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Experimental Study of the Effect of Worn-out Tire Fibers Addition on the Strength of R.C. Corners

Asst. prof.
Dr. Jasim Mahmud AL-Khafaji
Al-Mustansiriya University
College of Engineering
Civil Eng. Dep.

Lecturer
Dr. Zubaidah A.M. AL-Bayati
Al-Mustansiriya University
College of Engineering
Civil Eng. Dep.

Eng.
Jasim Jarallah Fahad Kaabi
Al-Mustansiriya University
College of Engineering
Civil Eng. Dep.

Abstract

The growing problem of worn-out 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, but usage of worn-out tires in civil engineering is currently very low. The current work aims to take advantage and get rid of car worn-out tires in the construction of reinforced concrete corners; such facility is cheap and environment friendly, with good thermal insulation and low density compared with the normal concrete .The worn-out tire fibers are added to the concrete mixture by replacing the weight of the coarse aggregate (gravel) with different ratios (5, 15, 25) percent, and for each replacing ratio , three different fiber lengths (2,4, and 6) cm are used and the width and thickness of each fiber is kept constant (1, 0.7) cm, respectively. Tensile reinforcement ratio adopted in the study for all specimens is (0.0081). Ten corner were specimens tested under static load tending to open the corner angle, nine of them with waste tire fibers and one without worn-out tire fibers .Length of the leg is (550) mm and cross section is (150×150)mm .The strength of corner samples were recorded during the test .Test results indicated a decrease in the strength of the corner about 21%, 30%, 43% for corners with fiber length 2cm and fiber ratios (5,15,&25) percentage respectively. When the length of the fiber changed to 4cm and 6 cm, the reduction in ultimate strength becomes (30%, 36%, 47%), and (32%, 38%, 49%) respectively.

الخلاصة

مشكلة تكدس نقايات اطارات السيارات المتنامية في العراق, يمكن التخفيف عنها اذا امكن العثور على طرق جديدة لاعادة تدويرالاطارات, واحدى الطرق المحتملة هي تدوير هذه المواد واستخدامها في الانشاءات والتي يعد استخدامها في

الهندسة المدنية قليل جدا في الوقت الحالي. تهدف الدراسة الى الاستفادة من اطارات السيارت المستهلكة في انشاء الوصلات الخرسانية المسلحة التي ستكون بتكاليف رخيصة وصديقة للبيئة وذات عزل حراري جيد وخفيفة الوزن وذات كثافات قليلة مقارنة مع الخرسانة الاعتيادية .يتم اضافة الياف الاطارات المستهلكة الى الخليط الخرساني بنسب وزنية مختلفة وهي (5%,15%,25%) من وزن الركام الخشن (الحصى) ولكل نسبة ثلاث اطوال مختلفة (6,4,2) سم, مع ثبات العرض والسمك لكل الالياف(1, 0,7) سم على التوالي . اما نسبة حديدالشد فكانت ثابتة بمقدار (0,0081) لكل النماذج. تم اجراء الفحص على كل الوصلات بطريقة التحميل بواسطة عزم يؤدي الى فتح الزاوية للنموذج.ان عدد نماذج الوصلات هو (10) 9منها معززة بالالياف المطاطية وواحدة فقط هي الخرسانة الاعتيادية بدون مطاط وهي المرجعية.طول الساق للنموذج (550) ملم اما ابعاد المقطع (150×150) ملم .تم حساب المقاومة لكل الوصلات اعطت النتائج مؤشرا على انخفاض في المقاومة بالنسب (21%,30%,43%) للوصلات الخرسانية المسلحة ذات الشرائح طول (2سم) ولنسب (5%,15%,25%) على التوالي وعند تغيير الاطوال الى (4 سم) و (6سم) انخفضت المقاومة بنسبة (30%,36%,47%) و (32%,38%,48%) على التوالي .

Introduction

In numerous structures, continuity between two adjacent members is necessary even though the members meet angle. The joint formed from this meeting usually refers to the "corner". The term "corner" in this investigation is used to describe a corner joint formed by the joining; at 90º, of the ends of two flexural members. The terms "opening" and "closing" the corner are used to describe the increase and decrease of this right angle, respectively. Result of the wide progress that was achieved in the transportation and the wide use of vehicles gave birth to various problems and one of them is the environmental pollution. The combustion of large quantities of worn-out tires got accumulated, thus facing very serious problems of safe disposal, either by the wide land which was needed to store or by the incineration of the large quantities. As the substance is little affected by water and biological factors and maintains its stability in nature for a relatively long time, some countries have adopted the method of burning worn-out tires underground as a mean of getting rid of them to avoid further pollution of the environment which may result from burning the material .Hence, to avoid the hazardous effect of chemical gases resulting from the burning process such as sulfur dioxide and the distribution of fine carbon particles in the air, many researches [(3)(8)(9)]have endeavored to make use of enormous quantity of waste rubber tires and decrease environmental pollution resulting from them. Generally speaking, this material was mixed with asphalt to produce road –paving mixtures that provide higher flexibility [(3)(8)(9)]and better shock-absorbance material in addition to its reducing noise resulting from the movement of vehicles and their friction with the ground .On the other hand, some countries use a small part of worn-out tires to manufacture shock protection layers for platforms subjected to sea waves and ship movement . Accordingly, the idea of using a material of chopped worn-out tires in construction material industry emerged as it enjoys several favorable characteristics such as high resistance to weather conditions, temperature and humidity, low water absorption and light weight in comparison with other materials that are usually used . it is also characterized by its high-insulation capacity.

Objectives of the Present research work

This research will focus on the study of strength and behavior of reinforcement concrete corner modified with recycled rubber from worn –out tires. This study attempts to use the tire rubber as a partial replacement of coarse aggregate to produce rubberized concrete. By using rubber waste to produce lightweight concrete expected to be more durable, less expensive (low material cost and easy to manufacture) and absorb higher energy under impact. The used tires will be replacing the coarse aggregate (gravel) at amounts of (5%, 15%, 25%) by weight for different corner samples. Corner strength and deflection will be investigated based on the above replacement ratios

This study also tends to comprise the following objectives:

1-Comparison between (rubberized concrete) and (normal concrete),

2-Production of cheap building elements from (waste tire)

3-Reduction of the solid waste to keep the environmental effects at the minimum levels especially in poor cities.

4-Help to encourage the industrials to recycle solid waste and use them in industrial production and improve solid waste management by using recycling of its parts in industrial technique.

5-Using clear production techniques and friendly environmental products in treatment and production of the material used industry from solid waste.

Material

Cement:

Ordinary Portland Cement, Type I, manufactured by a Lebanese factory is used in this study. Test results indicate that the adopted cement conforms to the Iraqi Specification No.5/1984.

Fine Aggregate:

Al-Ekhaider natural sand of 4.75 mm maximum size is used as fine aggregate. Results indicate that the fine aggregate grading is within the requirements of the Iraqi Specification No.45/1984

Coarse Aggregate:

Crushed gravel with maximum size of (10mm) is used in this study. The obtained results indicate that the coarse aggregate grading is within the requirement of the Iraqi specification No. 45/1984

Rubber aggregate:

Fiber rubber worn-out tires of small cars are used. Tires were cut by hand, into small fiber with different sizes (1 * 0.7 * 2) cm, (1 * 0.7 * 4) cm,(1 *0.7 *6)cm, and used with weight of coarse aggregate ratios (5%, 5%,25%) figure(1) .Table(1) percentages and dimensions Worn-out Tires rubber used, table (2)chemical composition of rubber Worn-out tire, and physical properties of tires are shown in table(3).

Figure (1) fiber lengths of rubber

Table (1) Percentages and Dimensions Worn-out Tires rubber used.

Batch number	Types	Waste Tires Replacement Ratio by Weight of Gravel (%)	Fiber Dimensions (mm)		
			Length	Height	width
1	**CR**	**0%**	**-**	**-**	**-**
2	**2C5**	**5%**	**20**	**7**	**10**
3	**2C15**	**15%**	**20**	**7**	**10**
4	**2C25**	**25%**	**20**	**7**	**10**
5	**4C5**	**5%**	**40**	**7**	**10**
6	**4C15**	**15%**	**40**	**7**	**10**
7	**4C25**	**25%**	**40**	**7**	**10**
8	**6C5**	**5%**	**60**	**7**	**10**
9	**6C15**	**15%**	**60**	**7**	**10**
10	**6C25**	**25%**	**60**	**7**	**10**

Table (2) Chemical composition of Worn-out Tire

Rubber Hydrocarbon (SBR)	**48%**
Carbon black	**31%**
Acetone extract	**15%**
Ash	**2%**
Residue Chemical balance	**4%**

Commented [i1]:

Table (3) Physical Properties of Worn-out Tire

Specific Gravity	**1.16**	**ASTM D792**
Density	**1.16 g/cm^2**	**ASTM D1895-03**
Ultimate Tensile Strength	**9 MPa (N/mm)**	**ASTM D412-02**
Elongation	**150%**	**ASTM D412-02**
Hardness	**64**	**ASTM D2240-05**
Absorption	**1.12%**	**ASTM D540**

Mixing Water:

Tap water is used for casting and curing all the specimens.

Steel Reinforcement:

Tensile test of steel reinforcement is carried out on (ϕ 10mm) deformed and (ϕ 6mm) plain hot rolled. Table (4) gives the results of tensile test for the used bars

Table (4) Properties of used Steel Reinforcement

Nominal Diameter (mm)	Measured Diameter (mm)	Yield Stress* (MPa)	Ultimate Stress (MPa)	Modulus of Elasticity** (GPa)
6	6.19	433	471	200
10	10.1	533	610	200

Curing and Age of Testing:

After (24) hours, the control specimens are stripped from the molds and cured (kept) in water bath for (28) days with almost constant laboratory temperature, and (24) hours before the time of test, they are taken out of the water bath and left in the air of dry surface and get tested in accordance with the standard specifications.

Rubberized concrete:

The concrete mixed with waste rubber added in different weight proportions is called rubberized concrete, and is an infant technology. Partially replacing the coarse or fine aggregate of concrete with some quantity of small waste tire fiber can improve qualities such as low unit weight, high resistance to abrasion, absorbing the shocks and vibrations, high ductility and low brittleness and so on to the concrete(13)(14). Moreover the inclusion of rubber into concrete results in higher resilience, durability and elasticity. The current work aims to take the worn-out tire fibers are added to the concrete mixture by replacing the weight of the coarse aggregate (gravel) with different ratios (5,15,25) percent, and for each replacing ratio , three different fiber lengths (2,4, and 6) cm are used and the width and thickness of each fiber is kept constant (1, 0.7) cm, respectively. Tensile reinforcement ratio adopted in the study for all specimens is (0.0081). Figure (2) details of Tested Corners

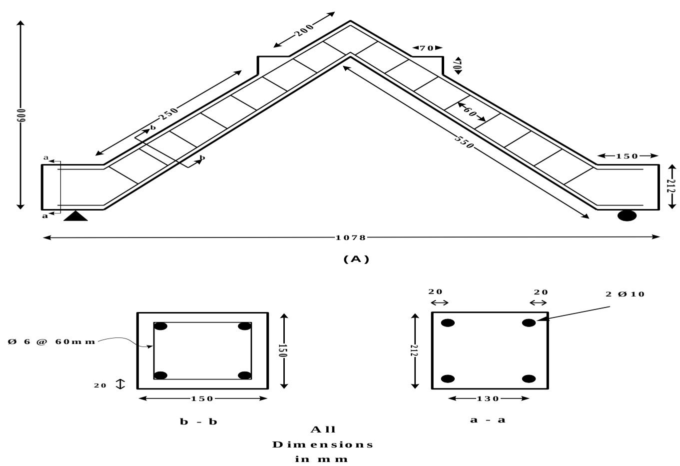


Figure (2), Details of Tested Corners: (A) Overall Dimensions (B) Leg Cross Section (C) Corner Base Cross Section

Testing of Corners

All corner specimens are tested by using the universal testing machine (MFL system) under monotonic loads to ultimate states. According to the circumstances of this test, the specimen (concrete corner) is supported to be hinged at one leg and rolled in the other leg upon this apparatus, using two hooks in one side to achieve the hinged situation. The upper and lower parts of concrete corner are modified to make the applied loads act as a coupled situation on each sides, this leads to open the corner , as shown in Figures (3) and (4)

Figure (3) Corner Set up

Thin wooden patches are inserted between the concrete and points of loads to provide even surface. The loads are applied in successive increments up to failure. All corners are tested at ages of (28) days. All models are failed with bearing. Figure (5-8), Failure Shape for Corners

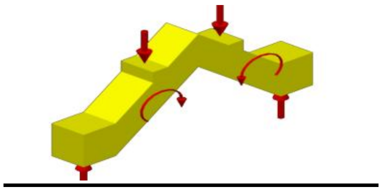
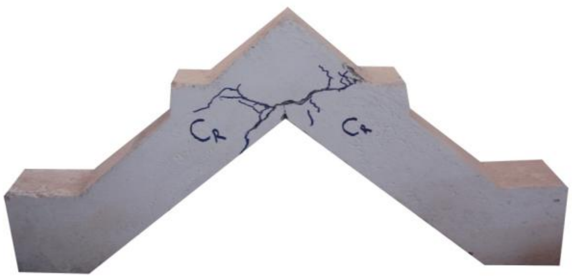


Figure (4), Details of Corner under Testing

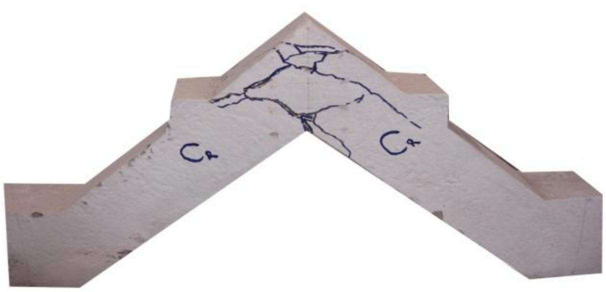
Ultimate Strength of Corners:

The applied load to corner tends to open the angle, using different fiber size, (2, 4, and 6 cm) and proportion (5%, 15%,, and 25%) has an important effect on strength of rubberized concrete corner. Table (5) and Figure (9) shows the ultimate strength of tested corners.

Test results show that, the rubberized concrete corner(2C5, 2C15, and 2C25) developed ultimate moment of 6.02 kN.m, 5.30 kN.m and 4.30 kN.m respectively. The decrease in strength is (21%, 30% and 43%) respectively, compared with ultimate strength of reference corner (CR). This decrease in strength is mainly due to increase of worn-out tire rubber proportion (5%, 15%,, and 25%) with fiber length of 2 c m.Test results show that, the rubberized concrete corner (4C5, 4C15, and 4C25) developed ultimate moment of 5.30 kN.m, 4.87 kN.m and 4.01 kN.m respectively.



Face A



Face B

Figure (5), Failure Shape for Corner (CR)

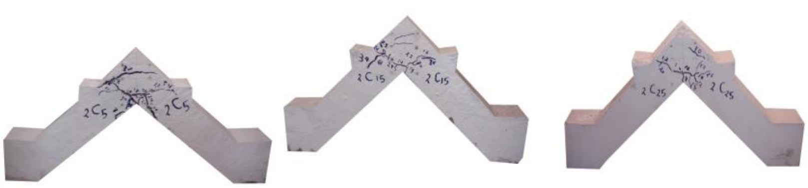


Figure (6), Failure Shape for Corners (2C5, 2C15, 2C25).

Figure (7), Failure Shape for Corners (4C5, 4C15, 4C25).

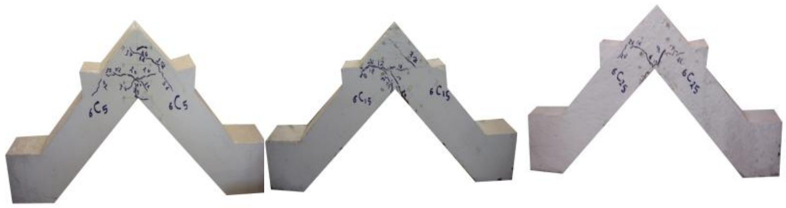


Figure (8), Failure Shape for Corners (6C5, 6C15, 6C25).

Table (5), Ultimate Strength for Tested Corners

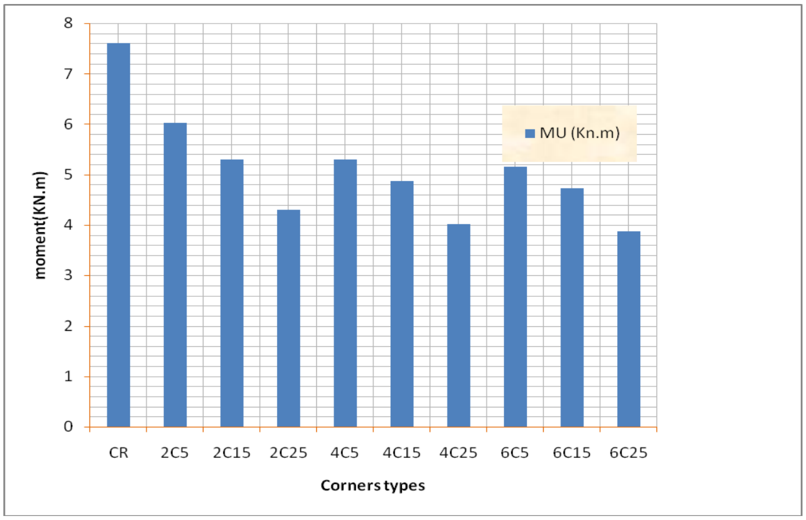
Corner No.	CR	2C5	2C15	2C25	4C5	4C15	4C25	6C5	6C15	6C25
Ultimate Strength(kN.m)	7.60	6.02	5.30	4.30	5.30	4.87	4.01	5.16	4.73	3.87
M_u / M_{uR}	1	0.79	0.70	0.57	0.70	0.64	0.53	0.68	0.62	0.51
Density Kg/m^3	2382	2311	2267	2074	2252	2151	2024	2252	2098	2000

CR = Reference corner
Mu = Ultimate strength of tested corners
MuR = Strength of reference corner = 7.6 kN.m

The decrease in strength is (30%, 36% and 47%) respectively, compared with ultimate strength of reference corner (CR). This decrease in strength is mainly due to increase worn-out tire rubber proportion (5%, 15%,, and 25%) and increase in the length fiber to 4 cm . Test results show that the rubberized concrete corner(6C5, 6C15, and 6C25) developed ultimate moment of 5.16 kN.m, 4.73kN.m and 3.87kN.m respectively. The decrease in strength is (32%, 38% and 49%)

respectively, compared with ultimate strength of reference corner (CR). This decrease in strength is mainly due to increase worn-out tire rubber proportion (5%, 15%,, and 25%) and it increases in the length fiber to 6cm.In general the addition of worn-out tire rubber proportion (5%, 15%,, and 25%) and the increase in length of fiber reduces the compressive strength , as shown in Figure(9). This reduction can be explained by the following:

1- The rubberized concrete containing mineral aggregates and rubber aggregates. Mineral aggregates usually have high crushing strength and are relatively incompressible, whereas rubber aggregates are ductile and compressible .It is affected by the strength of its components.
2- The number of voids increases in the mixes containing worn-out tire rubber which would affect the compressive strength negatively. It is well known that the presence of voids in concrete greatly reduces its strength: 5% voids can result in a strength reduction of more than 10% (Neville)
3- Rubber aggregates has a very low modulus of elasticity and a Poisson's ratio. Therefore rubber aggregates tend to behave like weak inclusions or voids in the concrete, resulting in a reduction in compressive strength.
4- The rubberized concrete requires higher W/C ratio to achieve suitable workability. This property results in the lower strength.
5- The lower density the lower the compressive strength as shown in Table (5).



CR Reference corner

Figure (9) The rubberized concrete corner strength.

Conclusions

Concrete mixes were prepared with worn-out tire rubber strips(rubberized concrete corners 2C5 ,2C15 ,2C25 ,4C5 ,4C15 ,4C25 ,6C5 ,6C15,and, 6C25). One corner made without addition of worn-out tire fibers(CR=Reference corner). The others were made with worn-out tires of different fiber lengths(2,4,and 6cm) and with different ratios (5%, 15%, 25%). From this research work several conclusions are reached:

1-In general the addition of worn-out tire rubber proportion (5%, 15%,and 25%) and the increase in length of fiber reduces the compressive strength

2- Rubberized concrete corners (2C5, 2C15, 2C25, 4C5, 4C15, 6C5 and 6C15), showed an increase in the total deflection such as (125%, 46%, 21%, 76%, 2%, 10% and 4%) respectively, compared with the total deflection of reference corner (CR) with more cracks.

3- Corners with worn-out tire fibers of lengths of (2 cm) showed better behavior than those with lengths of (4 cm, 6cm) .

4- The use of worn-out tire rubber in the concrete led to a lack of crumbled concrete and not disintegrate.

5- The addition of worn-out tire rubber to the concrete has contributed to the reduction of environment pollution and availability of clean places and saving money. Which might have been used to clear the worn-out tires.

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