



Utilizing recycled rubber in concrete: a study of some properties

*Salhin Alaud, Muhieddin S. Tughar, Sufian Rwini

Elmergib University, Garaboulli Engineering Faculty, Civil Engineering Department, Garaboulli, Libya

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ABSTRACT

This paper investigates the effects of adding recycled rubber to concrete in terms of its physical and mechanical properties. The study involved three mixes of concrete created by replacing the gravel with recycled rubber particles with varying percentages of rubber by volume, 10%, 15%, and 20%, and a control mix without rubber. A 1.5% superplasticizer (SP) was also added to other mixtures with rubber in the same proportions as before. The study was conducted on concrete cubes with dimensions of 100 mm. The physical properties of this sample were observed and compared with a control sample of regular concrete. A series of tests were carried out to measure the density, and compressive strength, of the sample. The ultrasonic pulse velocity (UPV) of the sample was also tested to evaluate its porosity. The results showed that the addition of recycled rubber to the concrete reduced the density and therefore its compressive strength by more than 26% with an increase in the rubber replacement ratio of 20%, while when using SP the resistance decreased by less than 20% for the same replacement ratio. The pulse velocity of the samples decreased with increasing rubber content. The results demonstrated that recycled rubber can be a viable additive for concrete in some applications, providing water resistance and impact load with minimal reductions in weight. This could lead to more environmentally friendly building materials with improved performance.

استعمال المطاط المعاد تدويره في الخرسانة: دراسة لبعض الخواص

*صالحين محمد العود و مكي الدين صالح التوغار و سفيان الرويني

جامعة المرقب، كلية الهندسة بالقره بولي، قسم الهندسة المدنية، القره بولي، ليبيا

الكلمات المفتاحية:

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مقاومة الضغط
سرعة نبض الموجة
الكثافة

الملخص

تبحث هذا الورقة في آثار إضافة المطاط المعاد تدويره إلى الخرسانة من حيث بعض الخواص الفيزيائية والميكانيكية. اشتملت الدراسة على ثلاث خلطات من الخرسانة بنسب متفاوتة من المطاط، 10%، 15%، 20%، وخلطة مرجعية بدون مطاط. كذلك تم إضافة الملدن الفائق بنسبة 1.5% إلى خلطات أخرى مع المطاط بنفس النسب السابقة. تم الحصول على المطاط المستخدم من الإطارات المستعملة، وتم فرمه إلى أحجام صغيرة. أجريت الدراسة على مكعبات من الخرسانة بحجم 100 ملم تحتوي على مطاط معاد تدويره. تمت ملاحظة الخصائص الفيزيائية لهذه العينة ومقارنتها مع العينة المرجعية من الخرسانة العادية. تم إجراء سلسلة من الاختبارات لقياس الكثافة ومقاومة الانضغاط للعينة. كما تم اختبار سرعة النبض للعينة بواسطة جهاز الموجات فوق الصوتية لتقييم مساميتها. أظهرت النتائج أن إضافة المطاط المعاد تدويره إلى العينة الخرسانية قللت الكثافة وبالتالي قوتها الانضغاطية بأكثر من 26% مع زيادة نسبة استبدال المطاط 20% من المطاط، بينما عند استخدام الملدن الفائق قلت المقاومة بنسبة أقل من 20% لنفس نسبة الاستبدال. قلت سرعة النبض للعينات مع زيادة نسبة المطاط. أظهرت النتائج أن المطاط المعاد تدويره يمكن أن يكون مادة مضافة قابلة للتطبيق للخرسانة في بعض التطبيقات، مما يوفر مقاومة للماء وتحمل الصدمات مع الحد الأدنى من التخفيضات في الوزن. هذا يمكن أن يؤدي إلى مواد بناء أكثر صداقة للبيئة مع أداء محسن.

Introduction

Today, recycled rubber (RR) is a widely used material in the live sector. It has been demonstrated to have a number of benefits,

*Corresponding author:

E-mail addresses: s.alaud@elmergib.edu.ly, (M. S. Tughar) mstughar@elmergib.edu.ly, (S. Rwini) sufian19501992@gmail.com

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including lowering the volume of waste dumped in landfills and offering a long-term answer to the environmental issues facing the sector. Styrene-butadiene rubber (SBR) and carbon black make up more than 90% of the chemical makeup of tire rubber granules; oxidized zinc and sulfur are present in much smaller amounts [1]. When rubber tires reach the end of their useful lives, they have an alarming likelihood of becoming hazardous waste. Concrete is one of the construction materials that RR is used in. There are still other possible methods that might be used in addition to recycling used tires to build concrete for disposal [2, 3].

Rubber concrete (RuC) is a type of concrete that contains rubber particles instead of, or in addition to, traditional aggregates like gravel or sand. The rubber particles used in this type of concrete can be sourced from old tires, and this makes RuC a more sustainable solution than traditional concrete [4]. There are many applications for RuC, including road and bridge construction, building and infrastructure repairs, and outdoor sports facilities like playgrounds and running tracks. With its many advantages, RuC is a promising solution that can improve the durability and sustainability of our built environment.

Rubber concrete has the advantages of being less expensive because of its reduced density as well as improved toughness and impact resistance [5].

RuC has several benefits. For one, it is more durable increase its flexibility, elasticity, and ability to absorb energy than traditional concrete, as the rubber particles help it absorb shock [6] and vibration, preventing cracking and damage [7]. According to an experimental investigation by Khern et al. [4], the increased friction between rubber aggregates (RA) reduces slump in fresh concrete when 8% of the natural aggregate is replaced with rubber particles. They attempted to alter the mixtures by adding NaOH and $\text{Ca}(\text{ClO})_2$, but there was no discernible difference in the slump. It is also more lightweight [1], which makes it easier to transport and work with. RuC also has excellent thermal insulation, which makes it ideal for colder climates. When rubber tires were used to replace 10 to 30% of the coarse aggregate in concrete, the thermal conductivity of the material decreased by around 20% to 50% according to Sukontasukkul [8], and the conductivity is in the range of 0.241 to 0.443 W/mK. The thermal conductivity and sound insulation were both lowered by 59 and 69%, respectively, when fine aggregates were completely replaced by rubber, according to a prior study [9]. Due to the rubber aggregate's weak interfacial bond to the cement paste, the compressive and tensile strength of concrete similarly decreases as RA content increase [10]. However, a study by Vadivel et al. [10] found that concrete specimens with 6% replacement of waste tire RA could have similar compressive, tensile, and flexural strength and follow the curvature of the conventional specimen in all tests.

This study examines the influence of RR on the mechanical and physical characteristics of concrete. Three concrete mixtures with varied percentages of rubber, three mixtures with rubber and superplasticizer, and a control mixture without rubber were all used in the study.

The purpose of this study was to look into how RR might affect certain concrete qualities. The evaluation of the efficacy, safety, and applicability of our strategy is another aim of these investigations. We can deduce the experiments' success or failure from the outcomes, and we can utilize this knowledge to guide future policy and practice decisions.

Experimental work

1. Materials Used

RuC is a type of concrete that contains rubber particles instead of traditional aggregates like gravel and sand.

The materials used in this investigation typically include:

Cement - Commonly used in the mixes as a binder is ordinary portland cement, grade 42.5N. The Arab Union Company produced the cement, which had a specific gravity of 3.15.

Water - tap water was used to hydrate the cement and initiate the chemical reaction.

Fine natural aggregates - from Zliten region's quarries which had a specific gravity of 2.587 and a fineness modulus of 1.38. The analysis

of the sieves produced results that were in accordance with the British Standard (BS 882-1992).

Gravel - when the sieves defined the particle sizes of gravel as being less than 4 mm. It was also designated as a fine aggregate.

Rubber particles - made from recycled tires (RT), these particles are added to the concrete mixture instead of traditional aggregates, containing RR with a size of 1-4 mm in diameter. Fig. 1 shows the shapes of the rubber tires used as additives.



Fig. 1: Recycled rubber used in the concrete

Superplasticizer SP - In order to change the properties of the concrete mixture and partially make up for the resistance loss caused by the inclusion of rubber, polycarboxylate superplasticizer (PCE) is added.

2. Experimental design

The investigations will be predicated on the supposition that RuC's usefulness as a building material may result in weight reduction, improved impact resistance, improved sound insulation, and other properties.

The experiment employed three concrete combinations with varying amounts of rubber—5%, 10%, and 15%—in place of gravel by volume, denoted by R10, R15 and R20 respectively, as well as a control mixture without rubber denoted Ref. The same rubber replacement combinations were used in three more mixes, which were conducted by adding 1.5% Superplasticizer of cement to the concrete marked by RS10, RS15 and RS20 respectively. These ratios are being imposed in an effort to determine values that keep concrete's mechanical and physical qualities while also making it lighter. The natural sand and gravel were subjected to preliminary physical and mechanical tests, such as adsorption, specific weight and sieve analysis

Forty-two concrete samples were made in the form of concrete cubes with a size of 100 mm.

To create mixes with good workability, the water/cement ratio was adjusted for each mixture. For all mixtures, the sand was the same. According to the volume replacement ratio, the rubber in the other mixes partially replaced the gravel, which was the same weight as the sand in the reference mix. The material weights for the mixtures are displayed in Table 1. For the past twenty-four hours, the materials were combined and promptly cast in the cubes under lab conditions (22 C°). The samples were demolded and immersed in water at lab temperature after 24 hours.

After a 7-day immersion period, three samples of each mix were removed from the water to determine the compressive strength. The remaining examples were removed from the water on the 28th, and an investigation into the concrete's density using ultrasonic pulse velocity was made. The concrete was then put through compressive testing, and the results were examined. The same process was applied to each sample.

After the samples had been crushed, the fracture texture was evaluated together with visual detection.

Table 1: Proportions for concrete mix designs (kg/m^3).

Mix	Cement	Water	Sand	Gravel	Rubber	SP
R0	350	206	600	600	0	0
R10	350	175	600	573	27	-

R15	350	175	600	560	40	-
R20	350	158	600	548	52	-
RS10	350	175	600	573	27	5.25
RS15	350	152	600	560	40	5.25
RS20	350	148	600	548	52	5.25

Results and dissection

1. Workability

Slump tests were carried out for all mixes after the mixing is done. The workability was investigated by slump test and ranges between 100 mm to 120 mm for mixes with only rubber, but the water cement ratio decreases with an increase in the RR replacement. In the mixes with rubber and superplasticizer, flow test was conducted and was 250 mm diameter for all mixes and also decrease in w/c with increase RR replacement. The slump and flow test results for the mixes are illustrated in Table 2. Rubber aggregate particles play a role in the drop in water to cement ratio that occurs when recycled rubber is used to partially replace natural gravel in concrete. Also, rubber is not as thirsty for water as the gravel, and the particles are angular and have a larger surface area than gravel. Additionally, the initial free water content of the aggregates affects the initial slump and water loss [11].

Table 2: Slump and flow test.

slump for Ref. (mm)	Slump test for RR mixes (mm)			Flow test for RS mixes (mm)		
Ref.	R10	R15	R20	RS10	RS15	RS20
120	100	110	100	250	250	250

2. Bulk density

By dividing the sample's weight at 28 days old by the concrete cube's volume, the bulk density of the sample is determined. A precise scale was used to measure the dried samples' weight (± 1 g). From the concrete density data, it was discovered that adding more RR to the concrete mixture significantly reduced the density of the concrete, as indicated in Table 3. For samples containing 10%, 15%, and 20% RR, the density dropped by 3.2%, 4.9%, and 6.3%, respectively. The density of samples replaced with RS also fell, though to a lower extent; for replacement ratios of 10%, 15%, and 20%, respectively, the declines were 7.2%, 7.4%, and 7.5%. It is obvious that there is a difference in the mixtures based on the outcomes of both RR and RS. The utilization of either combination as a structural element depends on the types of loads that this element is subjected to, even if both mixtures can be thought of as being in the ordinary weight range.

Table 3: Bulk density of mixes (kg/m³).

Ref. (mm)	RR mixes (mm)			RS mixes (mm)		
Ref.	R10	R15	R20	RS10	RS15	RS20
2257	2184	2146	2116	2095	2091	2088

3. Compressive strength

The most useful characteristic of hardened concrete, which serves as a key barometer of the material's strength, durability, and performance, is its compressive strength. On days 7 and 28, three cube samples of each mixture were tested for compressive strength. The average of the outcomes was calculated, as shown in Figs. 2 and 3.

The charts show that as the RR or RS replacement ratios grow, the results tend to decrease. Reduced ratios at day 7 for 10%, 15%, and 20% of RR replacement, respectively, were 8.3%, 17.5%, and 25.8%, which represents a considerable decrease in the mixes containing RR. The compressive strength dropped by 5%, 15.7%, and 18.4% with the identical substitution of RS at day 28.

Using the reference mix as a baseline, Fig. 4 examines the relative potency of RR and RS on the 28th day. The strength decline displays a comparable linear drop (negative correlation), however, the equation's values direction differs in the two combinations.

Because rubber is less dense than concrete, the lower strength behavior can be partly attributed to this. This decline is symmetrical with a number of previous research. These concretes can be used to

reinforce structural components that are subjected to impact loads or minor loads.

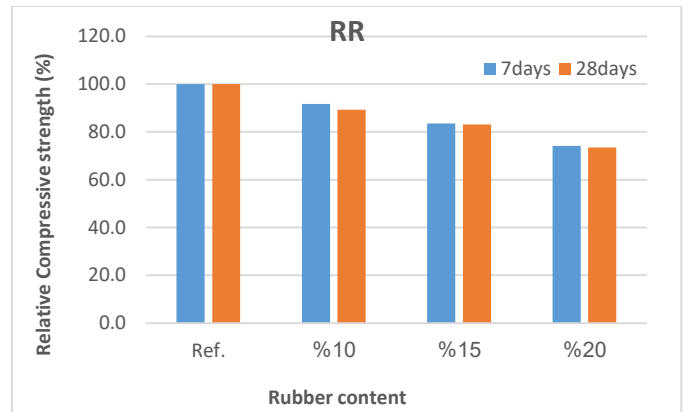


Fig. 2: Relative compressive strength of recycled rubber concrete RR with reference mix at 7th and 28th day.

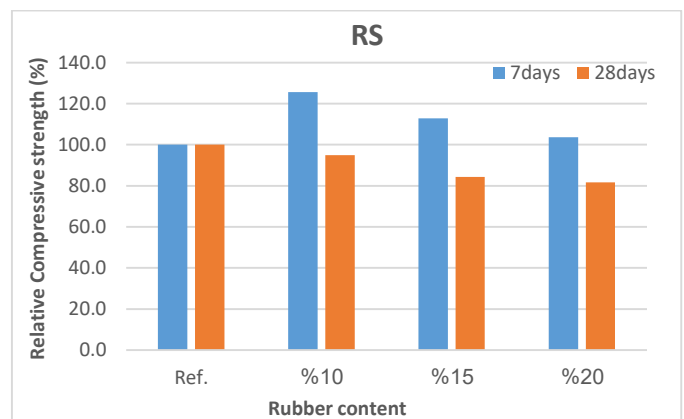


Fig. 3: Relative compressive strength of recycled rubber and superplasticizer concrete mixes RS with reference mix at 7th and 28th of day.

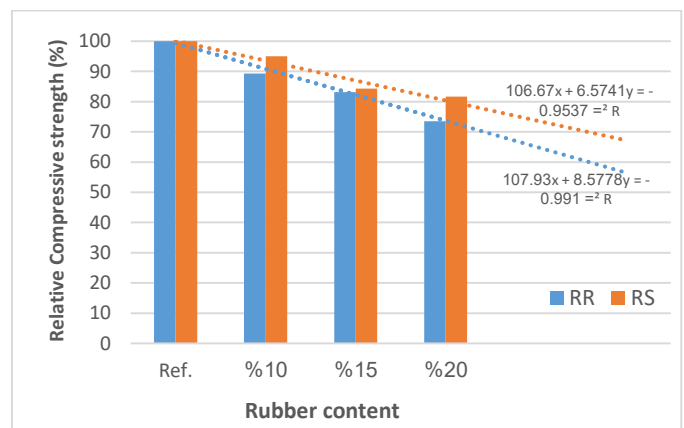


Fig. 4: Relative compressive strength of recycled rubber RR and rubber + superplasticizer RS concrete mixes with reference mix at 28th day.

4. Ultrasonic pulse velocity

The ultrasonic pulse velocity (UPV) is a test to assess the strength and quality of concrete by measuring the velocity of an ultrasonic pulse passing through it. Samples were extracted from the immersion after 28 days, after which the UPV test has performed before the compression test was conducted. An average of the three samples of UPV test was taken and the results are presented in chart as in Figure 5. The pulse velocity of concrete has slightly decreased by 3.8%, 12.7% and 14.7% for of RR mixes with 10%, 15% and 20%, respectively. The mixes with superplasticizer RS are less decreased, where in mixes with 10% and 15% were decreased 9.5%, while in mix with 20% was decreased 14.2%. These results shows that the amount less than 10% of rubber can be acceptable in concrete. Also,

superplasticizer may be added to compensate for the decrease in strength due to the addition of rubber. However, the results are in the 3.5 to 4.5 km/s range, which is considered to be of good quality by the majority of international standards.

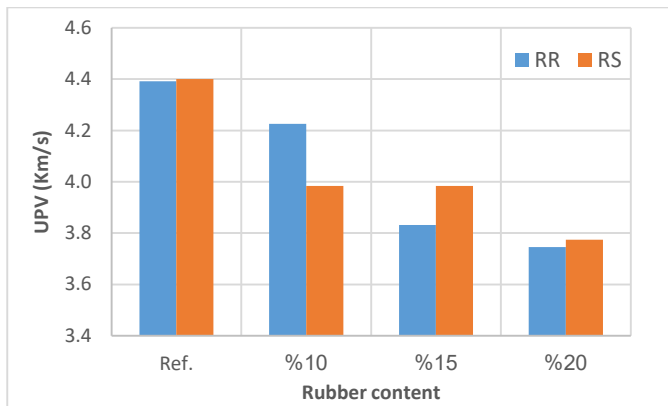


Fig. 5: Pulse Velocity at 28th day of the RR and RS mixes.

Conclusion

In conclusion, the utilization of recycled rubber in concrete has shown promising results in improving some of the properties of concrete. This study examined the effects of incorporating recycled rubber in concrete on various properties, including compressive strength, workability, and durability. The results showed that while the addition of rubber did decrease the compressive strength of the concrete mix, it did improve its workability and minimize the weight and thus decrease the dead load applied. Rubber-related strength loss in concrete can be made up for by additions that boost the material's strength. However, adding rubber in ratios not exceeding 10% is acceptable in order to enhance some features and gain from them simultaneously.

Overall, utilizing recycled rubber in concrete could be a viable solution for reducing waste while still maintaining acceptable performance characteristics. However, further research and testing is needed to fully understand its potential benefits and limitations.

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