RUBBERIZED CONCRETE: OPTIMUM DURATION OF PRETREATMENT OF RUBBER PARTICLES WITH ALKALINE SOLUTIONS

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Abstract- Rubberized concrete incorporates waste rubber particles as a partial replacement for sand, providing an innovative solution for the disposal of waste rubber tires and reducing the demand for natural sand in concrete production. Despite its environmental benefits, untreated rubber particles adversely affect concrete workability, density, and strength. However, pretreatment with alkaline solutions can mitigate these effects. This study investigates the impact of pretreatment with NaOH and bleaching powder solutions on the workability and density of rubberized concrete, focusing on the effect of soaking time. The results indicate that a 2-hour soaking time optimally enhances the workability and reduces the density of the concrete mix. Soaking beyond 2 hours results in a reduction in both slump and density, which could be detrimental to the concrete's strength.

Keywords- Rubberized concrete, pre-treatment, soaking time, alkaline solution.

1 Introduction

Approximately 30billiontons of concrete are produced globally in a year [1]. Natural aggregates for concrete are sourced from rocks and mountains, and the excessive use of natural sand in construction is disrupting the naturally balanced environment of the world [2]. Sand is not only heavily used in construction but also in electronic devices as a source of silicon. On the other hand, waste rubber tires are non-biodegradable and are often dumped in earth pits. In developing countries like Pakistan, people use them as fuel, which emits toxic gases into the environment. This situation necessitates the exploration of alternative materials to replace sand and the safe recycling of rubber tires. In the past, numerous studies have been conducted to recycle rubber tires in building materials. Due to the nature of rubber, many researchers believe that rubber can be used as a partial replacement for sand in cementitious materials. A few relevant past studies are described as follows:

Gerges et al. conducted a study using rubber powder as a partial replacement for sand in concrete. The replacement levels were fixed at 5%, 10%, 15%, and 20%. The results revealed a reduction in compressive strength with an increase in toughness and impact resistance. The reduction in compressive strength was attributed to the lower level of adhesion between the cement paste and the rubber particles. [3]. Khan et al. examined the effect of rubber particles as a partial replacement for sand in concrete. The substitution levels were kept at 0%, 5%, 10%, and 15%. The results demonstrated a decrease in mechanical strength. The rubberized concrete was reported to have lower density and lower thermal conductivity. The decrease in strength was attributed to the lower level of bonding between the cement paste and the rubber particles [4]. Anwar et al. developed a porous concrete with enhanced skid resistance using rubber particles as a fractional substitute for sand. The replacement proportions were fixed at 0%, 5%, 10%, and 15%. The rubberized concrete exhibited lower mechanical strength, lower density, higher thermal insulation, and higher skid resistance in both wet and dry conditions. The reduction in strength was attributed to the elastically deformable and softer nature of the rubber particles, which induced additional pores and resulted in lower adhesion between the cement paste and the rubber particles [5]. For the enhancement of the bonding between the cement paste and the rubber particles, several other researchers have proposed pre-treatment of rubber particles with a compatible chemical before mixing with the concrete ingredients. Roychand et al. pre-treated the rubber particles in tap water and in a 5% dilute sulfuric acid solution for 2 and 24 hours before mixing. The

authors reported an increase in bond strength between the rubber particles and the cement paste and enhanced overall strength with the pre-treated rubber particles soaked for 2 hours. They found that the water molecules present in the rubber particles replaced the air inside the pores, facilitating a higher degree of hydration, which improved the interstitial transition zone (ITZ) [6]. Sattar et al. investigated the effect of the nature of pre-treatment chemicals on the performance of rubberized concrete (1:2:4). The authors used two types of chemicals: caustic soda and bleaching powder. They reported that bleaching powder was more effective in enhancing the bond between the rubber particles and the cement paste. This was attributed to the higher strength, lower water absorption, and reduced porosity of the resulting concrete [7], [8].
This study aims to investigate the impact of pre-treatment and soaking time of rubber particles on the performance of rubberized concrete. Previous research shows that soaking times have explicitly defined. This work aims to explore an optimum soaking time for saving efforts. Building upon previous research, two pre-treatment chemicals were chosen: caustic soda (NaOH) and bleaching powder, also known as Calcium hypochlorite ($Ca(ClO)_2$). The soaking time for pre-treatment was set at 2 hours, 24 hours, and 72 hours. Sand in the concrete was replaced by 0%, 5%, and 10% rubber by mass of sand. The concrete's performance was assessed based on slump, fresh and hardened densities.

2 Research Methodology

2.1 Materials

For this study, a 1:1.5:3 concrete mix ratio was selected, commonly used for residential structures, commercial buildings, and pavements. Ordinary Portland Cement (OPC) from a local brand, Paidaar cement, was used, with its chemical composition detailed in Table 1. Sand was sourced from Lawrencepur, and coarse aggregates were collected from Margalla. The properties of these aggregates are provided in Table 1. Waste rubber was chopped from tires at a local dumping site. The rubber pieces were converted to fine powder of the size of the sand by shredding. The composition of the concrete mix is detailed in Table 2.

Table 1 Properties of cement and aggregates

Cement		Aggregates		
Component	**Percentage**	**Properties**	**Fine**	**Coarse**
SiO_2	21	Specific gravity	2.69	2.48
Al_2O_3	6.2	Fineness modulus	2.6	-
Fe_2O_3	2.4	Bulk density (kg/m^3)	1500	1598
CaO	62	Dry rodded density (kg/m^3)	1850	1610
MgO	1.2	Water absorption (%)	3.88	1.49
SO_3	3.7	Water content (%)	2.01	0.94
LOI	2.4	Impact value (%)	-	28.20
		Crushing value (%)	-	2.48

Table 2 Materials composition per cubic meter of concrete

Concrete Sample	Cement (kg)	Sand (kg)	Crumb Rubber (kg)	Coarse Aggregate (kg)	Water (L)
C0	244	365	0	730	116
RC5	244	346.75	18.25	730	116
RC10	244	328.5	36.5	730	116

The gradation of the fine aggregates with crumb rubber was checked and compared with the natural sand through sieve analysis according to ASTM C136 method [9]. The concrete samples were prepared as per ASTM C31 specifications [10]. Cylindrical specimens were prepared for testing purposes. The crumb rubber particles were soaked in caustic soda and bleaching powder solutions for 2 hours, 24 hours and 72 hours prior to mixing in concreteCaustic soda (NaOH) is frequently used as an industrial cleaning agent. When added to water and applied, it can dissolve grease, oils, fats, and protein-based deposits. Bleaching powder ($Ca(ClO)_2$) is a white color powder and is a cleaning agent like Caustic soda. Dilute solutions containing 5% by mass of caustic soda and bleaching powder were prepared. The rubber particles were immersed and stirred for uniform dispersion. Afterwards the rubber particles were left for soaking for a specific period.

2.2 Testing

The slump of the concrete mix was determined through ASTM C143-20 method [11]. The fresh and hardened densities were determined by ASTM C642-21 method [12].

3 Results

3.1 Workability

The results are presented in Figure 1. In the Figure 1, the "simply modified samples" refer to samples containing rubber content without any pre-treatment. The results demonstrated that pre-treatment significantly enhanced the slump values. Specifically, for 5% rubber content, the slump increased from 40 mm to 49 mm with NaOH pre-treatment and to 46 mm with bleaching powder pre-treatment. For 10% rubber content, the slump increased from 31 mm to 47 mm with caustic soda pre-treatment and to 44 mm with bleaching powder pre-treatment. Additionally, it was observed that a 2-hour soaking time was sufficient to enhance the workability, with longer soaking times (up to 24 hours) showing no further improvement and a decreasing trend in slump values observed at 72 hours.These results suggest that pre-treating rubber with either

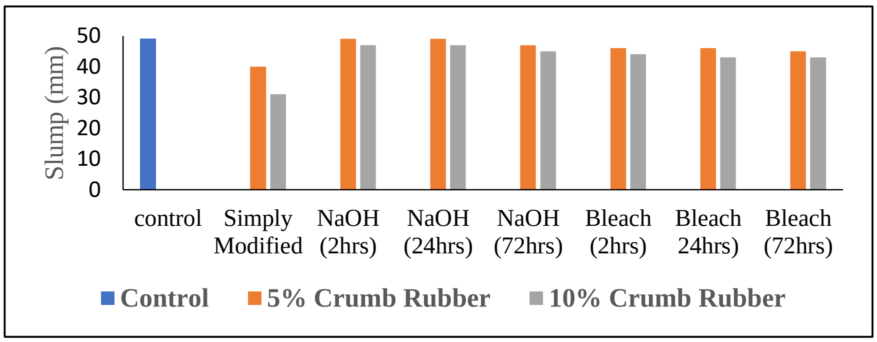


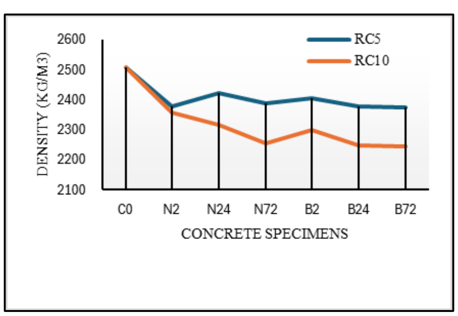
Figure 1 Effect of pre-treatment on workability of concrete

NaOH or bleaching powder significantly enhances the slump, thereby improving workability, with NaOH being slightly more effective. Cleaning agents like caustic soda and bleaching powder removed contaminants, enhanced particle roughness, increased hydrophilicity, and improved integration with the mix, thereby enhancing workability [13], [14].

3.2 Density

The fresh and hardened densities of the rubberized concrete are illustrated in Figure 2 (a) and Figure 2 (b) respectively. From these figures, it was evident that pre-treatment reduced the density of concrete. Additionally, the density decreased with an increase in rubber content. The lowest hardened density was observed in the samples treated with bleaching powder, showing a 12% decrease compared to the control specimen. In Figure 2, N2, N24, and N72 indicate specimens with rubber particles soaked in NaOH for 2, 24, and 72 hours, respectively, while B2, B24, and B72 refer to specimens with rubber particles soaked in bleaching powder for the same durations. The previous literature demonstrates that the cleaning agents owing to the enhanced bonding and surface characteristics, result in a reduction of air voids around the rubber particles, which improves the density [15], [16].

(a)



(b)

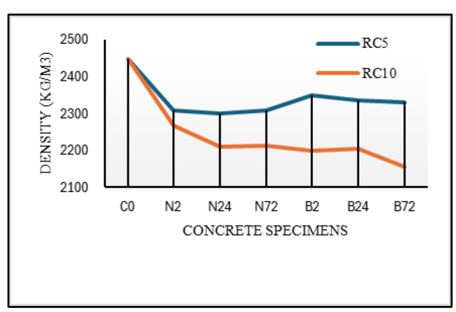


Figure 2: Effect of pre-treatment on (a) Fresh density, (b) Hardened density.

4 Conclusion

Based on the experimental work conducted, the following conclusions can be drawn:

1. The pretreatment of rubber particles with alkaline solutions, specifically caustic soda and bleaching powder, is an effective method for enhancing the workability of rubberized concrete.
2. A 2-hour soaking duration of rubber particles in caustic soda and bleaching powder solutions significantly improves the workability of rubberized concrete, increasing it by up to 22% compared to rubberized concrete with untreated rubber particles.
3. The 2-hour soaking treatment of rubber particles results in a 12% reduction in the density of the concrete compared to control specimens.
4. The study indicates that a 2-hour soaking time is optimal for achieving desirable slump and density values. Prolonged soaking times of 24 and 72 hours lead to a deterioration in workability and a further reduction in density, which negatively impacts the strength of the concrete.

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