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Research Paper

THE EFFECT OF RUBBER CRUMBS ON PROPERTIES OF CONCRETE

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Crumb rubber is a material produced by shredding and commutating used tires. There is no doubt that the increasing piles of tires create environmental concerns. The long term goal of this research is to find a means to dispose of the crumb rubber in Portland cement concrete and still provide a final product with good engineering properties. Several trail mix with replacement with rubber (5%,10% ,15%) of coarse aggregate and 5% of fine aggregate. Concrete laboratory tests included slump, density and compressive the slump decrease with increase of crumb rubber about 69% ,71% and 73% of 5% and 10% and 15% respectively of coarse aggregate and 70% of 5% of fine aggregate. The unit weight of the CRC mix decreased crumb rubber added about 3.7%, 9.5% and 1% of 5% and 10% and 15% respectively of coarse aggregate and 3% of 5% of fine aggregate. The compressive strength decreased as the rubber content increased about 46% , 70% and 15% of 5% and 10% and 15% respectively of coarse aggregate and 56% of 5% of fine aggregate .the compressive strength with replacement of 5% fine aggregate show higher strength about 19% than coarse aggregate.

Keywords: Crumb rubber, Concrete, Properties, Compressive strength

INTRODUCTION

The invention of concrete has been one of the key events in evolution because of its simplicity, strength, durability and the affordability for the society. It is the third most used substance in the world after air and water. One of the greatest challenges for the concrete industry is to help in the transformation of the consumption based society to a sustainable society by helping to lower the pollution of natural environment and to prevent the exhaustion of natural resources (Gencen *et al.,* 2012).

A huge amount of used rubber tires that are uniform it heaped up in the world each year – 275 million in the United States (Papakonstantinou and Tobolski, 2006) and about180 million in European Union (Silvestravieiete I, Sleinotaite-Budriene, 2002). Generally, the cheapest and easiest way

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to decompose used tire is by burning them. However, the pollution and enormous amount of smoke generated by this method makes burning quite unacceptable and in some countries it is prohibited by law. Thus, one of the most popular methods is to pile used tires in landfills, as due to low density and poor degradation they cannot be buried in landfills (Segre and Joekes, 2002). These tires can also be placed in a dump, or basically piled in a large hole in the ground. However these dumps serve as a great breeding ground for mosquitoes and due to the fact that mosquitoes are responsible for the spread of many diseases, this becomes a dangerous health hazard (Shuaib *et al.,* 1997).

During the last two decades, the possible usefulness of tire rubber particles in concrete and mortar has been investigated. Though most investigations about rubber concrete materials focused on using tire rubber particles as coarse aggregate in concrete, however, it has been suggested that scrap tires can be recycled into three major sizes: chipped rubber particles (size ranging between 13 and 76 mm) being used as coarse aggregate, crumb rubber particles being analogs to fine aggregate (size ranging between 0.075 and 4.75 mm), and finally ground rubber particles (size ranging between 0.15 and 19 mm) (Eldin, 1993; Siddique, 1993). It has recently been suggested that tire rubber ash can also be used to enhance concrete microstructure (Reda *et al.,* 2008).

Crumb rubber (CR) is a commodity made by re-processing (shredding) disposed automobile tires (Chesner *et al.,* 1998). Shredding waste tires and removing steel debris found in steel-belted tires generates crumb rubber. There are three mechanical methods used to shred apart these tires to CR: the cracker mill, granulator, and micro mill methods. CR can also be manufactured through the cryogenation method; this method involves fracturing the rubber after reducing the temperature with liquid nitrogen. CR is fine rubber particles ranging in size from 0.075-mm to no more than 4.75-mm. In the concrete mix, CR constitutes a portion of the aggregate in the concrete mix.Input Variables to Predict ConcreteStrength .

Early studies by Eldin and Fedroff explored the effect of rubber chips on the compressive and flexural strength of CRC mixes (Eldin, 1993; Fedroff, 1996), Schimizze *et al.* (1994) suggested using tires in light-duty concrete pavements. Biel and Lee (1994) experimented with a special cement (Magnesium Oxychloride type) for the purpose of enhancing the bonding strength between rubber particles and cement. Goulias and Ali employed the resonant frequency method to measure the dynamics modulus of elasticity and Poisson's ratio. They found that using rubber particles would improve the engineering characteristics of concrete. Toutanji's (1996) study focused on replacing mineral coarse aggregate with rubber tire chips. Freeze–thaw durability of rubber concrete was investigated by Fedroff *et al.* (1996) . Lee and Moon (1998) investigated adding crumb rubber into latex concrete. Khatib and Bayomy (1999) proposed a compressive strength reduction model of concrete mixes with added rubber content. Thong-On (2001) reported on the mechanical behavior of crumb rubber cement mortar.

Similar work on mechanical evaluation of rubber concrete has also been reported outside of the US. This included studies by Li *et al.* (1998) in Hong Kong; Hernandez-Olivares *et al.* (2002) in Spain provided Scanning Electron Microscope (SEM) photos of rubber/cement interface, as well as the evaluation of complex modulus. Most of the studies previously mentioned were analytical and/or laboratory based experimental work. The major findings were that rubber concrete would suffer a reduction in compressive strength while it may increase ductility. Whether rubber concrete is suitable for any practical application has remained to be explored (Abbas M Abd and Suhad Mm, 2012).

The main goal of this research is to find means to dispose of the crumb rubber by placement of the rubber in Portland cement concrete mix and still provide a final product with good engineering properties for certain specified engineering applications.

MATERIAL PROPERTIES AND MIX PROPORTIONS

Ordinary Portland cement manufactured in Iraq with trade mark of (Tassloga) has been used throughout this investigation. It has been stored in airtight plastic containers to avoid exposure to atmospheric conditions (Table 1) show the physical properties of cement and (Table 2) show chemical composition of cement . A crushed coarse aggregate brought from (Al-Soddor source), has been used throughout the work (Table 3) show the gradation of coarse aggregate. Normal sand has been used from (Ukhaydir source), as a fine aggregate (Table 4) show the gradation of fine aggregate. Tartan is a material produced by shredding and commutating used tires (Table 5) show the gradation of tartan.

The tartan concrete sample was obtained by replacement the fine and coarse aggregate about 5% and 10% and 15% of coarse aggregate and about 5% of fine aggregate and size of crumb rubber range between 4.75 to 9.5 mm.

Mix Proportioning

Concrete mix design in this experiment was designed, the Table 6 shows mix proportion of concrete and w/c ratio.

FRESH CONCRETE PROPERTY

Slump Test

To assess the workability of the adopted mixes, slump test was used for this purpose as shown in Figure 2.

Table 1: Physical Properties of Cement

Physical Properties	Test Results	Standard Specifications IQS 5/1984
Specific surface area (Blaine method), m2/kg	495	≥230
Setting time (Vicate apparatus),		
Initial setting, h:min		
Final setting, h:min	2:55	≥00:45
	4:35	≤10:00
Compressive strength, MPa		
3 days	33.5	≥15
7days	38.6	≥23
Soundness (Autoclave) method, %	0.3	≤0.8

Table 2: Chemical Composition of Cement

Oxides Composition	Content %	Standard Specifications IQS 5/1984
CaO	63.06	-
SiO_2	22.	-
Al_2O_3	6.25	-
Fe_2O_3	3.13	-
MgO	2.95	<5
SO_3	3.03	<2.8
LOI	3.33	<4
Insoluble residue	1.21	<1.5
Lime Saturation Factor L.S.F	0.88	0.66-1.02
Mineralogical Composition (Bogue's equations)		
C_3S	47.04	-
C_2S	28.11	-
C_3A	10.98	-
C_4AF	6.98	-

Table 3: Gradation of Coarse Aggregate

Sieve Size (mm)	Passing %	Limit of Iraq SpecificationNo.45-1984
12.5	100	100
9.5	88	100-85
4.75	10	25-0
2.36	2.5	5-0

Table 4: Gradation of Fine Aggregate

Sieve Size (mm)	Passing %	Standard Passing % of Zone (2)
4.75	93	90-100
2.7	83.4	75-100
1.18	69	55-90
0.6	47.31	35-59
0.3	15.405	8-30
0.15	0.707	0-10

Figure 1: Tartan

Table 5: Mix Proportioning

W/C ratio	Mix Design cement	Fine Aggregate	Coarse Aggregate
0.47	1	1.8	2.65

Figure 3: Slump Test

HARD CONCRETE PROPERTY

Density

150*150 cubic were used to determine the 28-day and 7 days densities for concrete specimens. The specimens kept in curing immediately after disjointed of molds for 28 days and then the specimen were weighted and the average densities were taken for each type of concrete.

Compressive Strength Test

The compressive strength test has been determined using cubic (150 x 150 mm) The cubic tested by using compressive strength machine Figure 3, with capacity (2000 kN) at loading rate (3 MPa/s), the average of three cubic were recorded at 7 and 28 days. Figure 4 shows typical failure of cubic specimen.

Figure 4: Typical Failure of Cubic Specimen

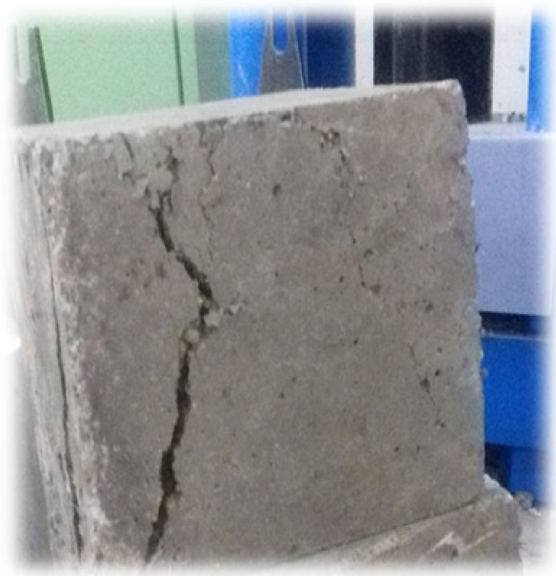
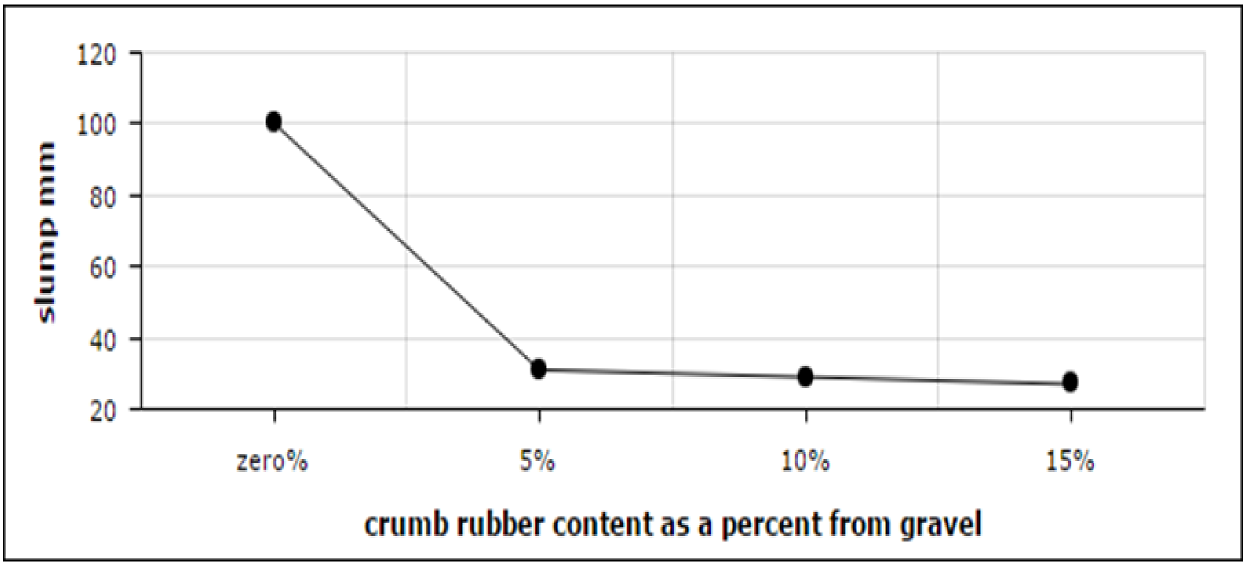


Table 6: Slump Test Results

Different Percentages of tartan replacement	Slump (mm)
Normal concrete	100
5% of coarse aggregate	31
10% of coarse aggregate	29
15% of coarse aggregate	27
5% of fine aggregate	30

Figure 5: The Effect of Crumb Rubber Content on Slump



RESULTS

Slump Test

The value of the slump for all mixes were as shown in Table7 and Figure 5:

The result show that the rubber decrease the workability with increase of the rubber content that because the rubber has high ratio of absorption and w/c ratio is little so the crumb rubber absorb the water and hence the mix become stiff and also the Surface texture is rough this make hard to the particle to slip one of each other compare to the aggregate and this lead to reduce workability and the replacement with coarse show higher slump.

DENSITY

The densities of different materials used in the production of cubic the densities are listed in Table 8 and Figures 6, 7, 8.

The result show the density decrease with rubber increase compared to the original one while the replacement of coarse and fine show that the replacement with fine has higher density that because the crumb rubber has lower weight

Table 7: Weight Densities Results

Different Percentages of Tartan Replacement	Density (kg/m^3) at 7 days	Density (kg/m^3) at 28 days
Normal concrete	2355	2400
5% of coarse aggregate	2305	2311
10% of coarse aggregate	2160	2171
15% of coarse aggregate	2139	2142
5% of fine aggregate	2321	2327

Figure 6: The Effect of Crumb Rubber Content on Weight Density at 7-days

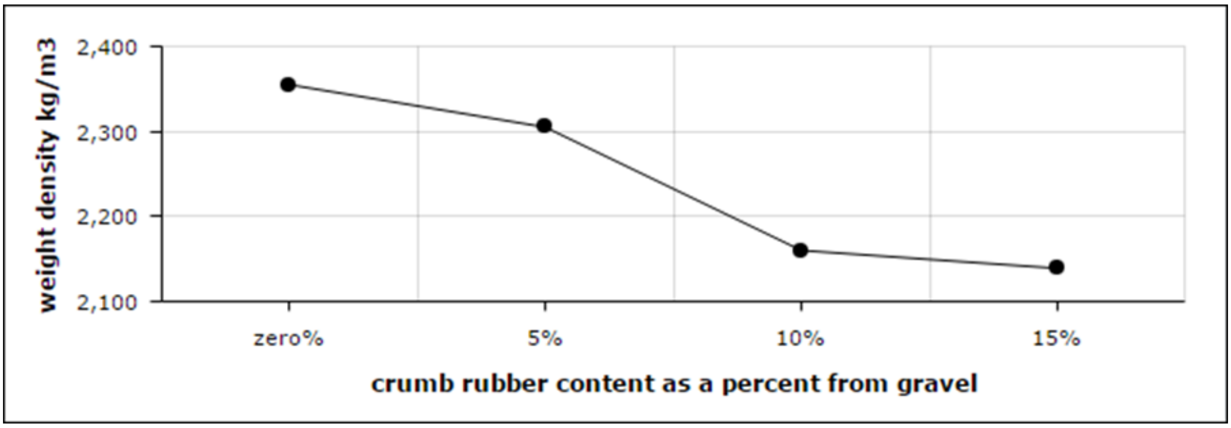


Figure 7: The Effect of Crumb Rubber Content on Weight Density at 28-days

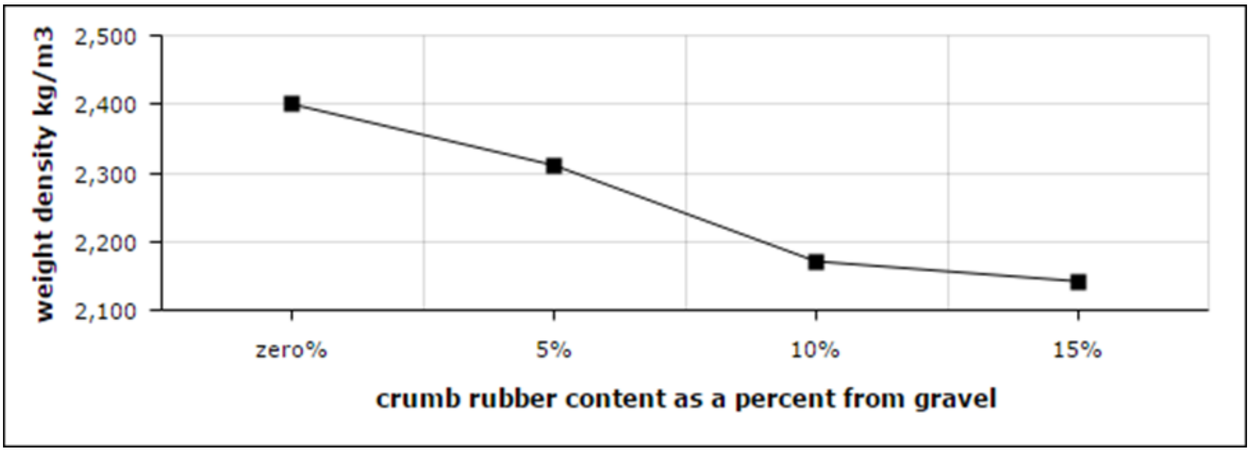


Figure 8: The Effect of Crumb Rubber Content on Weight Density 7 and 28-days

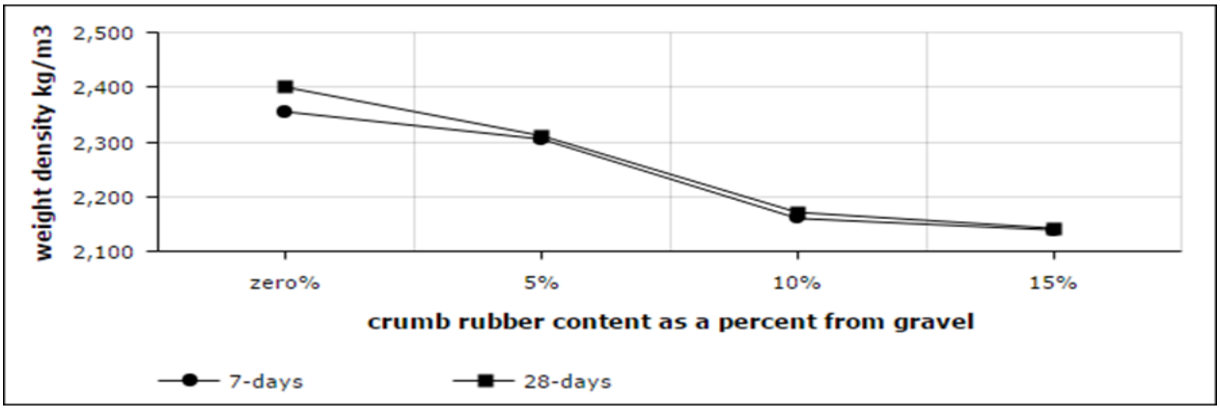


Table 8: Compressive Strength Results

Different percentages of tartan replacement	Compressive strength at 7 days	Compressive strength at 28 days
Normal concrete	24.8	30
5% of coarse aggregate	14.82	16.18
10% of coarse aggregate	7.52	8.97
15% of coarse aggregate	6.90	8.75
5% of fine aggregate	11.21	13.04

Figure 9: The Effect of Crumb Rubber Content on Compressive Strength at 7-days

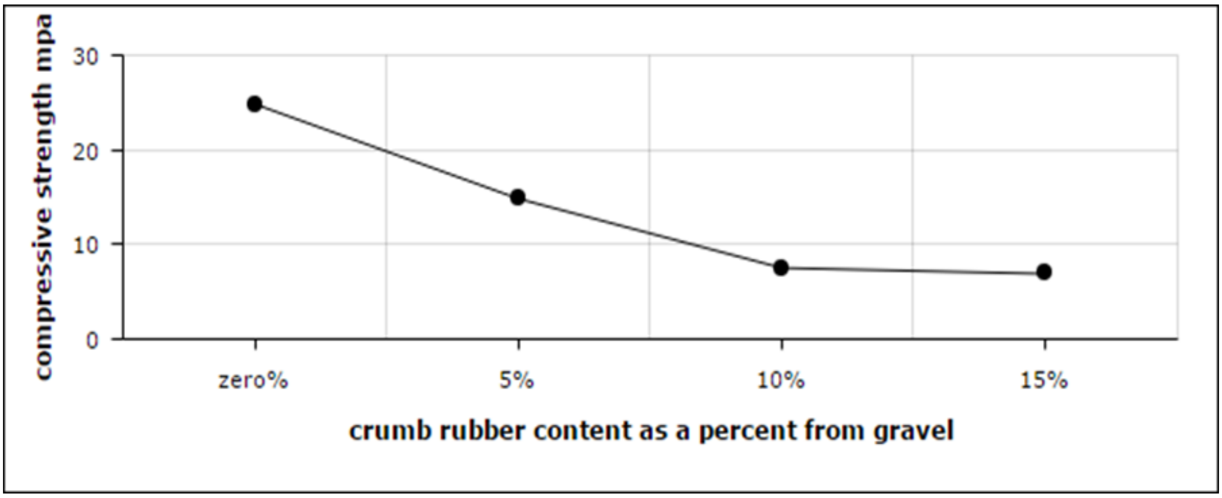


Figure 10: The Effect of Crumb Rubber Content on Compressive Strength at 28-days

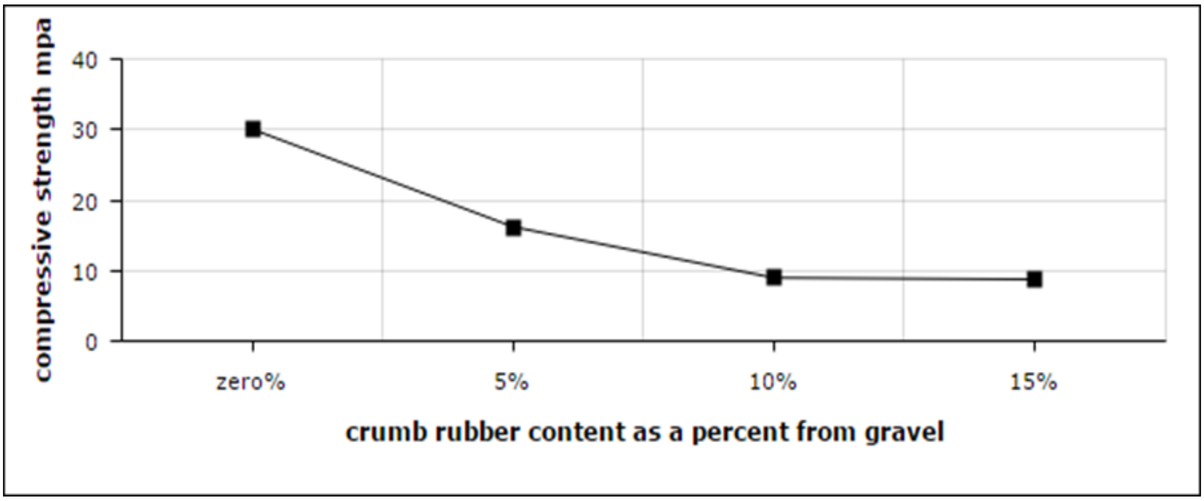
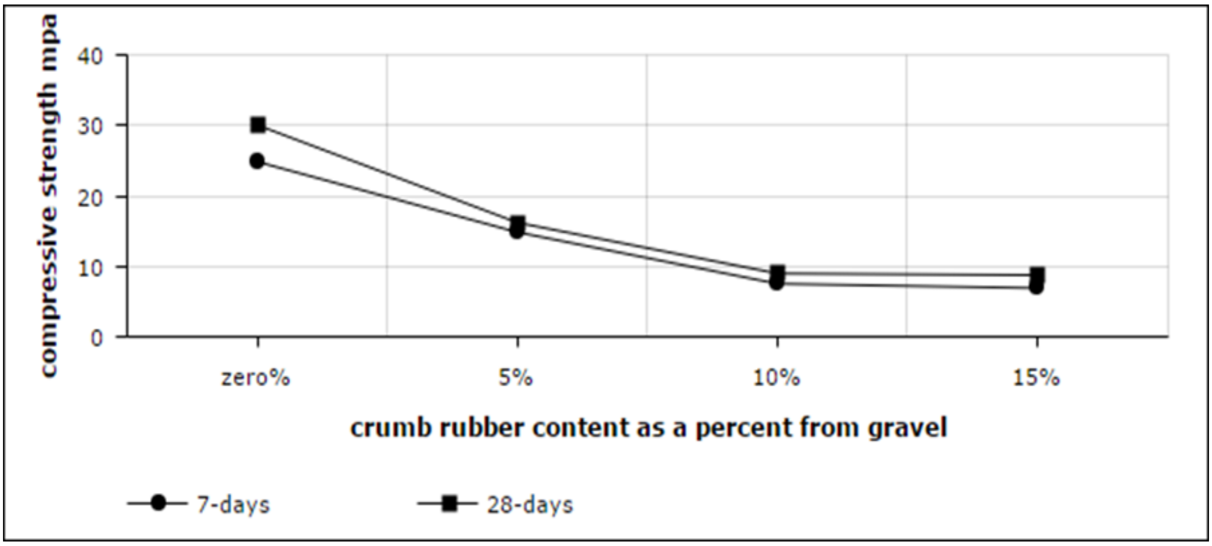


Figure 11: The Effect of Crumb Rubber Content on Compressive Strength at 7 and 28-days



compare to the aggregate and has higher air content this lead to reduce the weight.

Compressive Strength

The result of compressive strength of 9 and 28 days are shown in Table 4 and Figures 9, 10, 11.

The result show that the concrete with replacement of 5% with tartan of 7 days and 28 days was reduce approixtmaly to the half while the other mixes more than the half because Rubber is weaker and less rigid than the mineral aggregate that they replace, which reduces the compressive strength, and also the crumb rubber lead to increase the air content this become a weakness point and also the crumb rubber has low bond the compression between the replacement of fine and coarse show that the 5% replacement show higher strength than coarse .

CONCLUSION

There is no doubt that the increasing piles of tires create environmental concerns. Finding a way to dispose of the rubber in concrete would enhance the understanding on how to incorporate the crumb rubber in greater engineering usage .

Preliminary conclusions of this study are:

1. The slump decrease with increase of crumb rubber about 69%, 71% and 73% of 5% and 10% and 15% respectively of coarse aggregate and 70% of 5% of fine aggregate.
2. The unit weight of the CRC mix decreased crumb rubber added about 3.7%, 9.5% and 1% of 5% and 10% and 15% respectively of coarse aggregate and 3% of 5% of fine aggregate.
3. The compressive strength decreased as the rubber content increased about 46%, 70% and 15% of 5% and 10% and 15% respectively of coarse aggregate and 56% of 5% of fine aggregate. Part of the strength reduction was contributed to the entrapped air, which increased as the rubber content increased.
4. The compressive strength with replacement of 5% fine aggregate show higher strength about 19%than coarse aggregate.

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