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IMPACT OF RUBBER CRUMB FRACTION AND GRAIN SIZE ON CONCRETE STRENGTH

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ABSTRACT

Rubber Waste is produced largely worldwide every year. Its discharge is challenging to the environment and its decomposition takes long time. Therefore reuse of rubber in concrete mix is plausible. It was added to concrete as coarse aggregate and its different properties like compressive strength and flexural were investigated and compared with ordinary concrete. Results show that rubberized concrete is durable, less ductile, has greater crack resistance but has a low compressive strength when compared with ordinary concrete. This study is evaluating the properties of concrete mix with adding crumb rubber. In this study we focus on compressive and flexural strength of concrete by adding several percentages (1 to 5 %) of crumb rubber replacing cement in the mix. Using crumb rubber in concrete decreases compressive and flexural strength which means that it may not be suitable for rigid pavement. Rubber crumb size has an effect where fine grain rubber seems to minimize loss in concrete mix by 11% per 5 % increase in rubber. However, rubber enhances other properties that may be useful for special uses like noise reduction and water absorption reduction. The loss in compressive strength of rubberized concrete can be compensated by additives like silica.

Keywords: rubber waste, flexural strength, compressive strength ter, concrete, compressive, tensile, flexural, workability.

1. INTRODUCTION

Worldwide, the production of rubber increases every year. Different countries of the world has different rate of producing rubber, for instance United States produces 3.6 million tons of rubber per year [1]. The global rubber production is increasing annually with the increase in number of vehicles in use.

Research shows that scrapped rubber tires contain persistent materials that remain in the environment for long periods. One remedial option is burning, but that would also results in harmful air pollution. A more environmental solution is to incorporate rubber waste in Concrete and Asphalt [1].

Disposal sites of tire waste create environmental hazards like fire, surface water and groundwater pollution, air pollution and undesired aesthetics [2].

Management of rubber waste is challenging because of lack of effective degradation processes [3]. In the case of burning, the rubber waste has been utilized as fuel for the kilns, but the combustion of rubber in the kilns produces harmful emissions [1, 4].

Therefore, rubber can be used in concrete industry such as concrete mix, noise barriers, electricity posts, and asphalt mix [5, 6, 7]. Rubber waste can be added to concrete mix as aggregate replacement and it can modify concrete density to be lightweight, and improve elasticity [7].

Siddique and Naik [8] stated that using rubber waste in concrete mix is promising practice and the size of rubber grains used can affect concrete properties. Compressive strength of the concrete depend on the rubber aggregates size. Another advantage for using rubber waste is reducing rubber waste which reduces disposal cost.

Concrete is a composite man-made material that is the most used material in the construction industry. It consists of a rationally chosen mixture of binding material such as lime or cement, well graded fine and coarse aggregates, water and modifiers. Concrete played a major role in the buildings and roads construction worldwide. Using concrete for roads has advantages over asphalt especially in maintenance and deformation. The concrete pavement is exposed to weather effects which cause damages that require frequent inspection and repair. Therefore, using additives that enhance physical properties are desirable.

Rubber waste can be used as an additive and at the same time it has an environmental value. Rubber waste is generated in large amounts which add costs on municipalities to dispose and treat properly. Previous studies show that the mechanical behavior of the concrete filled with small volumetric fractions of crumbed tire rubber changes favourability for various properties [9].

In the United States alone has about 275 million scrap tires stockpiled across the country, with an annual increase of 290 million tires generated per year. [10]. The number of vehicles in Jordan has increased steadily in the last decade to reach over 2 million cars in 2017 [11].

Recently, many researchers evaluated adding crumb rubber to asphalt with and show increase in the asphalt pavement's resistance of permanent deformations and cracking [12].

In this research we focus on adding rubber to concrete mix. The objective of this study is to investigate the effect of crumb rubber in concrete that used in rigid pavement by calculating compressive and flexural strength.

2. MATERIALS AND METHOD

The crumb rubber is often sieved and separated in categories based on gradation to meet the requirements of a particular use.

Typically there are three classes of rubber waste, there are three main classes based on particle size: Grade A: 10 mesh coarse crumb rubber; Grade B: 14 to 20 mesh crumb rubber; Grade C: 30 mesh crumb rubber. Mesh size designation indicates the first sieve with an upper range specification between 5% and 10% of material retained.

Crumb rubber or rubber waste was obtained from recycled tires. Crumb rubber was used as fine and coarse aggregate in the mixture.

The dry process is a method where granulated or crumb rubber modifier (CRM) are added from scrap tires as a substitute for a percentage of the aggregate in the concrete mixture, not as part of the cement binder.

Crumb rubber (CR) is a rubber waste made by shredding disposed automobile tires. Shredding waste tires and removing steel wires found in steel-belted tires generates crumb rubber. Crumb Rubber is fine rubber particles ranging in size from 0.075-mm to no more than 4.75-mm.

There are several methods used to prepare Crumb Rubber, 1) the cracker mill, 2) granulator, and 3) micro mill methods.

In this experiment, crumb rubber are crushed and sieved using sieve No.40 then Five levels of coarse rubber are added to the concrete mix. The following two tests are performed compressive strength and flexural test as shown in Table-1.

Table-1. Concrete tests conducted on the developed concrete mixes.

CR percentage	Compressive Strength	Flexural test
1% rubber	√	√
2% rubber	√	-
3% rubber	√	√
4% rubber	√	-
5% rubber	√	√

The composition of the used concrete mixtures is summarized in the Table-2. Rubber content is considered as a replacement of cement content. Figure-1 show a picture of the concrete mix during preparation.

Table-2. Composition of concrete mix as a function rubber percentage.

Rubber percentage	Cement	Foleh	Adaseh	Symsemeh	Sand	Water	W/C
standard mix	280	430	460	230	680	151	54
1% rubber	277	430	460	230	680	151	54
2% rubber	274	430	460	230	680	151	55
3% rubber	272	430	460	230	680	151	56
4% rubber	269	430	460	230	680	151	56
5% rubber	266	430	460	230	680	151	57

Figure-1. A picture of the concrete mix prepared during the study.

3. EXPERIMENT RESULTS

For this study, compressive stress and flexural tests are conducted.

3.1 Compression test

Compression test is a method for determining the behavior of materials under a compression load. Compression tests are conducted by loading the test sample between two pressing plates and then applying a force to the sample by moving the crossheads together. The compression test is used to determine elastic limit, proportionality limit, yield strength and compressive strength. The compressive strength of ductile materials is determined by their degree of distortion during testing. Table-3 shows the result of compression test for fine rubber under for different ages.

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Table-3. Compressive Strength Results (N/mm2) for fine and coarse crumbed rubber at different ages.

Compressive strength	Fine rubber (passing sieve 40)				% change	coarse rubber (retained sieve 40)				% change
	3 days	7 days	14 days	28 days		3 days	7 days	14 days	28 days	
Standard	30.1	36.2	36.4	42.9		30.1	36.2	36.4	42.9	
1%	26.9	31	34.2	36.6	-14.7	26	29.7	32.6	38.1	-11.2
2%	25.8	29.8	32.7	35.4	-3.3	25.6	28.1	29.3	36.5	-4.2
3%	22.9	26.7	31.8	34.5	-2.5	23.1	25.9	28.9	33.8	-7.4
4%	21	24.5	27.6	32.3	-6.4	22	25.3	27.4	33.1	-2.1
5%	19.8	23.6	25.9	29.5	-8.7	20.9	24.1	27.2	31.6	-4.5

Highest strength is obtained at 28 days which is plotted in Figure-2. Generally, crumb rubber size did not show significant effect on compressive strength. However, increasing crumb rubber cause reduction in concrete compressive strength. This decrease is anticipated due to rubber physical properties.

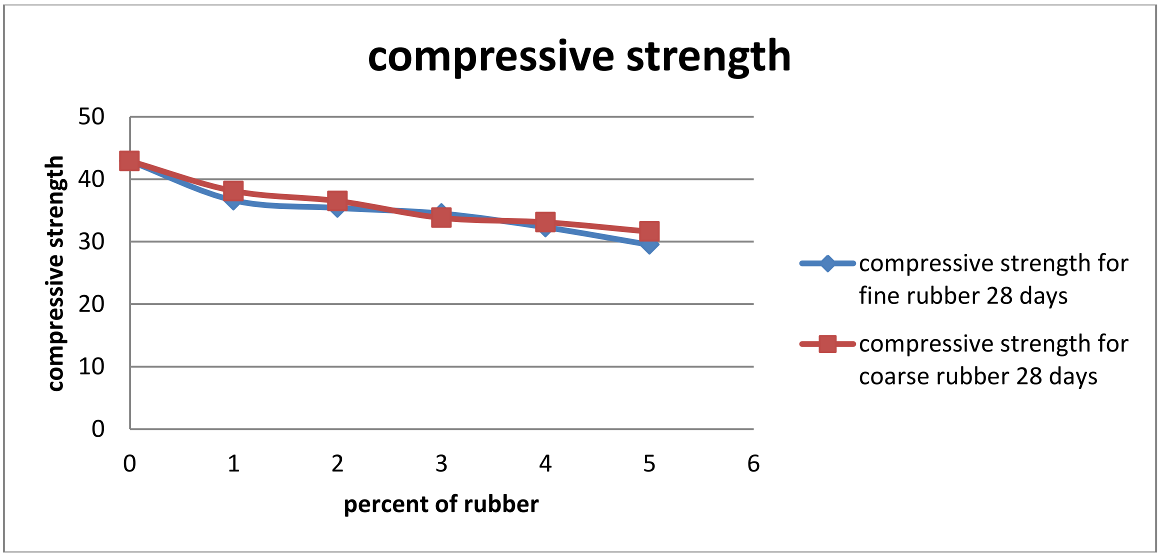

Figure-2. Concrete Compressive Strength (N/mm2) as a function Rubber Percentage at 28 days.

Adding rubber to the mix decreases compressive strength 11% per adding one percent of rubber which means that adding rubber to the mix does not contribute to improving the mix for compression.

The decrease in strength is due to the lack of cement bonding in the mix with the aggregate due to the replacement of rubber instead.

3.2 Flexural test

Flexure tests are used to determine the modulus of elasticity or flexural stress of a material. A flexure test is selected because it is more convenient than a tensile test. The material is laid horizontally over two points of contact (lower support span) and then a force is applied to the top of the material through either one or two points of contact (upper loading span) until the sample fails. The maximum force was obtained at 28 days. Also, using rubber caused decrease and

The test results are variable. The following table shows the result of flexural test. The effect of increasing rubber is reduction in flexural stress. This result is expect due to substitution of cement binding force with non binding rubber.

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Table-4. Results of Flexural test for fine and coarse rubber samples at different ages.

Rubber percentage	Fine rubber (passing sieve 40)				coarse rubber (retained sieve 40)			
	3 days	7 days	14 days	28 days	3 days	7 days	14 days	28 days
Standard	2.2	2.2	2.46	2.8	2.2	2.2	2.46	2.8
1%	2	2.2	2.4	2.6	1.98	2.16	2.4	2.64
3%	1.6	2.1	2.2	2.6	1.56	2.1	2.24	2.4
5%	1.58	1.7	1.9	1.96	1.44	1.68	1.9	1.92

Figure-3 show the change in flexural strength with increasing rubber percentage. Also, the texture of crumb rubber has an effect on flexural effect. Figure-3 show less decrease in strength when fine grains are used.

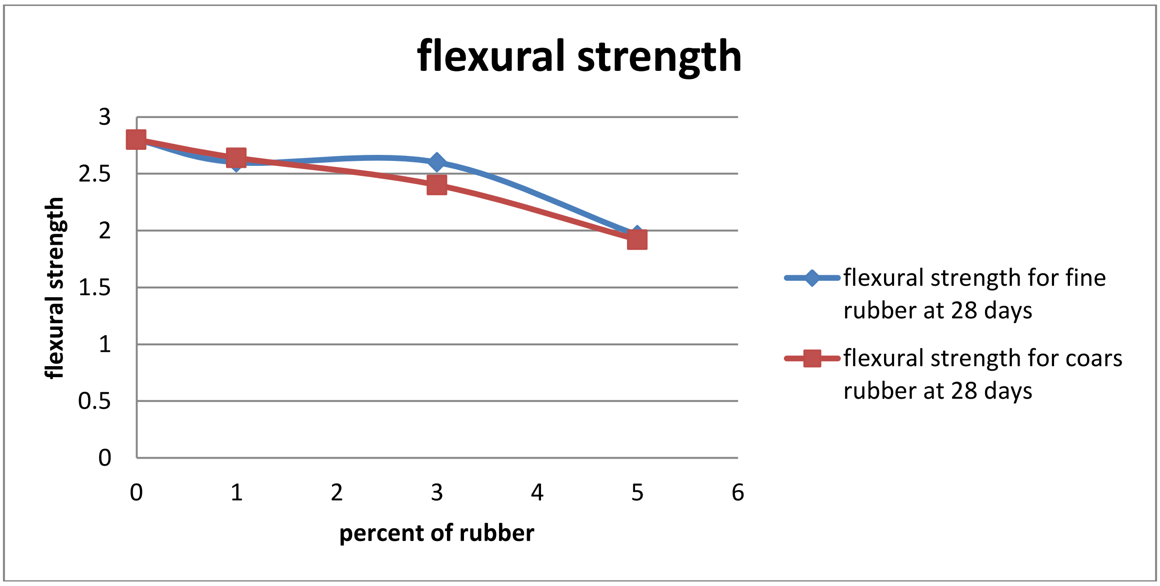

Figure-3. Results of flexural strength test (N/mm2). for fine and coarse grains.

4. CONCLUSIONS

Crumb Rubber is one of the most important waste materials that need to reduced with various applications to reduce the environmental risks. At the same time, integrating rubber waste may affect applications by causing changes to physical properties. In this study, we evaluated changes in compressive and flexural stresses at various levels of rubber percentage. Resulting from these materials and at the same time use them positively in improving mixtures used in construction.

The results show that crumb rubber modify concrete properties by reducing both compressive and flexural strengths. The crumb rubber was added as replacement of concrete which means less binding capacity. This effect can be reduced be using fine grain rubber instead of coarse grains. Concrete strength steadily declined, which means that the addition of crumb rubber is not suitable for concrete mixtures if the objective is to increase the compressive strength or flexural strength.

The use of rubber in concrete mix is useful in some applications like Asphalt mixes. However, for concrete mixes, not all uses are appropriate, non load uses like filling spaces, isolation, water and noise proofing.

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