Mechanical Properties of Light Weight Polymer Modified Concrete Made with Chopped Rubber Tires

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Abstract:

Lightweight concrete is highly used as loaded and unloaded parts in structures. The low values of compressive strength leads to the production of lightweight concrete blocks that can be used in partitions and the types that have more than 17 MPa and in some structural members that are not highly loaded. This research includes study of mechanical properties of this type of concrete which produced from the waste materials (chopped rubber tires) that are used as a percentage from coarse aggregates by the replacing method. The replacement was as 10%, 20%, 30%, 40% and 50% by weight of coarse aggregates. The mixes were modified by using the styrene butadiene rubber (SBR) to increase the values of the mechanical properties and durability. The aim of this investigation is to product special mixes of concrete with a low density and good mechanical properties to reduce the dead load and more economic construction . This study proof the CRT effect on compressive strength whereas it dropped from 62.5 Mpa to 40.8 Mpa by increase percentage of the CRT from 10% to 50%, but in the same time the density lowered up to 33%. The mixes with 10%, 20%, 30% can be regarded as a structural lightweight concrete (exceeded 17 MPa) and the other mixes can be used for the production of lightweight blocks used in partitions.

Keywords : Lightweight Concrete , Polymer Modified Concrete , Chopped Rubber Tires.

الخلاصة

تستخدم الخرسانة الخفيفة الوزن بشكل واسع في الأجزاء المحملة وغير المحملة للمنشات. تؤدي القيم المنخفضة لمقاومة الانضغاط الى أستخدام الخرسانة الخفيفة الوزن في القواطع والأنواع التي لها مقاومة أنضغاط اكبر من 17 ميكا باسكال كما يمكن أستخدامها في بعض أجزاء المنشات المحملة والتي لا تكون معرضة الى أحمال عالية.هذا البحث يتضمن دراسة الخواص الميكانيكية للخرسانة خفيفة الوزن التي تنتج من فضلات المواد (مفروم الإطارات المطاطية) والتي تستخدم كنسب من الركام الخشن بواسطة الاستبدال. هذا الاستبدال بنسبة 10%، 20% ،30% ، 40% و 50% من وزن الركام الخشن. الخلطات تم تطويرها بأستخدام (SBR) لزيادة قيم الخواص الميكانيكية والديمومة. أن الهدف من الدراسة هو لأنتاج خلطات خاصة من الخرسانة بكثافة قليلة وخواص ميكانيكية جيدة لتقليل الاحمال ولتكون أكثر اقتصادية. برهنت الدراسة على تأثير مفروم الأطارات المطاطية على مقاومة الأنضغاط حيث تنخفض مقاومة الانضغاط من 62.23 ميكا باسكال الى 40.89 ميكا باسكال بزيادة نسبة مفروم الإطارات المطاطية من 10%الى 50%،ولكن في نفس الوقت تنخفض الكثافة الى 33%. الخلطات ذات النسب 10% ، 20 و30% يمكن أعتبارها كمنشات خفيفة الوزن (مقاومة الانضغاط أكبر من 17 ميكا باسكال) والخلطات الأخرى يمكن أستخدامها في أنتاج خرسانة خفيفة الوزن تستخدم كقواطع.

الكلمات المفتاحية: الخرسانة خفيفة الوزن، الخرسانة المعدلة بالبوليمر، مفروم الإطارات المطاطية

Introduction :

The design of the economic concrete structures needs not only an economic design but also an economic materials, Millions of waste tires burned or put underground and caused environmental pollution in several industrial countries such as USA and UK **(Segre and Joekes, 2000)**. The same thing happened in Iraq. So the used of chopped tires in concrete gives benefit for less cost in the concrete production and less environmental pollution due to the burning of these chopped tires. The use of the chopped tires rubber in concrete with some admixtures leads to special lightweight concrete. Some of these types can be used as a structural lightweight (SLWC). The (SLWC) can be defined as the concrete has which a low density (less than 2200 kg/m^3) and a compressive strength exceeds 17 MPa **(National Ready Mixed Concrete Association, 2003)**. The low strength lightweight concrete is used as concrete blocks and partitions. Another benefits of using chopped tires rubber lightweight concrete can be summarized by their isolating properties, high impact strength, more durability, low cost of construction because of the lower dead loads and the less environmental pollution due to burned tires.

Experimental program:

The experimental program includes casting cubes, cylinders, short beams for testing the flexural strength. The program uses rich mixes as reference mixes with mixing proportions of (1 : 1.4: 2.4) and low w/c ratio of 0.3 for all the mixes to increase strength.

Materials and specimens :

The total specimens used in this study were 90 specimens including 18 beams for the flexural tests, 36 cubes for the compressive test, 18 small cylinders for the splitting tensile test and 18 large cylinders for the testing stress-strain relationship to find the modulus of elasticity. Table (1) shows the use of the maximum size aggregate of 10mm as coarse aggregates, and the grading method. Table (2) illustrates the sand confirming zone 3, and ordinary Portland cement, sky structural glenium (super plasticizer) used in mixes to reduce w/c ratio used in all mixes. The styrene butadiene rubber (SBR) is used as 10 % of cement weight to increase the strength and the durability (Radomir and Vlastimir, 1998). Compressive strength test had been done by using 100 mm*100 mm*100 mm steel cubes. Three cubes for each mix were used for this test and the average value was taken. Tensile strength test was done by 100 mm*200 mm cylindrical steel moulds for testing splitting tensile strength by using equation (1). Three cylinders for each mix were used. Stress-Strain behavior was done by 150 mm*300 mm cylinders with mechanical strain gauges as it is shown in Figure (2). ELE testing machine for a compressive and a flexural strength test was used in the tests. Figure (1) shows the specimen under loading for compressive and flexural tests. The flexural strength test was done by using 100 mm*100 mm*400 mm beams, and a third point loading test was used for all specimens as it is indicated by equation (2).

$Ft = 2p / \pi DL$ --(1)

Where

Ft : is the maximum splitting tensile strength (MPa).

P : is the maximum force from machine (Newtons).

D : is the diameter of cylinder (100 mm).

L : is the height of cylinder (200 mm).

$F_b = PL / (bd^2)$ --(2)

Where :

F_b : is the maximum flexural strength (MPa).

P : is the maximum force from machine (Newtons).

b : is the width of beam (mm).

d: is the total depth of beam (mm).

L: is the length of beam between supports (mm).

The modulus of elasticity was done according to ASTM – C-469 specifications (ASTM Committee, 1981). The modulus of elasticity was calculated from equation (3).

$Ec = (\sigma 2 - \sigma 1) / (\varepsilon_2 - \varepsilon_1)$ --(3)

Where :

Ec : is the chord modulus of elasticity (MPa).

Ơ2 : is the stress corresponding to 0.4 maximum compressive strength of concrete specimen(MPa).
Ơ1 : is the stress corresponding to strain of 0.00005 (MPa).
ε_2 : is the strain corresponding to Ơ2.
ε_1 : is the strain of the value equal to 0.00005.

The chopped tires rubber used in this study had a density of 450 kg/m^3 with sieve analysis as it is shown in **table (3)** .

Casting And Curing :

After mixing the materials, the vibrator table machine is used to compact the concrete. the specimens are left in moulds for two days (48 hrs). The specimens then cured in water for 26 days, then they are tested at the age of 28 days. **Figure 2** shows the specimen of beams under the test of flexural strength .

Table 1 : Sieve Analysis of Coarse Aggregates According to B.S. 882.

Sieve size	% passing by weight	B.S. 882 Specification
20mm	100 %	100%
10 mm	95.4 %	85 % – 100 %
5 mm	14.6 %	0.0 % - 25 %
2.36 mm	1.8 %	0.0 – 5 %

Table 2 : Sieve Analysis of Fine Aggregates According to B.S. 882.

Sieve size	% passing	Zone 1 specification	Zone 2 specification	Zone 3 specification	Zone 4 specification
10 mm	100	100%	100%	100%	100%
5 mm	100	90-100	90- 100	90-100	95- 100
2.36 mm	95.1	60- 95	75 - 100	85- 100	95-100
1.18 mm	84.6	30- 70	55- 90	75- 100	90 – 100
600 micron	77.3	15- 34	35- 59	60 -79	80 -100
300 micron	38.8	5- 20	8- 30	12- 40	15 -50
150 micron	7.8	0 - 10	0 - 10	0 - 10	0 – 15

Table 3 : Sieve Analysis for CTR (Chopped Tires Rubber).

Sieve size (mm)	% passing by weight
10 mm	100 %
5 mm	23.9 %
2.36 mm	4.8 %
1.18 mm	0.0 %

Results and Discussion :

Table 4 shows the compressive, tensile, flexural, density and modulus of elasticity test. The figures 3 to 8 show stress-strain behavior of mixes. The compressive strength of the reference mix has the value of 62.23 MPa. This value decreases to 40.89 MPa by using 10% replacement of coarse aggregates with (CTR), and it has less density and it can be used as a structural concrete because of the high value of the compressive strength. The modulus of elasticity also decreases from 38520 MPa to 31000 MPa but also remain a high value as compared with the ordinary concrete that has values ranged from 20000 to 25000 MPa **(Neville ,1995)**. This type of mixes with 10% CTR can be used in loaded structural members. The decreases in mechanical properties values by using CTR can be attributed to the formation of some voids inside the concrete and that leads to less density. The lower density causes to low values of compressive strength **(Jumaa, 2011)**. Adding 20% of CTR, gives 29.4 MPa compressive strength and a less density of 1997 kg/m^3 and the concrete has more than 20000MPa for modulus of elasticity. The replacement 30% from coarse aggregate by CTR , the compressive strength became 22.89 MPa. With using 40% CTR and 50% CTR, the compressive strength dropped under 17 MPa and these mixtures cannot be used as structural lightweight concrete. The tensile strength also decreases by the increase of the percentages of CTR and also of the values of flexural strength .The action of styrene butadiene rubber in concrete is very significant. **Table 5** shows the values of the compressive strength for this type of concrete without using SBR admixture. The use of SBR in reference mix increases the value of the compressive strength from 53.13 to 62 .23 Mpa. The increment here is about 17 %. As for other mixes, the clear increment in compressive strength by using the SBR, and that attributed to forming polymer films inside concrete structure and there SBR films bond with external silica of aggregates and bond with Ca ions liberate from hydration of cement , all of these bonds gives additional strength and low microcracks during loadings **(Ohama,2003 ; Sujjavnith and Lundy, 1998).**

Conclusions :

The results of tests show that the use of CTR leads to the production of a lightweight concrete with good properties. The values of compressive, tensile, flexural, and modulus of elasticity were decreased by increasing the percentages of CTR. The increase of CTR by 30% gives good results in term of the mechanical properties of the lightweight polymer concrete and it can be used in structural members. The compressive strength became under the limits of the structural lightweight concrete properties when CRT increases by about 40% and 50%. The use of styrene butadiene rubber improves the compressive strength and the properties of concrete. Mixes without SBR gives lower values of compressive strength of the lightweight concrete. Hence, the use of SBR gives an additional strength in the mechanical properties due to its action to reduce microcracks and bonds with silica surface of aggregates and also bonds with some of liberated compounds during hydration of cement.

Table 4 : Mechanical Properties of CTR Light Weight Polymer Concrete and Densities .

Mix type	Compressive strength MPa	Tensile strength MPa	Flexural strength MPa	Modulus of elasticity MPa	Density kg/m^3
Reference mix 1:1.4: 2.4 480:672:1152 w/c=0.3	62.23	4.88	8.34	38520	2450
1:1.4:2.4 with 10% replacement of aggregates with crushed tires rubber	40.89	3.39	5.17	31000	2218

1:1.4:2.4 with 20% replacement of aggregates with crushed tires rubber	29.40	2.95	3.39	22300	1997
1:1.4:2.4 with 30% replacement of aggregates with crushed tires rubber	22.89	2.31	2.85	21100	1784
1:1.4:2.4 with 40% replacement of aggregates with crushed tires rubber	16.58	1.96	2.34	14500	1588
1:1.4:2.4 with 50% replacement of aggregates with crushed tires rubber	11.44	1.55	1.87	11050	1368

Table 5 : Compressive Strength of Mixes without Using SBR Admixture

Mix type	Compressive strength (MPa)
1:1.4:2.4 without SBR and CTR	53.13
1:1.4:2.4 without SBR and with 10% CTR	33.38
1:1.4:2.4 without SBR and with 20% CTR	21.19
1:1.4:2.4 without SBR and with 30% CTR	15.87
1:1.4:2.4 without SBR and with 40% CTR	10.62
1:1.4:2.4 without SBR and with 50% CTR	6.46

Figure (1):Compressive and Flexural Strength Tests

Figure (2) : Testing Specimens for Stress- Strain Behavior

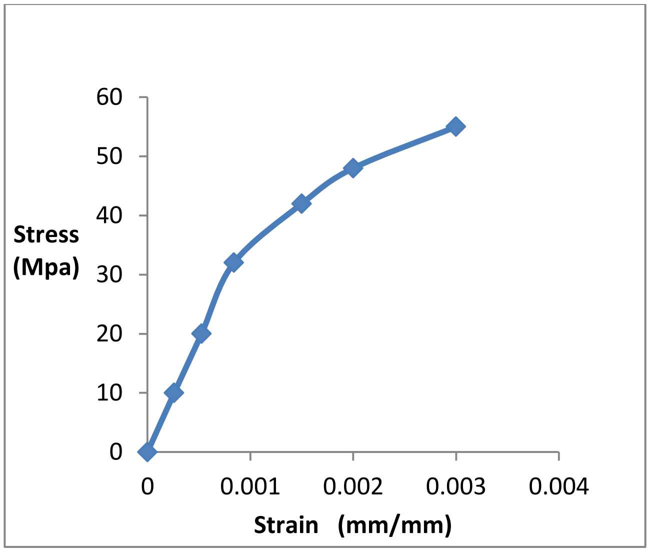

Figure (3): Stress – Strain behavior for Polymer Concrete Reference mix (1:1.4:2.4) , E=38520MPa, fcyl=55.6 MPa.

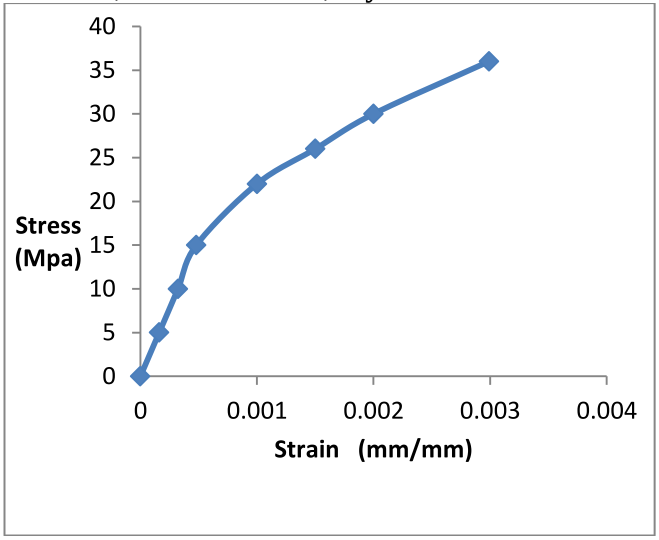

Figure (4): Stress – Strain Behavior for Polymer Concrete (1:1.4:2.4) with 10% CTR, E =31000 MPa , fcyl= 36.5MPa

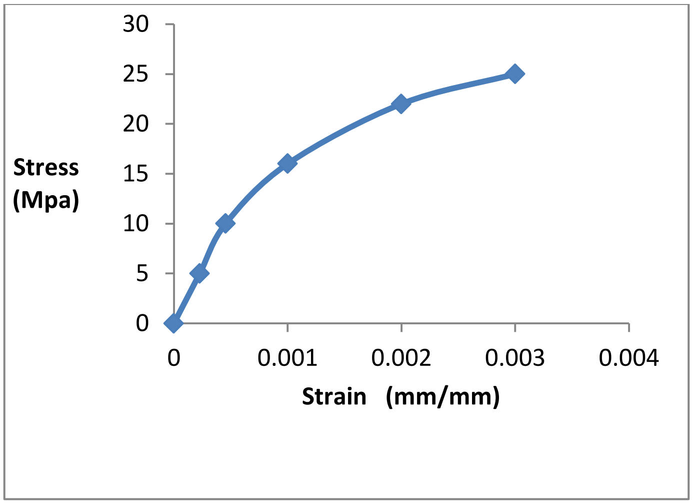

Figure (5): Stress – Strain Behavior for Polymer Concrete (1:1.4:2.4) with 20% CTR, E =22300 MPa , fcyl= 26.3MPa

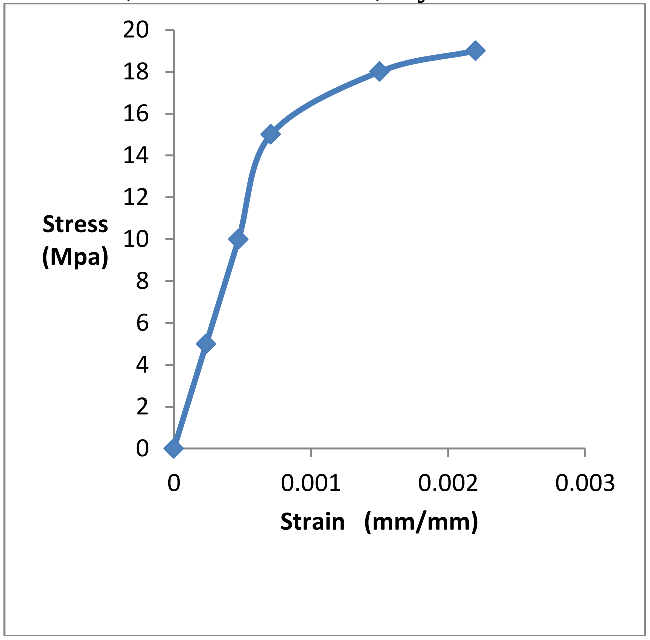

Figure (6): Stress – Strain Behavior for Polymer Concrete (1:1.4:2.4) with 30% CTR, E =21100 MPa , fcyl= 18.53MPa

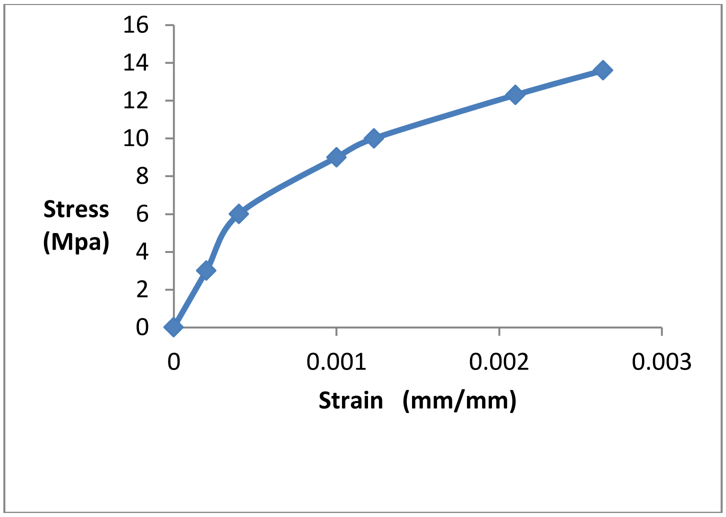

Figure (7): Stress – Strain Behavior for Polymer Concrete (1:1.4:2.4) with 40% CTR, E =14500 MPa , fcyl= 13.8 MPa

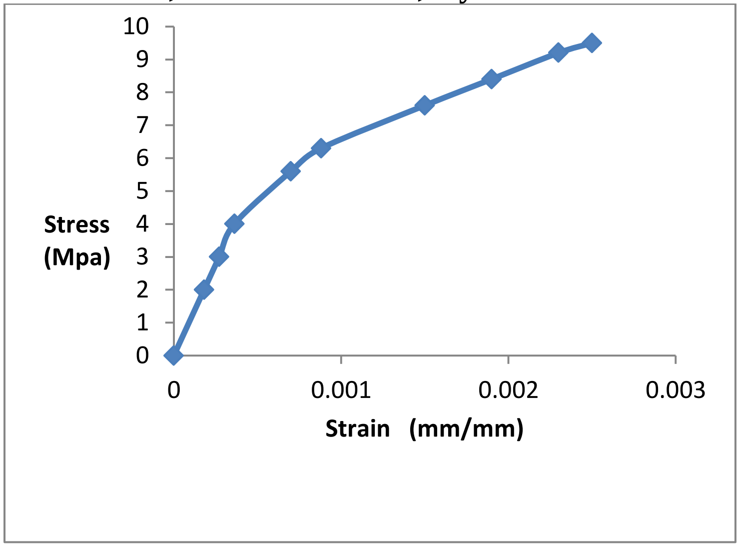

Figure (8): Stress – Strain Behavior for Polymer Concrete (1:1.4:2.4) with 50% CTR, E =11050 MPa , fcyl= 9.71 MPa

References

ASTM Committee, 1981, " Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression" C-469.

Jumaa,I,2011 "Influence Of Chopped Rubber Tires On Some of The Concrete Properties ", Technology Institute ,Baghdad .

National Ready Mixed Concrete Association , 2003 ," Structural Lightweight Concrete , Concrete in practice ",WWW. Nrmca.org.

Neville, A., 1995 "Properties of Concrete", 4th and Final Ed., London.

Ohama, Y.,2003 " Study on Properties and Mix Proportioning of Polymer-Modified Mortars for Buildings". Report of the Building Research Institute, NO. 65 100-104.

Radomir , J. and Vlastimir, S.,1998"Experimental Research on Polymer Modified Concrete ", ACI Mat.Journal.,463-469.

Segre, N. and Joekes, I., 2000; "Use of Tire Rubber Particles as Addition to Cement Paste", Cement and Concrete Research, Volume 30, Issue 9.

Sujjavnith, S.and Lundy,J.,1998" Development of Strength and Fracture Properties of Styrene – Butadiene Copolymer Latex – Modified concrete ", ACI Journal, No.95-M13:131-143.