International Journal of Engineering

Journal Homepage: www.ije.ir

Effect of using Waste Rubber as Partial Replacement of Coarse Aggregate on Torsional Strength of Square Reinforced Concrete Beam

A. A. H. Beiram*, H. M. K. Al-Mutairee

Civil Engineering Department, College of Engineering, Babylon University, Iraq

PAPER INFO

Paper history:
Received 18 October 2021
Received in revised form 20 November 2021
Accepted 25 November 2021

Keywords:
Rubberized Concrete
Chip Rubber
Pure Torsion
Angle of Twist
Replacement Aggregate

ABSTRACT

The aim of this study is to test the rubberized concrete beams subjected to pure torsional moments. The study focused on the effect of the partial replacement of coarse aggregates with waste rubber chips of different proportions 10%, 20%, and 30% in volume on the beams ultimate torque, and rotation, as well as the ductility index, stiffness, cracking torque, and failure modes. Six specimens of concrete beams as the same size (225×225mm) have been tested. The same steel reinforcement has been applied to four specimens and two without reinforcement. According to experimental findings for reinforced specimens, the ultimate torque for the control beam (without replacement) is higher than beams with replacement rubber but the angle of twist of beams with replacement rubber rose more than the control beam. the ultimate torque decreases compared with the control beam by 4.49%, 10.08%, 13.98%, while the twist angle increases at ultimate torque by 11.16%, 26.79%, 39.69% when the percentage replacement of rubber is 10%, 20%, 30% respectively. When coarse aggregate was replaced with 30% rubber, the ductility index of specimens increased by 39.83%, and ultimate cracking stiffness was lowered by 38.42% as compared with the control beam.

***doi**: 10.5829/ije.2022.35.02b.16*

1. INTRODUCTION

Cement and aggregates are the most important ingredients of concrete, which is one of the most commonly and consistently used as a construction material in the world. Due to the high demand for concrete as a building material in society, substitute materials derived from recycled or waste materials are needed to conserve natural aggregates [1].

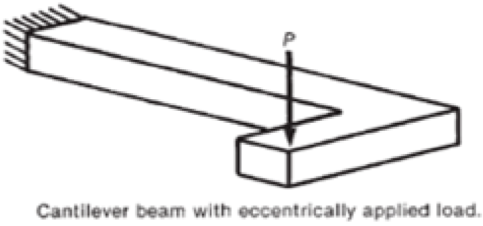
Since the car industry is rising, it is becoming increasingly difficult to get rid of waste tires as shown in Figure 1. Every year, a huge amount of waste tire rubber accumulates, and the easiest way to decompose it is to burn it; anyway, burning rubber causes a lot of smoke and emissions. Another way to get rid of waste rubber is to dump it; anyway, the supply and capacity of landfills is decreasing [1]. As a result, the best scrap tire management technique is recycling, which contributes to scrap tire use while minimizing environmental damage and enhancing natural resource conservation. Low unit weight, high abrasion resistance, toughness, stress and vibration absorption, and ductility can all be increased by partially replacing coarse particles in concrete with recycled discarded tires [2].

Torsion may be a major issue in concrete structural members including eccentrically loaded beams, horizontally bent beams, spandrel beams, and helical stairways, among others. Torsional loadings are divided into two types: equilibrium torsion, in which the torsional moment is necessary for the structure's equilibrium, and compatibility torsion, in which the torsional moment is induced by the compatibility of deformations between members meeting at a joint as shown in Figure 2 [3].

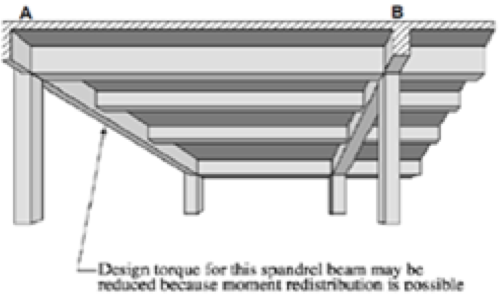
*Corresponding Author Institutional Email: ammar@atu.edu.iq (A. A. H. Beiram)

Please cite this article as: A. A. H. Beiram, H. M. K. Al-Mutairee, Effect of using Waste Rubber as Partial Replacement of Coarse Aggregate on Torsional Strength of Square Reinforced Concrete Beam, ***International Journal of Engineering, Transactions B: Applications***, Vol. 35, No. 2, (2021) 397-405

Figure 1. Industrial landfill for processing of waste tires [4]



(a) Equilibrium torsion



(b) Compatibility torsion

Figure 2. Illustrates example of torsion [3]

Aiello and Leuzzi [5] replaced coarse aggregates with chip tire rubber by volume of coarse aggregate, chip rubber accounted for 25%, 50%, and 75%. They discovered that as the chip tire content grew, the workability also did. Additionally, as the rubber percentage increased, the unit weight, compressive strength, and flexural strength decreased.

Gunasekaran et al. [6] studied eight beams, four of which are made of coconut shell concrete and four of which are made of normal concrete subjected to pure torsion, the results proved that the concrete specimens made from coconut shells are more ductile than conventional concrete specimens. Also, Both normal and coconut shell concrete with corresponding reinforcement ratios have almost identical crack widths at initial cracking torque.

Mohaisen et al. [7] investigated the effect of pure torsion on reinforced concrete continuous beams with variable load eccentricity. They discovered that when load eccentricity rose from 30cm to 60cm, the angle of twist enhanced by 45.76% and the final failure loads reduced by 49.65%.

Siddiqui [8] investigated rubber fragments as a partial substitution for gravel in concrete. The varying percentages of partial replacement of rubber was from 0 to 15% of normal aggregates. From the experimental test results rubberized concrete leads to decrease in slump, workability, unit weight and compressive strength compared to normal concrete.

Kadhim and Al-Mutairee [9] studied chip and crumb rubbers as a partial volumetric replacement for aggregate (gravel and sand) in four separate amounts (5, 10, 15 and 20 %). When 20 % aggregates (gravel and sand) were replaced with crump and chip tier rubber, mechanical properties (compressive, flexural, and splitting tensile strength) were reduced, but impacts resistance has increased by 426 % and 396 %, respectively.

Sahib and Al-Mutairee [10] investigated rubberized concrete's behavior in flat plate punching shear. By punching, the 10-sample experimental model is supposed to fail. The model form column (square and rectangular) and the chips rubber ratios were (0, 5, 10, 15 and 20%), which used instead of coarse aggregate. The experimental findings show that replacing coarse aggregate with chips rubber from zero to 20% decreases the punching shear capability by 13.54% and 18.52% in two case studies (square and rectangular) column, while increased ductility by 20.38% and 15.60%, respectively, and substantially improved the energy absorbing index by 41.41% and 28.75%, respectively.

Kadhim and Al-Mutairee [11] studied 14 continuous deep beams had two-span made of normal concrete with steel reinforcement served as an indication and rubberized reinforced concrete. Rubber ratios can be used to partially replace gravel and sand, as well as shear span/depth ratios of 1.33 and 1.66, are the key parameters. Rubbers (Chip and crumb) were used in four different quantities by volume to substitute coarse and fine aggregate, respectively (5, 10, 15 and 20%). While still producing structural concrete, the proposed mix will substitute 20% of the aggregate (gravel or sand). The data indicated that substituting tier rubber for natural coarse or fine aggregates by 20% decreased the ultimate load upon twin span deep beams by 32.06 and 32.65 percent, respectively, and increased the maximum deflection by 83.07 and 106.28 percent. When crumb rubber is used as a 20% replacement, the ductility of rubberized beams increases to 36.95%.

Other researchers looked at the impact of partially replacing aggregate with rubber or other material on concrete characteristics [12-14].

The majority of current research has focused on the structural behavior of beams normal concrete or with strengthened material under the effect of combined loads or pure torsion, but research on reinforced concrete beams under pure torsion with partial replacement of corse aggregate with rubber is too limited or otherwise unavailable. To the best of the authors' knowledge, this is the first experiment to compare the structural performance of rubberized concrete beams to normal concrete beams under pure torsion. The major goal of this study is to determine the differences in behavior between a conventional concrete beam and a rubberized concrete beam under pure torsion, as well as the effect of the volumetric ratio of replacement rubber and steel reinforcement on structural behavior. As a result of the laboratory results, it was determined that the traditional method of beam design for pure torsion needs to be modified to include the rubber effect resulting from partial replacement of coarse aggregate, that their torsional strength was also lower than the normal concrete beam, and their angle of twist was greater than the normal concrete beam.

2. EXPERIMENTAL WORK

2. 1. Specimens Preparation Six specimens were tested as part of the experimental program with dimensions 225 mm width, 225 mm height and 2200 mm total length and effective span 1800 mm. The variable of this study is the replacing the waste rubber chips partially to the coarse aggregate in concrete with different volumetric percentage as 10, 20 and 30%. Four beams have the same torsional steel reinforcement as shown in Figure 3 and other two beams without steel reinforcement (plain concrete). The beams' cross section, main reinforcement, and transverse reinforcement are all chosen to meet the specifications of ACI Code 318-19 [15]. All beams tested under pure torsion to find the effect of rubber replacement on the beams ultimate torque, angle of twist, ductility index, stiffness, cracking torque, and failure modes. The details and properties of all beams as illustrated in Table 1.

2. 2. Properties of Material The form of cement used in this study was ordinary Portland cement; cement is needed to stratify the specification (Iraq Specification No. 5) limitations [16]. As fine aggregates, natural sand with a maximum size of (4.75) mm was used, which complies with Iraqi requirements (Iraq Specification No.45), Zone (2) [17]. The coarse aggregate in this experiment is rounded gravel with a maximum size of 14 mm. The coarse aggregate grading is verified to the IQS No.45 [17]. The rubber samples for the study were collected by cutting scrap tire rubber and passing it through a 14 mm sieve**.** The specified size was that grading is similar to that of coarse aggregates. Glenium 54 (G54), a high-range water-reducing admixture, is used to change the workability of concrete mixtures. It is

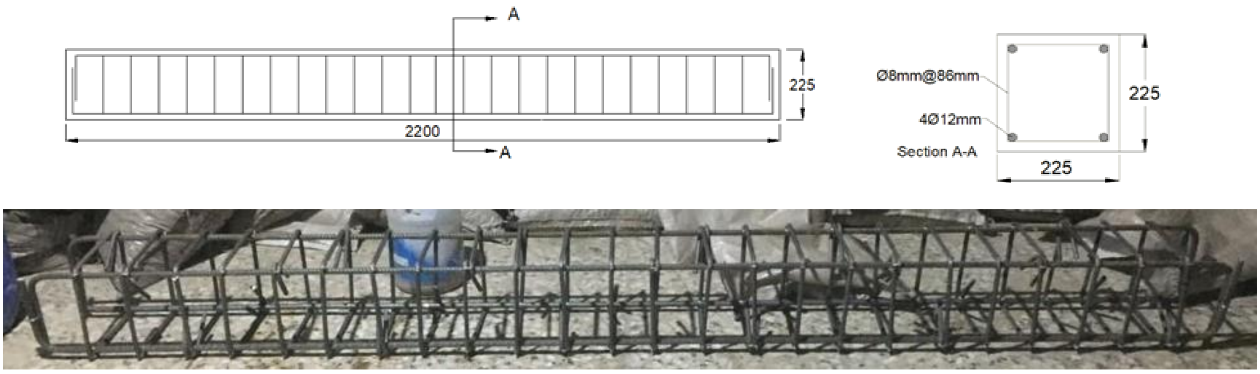


Figure 3. Geometry and details of reinforcement of specimens

TABLE 1. Summary of all specimens

Symbol	Beam Details	% Rubber by vol.
S0	Beam of normal concrete with steel reinforcement	0
S10		10
S20	Beams with steel reinforcement & partial replacement of coarse aggregate by recycle rubber	20
S30		30
S0P	Beam of normal concrete without steel reinforcement (plain concrete)	0
S30P	Beam without steel reinforcement (plain concrete) & partial replacement of coarse aggregate by recycle rubber	30

manufactured by the corporation (BASF) and meets the specifications of (ASTM C494/C494 M) [18]. The primary longitudinal reinforcement was made of 12 mm diameter deformed steel reinforcement, while the transverse reinforcement was made of 8 mm diameter deformed steel reinforcement. The yielding and ultimate strength are summarized in Table 2. according to ASTM A615 [19].

2. 2. Mix Design and Casting Many trial mixes were designed to achieve cylinder strength of reference concrete mixture equal to 35MPa at 28 days. Water/cement ratio was 0.36. The amount of cement and water in the mix remains constant with the following values (440, 158.4 kg/m^3), respectively. Fine aggregate content is constant and equal to 710 Kg/m^3. The superplasticizer percentage is constant with value 0.45% from cement content. Table 3 shows the composition of the mixture.

The first step was to choose the materials, which were prepared and weighed according to the mix's volume requirements. All of the specimens utilized in this study were cast in plywood moulds with a specific dimension of (225×225×2200 mm) as shown in Figure 4. Before putting the steel reinforcement inside the formworks, the inner faces of the plywood formworks were oiled to ensure the ease of the demoulding and using 20 mm concrete spacers as a concrete cover from all sides. Electric concrete mixer used to mix concrete and cast the concrete into the formwork then a vibrator was used to help the trapped air to escape. After 24 hours the plywood mould removed and curing the specimen.

According to ASTM C78-02 [20], the flexural tensile strength of prisms with dimensions of (100×100×400) mm was calculated. Tensile strength is also tested using the ASTM C496/C496M-04 method for concrete cylinders with a diameter of 100 mm and a length of 200 mm [21]. The concrete modulus of elasticity was tested using cylindrical specimens with a dimension of (100×200) mm, according to the method (ASTM C469-14) [22]. The hardened properties were evaluated by

TABLE 2. Steel reinforcement test results

ϕ (mm)	Fy (MPa)	Fu (MPa)
8	543.3	665.1
12	570.8	718.1

TABLE 3. Details of the mixture

Specimens	Gravel (Kg/m^3)	rubber (Kg/m^3)
S0	1050	0
S10	945	31.82
S20	840	63.64
S30	735	95.45
S0P	1050	0
S30P	735	95.45

(a) Prepair mold (b) Casting & vibrator (c) finishing (d) curing

Figure 4. Prepair mold and casting Specimens

compressive strength, splitting tensile strength, flexural tensile strength, and modulus of elasticity test as mentioned in Table 4.

2. 3. Test Setup and Procedure Every one of the specimens were tested using a basic span (L) of 1800 mm between supports and were painted white to aid in crack detection. The load must be transmitted from the testing hydraulic machine's core to external sites reflecting load eccentricity, such as the torsion arm, according to the experimental requirements. The unique clamping loading frame used in this study is shown on both ends of the beam as demonstrated in Figure 5. The centre of support must correspond with the centre of the torsion arm, the torsion moment arm (500mm) from the middle of the beam, so as to achieve pure torsion. The twist angle of the bottom fibre at the near corner of the beam end was determined using a dial gage with 0.01 mm divisions and a 30 mm capacity at the end of the beam span. After being measured under pure torque, the beams were loaded at a constant concentration of 0.1 KN/s. At each loading interval, the twist angle readings were registered, as well as the load of the first crack was recorded, to monitor the types of cracking and load failure as shown Figure 6.

TABLE 4. Hardened properties of mixes

Specimens	(fc') for cylinder (MPa)	Splitting Tensile Strength (ft) (MPa)	Modulus of Rupture (fr) (MPa)	Modulus of Elasticity (GPa)
S0	34.97	3.65	4.67	27.68
S10	28.67	3.18	3.95	21.228
S20	23.46	2.83	3.20	16.582
S30	18.31	2.36	2.58	13.705
S0P	34.97	3.65	4.67	27.68
S30P	18.31	2.36	2.58	13.705

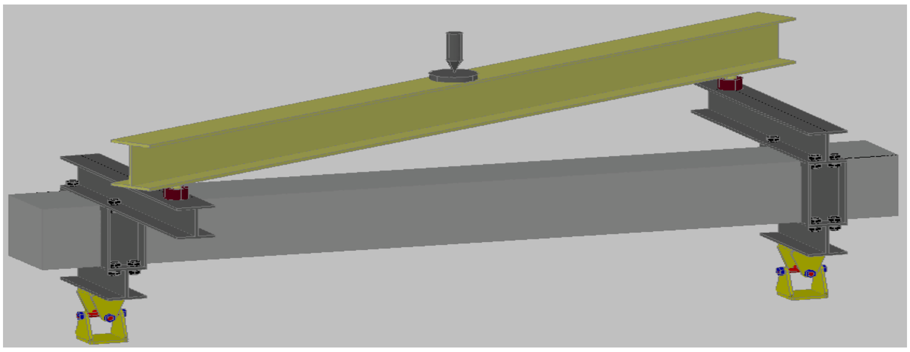


Figure 5. Set-up a mutual of pure torsion in a schematic test diagram

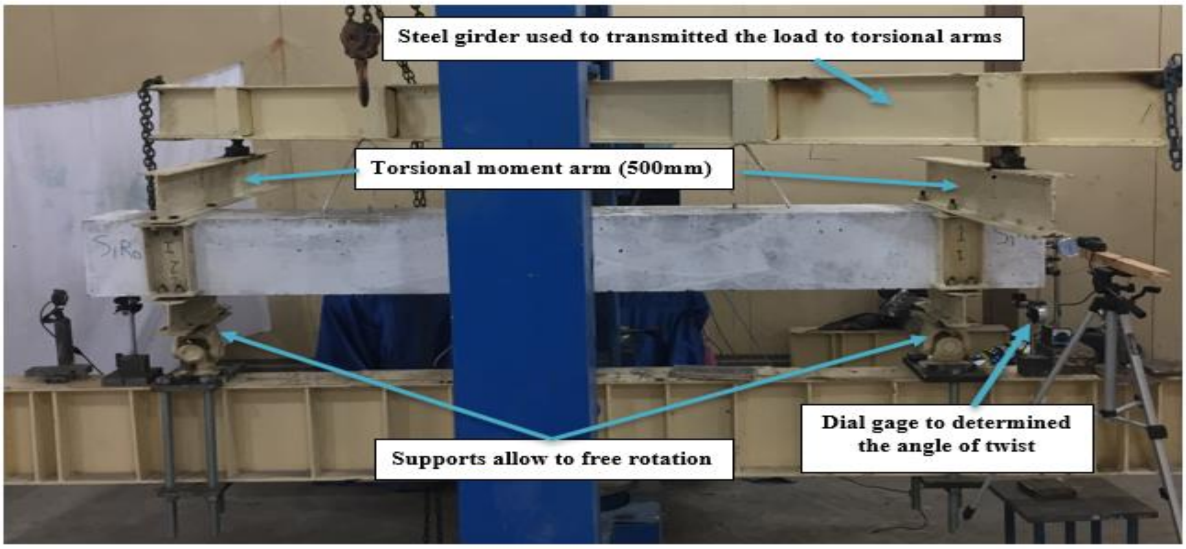


Figure 6. The universal measuring machine is used to test specimens

3. DISCUSSION OF THE FINDINGS

3. 1. Failure Modes of Specimens

Tables 5 and 6 show the experimental test results for beams S0, S10, S20, and S30. It can be noticed that, prior to breaking, both cases of beams displayed a linear torque versus twist relationship, indicating that both normal and rubberized concrete beams were elastic. The curves become non-linear after cracking. The first cracks emerged on one of the beam's two wider faces and quickly travelled along with the entire depth of the face, before spreading to the shorter face and failing. As stated in ACI 318-19 [15], concrete behaves as a nonlinear discontinuous medium after cracking, generating a truss action in which reinforcement serves as a tensile link and concrete acts as a compression diagonal. The spiral cracks developed at about 45 degrees and propagated across the test zone as the applied torque increased. When replacing gravel with rubber, the spread of cracks increases along the beam, and the width of the cracks decreases as the percentage of rubber increases. During the first cracking period, the torque decreased as the percentage of rubber increased from 10 to 30%, about 4.82 to 10.18%, whereas the angle of twist increased with values equal to 7.96, 15.83, and 24.02% compared to the control beam S0. At the ultimate stage, the torque decreased by about 4.49, 10.08, and 13.98% when the percentage of chip rubber was increased from 10 to 30%, whereas the twisting increased by about 11.16, 26.79, and 39.69% compared with the control beam S0 as shown in Figure 7. The cracks formed on all other faces formed a helical pattern around the beam scattered along the beam shown in Figure 8.

The reason for the reduction in torque and increased angle of twist is that the difference in particle softness between scrap tire rubber and aggregates is the cause of this reduction. Rubber and cement paste has poor adherence (The interfacial transition area between the rubber particles and the cement paste has low strength).

Increased rubber substitution for gravel particles in concrete lowers the elastic modulus and, as a result, the elastic modulus for concrete, which is mainly correlated here to the proportion of rubber provided, due to the lower rubber module of elasticity, therefore the rubber cement combination becomes more flexible.

The failure torque of plain concrete beam (S30P) decreased about 8.84% with respect to beam (S0P) but the angle of twist increased about 25.43% as shown in Table 7. The cracking torque for plain concrete is roughly equal to the ultimate torque because the beam would fail in a brittle manner once the maximum shear stress equals the concrete tensile cracking strength. The effect of reinforcement can be noted by comparing the results of specimen S0 with S0P and specimen S30 with S30P for normal and rubberized concrete respectively. The failure torque of beam (S0P) reduced about 33.41% compared with failure torque for beam (S0) and that the angle of twist decreased about 73.52%. Also, the failure torque of beam (S30P) reduced about 29.43% compared with failure torque for beam (S30) and that the angle of twist decreased about 76.22% as shown Figure 9. The failure shape of beams is depicted in Figure 10.

3. 2. Ductility of Beams

A structure's ductility is defined as its ability to withstand load after deformation beyond the initial yield deformation. The rotation ductility factor (μ) required formula ϴmax/ ϴY to determine the ductility of the tested specimens, where

TABLE 5. Results of testing RC beams at cracking torque

Sample	Torque (kN.m)	*Decreeing in Torque%	Twist ×10^{-3} (rad/m)	**Increasing in Twist %
S0	9.33	-----	12.82	-----
S10	8.88	4.82	13.84	7.96
S20	8.60	7.82	14.85	15.83
S30	8.38	10.18	15.90	24.02

* Compare the torque with control beam(S0).
** Compare the twist with control beam (S0).

TABLE 6. Results of testing RC beams at ultimate torque

Sample	Torque (kN.m)	*Decreeing in Torque%	Twist ×10^{-3} (rad/m)	**Increasing in Twist %
S0	13.59	-----	52.26	-----
S10	12.98	4.49	58.09	11.16
S20	12.22	10.08	66.26	26.79
S30	11.69	13.98	73.00	39.69

* Compare the torque with control beam(S0).
** Compare the twist with control beam (S0).

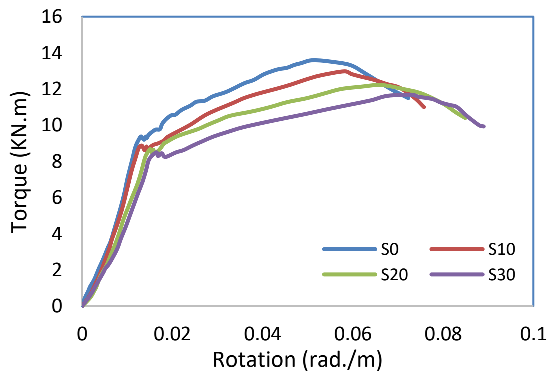


Figure 7. Variation of torsional moment with angle twist for rubberized concrete

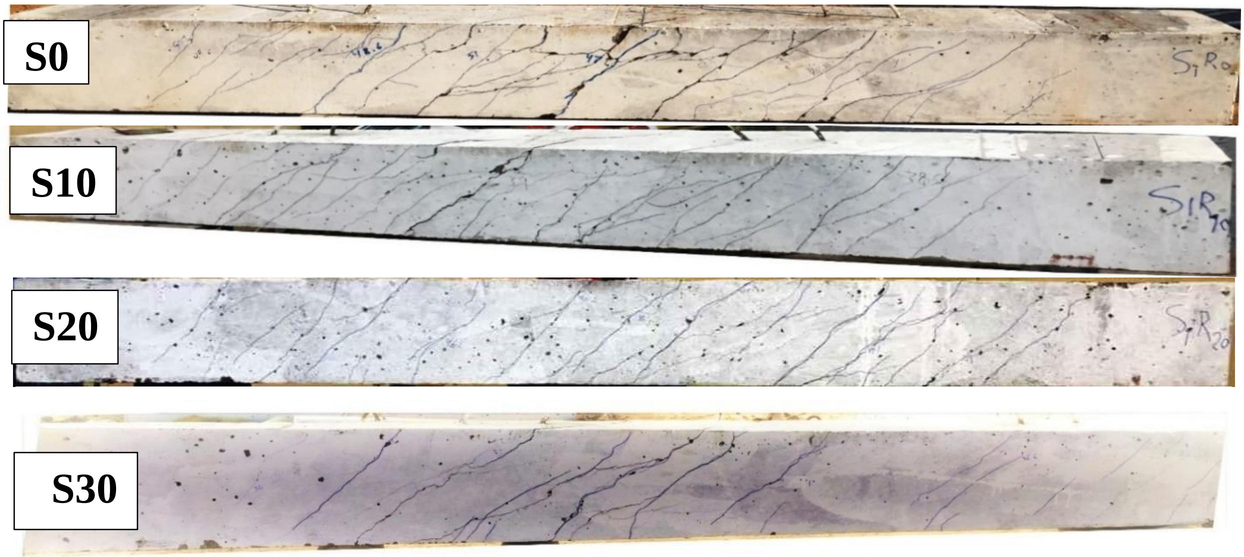
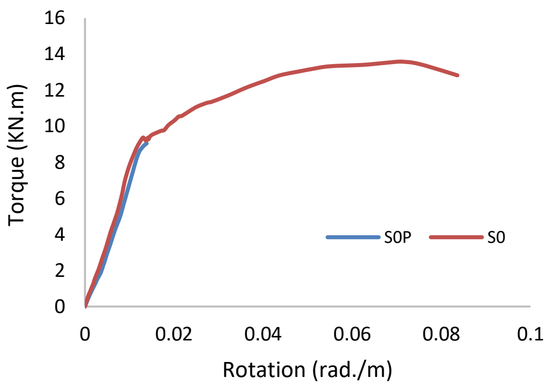


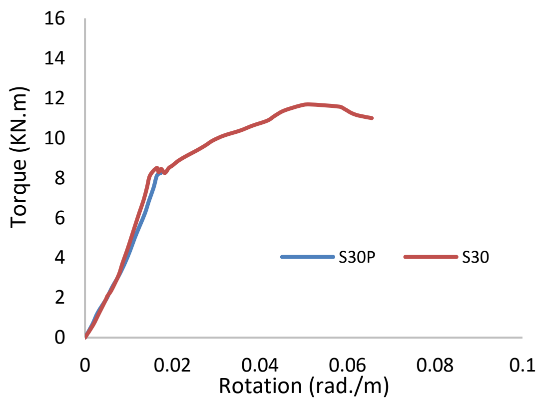
Figure 8. R.C. beam crack patterns : (a) S0 , (b) S10, (c) S20, (d) S30

TABLE 7. Experimental test results of plain concrete beams

Sample	Torque (kN.m)	Decreeing in Torque%	Twist, θ (Rad/m) $\times 10^{-3}$	Increasing in Twist %
S0P	9.05	-----	13.84	-----
S30P	8.25	8.84	17.36	25.43



(a) Normal concrete



(b) Replacement 30%

Figure 9. Variation of torsional moment with angle twist of plain concrete with reinforced concrete (a, b)

Ɵmax is the maximum rotational just at the plastic hinge and ƟY is the rotational in the plastic hinge region at yield as shown Figure 11 [23-24]. The twist–rotation curve was used to tabulate the results of the ductility index of beams in Table 8.

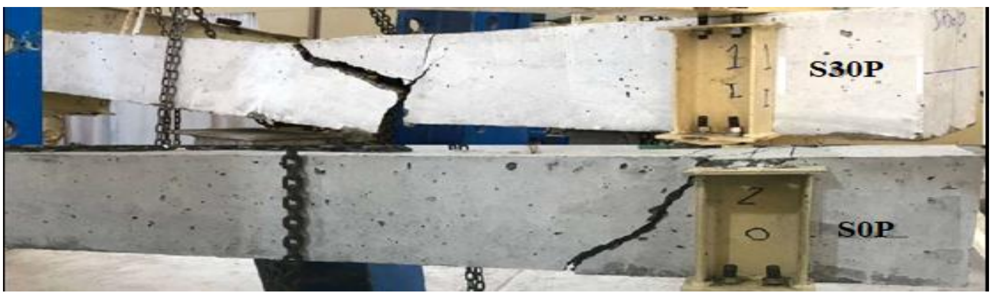
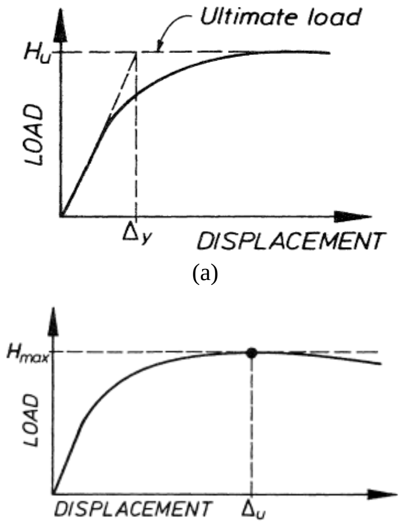


Figure 10. Failure shape of plain concrete beams



(b)

Figure 11. Definitions of ductility, (a) Θ_Y: Based on Equivalent Elasto-Plastic Yield,(b) Θ_{max}: Based on peak torque [23]

TABLE 8. Ductility index of test beams

Sample	Θ_{max} (rad./m)	Θ_Y (rad./m)	μ
S0	0.0523	0.0210	2.49
S10	0.0581	0.0190	2.83
S20	0.0663	0.0195	3.11
S30	0.07300	0.0185	3.35

The ductility of rubberized concrete increased by about 13.65, 24.90 and 34.54% when the ratio of replacing coarse aggregate with chip rubber increased from 10% to 30% compared with control beam S0.

3. 3. Stiffness of Beams The rigidity of an object and the range to which it resists deformation in response to an applied force are the basic concepts of stiffness. As shown in Figure 12, the stiffness of all specimens was determined as the ratio of ultimate torque to angle of twist from the experimental findings [6]. Cracking stiffness is a proposed method for determining the stiffness of concrete structures (K). Table 9 shows the results of cracking stiffness testing.

Replacement chips rubber with 10%, 20%, and 30% reduced the torsional stiffness of the specimens by 14.07%, 29.13%, and 38.42%, respectively.

From the results above, the control beam (S0) has the better ultimate torque but low rotation, whereas the beam S30 has reduced torque by about 13.98% and increased rotation by about 39.69%. It also increased ductility by about 34.54% compared with beam S0. Therefore, the beam S30 is considered the best beam for a structure that needs more flexibility, such as structures exposed to earthquakes, explosions, and shocks.

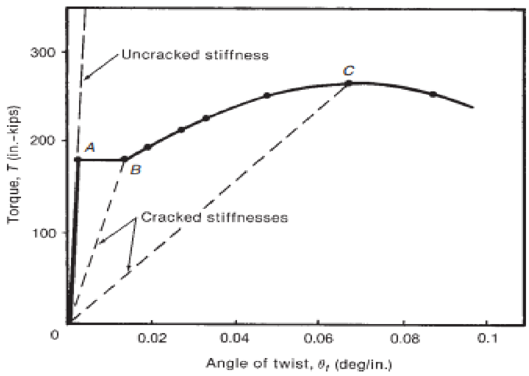


Figure 12. Calculation cracking stiffness [3]

TABLE 9. Cracking stiffness of test beams

Sample	Tu (kN.m)	Θu (rad./m)	Kθ (kN.m)
S0	13.59	0.05226	260.05
S10	12.98	0.05809	223.45
S20	12.22	0.06626	184.42
S30	11.69	0.07300	160.14

4. CONCLUSION

From the experimental program, specimens under pure torsion, the results where:

1- The decrement in ultimate torque is 4.49, 10.08, 13.98% and the increment in twist angle is 11.16, 26.79, 39.69% compared with references beam (S0) when replacement of rubber of 10, 20, 30%, respectively.
2- The torque decrement at first crack was 4.82, 7.82 and 10.18%, when increase in rubber percentage of 10%, 20%, and 30%, respectively, compared with references beam (S0).
3- As rubber was replaced at 0% and 30%, the ultimate torque for non-reinforcement beams decreased by 33.41 and 29.43%, respectively, as compared to reinforced beams.
4- By comparing reinforced and non-reinforced beams, the ultimate twist of the non-reinforced beam decreased by 76.22% for replacement of rubber 30%.
5- The increment in twist angle is 25.43% with the percent replacement of rubber 30% for non-reinforcement beam as compared to control beam (S0P).
6- The ductility index of specimens increased by 13.65, 24.90and 35.54% when coarse aggregate was replaced with 10, 20 and 30% rubber respectively.

7- Increases in rubber replacement ratio from 0 to 30% reduced cracking stiffness by 14.07, 29.13 and 38.42 %, respectively.

4. REFERENCES

1. H. A. Darshan, U. G. Puru V, U. G. Manjunatha R, U. G. Naveen Kumar N V, and U. G. Naveen B M, "An Experimental Study on Rubberized Concrete," ***International Journal of Innovative Research in Science, Engineering and Technology***, Vol. 6, No. 7, (2017), 12543-12550, doi: 10.15680/IJIRSET.2017.0607012.
2. S. M. DUMNE, "An Experimental Study on Performance of Recycled Tyre Rubber-Filled Concrete," ***International Journal of Engineering Research & Technology***, Vol. 2, No. 12, (2013), 766-772, doi: IJERTV2IS120377.
3. James K. White and J. G. Macgregor, *REINFORCED CONCRETE Mechanics and Design*, 6th Editio .(2012).
4. S. A. Alfayez, A. R. Suleiman, and M. L. Nehdi, "Recycling tire rubber in asphalt pavements: State of the art," ***Sustainability*** *(Switzerland)*, Vol. 12, No. 21, (2020), 1-15, doi: 10.3390/su12219076.
5. M. A. Aiello and F. Leuzzi, "Waste tyre rubberized concrete: Properties at fresh and hardened state," ***Waste Management***, Vol. 30, No. 8-9, (2010), 1696-1704, doi: 10.1016/j.wasman.2010.02.005.
6. K. Gunasekaran, R. Ramasubramani, R. Annadurai, and S. Prakash Chandar, "Study on reinforced lightweight coconut shell concrete beam behavior under torsion," ***Materials and Design***, Vol. 57, (2014), 374-382, doi: 10.1016/j.matdes.2013.12.058.
7. S. K. Mohaisen, A. A. Abdulhameed, and M. M. Kharnoob, "Behavior of Reinforced Concrete Continuous Beams under Pure Torsion," ***Journal of Engineering***, Vol. 22, No. 12, (2016), 1-15,
8. M. M. A. Siddiqui, "Study of Rubber Aggregates in Concrete an Experimental Investigation," ***International Journal of Latest Research in Engineering and Technology***, Vol. 02, No. 12, (2016), 36-57, [Online]. Available: http://www.iaeme.com/MasterAdmin/UploadFolder/STUDY OF RUBBER AGGREGATES.pdf.
9. A. Abdulameer and H. M. K. Al-mutairee, "An Experimental Study on Behavior of Sustainable Rubberized Concrete Mixes," ***Civil Engineering Journal***, Vol. 6, No. 7, (2020), 1273-1285, doi: http://dx.doi.org/10.28991/cej-2020-03091547.
10. F. N. Sahib and H. M. K. Al-mutairee, "Punching strength behavior of reinforced concrete slabs with chips waste tire rubber," ***Periodicals of Engineering and Natural Sciences***, Vol. 8, No. 4, (2020), 2389-2404, doi: DOI: http://dx.doi.org/10.21533/pen.v8i4.1735.
11. A. Abdulameer Kadhim and H. Mohammed Kadhim, "Experimental Investigation of Rubberized Reinforced Concrete Continuous Deep Beams," ***Journal of King Saud University - Engineering Sciences***, Vol. 33, No. 4, (2021), 1-11, doi: 10.1016/j.jksues.2021.03.001.
12. A. A. Kadhim and H. M. Kadhim, "Loading Capacity Prediction of Rubberized Reinforced Concrete Continuous Deep Beams," IOP Conference Series: Materials Science and Engineering, Vol. 1090, No. 1, (2021), 012031, doi: 10.1088/1757-899x/1090/1/012031.
13. H. M. K. Al-Mutairee and O. M. Makki, "Rubberized concrete mix - discussions for literature review," Journal of Physics: Conference Series, Vol. 1895, No. 1, (2021), 012011, doi: 10.1088/1742-6596/1895/1/012011.
14. K. Gunasekaran and S. Choudhury, "Experimental Study on Single Bay Reinforced Coconut Shell Concrete Portal Frame under Lateral and Cyclic Load," ***International Journal of Engineering, Transactions B: Applications***, Vol. 34, No. 08, (2021), 1905-1912, doi: 10.5829/ije.2021.34.08b.12.
15. ACI 318-19, "Building Code Requirements for Structural Concrete and Commentary," American Concrete Institute. p. 628, (2019), doi: 10.14359/51716937.
16. The second modify, Iraqi Specification No.5 -1984, "Portland cement." (2010).
17. Second modify, Iraq Specification No.45/1984, "Natural Sources for Gravel that is used in concrete and construction." Baghdad, (2010).
18. ASTM C494/C494M, "Standard Specification for Chemical Admixtures for Concrete," (2017), doi: 10.1520/C0494_C0494M-17.
19. ASTM A615 / A615M-16, "Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement." ASTM International, West Conshohocken, PA, (2016), doi: 10.1520/A0615_A0615M-16.
20. A. C78/C78M-18, "Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading) 1," ASTM International, Vol. C78-18, No. C, (2018), 1-4, doi: DOI: 10.1520/C0078_C0078M-18. 2.
21. ASTM C496/Ca96M-11, "Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens," ASTM International, (2011), 1-5, doi: 10.1520/C0496_C0496M-11.
22. ASTM C469/469M-14, "Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete," *A*STM International, 2-6, (2014), doi: 10.1520/C0469-C0469M-14.
23. R. Park, "Structural Assemblages from Laboratory Testing," Bulletin of the New Zealand National Society for Earthquake Engineering, vol. 22, No. 3, (1989), 155-166.
24. M. S. Mohsin, N. A. Alwash, and M. M. Kadhum, "Comparative Study on Structural Behavior of Reinforced Concrete Straight Beam and Beams with out Plane Parts," ***International Journal Engineering, Transactions A: Basics***, Vol. 34, No. 10, (2021), 2280-2293, doi: 10.5829/ije.2021.34.10a.09.

Persian Abstract

چکیده

هدف از این مطالعه آزمایش تیرهای بتنی لاستیکی شده در معرض گشتاورهای پیچشی خالص است. این مطالعه بر روی تأثیر جایگزینی جزئی سنگدانه‌های درشت با تراشه‌های لاستیکی ضایعاتی با نسبت‌های مختلف ۱۰٪، ۲۰٪ و ۳۰٪ در حجم بر گشتاور و چرخش نهایی تیرها و همچنین شاخص شکل‌پذیری، سفتی، ترک‌خوردگی متمرکز بود. حالت های گشتاور و خرابی شش نمونه از تیرهای بتنی به همان اندازه (۲۲۵×۲۲۵ میلی متر) آزمایش شده است. همان آرماتور فولادی روی چهار نمونه و دو نمونه بدون آرماتور اعمال شده است. بر اساس یافته‌های تجربی برای نمونه‌های تقویت‌شده، گشتاور نهایی برای تیر کنترل (بدون تعویض) بیشتر از تیرهای با لاستیک جایگزین است اما زاویه پیچش تیرها با لاستیک جایگزین بیشتر از تیر کنترل افزایش یافته است. گشتاور نهایی در مقایسه با پرتو کنترل ٤٫٤٩٪، ۱۰٫۰۸٪، ۱۳٫۹۸٪ کاهش می یابد، در حالی که زاویه پیچ در گشتاور نهایی ۱۱٫۱٦٪، ۲٦٫۷۹٪، ۳۹٫٦۹٪ زمانی که درصد جایگزینی لاستیک ۱۰٪، ۲۰٪، ۳۰٪ است افزایش می یابد. به ترتیب. هنگامی که سنگدانه درشت با لاستیک ۳۰٪ جایگزین شد، شاخص شکل پذیری نمونه ها ۳۹٫۸۳٪ افزایش یافت و سفتی نهایی ترک ۳۸٫٤۲٪ در مقایسه با تیر کنترل کاهش یافت.