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Effect of Steel Bead Wires Extracted from Recycled Tires on the Mechanical Properties of Concrete

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Abstract

Concrete plays an important role as a construction material in the worldwide for compressive strength. But the use of concrete as a structural material is limited to a certain extent by deficiencies like brittleness, poor tensile strength and poor resistance to impact strength, fatigue, low ductility, and low durability. Recently, worldwide researches have been devoted to the use of steel fibers recovered from consumed tires in concrete. For this goal, a bead wire having a diameter of 0.8 mm from recycled tires was extracted by a tire wire bead removal machine. A mix with a cement content of 420kg/m3 was produced with incorporating two different volumes of fiber 0.5%, and 1% of concrete volume, respectively, in addition to the reference samples (control) without steel fiber. Three different lengths 30-40-60 mm with the aspect ratio 37.5-50-75 respectively were used. Two maximum sizes of coarse aggregate were selected for the research. The maximum coarse aggregate sizes were 10 mm and 20 mm. A total of 36 cubes with 100 x 100 x 100 mm, 18 prisms with 150 mm x 150 mm x 750 mm, 36 cylinders with 150 mm diameter and 300 mm height were carryout and prepared in order to study the effect of the steel fibers (bead wires) on the mechanical properties of concrete. One mix was made without steel fibers (bead wire) extracted from recycled tires to be controlled. Samples of concrete incorporated with RTSF were tested compressive strength for cubic samples, indirect tensile strength test (Brazilian split test) for cylindrical samples, and flexural test for prismatic samples.

Keywords: *Recycled Tire Steel Fiber Reinforced Concrete, compressive strength, indirect tensile Strength, Flexural Strength.*

1. Introduction

Concrete is a non-homogenous material that contains fine and coarse aggregate that is randomly distributed within the cement paste, making its behavior very different from that of homogeneous materials such as metals. Concrete is classified as a fragile material, primarily because of its low tensile strength and low tensile strain capacity. This is a weakness in the properties of the concrete, which is avoided by reinforcing the concrete. Since 1960 researches have begun to use fiber as another type of reinforcement in concrete. Fibers are discontinuous elements that are randomly distributed within the concrete mix. Many types of fibers are used in concrete, including natural, synthetic and metal [1]. But the commercial use was in 1971 at a truck weighing station in Ohio in the United States. Over the past decades, concrete technology has changed considerably in terms of materials used and mix design. In conjunction with a greater understanding of the chemical and physical processes that control the behavior of the material. This has opened up new horizons in structural applications of concrete with steel fibers. Because the concrete bears exceptional pressure and can be formed in a large number of forms at a relatively inexpensive cost, it can be used in residential buildings, paving layers for roads, airstrips, and dams even in nuclear reactor installations [2]. This paper focus on the use of steel fibers extracted from scraped tires in concrete develops refractive behavior, especially with respect to the mechanical properties of concrete for different ratios of steel fibers.

2. The Experimental Work

This part describes the properties of materials of concrete mix design, aggregate, cement and water. In addition, the mixing, casting, and curing of concrete specimens.

2.1 Cement

Portland cement type I 42.5N was used in this study. The cement was supplied by Zliten Factory.

2.1.1 Specific gravity of cement

This test was done according to [Annual Book of ASTM 1989 C187-86]. The specific gravity, as measured by the experiment, was 3.15.

2.1.2 Fineness of cement

The test was done according to [Annual Book of ASTM 1989 C184-83], using sieve № 200. % retained after sieving was 4.8, which was less than the acceptable limit of this sieve (10%).

2.1.3 Setting times of cement (initial and final)

The test was done according to ASTM standards, using Vicat apparatus [3]. The initial setting time was 120 min and the final setting time was 195 min.

2.2 Aggregates

2.2.1 Fine aggregate:

The fine aggregate used for the entire research was natural sand obtained from Alsawawa, which is about 7 km east of Sirte city. The particle size analysis of used sand determined by dry sieve analysis as recommended by [4]. As can be observed from fig.1, the grading of the used fine aggregate was within the acceptable limits of the specifications.

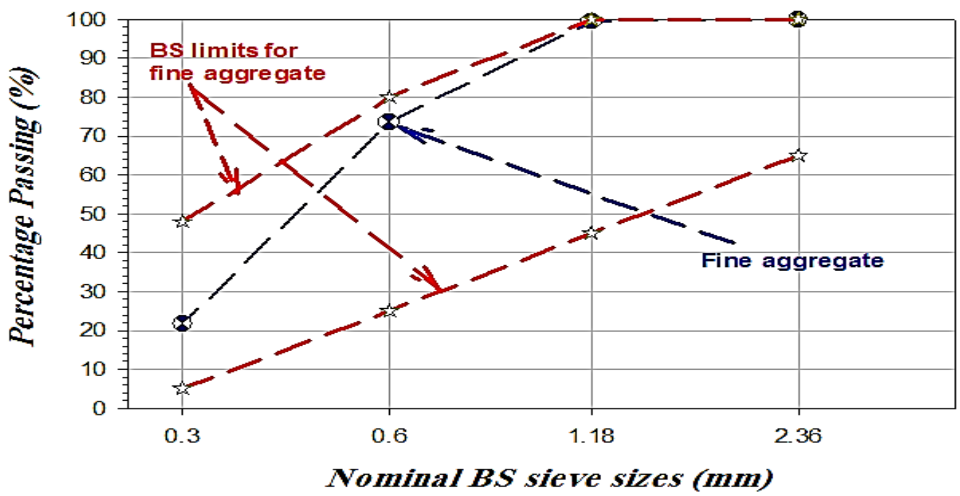

Figure 1: Grading curves of Fine aggregate according to BS 882:1992

2.2.2 Coarse aggregate:

The coarse aggregate used for the preparation of the specimens with a maximum size of 20 mm and 10 mm. 20mm brought from Alsawawa Construction crusher site, but 10 mm brought from Ashbilia Construction crusher site, located at Sirte, which is inside Sirte University. Particles size distribution of the gravel (10mm -20mm) used in concrete mixes presented in Figure 2. As can be observed, the grading of the used coarse aggregate was within the acceptable limits of BS specifications.

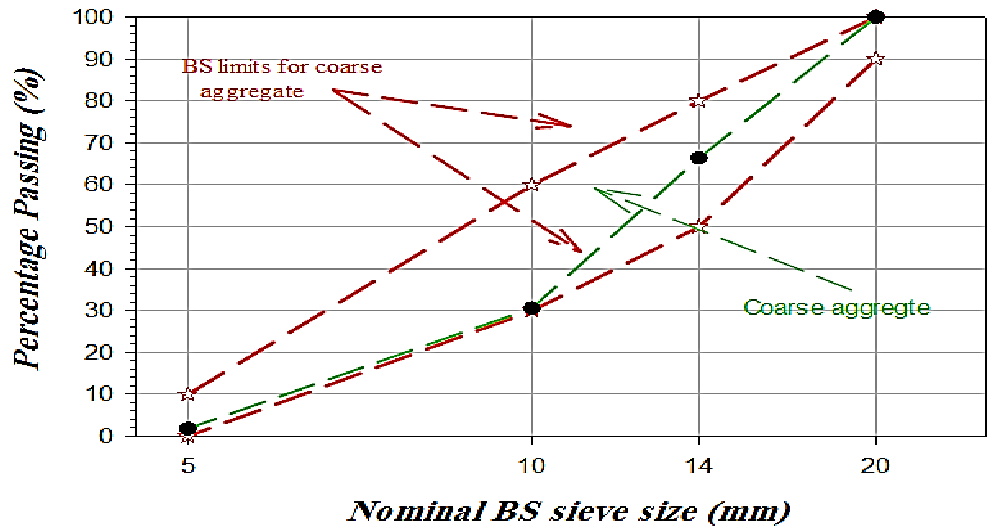

Figure 2: Grading curves of coarse aggregate size (10mm- 20mm) according to BS 882:1992

2.3 Water

Potable water free from chlorides and sulphates is used for mixing as well as for curing the concrete.

2.4 Steel Fibers

Steel fibers used in this research were from cutting of recycled normal strength tire steel wires from waste tires. These steel wires were one of the products of consume tire wire bead removal machine. The properties of steel (bead wire) fibers are shown in table 1. The steel wires were cut into three different lengths in Al-Saadi's workshop by using an abrasive wheel-grinding device. A bead wire having a diameter of 0.8 mm from recycled tires, which are extracted by bead removal machine. [5]

Table 1: Properties of the recycled tire steel fibers [Bead wire].

Property	Steel [Bead wires]		
Length (mm)	30	40	60
Diameter (mm)	0.8	0.8	0.8
Aspect Ratio (l/d)	37.5	50	75
Specific gravity (g/cm^3)	7.85	7.85	7.85
Geometry	Straight		

3. Mix Designs:

Concrete mix of class C-35 from Intermediate strength produced incorporating two different volume fractions, which are 0.5%, and 1%. Each volume fraction enclosed three different fiber lengths namely 30mm, 40mm and 60mm throughout the experimental work. The control mix is designed to achieve concrete Characteristic compressive strength of 35 MPa after 28 days. [6] The design was according to Absolute volume method. The grade C35 adopted as control was designed to have slump value with range between 60 - 180 mm and the water cement ratio (w/c) was 0.5. Concrete mix proportions are as shown in table 2.

Table 2: Concrete mix proportions.

Mix Constant.	Cement	Fine agg.	Coarse agg.	Water
By ratio	1	1.55	2.74	.05

3.1 Casting, compaction and curing of specimens.

The percentages of fibers used in this research are 0.5 and 1%. Table 3 gives the mix constituents required for 1 m^3 concrete.

Table 3: Mix constituents required for 1 m^3 concrete

Mix Type	Fiber (%)	Ingredients (Kg/m^3)					
		Cement	Fine agg.	Coarse agg.		Water	Fiber
				10mm (30%)	20mm (70%)		
RTSF - 0	0	420	650	345	805	210	0
RTSF - 0.5	0.5	420	650	345	805	210	39.25
RTSF - 1	1	420	650	345	805	210	78.5

The materials used in concrete mixes were all prepared before the mixing. The materials were weighed using appropriate digital balance to the nearest gram. The mixing process was carried out using a pan mixer of 0.08 m^3 capacity. The technique for mixing adopted in this research was a particular procedure for all mixes so as to achieve a uniform dispersion of fibers in the mix and to avoid balling effects. [7] Gravel, sand and cement were placed into the mixer and dry mixed for 3 minutes, then water was added in the space of 1 minute immediately, the mix was showing appearance of wetness. The fibers were added last and then a further one to two minutes mixing period was allowed to have the material sufficiently mixed. [8] The mixing period for each mix was between five and six minutes to ensure the fresh RTSFRC was homogeneous and without balling effect as shown in Figure 3. The control experiments were mixed following the same pattern except without inclusion of RTSF and the process completed within a shorter time.

Figure 3: Homogenous fresh steel fiber reinforced concrete after mixing

In the first series of experiments, the freshly mixed plain concrete [control] and RTSFRC were casted into 100x100x100mm cubes, prisms of 150x150x750mm and cylinders with 150 mm diameter and 300 mm height for each mix. After casting, all samples removed from their molds after 24 hours. The specimens are kept in the curing tank until testing day that is at seven and twenty-eight days. A total of 36 cubes with 100 x 100 x 100 mm, 18 prisms with 150 x 150 x 750 mm and 36 cylinders were cast and prepared for each mix. One mix made without steel fibers (bead wire) to be controlled. Cubes were used for the determination of 7 and 28 days compressive strength. Cylinders were used for the determination of 7and 28 days indirect tensile (Brazilian Split test). Prisms were used for the determination of 28th day flexural strength. [9]

4. Results and Discussion

The results obtained from the experimental program are analyzed to investigate the effect of steel fibers recovered from consumed tires on the mechanical properties of concrete. Three types of specimens (cubes, cylinders and prism) tested to measure the compressive, splitting tensile and flexural strengths of concrete.

4.1 Workability

In order to know the effect of incorporated bead wires on workability of concrete, the slump test performed on the fresh concrete for each mix and the results showed it in figure4. The slump values of concretes are varying between 140mm to 160 mm. It can note that the presence of the RTSF strongly affected the workability of the fresh concrete. The test results in all mixes indicated that as the volume fraction of the fiber increases the workability tend to decreases significantly. [10]

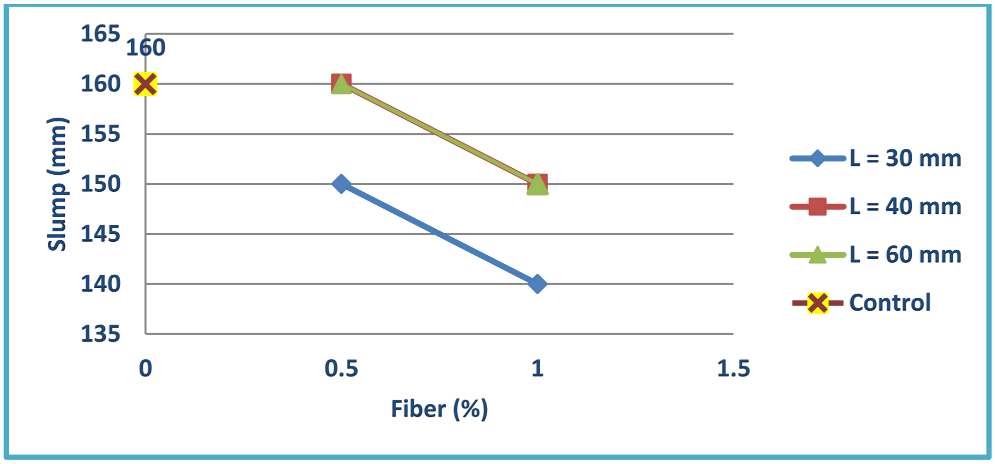

Figure 4: The Slump test results of concrete with and without RTSF.

4.2 Compressive Strength

At 7 days for 0.5% of RTSF concrete mixes investigated, a noticeable slightly increment, in compressive strength of concrete was observed when the fiber length was 30 mm, while 3% and 31.40% were noticeable when the fiber lengths were 40 and 60 mm respectively compared to that of the control mix. [11] For 1% of RTSF concrete mixes investigated, a noticeable 39.63% incensement in compressive strength of concrete was observed when the fiber length was 30 mm length, while 39.10 and 40.20% were noticeable when the fiber lengths are 40mm and 60 mm respectively compared to that of the control mix. At 28 days for 0.5% of RTSF concrete mixes investigated, a noticeable 2.60% incensement in compressive strength of concrete observed when the fiber length was 30 mm length, while 19.30 and 41.60% were noticeable when the fiber lengths were 40mm and 60 mm respectively compared to that of the control mix. For 1% of RTSF concrete mixes investigated, a noticeable 34.56% incensement in compressive strength of concrete observed when the fiber length was 30 mm, while 38.28 and 52.77% noticeable when the fiber lengths are 40mm and 60 mm respectively compared to that of the control mix.

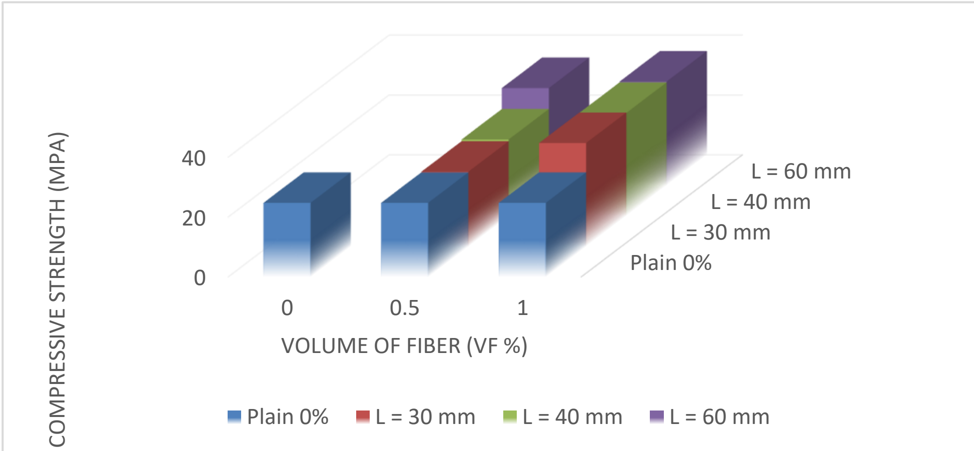

Figure 5: Cubes Compressive strength of RTSFRC concrete at 7 days

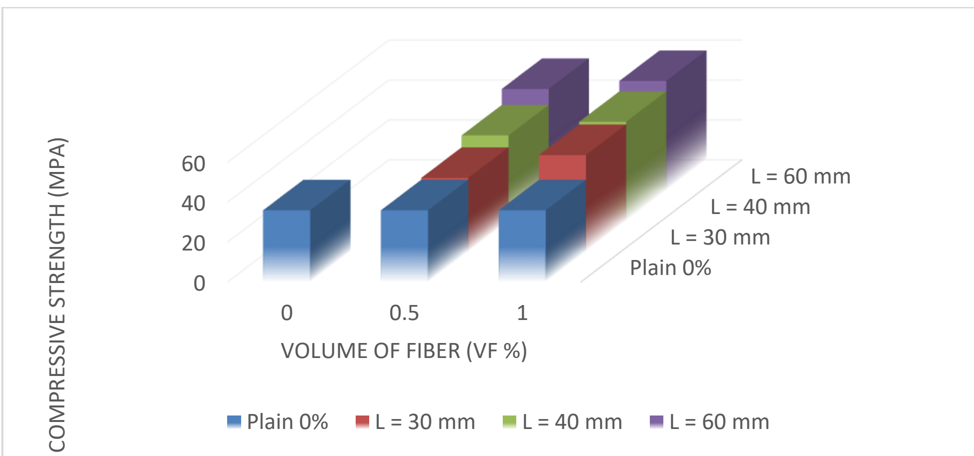

Figure 6: Cubes Compressive strength of RTSFRC concrete at 28 days.

4.3 Splitting Tensile Strength

At 7 days age for 0.5% of RTSF concrete mixes investigated, a noticeable 2.16% incensement in splitting tensile strength of concrete observed when the fiber length was 30 mm length. While 8.22% and 38 % were noticeable when the fiber lengths were 40mm and 60 mm respectively compared to that of the control mix. For 1% of RTSF concrete mixes investigated, a noticeable 6.9% incensement in splitting tensile strength of concrete observed when the fiber length was 30 mm length. While 16.88% and 40.26% were noticeable when the fiber lengths are 40mm and 60 mm respectively compared to that of the control mix. At 28 days age for 0.5% of RTSF concrete mixes investigated, a noticeable 45% incensement in splitting tensile strength of concrete observed when the fiber length was 30 mm length. While 17.49% and 38.40 % were noticeable when the fiber lengths were 40mm and 60 mm respectively compared to that of the control mix. For 1% of RTSF concrete mixes investigated, a noticeable 33.50 % incensement in splitting tensile strength of concrete observed when the fiber length was 30 mm length. While 34.20% and 47.10% were noticeable when the fiber lengths are 40mm and 60 mm respectively compared to that of the control mix.

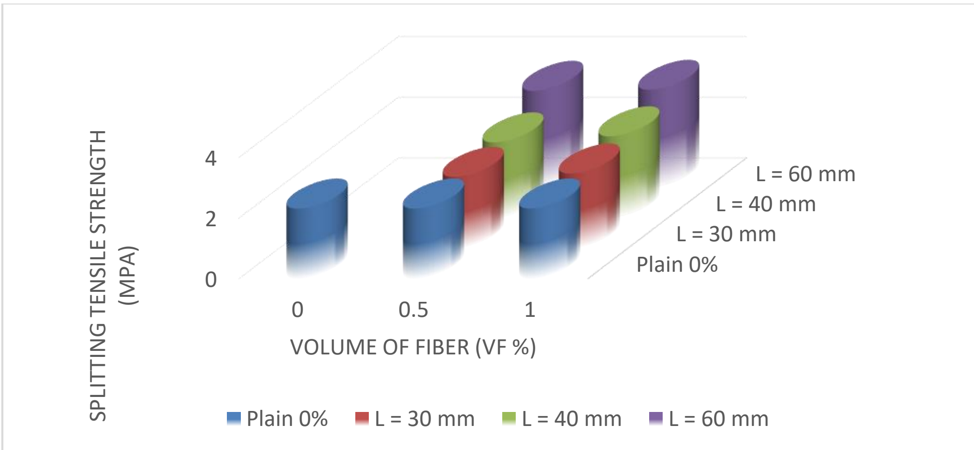

Figure 7: Splitting tensile strength of cylindrical RTSFRC concrete specimen at 7 days

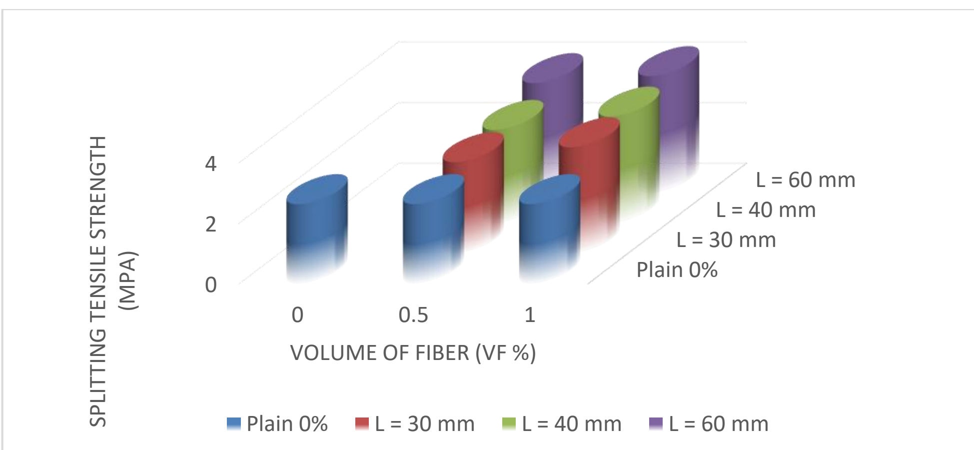

Figure 8: Splitting tensile strength of cylindrical RTSFRC concrete specimen at 28 days

4.4 Flexural Strength:

For 0.5% of RTSF concrete mixes investigated, a noticeable 14.14% incensement in the flexural strength of concrete observed when the fiber length was 30 mm length. While 14.30% and 17.84 % were noticeable when the fiber lengths were 40mm and 60 mm respectively compared to that of the control mix. For 1% of RTSF concrete mixes investigated, a noticeable 11.36 % incensement in flexural strength of concrete observed when the fiber length was 30 mm length. While 30.10% and 30.41% were noticeable when the fiber lengths are 40mm and 60 mm respectively compared to that of the control mix.

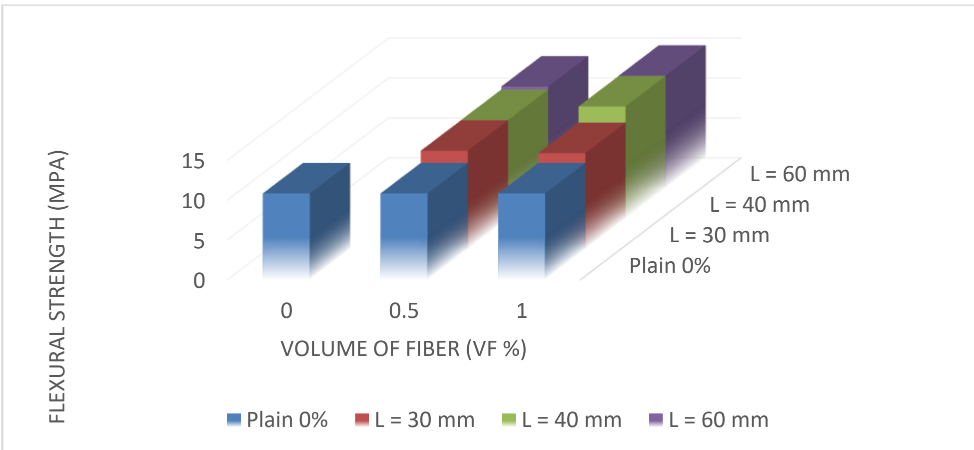

Figure 9: Flexural strength of prismatic RTSFRC concrete specimen at 28 days

Conclusion

1. The incorporation of steel fiber (Bead wire) up to 1% in concrete increases the compressive, indirect tensile and flexural strength of concrete.
2. The results of slump showed that as the fiber length and the fiber volume of fraction increases, the workability of concrete tends to decrease significantly.
3. From the failure moods the concrete enhanced with RTSF has much greater toughness compared to control concrete samples, the cylinder did not split during tensile test because of the presence of RTSF as reinforcement. Whereas, prism also did not break into two pieces because of the presence RTSF in concrete.

4. Concrete reinforced with 1% recycled tire fiber with length of 60mm is the most suitable to be used because it gives the highest strength of compressive, indirect tensile, and flexural strength test.

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