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Ameliorating Precast Concrete Curbs Using Rubber and Nano Material

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Abstract

Disposal of waste tire rubber has become one of the major environmental issues in each part the World. One of the possible solutions to dispose of scrap tire rubber is using them into concrete curbs. This paper presents a new method to ameliorate the rubber concrete using a particular rubber size and Nano Material. Initially six mix designs were performed to determine the optimized size and percentage of rubber according to compressive strength. Afterwards, the major concrete curbs were made with the optimum mix design. Three different samples were made to determine the effects of rubber and Nano. One of which was made without rubber and Nano, the other was made with rubber and the last with rubber and Nano. Experiments were carried out to determine the durability and strength of specimens according to ISIRI-12728.

Keywords: Precast Concrete Curb; Waterproof; Tire Rubber.

1. Introduction

Disposal of waste tire rubber has attracted much attention among researchers due to whose major environmental issues across the world. Population growth and the greater use of vehicles have increased the generation of tire rubber. Millions of tires are discarded, thrown away or buried every year, representing a considerable threat to the environment. It was estimated that almost 1000 million tires end their service life every year and out of that, more than 50% are discarded to landfills or garbage without any treatment. It is forecasted that by the year 2030, there would be 5000 million tires to be discarded on a regular basis [1]. Many attempts have been made to address this problem, such as: (1) Incineration of scrap tire rubber for production of steam and (2) Reuse of tire rubber in cement concrete. Application of waste tire rubber as fuel is technically feasible, while it is not economically attractive due to high initial investment. The carbon black produced from pyrolysis of tires is of lower quality and more expensive comparing to that produced from petroleum products [1, 2].

Several researches have been carried out studying addition of scrap tire rubber as a replacement for aggregates in concrete [1-20]. Predominantly, Properties of rubber concrete are affected by the size and percentage of rubber. When used in concrete curbs, waste tire benefits concrete properties, including lower unit weight, higher ductility and freeze-thaw resistance [3]. A reduction in compressive strength and penetration resistance is also noticed with the increase of rubber percentage [4-6].

2. Literature Review

One of the most effective internal factors in concrete durability is permeability. A reduction in permeability of concrete would lead to an improvement of concrete characteristics including freeze-thaw resistance and corrosion of

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concrete and steel bars exposed to acids. Richardson et al. (2015) examined the optimum particle size of crumb rubber, used as an additive to concrete that would provide maximum freeze-thaw protection whilst minimizing the compressive strength loss. They implement crumb rubber divided into five batches, graded from <0.5 to 2.5mm. A notable improvement in freeze-thaw resistance observed [3]. Ganjian et al. (2009) carried out an experimental to investigate the effect of scrap tire rubber on water permeability. It was found that replacing the aggregates by rubber increased water permeability [4].

Generally, the main issue regarding the durability of rubber concrete curbs is to face with high permeability. Previous studies have used surface coating materials to improve permeability of concrete [21-23]. The aim of this study is to ameliorate the properties of rubber concrete such as penetration resistance. To improve penetration resistance of rubber concrete, a Nano material with Nano-organo silicon compound was used. The catalyst implemented in Nano material was environmentally friendly [24].

3. Test of Mechanical Properties

Avoiding absorption of concrete mixture water, the interior of mixing drum was wetted. Achieving saturated surface dry (SSD), aggregates were mixed first, followed by the required amount of water. After casting, all concrete specimens were stored in laboratory condition at 22 °C and 50% relative humidity for 24 hours and then were kept in completely humid environment for 28 days.

3.1. Test Materials

Ordinary Portland cement type-II (ASTM C150, Type-II) and tap water was used in performing tests. Calcareous aggregates were employed for both coarse and fine aggregates. Maximum size of coarse aggregates used to make concrete test samples was 19mm. The relative density and fineness module of the coarse aggregate were 2.6 and 5.6, respectively. The fineness module of fine aggregates was 3.3. Grain size distributions for fine and coarse aggregates are shown in Table 1 and 2.

Table 1. Fine aggregate grain size distribution

Sieve number	Mass of fine aggregate retained on each sieve (gr)	Cumulative retained (%)	Percent finer (%)
3/8	0	0.00	100.00
4	5	0.33	99.67
8	400	26.82	73.18
16	357	50.46	49.54
30	281	69.07	30.93
50	203	82.52	17.48
100	96	88.87	11.13
PAN	168	100.00	0.00

Table 2. Coarse aggregate grain size distribution

Sieve number	Mass of coarse aggregate retained on each sieve (gr)	Cumulative retained (%)	Percent finer (%)
1/2	0	0	100
3/8	146	10.62	89.38
4	1144	93.82	6.18
8	81	99.71	0.29
16	0	99.71	0.29
30	0	99.71	0.29
50	0	99.71	0.29
100	0	99.71	0.29

The rubber aggregates utilized to make concrete specimens were prepared from Waste Management Institute, Mashhad Branch. Rubber aggregates graded from 6 to12mm in size where in B specimens are 10% replaced with coarse aggregates. The specific gravity of rubber aggregates was 1.1 (Figure 1).

Figure 1. Rubber aggregates

Three heteropolyacids were used in the synthesis of a nano organo-silicon compound to build waterproof material. The product is uniform and the mean size is about 60-70 nm. Due to size range, Nano material can easily penetrate 3 mm in concrete via either spraying or brushing [24].

3.2. Mix Design

Mix designs are displayed in Table 1. Group A were to gain the maximum compressive strength and group B, on the other hand, were the major test samples that concrete curbs are made with. B1 is the mix design that is used in Takin-beton curb production. B2 is the optimized mixture obtaining from group A. B3 is the same mixture as B2 but Nano material was sprayed after two weeks.

Table 3. A group mix design for obtaining optimized mixture

Specimens	Cement (kg/m^3)	Water (kg/m^3)	Fine aggregates (kg/m^3)	Coarse aggregates (kg/m^3)	Chipped rubber by volume %	Crumb rubber by volume %
A-1	350	140	1159	483	15%	0
A-2	350	140	1159	193	30%	0
A-3	350	140	1069	667	0	10%
A-4	350	140	966	579	10%	10%
A-5	350	140	869	772	0	15%
A-6	350	140	1069	667	10%	0

4. Experimental Results and Discussion

The results of tests and their analysis are given below.

4.1. Water Absorption

Water absorption tests were performed where specimens were placed 72 hours in water and afterwards, 24 hours in oven. Results suggest less water absorption for specimens sprayed with Nano material compared to both normal and rubber concrete as can be seen in Figure 2. It is suggested that the nano-metric size of nano material cause easily penetration inside pores in the rubber concrete and provide molecular level hydrophobicity to the treated surface.

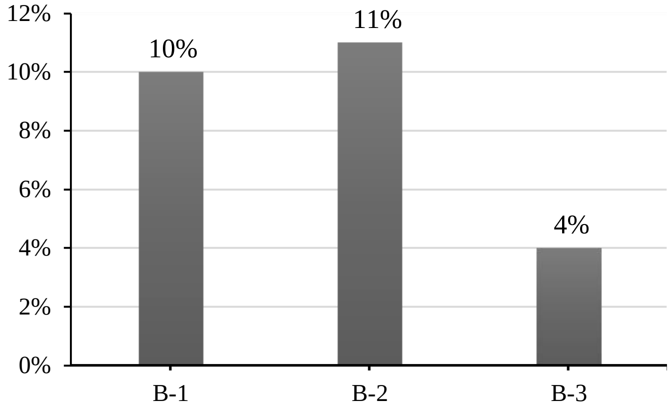

Figure 2. Result of water absorption for specimens B group

4.2. Compressive Strength

Compressive test were conducted at the age of 28 days using cylinder specimens 15cm × 30cm. The samples were cast and stored in ambient condition for 24 hours, and then cured in water reservoir for 28 days. Results are illustrated in Figure 3. Based on Figure 3 in line with the findings of other researchers, the highest compressive strength of specimens was observed in normal concrete.

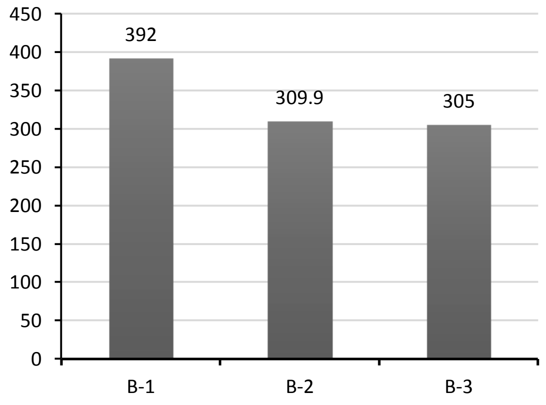

Figure 3. Result of compressive strength for specimens B group

4.3. Freeze-Thaw Resistance

Freeze-thaw resistance test was performed using 15cm ×15cm ×15cm cubic specimens. The surface was covered with 3% salt and was performed 28 freeze-thaw cycles. At the end, segregated particles are weighted and results are presented in kg/m^2. Results are shown in Figure 4. and compare to normal concrete addition of rubber can improve freeze-thaw resistance impressively.

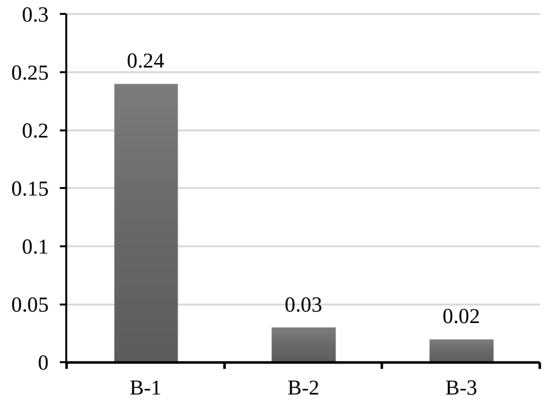

Figure 4. Result of freeze-thaw resistance for B group

4.4. Abrasion Resistance

According to ISIRI-12728 specimens using for abrasion test, must be $10cm \times 10cm \times 10cm$ [25]. Figure 5. demonstrates the results. Based on Figure 5, Abrasion resistance of concrete was increased with replacement of rubber.

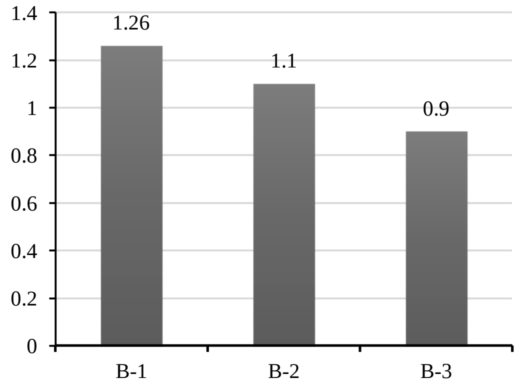

Figure 5. Result of abrasion B group

4.5. Splitting Tensile Strength

Splitting tensile strength test were performed using $15^{cm*}30^{cm}$ cylinder specimens and results are shown in Figure 6. As expected, due to weak bonding between rubber and cement paste tensile strength of concrete was reduced with replacement of rubber (Figure 7).

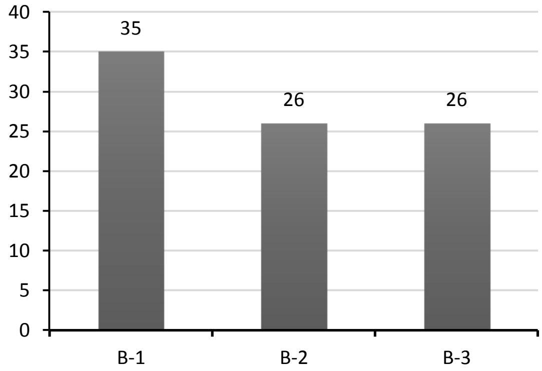

Figure 6. Result of splitting tensile strength B group

Figure 7. Splitting tensile strength test

5. Conclusion

According to examined samples and analysing data, the most important results were as follows:

- As nano-metric size of nano material cause easily penetration inside pores in the rubber concrete and provide molecular level hydrophobicity to the treated surface, water absorption of rubber concrete reduced.
- Specimens with rubber size range from 6 to 12mm, have more compressive strength compared to those less than 6mm and due to easier fragment process, have more economical reasons.
- Among all specimens, the maximum compressive strength was observed in normal concrete and compared with normal concrete; rubber concrete compressive strength is 20 percent lower.
- Tensile strength of concrete reduced with the replacement of rubber. Since bonding between rubber and cement paste is poor, the addition of rubber reduces the bonding and cause reduction in tensile strength.
- Due to freeze-thaw resistance test, rubberized concrete has better performance than normal concrete. This can make usage of rubber in concrete curbs reasonable.
- Abrasion resistance test indicates higher resistance of rubber concrete and utilizing of nano material can also improve abrasion resistance.

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