Analysis of Compression and Tension in Concrete with Recycled Rubber Fibers

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***Abstract*— Concrete is a composite material widely used in construction, it has high resistance to compressive stress, but the tensile strength is very low, it varies from 10% to 15% of its compressive strength. Given the low resistance to tensile stress, we are working on projects that help increase its capacity. In the present research work the incidence of rubber fibers graded by the # 4, # 8, # 16 and # 30 meshes in concrete mixtures is evaluated, a base mixture with compression resistance of 250 kg / cm2 was designed at the 28 days that is compared with mixtures added with rubber fibers in 8%, 10%, 12%, 14% and 16% depending on the cement content of the base mixture; The resistance to compression, indirect tension and bending were analyzed, cylinders were made that were tested at ages of 7, 14 and 28 days and beams with curing of 28 days in total water immersion, obtaining that with the addition of the fibers it decreases compression but tension and bending increase.**

***Index Terms*— Composites, concrete, mechanical stress, rubber fibers.**

I. Introduction

Concrete is a heterogeneous compound of cement, water, sand and gravel, and in some cases, additives [1], this composite material is widely used in construction due to its mechanical properties such as high resistance to compression, it is durable and does not require a large investment for its maintenance [2], however, this material has the disadvantage of a low tensile strength that varies from 10% to 15% of its compressive strength [3]; For this reason, alternatives have been sought to counteract its weakness. One option is the use of fibers in the concrete mix and can be made of steel, plastic, glass, natural and synthetic materials with a wide variety of shapes, sizes, and thickness [4]. In the last three decades, interest in the use of fibers to produce fiber reinforced concrete (FRC) has increased [4]. The reduction in compressive strength limits the use of the mixture, but is rewarded with a decrease in its density, an increase in impact resistance, ductility and acoustic insulation [5], on the other hand, [6] elaborated concrete mixtures with replacement of the coarse and fine aggregate by rubber in different proportions, but the results did not show any improvement in the mechanical properties, contrary to the previous investigation, when adding granulated rubber as filler to the concrete, replacing 5% from the coarse aggregate by rubber in flake forms, an increase in the resistance to compression of the mixture was obtained [7]; Various authors [8]-[12] carried out tests on mixtures of concrete added with rubber with a variety of graduations, but all the specimens showed reduction in their resistance to compression, tensile stresses and modulus of elasticity, due to this Investigate the incidence of rubber fibers characterized by # 4, # 8, # 16 and # 30 sieves, as this type of material presents areas of opportunity for application in concrete mixtures. The objective in this work is evaluating the incidence of fibers from tire reconditioning on compression and tension stresses in a conventional concrete mix with a specified resistance of 250 kg/cm² at 28 days' age, and giving a second use to the waste, helping to reduce environmental impact.

II. Mataterials and Mnetods

A simple concrete mixture was made, and rubber fibers from disused tires were added, the mixtures were manufactured with different percentages, and the incidence on the concrete compressive strength, indirect tensile strength, and bending was measured.

A. Materials

Existing stone aggregates from the Durango lagoon region were used. The sand was subjected to a modification process to comply with the correct particle size distribution standards established in the NMX-C-077-1997-ONNCCE standard [13]. The materials are as follows:

- water
- CEMEX CPC 30R cement
- coarse aggregate, crushed limestone gravel
- fine aggregate, river sand, hybrid sand
- tire rubber fiber

B. Methods

The rubber fibers were characterized according to their aspect ratio, retained fibers in the # 4, # 8, # 16, and # 30 sieves were used. The mixture was designed for the resistance of 250 kg/cm², and a slump of 15cm ± 2.5 cm. The design was according to the absolute volume method presented by the Portland Cement Association [4]. A base mixture was used, and from it, different percentages of fibers were added to the mixtures, the percentages were 8 %, 10 %, 12 %, 14 %, and 16 %, these were added depending on the cement content.

In total, 6 mixtures of 0.073 m^3 each were manufactured, base mixture (M1) and the others with the different percentages of rubber added 8 % (M2), 10 % (M3), 12 % (M4), 14 % (M5) and 16 % (M6). The tests in fresh state: temperature, slump, and volumetric weight were carried out, the specimens were elaborated and cured in total immersion in water to obtain the resistance to compression at the age of 7, 14, and 28 days, and tensile strength at the age of 28 days.

III. RESULTS

The test of the specimens was carried out based on the NMX-C-083-ONNCCE-2002 standard [14], the results obtained from the compression resistance test in the hydraulic press are presented in table 1 and fig 1.

As can be seen in table 1, mixtures M2 and M3 showed an increase in compressive strength compared to the base mixture M1, but mixtures M4, M5 and M6 suffered an effect on this mechanical property. mention that no mixture achieved the 70 % compressive strength that should be obtained at the age of 7 days [4].

Table 1.- Compressive strength 7 days.

Mixture	f´c (kg/cm^2)	Ratio %
M1	140.05	56
M2	144.83	58
M3	142.92	57
M4	104.72	42
M5	125.73	50
M6	97.08	39

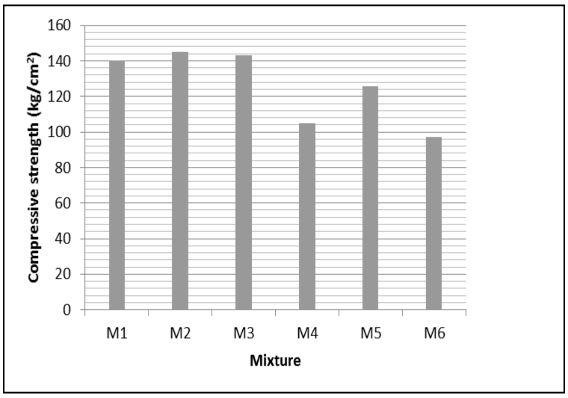

Fig 1.- Resistance at 7 days.

The compressive strength at 14 days is presented in Table 2 and fig 2, where it is seen that the base mixture (M1) developed a greater compressive strength than the other samples with the addition of rubber, on the other hand, the specimens that contain a higher percentage of fibers presented a greater compression deficiency.

Table 3 and fig 3 present the results obtained from the compressive strength test at the age of 28 days, the sample that presented the highest compressive strength was M1 compared to the mixtures with the addition of rubber fibers, however, no specimen obtained 100 % of the design strength.

Table 2.- Compressive strength 14 days.

Mixture	f´c (kg/cm^2)	Ratio %
M1	171.88	69
M2	141.96	57
M3	139.10	56
M4	124.14	50
M5	109.81	44
M6	120.95	48

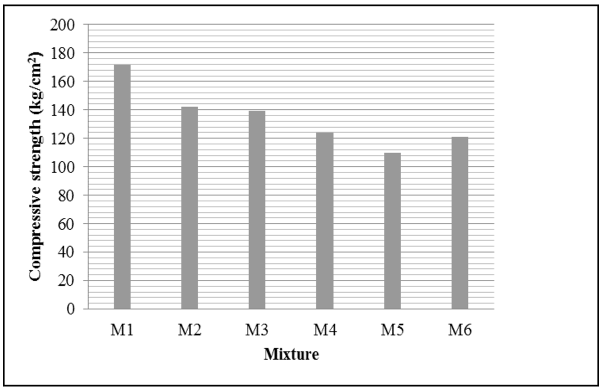

Fig 2.- Resistance at 14 days.

Table 3.- Compressive strength 28 days.

Mixture	f´c (kg/cm^2)	Ratio %
M1	221.22	88
M2	181.43	73
M3	163.92	66
M4	127.32	51
M5	155.97	62
M6	150.87	60

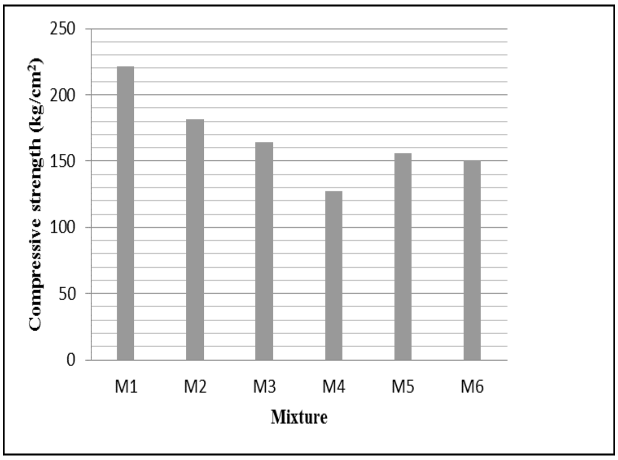

Fig 3.- Resistance at 28 days.

The indirect tension test was carried out based on the NMX-C-163-ONNCCE standard [15], in table 4 and fig 4 the results of the test are shown, it is observed that the specimens containing rubber fibers showed an increase in tensile stress as the percentage of fibers contained in the blend increased.

The bending test was carried out according to the NMX-C-191-ONNCCE-2015 standard [16], the results are shown in table 5 and fig 5, it is seen that the M4 mixture obtained a bending stress greater than the Furthermore, it is also noted that all the specimens with the addition of rubber exceeded the flexural strength of the base sample M1.

Table 4.- Indirect tensile strength.

Mixture	Tensile strength (kg/cm²)	Ratio %
M1	21.22	9.59
M2	21.71	11.96
M3	18.68	11.39
M4	18.71	14.69
M5	20.62	13.22
M6	23.08	15.30

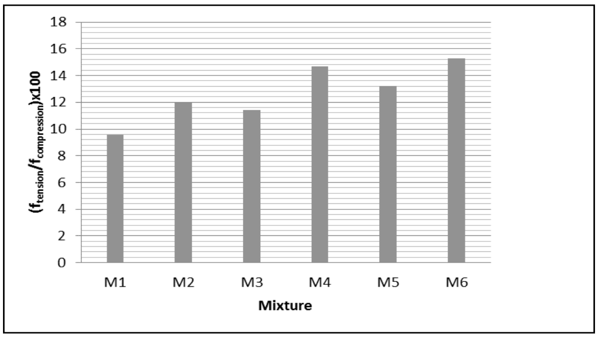

Fig 4.- Indirect tensile strength.

Table 5.- Flexural strength.

Mixture	Bending stress (kg/cm²)	Ratio %
M1	45.18	20.42
M2	39.62	21.84
M3	42.96	26.20
M4	35.55	27.92
M5	35.18	22.55
M6	34.44	22.82

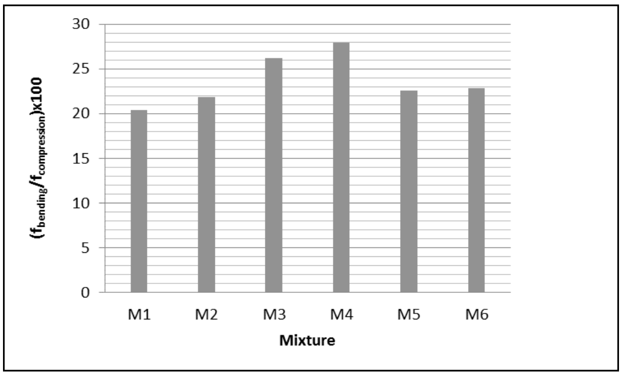

Fig 5.- Flexural strength.

The compressive strength at 7 days was increased in the specimens with 8 and 10 percent of rubber fiber, while at the ages of 14 and 28 days all the specimens with the addition of rubber showed a reduction in their resistance; It is observed that the rubber fibers characterized by the # 4, # 8, # 16 and # 30 sieves negatively affect the compressive strength, with decrease values of between 17.98 % and 42.44 % of the M1 resistance.

The indirect tensile strength had an increase in all the mixes with the addition of rubber fibers compared to the base mix (M1), varying from 11.39 % (M3) to 15.3 % (M6) of the compression resistance, while the base sample had a result of 9.57 %, for this reason it is concluded that the rubber fibers positively favor the tensile strength of a conventional concrete from 1.82 % to 5.73 %.

The bending stress presented in the specimens with rubber was higher in all the tests compared to the base sample (M1), this difference varies in the M2 - M6 specimens from 21.84 % to 27.92 % of the compressive strength, on the other hand, the mixture M1 obtained a value of 20.42 %; therefore, the flex increase ranges from 1.42 % to 7.5 %.

When comparing the mechanical characteristics of the specimens with rubber, it is observed that although the compressive strength is affected in the samples with the addition of fibers, it is discerned that there is a mixture in which the reduction in the compressive strength does not is so significant and its properties to resist tensile stresses are better than that of M1, of the mixtures with the addition of rubber fibers, the mixture with the best properties is M2 with an addition of 8 %.

IV. Conclusion

Based on the results obtained from the experimentation, it is concluded that a mixture of concrete added with rubber fibers characterized by meshes # 4, # 8, # 16 and # 30; negatively affect the compressive strength of a conventional concrete, on the other hand, it increases the resistant tensile stress and the modulus of rupture, having the best result adding 8 % since its loss of compressive strength was 17.98% of M1, the lowest reduction presented in relation to its resistance to tension and bending.

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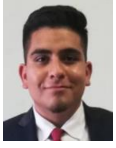

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