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EFFECT OF WASTE TYRE RUBBER ADDITIVE ON CONCRETE MIXTURE STRENGTH

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ABSTRACT: *This paper studies the influence of shredded rubber from waste tyres on concrete strength .These shredded particles from waste tyres were used to replace the 20mm size aggregate in different percentages (5%, 10% and 15% in volume). Concrete mixtures without these additives were also tested. The experimental results show a reduction of the compressive strength as the percentage of rubber particles increases. Four point bending test conducted on six samples of each specimen also unveil a reduction in the flexural strength and bending capacity of concrete as the rubber content increases. Deflection at failure of the rubberized concrete is more than that of the plain concrete which unveils the ability of the rubberized concrete to withstand larger deformations than the plain concrete*.

KEYWORDS: Tire shreds, Rubberized concrete, compressive strength, deflections, flexural strength.

INTRODUCTION

The management and disposal of waste tyres from vehicles is of great concern to most countries. Stockpiling of these scrap tyres do not only result to negative impacts to the environment but also a source of fire hazards and breeding ground to rats, mosquitoes etc. (Toutanji, 1996; Ghally and Chill, 2005; Khatib and Bayomy, 1999). The aforementioned issues call for the need to devise means of recycling and reusing these large volumes of scrap tyres. At the moment, quite a little percentage of the scrap tyres are recycled for other applications; break waters, fuel for energy generation, crumb rubber asphalt pavement, light weight fills for embankments etc. However, additional means of recycling these solid wastes (scrap tyres) is needed to be devised in order to curtail the negative environmental hazards caused by it. The increased consumption of concrete material in the construction industry has lead to the constant demand for natural resources (mineral aggregates, sand) coupled with the set back associated with the brittle nature of concrete. The above enumerated issues capture the attention of researchers not only to improve the performance level of concrete but also to save guard our environment from dangers associated with waste tyres and constant demand of natural resources.

Research has over the years focused on the use of different shapes and size of waste tyres in different proportion in concrete. A mixture of ordinary concrete and rubber particles from waste tyres has been presented in literatures as “rubberized concrete” or “rubber modified concrete”. The waste tyres obtained are usually from motor vehicles and trucks. In some occasions the rubber particles from waste tyres are pre-treated with chemicals before

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incorporating into concrete in order to ensure proper bonding with the grout. The use of waste tyres in concrete has gained worldwide recognition in the field of engineering, prompting many researchers in recent years to further investigate the use of rubber particles in concrete [Gaily and Cahill, 2005; Toutanji, 1996; Silvestravičiūtė, et al, 2002; Ghally and Chill, 2005; Papakonstantinou et al,2006; Khatib and Bayomy, 1999; Stankevičius et al. 2007; Eldin and S enouci, 1993; Batayneh et al., 2008; Gintautas SKRIPKIŪNAS et al 2007;Ali R. Khaloo *, M. Dehestani, P. Rahmatabadi 2008; Eshmaiel Ganjian et al 2008; Eldin, Senuoci 1993; Khatib and Bayomy 1999]. In all the studies, the size, surface texture and the volume of the rubber particles influences the mechanical properties of the concrete.

Rubber aggregates used in concrete production are generally classified into four groups depending on the size of the particles, namely shredded particles which ranges from 2 to 20mm in size, crumb rubber particles ranges from 4.75- 0.425mm and the grounded rubber (100% passing 0.425mm) (Najim and Hall, 2010). The rubber material is characterized of low unit weight of 0.95kg/m3, high dynamic modulus and damping, low thermal conductivity (0.14 W/m K), very low water absorption rate and a non biodegradable material (high resistance to weathering) (Al – Sakini 1998).

The rubberized concrete generally posses low unit weight, high deformability, high toughness and damping properties. The major drawback of the rubberized concrete is the low compressive and flexural strength. This is due to the low bonding that exists between the rubber particles and the concrete mix [Toutanji, 1996; Ali R. Khaloo *, M. Dehestani, P. Rahmatabadi 2008; Khatib and Bayomy, 1999]. Replacement of mineral aggregates with rubber particles should not exceed 25% for structural application due to its rapid decrease in strength (Ali R. Khaloo et al 2008). The workability of the rubberized concrete decreases as the concentration of the rubber particles increases. However rubberized concrete made with fine rubber particles tend to exhibit acceptable workability compared to the conventional concrete [Ali R. Khaloo et al 2008].

The aim of this paper is to investigate the influence of the rubber particles from waste tyres on the strength of concrete. Detailed experimental studies of concrete containing different percentages of rubber particles will be conducted on the hardened concrete.

EXPERIMENTAL DESIGN

Materials

The constituent materials used for this research (concrete mixes) includes the Portland cement of class 42.5 complying with the type CEM 1, BS EN 197-1:2000, the Thames Valley flint gravels of less than 20mm maximum size, uncrushed river sand of less than 5mm maximum size. The absorption to the saturated surface dry condition of Thames Valley aggregates are as follows; 1.2% for 20mm aggregate size, 3.6% for 10mm aggregate size and 1.8% for sand.

The shredded rubber particles used for this study are obtained from discarded car tyres. The shredded tyres range from 10- 20mm length without wire strings. There was no pre treatment of the shredded tyres before incorporating into the concrete mix.

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Mix design and specimen preparation

In carrying out the experiments, a control mix without rubber particles is used for the conventional concrete and 5%, 10% and 15% by volume of tyre shreds was used to replace the 20mm size aggregates for the rubcrete mix while maintaining the proportion or quantity of every other constituent material. The 15% maximum replacement was adopted based on recommendations made by previous researchers in order to retain some of the mechanical properties of the concrete mix [T. C. Ling MEng et al 2010; Ali R. Khaloo et al 2008]. The surfaces of these shredded tyres are rough and damaged due to the splitting process. The apparent density of the shredded tyres is 468kg/m^3 and is free of steel wires.

Samples were cured at 20 ±1 ^{o}c and a relative humidity greater than 95% for 28 days prior to testing in a controlled environment. The fresh concrete mix was well place in the moulds and compacted by means of a vibrating table. The samples were cured for a minimum of 24 hours before de-moulding for the curing process.

The table 1 and 2 shows the mix proportion and the required number of samples for each test to be conducted. The C mix represents conventional concrete without rubber particles while the TS5, TS10 and TS15 are concrete with 5%, 10% and 15% replacement of the 20mm size coarse aggregate with the tyre shreds.

Table 1: Concrete mix proportion

Specimen designation	**Tyre shred aggregates (%)**	**20mm coarse aggregates (%)**	**10mm coarse aggregates (%)**	**Sand (%)**
C	0	100	100	100
TS5	5	95	100	100
TS10	10	90	100	100
TS15	15	85	100	100

Table 2: Sample Specifications in millimetres and required number per test.

Specimen designation	Flexural test (100 x 100X 500)mm	Compressive strength test (100 X 100 X100)mm
C	6	6
TS5	6	6
TS10	6	6
TS15	6	6

Test procedures

The flexural strength test of specimens was carried out based on the specifications made in BS 1881-1881:1983.Specimen size 100mm X 100mm X 500mm for both the conventional

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concrete and rubcrete (rubber modified concrete) was used for this test in estimating their flexural strength after 28days of curing. The beam samples were loaded at the speed of 0.11mm/min. Experimental set up of the loading arrangement of the specimens is shown in figure 2.

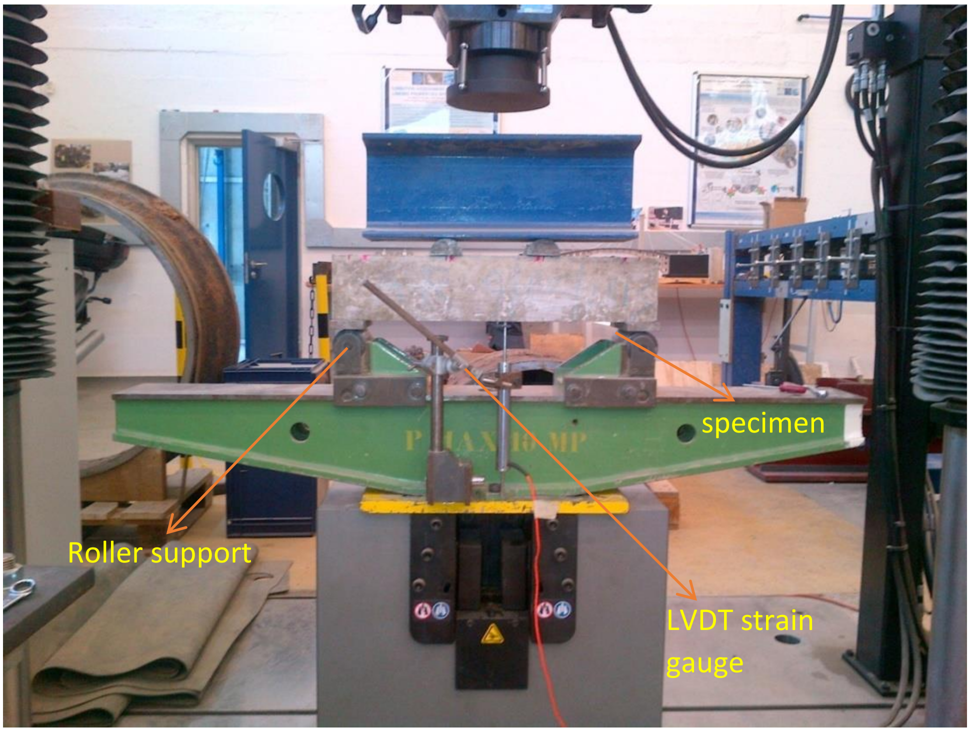

Figure 2: Experimental set up for the four point bending test.

After ascertaining the load that causes failure of specimen from the test, the flexural strength based on BS 1881-118:1983 can be estimated from the equation 1 given below.

$$f_{cf}\left(N/mm^2\right) = \frac{F * l}{d_1 * d_2^{\,2}} \qquad \text{.......... 1}$$

Where;

F is the load that causes failure of specimen (breaking load) in Newton's (N).

l is the distance between the supporting rollers in mm.

d_1 is the width of the cross- section in mm.

d_2 is the depth of the cross- section in mm.

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RESULTS AND DISCUSSION

Flexural Strength, Deflection and Compressive Strength

The flexural strength decreases as the percentage of rubber particles increases in the concrete. For 5%, 10% and 15% volumetric replacement of aggregate with tyre particles, 4%, 14% and 16% reduction of flexural strength were observed respectively as shown in figure 3 below. These results are consistent to the findings of [H.A toutanji, 1996; Eshmaiel Ganjian et al 2008]. The reduced flexural capacity of the rubcrete specimen was attributed to the weak bonding between the rubber particles and the cement paste.

It was also discovered from the experimental results that the deflection of the rubcrete specimen (TS5, TS10 and TS15) at failure is higher than that of the control concrete mix. For 5% replacement, there is no significant difference in deflection at failure as shown in figure 4 but for 10% and 15% replacement of aggregates with rubber particles, deflection at failure increases with 12% and 45% respectively. This result is in conjunction with the findings of [H.A toutanji, 1996] and also gives a better understanding of the ability of the rubberized concrete to undergo large elastic deformation before failure compared to the conventional concrete.

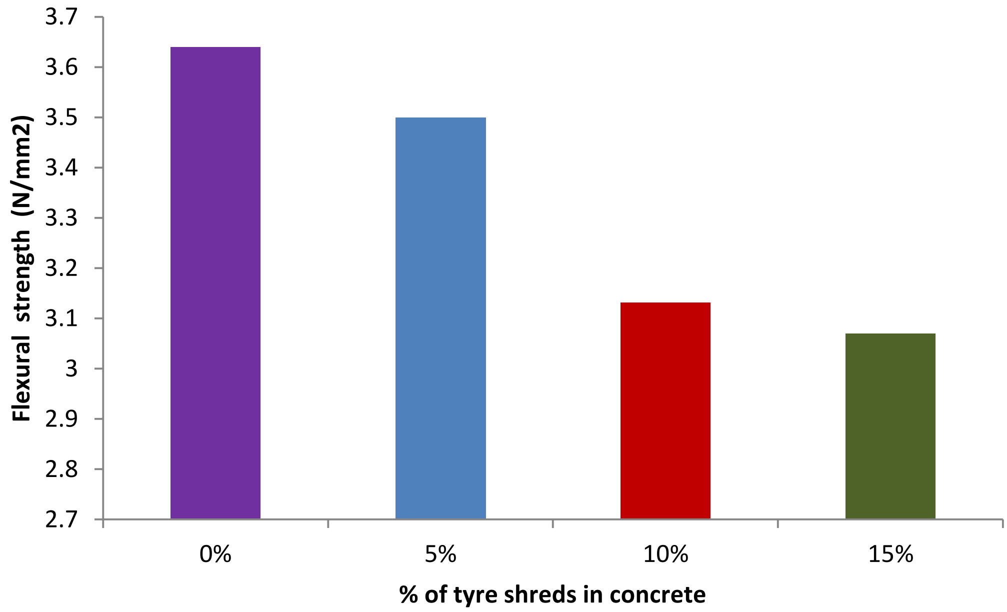

Figure 3: Flexural strength as a function of different percentage of rubber particles.

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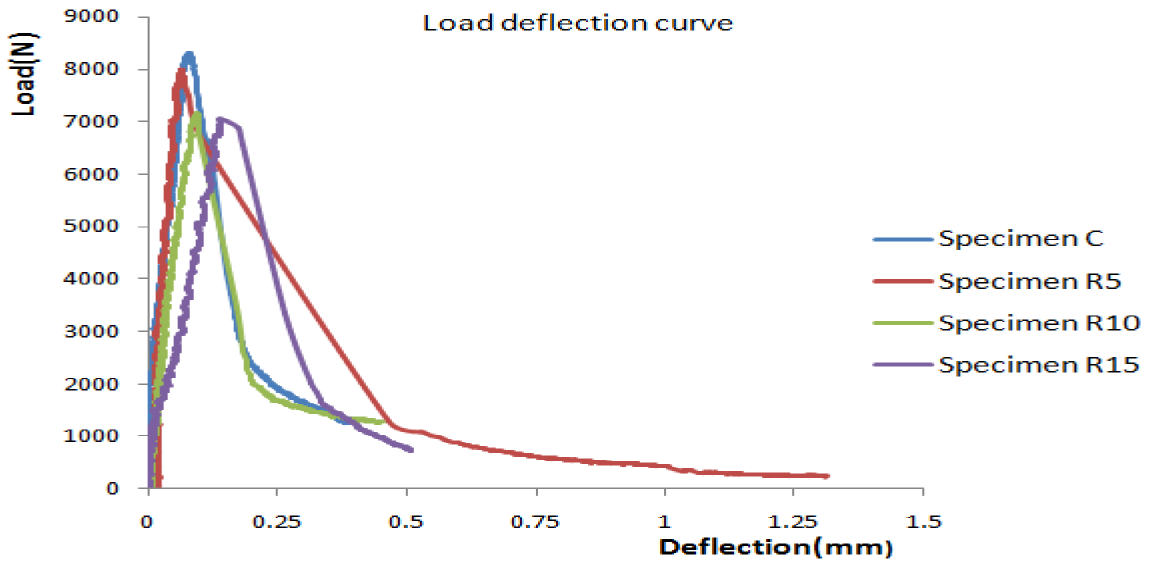

Figure 4: Load deflection curve as a function of different percentage of rubber particles.
The compressive strength of the concrete also decreases with an increase in the percentage of rubber particles in concrete. For TS5, TS10 and TS15 specimens, the compressive strength is reduced by 21%, 32% and 38% respectively as shown in figure 5. This behaviour may be attributed to the fact that the rubber particles are weaker and more elastic than the cement paste surrounding it which propagates cracks from the contact zone of the rubber and cement matrix. Also a high density aggregates replaced with rubber particles of low density will definitely reduced the compressive strength of the concrete [H. A. Toutanji1996; Ali R. Khaloo etal 2008; Eldin, N.N., Senouci, A.B., 1993].

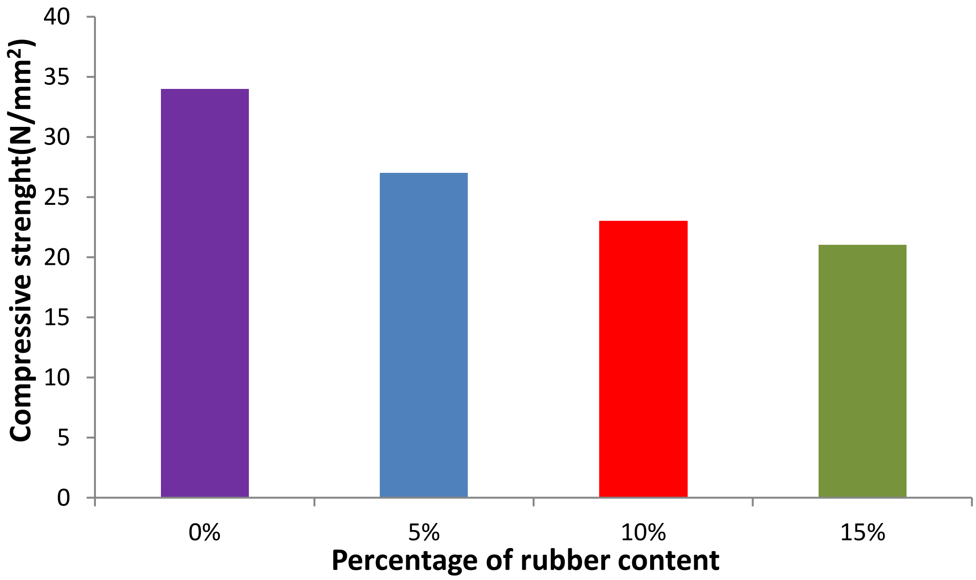

Figure 5: Compressive strength of hardened concrete as a function of rubber content.

It was also found that the reduction of the compressive strength is higher than that of the flexural strength. This leads to the findings that rubberized concrete perform better under

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bending than in compression. Though the reductions in both strengths are not linear as shown in figure 6 below. This finding was also in line with the results of [H. A. Toutanji 1996].

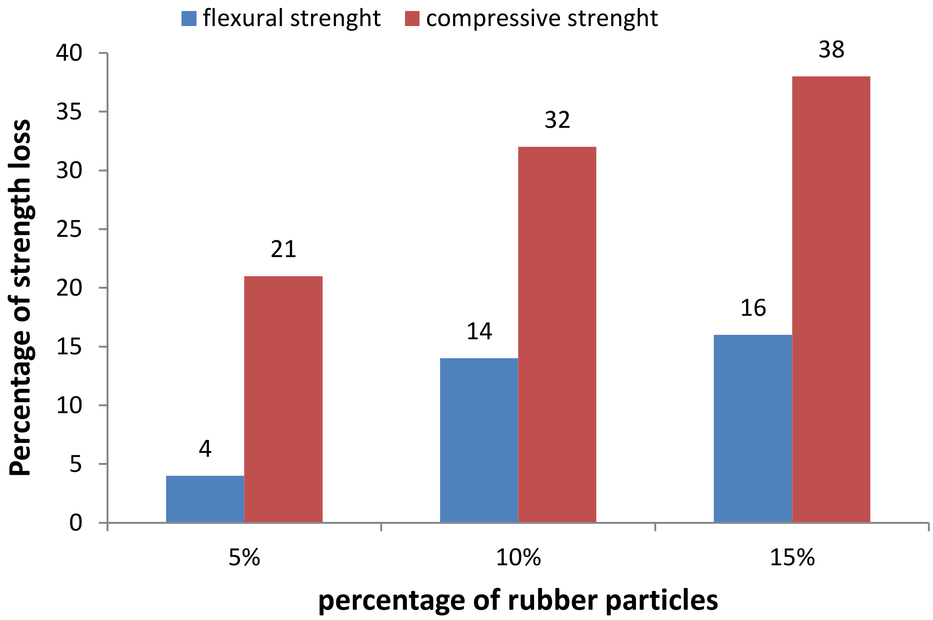

Figure 6: Loss of strength of hardened concrete as a function of rubber content.

CONCLUSIONS

The incorporation of tyre shreds from waste tyres in concrete reduces its strength. Though this reduction can be minimize by limiting the percentage of the tyre shreds of the coarse aggregate volume in concrete in order to be employed in structural and non structural applications.

1. There was a decrease in the flexural and compressive strength of the concrete by 16% and 38% respectively when 15% by volume of rubber particles of the total coarse aggregates are incorporated into the concrete mix. The reduction in strength is attribduted to the low strength of the rubber particles compared to the replaced coarse aggregates, weak bonding between the rubber particles and the cement paste.
2. For 15% replacement of coarse aggregates with rubber particles in concrete, the reduction in compressive strength is 57.8% more than the flexural strength.
3. The results of the four point bending test shows that the deflections at failure of the rubber modified concrete were higher than the conventional concrete. Deflections increases by 12% and 45% respectively for 10% and 15% of rubber particles of the aggregates volume in concrete but there was no significant difference in deflection for 5% of rubber particles in the concrete. This actually unveils the ability of the rubberized concrete to withstand large plastic deformations before failure.
4. To retain the mechanical properties of concrete, rubber particles used in replacing coarse aggregates should not exceed 15%.

FUTURE RESEARCH

1. The durability of rubber modified concrete.

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2. A large scale experimental test should be conducted on the rubberized concrete.

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