Experimental Investigation on Concrete with Partially Replacement of Coarse Aggregate by Junk Rubber

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دراسة تجريبية على الخرسانة مع استبدال جزئي للركام الخشن بواسطة المطاط غير المرغوب فيه

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Abstract

The growing problem of waste tires disposal in Iraq can be alleviated if new recycling routes can be found for the surplus tires. One of the largest potential routes is in construction. However usage of waste tires in civil engineering is currently very low. The use of recycled tire rubber as partial aggregate in concrete has great potential to positively affect the mechanical properties of concrete in a wide spectrum. Concrete is one of the most popular construction materials. Due to this fact, the construction industry is always trying to increase its uses and applications and improving its properties, while reducing cost. The objective of this experimental study is to test the properties of concrete when recycled rubber from automotive tires is used as a partial aggregate. Tests were carried out on concrete specimens containing 0%, 5%, 10% and 15% substitution of junk tire rubber as a natural aggregate. The replacement of coarse aggregate by junk rubber in concrete has resulted in reduced compressive strength and density. The reductions in compressive strength and density depended on the amount of rubber added. Loss of mechanical strength and relatively high variability in durability performance are major factors preventing large-scale utilization of scrap tire waste in concrete. The addition of supplementary cementitious materials has been investigated in this paper in order to mitigate the loss of mechanical properties in rubberized concrete. Hence, some mixtures also contain silica fume at 15% cement replacement by volume. The results reveal that although the strength improvement due to pre-coated crumb rubber alone was minor, the synergistic effect of pre-coated crumb rubber and silica fume as cement replacement material significantly enhanced the mechanical properties of mixtures.

Keywords: Compressive Strength; Split Tensile Strength; Junk Rubber.

المستخلص

يمكن تخفيف حدة مشكلة التخلص من نفايات الإطارات في العراق إذا تم العثور على طرق جديدة لإعادة تدوير للإطارات الفائضة. واحدة من أكبر الطرق المحتملة هي في البناء. ومع ذلك، فإن استخدام إطارات النفايات في الهندسة المدنية منخفض للغاية في الوقت الحالي. إن استخدام مطاط الإطارات المعاد تدويره كنسبة من ركام الخرسانة له قدرة كبيرة على التأثير الإيجابي على الخواص الميكانيكية للخرسانة في نطاق واسع. الخرسانة هي واحدة من مواد البناء الأكثر شعبية. وبسبب هذه الحقيقة، تحاول صناعة البناء دائمًا زيادة استخداماتها وتطبيقاتها وتحسين خصائصها، مع تقليل

التكلفة. الهدف من هذه الدراسة التجريبية هو اختبار خواص الخرسانة عند استخدام المطاط المعاد تدويره من إطارات السيارات كنسبة من الركام. أجريت الاختبارات على عينات خرسانية تحتوي على نسب صفر٪ و5٪ و10٪ و15٪ من مطاط الإطارات تساوي الركام الطبيعي. وقد أدى استبدال الركام الخشن بالمطاط غير المرغوب فيه في الخرسانة إلى تقليل قوة الضغط والكثافة. تعتمد التخفيضات في قوة الضغط والكثافة على كمية المطاط المضافة. إن فقدان القوة الميكانيكية والتقلبية العالية نسبيا في أداء المتانة هما عاملان رئيسيان يمنعان استخدام نفايات الإطارات التالفة على نطاق واسع في الخرسانة. تم دراسة إضافة مواد إسمنتية تكميلية من أجل تخفيف فقدان الخواص الميكانيكية للخرسانة المطاطية. أن بعض الخلطات، تحتوي بعض أيضًا على دخان السليكا عند استبدال السمنت بنسبة 15٪ من حيث الحجم. وتكشف النتائج أنه على الرغم من أن تحسن القوة بسبب المطاط المطلي سابقًا كان بسيطًا، إلا أن التأثير التآزري لمطاط المطلي مسبقًا وأبخرة السليكا كمادة بديلة للإسمنت عززت بشكل كبير الخواص الميكانيكية للخلطات الخرسانية.

الكلمات المفتاحية : مقاومة الانضغاط ،مقاومة الانشطار الشد,المطاط غير المرغوب فيه.

1. Introduction

In 1990, over 240 million scrap tires were discarded in the United States and approximately 3 billion waste tires had accumulated in stockpiles or uncontrolled tire dumps throughout the country, with millions more scattered in ravines, deserts, woods and empty lots. Each year, over 77% of the annual production of scrap tires, about 188 million tires per year, were landfilled, stockpiled or illegally dumped. Tires are bulky, and 75% of the space a tire occupies is void, so that the land filling of scrap tires has several difficulties:

• Whole tire landfilling requires a large amount of space.

• Tires tend to float or rise in a landfill and come to the surface.

• The void space provides potential sites for the harboring of rodents.

• Shredding the tire eliminates the above problems but requires high processing costs.

Because of the above difficulties and the resulting high costs, tire stockpiles have turned up across the United States. These waste tires represent significant environmental, human health, and aesthetic problems.

Concrete has been the most widely used construction material nearly for a period of a century. Some of the peoples research the rubberized concrete: Eldin and Senouci (1993),"Rubber tire particles as coarse aggregates "examined compressive and tensile strengths of rubberized concrete. They noted that rubberized concrete didn't perform as well as normal concrete under repeated freeze-thaw cycles. It exhibited lower compressive and tensile strength than of normal concrete but unlike normal concrete, rubberized concrete had the ability to absorb a large amount of plastic energy under compressive and tensile loads. It didn't demonstrate the typical brittle failure, but rather ductile, plastic failure mode.

Iraq has taken major initiative on developing the infrastructures such as express highways, power projects and industrial structures. to meet the requirements of globalization. In the construction of buildings and other structures, concrete plays rightful role and a large quantum of concrete is being utilized. Coarse aggregate, which is one of the constituent used in the production of conventional concrete has become highly expensive and also scarce. In the backdrop, there is large demand for alternative materials from wastes. Waste tire dumping or disposal of these materials causes environmental and health problems. Waste tire management is a serious global concern. Millions of waste tires are generated and stock piled every year, often in an uncontrolled manner, causing a major environmental problem. As tires are durable and not naturally biodegradable, they remain in dump sites with little degradation overtime, presenting a continuing environmental hazard. Therefore, recycling of waste materials plays a vital role in concrete industry.

2. Literature Review

Garrick (2005), showed the analysis of waste tire modified concrete used 15% by volume of coarse aggregate when replaced by waste tire as a two phase material as tire fibers and chips dispersed in concrete mix. The result is that there is an increase in toughness, plastic deformation, impact resistance and cracking resistance. But the strength and stiffness of the rubberized sample were reduced. The control concrete disintegrated when peak load was reached while the rubberized concrete had considerable deformation without disintegration due to the bridging caused by the tires. The stress concentration in the rubber fiber modified concrete is smaller than that in the rubber chip modified concrete. This means that the rubber fiber modified concrete can bear a higher load than the rubber chip modified concrete before the concrete matrix breaks.

Kamil *et.al*. (2005), analyzed the properties of Crumb Rubber Concrete (CRC). The unit weight of the CRC mix decreased approximately 0.287 kPa for every 22.68 kg of crumb rubber added. The compressive strength decreased as the rubber content increased. Part of the strength reduction was contributed to the entrapped air, which increased with the rubber content. Investigative efforts showed that the strength reduction could be substantially reduced by adding a de-airing agent into the mixing truck just prior to the placement of the concrete.

Taha *et.al*. (2008), presents the results of experimental investigations on rubber concrete. Chipped and crumbed tire rubber particles were used to replace coarse and fine aggregate with different volume replacement levels. The mechanical and fracture properties of rubber concrete were examined. Quasi-brittle fracture mechanics models were used to determine the effect of incorporating tire rubber particles on the fracture performance of rubber concrete. Finally, some microstructural features of rubber concrete were also reported. It is concluded that the choice of the optimal replacement ratio of the tire rubber particles can yield concretes with desirable strength and fracture toughness criteria for different applications.

Abaza and Shtayeh (2010), aimed to explore the potential utilization of crumb rubber from used tires in various types of Portland cement concrete (pcc) for the production of non-structural PCC with special applications requiring attention to thermal and noise insulation, and material elasticity. Fine aggregate (beach sand) was replaced using the volumetric method by use crumb tires at different percentages of replacements for the various types of PCC (B-150, 200, 250, 300, and 450 kg/cm^2). Physical characteristics on fresh and hardened concrete were studied using various laboratory tests. Concrete mixtures contained crumbed rubber were compared with those of PCC without crumb rubber. Analysis showed that the compressive strength, density and modulus of elasticity decrease as the percent replacement by crumb rubber increases. Water absorption increased as the percentage of replacement increased and slump did not show significant change. Abrasion resistance, noise insulation and thermal insulation increased as the percent replacement increased. The research recommended that crumbed rubber can be used for non-structural PCC, such as floor rips, partitions, support stone structures, concrete board siding, concrete blocks and other non-structural uses.

Reddy *et. al*., (2013), conducted an experimental study to analyze the behaviour and failure characteristics of rubberized concrete where tire rubber was partially replaced with coarse aggregate. The use of recycled tire rubber as partial aggregate in concrete has great potential to positively affect the properties of concrete in a wide spectrum. Concrete is one of the most popular construction materials. Due to this fact, the construction industry is always trying to increase its uses and applications and improving its properties, while reducing cost. The objective of the experimental study was to test the properties of concrete when recycled rubber from automotive tires was used as a partial aggregate. Tests have been carried out for concrete specimens contains 10%, 15% substitution of junk tire rubber as a natural aggregate. The replacement of coarse aggregate by junk rubber in concrete has resulted in reduced compressive strengths and densities. The reductions in compressive strength and density depended on the amount of rubber added.

Kumar *et. al*., (2014), presents results, obtained after replacement of fine and coarse aggregates, in concrete mix, with tire rubber. The tire rubber, which has been used in the study was obtained after the mechanical trituration process of post – consumed tires from trucks. Researchers had investigated, over the years, the use of recycled tire rubber waste as a replacement for aggregate in concrete and its effectiveness. “Rubcrete-Mix” which would result from such replacement was found to have many engineering applications and holds promise in future. Rubcrete also possesses good mechanical properties and is considered to be one of the best and economical ways of recycling the used tires. The experimental study had the aim of arriving at the optimum quantity of the replacement material for the aggregates in concrete mixtures, for various engineering applications. For achieving a proper bond with the surrounding concrete paste, the recycled aggregates have been designed with respect to their size, shape and gradation. With the water – cement ratio being kept constant fine and coarse aggregate has been replaced with tire rubber powder and chipped rubber and also cement has been replaced with silica fume. In preparing the concrete, Portland slag cement has been used along with super plasticizer less than 1%

by weight of cement to achieve required workability of the resulting concrete. Furthermore, durability studies have been conducted and mixes have been designed for M30 grade concrete.

Elchalakani (2015), provided strength and durability test results for rubberized concrete that contained silica fume (micro-silica) for road side barriers with the intent to reduce injuries and fatalities during crashes. The test program involved the preparation of normal and high strength concretes made out of recycled waste tire rubber. The high strength was obtained by adding silica fume which enhanced the interfacial transition zone bonding. Tire rubber particles composed of a combination of crumb rubber and fine rubber powder were used to replace 10%, 20%, 30%, and 40%, of the total weight of the fine mineral aggregate. The fresh rubberized concrete exhibited lower unit weight and acceptable workability compared to normal concrete. The results of the uniaxial compressive and flexural tests conducted on hardened concrete specimens indicated considerable reductions in compressive strength, flexural strength and tangential modulus of elasticity. Cube drop tests were performed and showed good resilience of the rubberized concrete. New design guidelines in accordance with the Australian Bridge Design Code AS 5100 for strength and serviceability of rubberized concrete road side barriers were derived based on the test results. New moment–thrust interaction curves and shear strength equations were derived for the rubberized concrete road side barriers. The newly derived design rules showed that shear strength is critical compared to the combined moment and axial thrust and the maximum rubber contents were 17% and 30% for normal and high strength concretes, respectively.

3. Objective of the Research

The main aims of this research study are as follows:

1. Investigating effect of crumb rubber added to concrete mixes in ratios of 5, 10, and 15 % of the weight of coarse aggregate with dimensions of (width 10 mm, thickness 7 mm, and length 20 mm) on compressive strength, split tensile strength and flexural strength.
2. Using consumer tire material in construction materials industry to produce light weight concrete having suitable properties.
3. Investigation the strength by adding silica fume which enhanced the interfacial transition bonding zone.

4. Experimental Work

In this work an attempt is made to produce concrete using different ratios of granular rubber tire as percentage of the weight of the coarse aggregate as pieces which have dimensions of (width 10 mm, thickness 7 mm, and length 20 mm), natural sand as fine aggregate, with ordinary Portland cement. This research describes materials used in regards properties, mix proportions, mixing procedure, casting, curing condition and testing procedures adopted throughout this study. The tests have been carried out in the laboratory of Material and Construction College of Al-Esra'a University.

4.1 Properties of Construction Materials

4.1.1 Cement

Ordinary Portland cement (Type-I) produced at northern factory (Tasluja-Bazian) is used throughout this study. It was stored in air-tight plastic containers to avoid exposure to atmospheric conditions like humidity. Tables (1) and (2) show the chemical composition and physical properties of the cement used throughout this study. Test results indicate that the adopted cement conforms to the **Iraqi specification No. 5/1984 [10]**. The chemical and physical tests were made at the National Center for Construction Laboratories and Research (NCCLR).

Table (1) Chemical composition of cement

No.	Compound Composition	Chemical Composition	%(weight)	Iraqi specification No. 5/1984
1	Lime	CaO	63.19	-
2	Silica	SiO2	20.60	-
3	Alumina	Al2O3	4.10	-
4	Iron Oxide	Fe2O3	4.48	-
5	Magnesia	MgO	2.28	5*
6	Sulfate	SO3	1.98	2.8*
7	Loss on ignition	L.O.I	2.45	4.0*
8	Insoluble residue	I.R	0.47	1.5*
9	Lime saturation factor	L.S.F	0.94	0.66-1.02
10	Tri calcium aluminates	C3A	3.3	5*
11	Tri calcium silicate	C3S	61.02	-
12	Di calcium silicate	C2S	13.35	-
13	Tri calcium alumina ferrite	C4AF	13.62	-

¤ Tests were carried out at the National Center for Construction Laboratories and Research (NCCLR).

*Maximum limit.

Table (2) Physical Composition of Cement

Physical Properties	Test Results	Iraqi specification No. 5/1984
Fineness using Blain air permeability apparatus(m2/kg)	280	230**
Soundness using autoclave method	0.14%	0.8%*
Setting time using Vicat's instruments		
Initial(min.)	190	45**
Final(hr)	4.5	10*
Compressive strength for cement Paste Cube(70.7mm) at:		
3days(MPa)	19.35	5**
7days(MPa)	27.23	23**
28days(MPa)	41.2	
56days(MPa)	59.87	

¤ Tests were carried out at the National Center for Construction Laboratories and Research.

*Maximum limit

**Minimum limit

4.1.2. Fine Aggregate

Natural sand brought from Al-Ukhaidher region was used for the concrete mix proportion study. The fine aggregate had (4.75mm) maximum size with rounded particle shape and smooth texture with fineness modulus of (2.84). The grading of the fine aggregate is shown in Table (3). The obtained results indicate that the fine aggregate grading and the sulfate content were within the **Iraqi specification No. 45/1984 [11]**. Table (4) shows the specific gravity, sulfate content and absorption of the fine aggregate.

Table (3) Grading of fine aggregate

No.	Sieve Size	% Passing	
		Fine Aggregate%	Iraqi specification No. 45/1984 for Zone(2)
1	4.75 mm	90.56	90-100
2	2.36 mm	74.69	75-100
3	1.18 mm	60.44	55-90
4	600 µm	43.47	35-59
5	300 µm	13.72	8-30
6	150 µm	1.98	0-10
7	Pan	0	-

Table (4) Physical properties of fine aggregate ¤

Physical properties	Test Results	Iraqi specification No. 45/1984 for Zone(2)
Specific Gravity	2.73	-
Sulfate Content	0.08 %	≤ 0.5 %
Absorption	0.70 %	-

¤All tests were made at the National Center for Construction Laboratories.

4.1.3. Coarse Aggregate

Crushed gravel with maximum size of (14 mm) was used throughout the tests. The crushed river coarse aggregate was washed, then stored in air to dry the surface, and then stored in a saturated dry surface condition before using. The specific gravity and absorption were (2.66) and (0.66%) respectively. The grading of the coarse aggregate is shown in Table (5). The obtained results indicated that the coarse aggregate grading was within the requirement of the **Iraqi specification No. 45/1984 [11]**.

Table (5) Grading of coarse aggregate

No.	Sieve Size	% Passing	
		% Coarse Aggregate	Iraqi specification No. 45/1984
1	14 mm	98.13	90-100
2	10mm	57.57	50-85
3	5mm	1.6	0-10
4	Pan	0	-

4.1.4. Water

Clean tap water was used for both mixing and curing. For concrete mixing, the used water-cement ratio (w/c) for normal strength concrete was (0.5).

4.1.4. Chipper Rubber

Consumed tire rubber fibers (TRF) for small vehicles cut by hand to small pieces which have dimensions of (width 10 mm, thickness 7 mm, and length 20 mm). Three percentages of (TRF) were used, 5 %, 10%, and 15% as percent of the weight of coarse aggregate as shown in Figure (1). Chemical composition and physical properties of (TRF) are shown in Table (6).

Figure (1): Tire rubber fibers (length = 20 mm)

Table (6) Chemical composition and physical properties of (TRF) used in the present work

Chemical Composition of (TRF) [5]		Physical Properties of (TRF)	
Rubber hydrocarbon	Cumulative % passing	Specific Gravity	1.106
Carbon black	31 %	Density	1.16 g/cm^3
Acetone extract	15 %	Ultimate Tensile Strength	9 MPa
Ash	2 %	Elongation at Break	150 %
Residue chemical balance	4 %	Hardness shore A	64

* The physical properties of (TRF) tests are made at the National Center of Construction Laboratory and Research (NCCLR).

4.1.5 Silica Fume

The silica fume–Astra chemicals Lit-Chennai which conform to ASTM C 1240 and IS 15388: 2003 was used in this investigation. The Silica fume is usually used as a partial replacement of cement. The optimum replacement of silica fume is (0.1 - 0.15) **[14]**. The properties of silica fume are shown in Table (7).

Table (7) Properties of silica fume used in this study [14]

Specific Gravity	2.2
Bulk Density	576 (Kg/m^3)
Surface Area (m^2/kg)	20,000
Size, (Micron)	0.1
$Si0_2$	(90-96) %
Al_2O_3	(0.5 -0.8)%

4.2 Mix Proportion

The normal strength concrete has been designed in accordance with Neville, A. M. (1978) [6] mix design with nominal 28-day cube compressive strength of (25 MPa). Mixture details are given in Table (8). It was found that the used mixture produces good workability and uniform mixing of concrete without segregation.

Table (8) Properties of concrete mixes

Parameter	Normal strength concrete
Water/cement ratio	0.5
Water (kg/m3)	200
Cement (kg/m3)	400
Fine aggregate(kg/m3)	692
Coarse aggregate(kg/m3)	1058
Density (kg/m3)	2336

In order to determine the concrete compressive strength and other mechanical properties, for normal concrete, groups of (72) cubes, cylinders and prisms, were prepared. The mix proportions of different types of percentages of replacement mixes and obtained quantities for mixes are tabulated as below. Table (9) shows the mix proportions for the percentage replacement of coarse aggregate with chipped rubber and Table (10) shows replacement of cement with silica fume of percent 15% and different percentage of rubber chipper.

Table (9) Percentage of coarse aggregate replaced with chipper rubber

W/C ratio	Water	Cement	Fine Aggregate	Coarse Aggregate	Rubber Chipped	
	(Kg/m^3)	(Kg/m^3)	(Kg/m^3)	(Kg/m^3)	% Replacement	(Kg/m^3)
0.5	200	400	692	1058	0 %	0
0.5	200	400	692	1005.1	5 %	23.07
0.5	200	400	692	952.2	10 %	46.14
0.5	200	400	692	899.3	15 %	69.21

Table (10) Replacement of cement with silica fume and percentage of coarse aggregate replaced with chipper rubber

W/C ratio	Water	Cement	Silica Fume Replaced %15	Fine Aggregate	Coarse Aggregate	Rubber Chipped	
	(Kg/m^3)	(Kg/m^3)	(Kg/m^3)	(Kg/m^3)	(Kg/m^3)	% Replacement	(Kg/m^3)
0.5	200	340	60	692	1058	0 %	0
0.5	200	340	60	692	1005.1	5 %	23.07
0.5	200	340	60	692	952.2	10 %	46.14
0.5	200	340	60	692	899.3	15 %	69.21

4.3 Preparation and Casting of Specimens

A total of 8 mixes were prepared in this study and 48 cube samples were prepared (150 x 150 x 150 mm) for conducting the compressive strength test. Also, 48 samples of prisms (100 x 100 x 500) mm for flexural strength test and 48 samples of cylinders (150 diameter x 300 height) mm for split tensile strength test were prepared. Samples of 6 cubes, 6 cylinders and 6 prisms were tested at two ages (7 and 28 days) and for each type of percentage replacement mixes of coarse aggregate with rubber chipper in various percentages of 5%, 10%, and 15% as shown in Figure (2). Finally, Portland cement was replaced with silica fume in optimum percentages of 15%. The sample were cast, kept in curing tank for 7 and 28 days and after they were tested for compressive strength, tensile strength and flexural strength test.

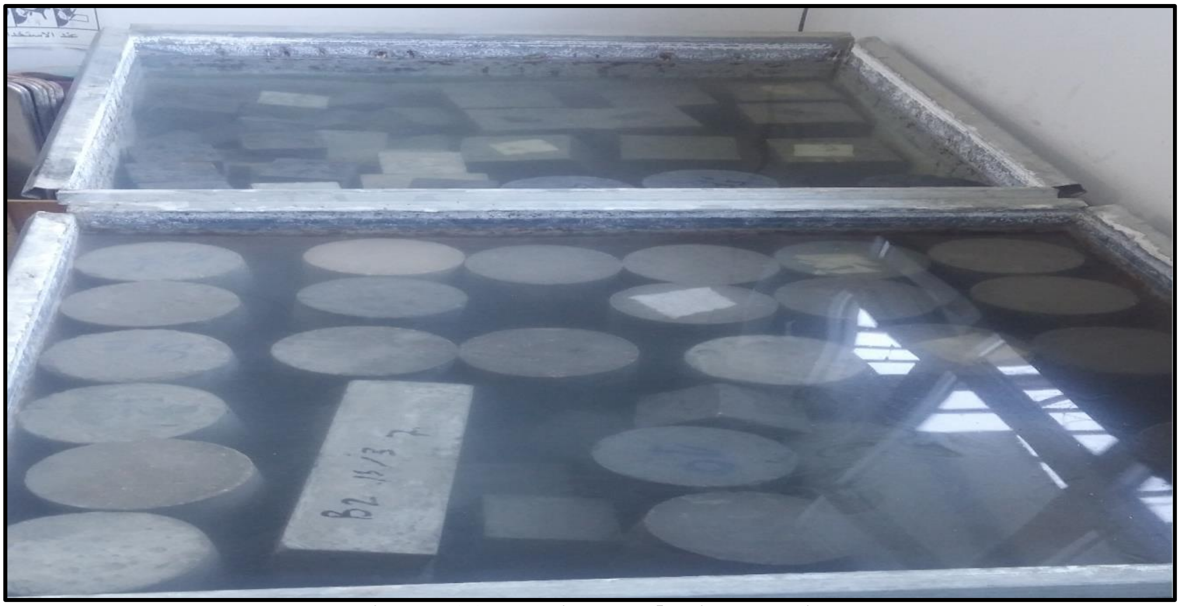

Figure (2) Specimens during Curing

5. Results and Discussion

5.1 Compression Strength Test The cubes were cast and tested after 28 days of curing period as shown in Figure (3). Results were presented in Figure (4). Which indicates the strength pattern when coarse aggregate was replaced with chipped rubber and silica fume. It was observed that 33% of compressive strength was reduced with replacement of course aggregate with chipped rubber by 15%, and 22% reduction of compressive strength was observed when cement was replaced with silica fume 15% and coarse aggregate was replaced with chipped rubber by 15 %. This is due to the weakness of bond between the cement matrix and tire rubber when compared with the coarse aggregate.

Figure (3): Compressive strength test of concrete

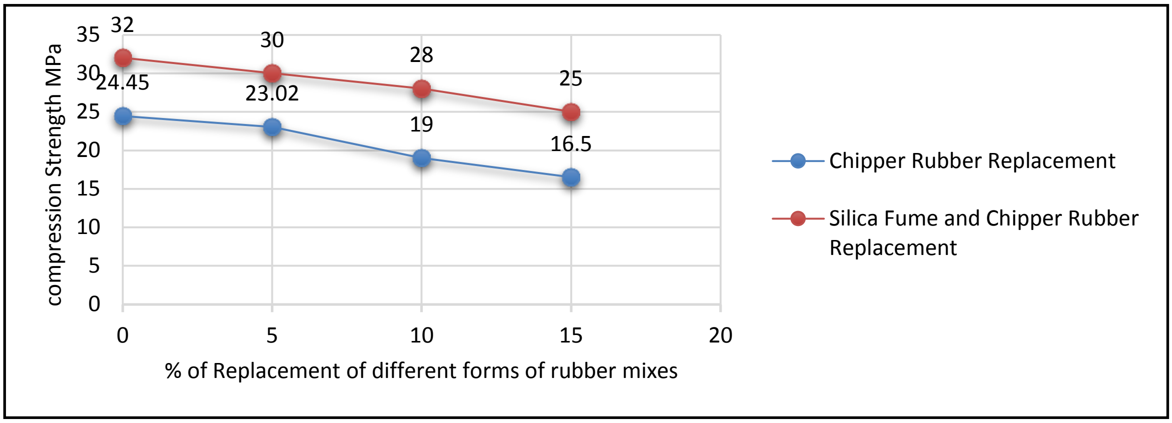

Figure (4) Compression strength of cubes tested at age of 28 days

5.2 Split Tensile Strength

The cylinders were cast and tested after curing period of 28 days as shown in Figure (5). Results are presented in Figure (6).The results indicate the strength pattern, when coarse aggregate was replaced with chipped rubber, it was observed that 24 % of the split tensile strength was reduced, by increasing the percentage replacement of coarse aggregate with tire Rubber up to 15%. Finally, 20% reduction of strength was observed when replacing 15% of the cement with silica fume and replacing 15% of the coarse aggregate with chipped rubber. This can be explained by the poor bond between the cement paste and the tire rubber powder. Interface zone is likely to reduce the bond between the cement paste and the tire rubber powder.

Figure (5) Splitting tensile strength test

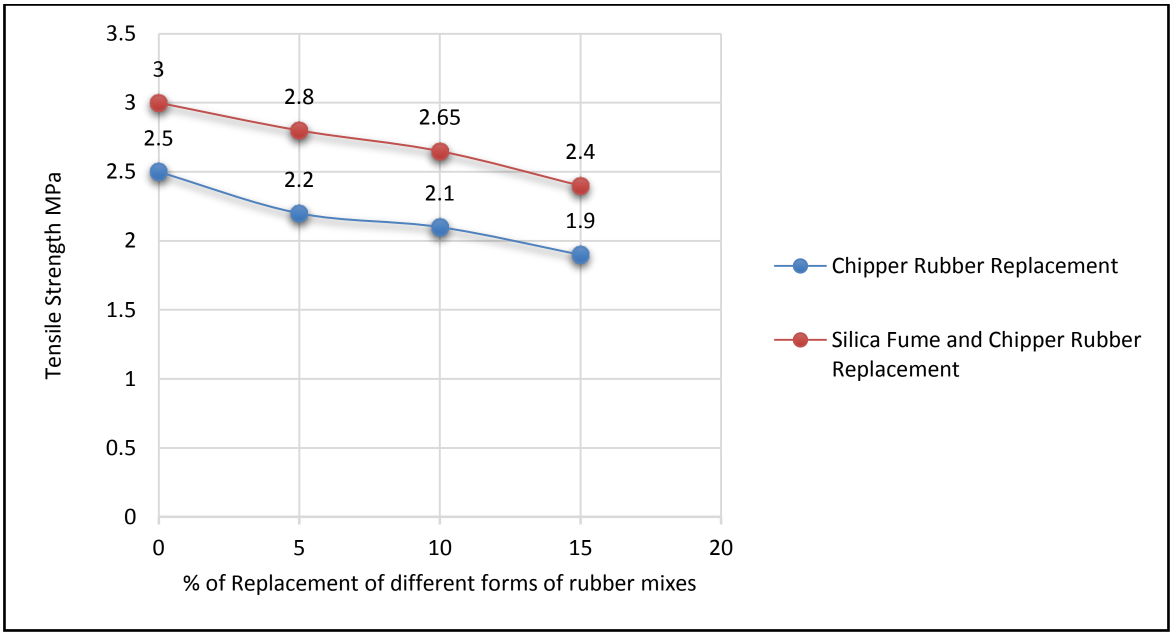

Figure (6) Split tensile strength of cylinders at age of 28 days

5.3 Flexural Strength Test

The prims were cast and tested after curing period of 28 days as shown in Figure (7). The flexural strength reduced by 25% due to replacement of tire chipped rubber by 15% in place of coarse aggregate. In addition to this 15 % of flexural strength reduction was observed when both cement was replaced with silica fume and coarse aggregate was replaced with chipped rubber. The likely reason for this reduction of strength is that, there will be a very weak bond between the cement paste and the tire rubber powder. The obtained results are shown in Figure (8).

Figure (7) Modulus of rupture test

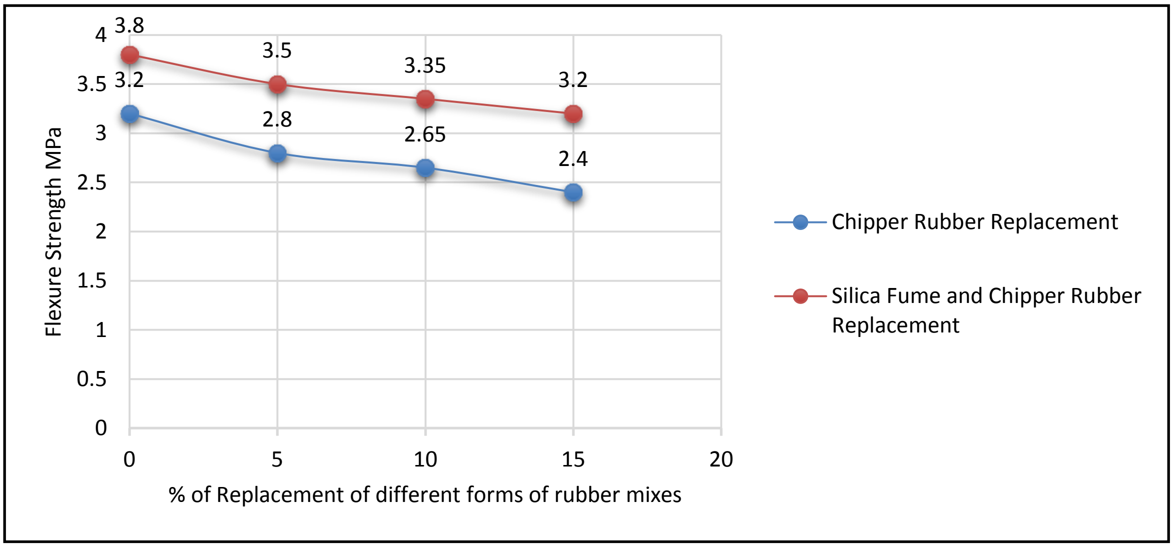

Figure (8) Flexure strength of beams at age of 28 days

6. Conclusions

Based on the experimental results of cubes, cylinders and prisms with and without the addition silica fume, with dimensions of fibers (width 10 mm, thickness 7 mm, and length 20 mm) for three different percentages (5, 10, and 15%) by weight of coarse aggregate. the major conclusions can be drawn as follows:

1- The addition of (TRF) decreases the compressive strength of cubes specimens in the range between 6% and 33 % and decreases the compressive strength for concrete with silica fume in the range between 6% and 22% compared with the compressive strength of the reference concrete, without (TRF). Part of the strength reduction was contributed to the entrapped air, which is increased with the rubber content.
2- The increase of (TRF) causes a decrease in density within the range between 3 and 13% compared with that of normal concrete.
3- The increase of (TRF) causes a decreasing in the tensile strength ranging between 12 and 24 %, and decreases the tensile strength for a concrete with silica fume in the range between 7 and 20% when compared with the normal concrete.
4- The increase of (TRF) causes decrease in flexure strength ranging between 13 and 25 %, and decreases the flexure strength of concrete with silica fume in the range between 7 and 15% when compared with that of normal concrete.
5- Utilization of waste tires in the study process has been focus to reduce tire wastes, economic and environmental management.
6- The silica fume used as cement replacement to enhance the mechanical and durability properties of concrete containing scrap tire rubber.

7- Based on the presented experimental results, a significant improvement in compressive and tensile strengths and flexure strength was recorded for mixtures containing crumb rubber and silica fume.

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