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Strength Evaluation of Ordinary Concrete having Crumb Rubber Pre-treated with Caustic Soda and Bleaching Powder Solutions

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ABSTRACT

In this investigation crumb rubber was pre-treated with the alkaline solutions of NaOH and Chloride of lime (calcium hypochlorite) for one day before employing in concrete as a fractional substitute of sand. The substitute proportions were fixed as 5% and 10%. Compressive, flexural, and split cylinder strengths of rubberized concrete were investigated. Rubberized concrete was also evaluated in terms of porosity. The incorporation of treated rubberized particles reduced the strength of the end products. The porosity was enhanced by incorporating treated crumb rubber. However, the concrete samples having crumb rubber treated with bleaching powder provided comparatively better results in terms of strength as well as water absorption. The use of crumb rubber to develop rubberized concrete will decrease the geohazard produced by the blazing and disposal of trash tire rubber.

KEYWORDS: Rubberized concrete, alkaline treatment, mechanical strength, porosity.

1 INTRODUCTION

Concrete is a versatile material and is used in constructing different residential, commercial and industrial buildings. Concrete has good properties and is a cost-effective structural material. Precious natural resources like clay, sand and rocks are used for manufacturing of concrete. Sustainable development goals demand for preservation of natural resources. Researchers are interested in exploring alternatives to concrete ingredients. Use of crumb rubber in place of sand is one of the efforts. Upcycling of waste rubber tires has two advantages: preservation of sand and safe disposal of tires [1,2]. The discarding of waste tires is an important environmental obligation and concern. Since the trash tires degrade at an extremely slow rate and their decomposition takes hundreds of years in ambient conditions, they are normally buried in landfills [3]. Worldwide, about one thousand million waste tires are generated annually. By the next one decade, the digits are anticipated to increase by about 20% [4]. In the developed countries, the most common method of getting rid of these waste materials is to bury them in landfills. However, the huge number is continuously reducing the service life of the dumping lands, which largely compromises the efforts for sustainability. The effective recycling of trash tires is therefore an instant and critical matter for nature conservation [5], [6]. Several researchers have worked out reusing waste tire particles in concrete. Some literature reviews are presented here.

Gerges et al. re-used the crumb rubber at rate of 5%,10%. 15% and 20% by volume of sand in concrete. The recycling reduced the compressive strength and density but enhanced the dynamic properties [7]. The dynamic performance was examined through toughness and impact resistance. Letelier et al. recycles the waste tires powder as a fractional substitute of fine aggregates for producing rubber mortars. The substitute was added by 10% and 15%. The substitution reduced the density of the mortars. The strength increased at 10% substitution and decreased at 15% [8]. Cotter et al. added shred rubber to reinforced concrete. The mix contained 34 kg cement, 10 kg sand and 12.4 kg rubber. The authors have reported that the hardened concrete can be nailed with the same ease as the lumber. It has also been added that the concrete has a higher strength than the lumber and is ductile in nature [9]. Pham et al. developed a low-weight concrete by partially substituting sand and gravel with rubber particles. The substitution levels were fixed as 15% and 30%. Their developed concrete was higher in impact resistance than the control concrete. The authors have reported that the increase was 50% and 80% for 15% and 30% replacements. [10]. Matsimbe et al. developed a rubber concrete by replacing fine aggregates with shred rubber. The substitution levels were fixed as 5%, 10%, and 15%. They have reported that up to 5% partial substitution of sand with rubber, the strength of the material was higher than the reference sample. The density and thermal insulation were also improved with rubber. The authors attributed the reduction of strength beyond 5% to higher porosity, inferior binding of the rubber with cement paste and a weak interstitial transition zone [11]. Choudhary et al., developed a rubber concrete by partially substituting sand with rubber at the rate of 10%, 20% and 30%. The authors identified a reduction in the slump as well as in the compressive strength with rubber content. [12]. Deshpande et al. investigated the effect of pre-treatment of rubber particles on the characteristics of the concrete. The investigators soaked the rubber particles in a solution Caustic Soda before mixing with the concrete ingredients. The authors revealed that the pretreatment leads to a higher strength than that with untreated rubber particles [13].

The purpose of the present research is to improve the bonding between the rubber particles and the cement paste by pretreatment of rubber particles with caustic soda and beaching powder solutions. The performance of the prepared samples was evaluated through voids content and strength. The goal is to effectively dispose of this important waste in making an important industrial material, concrete. This will reduce the environmental burden and make the construction eco-friendlier.

2 MATERIALS AND METHODS

For this work, three types of concrete mixtures were prepared: control specimens, and the specimens containing crumb rubber pretreated with NaOH and bleaching powder. In the later, 5 and 10% sand was replaced with crumb rubber. Grade 53 cement, Lawrencepur sand and Margalla crush were used. The concrete mix composition is shown in Table 1. Whereas the material properties of sand and crumb rubber are mentioned in Table 2. The particle size distribution is shown in Figure 1. The particle size distribution was within the limits as specified in ASTM limits.

Table 1: Mix composition of concrete

Sample	Cement (kg)	Sand (kg)	Coarse aggregates (kg)	Crumb rubber (kg)	Water (l)
C0	36	72	144	0	18.72
C5	36	68.4	144	3.6	18.72
C10	36	64.8	144	7.2	18.72

Table 2: Comparison of physical properties between sand and crumb rubber

Material	Specific gravity	Water absorption	Fineness modulus
Sand	2.69	3.8%	2.7
Crumb rubber	1.62	1.27%	3.5

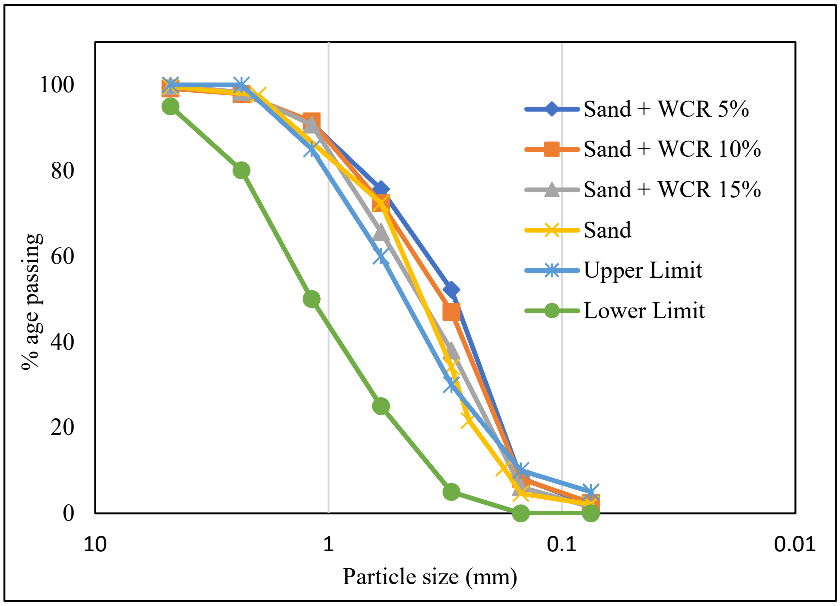

Figure 1: Sieve analysis of fine aggregates containing crumb rubber

The crumb rubber, caustic soda and bleaching powder are shown in Figure 2. The concrete mix was prepared, cast and cured according to ASTM C192 standard method [13] as shown in Figure 2. Two types of samples were prepared: cylinders (150 mm ø x 300 mm) for compressive test, and beams (100 mm x 100 mm x 500 mm) for flexural strength. For each test, three specimens were prepared to arrive at an average and true representative of the parameter.

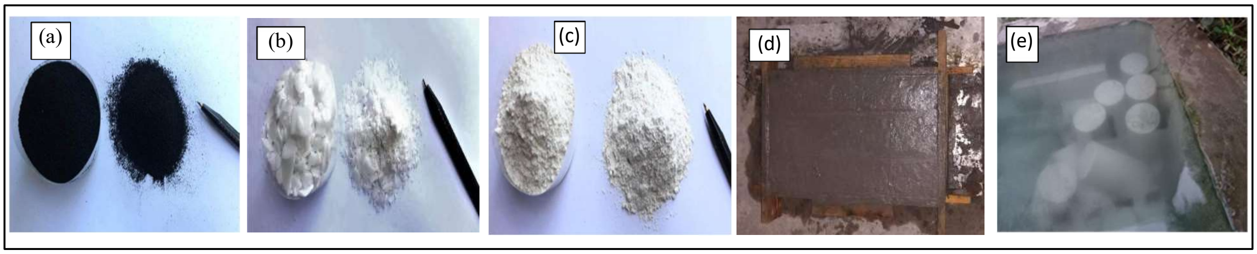

Figure 2: (a)Crumb rubber, (b)Caustic soda, (c)Bleaching powder, (d) casting and (e)curing

The prepared specimens were tested for their mechanical properties and porosity. The compressive strength was determined with ASTM C39 [14]. The flexural and split cylinder tensile strengths were determined with ASTM C78 [15] and ASTM C496 standard methods [16] respectively. The porosity was determined with standard water absorption method ASTM C949-80 [17].

3 RESULTS AND DISCUSSION

3.1 Compressive strength

The results of the compressive strength are provided in Figure 3. The compressive strength decreases with rubber content. There is a reduction of 8% in compressive strength with 5% replacement, whereas with 10% replacement, the reduction of 32% took place. The compressive strength depends on the density of the material [18], and since rubber particles reduce the density, the compressive strength gets reduced.

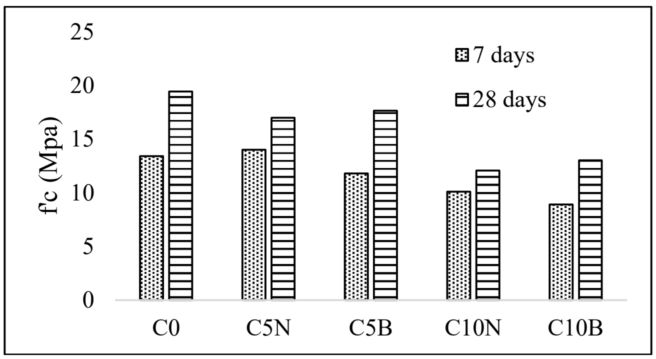

Figure 3: Compressive strength (MPa) as a function of crumb rubber quantity

3.2 Flexural strength

The results of the flexural strength are presented in Figure 4. The flexural strength considerably reduces with the rubber content. The typical flexural strength of normal concrete ranges from 2-3.5 MPa. Moreover, it depends on the bond between the concrete ingredients [19]. The results demonstrate that the rubber particles provide weaker bond, which results in a lower flexural strength.

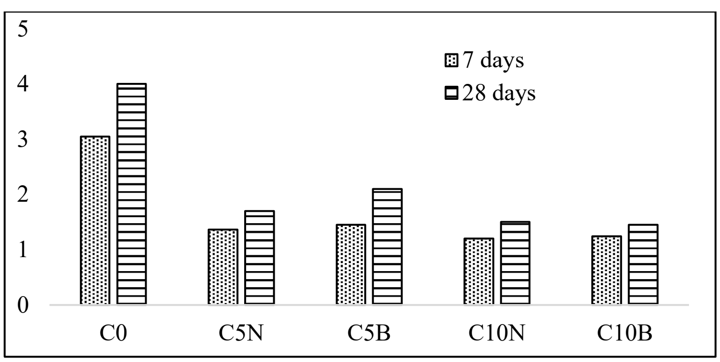

Figure 4: Flexural strength (MPa) as a function of crumb rubber quantity

3.3 Split cylinder tensile strength

The results of the indirect tensile strength are displayed in Figure 5. The tensile strength results are better than those of the flexural strength. The tensile strength follows the same trend as compressive strength. There is a reduction of 16% and 30% with 5% and 10% replacement respectively.

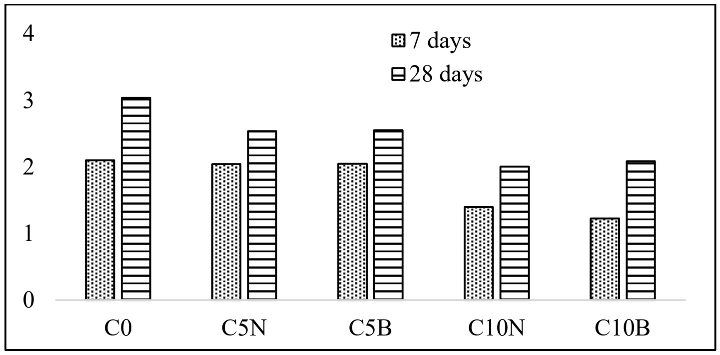

Figure 5: Split cylinder tensile strength (MPa) as a function of crumb rubber content

3.4 Porosity

Porosity was measured in terms of water absorption in the concrete samples and the results are shown in Figure 6. The results demonstrate that the water absorption increases with increase in rubber content, which is an indirect measure of porosity. The results also indicate that bleaching powder comparatively induces lesser porosity than the caustic soda. And this explains the marginal increase in strength with bleaching powder than with the caustic soda.

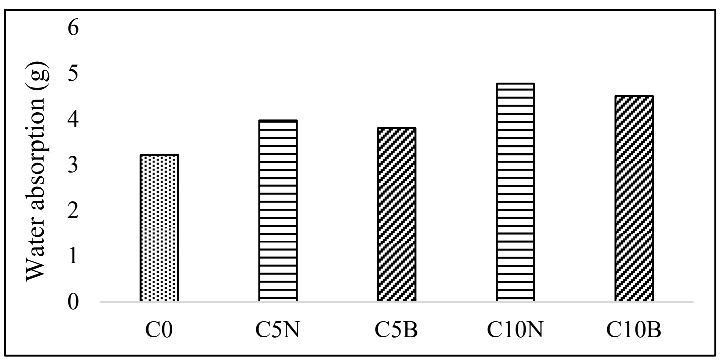

Figure 6: Water absorption as a function of rubber content

4 CONCLUSIONS

This study investigates the effect of rubber content pretreated with caustic soda and bleaching powder and added as a fractional substitute of fine aggregates in concrete. Based on the experimental results, the followings are concluded:

1. The compressive strength reduced by 12% and 37% for 5% and 10% replacement respectively by rubber particles treated with caustic soda.
2. The compressive strength reduced by 8% and 33% for 5% and 10% replacement respectively by rubber particles treated with bleaching powder.

3. The split cylinder tensile strength trails the same pattern as that of the compressive strength.
4. The water absorption increased by 25% and 50% for 5% and 10% replacement respectively while using caustic soda. Whereas the water absorption was enhanced by 18% and 40% for 5% and 10% replacement respectively with bleaching powder.
5. The results demonstrate that the porosity has a direct relationship with the mechanical strength and the type of chemical for pretreatment influences the mechanical strength.

REFERENCES

1 Khan, R.B.N., and A. Khitab, .*Enhancing physical, mechanical and thermal properties of rubberized concrete*. Engineering and Technology Quarterly Reviews, 2020; **3**: p.33–45.

2 Khitab, A., and R.B.N. Khan, .*SUITABILITY of concrete incorporated with scrubbed rubber tire particles: assessment based on destructive and non-destructive testing*. Pakistan Journal of Engineering, 2022; **1**: p.6–22.

3 Parvez, N.,, J. Khatti, and K.S. Grover, .*Effect of waste tyres as partial replacement of fine aggregate in concrete for construction*. SSRN Electronic Journal, 2019; : p.313–20.

4 Pacheco-Torgal, F.,, Y. Ding, and S. Jalali, .*Properties and durability of concrete containing polymeric wastes (tyre rubber and polyethylene terephthalate bottles): an overview*. Construction and Building Materials, Elsevier Ltd; 2012; **30**: p.714–24.

5 Hernández-Olivares, F.,, G. Barluenga,, M. Bollati, and B. Witoszek, .*Static and dynamic behaviour of recycled tyre rubber-filled concrete*. Cement and Concrete Research, 2002; **32**: p.1587–96.

6 Yung, W.H.,, L.C. Yung, and L.H. Hua, .*A study of the durability properties of waste tire rubber applied to self-compacting concrete*. Construction and Building Materials, 2013; **41**: p.665–72.

7 Chen, H.,, D. Li,, X. Ma,, Z. Zhong, and E.S. Abd-Elaal, .*Mesoscale analysis of rubber particle effect on young's modulus and creep behaviour of crumb rubber concrete*. International Journal of Mechanics and Materials in Design, Springer Netherlands; 2021; **17**: p.659–78.

8 Letelier, V.,, M. Bustamante,, P. Muñoz,, S. Rivas, and J.M. Ortega, .*Evaluation of mortars with combined use of fine recycled aggregates and waste crumb rubber*. Journal of Building Engineering, 2021; **43**: p.103226.

9 Pham, T.M.,, J. Liu,, P. Tran,, V.L. Pang,, F. Shi,, W. Chen,, H. Hao, and T.M. Tran, .*Dynamic compressive properties of lightweight rubberized geopolymer concrete*. Construction and Building Materials, 2020; **265**.

10 Matsimbe, J., .*Engineering and technology quarterly reviews*. 2020; : p.82–90.

11 Choudhary, R.,, J. Khatti, and K.S. Grover, .*Effect on water retention of different mortar mix with different percentage of fine crumb rubber*. SSRN Electronic Journal, 2019; .

12 Deshpande, N.,, S.S. Kulkarni,, T. Pawar, and V. Gunde, .*Experimental investigation on strength characteristics of concrete using tyre rubber as aggregates in concrete*. International Journal of Applied Engineering Research and Development (IJAERD), 2014; **4**: p.97–108.

13 ASTM C192/C192M-19, .*Standard practice for making and curing concrete test specimens in the laboratory*. West Conshohocken, PA, 19428-2959 USA; 2020.

14 ASTM C39, .*Standard test method for compressive strength of cylindrical concrete specimens*. American Society for Testing and Materials, 2016; : p.1–7.

15 ASTM C78/C78M, .*Standard test method for flexural strength of concrete (using simple beam with third-point loading)*. West Conshohocken, Pennsylvania UnitedStates; 2018.

16 ASTM C496 / C496M-17, .*Standard test method for splitting tensile strength of cylindrical concrete specimens*. West Conshohocken, PA; 2017.

17 ASTM C949-80(2020), .*Standard test method for porosity in vitreous whitewares by dye penetration*. West Conshohocken, PA, 19428-2959 USA; 2020.

18 Subhani, A.K.,, M. Nisar, and A. Khitab, .*Improvement of early-age mechanical properties of cement mortar by adding biochar of the santa maria feverfew plant*. *CSCE 2023*. Basel Switzerland:

MDPI; 2023. p. 7.

19 Tayyab, S.,, A. Khitab,, A. Iftikhar,, R.B.N. Khan, and M.S. Kirgiz, .*Manufacturing of high-performance light-weight mortar through addition of biochars of millet and maize*. Waste Disposal & Sustainable Energy, 2023; **5**: p.97–111.