ABRASION RESISTANCE OF CEMENT CONCRETE CONTAINING WASTE TIRE RUBBER

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ABSTRACT. Disposal of waste tire rubber has become a major environmental issue in all parts of the world. Every year millions of tires are discarded, thrown away or buried all over the world, representing a very serious threat to the ecology. In this study, waste tire rubber particles were partially substituted for fine aggregates in normal strength and high strength cement concrete and the resistance to abrasion was measured. The results show that the use of tire rubber particles can improve the abrasion resistance of concrete, and can ensure its applications in pavements, tiles, or in places where there are abrasive forces between surfaces and moving objects.

Keywords: Recycling, Waste Tire Rubber, Abrasion.

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INTRODUCTION

Disposal of used tires is a global problem. It is estimated that, every year almost 1000 million tires end their service life and more than 50% are discarded without any treatment. By the year 2030, the number would reach to 1200 million tires yearly. (Including the stockpiled tires, there would be 5000 million tires to be discarded on a regular basis.) The practice of disposal by burning has proved to create serious fire hazards and environmental pollution. Disposal by land filling has become difficult because of the depletion of the available sites and due to sanitary infections by insects and rodents (Garrick, 2001; Benazzouk et al., 2007; Onuaguluchi et al., 2014; Su et al., 2014; Thomas et al., 2015).

One of the possible solutions for the use of waste tire rubber is to incorporate into cement based materials, to replace some of the natural aggregates. This attempt could be environmental friendly (as it helps to dispose the waste tires and prevent environmental pollution) and economically viable (as some of the costly natural aggregates can be saved) (Raghavan et al., 1998; Flores-Medina et al., 2014; Thomas et al., 2015).

Guneyisi (2010) explained that the use of crumb rubber as fine aggregates prolonged the setting time and the viscosity of concrete. Use of fly ash helped to diminish the negative effect of the crumb rubber and decrease the viscosity of the concrete. Issa and Salem (2013) studied on the use of recycled crumb rubber as fine aggregates in concrete. They have recorded good compressive strength for less than 25% replacements (for fine aggregates), while huge drop was noticed beyond 25% replacements. In the specimens with 25% crumb rubber, almost 8% reduction in concrete density was noticed. Dong et al. (2013) explained that the compressive and splitting tensile strength of concrete with treated rubber increased by 10-20% when compared to the concrete with uncoated rubber. The chloride ion resistance of concrete with coated rubber and the concrete without rubber were almost similar. The energy absorption capacity of the concrete with coated rubber had shown improvement.

Hence, the reuse of waste tire rubber in concrete could have both environmental advantages and at the same time ensure economic viability. In this regard, an attempt may be done to control the environmental pollution and to save the natural resources by using the discarded tire rubber for partial replacement for fine aggregates in cement concrete. In the literatures, the studies on the behaviour of rubberized concrete in sulphuric acid, silver nitrate spray test for rubberized concrete and the corrosion studies of reinforcement are missing.

In this paper, a comparative study on the resistance to acid attack of rubberized concrete and control mix concrete has been reported. Waste tire rubber in the form of crumb rubber was replaced for natural fine aggregates from 0% to 20% in multiples of 2.5%.

MATERIALS AND METHODS

The properties of the raw materials and the methods of preparation of the specimens for testing are described below.

Ordinary Portland Cement of grade 43, conforming to IS: 8112-1989 was used. Tire rubber was grinded into three sizes (powder form of 30 mesh, 0.8 to 2 mm, 2 to 4 mm). The Specific gravity of rubber powder was 1.05 and that of the other two sizes were 1.13. The three sizes of crumb rubber were mixed in definite percentages (2 to 4 mm size in 25%, 0.8 to 2 mm size in 35% and rubber powder in 40%) to bring it to zone II. The physical properties and chemical composition of cement are given in Thomas et al., 2014. The properties of cement were measured as per IS 8112:1989 and IS 4031. The physical properties of aggregate are measured as per the procedures given in IS 2386.

To investigate the suitability of discarded tire rubber as a substitute for fine aggregates in concrete, design of concrete was done as per IS: 10262-2010 with water-cement ratio 0.4. Water-cement ratios of 0.45 and 0.5 were also studied to study the variation in different properties. Crumb rubber was replaced for natural fine aggregates from 0% to 20% in multiple of 2.5%. The mix proportions of the control mix are given in Table 1. Super plasticizer was used as the admixture to arrive at the desired workability (above 0.91 in compacting factor test, given in Thomas et al., 2014). In these mixes, fifteen concrete specimens of size 100 mm were casted for acid attack test. The mixtures were prepared and casted at indoor temperature of 25-30°C. Moulds were covered with plastic sheets, soon after casting and de-moulded after 24 hours. Curing was done for 28 to 90 days in water tank, with controlled temperature of 25-27°C.

Table 1 Mixture Proportions of Fresh Concrete

WATER-CEMENT RATIO	CEMENT KG/M^3	WATER KG/M^3	COARSE AGGREGATES 10 MM KG/M^3	COARSE AGGREGATES 20 MM KG/M^3	FINE AGGREGATES KG/M^3	ADMIXTURE %
0.40	388.0	155.0	465.0	737.2	698.4	0.65
0.45	388.0	174.6	465.0	737.2	698.4	0.30
0.50	388.0	194.0	465.0	737.2	698.4	0

EXPERIMENTAL PROGRAM

Degradation can take place if the concrete is exposed to sulphuric acid environments. It is one of the key durability issues that affect the maintenance costs and life cycle performance of all the concrete structures. There can be presence of sulphuric acid in chemical waste, ground water, etc. In the case of concrete structures in industrial zones, there can be possibility of deterioration due to acid rains in which sulphuric acid can be one of the key components. Sulphuric acid attack is more disastrous than sulphate attack because of the fact that there would be a dissolution effect by the hydrogen ions in addition to the attack by sulphate ions. Corrosion of concrete due to the action of sulphuric acid can be characterized by the following reactions (Bassuoni and Nehdi, 2007; Thomas et. al, 2015).

Acid attack test was performed as per ASTM C 267-97 for a period of for total 84 days. Sulphuric acid of 3% concentration was taken as a medium for acid resistance test. Concrete specimens of 100 mm size were immersed in a container with dilute sulphuric acid solution. The solution was replaced once in 4 weeks. Three different tests were done on acid attacked specimens. Water absorption test was performed ASTM C 642 (2006) to study the changes in porosity of concrete due to acid attack. The concrete specimens were tested for water absorption after 28, 56 and 84 days of immersion in dilute sulphuric acid. The specimens were oven dried at 60°C for 3 days and then kept at room temperature for atleast 1 day (24 hours) and initial weight noted. Then it was immersed in water such that about 50 mm water was maintained on the top surface of the specimen. Then the final weight was noted after 48 hours. The values were compared with the water absorption values of the non-acid attacked specimens (Thomas et. al, 2015).

The saturated surface dry weight of concrete specimens immersed in sulphuric acid solution was determined after a light surface brushing and washing them lightly in tap water. Weight measurement was done after 28, 56, and 84 days of immersion in acid. The variation in weight was compared with the initial weight before immersion in acid solution. The compressive strength of acid attacked specimen was determined after 28, 56 and 84 days of immersion in acid solution. The cube specimen was placed on the compression testing machine in such a manner that the load was applied to the opposite side of cubes as cast (not to the top and bottom.) The load was applied without shock and increased gradually at a rate of 140 kg/sq cm/min until the resistance of the specimen breaks down to a stage where no greater load can be sustained. It was compared with the compressive strength of normal concrete (non-acid attacked), which was water cured for 28 days after casting (as given in Thomas et al., 2014) and the percentage loss in weight was reported.

RESULTS AND DISCUSSION

The results obtained from the experimental procedure were analyzed and discussed as below (Thomas et. al, 2015):

Acid Attack Test

Concrete specimens were immersed in 3% sulphuric acid solution for a period of 84 days. The following 3 tests were performed on the acid attacked specimens. Azevedo et al. (2012) studied on the acid resistance of HPC with 10% concentration of sulphuric acid. Increase in the rubber content lead to high mass loss degree. The concrete mix with 5% rubber, partial cement replacement with 15% flyash and 15% metakaolin exhibited almost same resistance of the control mix. The mix with 45% flyash and 15% metakaolin showed much higher acid resistance than the control mix.

Water Absorption of Acid Attacked Specimen

Figures 1 to 3 shows the comparison of the water absorption values of acid attacked specimens at 28, 56 and 84 days. In the case of concrete mixes with water-cement ratio 0.4; gradual increase in the amount of water absorption was noticed at 28 days in the mixes where the crumb rubber was replaced from 0% to 20% for fine aggregates. Same trend was noticed at 56 days and 84 days. At 84 days, the amount of water absorption for control mix was 2.89%, for the mix with 10% crumb rubber it was 3.15% and for the mix with 20% crumb rubber it was 3.32%. Similar pattern was observed for the series with water-cement ratios 0.45 and 0.50.

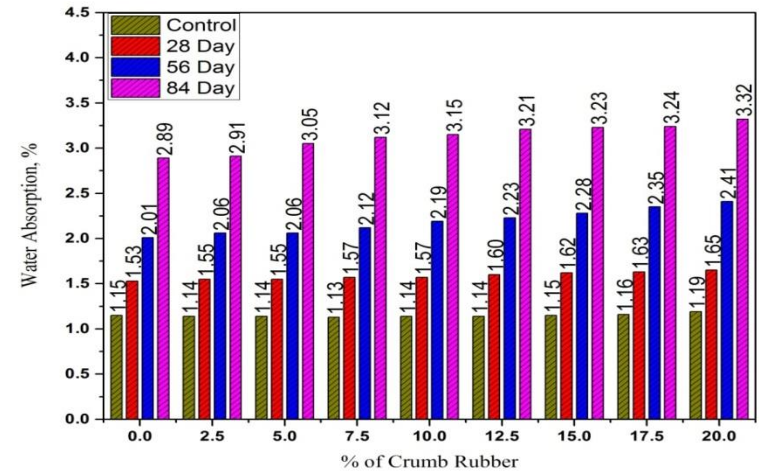

Figure 1 Water absorption of acid attacked specimens, water-cement ratio 0.4

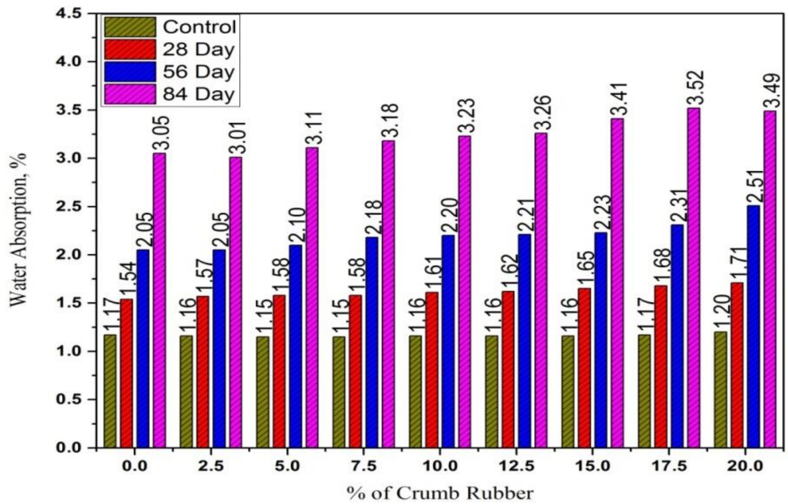

Figure 2: Water absorption of acid attacked specimens, water-cement ratio 0.45

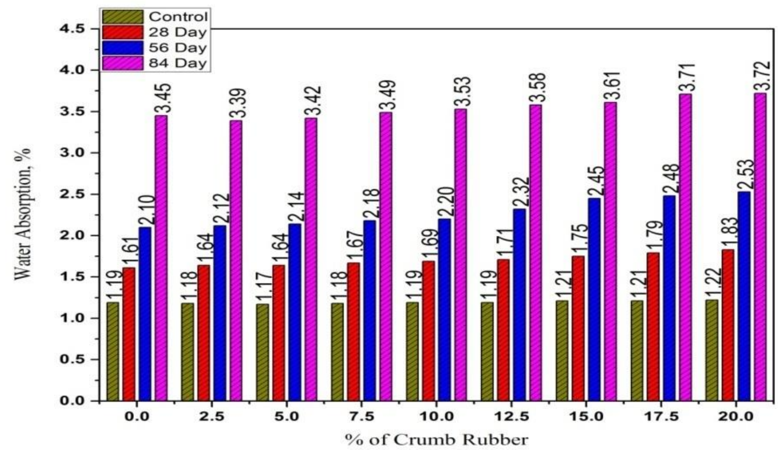

Figure 3: Water absorption of acid attacked specimens, water-cement ratio 0.5

The amount of water absorbed by the specimens had increased in all the concrete mixes when compared to the control mix with respect to the amount of crumb rubber and with respect to age. At the end of 28, 56 and 84 days, more destruction of the specimen took place with respect to the increase in the amount of crumb rubber. This may cause the occurrence of micro voids around the surface of the specimen and have enabled more water absorption. When we compare the water absorption of the control mix and that at 28, 56 and 84 days of acid attack, we can observe that the water absorption of specimens increases with time. As the water-cement ratio increases, the internal voids increases resulting in the increase in amount of water absorption for the increase in the rubber content.

When we observe Figure 4, the top layer of the concrete specimens with 0% crumb rubber was completely removed (100%) by the action of sulphuric acid. In the case of the mix with 20% crumb rubber, less than 100% top surface were attacked by acid. The rubber particles and the cementitious layer surrounding the rubber particles were unaffected by acid and have projected outwards by providing extra pockets to arrest the water. So the water absorption of rubberized concrete was higher than the control mix concrete.

Figure 4: Images of acid attacked specimen at 84 days. The specimen with 0% (left) and 20% (right) crumb rubber

Weight Loss of Acid Attacked Specimen

Figures 5-7 shows the comparison of the weight loss values of acid attacked specimens at 28, 56 and 84 days. At water-cement ratio 0.4, 0.45 and 0.5; more amount of weight loss was observed in the control mix specimens and it was found decreasing as the amount of crumb rubber was increased in the concrete. It means that the control mix specimens have recorded maximum loss in weight and the specimens with 20% crumb rubber have recorded the least loss in weight. In the case of w/c 0.4 and at 84 days, Maximum weight loss (8.5%) was recorded for the control mix and minimum weight loss was for the mix with 20% crumb rubber (7.24%). The percentage loss in weight was 7.61 for the mix with 10% crumb rubber. Similar trend has been observed for the series with water-cement ratios 0.45 and 0.50.

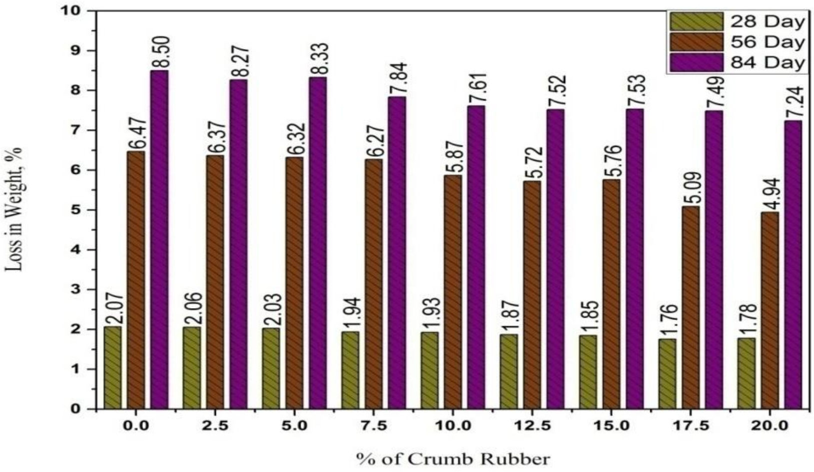

Figure 5: Weight loss of acid attacked specimens, water-cement ratio 0.4

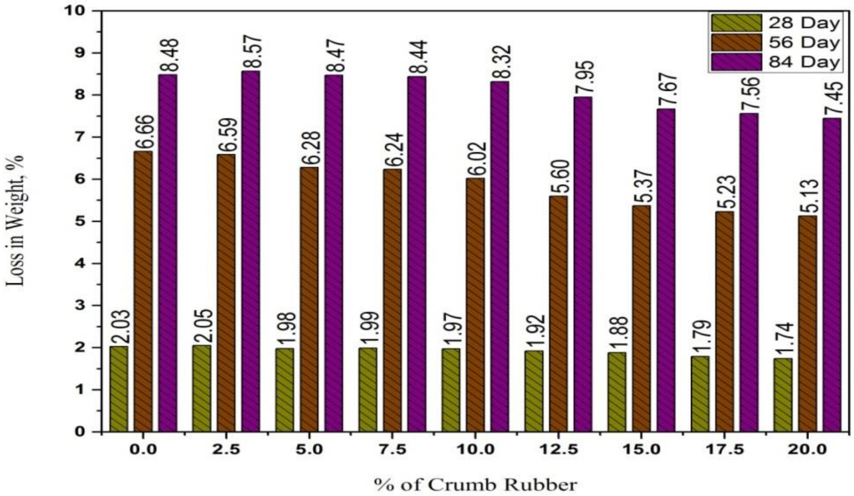

Figure 6: Weight loss of acid attacked specimens, water-cement ratio 0.45

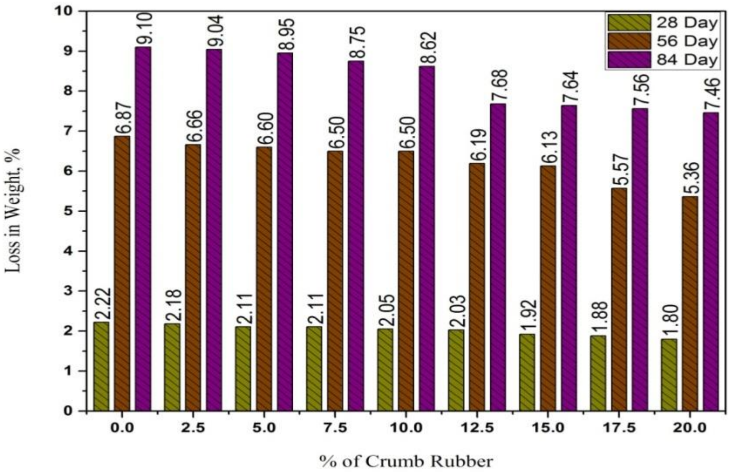

Figure 7: Weight loss of acid attacked specimens, water-cement ratio 0.5

The crumb rubber particles present in the rubberized concrete was holding the constituent particles of the concrete from breaking away by preventing the formation of cracks and material separation. While in the concrete with no crumb rubber or less amount of crumb rubber, more cracks were developed and the constituent materials were easily separated.

Compressive Strength Loss of Acid Attacked Specimen

Figures 8-10 shows the comparison of the compressive strength loss values of acid attacked specimens at 28, 56 and 84 days. There was more loss in compressive strength for the entire concrete specimen with respect to age and with respect to water-cement ratio. In the case of concrete mixes with w/c 0.4, 0.45 and 0.5, more reduction in compressive strength was observed when the exposure time in sulphuric acid was increased. Also, gradual reduction in the 'loss' was observed with the increase in the percentage of crumb rubber in concrete. In water-cement ratio 0.4 and at 84 days, the maximum loss in compressive strength (77.65%) was recorded for the control mix with 0% crumb rubber. The value was 65.67% for the mix with 10% crumb rubber and it was 56% in the mix with 20% crumb rubber. Similar trend has been observed for the mixes with water-cement ratios 0.45 and 0.5.

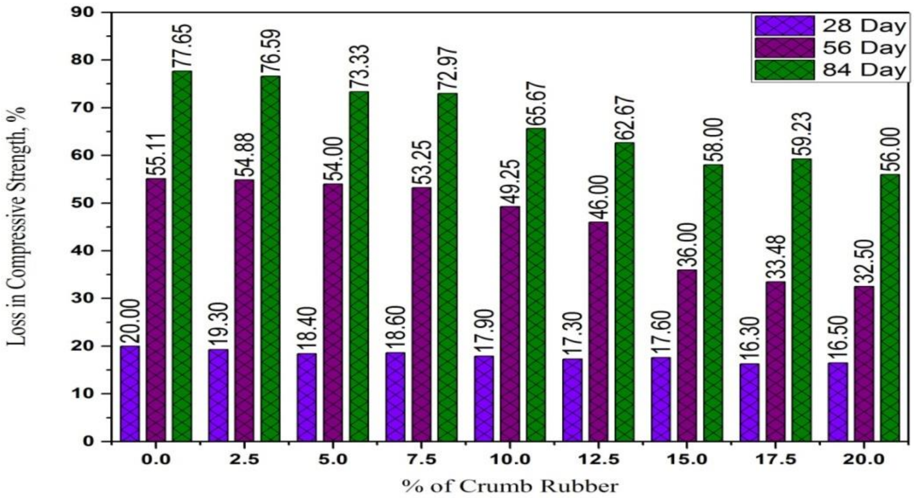

Figure 8: Reduction in compressive strength of acid attacked specimens, water-cement ratio 0.4

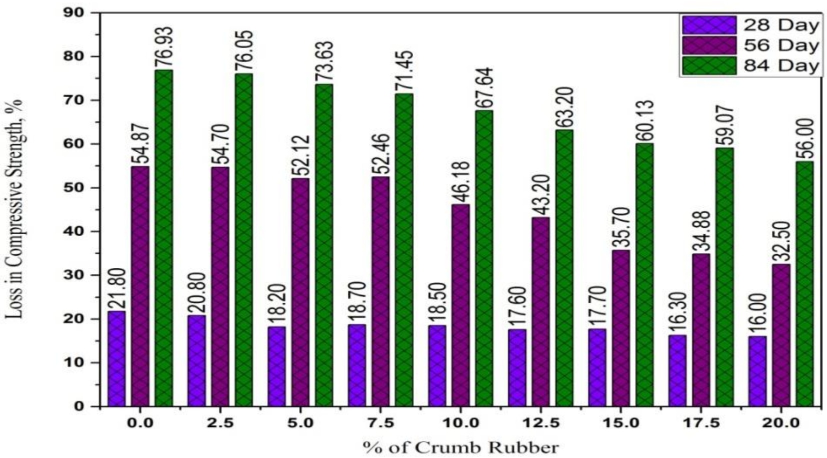

Figure 9: Reduction in compressive strength of acid attacked specimens, water-cement ratio 0.45

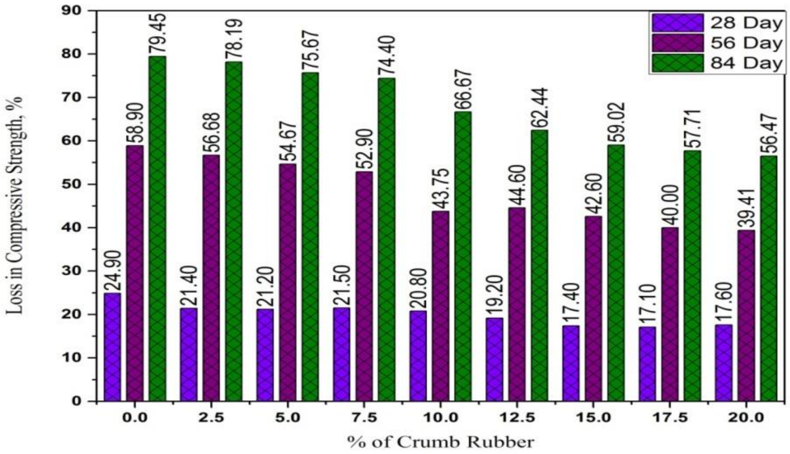

Figure 10: Reduction in compressive strength of acid attacked specimens, water-cement ratio 0.5

The crumb rubber particles present in the rubberized concrete was holding the constituent particles of the concrete from breaking away by preventing the formation of cracks and material separation. While in the concrete with no crumb rubber or less amount of crumb rubber, more cracks were developed and the constituent materials were easily separated. This may be one of the reasons for reduced loss in compressive strength for rubberized concrete. In the case of control mix concrete, it was noticed that all the six surfaces were affected by acid attack and 100% surface layer got deteriorated. In the case of rubberized concrete, all the six surfaces were affected by acid but less than 100% surface layer got deteriorated. Reduction in cross section of control mix was more than that of the rubberized concrete. After the acid attack, the net cross section of rubberized concrete was more than the control mix specimens**.**

CONCLUSIONS

The key findings from the experimental procedure of using crumb rubber as a partial substitute for fine aggregates in cement concrete are as follows:

. In the water absorption test of acid attacked specimens, gradual increase in the percentage of water absorption was observed as the percentage of crumb rubber was increased. In the weight loss test of acid attacked specimens, the maximum weight loss was observed in the control mix concrete and the minimum was observed in the mix with 20% crumb rubber. After acid attack, more losses in the weight and compressive strength were observed in the control mix concrete than the rubberized concrete. So it is clear that the rubberized concrete is highly resistant to the aggressive environments and can be implemented in the areas where there are possibilities of acid attack.

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