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The Effects of Seawater to Rubberized Pavement

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Abstract— *Recycling and Utilizing waste rubber as a replacement for natural aggregate in concrete is a promising environmentally friendly solution. The objective of this study is to evaluate the performance of concrete in terms of compressive and flexural strengths where the recycled rubber partially replaces the coarse aggregate. Seven different mixes were produced in which crumb rubber partially replaced fine aggregate by 0%, 10%, 20%, 30%, 50%, 75%, and 100% of volume. Rubberized concrete was tested for the slump, compressive strength, flexural strength, density, and seawater effect. The rubberized concrete mixes were easier to work with and had a lower density than the control mix. With increasing the coarse rubber content, compressive, tensile, and flexural strength were all reduced. The rubberized concrete mixtures performed well in seawater after only 28 days of curing. This study's findings provide an overview of the effect of adding recycled rubber to concrete used for various road constructions that are regularly susceptible to seawater intrusion, up to a 30 percent volume replacement of rubber cuts.*

Keywords— *Rubberized Pavement, Seawater, Flexural Strength, Compressive Strength.*

I. INTRODUCTION

The inclusion of appropriate materials to modify concrete properties is a popular field of concrete research. The brittle nature of concrete, as well as its poor loading toughness when compared to other materials, has spurred the usage of scrap tire particles as a concrete aggregate to potentially alleviate or lessen these drawbacks. Concrete qualities could be improved by using elastic and deformable tire–rubber particles. [1][2][3]. In many nations, waste tire management and disposal is a major environmental concern. Stockpiling is risky not just because of the potential negative environmental impact but also because it can cause fires and serve as a breeding ground for vermin, mice, insects, and flies [4][5][6].

The necessity of recycling old tires prompted researchers to look into using rubber as a partial replacement for rocks in concrete mixes in order to predict concrete qualities for various applications [7][8]. Several studies have found that increasing the rubber content of fresh rubberized concrete reduces its workability [9–13]. The slump of rubberized concrete decreased as the rubber content increased; the reduction was more substantial when utilizing relatively bigger tire chips than smaller crumbed rubber particles, and it was also more significant at high rubber particle substitution ratios [10][19].

Several authors confirm a steady decline in the density of rubberized concrete that they attributed to the lower relative density of rubber compared to natural aggregates [10][14][15–18]. Using chipped tire or crumbed rubber to replace coarse or fine aggregate at various replacement levels resulted in compressive strength losses in both cases, but the reduction in coarse aggregate replacement was greater than the reduction in fine aggregate replacement [10][20].

The primary goal of this research is to determine the compressive and flexural strengths of concrete incorporating recycled rubber from 0%, 10%, 20%, 30%, 50%, 75%, and 100% volume replacement to coarse aggregates. Slump, compressive strength, flexural strength, and density were evaluated. Also, this study will determine the amount of rubber replacement to the volume of coarse aggregates that can be used for roads frequently intruded by seawater.

II. MATERIALS AND METHODS

2.1. Materials

The following materials used in this research were as follows:

2.1.1. Cement: Ordinary Portland Cement (OPC) with a specific gravity was purchased from a local construction supply. The OPC compiles with the Type IP Portland cement as in Standard ASTM C150-05 (2005) (Specification for Portland Cement) specification.

2.1.2. Fine Aggregates: Source of fine aggregates from a local supplier taken from a quarry source with a maximum size of 4.76 mm.

2.1.3. Coarse Aggregates: Crushed stone coarse aggregates with a maximum size of 0.75 in or 19 mm.

2.1.4. Mixing Water: Potable water was used for concrete mixing from water supply sources. Water-cement ratio is 0.50.

2.1.5. Rubber Tire Chips: Maximum size is 0.50 inch or 12.7 mm without steel wires.

2.2 Methods

The following methods were adopted in this research were as follows:

2.2.1 Mixture proportion: The table shows the quantities of cement, sand, coarse, and rubber cuts per design mix. The mix required a 0.50 water-cement ratio. The control mix, A0 was used as the basis for preparing the other mixes: Mix B10, tire rubber cuts replaced 10% of the coarse volume; Mix C20, tire rubber cuts replaced 20% of the coarse volume; Mix D30, tire rubber cuts replaced 30% of the coarse volume; Mix E50, tire rubber cuts replaced 50% of the coarse volume; Mix F75, tire rubber cuts replaced 75% of the coarse volume and Mix G100, tire rubber cuts replaced 100% of the coarse volume.

2.3 Laboratory tests

2.3.1 Specific Gravity and Water Absorption of Fine and Coarse Aggregates: The test for the specific gravity and water absorption of aggregates was following ASTM C 128-79 (Used for Standard Criterion of Test for fine aggregates' Specific Gravity and Absorption). Specific gravity and percent absorption of fine aggregates was 2.68 and 3.63%, respectively. Specific gravity and percent absorption of coarse aggregates was 2.65 and 3.43%.

TABLE 1. Mix Design of Cement, Sand, Coarse and Tire Rubber Cuts

Mix Design	Cement (m^3)	Sand (m^3)	Coarse (m^3)	Tire Rubber Cuts (m^3)
Mix A0	0.01064	0.0216	0.0324	0
Mix B10	0.01064	0.0216	0.2916	0.00324
Mix C20	0.01064	0.0216	0.2592	0.00648
Mix D30	0.01064	0.0216	0.02268	0.00972
Mix E50	0.01064	0.0216	0.0162	0.0162
Mix F75	0.01064	0.0216	0.0081	0.0243
Mix G100	0.01064	0.0216	0	0.0324

2.3.2. Specific Gravity of Cement: The test for specific gravity of cement in the control and design concrete mixtures followed ASTM C150 (Standard Specification for Portland Cement). The specific gravity of cement was 3.15.

2.3.3. Sieve Analysis: Standard test method ASTM C136 was used for sieve analysis of fine and coarse aggregates. Sand passing through a 4.76 mm sieve was used in the concrete mix as fine aggregates.

2.3.4. Unit Weight of Aggregates: The unit weight of aggregates in a compacted or loose state was determined according to ASTM C 29-78 (Standard Method of Test for Bulk Density (Unit Weight) and Voids in Aggregates).

2.3.5. Mixing Procedure: To achieve uniformity, ASTM C305-82 (Standard Criterion for Cement Pastes and Mortars for Plastic Consistency) required proper mixing of cement, water, and aggregates. The homogeneity and blending of the ingredients determine the sample's strength.

2.3.6. Curing: ASTM C140-91 (Standard Test Methods for Sampling and Testing) was used, and the test specimen was stored at room temperature for 20 to 48 hours before being removed. After the specimens were removed, they were placed in a curing tank that was kept at room temperature. The curing periods were 7, 14, and 28 days for water and seawater, respectively.

2.3.7. Compressive Strength Test: The average compressive strength of concrete specimens was determined under a normal curing period of 7 days, 14 days, and 28 days of water and seawater. Standard test method ASTM C39-86 was used for the test.

2.3.8. Flexural Strength Test: The specimen was tested for flexural strength using the ASTM C 293 method (Standard Test Method for Flexural Strength of Concrete Using Simple Beam with Center-Point Loading).

III. RESULTS AND DISCUSSION

Table 2 shows the slump variations of new mix concrete. The control mix A0 has the most slump, whereas mix G100 has the least, as seen in the table. From Mix B10 to Mix D30, the slump increased, but from Mix D30 to Mix G100, it decreased. Even if the slumps fluctuated, as illustrated in Figure 1, the rubberized concrete sample demonstrated adequate workability for handling and placement.

TABLE 2. Slump Test Results

Mix Design	Slump, cm
A0	5.0
B10	2.4
C20	3.0
D30	3.3
E50	2.6
F75	2.3
G100	2.0

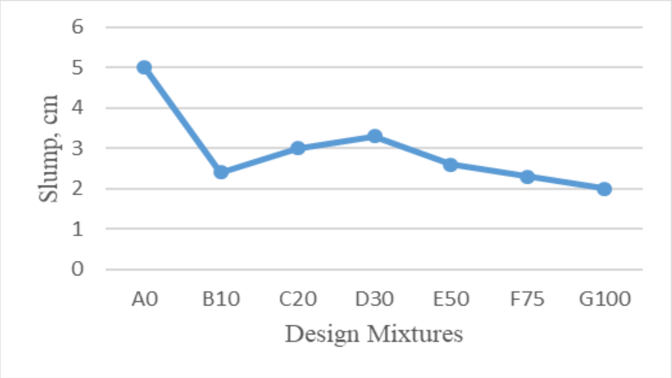

Fig. 1. Property of Concrete, Slump

As demonstrated in Table 3 and Figure 2, the unit weight of concrete falls from Mix A0 to Mix G100. The unit weights decrease as the percentage of tire rubber cuts to coarse volume is increased. The lower weight of tire cuttings replaced the considerably heavier coarse aggregates, resulting in a reduction in unit weight.

TABLE 3. Quantities and Properties of Materials

Mix Design	Density, kg/m^3
A0	2302.40
B10	2285.50
C20	2102.50
D30	1758.05
E50	1405.65
F75	1025.78
G100	865.24

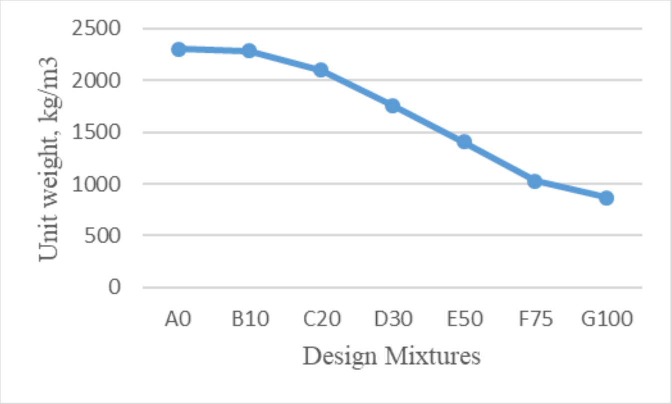

Fig. 2. Property of Concrete, Unit Weight

The results of the 7, 14, and 28-day compressive strength tests with a proportion of rubber substituting the coarse aggregate of the mix are shown in Table 4 and Figure 3. With more rubber substituting coarse aggregates, there is a considerable reduction in compressive strength. The strength decreased by 9.84 percent, 24.41 percent, 13.68 percent, 30.24 percent, 24.46 percent, and 20.39 percent from A0 to G100, respectively.

TABLE 4. Compressive Strength of Specimens (fc'), MPa

Mix Design	**Curing Period**		
	7 days (water)	**14 days (water)**	**28 days (water)**
A0	27.20	28.50	34.85
B10	25.80	26.7	31.42
C20	17.40	25.10	23.75
D30	13.38	18.6	20.5
E50	8.91	12.85	14.20
F75	6.30	9.12	10.3
G100	5.60	6.95	8.2

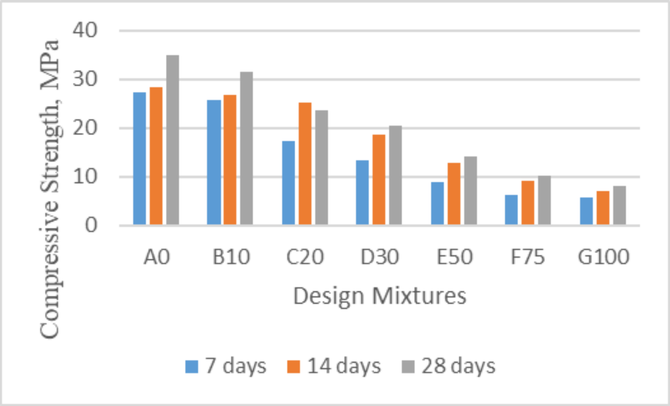

Fig. 3. Compressive Strength of Concrete (water curing)

The findings of the 28-day compressive strength of concrete cured in water and seawater are shown in Table 5 and Figure 4. After 28 days in seawater, the compressive strength of rubberized concrete specimens increased significantly for mixes B10, C20, and D30 increased slightly for E50, and decreased slightly for F75 to G100. This could be due to the reaction of seawater with the concrete mix.

TABLE 5. Compressive Strength of Specimens (fc'), MPa

Mix Design	**28 days (in water)**	**28 days (in seawater)**	**Difference**
A0	34.85	30.25	-4.6
B10	31.42	34.87	3.45
C20	23.75	26.02	2.27
D30	20.5	21.79	1.29
E50	14.20	15.04	0.84
F75	10.3	9.75	-0.55
G100	8.2	6.34	-1.86

Table 6 and Figure 5 below show the flexural strength of the specimens. The results showed that the flexural strength decreased as the rubber content in the mixture decreased. A considerable difference was seen for Mix B10, C20 and D30. As shown in the results, percent replacement of coarse aggregates is acceptable up to 30% with a strength of 4.22 MPa.

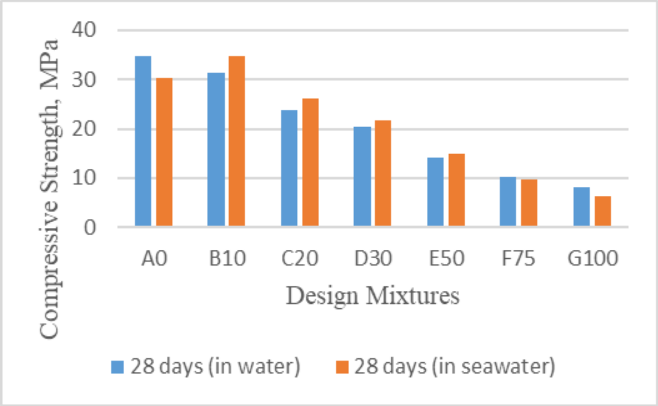

Fig. 4. Compressive Strength of Concrete

TABLE 6. Flexural Strength of Specimens, MPa

Mix Design	**Curing Period**		
	7 days	**14 days**	**28 days**
A0	7.08	9.59	11.43
B10	6.31	7.91	9.42
C20	4.98	6.05	7.12
D30	1.80	3.62	4.22
E50	1.38	2.90	3.34
F75	1.22	2.42	2.95
G100	0.92	2.20	2.62

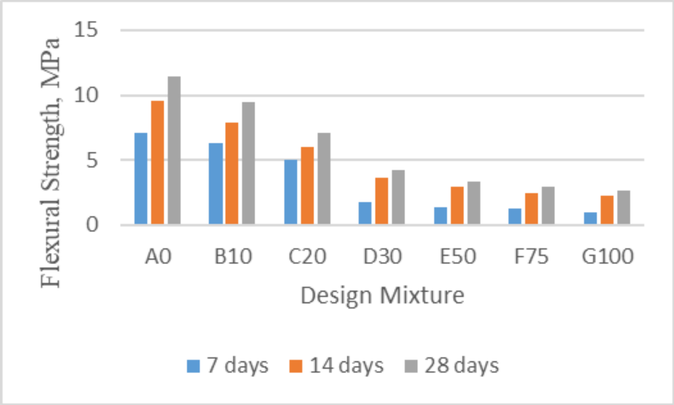

Fig. 5. Flexural Strength of Specimens

The comparison of flexural strength of concrete completely immersed in water and seawater is shown in Table 7 and Figure 6. Mixes B10, C20, and D30 showed an increase in flexural strength, while Mixes E50, F75 and G100 showed a decrease in flexural strength when completely immersed in seawater for 28 days. It was observed that Mix D30 could be recommended for roads with frequent water intrusion, having a strength of 4.31 MPa.

TABLE 7. Flexural Strength of Specimens, MPa

Mix Design	**28 days (in water)**	**28 days (in seawater)**	**Difference**
A0	11.43	12.85	1.42
B10	9.42	9.54	0.12
C20	7.12	7.44	0.32
D30	4.22	4.31	0.09
E50	3.34	2.42	-0.92
F75	2.95	2.0	-0.95
G100	2.62	1.80	-0.80

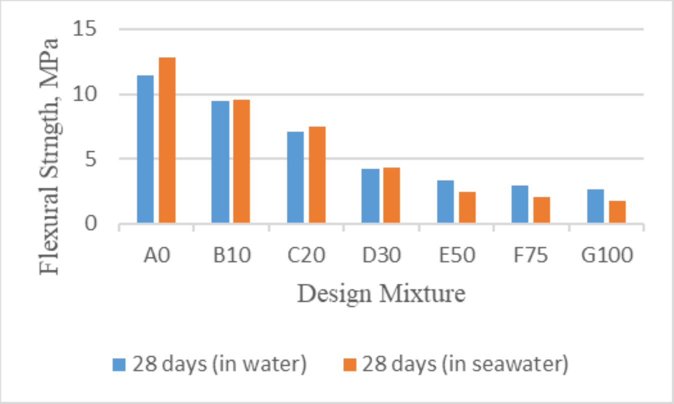

Fig. 6. Flexural Strength of Specimens

IV. CONCLUSIONS, RECOMMENDATIONS

4.1 Conclusion

4.1.1. Regardless of the amount of rubber cuts replaced with coarse aggregates, compressive strength decreased with increasing the proportion of rubber on both water and seawater curing. On the 28th day of saltwater curing vs. water curing, the compressive strength for 10%, 20%, and 30% rubber replacement to coarse aggregates showed a slight increase, opening the possibility of employing rubberized concrete with replacement levels up to 30% in on roadways often intruded by seawater.

4.1.2. The density of concrete reduces as the percentage of coarse rubber cuts replaced by coarse particles by volume increases.

4.1.3. The study found that slump outcomes fluctuated.

4.1.4. Flexural strength studies indicated that replacing 10%, 20%, and 30% of coarse rubber with coarse aggregates by volume increased flexural strength after 28 days of seawater curing, but that replacing 50%, 75, and 100% by volume decreased flexural strength.

4.1.5. In road construction susceptible to seawater intrusion, 30 percent of rubber to coarse aggregates in concrete mix can be used.

4.2 Recommendation

The tests were limited to compressive and flexural strengths, and the investigation was limited to coarse size rubber as a partial replacement for coarse aggregates. More research into the effects of seawater on rubberized concrete for extended seawater curing periods is needed. To check the overall performance of rubberized concrete, additional mechanical and chemical tests may be done.

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