

# Behaviour of Treated Rubberised Fiber Concretes at Higher Temperatures

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## ABSTRACT

The fundamental aim of this study is to determine the effect of high temperature on the behavior of concrete consists NaOH treated rubber and steel fibers (TRSF-Con). During the experiment, four different concrete mixes were prepared; the first one is the control mix (CM) which was made with natural coarse and fine aggregates, cement, and water, while the other three concrete mixes were with the replacement rates of 10%, 20% and 25% of the natural coarse and fine aggregates by TRSF from used tires. The specimens were exposed for a period of 1 hour to design temperature-time curve up to 800°C followed by cooling to room temperature. Compressive strength, flexural strength, weight loss were determined and compared with that of control specimens. The ductility of the concrete increased with the increased of TRSF contents, increases the damping properties, and while the compressive strength of the concrete reduced with the increment of TRSF contents. Although data obtained in all parameters were lower than the control specimens, concrete containing treated rubber and steel fiber can be suitable for non- structural member in concrete and driveways or road constructions.

**Keywords:** Concrete, Treated Crumb Rubber, Steel Fiber, Compressive Strength, Flexure Strength

## 1. INTRODUCTION

The increasing numbers of waste rubber produced by rubber tires exposed to environmental areas are increasing drastically, and that caused a negative effect to the environmental health. According to Sandra [1], in Malaysia, it is estimated that the yearly increment of waste tire is about 57,391 to 8.2 million tonnes, 60% of the waste tires are disposed through unknown or illegal routes. Based on rubber consumption, Malaysia is in the 9<sup>th</sup> position in top 10 world ranking, while Brazil, China, Germany, India, Indonesia, Japan, Thailand, USA and Russia goes to top ten ranking [2].

Rubber tires are the types of essential resources in which they cannot be decomposed naturally even after a long period of landfill process. A modest quantity of unprocessed scrap tires are used to provide shock protection for marine platforms against impact from waves or ships, whilst in some parts of the world people still resort to burn this wastes which produces unacceptable levels of pollution [3]. The simplest way of decomposing used tire is by burning it; furthermore, burning out tires in some countries is against the law due to the fact that it's creating a smoke and pollution to the environmental area [4]. Therefore, waste management is needed to take account the global environmental issues. Eldin [5] shown the reutilization of the waste materials, crumb rubber concrete and recycled steel fiber that he conducted seems promising in reducing environmental hazard and improved on the effects of rubber chips towards the compressive and flexural strength of concrete containing crumb rubber and fibre steel.

The main goals of this research is to investigate the effect of replacing fine and coarse aggregates with NaOH treated crumb rubber and steel fiber from used tires in concrete constituents exposed to high temperature. Characteristic of concrete containing crumb rubber and steel fiber at high temperature such as compressive strength, flexural strength, and weight loss are compared with the control samples.

## 2. LITERATURE REVIEW

### 2.1 Crumb Rubber (CR)

There is a difference in constituent of materials between car tires and truck tires. The production of car tires is higher than truck tires [6]. Besides that, Sherwood [7] claimed that the material produced from truck or car tyres and the associated processing technique, can affect its suitability as a rubber aggregate through the quantity of steel and textile fiber reinforcement present, and the shape and texture of the particles. Basically in local reclaimed rubber manufacturer is produced from selected discarded or worn rubber products.

During the main stage of the process-technology the raw materials were selected. It has to be cleaned, cut and ground progressively to very fine powder after removal of all ferrous metal and non-ferrous contaminant. The fine powder is then depolymerised under controlled conditions of temperature and steam pressure in the rotary autoclaves aided with suitable process oils and strained and finally refined to silky-smooth leaves which are built up into sheets for ease of handling. The end-product is then rigorously tested before approval for dispatch. There are three categories of used rubber that has been considered for Figure 1:

1. Shredded or Chipped rubber, with the size range of 25-30 mm, and were usually used to replace coarse aggregate in the concrete mix.
2. Crumb rubber which has the size range between 3-10 mm and it's usually irregular in shape. This size particle was used for the replacement of sand.
3. Ash rubber, the size of this one is less than 1 mm, and it was used to replace some percentage of cement paste in concrete.



Figure 1 Types of the sized of crumb rubbers used in the test [6]

### 2.2 Fiber Used in Concrete

Fiber can be classified into two categories, depending on their origin or modulus of elasticity. In terms of their modulus of elasticity, fiber can also be classified into two different group, the fibers which are having a high elastic modulus compared to concrete mix called hard intrusion, and those that are having lower elastic modulus when compared with cement mortar were called soft intrusion. Glass, steel, and carbon are having a higher elastic modulus than cement mortar, while polypropylene and vegetable fibers are categorized as low elastic modulus fibers. The high elastic modulus fibers have the ability of improving both flexural strength and impact resistance, while the low elastic fibers can only be able to contribute in improving the impact resistance [8]

More so, in terms of fibers origin, fiber can be classified into three groups, metallic fibers (includes stainless steel, carbon steel, and steel), mineral fibers (glass and asbestos fibers), and organic fiber which can be split into natural and man-made fibers, hence, the below flow chat demonstrated the classes of fibers [8]. Classification of fiber is shown in Figure 2.

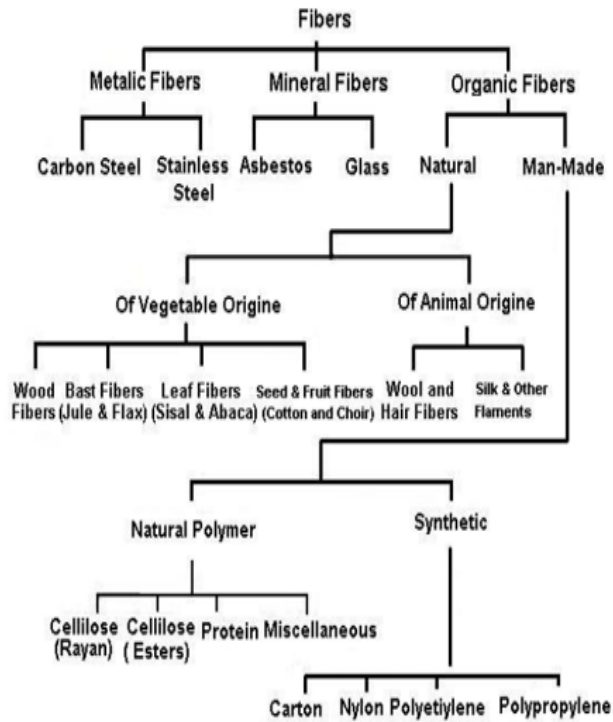


Figure 2 Flow chart of Fibers [8]

Johnston and Colin studies, few typical types of fibers are recommended for application in the field of civil engineering. Properties of typical types of fibers are shown in Table1 [9]

Table 1 Properties of Fibers [9]

Fibers	Diameter ( $\mu\text{m}$ )	Specific Gravity	Modulus of Elasticity (GPa)	Tensile Strength (GPa)	Elongation to Failure (%)
Chrysotile Asbestos	0.02 – 20	2.55	164	3.1	2 – 3
Crocidotile Asbestos	0.1 – 20	2.55	196	3.5	2 – 3
E-Glass	9 – 15	2.56	77	2 – 3.5	2 – 3.5
AR-Glass	9 – 15	2.71	80	2 – 2.8	2 – 3
Fibrillated Polypropylene	20 – 200	0.91	5	0.5	20
Steel	5 – 500	7.48	200	1 – 3	3 – 4
Stainless steel	5 – 500	7.48	160	2.1	3
Carbon Type I	3	1.90	380	1.8	0.5
Carbon Type II	9	1.90	230	2.6	1.0
Aramid (Kevlar)	10	1.45	65 – 133	3.6	2.1 – 4.0
Cellulose	-	1.2	10	0.4	-
Wood	-	1.5	71.0	0.9	-
Nylon (Type 242)	< 4	1.14	4	0.9	15

### 2.3 Crumb Rubber Concrete (CRC)

Studied the addition of crumb rubber in concrete mix design, in which their stated that, the presence of crumb rubber in concrete mix enhanced the structure to overcome the blast effect. Replacing some amount of coarse aggregate or fine aggregates with the particles of crumb rubber will produce a crumb rubber concrete with a very good ductility [10].

Bonding between rubber and cement have been studied by Biel Timothy and Lee which used special cement and magnesium oxychloride to provide a strong bonding strength between cement and rubber particle [11]. Furthermore, the amount of crumb rubber in concrete constituents is suggested between 17% to 20% of the total volume of aggregates will effect differently to concrete properties freeze-thaw durability [12-14].

### 2.4 Fiber Reinforced Concrete (FRC)

Fiber Reinforced Concrete (FRC) is made by mixing product of fiber materials with cement, water, fine and coarse aggregate in the mixture to form a FRC. The fiber is measured before adding to the portion of total volume of concrete, means the control samples were cast in every batch of the mix before addition of fibers. Amount of fiber is categorized into three parts, low, moderate and high volumes of fibers addition [10].

Usually, for the applications that involved a large volume of concrete, typically, the low volumes of fiber composites are mostly taking into account suggested that the volume fraction of steel fibers should be range from 0.4 to 2 percent, and polymer fiber should range from 0.06 to 0.5

percent, due to the facts that these ranges of fibers provided reasonable results after testing FRC [15].

### 3. MATERIALS AND METHOD USED

#### 3.1 Mix Design

Table 2 shows the typical mix design used in this study. There were 13 batches of concrete mix during the experiment, each batch consists four cubes for compression test, and three beams for flexural test. The total volume of each batch is 0.022 m<sup>3</sup>. Thus, Table 3 demonstrated the amount of treated fine and coarse aggregate rubber replacement used in the experiment, while the amount of steel fiber used in this experiment is shown in Table 4.

Table 2 Concrete Mix Design

Item	Mass (kg)
Cement	10.50
Fine Aggregate	17.50
Coarse Aggregate	22.20
Water	4.70

Table 3 Percentage of Treated Crumb Rubber and steel fibre in concrete mix

Treated Rubber	Cement (kg)	Water (kg)	Treated Crumb Rubber (kg)	Fine Aggregate (kg)	Treated Crumb Rubber (kg)	Coarse Aggregate (kg)
0% of Treated Rubber	10.50	4.70	1.75	15.75	2.22	19.98
10% of Treated Rubber	10.50	4.70	3.50	14.00	4.44	17.76
15% of Treated Rubber	10.50	4.70	4.38	13.13	5.55	16.65

Table 4 Concrete samples including percentage of Steel Fiber used

Steel Fiber (Wired chord)	Mass(kg)	Volume, m <sup>3</sup>	Concrete Samples
<b>0.50%</b>	0.115	0.000115	TRSF1-Con
<b>1.00%</b>	0.230	0.00023	TRSF2-Con
<b>0.50%</b>	0.115	0.000115	TRSF1-Con 10
<b>1.00%</b>	0.230	0.00023	TRSF2-Con 10
<b>0.50%</b>	0.115	0.000115	TRSF1-Con 15
<b>1.00%</b>	0.230	0.00023	TRSF2-Con 15

## 4 RESULTS AND DISCUSSIONS

### 4.1 Ultrasonic Pulse Velocity (UPV) test

Among the available methods of non-destructive test (NDT) of hardened concrete, the UPV methods can be considered as one of most promising methods for evaluation the concrete structures to examine of the material homogeneity. The concept of this test is the transmitter will generate pulse and receiver will receive the pulse. Direct transmission is the method used in this research, and it is propagating and receiving ultrasonic pulse, it's shown in Figure 2.

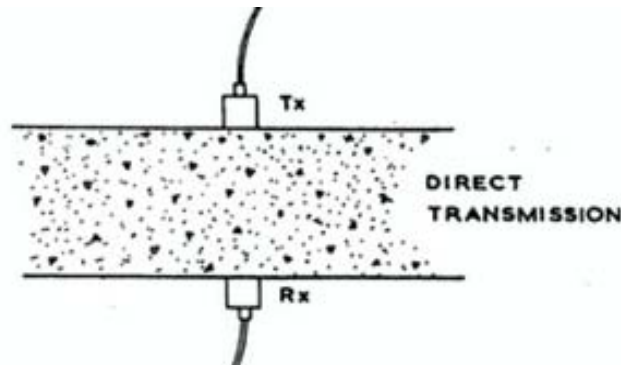


Figure 2 Direct transmission test set up

The results for UPV test are shown in Figure 3 and Figure 4. As it can be seen, velocity in the concrete higher with increasing replacement of treated crumb rubber and steel fibre in the concrete mix. This determines that the quality of these concrete is acceptable.

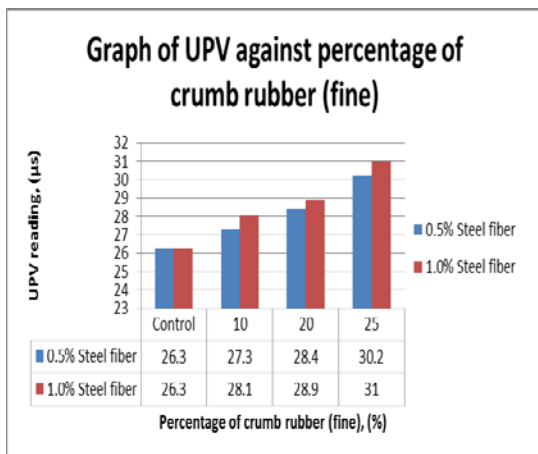


Figure 3 Graph UPV test for cube

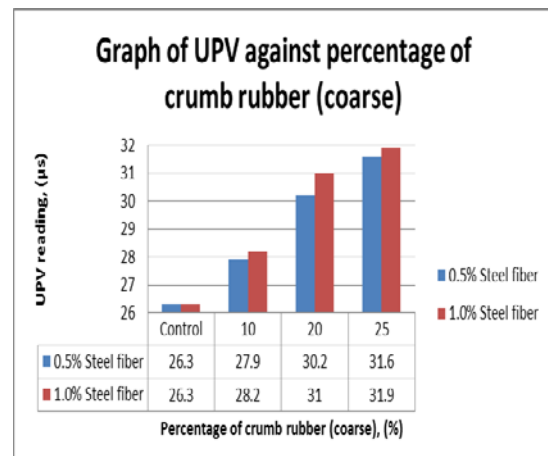


Figure 4 Graph UPV test for cube

### 4.2 Compression test

Three samples of 100mm x 100mm x 100mm cubes in each batch were used for compression test. In this test, 91 samples of the concrete were used for compression test at the age of 7 days. Concrete samples containing only fine crumb rubber and coarse crumb rubber, and control concrete are casted for the comparisons. From the impact of using scrap tyre rubber aggregate as a partial replacement for natural aggregates on the compressive strength has been well documented in Figure 5 and 6. Across a large number of previous studies, all reported that the compressive strength

decrease significantly with increased quantities of rubber aggregate [16-25]. Figure 5 and Figure 6 illustrates the additional percentage of both fine and coarse crumb rubber decreased the value of compressive strength. The reduction is due to poor development of the interfacial transition zone [10]. Only one study found that it is possible to replace the rubber for both fine and coarse crumb rubber which at 10% replacement with 1.0% steel fiber is promising [8]

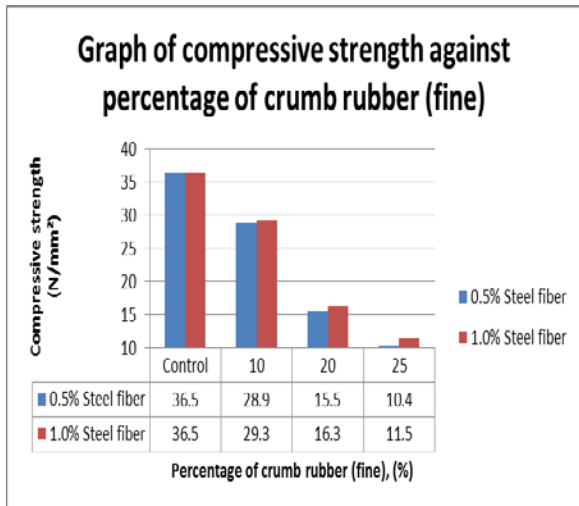


Figure 5: Graph for compression test

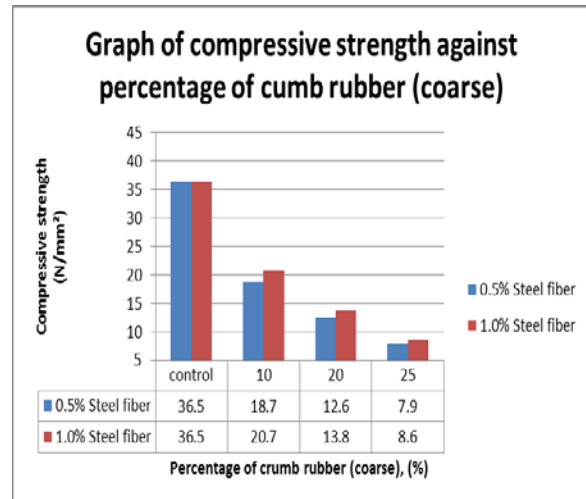


Figure 6: Graph for compression test

### 4.3 Flexural test

Flexural test is a destructive test is expressed the modulus of rupture for concrete, therefore flexural strength is used to determine the ductility of each beam. Three beam samples were prepared from each batch of concrete mix for flexural test, and cured them for 7 days. Each sample was tested under two point of loading system, and the size of the sample used was 100 × 100 × 500 mm. Figure 7 shows the flexural test set up.



Figure 7 Flexural test set up

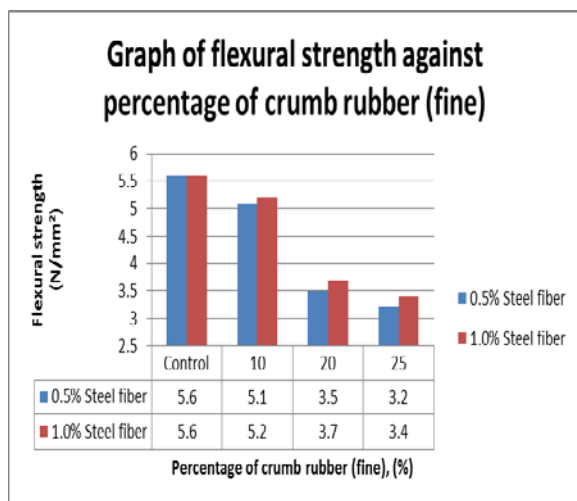


Figure 8 Graph for flexural test

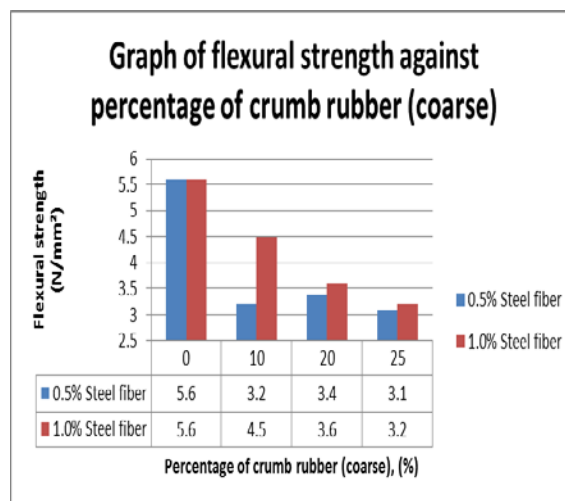


Figure 9 Graph for flexural test

The flexural strength of cylindrical concrete contains NaOH treated crumbed rubberized (fine and coarse) at 7 days curing is illustrated in Figure 8 and Figure 9. It can be seen that significant decline in flexural strength for both fine and coarse crumb rubber occur until 25% by weight replacement, whereas control or known as larger than 0% by weight replacement and is proportionally much greater compared with crumb rubber. Flexural strength of concrete contains 10% replacement of fine aggregate 16% higher than is replacement of course aggregate with 1.0% steel fiber. This has proved that the ideal quantity of 3-10 mm crumb rubber can be used in concrete mix. This has been supported through the finding by Topcu and Bilir where shown that 4mm with 180 kg/m<sup>3</sup> aggregate replacement is an ideal replacement [24].

## 5 CONCLUSIONS

This study highlights the contribution in crumb rubber and steel fibre from used tyres in concrete mix range from 0% to 25% exposed to higher temperature. The following conclusions are presumed.

- The addition of rubber particles resulted in a reduction of flexural strengths of the concrete mixes. The decrease in strength was dependent on the content of rubber granules or shreds and the volume of steel fibre.
- Increasing the bending strength of the concrete under flexural test, the bending strength of the concrete increased with the increased of steel fiber contents, and it could be positive usage in highway barriers or some other similar shock resisting elements.
- The increment of rubber contents reduces the compressive strength, lower the flexural strength; however, the lower amount of rubber contents produced a reasonable result of compression strength.
- Replacement of crumb rubber in fine aggregates can be sufficiently better than replaced the coarse aggregates.
- The used of chipped or shredded rubber aggregate in preference for crumb rubber and the replacement ratio should not exceed 30% of total aggregate volume, in order to maintain acceptable levels of strength and stiffness for rubberized concrete to be serviceable.



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