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Experimental Characteristics of Rubberized Concrete

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Crumb rubber, Rubberized concrete, Brittle Failure, Ductility, Optimum concrete mix.

Abstract

One of the construction industry's main interests is using innovative materials to facilitate construction, extend service life, and minimize maintenance and rehabilitation costs. Recycling waste tire rubbers into conventional concrete materials constitutes one of the biggest and challenging issues in modern concrete technology, which can significantly relieve critical environmental issues. However, the compressive strength reduction caused by the added rubber aggregates, albeit with significant ductility enhancement, has limited its application in concrete structures. The present study aimed at attaining the optimum ratio of crumb rubber with minimal reduction in compressive strength to be used in large scale elements in which the ductility constitutes a critical design parameter. Different rubberized concrete mixes with different percentages of crumb rubber (CR) and different treatment were investigated. The main parameters were the type of crumb rubber (course or fine), the percentage of replacement (5%, 10%, 20%, and 30%), the treatment conditions (treated with NAOH, or without treatment), and using silica fume as partial replacement of cement. The test data were analyzed considering the workability, the compressive, tensile, and flexural strengths. The results revealed that the most appropriate concrete mix is using a 20% treated fine crumb rubber, with silica fume incorporation.

1. Introduction

With the rapid development of the worldwide automobile industry, the production of tires has increased enormously in recent decades. Tremendous stockpiles of waste tires are being generated annually. One of the most common waste tires disposal methods is landfilling. This in turn constitutes prominent environmental, health and aesthetic problems since, when waste tires occupy large landfill spaces, it becomes a nest for insects and rats [1-3]. Furthermore, the waste tire could become a fire hazard because of its flammability. One viable solution to override the waste tire induced problems is its use as partial replacement of aggregate in concrete production and road pavements [4-10]. These solutions can pave the way for constructing eco-friendly buildings and encourage the concept of sustainable production.

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Extensive studies have been conducted in the early 1990s to explore the effect of aggregate replacement with waste tire rubber on different physical, and mechanical properties of concrete to validate their using in concrete structures. Compared to conventional concrete, rubberized concrete has some advantages such as higher toughness, ductility, better sound insulation, lower density, and resistance against cracking [11-17]. However, as reported by different research groups around the world, replacing aggregate with waste tyre rubber associated with significant reduction in compressive strength, tensile strength, flexural strength, and modulus of elasticity [18-23]. The strength reduction is attributed to the low stiffness of rubber and incompatibility between rubber and cement paste. Many investigations have been conducted to overcome or even mitigate the strength reduction. Some research groups suggested pretreatment of rubber with sodium hydroxide solution or using cement coating to enhance the bond strength between rubber and cement paste [24-26]. However, the investigations are still early in developing a specific solution for the problem. Furthermore, there is a lack of data available regarding the performance of full-scale rubberized concrete elements, especially structural elements that are suffering from brittle failure and in need of ductility. The experimental study reported here is part of an ongoing comprehensive research program that aimed at attaining the optimum ratio of crumb rubber ratio with minimal reduction in strength to be used in large scale columns and deep beams. The present paper reports the results of the first stage of developing optimum rubberized concrete considering the fresh and hardened concrete properties.

2. Experimental Program

The experimental program included testing twenty-five concrete mixes. Thirteen concrete mixes were reported by Arafa et al. [27] and were used as a reference in the present paper. One concrete mixture was used as a control mix without aggregate replacement, while for the other specimens crumb rubber was used. The variables involved the following points:

1. Type of crumb rubber (coarse and fine rubber as partial replacement for coarse, and fine aggregate, respectively)
2. The replacement ratio (5%, 10%, 20% and 30% by volume of sand or gravel wherever it is applicable)
3. The pre-treatment with NAOH
4. The use of silica fume as a partial replacement of cement (33% of the cement weight)

For ease of referencing, the concrete mixes are identified by the concrete mix type (R for refence specimen, G, and S for the concrete mixes in which the gravel, and the sand was replaced by crumb rubber, respectively) followed with the replacement ratio. This was followed by two letters; T for treated crumb rubber and S for concrete mix in which a portion of cement was replaced with silica fume, if any. The concrete mix proportions of each batch of tested concrete mix are shown in **Table1**. It should be mentioned that the used silica fume quantity was selected such that the mix record similar slump compared with its reference without silica fume in the same group. This has been achieved after testing different silica fume quantities from which the reported quantity in the paper was concluded.

Table 1: Concrete mixes proportions of each batch of concrete, kg/m^3

Mix. No.	Mix designation	Mix proportions (kg/m^3)					
		Cement	Silica fume	Coarse aggregate	Fine aggregate	Rubber	Sp
1	MR-0CR	400	-------	1127	624	---------	9.5
2	MG-5CR	400	-------	1070	624	18.7	9.5
3	MG-10CR	400	-------	1014	624	37.4	9.5
4	MG-20CR	400	-------	901	624	74.8	9.5
5	MG-30CR	400	-------	788	624	112.2	9.5
6	MG-5CR-T	400	-------	1070	624	18.7	9.5
7	MG-10CR-T	400	-------	1014	624	37.4	9.5
8	MG-20CR-T	400	-------	901	624	74.8	9.5
9	MG-30CR-T	400	-------	788	624	112.2	9.5
10	MG -5 CR- TS	300	100	1070	624	18.7	9.5
11	MG -10 CR- TS	300	100	1014	624	37.4	9.5
12	MG -20 CR- TS	300	100	901	624	74.8	9.5
13	MG -30 CR- TS	300	100	788	624	112.2	9.5
14	MS-5CR	400	-------	1127	592.8	10.36	9.5
15	MS-10CR	400	-------	1127	561.6	20.72	9.5
16	MS-20CR	400	-------	1127	499.2	41.43	9.5
17	MS-30CR	400	-------	1127	436.8	62.15	9.5
18	MS-5CR-T	400	-------	1127	592.8	10.36	9.5
19	MS-10CR-T	400	-------	1127	561.6	20.72	9.5
20	MS-20CR-T	400	-------	1127	499.2	41.43	9.5
21	MS-30CR-T	400	-------	1127	436.8	62.15	9.5
22	MS -5 CR- TS	300	100	1127	592.8	10.36	9.5
23	MS -10 CR- TS	300	100	1127	561.6	20.72	9.5
24	MS -20 CR- TS	300	100	1127	499.2	41.43	9.5
25	MS -30 CR- TS	300	100	1127	436.8	62.15	9.5

Sp: Superplasticizer dosage,

2.1. Material Properties

Aggregates: Locally available aggregates were used in our study that included two types of sand and crushed gravel. The physical and chemical properties of the used aggregates agreed with ECP 203 requirements [28]. River sand was used as fine aggregate. The coarse aggregate used was natural gravel with a maximum aggregate size of 10 mm. **Table 2** lists the physical properties of the used aggregates.

Table 2: Physical properties of the used aggregates

	Specific gravity	Volume weight (t/m³)	Specific surface area (cm²/gm)	Fineness modulus	Crushing value (%)	Maximum Nominal size (mm)
Sand	2.5	1.68	43.82	2.88	-------	----------
Gravel	2.5	1.58	1.94	6.95	18.2	10

Cement: Portland cement of grade 32 N, used in construction works, was used. The mechanical and physical properties met the requirements of ECP 203 [28] as shown in **Table 3**, and **Table 4**. The used Silica fume had a specific gravity of 2.0. Its chemical composition and physical properties met the requirements of ASTM C1240-03a [29].

Table 3: Physical properties of Portland cement

	Average Results	Egyptian Specifications [28]
Mgo	1.4	
SO3	2.75	Not more than 3.5%
Loss of ignition	2.5	Not more than 5%
Insoluble residues	5.5	Not more than 5%
Chlorides Contents	0.03	Not more than 0.10%
Clinker Contents		
C3S	52.5	
C2S	22.5	
C3A	6.5	
C4 AF	12	
Lime Saturation Factor	0.93	

Table 4: Physical properties of Portland cement

	Average Results	Egyptian Specifications [28]
Surface area cm^2/gm (Blaine Method)	3200	N.R.
Setting time Initial setting time	150	Not less than 75 min.
Soundness (Le Chatellee)	0.5	Not more than 10 mm
Compression Strength N/mm^2		
After 2 days	17	N.R.
After 7 days	25.5	Not less than 16 N/mm^2
After 28 days	36	Not less than 32.5 N/mm^2

Silica fume: Silica fume was used as supplementary cementitious material (SCM) with specific gravity of 2.0. Its chemical composition and physical properties met the requirements of ASTM C1240-03a [29].

Crumb Rubber: A crumb rubber aggregate (with no steel wires) having a maximum size of 4.65 mm, and 10 mm with a specific gravity of 0.83 and a negligible absorption was used as a partial replacement of the fine, and coarse aggregate in the tested concrete mixes, respectively. **Fig. 1** shows the used crumb rubber.

(a) (b)

Fig.1: The used crumb rubber (a) fine crumb rubber, (b) coarse crumb rubber

Superplasticizer: A superplasticizer called Sikament -NN (Produced by Sika company) was used to overcome the workability-induced problems.

2.2. Pre-Treatment of Rubber

The necessity of pre-treatment of the rubber particles for having effective concrete is well documented in the literature [10-20]. The most common used method is using a Sodium Hydroxide (NaOH) solution to enhance the adhesion between the cement and the rubber [24-25]. The laboratory results demonstrated that the pre-treatment of rubber using a NaOH solution should be implemented within 30 minutes. Pre-treatment for longer period associated with negative effect on concrete mechanical properties. This observation was carefully considered in our study; the used crumb rubber was immersed in a 10% NaOH solution for 30 minutes only. The rubber was then washed vigorously and continuously to remove the NaOH. This was done until the rubber pH returned to 7, which was measured using a pH meter. After draining, the rubber was allowed to air dry in trays lined with paper towels. **Fig. 2** shows the steps of the rubber pre-treatment process.

(a) (b) (c) (d)

Fig. 2: Steps of rubber particles pre-treatment: (a) adding rubber to NaOH solution, (b) submerging rubber during the treatment period, (c), vigorously washing the treated rubber, and (d) spreading rubber to air dry.

2.3. Mixing Procedure and Casting

In mixing the concrete recipes, an electrical rotational drum mixer was used. Both coarse and fine aggregates, including crumb rubber, if any, were first mixed for three minutes. The binders (cement and fly ash) were then added and mixed for two minutes. This was followed with adding the half of the water quantity and mixed for two minutes. The super plasticizer was properly blended with the rest of the water and added to the concrete mix for three minutes of mixing. **Fig. 3** shows the concrete mixing process.

Fig. 3: Mixing procedure

3. Test Methods and results

3.1. Workability

As reported by many investigations [29-32], the rubberized concrete has a lower workability compared to normal concrete. This is due to the higher water absorption ability of crumb rubber in comparison to the normal aggregates. Furthermore, the crumb rubber is usually having higher service area than the normal aggregate and non-uniform shapes that in turn consumes large amount of water. This is the main reasons that make the workability of rubberized concrete mixes constitutes a big problem in their design. To mitigate the effect of this problem, using a super plasticizer would be the most appropriate tool. By doing so, many routes have been taken to control the concrete mixes in attaining the maximum superplasticizer dosage such that the concrete has no segregation or strength reduction. It was found that using 2.25% of the cement weight had the best results. Accordingly, this dosage was used for all test concrete mixes. The workability was measured following the most common slump cone test. **Fig. 4** shows a sample under test.

Fig. 4: Slump test

The measured slumps for different concrete mixes were plotted in **Fig. 5**. Using crumb rubber as partial replacement for gravel caused a reduction in the slump ranging between 25% and 75%. The reduction was alleviated in the case of sand replacement as the reduction was in the range of 6% to 70%. This is attributed to the lower weight of sand relative to gravel. The difference in slump appears to be similar at replacement ratio of 30%, regardless the replacement type (see **Fig. 5**). This indicates that this replacement level is very critical concerning the concrete workability.

The pre-treatment seems to have no effect on the workability since similar slump was measured for the pre-treated or un-treated specimens. Cement replacement with silica fume has a slight workability enhancement. Within the range of the tested replacement ratio, using a 10%

replacement of gravel or 20% replacement of sand showed a slump of 9 cm that would be suitable in beams and columns according to code specification. Concrete with higher replacement ratio would be suitable in roads pavement.

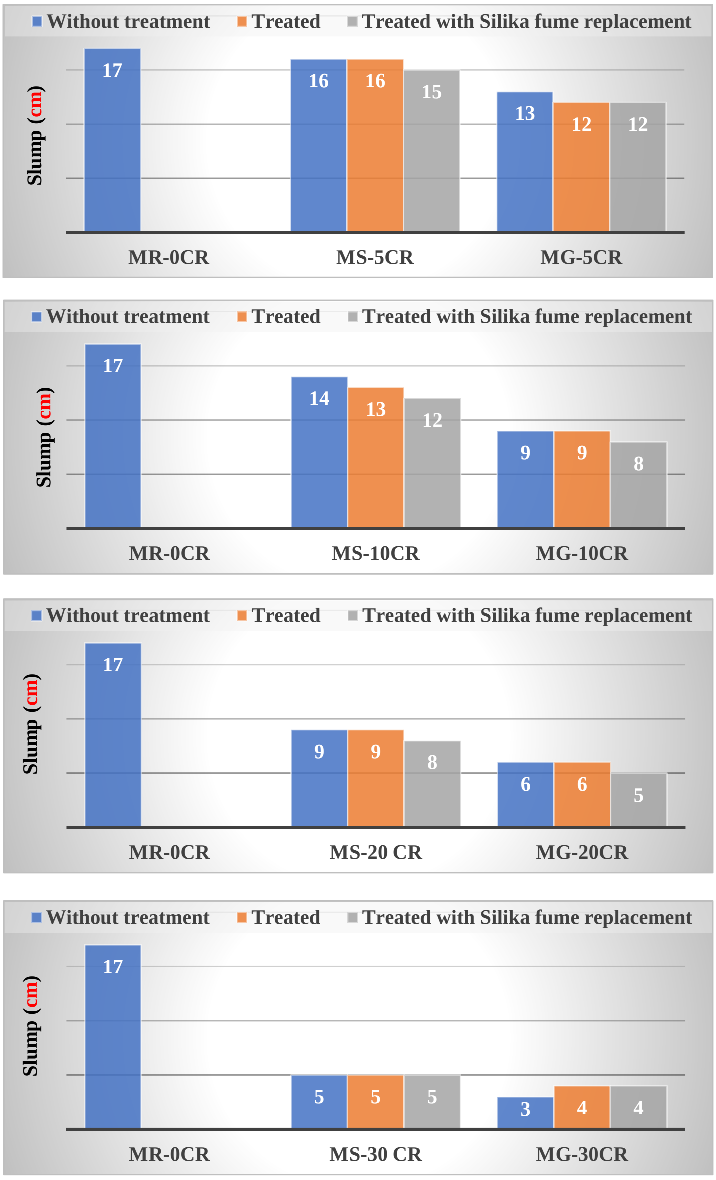

Fig. 5: Measured slump for test specimens

3.2. Unit Weight

The unit weight of the concrete is critical index in the structure design. As much as we could reduce the concrete weight the much lower needed reinforcement, accordingly an economic design can be achieved. In this context, using rubber as partial replacement can be a viable tool in reducing the concrete weight. This is attributed to two main reasons; (1) the specific gravity of the rubber is much lower than the specific gravity of the aggregate (0.83 compared with 2.5, respectively), (2) The low adhesion between rubber and cement paste in concrete which make rubber act as a void in the concrete matrix that increases its porosity, thereby resulting in a low unit weight. In the present study, the reduction in the unit weight ranged between 5% to 22% as function of the type and replacement ratio as shown in **Fig. 6**. Specimens with gravel replacement showed the lowest reduction in the unit weight. Overall, using rubber as partial replacement would be beneficial in term of reducing the weight of structure.

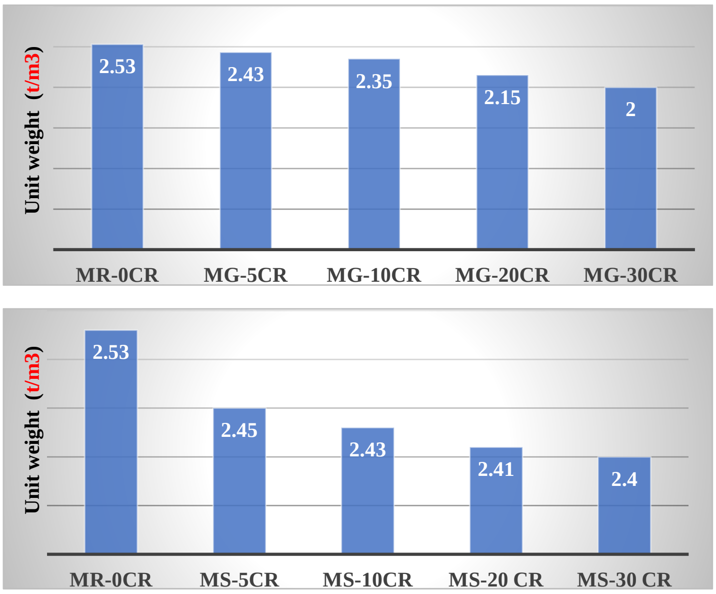

Fig. 6: Calculated unit weight for the test specimens

3.3. Compressive Strength

There is an agreement between amongst research groups that the rubberized concrete is suffering from compressive strength reduction induced problems. The compressive strength of concrete is correlated with three parameters: (1) the voids ratio, (2) the bond between the concrete materials and (3) the compressive strength of the material itself. In case of using rubber, the non-polar nature of the crumb rubber creates voids in concrete. Additionally, the cohesion and the bond strength are weak between the rubber and cement paste. Furthermore, the compressive strength of crumb rubber is much lower than aggregate. All these factors induce a significant reduction in the compressive strength. Therefore, all studies are searching for an effective solution to address this problem. Since the crumb rubber has its inherent characteristics in term of compressive strength, that can't be changed, the focus of this study is therefore to enhance the bond strength and decrease the voids ratio as much as possible. The pre-treatment of the rubber with NAOH was conducted to enhance the bond strength, while silica fume was used to reduce the voids ratio. To see the effect, the compressive strength was measured based on the average results of six cubes of dimensions 150 × 150 × 150 mm from each concrete mix at the age of 28 days (See Figure 7 the specimens under testing). The results are plotted in **Figure 8** for different test specimens. It is clear that the gravel replacement showed the highest reduction in strength relative to their sand replacement counterparts. More specific, the reduction ratios in the compressive strength were respectively 13%, 35%, 58% and 65% corresponding to 5%, 10%, 20% and 30% of coarse aggregate replacement. Meanwhile, the reduction ratios were 7%, 13%, 23%, and 46%, respectively in case of sand replacement. Either rubber pre-treatment or using silica fume as partial replacement for cement noticeably enhanced the compressive strengths, nevertheless, using both appears to have the best results. For example, for gravel replacement, the strength reduction ratios changed to 10%, 29%, 55%, and 58%, respectively for treated rubber, and 6%, 26%, 42%, and 45%, respectively after using silica fume. Similarly, the reduction ratios for sand replacement recorded 7%, 10%, 19%, and 39%, respectively in the former case, while 0.0%, 6%, 13%, and 26%, respectively in the later.

Within the context of the present paper, it is of interest to check the most suitable rubberized concrete with the high replacement ratio, while the strength reduction is minimal. Considering the obtained results in **Fig. 8** for the compressive strengths, it can be found that the aggregate replacement ratio with rubber should not be higher than 10%, 20% in case of gravel, and sand replacement, respectively, with reduction in compressive strength was 21%, and 13%, respectively. A higher replacement ratio would be impractical since it is associated with unacceptable strength reduction. Additionally, it can be inferred that sand replacement would be preferable since it led to comparable strength compared with the normal concrete.

Fig. 7: Compressive strength test

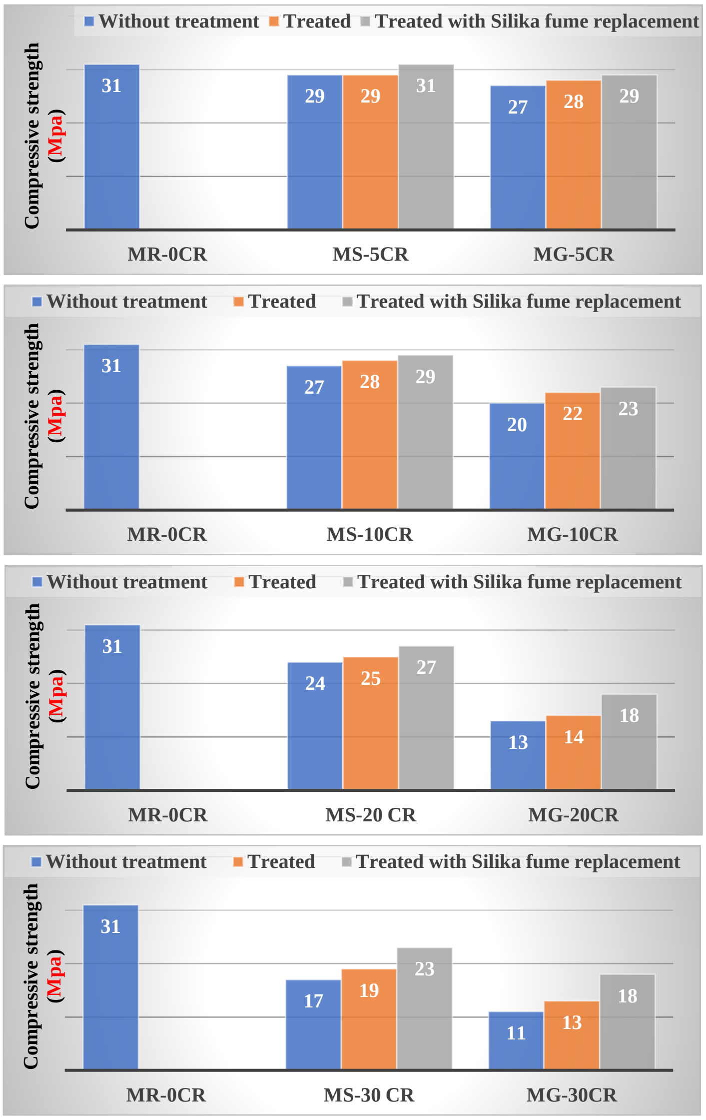

Fig. 8: Measured concrete compressive strengths for test specimens

3.4. Tensile Strength

Tensile strength determined from splitting tensile tests. For each concrete mix, at least six standard cylinders with dimensions of 150 mm diameter × 300 mm height were cast and tested as shown in **Fig. 9**. The following equation was used in splitting tensile strength calculations:

$$f_{sp} = \frac{2P}{\pi d L_1} \quad \textbf{(1)}$$

where f_{sp} is the splitting tensile strength, P is the maximum splitting tensile load, L_1 is the height of cylinder sample, d = diameter of cylinder sample.

Fig. 9: Splitting test

The variation of splitting tensile strength of the test specimens with crumb rubber content, size, treatment, and silica fume addition is shown in **Fig. 10**. Generally, using crumb rubber appears to have drastic effect on the tensile strength; the reduction ranged between 14% - 62% in case of gravel replacement, while ranged between 5% - 40% for sand replacement. The ratio is function of the replacement ratio; the higher the replacement ratio, the higher tensile strength reduction occurred. Many reasons for this phenomenon were previously reported. The surface where crumb rubber and cement paste come in contact acts as a micro-crack, whereas the crumb rubber acts as cavity; therefore, the overall tensile strength of rubberized concrete is lower than that of normal concrete. Weak interfacial transition zone and stress concentration along such zones accelerate failure under tensile stress. This effect, however, diminishes with pre-treatment and silica fume usage, since the reduction ratios shifted to be 1% to 22% in the case of gravel replacement, and 8% to 50% in case of sand replacement. The results in **Fig. 10** also support the finding that most suitable used replacement ratio is 10% replacement of gravel, and 20% replacement of sand: the tensile strength reduction was14%, and 23%, respectively.

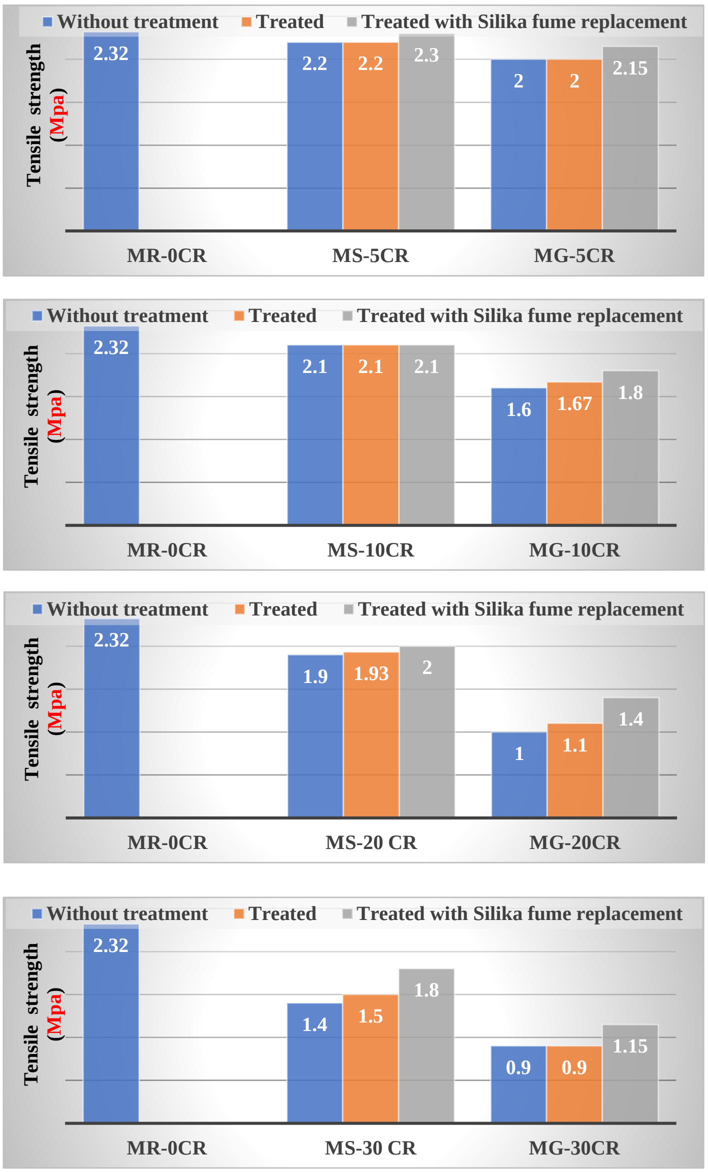

Fig. 10: Measured splitting tensile strengths

3.5. Modulus of Rupture

The flexural tests were conducted with a four-point loading beam scheme as shown in **Fig. 11**. The specimens' dimensions are 150 × 150 × 600 mm.

Fig. 11: Flexural test

The decreasing trend of modulus of rupture of rubberized concrete is nearly similar to the compressive and the splitting tensile strength as shown in **Fig. 12**. The reduction in flexural strength is ranged between 3% - 31% for sand replacement, and between a 9 – 49% for gravel replacement. The results agree with the recommendation that a 20% sand replacement is the most appropriate for rubberized concrete (the reduction in strength was 8% relative to the control specimen), and a 10% replacement is the best for gravel replacement (the reduction in strength was 17% relative to the control specimen).

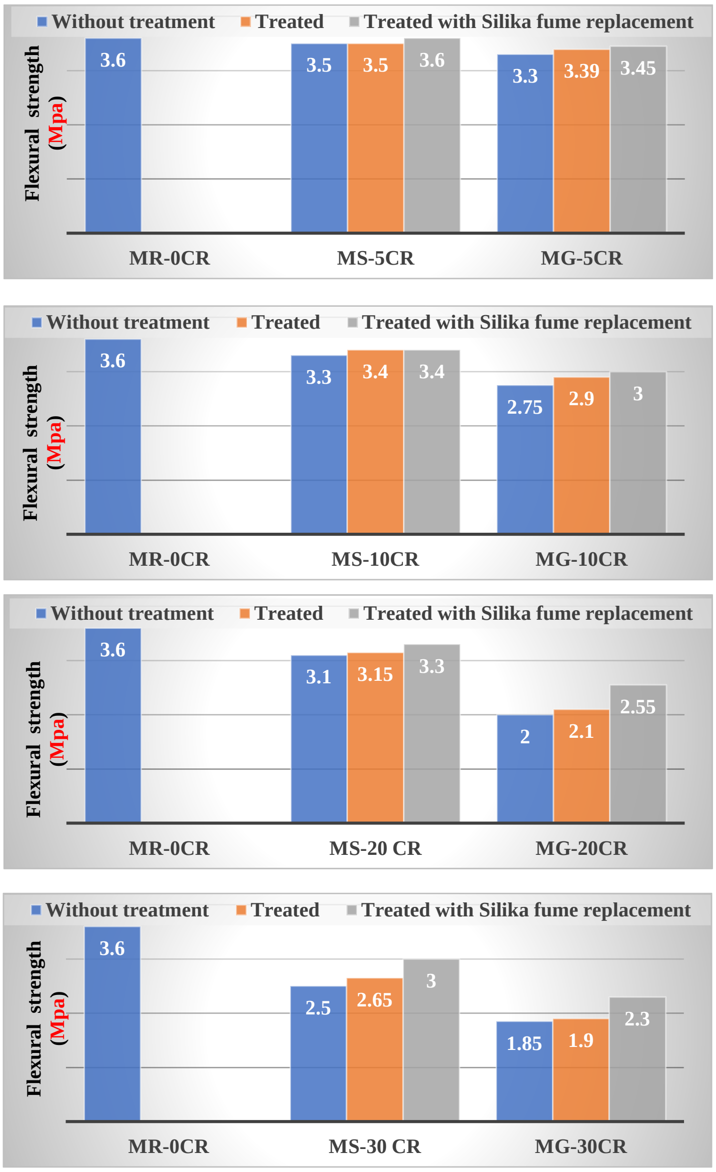

Fig. 12: Measured flexural strengths

4. Conclusions

The disposal of waste tires constitutes a major environmental problem. So, finding a technical economic solution to reuse and utilize waste tires in a sustainable environmentally friendly concrete is currently being tested as a vital solution for the problem. This study represents an investigation of utilizing waste tire rubber to partially replace the natural aggregates in concrete mixes. The study aimed at enriching the literature by reporting the mechanical characteristics of rubberized concrete and proposing the optimum rubberized concrete with minimal strength reduction. Based on the test results and discussions, the following conclusions can be drawn:

1. The addition of rubber in concrete caused significant reduction in the fresh and aged mechanical properties of concrete, and the reduction increases with rubber's size and content.
2. The pre-treatment of rubber in addition to using silica fume is necessary to balance the strength reduction.
3. The replacement ratio of aggregates should be limited to 10% by volume of gravel, and 20% by volume of sand. Using higher values will be associated with unacceptable concrete properties.

Overall, with the tested concrete mixes and variables herein, it can be concluded that using pre-treated 20% fine crumb rubber by volume of sand and silica fume had the best result with insignificant reduction in strengths and it can be recommended as the optimum concrete mix.

Future Research Work: The reported results were obtained from testing of fresh and hardened rubberized concrete and concluded by reporting the optimum rubberized concrete mixture. As result, a laboratory testing is ongoing at Assuit University on the behavior of full-scale deep beams and columns cast with the optimum rubberized concrete. The test results will be a step forward the development of design recommendations for using rubberized concrete in structures. The results of these studies will be reported in subsequent papers.

References

[1] Oikonomou, N., and Mavridou, S. "*The Use of Waste Tyre Rubber in Civil Engineering Works Sustainability of Construction Materials." Wood Head Publishing Limited, Abington Hall, Cambridge,* U. K., 2009.

[2] Dong, Q.B., Huang, and Shu X. "*R*ubber Modified Concrete Improved by Chemically Active Coating And Silane Coupling Agent." *Construction and Building Materials*, Vol. 48, No.116, 116 - 123, 2013.

[3] Huang, B.X., Shu, and Cao, J. "A Two-Staged Surface Treatment to Improve Properties of Rubber Modified Cement Composites." C*onstruction and Building Materials*, Vol. 40, 270 - 274, 2013

[4] Zhang, Z., Ma, H., Qian. "Investigation on Properties of ECC Incorporating Crumb Rubber of Different Sizes.*" Journal of Advanced Concrete Technology*, Vol. 13, 241–251, 2015

[5] Azevedo, F., Pacheco-Torgal, F., Jesus, C., Barroso, de Aguiar J.L., Camões, A.F. "Properties and Durability of HPC with Tyre Rubber Wastes." *Constr. Build. Mater*, Vol. 34, 186-191, 2012.

[6] Pacheco-Torres, R., Cerro-Prada, E., Escolano, F., Varela, F. "Fatigue Performance of Waste Rubber Concrete for Rigid Road Pavements." Journal of Construction Building Material, Vol. 176, 539-548, 2018

[7] Asutkar, P., Shinde, S.B., Patel R. "Study on the behaviour of rubber aggregates concrete beams using analytical approach." J*ournal of Engineering Science Technology*, 151-159, 2017.

[8] Gerges, N.N., Issa, C.A., Fawaz, S.A. "Rubber Concrete: Mechanical and Dynamical Properties.*" Construction Material Journal*, Vol. 9, 2018.

[9] Senin M.S., Shahidan S., Abdullah S.R., Guntor N.A., Leman A.S. "A Review on the Suitability of Rubberized Concrete for Concrete Bridge Decks.*" IOP conference. Ser. Material Sceince Engineering*, Vol. 271, 2017

[10] Grinys, A., Sivilevicˇius H., Daukšys M. "Tyre Rubber additive Effect on Concrete Mixture Strength.", *Journal of Civil Enineering Management*, Vol. 18, 393-401, 2012

[11] Hameed, A.S., Shashikala A.P. "Suitability of Rubber Concrete for Railway Sleepers." *Perspect. Sci*., Vol. 8, 32-35, 2016.

[12] Xiao, F. F., Wenbin Zhao, P.E., Amirkhanian, S.N. "Fatigue Behavior of Rubberized Asphalt Concrete Mixtures Containing Warm Asphalt Additives." *Construction Building Material Journal*, Vol. 23, 2009

[13] Li, D., Zhuge, Y., Gravina, R., Mills, J.E. "Compressive Stress Strain Behavior of Crumb Rubber Concrete (CRC) and Application in Reinforced CRC Slab." *Construction Building Material Journal*, Vol. 166, 745-759, 2018

[14] Moustafa, A., ElGawady, M.A. "Strain Rate Effect on Properties of Rubberized Concrete Confined with Glass Fiber-Reinforced Polymers." *Journal of Composit for Construction*, https://doi.org/10.1061/(ASCE), 2016

[15] Gonen, T. "Freezing-Thawing and Impact Resistance of Concretes Containing Waste Crumb Rubbers." *Construction Building Material Journal*, Vol. 177, 436–442, 2018.

[16] Si, R., Wang, J., Guo, S., Dai, Q., Han, S. "Evaluation of Laboratory Performance of Self-Consolidating Concrete with Recycled Tire Rubber." *Journal of Clean Products*, Vol. 180, 823-831, 2018.
[17] Li, G., S.- Pang, S., Ibekwe, S.I. "FRP Tube Encased Rubberized Concrete Cylinders." *Material Structure Journal*, Vol. 44, https://doi.org/10.1617/s11527-010-9622- 8, 2011.
[18] Thomas, B.S., Chandra Gupta, R. "Properties of High Strength Concrete Containing Scrap Tire Rubber.", *Journal of Clean Products*, Vol. 113, 86–92, 2016.
[19] Najim, K.B., Hall, M.R. "A review of the Fresh/Hardened Properties and Applications for Plain- (PRC) and Self-Compacting Rubberised Concrete (SCRC)." *Construction Bulding Material,* Vol. 24, 2043-2051, 2010.
[20] Pham, T.M., Zhang, X., Elchalakani, M., Karrech, A., Hao, H., Ryan A. "Dynamic Response of Rubberized Concrete Columns with and Without FRP Confinement Subjected to Lateral Impact.", C*onstruction Bulding Material*, Vol. 186, 207-218, 2018
[21] Gesogˇlu, M., Güneyisi, E., Khoshnaw, G., Ipek, S. "Investigating Properties of Pervious Concretes Containing Waste Tire Rubbers." *Construction Bulding Material*, Vol. 63, 206-213, 2014
[22] Topçu, I.B., Demir, A. "Durability of Rubberized Mortar and Concrete." Journal of Material Civil Engineering, Vol. 19, 173-178, 2007.
[23] Topçu.B., Unverdi A. "Scrap Tires/Crumb Rubber." *Waste Suppl. Cem. Mater. Concr.*, 51–77, 2015
[24] Si, R., Guo, S., Dai, Q. "Durability Performance of Rubberized Mortar and Concrete with NAOH-Solution Treated Rubber Particles." *Construction Building Material,* Vol. 153, 496-505, 2017.
[25] Guo, S., Dai, Q., Si, R., Sun, X., C. Lu, "Evaluation of Properties and Performance of Rubber-Modified Concrete for Recycling of Waste Scrap Tire." *Journal of Clean Products*, Vol. 148, 681–689.
[26] Najim, K.B., Hall, M.R. "Crumb Rubber Aggregate Coatings/Pre-Treatments and Their Effects on Interfacial Bonding, Air Entrapment and Fracture Toughness in Self-Compacting Rubberised Concrete (SCRC)" *Material Structures*, Vol. 46, 2029-2043, 2013.
[27] Arafa A., Abdel Elghany N., Farghal O. A., Ahmed A. M. " A step *Towards Developing a* Rubberized *Concrete to be Used in Rc Deep Beams*." *Sohag Engineering Journal (SEJ)*, Vol. 1, NO. 2, DOI: 10.21608/sej.2021.92961.1002, 2021
[28] Housing and Building National Research Center, Egyptian code for Design and Construction the Reinforced Concrete Building (ECP 203-2018). 2018.
[29] ASTM C 1240-03a, Standard Specification for Silica Fume Used in Cementitious Mixtures. 2003.

الخواص المعمليه للخرسانه المضاف إليها مفروم الإطارات المستهلكه

الملخص العربي

يعتبر إستخدام مواد مبتكره والتي من شأنها تسهيل عملية الإنشاء وزيادة عمر المبني مع تقليل الصيانه أحد اهتمامات صناعة البناء الحديثه. في هذا الصدد يعتبر اعادة تدوير الإطارات المستهلكه من خلال فرمها وإضافة ناتج الفرم من مطاط إلي الخرسانه هي أحدي التحديات والتي من شأنها تقليل المشاكل البيئيه المرتبطه بالإطارات المستهلكه. ولكن نتيجه للنقص الشديد في مقاومة الضغط لمثل هذا النوع من الخرسانه ,وإن كان هناك تحسن في خواص الممطوليه, أدي إلي الحد من إستخدامها في المنشئات . لذلك تهدف هذه الدراسه إلي التغلب علي هذه المشكله مع الوصول إلي النسبه المثلي لإضافة المطاط من أجل إستخدامها في العناصر الإنشائيه والتي تمثل الممطوليه تحدي كبير في تصميمها. ولقد شملت الدراسه تأثير ثلاثة متغيرات وهي: ١- نوع الإحلال (إحلال للرمل أو إحلال للزلط) ٢- نسبة الإحلال (٥٪ ,١٠٪, ٢٠٪ , ٣٠٪) ٣- معالجة المطاط بإستخدام هيدروكسيد الصوديوم ٤ – إستخدام سيليكا فيوم كإحلال جزئي للأسمنت. تم تحليل النتائج من خلال تأثير المتغيرات المختلفه علي قابلية التشغيل للخرسانه و مقاومة الضغط والشد والإنحناء. وقد بينت النتائج أن نسبة الإحلال المثلي هي ٢٠٪ من الرمل المستخدم بالحجم مع إستخدام سيليكا فيوم وعمل معالجه بإستخدام هيدروكسيد الصوديوم.