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Sustainable Concrete with Waste Tyre Rubber - An Overview

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ABSTRACT

Natural aggregates in concrete can be replaced with scrap tyre rubber which seems to be the best way to use waste tyre rubber. This paper reviews the tests performed to determine the compressive strength, flexural tensile strength, water absorption and water penetration of using rubber tyre waste in concrete. Scanning Electron Microscopy (SEM) images were also presented in this paper. Researchers have been concluded that incorporation of waste tyre rubber in concrete shows better results when compared with conventional concrete mix.

KEY WORDS: Rubber tyre waste, Compressive strength, Flexural strength, Durability.

1. INTRODUCTION

Due to particular shape and impermeable nature of waste tyre rubber, it provides a breeding habitat for mosquitoes and various pests when it is disposed to lands. Burning of tyres leads to high temperature and formation of toxic fumes. Classification of scrap rubber tyre are: chipped, crumb and ground rubber. In micro milling process the particles made are in the range of 0.075–0.475 mm. NaOH solution gave the best result during the surface treatments test of the rubber surface. Due to high complex configuration of the ingredient materials, accumulation of discarded tyres is a major problem. As per literatures better results were obtained when fine aggregates are replaced with waste rubber tyres. This would facilitate the effective use of the waste also to minimize the accumulation of the tyres. Resistance to chloride ion penetration was reported by when w/c of 0.65 was adopted. When 2.5 % to 15% granulated rubber content was used as a partial replacement of sand, reduction chloride ion penetration was observed in mortar specimens. It observed that chloride-ion penetration increases when crumb rubber and rubber chips are partially replaced for coarse aggregate and fine aggregate. Also it observed that when silica fume was added chloride ion permeability value get reduced.

Material properties: OPC 43 grade of cement was used. Specific gravity of natural river sand was found to be 2.63, free surface moisture was 1%, water absorption was 1.5% and fineness modulus was 2.83. Coarse aggregate of 10 mm size of 40% was used, its fineness modulus was 5.573, water absorption was 0.3% and 20 mm size of 60% was used. Stages of rubber tyre are shown in Figure 1. Crumb rubber was supplied by a local industry. Tyre rubber was ground into three sizes namely 30 mesh, 0.8 to 2 mm and 2mm to 4 mm after removing the steel and textile fibers. The specific gravity of rubber powder was 1.05 and 1.13. Crumb rubber seems to have a smooth surface when compared with river sand. Silica fumes was also used to enhance the interfacial transition zone bonding. Silica fume is more reactive than fly ash at ordinary temperatures. Poly carboxylic ether-polymer was used to achieve proper workability of concrete mixes. Figure 2-4 shows the scanning electron microscopic images of rubber tyre. Table 1-2 shows the slump performance of crumb rubber content.

Table.1. Slump performance according to crumb rubber content

Rubber content (%)	Slump (mm)
0	75
20	61
40	36
60	18
80	10
100	5

Table.2. Slump tests of fresh concrete with aggregates replaced by rubber particles

Mixture	Slump (mm)
Reference concrete with rubber waste replacing coarse aggregate (W/B = 0.52)	180
25% rubber volume	220
50% rubber volume	215
75% rubber volume	215
Reference content with rubber waste replacing fine aggregate (W/B =0.60)	180
15% rubber volume	220
30% rubber volume	220
50% rubber volume	215
75% rubber volume	225

Figure.1. Crushed rubber from waste tyre

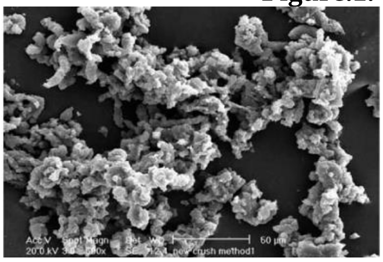


Figure.2. SEM micrograph of waste rubber powder

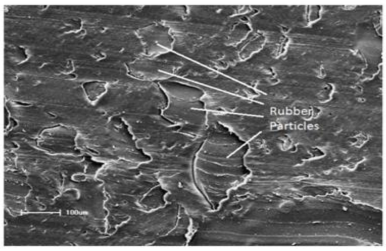


Figure 3 SEM micrograph of the HDPE/C2C8/RTP

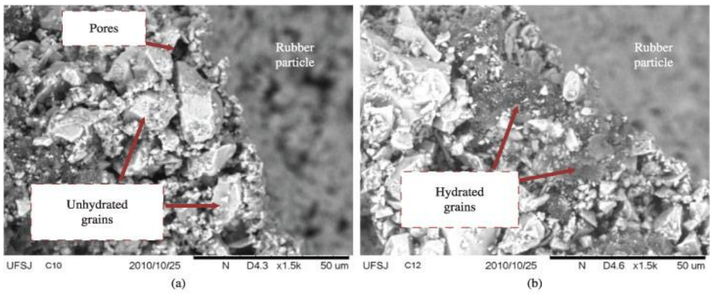


Figure.4. Backscatter Electron imaging @1500 X of magnification composites a) 15% rubber @ w/c ratio = 0.5 (b) 30% rubber @ w/c ratio =0.5

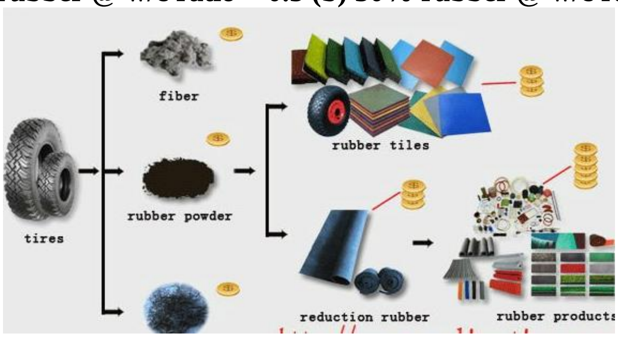


Figure.5. Flow diagram of waste tyre recycle

Figure 5 shows the flow diagram of waste tyre recycle. 0.8 was the relative density (specific gravity) of ground tyre powder was 0.8. Mixture preparation in the first mixture, 5%, 7.5%, and 10% by weight of coarse aggregates were replaced by chipped tyre rubber. Mixture proportioning specifications are detailed in Table 3.

Table.3. Concrete Mix proportions

Description	Cement (kg/m^3)	Weight of material (kg/m^3)		Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)
		Chipped	Powder		
Control	380	0	0	858	927
Replacing 5% by weight rubber particles for aggregates	380	46.40	0	858	884
Replacing 7.5% by weight rubber particles for aggregates	380	69.50	0	858	861
Replacing 10% by weight rubber particles for aggregates	380	93	0	858	839
Replacing 5% by weight rubber powder for cement	361	`0	19	858	927
Replacing 7.5% by weight rubber powder for cement	352	0	28	858	927
Replacing 10% by weight rubber powder for cement	342	0	38	858	927

Mechanical Properties:

Compressive strength: The variations in compressive strength (Figure 6) obtained for different curing periods. When crumb rubber (%) increases compressive strength decreased. When 20% rubber waste was used compressive strength increased by 50% than the value of the conventional concrete. Compressive strength was found to be 65.5 N/mm^2 27 N/mm^2 at a curing period of 7 days for conventional concrete mix and crumb rubber (20%) concrete mix.

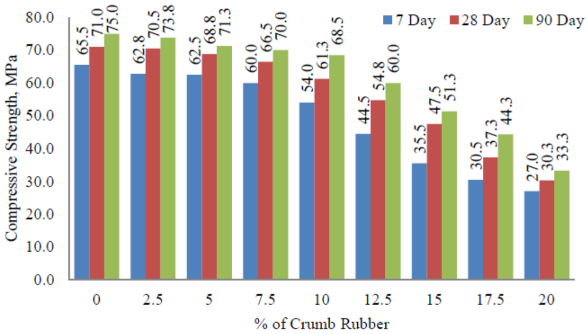


Figure.6. Compressive strength of varying crumb rubber (%)

Brittle failure was found in control concrete whereas concrete with rubber did not show brittle failure. For control concrete diagonal cracks were seen and for concrete using waste tyre rubber formation of horizontal cracks were observed. Pelisser (2011), observed that there is some loss in mechanical properties of concrete using rubber waste. The cement paste containing rubber particles are very soft when compared with conventional concrete. Due this reason, development of cracks will occur during loading. Figures 7-8 shows the compressive strength of concrete for varying water-cement ratio. It can be seen strength decrease with increase in rubber fibres. The reason for reduction may be due to (i) use of less dense rubber as aggregate (ii) lesser stiffness of the substitute material.

Table.4. Compressive strength of concrete with aggregate replaced by rubber

Mixture	Compressive strength (N/mm^2)	Compreesive strength decrease (%)
Refernce concrete with rubber waste replacing coarse aggregate (W/B = 0.52)	45.80	-
25% rubber volume	23.90	47.80
50% rubber volume	20.90	54.40
75% rubber volume	17.40	61.90
Reference content with rubber waste replacing fine aggregate (W/B =0.60)	27.10	-
15% rubber volume	24.00	11.60
30% rubber volume	20.40	24.70
50% rubber volume	19.50	28.30
75% rubber volume	17.10	37.10

Figures 7 and 8 shows the compressive strength tests for concrete mixtures. For chipped rubber, strength gets reduced. Strength reduction of 10-23% was observed when replacements of 7.5% and 10% of rubber powder were used.

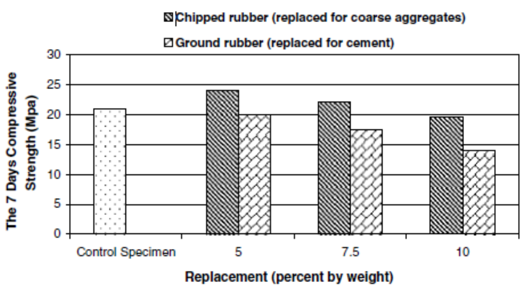


Figure.7. Compressive strength @ a curing period of 7 days

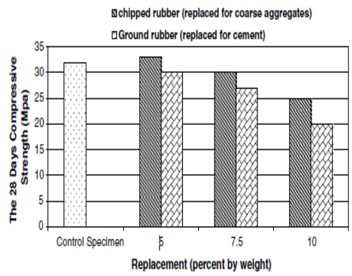


Figure 8 Compressive strength @ a curing period of 28 days

Flexural Strength: The flexural tensile strength variations of curing period was shown in Figure 9. When crumb rubber (%) increases flexural strength decreased.

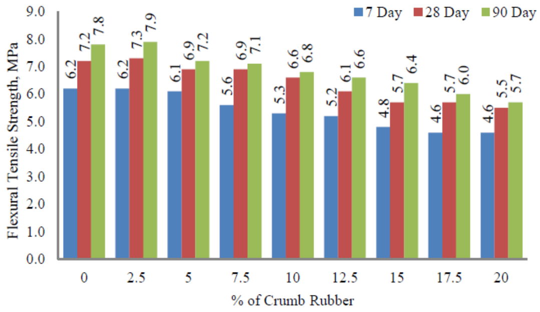


Figure.9. Flexural tensile strength for varying curing period 7 days, 28 days and 90 days

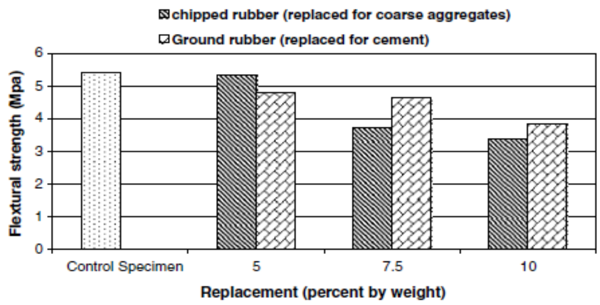


Figure.10. Flexural strength test for varying (%) of crumb rubber

Under flexural tensile loading brittle failure was observed. When rubber content increased from 20-30% the flexural strength decreases. The results of flexural strength tests are shown in Figure 10. There is a strength reduction of about 37% when compared with the control concrete.

Modulus of elasticity: Elastic Modulus of concrete are given in Figure 11. Elastic Modulus of rubber concrete reduced when rubber content increased.

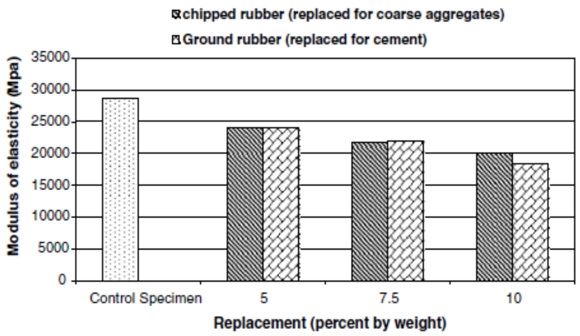


Figure.11. Modulus of elasticity for varying crumb rubber (%)

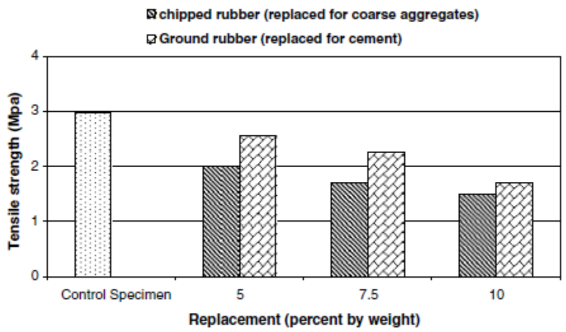


Figure.12. Tensile strength for varying crumb rubber (%)

Tensile strength: Tensile strength test results are given in Figure 12. Tensile strength reduced by 44% when 7.5% (rubber waste) was used and reduced by 24% when compared to conventional concrete.

Durability studies: Yilmaz and Degirmenci (2009) mentioned water absorption decreases upon increase in size of the rubber particles. Bravo and De Brito (2012) have stated water absorption increases as the particle size of rubber increases. Li (2004) observed that higher strength and stiffness was achieved for rubber concrete.

Table.5. Chemical composition of crumb rubber

Test	Results
Ash Content %	5.11
Carbon black content %	28.43
Acetone extract %	9.85
Volatile matter %	0.56
Hydrocarbon content %	56.05
Polymer analysis	SBR

Chloride ion penetration: Chloride penetration for varying w/c of 0.4 and 0.45 are reported in Figures 13-14. It was observed that for higher w/c ratios the increases the depth of chloride ion penetration.

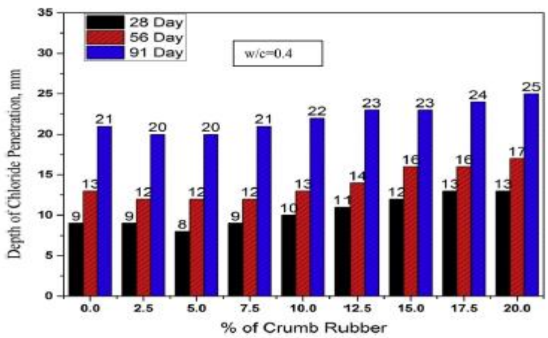


Figure.13. Depth of chloride penetration of specimen with w/c ratio 0.4

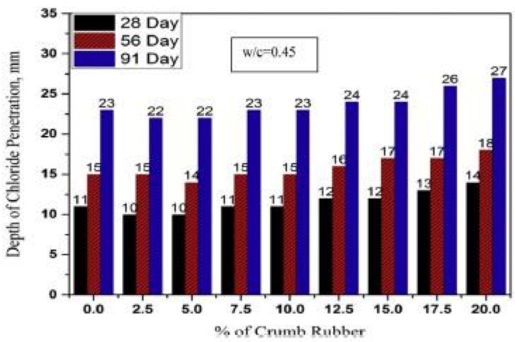


Figure.14. Depth of chloride penetration of specimen with w/c 0.45

Water absorption of specimens attacked by acid: Figure 15 shows the water absorption values of specimens attacked by acids for varying curing period. Water absorption increases gradually when rubber waste (%) was replaced from 0% to 20% for fine aggregate. When rubber content increases the internal voids increase resulting in the increase in amount of water absorption.

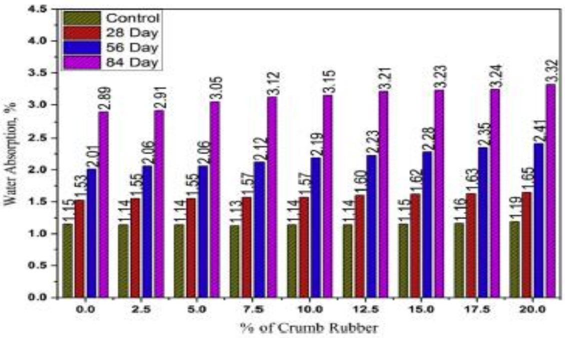


Figure.15. Water absorption of acid attacked specimens, w/c 0.4

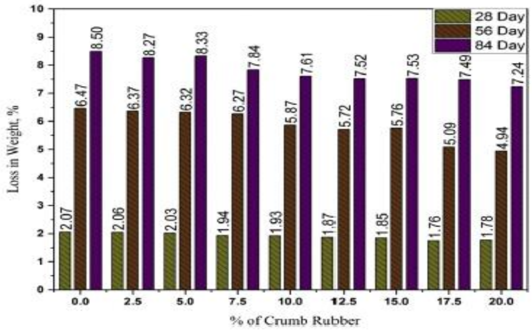
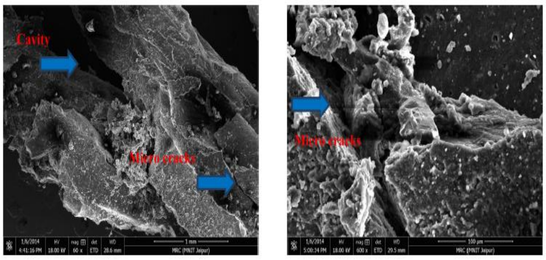


Figure.16. Weight loss of acid attacked specimens, w/c 0.4

Weight loss of acid attacked specimen: Figure 16 shows the weight loss values of acid attacked specimens. For 10% crumb rubber the loss in weight was found to be 7.61% when 10% crumb rubber were used. Formation of cracks and material separation were arrested by the crumb rubber particles present in the rubberized concrete. More cracks were developed with no crumb rubber or less amount of crumb rubber. Figure 17 shows the SEM image of acid attacked specimens.



(a) (b)

Figure.17. a) SEM image of rubber fiber @ 60 X magnification, b) SEM image of rubber fiber @ 600 X magnification

2. CONCLUSION

The presence of waste tyre rubber in concrete gradually decreases the flexural and compressive values. Abrasion resistance was observed better in rubberized concrete in comparison with the conventional concrete. The water penetration of rubber concrete was higher than control mix concrete. Therefore, its main application may be focussed in pavements, floors and concrete highways, hydraulic structures such as tunnels and dam spillways, etc., where the abrasive forces are applied by moving objects during service. Water absorption increases when the percentage of crumb rubber increases. Weight loss due to acid attacked specimen was very less when compared to conventional concrete. The areas of possibilities of acid attack can be utilized by the rubberised concrete, since it is highly resistant to aggressive environments.

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