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Increased Bending Strength in Beam Samples Using Waste Textile Fibers

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Abstract: High-ductility concrete has been found to lessen the number of fatalities during earthquakes since it absorbs more energy. In this study, the tensile strength region of the beam components in the constructions was enhanced by the use of waste textile fabrics, which also increased the ductility in that area. 10 x 10 x 50-centimeter concrete beam samples were filled with a predetermined number of waste textile fabrics that had been chopped into 2 cm long threads. Class C25 concrete was used according to TS 500 standard. Self-compacting concrete (SCC) was used according to TS EN 12350 standard. It is understood that the results are somewhat improved by the bending values of the beam samples as compared to the prepared reference sample. Waste fibers are believed to help produce recyclable, ecologically friendly concrete by being used in concrete. Additionally, the ANSYS program's finite element method was used to examine the growing stress zones in beams.
Keywords: Fiber; Sustainable; Waste textile materials; Concrete; Beam.

1. Introduction

The ability of concrete to maintain ductility under both vertical and horizontal loads is a desired quality. The strong column-weak beam phenomenon dictates that the beam's dimensions should be fairly small [1], yet this ratio must be optimal in accordance with the Earthquake Code. Ultimately, the beam cannot be selected in extremely small sizes since it will transfer the floor's loads to the columns. Obtaining a rigid beam depends on various parameters such as concrete class, reinforcement, pozzolans, additives, and fibers. In recent years, recycling of waste products has gained importance in terms of environmental cleanliness and sustainability. This idea has also found its way into the concrete world and experimental studies have been conducted on this subject.

In previous studies, a jute fabric mesh layer was also placed between the samples as reinforcement. The position and number of layers of the fabric mesh was changed to improve bending capacity. From yield point to fracture, the samples did not receive much load due to the compression yield behavior of the flax-lime, and the increased number of jute fabrics increased the ductility of the beam samples [1]. The experimental results of carbon fibers used in FRCM (Fabric Reinforced Concrete Matrix) systems showed an increase in the ultimate capacity of the reinforced beams [2-5]. Instead of these petroleum-containing products, waste textile products were applied in beam samples. With the use of Fiber Reinforced Polymer (FRP), a new composite system known as the FRCM or Textile Reinforced Mortar (TRM) [6-10] has been formed [11-12]. Different types of fibers, such as carbon, glass, basalt, or Polyparaphenylene Benzobisoxazole (PBO) [13-15], can be used in fabricating the FRP mesh/grid in FRCM technique [16-17]. Adding various polymer fabrics in the concrete of beam and cube samples significantly improved the freeze-thaw resistance of concrete [18]. Tensile strengths of fiber strips placed in the form of a grid were tested. If FRP [19-21] rids are utilized, abrupt collapse can be avoided. Because FRP [22-26] strips flow through the cracks in fractured concrete and stop them from spreading.

In comparison to the quantity of studies on FRP systems, experimental and theoretical research on FRCM composites is currently quite scarce [27-28]. In addition, there are relatively few experimental studies on the behavior of concrete elements reinforced with FRCM systems [11]. In the tensile loading test, the usage of carbon and glass fabric knitted fibers in concrete yielded the maximum load strength and ductility, particularly in carbon fabrics [29]. Waste fiber fabrics have become a very important problem in terms of environmental pollution. Waste fiber fabrics were cut and used in concrete. It has been observed that concrete in which fabric fiber was used has more ductile break than PC concrete [30-31]. Compared to non-fiber concrete, it increased the compressive strength of fiber concrete by up to 41% [32]. Concrete's resistance to freezing and thawing was greatly improved by the addition of various polypropylene textiles [33]. The mechanical properties of prestressed fabric fiber reinforced cement-based matrix composite (PFRCM) were investigated. PFRCM concretes have increased their resistance to crack formation over 30% [34]. With more textile layers, basalt textile reinforced concrete (BTRC) samples' flexural strength was found to rise [35]. Comparing the effectiveness of natural fiber reinforced polymer

(NFRP) and carbon fiber reinforced polymer (CFRP) in flexural strengthening of RC beams allowed for a multi-purpose evaluation to be made. Due to the large volume fractions of epoxy resin, the cost of epoxy resin partially or completely eliminated the advantages of natural fibers over carbon fiber [36]. This article analyzes several recycling techniques for carbon fiber reinforced composites as well as the effects of waste carbon fibers on shear strength on beams during manufacture. The primary issues with this study appear to be the reduced mechanical qualities and altered surface chemistry of regenerated fibers [37].

In this study, unlike some of the literature studies given above, it is aimed to both prevent environmental pollution and make a positive contribution to the flexural strength of concrete by using waste textile fibers as strip fabrics in concrete beam samples in certain layers and numbers. Programs like ANSYS, LUSAS, and ABAQUS help to identify the deformation zones and stress values of the samples. The finite element approach of the ANSYS program was used to identify the deformation zones in the beam in this study [38].

2. Experimental program

2.1 Sample design

The beam samples that were produced are 10*10*50 cm in size. Waste textile fibers used in the produced samples were placed in two stages. The fibers were produced by placing them at the 1/3 level of the concrete beam in the first samples, and at both 1/3 and 2/3 levels in the others. Additionally, whereas each level in the determined samples used two fibers, the other determined samples each utilized three fibers. Each used textile was divided into 2 cm broad strips. The samples had fibers that were arranged both straight and diagonally. The fibers were positioned at a level just below the samples' tensile region, which is near to the lower part of the samples.

In Figure 1, pictures of the experiments are given. In Figure 2, the stages of the experimental study are given schematically.

Figure 1. Conducting experiments

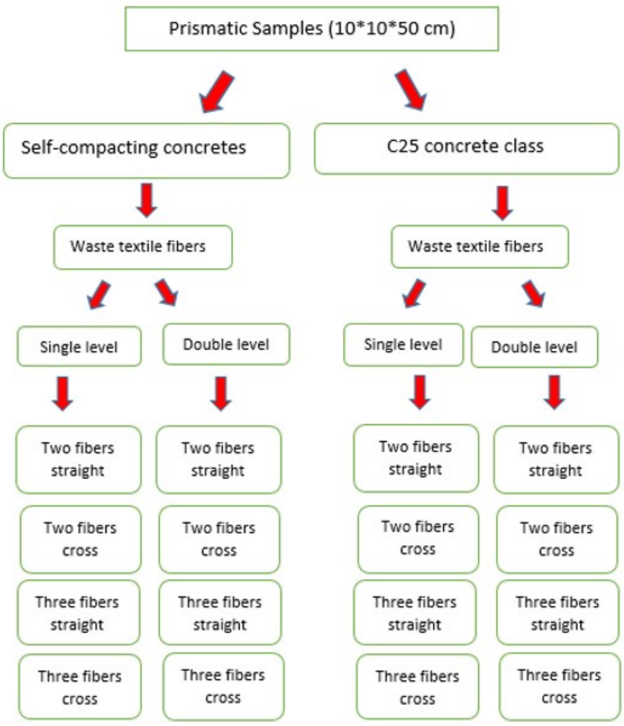


Figure 2. Stages of experimental study

2.2 Materials

Table 1 and 2 show the mix proportions of the concrete used in the experiment.

Table 1. Mix proportions of SCC concrete used in this study

Materials	Content
Cement (kg/m^3)	425
Fine aggregate (kg/m^3) (0-5 mm)	686
Coarse aggregate (kg/m^3) (5-20 mm)	838
Fly ash (l/m^3)	85
Water (l/m^3)	148
Superplasticizer	17

Table 2. Mix proportions of C25 concrete used in this study

Materials	Content
Cement (kg/m^3)	325
Fine aggregate (kg/m^3) (0-5 mm)	1050
Coarse aggregate (kg/m^3) (5-12 mm)	340
Coarse aggregate (kg/m^3) (12-22 mm)	425
Water (l/m^3)	180

Usak University's Scientific Analysis and Technological Application and Research Center measured the tensile strength of waste textile fibers in the weft directions in line with TS EN ISO 13934-2 standard. The TS EN ISO standard specifies that the test samples' size must be 50 mm x 200 mm. The results are presented in Table 3.

Table 3. Waste textile rupture strength values

Number	Specimens	Weft rupture strength values (N)
1	Waste textile fibers	324.65

2.3 Test methods

Bending tests were carried out in accordance with TS EN 12390-5 standards and the experimental study is shown in Figure 3.

Figure 3. V-funnel test in self-compacting concrete and bending test

3. Results and discussion

3.1. 28-Day bending test

The 28-day flexural strength values of C25 and SCC samples are given in the graph in Figure 4. The graph shows that while waste textile fibers in C25 concrete samples performed better, flexural strength values from self-compacting concrete (SCC) performed even worse than non-fiber samples.

It is feasible to state that for both types of concrete, the flexural strength values improve as the number of fibers increases, and that samples with 6 fibers have results that are nearly twice as good as the reference sample. It is found that textile fibers positioned crosswise perform worse than those positioned straight wise. In this case, it is assumed that, the diagonally positioned textile fibers in the beam are longer than the straight-positioned fibers, and because of their loose location, they are unable to support the entire weight applied to the beam. In fact, it is seen that the performance of 3 cross-positioned fibers is inferior to that of the reference sample. It is also thought that the adhesion of the cross-positioned fibers with the concrete has decreased due to their position relative to the straight-positioned fibers [39].

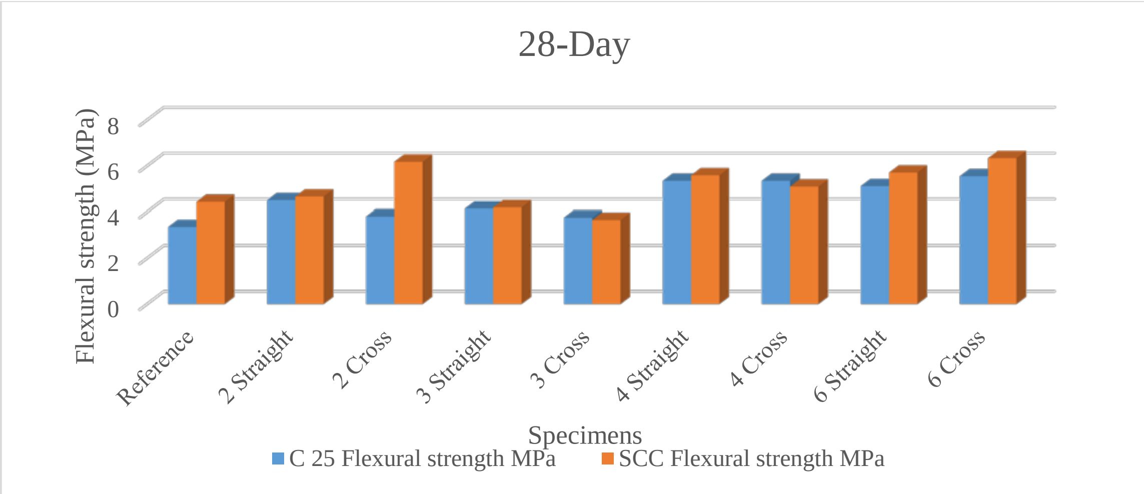
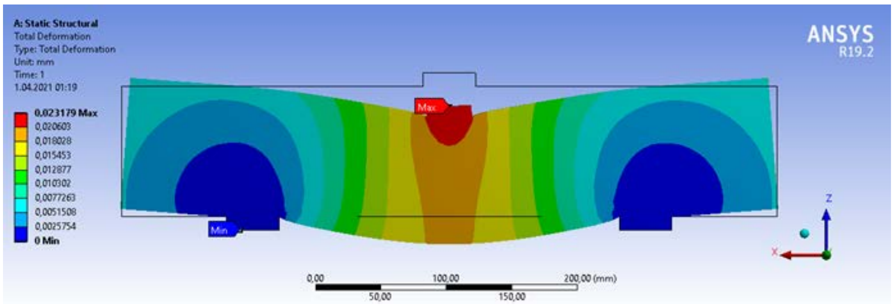


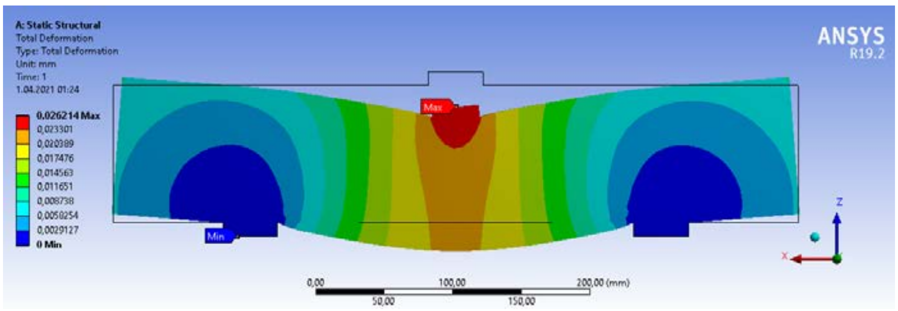
Figure 4. 28-day flexural test results in C25 and SCC concrete specimens

Finite Element Modeling (FEM) was performed with the ANSYS program for the deformation analysis of the beams. Linear (static) analysis method was used. In Figures 5 and 6, flexural strength values of 28-day-old beam samples containing waste textile fibers and reference samples were tested in the laboratory and the deformations of the beams under bending behavior were modeled with ANSYS software. Modeled beams have a width of 100 mm, a depth of 100 mm and a length of 500 mm. All beams have a different number of textile fibers and a four-point flexural test is applied. The final bending loads from the trials were utilized for the model's deformation estimation, and the ANSYS program was used to define waste textile fiber and C25 and SCC concrete classes under static loading. By lowering their deflection values and ensuring their ductility, the study's goal is to simulate the actual behavior of beams made of various fibers. The linear increase of fibers in beams, as illustrated in Figures 7 and 8, raises the deformation values, causing a more ductile fracture and raising the capability for load bearing.

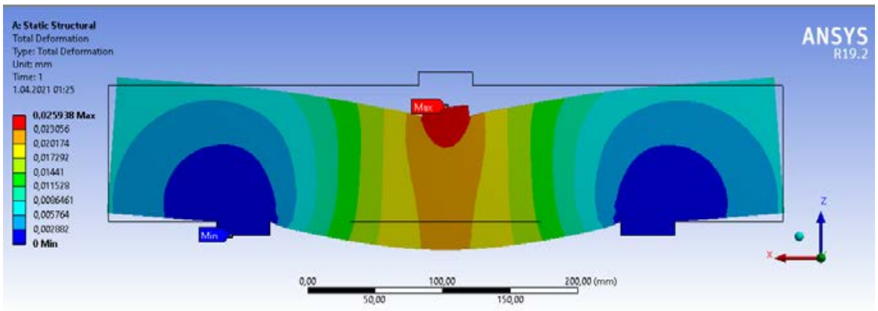
All the experimental studies in this area reveal the obvious conclusion that FRPs can reduce the overall deflection of the reinforced concrete beam [40]. In this study, it was observed that waste textile fibers increased the deformation in the beam when loaded, in this case, it did not reduce the deflection by acting as rigid as the fibers, but increased the ductility of the beam by making more deformation.



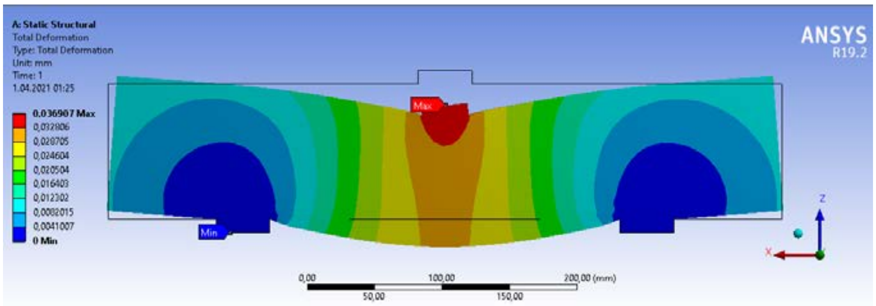
C25 concrete reference sample (maximum deformation:0,023 mm)



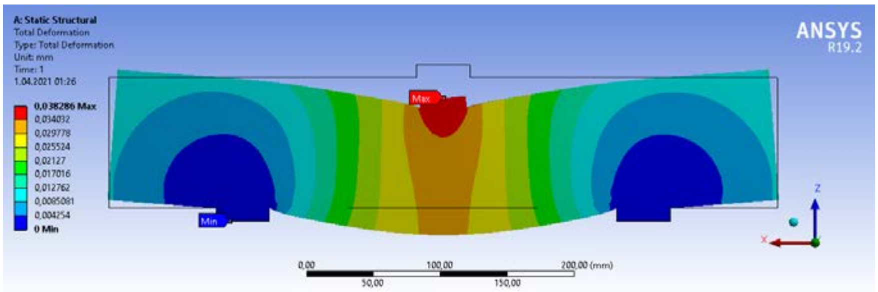
C25 Waste textile fibers (2 cross fibers, maximum deformation:0,026 mm)



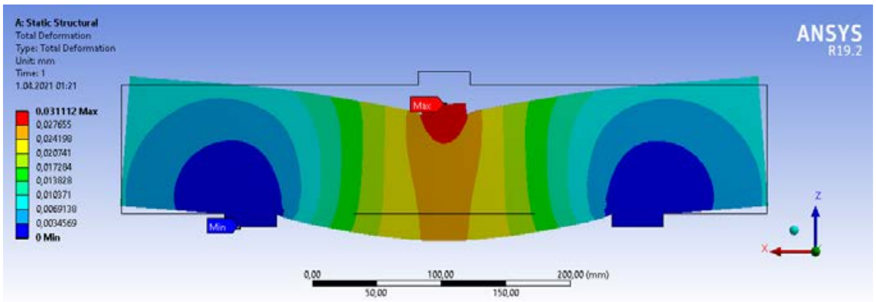
C25 Waste textile fibers (3 cross fibers, maximum deformation: 0,025)



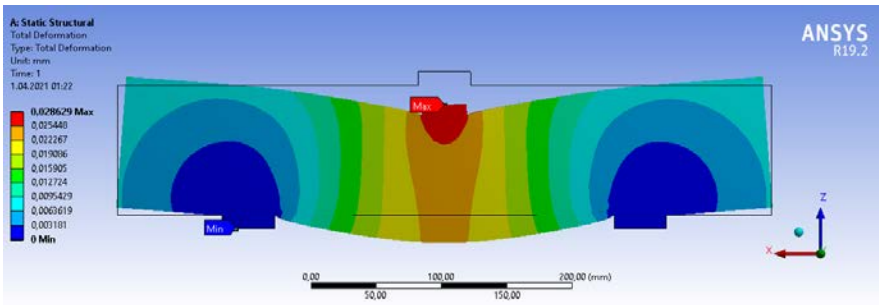
C25 Waste textile fibers (4 cross fibers, maximum deformation: 0,036)



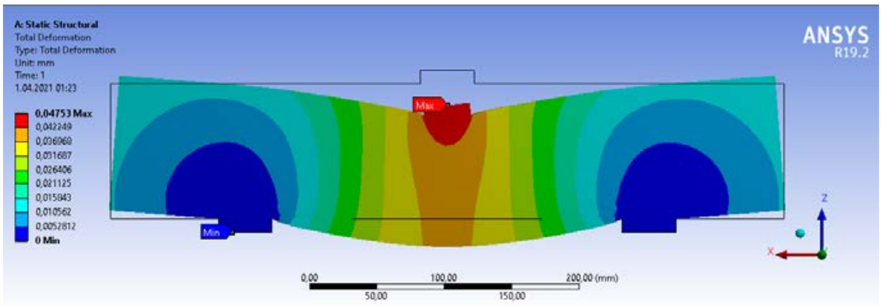
C25 Waste textile fibers (6 cross fibers, maximum deformation: 0,038)



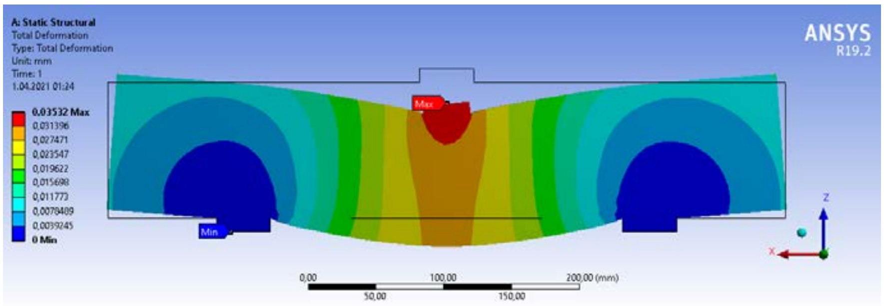
C25 Waste textile fibers (2 straight fibers, maximum deformation: 0,031)



C25 Waste textile fibers (3 straight fibers, maximum deformation: 0,028)

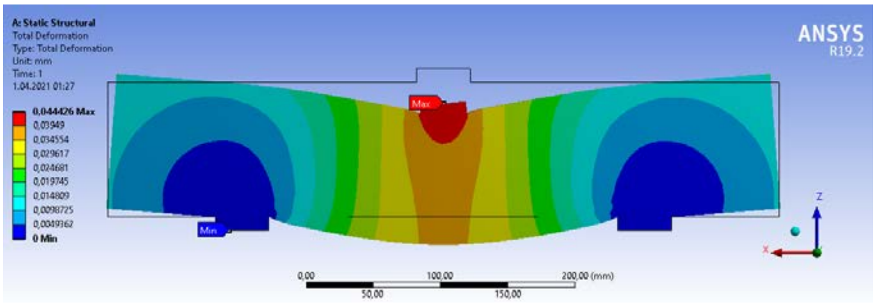


C25 Waste textile fibers (4 straight fibers, maximum deformation: 0,047)

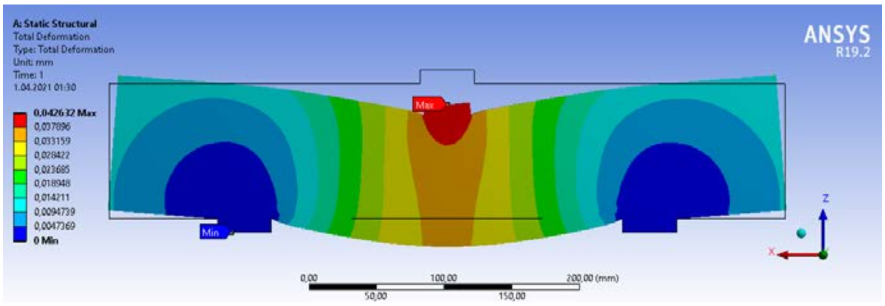


C25 Waste textile fibers (6 straight fibers, maximum deformation: 0,035)

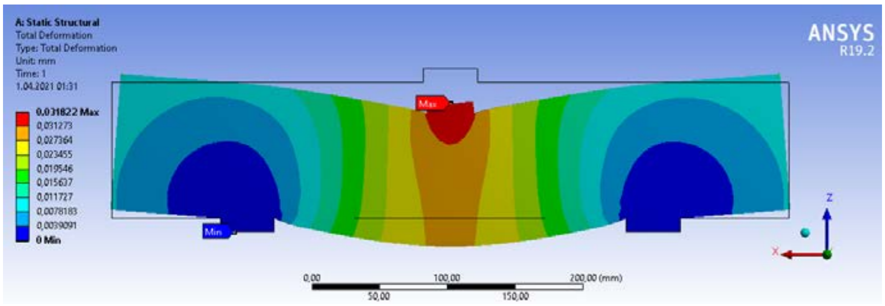
Figure 5. C25 concrete waste textile fibers 28-day samples ANSYS analysis deformation values



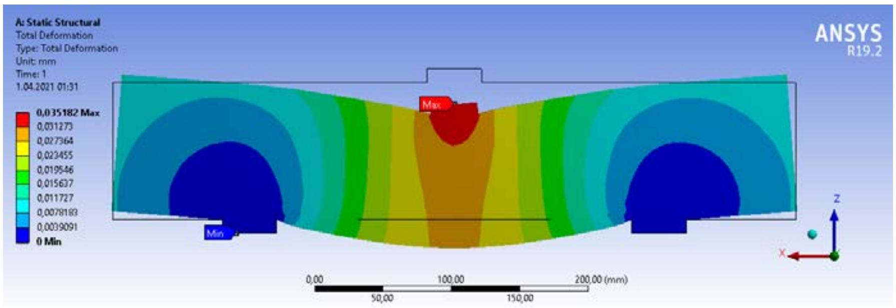
SCC concrete reference sample (maximum deformation: 0,044 mm)



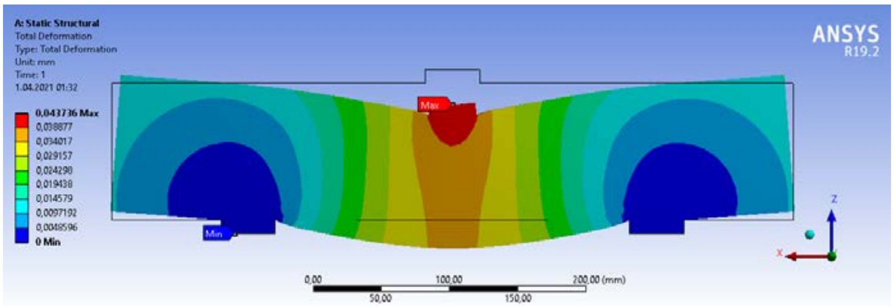
SCC Waste textile fibers (2 cross fibers, maximum deformation: 0,042 mm)



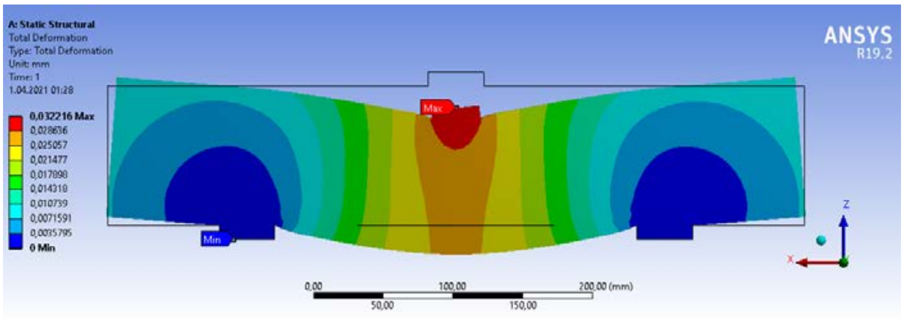
SCC Waste textile fibers (3 cross fibers, maximum deformation: 0,031 mm)



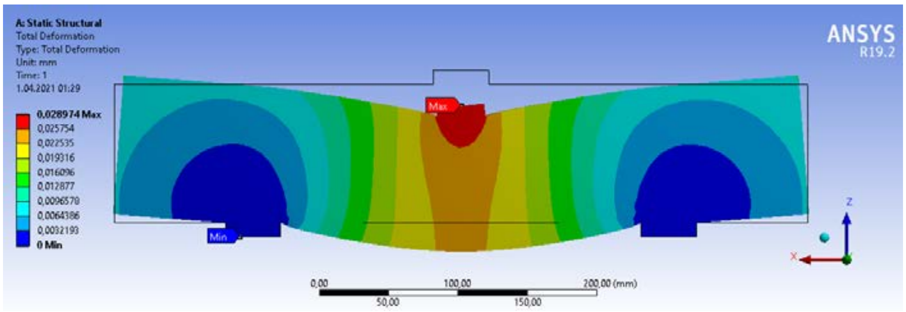
SCC Waste textile fibers (4 cross fibers, maximum deformation: 0,035 mm)



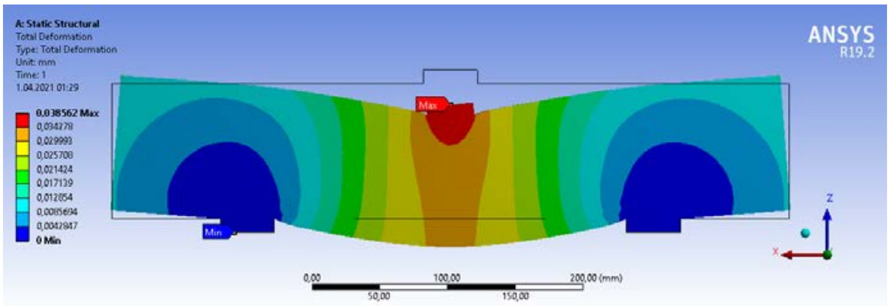
SCC Waste textile fibers (6 cross fibers, maximum deformation: 0,043 mm)



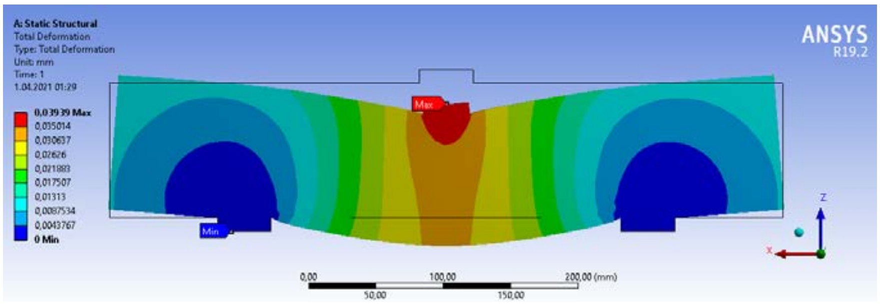
SCC Waste textile fibers (2 straight fibers, maximum deformation: 0,032 mm)



SCC Waste textile fibers (3 straight fibers, maximum deformation: 0,028 mm)



SCC Waste textile fibers (4 straight fibers, maximum deformation: 0,038 mm)



SCC Waste textile fibers (4 straight fibers, maximum deformation: 0,039 mm)

Figure 6. SCC concrete waste textile fibers 28-day samples ANSYS analysis deformation values

3.2 90-Day bending test

In Figure 7, results obtained from 28-day samples and 90-day samples were similar. However, it can be argued that the graphs do not show any further radial growth and that the values obtained are close to each other. The samples comprising six fibers of C25 concrete put flat yielded the greatest value. The outcomes in this graph remained constant, and straight fibers had the best outcomes.

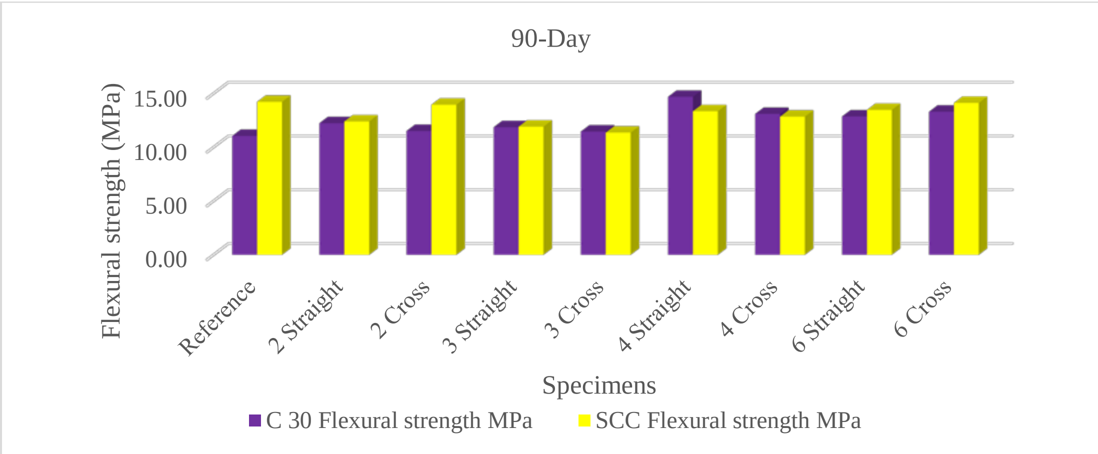


Figure 7. 90-day flexural test results in C25 and SCC concrete specimens

3.3 Durability tests in sulphated waters

Durability tests in sulfated waters were carried out according to ASTM C1012 standards. In Figures 8 and 9, the flexural strength of C25 and SCC samples, which were kept in 5% Na_2SO_4 solution for 3 months, decreased significantly compared to the samples kept in water for 90 days. The reduction values in bending strength of the reference samples and the samples containing waste fiber were quite similar, indicating that the fibers did not have a beneficial effect in sulfated settings. In this case, waste textile fibers are believed to dissolve in sulfated water. However, no negative situation was encountered in the durability tests performed on concretes using steel and polypropylene fiber [41-42].

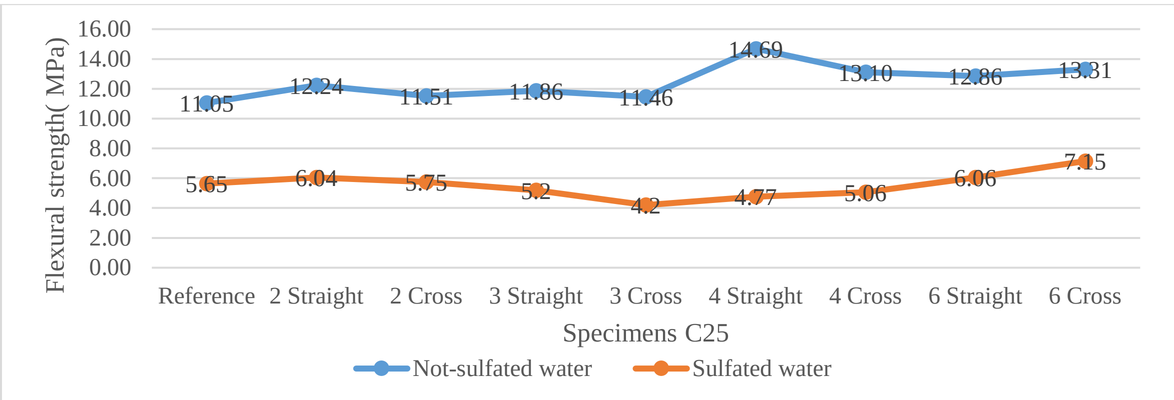


Figure 8. C25 specimens kept in sulfated water for 90 days

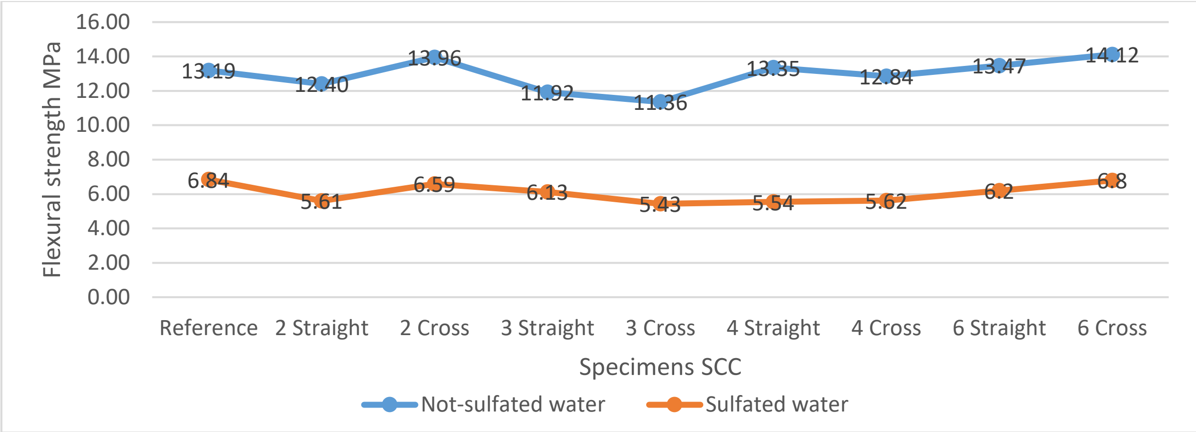


Figure 9. SCC specimens kept in sulfated water for 90 days

4. Conclusions

1) The waste textile sample with four fibers in a straight position had the greatest flexural strength value among the 28-day samples, measuring 6.89 MPa (2 levels x 2 fibers).).

2) The waste textile samples in straight positions and four fibers had the greatest flexural strength value among the 90-day samples, measuring 14.69 Mpa (2 levels x 2 fibers).).

3) The samples were stored in sulfated water for 90 days, and the highest flexural strength value was 7.15 MPa with 6 fibers (2 levels x 3 fibers) and the cross-positioned sample.

4) The 28-day waste textile samples have higher flexural strength values overall than the reference sample.Some of the waste textile samples that were stored in sulfated water for 90 days had bending strength values that were less than those of the reference sample.

5) Fiber-containing samples stored in sulfated waters did not yield positive results. The findings of this study allow for the usage of waste textile fibers to be taken into consideration, improving the bending strength of the beams while also having a good environmental impact. Future research can further enhance the performance of bending values achieved utilizing various waste textiles.

6) The ANSYS finite element analysis software was used to model each and every beam sample. With the experimental settings, the load-deflection curve anticipated by the results was confirmed.

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