was increased constantly at a rate of 150 Kg/cm2/minute, till the concrete specimen develops cracks and breaks down or it was crushed [27]. Test results are shown in the table 2.

Table 2. Compression test results

Sample	Force N	Compressive Strength MPa
1.1	341.1	34.4
1.2	317.6	31.4
2.1	239.5	24.7
2.2	244	25.5
3.1	237.7	23.9
3.2	282.3	28.1
5.1	218.8	22.8
7.1	235.7	23.7
8.1	272.3	26.7
8.2	266.1	26.5
Average		**26.77**

From the obtained results we can observe that the average compressive strength is 26.77 MPa, that is a good value for concrete under compression with no reinforcement and aggregates.

3.2 Fibers Pull-Out

Results shows the process of pulling out of seven Dramix steel fibers from the concrete matrix and indicate the average values of the peak pull-out load. Before starting the testing, all concrete samples are marked with their number and band width to identify it easily [24]. In the starting load is up to 30N fibers were in the matrix without any pull-out. Afterwards force reaches 150 N then fiber starts to slide. This reaction on the fiber is due to its shape because it is 3D 80/60BG, so it has bended ends on both sides [28] [18] [29].

Table 3. Pull out results of fiber from non-heated end

Sample	Force N	Strength MPa
1	639.34	135.67
2	607.00	128.81
3	673.89	143.00
4	682.48	144.82
5	704.41	149.48
6	595.54	126.37
7	566.08	120.12
Average		**135.47**

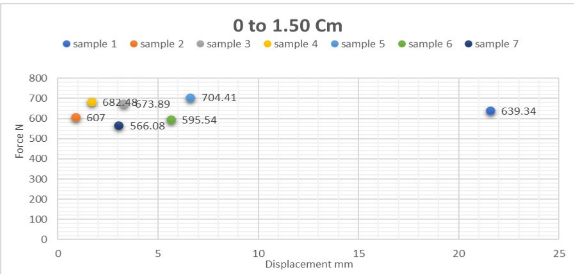

Fig.6. Force and Displacement graph for fibers obtained from first slice (0 to 1.50 cm).

Jumps in the force value may be observed during the entire pullout, this could be explained by the fact that spalling microparticles of the concrete matrix are pulled with friction-forming plugs, and that SF and concrete matrix are bonded together via a weak interface. The investigation of this interfacial behavior is critical for understanding the mechanical behavior of SFRC.

Table 3. Pull out results of fiber from heated end

Sample	Force N	Strength MPa
1	133.9	28.41
2	112.64	23.90
3	203.30	43.14
4	144.31	30.62
5	192.90	40.94
6	185.57	39.38
7	217.3	46.11
Average		**36.07**

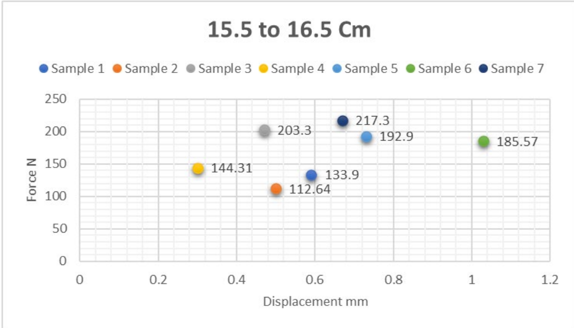

Fig.7. Force and Displacement graph for fibers obtained from last slice (15.5 to 16.5 cm).

3.3 Examine of tested samples

All the tested sample are collected and checked in the microscope again in order check the breakage of the fiber and to examine the surface crack of the fiber. For this process again, the same procedure is followed as was done earlier, all the fibers are viewed on the microscope and amazing images are picturized for the further analysis. Some of the images are shown below,

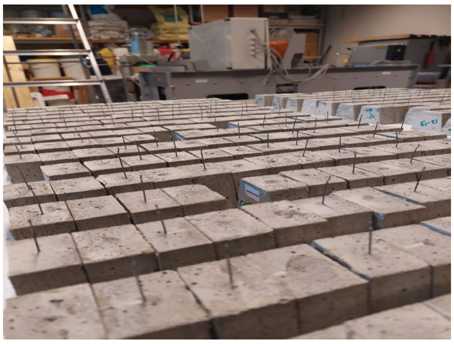

Fig. 8. Tested samples.

Fig. 9. Tested sample from non-heated end.

Fig.10. Tested samples from heated end.

From these pictures it is easy to notice that the oxidized layer in fiber from heated end has been destroyed during the bull-out friction applies and the core filament remains.

IV.CONCLUSION

1. Steel fiber degradation degree in the fiberconcrete slab depends on fiber location in the slab. Degradation was evaluated as pull-out load bearing capacity decrease.
2. Fibers located in the layer 0 to 1.5cm from the surface subjected to open flame had 3.76 times lower load bearing force comparing with fibers located in the layer 16.5 to 18cm from the surface subjected to open flame.
3. Microscopical analysis shown. Each fiber in the fiberconcrete slab, subjected to open flame is becoming "softer" yield stress is slightly decreases. Outer surface of every fiber is subjected to oxidation. Oxide has bigger volume, fiber is increasing in diameter. Oxide strength is much lower comparing with steel yield stress.

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