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INFLUENCE OF TIRE CHIPS SIZE ON THE DURABILITY BEHAVIOR OF RUBBERIZED CONCRETE

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ABSTRACT

This study describes the effect of the tire chips size on durability properties of rubberized concrete. Recently a large no of researcher's point of interest is to work with rubberized concrete. They are hardly trying to utilize waste, discarded tires in environmentally safe ways. The rubberized concrete is one of those techniques. It is benificial to use scrap tire in concrete but durability of resulting concrete is one of the major concerns. Concrete structures may occasionally exposed to adverse weather, chemical attack, abrasion, electrolytic action etc. Although there are a different ways of testing durability of concrete like absorption test, rapid chloride permeability test etc. in this work, durability test by acid curing is adopted. The rubberized concrete is prepared with partially 7.5% aggregate replacement with tire chips. Same amount of coarse aggregate was replaced with different size tire chips as like 5mm×5mm, 10mm×10mm, 15mm×15mm and 20mm×20mm. After 28 days normal water curing the concrete specimens are kept in 5% H_2SO_4 acid curing for another 28 days. After that the compressive strength test is performed as the principal test criteria. The weight loss test is also carried out as reference. From durability point of view it is clear that tire chips size has strong relations with the durability behavior of rubberized concrete. Tire chips with smaller fragments are found to produce more durable concrete than larger fragments from compressive strength point of view. 5mm×5mm rubber performs best with a minimal strength reduction of 10.60% as compared to the same specimen in case of normal water curing. Recommendation is therefore made to use 5mm×5mm rubber chip replacement to get best result and the resulting concrete can be conveniently used for plain concrete slabs, embankment protection blocks, cement concrete pavements for low to moderately loaded roads etc.

Keywords: *Durability, Rubberized concrete, Scrap tire, Acid curing, Compression strength.*

1. INTRODUCTION

The durability of cement concrete can be defined as its ability to resist weathering action, chemical attack, abrasion and any other phenomenon of deterioration. Durable concrete will retain its original form, quality and serviceability when revealed to its environment. For a long time, concrete was considered to be very durable material requiring a little or no maintenance. The assumption is largely true except when it is subjected to highly aggressive environments. We build concrete structures in highly polluted urban areas and industrial areas, aggressive marine environments, harmful sub-soil water in coastal area and many other hostile conditions where other materials of construction are found to be non-durable and unsuitable. Since the use of concrete in recent years, have spread to highly harsh and hostile conditions, the earlier impression that concrete is a very durable material is being threatened, particularly on account of premature failures of number of structures in the recent past. In the past days, only strength of concrete was considered in the concrete mix design procedure assuming strength of concrete is an all-pervading factor for all other desirable properties of concrete including durability. Although compressive strength is a measure of durability to a great extent but it is not entirely true that the strong concrete is always a durable concrete. For instance, while it is structurally possible to build a jetty pier in marine conditions with 20 MPa concrete, environmental condition can lead this structure to a disastrous consequence. In addition to strength of concrete another factor, environmental condition or what is generally call exposure condition has become an important consideration for durability now-a-days. Concrete having a low permeability to water and dissolved chemicals will generally be durable in most exposure conditions. Permeability of concrete is impacted by water to cementitious materials ratio (w/cm), and type and proportions of cementitious materials used in the mixture. The w/cm is the ratio of the weight of mixing water to the weight of all cementitious materials. (Shetty, 2005).

A study on the experimental investigation of durability test on concrete cubes was held which is the characteristic strength for M30 grade of concrete and for micro concrete is checked. The cubes after 28 days of curing in water is immersed in 5% H_2SO_4 and 5% HCL of the total volume of water separately for 28 and 56 days to evaluate the decrement in the strength as compared to normal condition and showed that the compressive strength is reduced and the reduction slightly more at immersing in H_2SO_4 as compared to HCL (Patel et al., 2017). ACI 318 defines Exposure Classes (EC) within each Exposure Category based on the severity of exposure. Increasing severity is represented by higher numerical value in the EC designation. The numeral number “0” is used when the condition does not apply. The designer is required to assign the durability EC for each member type in a structure. This sets the basis and lends clarity to the requirements for concrete. Following Table 1 shows durability requirements for different exposure classes as described below in accordance with American Concrete Institute (ACI) standards.

Table 1: Minimum specified strength f_c' and max w/cm for ACI 318 durability exposure classes

Exposure Class	**Max w/cm**	**Min f_c' (psi)**
F0, S0, W0, C0, C1	None	2500
F1	0.55	3500
S1, W1	0.50	4000
S2, S3, F2, F3 (plain)	0.45	4500
C2, F3 (reinforced)	0.40	5000

The exposure classes are explained as:

Freezing and thawing exposure (Category F)

F0 for no exposure

F1 for a lower level of saturation when exposed to freezing

F2 for higher level of saturation and
F3 for higher level of saturation and the potential for application of deicing chemicals

Sulfate Exposure (Category S)
ECs (Exposure Classes) are defined based on concentration of water-soluble sulfates (SO_4^{2-}) in soil (% by mass) or water (ppm) in contact with the member.

S0	<0.10%	<150ppm
S1	0.10-0.20%	150-1500 ppm and seawater
S2	0.20-2.00%	<1500-10000 ppm
S3	>2.00%	>10000 ppm

Corrosion protection of reinforcement (Category C)
C0 for members dry in service
C1 for moist in service
C2 for moist and exposed to an external source of chlorides

Concrete in contact with water (Category W)
W0 for dry in service or in contact with water where low permeability is not required
W1 for concrete in contact with water requiring low permeability

2. METERIALS AND METHODS

2.1 Materials

In this study the materials used to produce the concrete mixtures were sand as fine aggregate, stone chips as coarse aggregate, cement as binder, water and tire chips (Figure 1) as partial replacement of coarse aggregate. Sulphuric acid was used for acid curing to observe durability characteristics (Patel et. al., 2017). All these materials were collected from convenient local sources in Dinajpur, Bangladesh. Maximum size of coarse aggregate was 19 mm. Potable water was used for concrete preparation conditioned to the room temperature. The waste tires were collected from local machinery workshop. The tire fibers without any metal wire had been selected and cut in different sizes as per requirement. The collected tire was cut into 5mm×5mm, 10mm×10mm, 15mm×15mm and 20mm×20mm sizes. American Society for Testing and Materials (ASTM) standard procedures were adopted to determine several properties of materials. Properties of materials are presented in Table 2.

Coarse aggregate   Fine aggregate

Tire chips

Figure 1: Materials; coarse aggregate, fine aggregate and tire chips

Table 2: Material Properties

Coarse Aggregate (Stone Chips)	Specific Gravity:2.73 Water Absorption: 1.12% Fineness Modulus: 6.87
Fine Aggregates (Sand)	Specific Gravity: 2.67 Water Absorption: 1.35% Fineness Modulus: 2.71
Tire Chips	Specific Gravity: 1.26 Water Absorption: 0.03% Thickness: 5 mm Colour: Ashy
Binding Materials (Ordinary Portland Cement)	Normal Consistency: 24% Initial setting time: 120 min Final setting time: 300 min 3-days compressive strength (50 mm cube): 22.9 MPa 7-days compressive strength (50 mm cube): 34.8 MPa 28-days compressive strength (50 mm cube): 41.4 MPa
Water	Potable water
Acid	5% Sulphuric acid

2.2 Identification of Mix Arrays

Tire chip or rubber content was kept fixed as 7.5% of coarse aggregate volume and water cement ratio was also kept constant as 0.45. A typical 1:1.5:3 proportioned (volumetric) concrete mixes was taken into account. Keeping all other factors identical, only variation was made in size of tire chips. Each of the mixes with different rubber sizes are designated with a letter as presented in Table 3.

Table 3: Designations of mix arrays

Mix Designation	Size of added tire chips (mm×mm)
A	-
B	5×5
C	10×10
D	15×15
E	20×20

2.3 Preparation of Specimen

Coarse aggregates are sieved and a well graded aggregate is prepared for the specimens. Collected tire is cut into required sizes manually. Concrete mix was prepared (Figure 2) and filled in the mold of size 100mm × 200mm. Mold is filled in 3 equal layers, layers are being compacted by a compaction rod with 25 strokes as per ASTM standard. Total 12 specimens for each mix designation were prepared among which 6 are for compressive strength test and the other 6 are for durability test.

Figure 2: Preparation of specimen

2.4 Laboratory Tests

The test specimens were subjected to compressive strength tests and durability tests. Compressive strength tests were conducted after 28 days curing of the cylindrical specimens following standard procedure as described in ASTM C39/C39M-12. To observe the behavior of rubberized concrete durability test by acid curing was adopted. The specimens were cured in water for 28 days. After 28 days curing in ordinary water, the specimens were allowed to cure for further 28 days in 5% sulphuric acid solution. At the end of acid curing, the specimens were subjected to compressive strength test.

3. RESULTS AND DISCUSSIONS

The durability of concrete can be defined as its ability to withstand weathering action, chemical attack, abrasion or any other process of deterioration. Durable concrete will retain its original form, quality and serviceability when exposed to its environment. In addition to strength of concrete another factor, environmental condition or what is generally called exposure condition has become an important consideration for durability. The test specimens for durability test were primarily cured in potable water. At its 28 days curing, cylinder surfaces were cleaned and weighed. The identified specimens were then immersed in 5% sulfuric acid solution for another 28 days. Compressive strength test results after acid curing of the specimens are given in Table 4.

Table 4: Compressive strength after water curing and acid curing

Mix type	Added rubber chips size	Strength after water-curing (MPa)	Strength after acid-curing (MPa)	Reduction of Strength (%)
A	-	29.51	26.2	11.22
B	5mm×5mm	26.31	23.52	10.60
C	10mm×10mm	20.11	16.94	15.76
D	15mm×15mm	17.64	14.55	17.52
E	20mm×20mm	15.93	12.52	21.41

The Table 4 shows the strength loss due to acid curing which gives an indication of its durability. The changes are presented graphically in Figure 3.

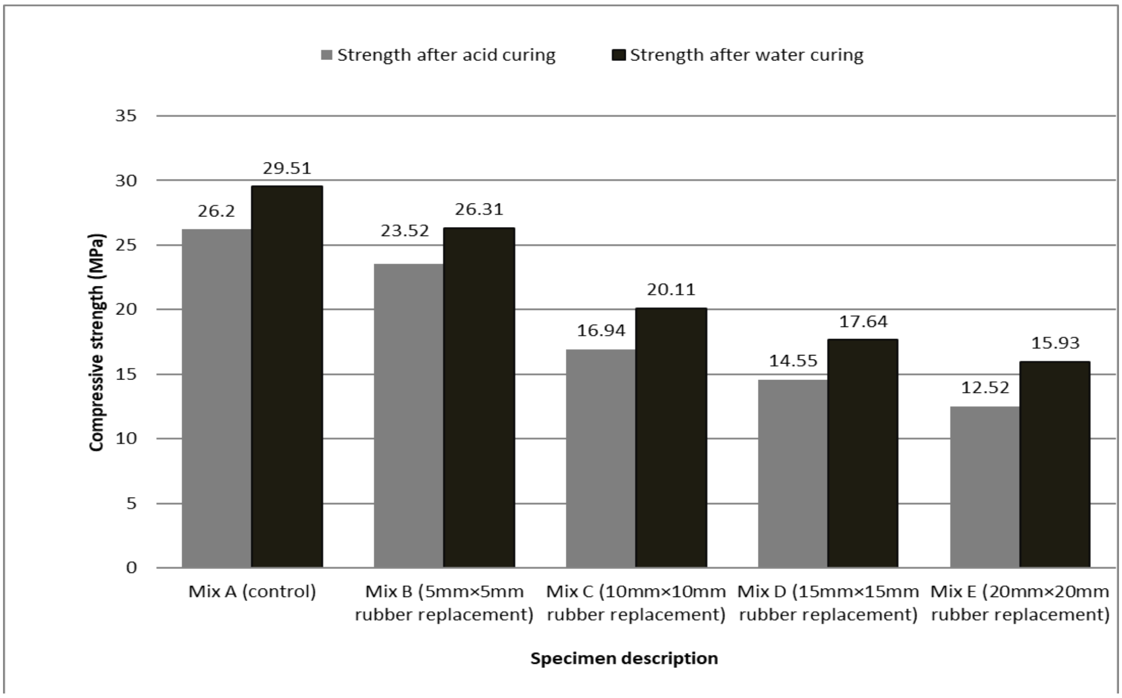

Figure 3: Compressive strength before and after durability test

According to ACI 318 Exposure Classes (EC), control specimen is durable for F1, F0, S0, W0, C0 and C1exposure conditions whereas mix B is applicable in F0, S0, W0, C0, C1 conditions. Due to rubber addition, the mix B fails to satisfy the requirement for exposure F1 condition. The other mixes C, D and E are not applicable in any of the exposure conditions defined by ACI 318 from durability point of view. A comparative picture of strength loss due to acid curing is shown in Figure 4.

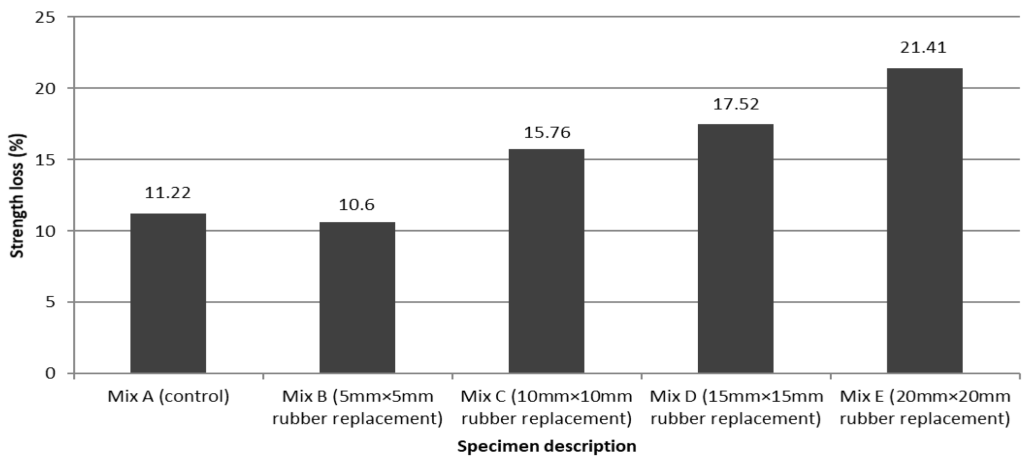

Figure 4: Strength losses due to acid curing

Weight loss measured after end of acid curing are tabulated at Table 5. The graphical representation of that is presented immediately below the table.

Table 5: Weight loss (%) due to 28 days acid curing

Specimen No	Added rubber chips size	Weight loss (%)
A	-	3.9
B	5mm×5mm	2.4
C	10mm×10mm	1.77
D	15mm×15mm	0.99
E	20mm×20mm	0.97

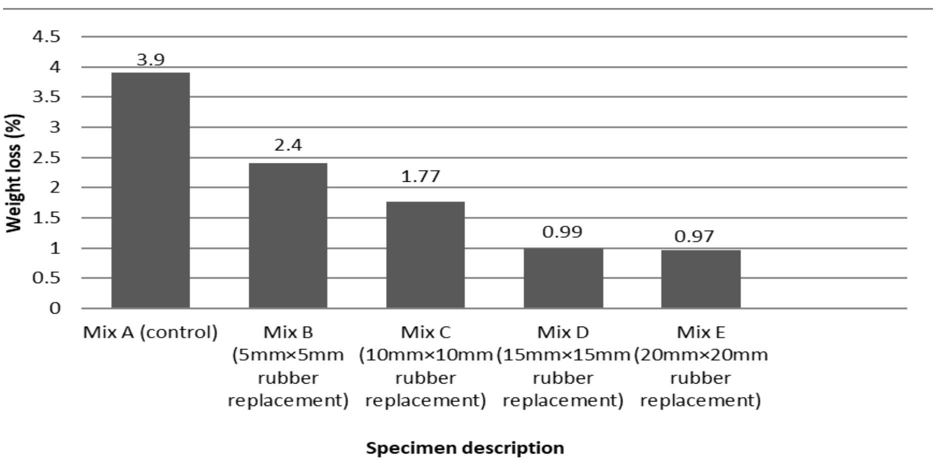

Figure 5: Weight loss due to acid curing

In case of rubberized concrete specimens, there was reduction in weight loss with the size of rubber chips increment. The reason behind this matter of fact may be the reaction between sulfuric acid and the cement constituent of concrete which causes the conversion of calcium hydroxide to calcium sulfate which, in turn, may be converted to calcium sulfoaluminate. The formation of calcium sulfate leads to softening of the concrete (Attiogbe et. al., 1988).

4. CONCLUSIONS

In this research work 7.5% rubber derived from waste tire was used to replace the coarse aggregates. Different size fractions were used as 5mm×5mm, 10mm×10mm, 15mm×15mm and 20mm×20mm. It is clear that tire chips size has strong relations with the durability behavior of rubberized concrete. Tire chips with smaller fragments are found to produce more durable concrete than larger fragments from compressive strength point of view. By durability concern the rubber chips of size 15mm×15mm and 20mm×20mm are totally rejected, 10mm×10mm may be accepted with cautions and 5mm×5mm can be accepted conveniently for various exposure conditions.

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