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RESEARCH NOTE

Enhancement of the Shear-flexural Strength of the Rubberized Concrete Prism Beam by External Reinforcement

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ABSTRACT

It has become necessary to use damaged tires from various vehicles to produce rubberized concrete structures as a good solution to treat environmental pollution and reduce the total cost of construction. In general, concrete structures, for many reasons, may need to be strengthened. Recently, fiber-reinforced polymer (FRP) sheets have been used to reinforce existing concrete structural elements that were deficient. FRP is an effective solution and is moderately common for strengthening and improving the properties of the structural element. Firstly, concrete mixes were poured with replaced sand, with the percentages varying from 0, 10, 20, and 30%. Thus, some mechanical properties in terms of the workability of concrete, compressive strength, tensile strength, and density of recycled concrete were studied using rubber from tires as an alternative to fine aggregate. Secondly, concrete prisms were poured with different proportions of rubber instead of sand. Twelve rubberized concrete prisms measure 100 mm x 100 mm x 600 mm. Then, the effect of fiber reinforced polymer with different forms on concrete prisms was investigated. The results revealed a decrease in the workability, density, and compressive strength of the rubber concrete samples with an increase in the proportions of replaced sand with rubber content. It is also observed that FRP improves the strength, stiffness, and ductility of all concrete prism beams with a different ratio of recycled rubber. In addition, the test results clearly show that the strengthening by width sheets of FPR behaved more favorably than the thin sheets having the same cross-section.

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1. INTRODUCTION

The consumption of rubber tires for a lot of cars has significantly increased in recent times. As a result of the increase in the amount of rubber waste generated from used tires across various means of transportation, there is an environmental problem [1]. Accumulations of tires lead to pollution as well as diseases due to the burning and the gathering of mosquitoes [2]. Therefore, a solution must be found to get rid of tires for a sustainable environment by adding recycled rubber to produce sustainable concrete [3].

There are many studies on the use of tire rubber as a substitute for aggregate in concrete mixes [4, 5]. The use of rubber recycling to produce concrete mechanical and ductile properties for improving sustainability was investigated, but it was discovered that the dynamic properties of rubberized concrete elements had been reduced [6]. Also, the ultimate strength of specimens as beam and column was lower with an increase in the percentage of rubber used, as well as compressive strength [7]. Therefore, it is necessary to strengthen the rubberized concrete structure using fiber-reinforced polymer.

Recently, fibre reinforced polymer (FRP) sheets were used to strengthen the defective existing concrete structural elements [8]. The FPR material has extensive properties like high tensile strength and lightweight to enhance the service life of concrete elements [9]. Accordingly, the structural elements were strengthened to increase strength and durability by rehabilitating deteriorated concrete using FRP sheet [10, 11]. Many

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advantages have been reported by strengthening concrete using FRP compared to other traditional materials such as steel [12]. The effectiveness of the bending and shear strengthening depends on the bond between FRP and concrete, so that increase resistance by restricting external confinement [13]. The efficiency of FRP use dramatically affects the mechanical properties of rehabilitation concrete construction [14]. Various cases of strength have been depended on strip length, number and spacing or other standard methods for improving the behaviour of concrete elements [15-19].

In this paper, as in previous researches, waste tire rubber was first used as a substitute for fine aggregates to study the mechanical properties of rubber concrete. Secondly, the strengthening of rubber concrete prisms with carbon fibre was studied to improve the properties of these beams under the influence of two loading points. Thus, this research focuses on enhancing the strength of concrete containing different proportions of rubber using carbon fiber reinforced sheets.

2. SIGNIFICANCE OF STUDY

Concrete mixes in this paper are 1:1.5:3 (cement: sand: gravel) by weight, with a water-to-cement ratio of 0.5. Part of the sand was replaced with 10-30% rubber tire in the concrete mixes for comparison with a reference mix without rubber. Firstly, the effect of different proportions of rubber instead of sand in producing sustainable concrete must be studied. Therefore, the slump test, compressive strength at age 7, 28 days, tensile strength, and flexure strength at 28 days were examined to understand the effect of substitution on rubber concrete properties. Secondly, the use of rubber concrete in buildings subjected to increased loading needs to be strengthened properly. Therefore, twelve rubberized concrete prisms were cast. Then, some common types of external reinforcement (FRP sheets) were used to strengthen the rubber concrete prism to verify the importance of strengthening; thus, improving the shear-bending behavior.

3. EXPERIMENTAL WORK

In this study, rubber crumbs from car tires were used to evaluate their performance as a substitute for sand for producing concrete mixes. Rubber crumbs with dimensions less than 1 mm were obtained from mechanical shredding of car tires without any treatments. The mixes included cement, sand, gravel and water. Ordinary Portland cement (Type I) Al-Mass has been used to conform to the Iraqi standard specifications (I.Q.S 5:1984). Meanwhile, crushed coarse gravel was used from the Al-Nibaee area where the sieve analysis was identical with (I.Q.S 45:1984) data as shown in Figure 1. Also, the natural sand was from the al-Akheder area conforming to (I.Q.S45:1984) data as shown in Figure 2. Drinking water was used for concrete mixes that were designed following ACI 211.1 and for curing concrete samples. In order to prepare, the concrete mix is satisfied in the works of residential buildings. The trial and error method was also used to produce concrete grade M25.

Waste rubber tires were used as an additive to concrete at a rate of (10, 20, and 30%). As a substitute for a portion of fine aggregate (sand), use (water/cement ratio of 0.5 for all concrete mixes (1 cement: 1.5 sand: 3 gravel). Some mechanical properties in terms of the slump of concrete, compressive strength, tensile strength, and density of rubberized concrete were investigated. The main components of the reference concrete mixes (1 cement: 1.5 sand: 3 gravel) used in this research, as well as replacing the minced tires in different proportions (10, 20, and 30%), are shown in Figure 3 as a substitute for the fine aggregate, which which was encoded below:

M0: A reference concrete mix that does not contain minced used tires.

M10: A concrete mix containing 10% of the minced used tires

M20: A concrete mix containing 20% minced used tires.

M30: A concrete mix containing 30% minced used tires.

3. 1. FRP Strengthening

Rubberized concrete prisms have normal compressive strength fluctuate from 29-32 MPa that all prisms were cured in water at 28 days.

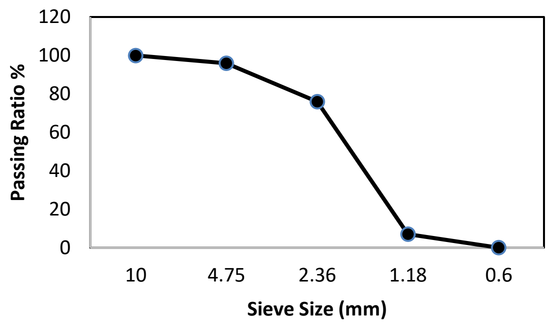

Figure 1. Sieve analysis of coarse aggregate

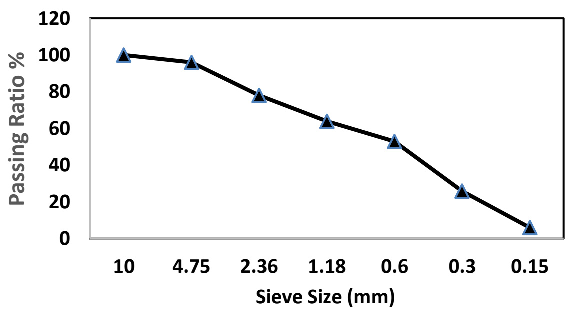

Figure 2. Sieve analysis of natural sand

Figure 3. Preparation of specimens

For strengthening prism by fiber-reinforced polymer that the type of FRP has been used Sikadur-300 Product as present in Table 1. Concrete prism is grinded to make a rough surface for perfect bonding between fiber-reinforced polymer with concrete prism [20] (see Figure 4).

3. 2. Prism Beam Details The prisms were strengthened on their tension side with a glued-on fiber-reinforced polymer sheet, which was put in the middle of the prism beam. Cases of reinforcement of beams using FRP carbon fiber reinforced sheets have been identified, namely:

Prism beam without strengthening, as a control prism beam, P-R0-ST0, P-R10-ST0, P-R20-ST0, and P-R30-ST0.

The prism beam is only strengthened by FRP strip closed between the loading point and support in the shear-flexure zone with lower surface 50 mm, P-R0-ST50, P-R10-ST50, P-R20-ST50, P-R30-ST50.

The prism beam is strengthened by both FRP strip closed with a lower surface of 100 mm, P-R0-ST100, P-R10-ST100, P-R20-ST100, and P-R30-ST100.

The details of concrete prisms are described in Figure 5.

3. 3. Setup Test An experimental test was set up where the rubberized concrete prism was put on supports at both ends. A two-point load test was performed on a strengthened rubberized concrete prism beam to determine its maximum failure strength, as revealed in Figure 6.

Figure 4. A rough surface for perfect bonding

TABLE 1. Mechanical properties of fiber-reinforced polymer

Laminate Nominal Thickness (mm)	Tensile Resistance (N/mm)	Modulus of elasticity (GPa)
0.167	585	220

*Sikadur®-300 Product Data Sheet

Figure 5. Concrete prisms

4. RESULTS AND DISCUSSION

4. 1. Slump and Workability The slump test was performed on all mixes containing different percentages of rubber: 0, 10, 20 and 30%, using a standard slump cone to determine the workability. It was found in Figure 7 that adding rubber to the concrete mixes reduces the slump, i.e. it notices a decrease in the workability. The addition of replaced rubber at 0, 10, 20 and 30% led to a decrease in slump at 4 cm, 3.2 cm, 2.8 cm, and 2.6 cm,

Figure 6. Testing procedures

Figure 7. Concrete prisms

respectively. The decline in the slump ratio was 20, 30 and 35% due to the rubber replacement ratio of 10, 20 and 30%, respectively, to the concrete mix without rubber due to the moisture-absorbing property of rubber as shown in Table 2. Accordingly, the slump of the concrete mix containing rubber was reduced when compared with the control concrete mix 1:1.5:3. The slump is inversely proportional to the amount of rubber added, which agrees well with another research [21].

4. 2. Compressive Strength The compressive strength of concrete mixes containing rubber in different proportions instead of sand has been studied. It was found from the results that increasing the amount of rubber replaced decreases the compressive strength of cubes with dimensions of 10 x 10 x 10 cm. The percentages of compressive strength at 7-day decreased by about 1.8, 3.7, and 6.2% for the proportions of rubber at 10, 20 and 30%, respectively, when compared with the reference concrete mix without rubber. While the percentages of compressive strength at 28 days were less than 1.3, 6.7 and 9.8% for proportions of rubber at 10, 20, and 30%, respectively, when compared with the reference concrete mix without rubber as indicated in Table 3. The compressive strength result showed no significant change in 10% rubber at 28 days. Meanwhile, it was observed that the lowest decrease in compressive strength was 9.8% when the rubber replacement ratio was set at 30%. Accordingly, the compressive strength decreases with an increase in the proportion of rubber replaced (see Figure 8).

4. 3. Split Tensile Strength It is necessary to conduct a cracking resistance test for cylinders with a diameter of 10 cm and a height of 20 cm. The results are 2.51, 2.48, 2.47, and 2.33 MPa for tensile strength for rubber ratios of 0, 10, 20 and 30% at 7 days, respectively. Hence, at 28 days, tensile strength is 3.04, 2.94, 2.78, and 2.75 MPa for rubber ratios of 0, 10, 20, and 30%, respectively, as in Table 4. In other words, the higher the percentage of rubber replaced, the lower the tensile strength (see Figure 9).

4. 4. Flexural Strength The flexure strength of a rubberized-concrete prism with dimensions of 10 cm x 10 cm x 60 cm for 0, 10, 20 and 30% rubber substituted sand is given at 3.96, 3.80, 3.59, and 3.49 MPa at 28 days, respectively. That is, the higher the percentage of the rubber replaced, the lower the flexural resistance by 4.2, 9.53 and 12.03% with comparison without rubber

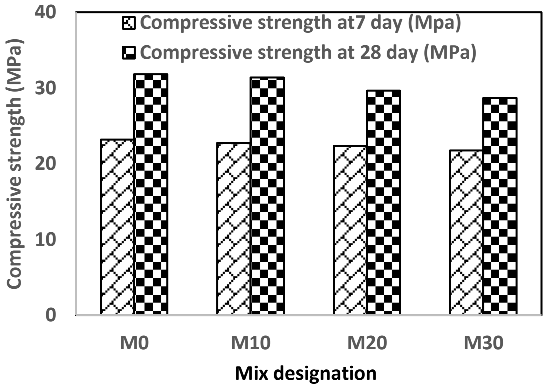

Figure 8. Compressive strength test results

TABLE 2. Concrete prisms

Mix code	Slump (cm)	Decrease ratio (%)
M0	4.0	0.0
M10	3.2	20%
M20	2.8	30%
M30	2.6	35%

TABLE 3. Compressive strength test results

Mix code	Compressive strength at 7 day (MPa)	Compressive strength at 28 day (MPa)
M0	23.21	31.80
M10	22.79	31.39
M20	22.35	29.67
M30	21.77	28.68

TABLE 4. Tensile strength test results

Mix code	Tensile strength at 7 day (MPa)	Decrease (%) 7 days	Tensile strength at 28 day (MPa)	Decrease (%) 28 days
M0	2.51	0%	3.04	0%
M10	2.48	-1.20%	2.94	-3.29%
M20	2.47	-1.59%	2.78	-8.55%
M30	2.33	-7.17%	2.75	-9.54%

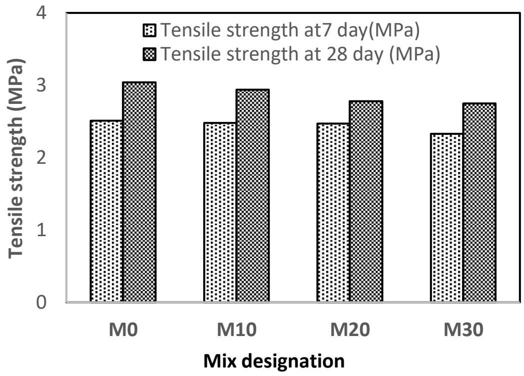

Figure 9. Tensile strength test results

is present in Table 5. The type of failure of the rubber-concrete prism is shown in Figure 10 after the testing.

4. 5. External Fiber-reinforced Polymer Effect on Rubberized Concrete Prism Concrete The types of failure of rubberized concrete prisms with fiber-reinforced polymer external are shown in Figure 10. It is observed that the FRP improves the strength and ductility of the prism beam compared to the control beam. Rubberized concrete prisms without strengthening, as control prism beams have the lowest strength. Meanwhile, the control rubber-concrete prism was observed in flexure failure, so a crack began in the middle of the concrete. Hence, strengthened rubber-concrete prisms in the shear-flexure zone with a lower surface of 50 mm of fiber-reinforced polymer, it was found that the type of failure in the flexural zone. Meanwhile, the behaviour of strengthened prism beams with both fiber-reinforced polymer strip and lower surface of 100 mm is the highest compared to other prism beams, which is consistent with the results reported by previous researchers [22, 23]. In other words, the failure rate in the shear zone was higher when the FRP external reinforcement was installed on the lower surface. The crack occurred in the protective layer for the strengthened rubber concrete prism beam. The percentage of increase in loading resulted in strengthened rubber concrete prisms as compared with control concrete prisms as well as types of failures are described in Table 6. It is also found that the strength of the rubberized concrete prism strengthened by both FRP strip with a lower surface of 100 mm is the highest and favorably the strongest.

TABLE 5. Flexure strength test results

Designation	Flexure strength at 28 day (MPa)	Decrease ratio at 28 day (%)
P-R0-ST0	3.96	0%
P-R10-ST0	3.80	4.20%
P-R20-ST0	3.59	9.53%
P-R30-ST0	3.49	12.03%

TABLE 6. Flexure strength test for strengthening rubberized concrete prisms

Designation	Flexure strength at 28 day (MPa)	Increase ratio (%)	Type of failure
P-R0-ST0	3.96	0.0	Flexure
P-R10-ST50	7.73	95	Flexure
P-R10-ST100	11.42	188	Shear
P-R10-ST0	3.80	0.0	Flexure
P-R10-ST50	7.52	98	Flexure
P-R10-ST100	11.04	191	Shear
P-R20-ST0	3.59	0.0	Flexure
P-R20-ST50	7.06	97	Flexure
P-R20-ST100	10.58	195	Shear
P-R30-ST0	3.49	0.0	Flexure
P-R30-ST50	6.52	87	Shear
P-R30-ST100	10.77	209	Shear

Figure 10. Failure observation of strengthening rubberized concrete prisms

5. CONCLUSIONS

The tire rubber used in different proportions instead of sand effects on the properties of concrete as follows:

- The workability of concrete decreases with increasing proportions of rubber replaced.
- The compressive strength, tensile strength, and flexural strength of hardened concrete increase as the proportions of rubber substitute decrease.
- The FRP improves the strength, stiffness, and ductility of all rubberized concrete prism beams.
- The types of failure of rubberized concrete prisms were flexure failure or shear failure, which depend on the type of external strengthening.

- It was also observed that the strengthening of FRP width sheets is favourably higher than that of FRP thin sheets.

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Persian Abstract

چکیده

استفاده از لاستیک های آسیب دیده وسایل نقلیه مختلف برای تولید سازه های بتنی لاستیکی به عنوان راه حل مناسبی برای درمان آلودگی های زیست محیطی و کاهش کل هزینه های ساخت ضروری شده است. ه طور کلی سازه های بتنی به دلایل زیادی ممکن است نیاز به مقاوم سازی داشته باشند. اخیراً از ورق های پلیمری تقویت شده با الیاف (FRP) برای تقویت عناصر ساختاری بتنی موجود استفاده شده است. FRP یک راه حل موثر و نسبتا رایج برای تقویت و بهبود خواص عنصر ساختاری است. در این مقاله ابتدا مخلوط های بتن با ماسه جایگزین ریخته شد که درصد آن از ۰، ۱۰، ۲۰ و ۳۰ درصد متغیر است. بنابراین، برخی از خواص مکانیکی از نظر کارایی بتن، مقاومت فشاری، مقاومت کششی و چگالی بتن بازیافتی با استفاده از لاستیک لاستیک به عنوان جایگزینی برای سنگدانه های ریز مورد مطالعه قرار گرفت. ثانویه، منشورهای بتنی با نسبت های مختلف لاستیک به جای ماسه ریخته شدند. دوازده منشور بتنی لاستیکی در ابعاد ۱۰۰ میلی متر در ۱۰۰ میلی متر در ٦۰۰ میلی متر هستند. سپس تأثیر پلیمرهای تقویت‌شده با الیاف با اشکال مختلف بر روی منشورهای بتن بررسی می‌شود. نتایج کاهش کارایی، چگالی و مقاومت فشاری نمونه‌های بتن لاستیکی را با افزایش نسبت جایگزینی ماسه با محتوای لاستیک نشان داد. همچنین مشاهده می شود که FRP استحکام، سختی و شکل پذیری تیرهای منشوری بتنی را با نسبت های مختلف لاستیک بازیافتی بهبود می بخشد. علاوه بر این، نتایج آزمایش به وضوح نشان می‌دهد که استحکام با ورق‌های پهن FPR نسبت به ورق‌های نازک دارای سطح مقطع یکسان رفتار مطلوب‌تری داشت.