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A Review on Properties of Concrete Having Crumb Rubber as Partial Replacement of Fine Aggregates

Shaheer Ahmed[1], Majid Ali[*1]

[1]*Capital University of Science and Technology, Islamabad, Pakistan.*
*Corresponding author/ E-mail: majid.ali@cust.edu.pk

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ABSTRACT. *The problem of waste rubber tires is one of the most serious environmental challenges. Crumb rubber has often been utilized to improve the characteristics of concrete composites. Mechanical treatment, chemical treatment, and thermal treatment are all options for improving the adhesion of crumb rubber aggregates to cement mortar. The purpose of this research is to examine the impact of employing crumb rubber as a partial replacement material in concrete on its fresh and mechanical qualities in order to produce sustainable concrete. The results show that the compressive strength of concrete containing crumb rubber decreases as the proportion of crumb rubber increases.*

Keywords: Crumb Rubber, Density, Compressive Strength, Split Tensile Strength

1. INTRODUCTION

Concrete is frequently used in many different types of building construction. The annual usage of concrete worldwide surpasses 25 billion tonnes [1]. There has been a huge increase in the usage of natural resources and raw materials needed for massive production of concrete. More than half of the total materials used in mixing are made up of hills, rivers, or the ocean. The estimated annual demand for concrete in 2050 will be roughly 9 billion tonnes [2]. Without proper planning and environmental consideration, the aggregate harvesting industry has the tendency to destroy the beauty, converting it into a barren area exposed to erosion during the rainy seasons [5]. In reality, it is important to note that certain nations are importing aggregates to help with the problem of a local shortage of natural aggregate supplies [6]. In order to preserve the environment, it is necessary to address the extensive use of aggregate in concrete, which has led to a significant depletion of these non-renewable resources [7]. Thus, eco-friendly concrete with waste materials will generate a viable solution in mitigation of this aspect. Moreover, fiber composites prepared from numerous fibrous and waste materials provide a viable solution to the emission of greenhouse gases (GHG).

Concrete's properties are highly dependent on its pore structure characteristics, with porosity being a critical one. The porosity and pore size distribution influence the mechanical properties of the concrete matrix. Compressive strength is a widely used parameter to specify structural concrete properties. This is directly linked with the pore's size and its distribution as fewer pores in cementitious matrix give higher strength and vice versa. Furthermore, the water-cement ratio (w/c) is well recognized to influence concrete strength However, even for a given w/c, concrete strength can vary greatly depending on the constituent materials utilized [3].The coarse aggregate is known to significantly affect the characteristics of both fresh and cured concrete. Thus, choosing appropriate particle size distribution for concrete mix is critical to its expected performance. Compared to conventional strength concrete, high-strength rubberized concrete has better mechanical properties and durability [4].

This study utilize locally available crumb rubber with partial replacement of fine aggregate to make eco-friendly concrete. Thus, the intrusion of this material will minimize the malignant effect on

environment by making sustainable concrete. This will help in mitigation of CO2 emissions by reducing the usage of concrete and reduces adverse effect of concrete to the environment.

2. UTILIZATION OF CRUMB RUBBER AS CONSTRUCTION MATERIAL

In underdeveloped countries, the utilization of waste materials is still in its infancy. The experiments showed that, even though incorporating tire crumbs decreases the compressive strength, it still meets the standards for light weight concrete. The results and observations indicate that the mix's workability is only slightly affected by the addition of crumb rubber [11]. Utilization of crushed discarded tires as a substitute in concrete can help address the issue of waste tire accumulation and disposal. However, it is important to consider that the use of waste tire crumb rubber in concrete can have a negative impact on fresh concrete's workability and its ability to bond to the cementitious matrix [8].

The compressive strength of concrete that includes recycled rubber particles can be increased by applying a cement coating to the rubber surface. Researchers studied the relationship between the microstructural properties and compressive strength of 3D-printed rubberized mortar made with cement-coated crumb rubber. They found that the quality of the cement coating on the rubber impacts the compressive strength of the concrete [9]. When compared to traditional concrete, crumb rubber concrete (CRC) has several significant mechanical performance drawbacks, particularly in terms of compressive strength. Rubber particles were pre-treated in NaOH to increase slump. The mechanical characteristics of concrete worsen when silica fumes are used as a partial replacement for cement [10]. In self-compacting concrete, partial replacement of natural aggregates can be used by utilizing CR (crumb rubber) made from recycled tires [12].

An investigation was made into the SEM/XRD analysis as shown in Figure1, fresh characteristics, and strength of high strength concrete that contained metakaolin and crumb rubber as 15% and 30% respectively, as a fine aggregate replacement for up to 90 days. The results demonstrated that adding 15% MK and replacing sand up to 20% in the concrete with tyre CR has the ability to produce concrete with compressive strengths more than 60 MPa [13]. Another investigation examined the utilization of various treatments of CR on the properties of CRC durability. The incompatibility of CR particles with the other components of concrete has a malignant effect on concrete's durability that incorporates crumb rubber (CR). Water absorption of CRC is reduced by utilization of treated CR. This led to an increase in CRC's durability [14].

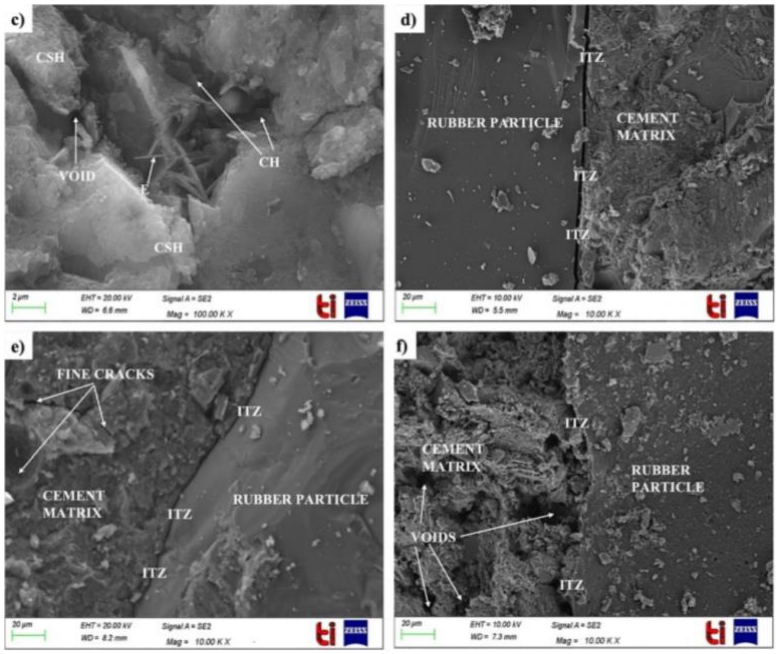

Fig-1: SEM of rubberized concrete [13]

The construction activities due to the advancement in modernization and mega structures cause an adverse impact on the environment with the passage of time. Thus, remedial measures have been used to counter the negative side of concrete by utilization of waste materials in construction. Thus, CR utilization can help in the mitigation of waste and ultimately enhances properties of concrete. A SEM analysis of concrete and CR particle bond showed clearly the presence of voids between them, presenting weak ITZ. This is due to the properties of untreated rubber that it does not creates a strong bond with concrete. It is observed that researchers used CR with admixtures to make strong bond between adjacent matrix in order to improve the mechanical characteristics of concrete. This shows that CR can be utilized in concrete composites for making a sustainable concrete.

3. PROPERTIES OF CONCRETE HAVING CR

3.1 Fresh Properties

Rubbercrete's workability has been improved by replacement of sand up to 50% with CR [21]. Consistency improved as the proportion of CR in the dry mix in rubbercrete increased [16]. However, the use of crumb rubber as an aggregate may negatively impact the workability of the mixture due to its small size and rough surface. The increased friction caused by the increased surface area of the crumb rubber could reduce the flowability of the rubbercrete mixture [15]. Crumb rubber acts as an air entraining agent by trapping air on its surface due to its hydrophobic properties. As a result, CR is being utilized to provide more air to rubbercrete in order to strengthen its resistance to freeze and thaw [17]. Higher air concentration in rubbercrete, however, causes a decrease in unit weight [18].

Table-1: Fresh properties of rubberized concrete

Sr No	Concrete Mix	CR %	Slump (mm)	Compaction Factor	Density (Kg/m^3)	Reference
1	1 : 1.85 : 2.75	0	120	-	2401.59	[23]
		10	125	-	2307.15	
		15	128	-	2257.09	
		20	130	-	2189.51	
2	1 : 1.77 : 2.66	0	226	-	2430	[25]
		5	214	-	2404	
		10	206	-	2378	
		15	204	-	2351	
		20	192	-	2325	
3	1 : 1.9 : 2.3	0	757	-	-	[26]
		10	762	-	-	
		20	766	-	-	
		30	752	-	-	
		40	747	-	-	
		50	738	-	-	

Crumb rubber has a density that is 192% lower than fine sand, which helps to decrease the unit weight of concrete [19]. About 26% of air content increased and 2% of density decreased by replacement of 1.5% of the weight of crumb rubber with fine aggregate [20]. Many researchers have conducted experimental studies by varying crumb rubber percentages in concrete mix [23,25,26]. If we compare the results of previous researchers, increase in crumb rubber percentage showed a prominent change in value of slump as shown in as shown in Table 1. Moreover, increase in CR quantity decreases the density trend of CRC as shown in Table 1.

3.2 Mechanical Properties

Crumb rubber is a hydrophobic material and its presence in concrete leads to more air content and voids in hardened concrete. These voids can cause stress to concentrate at certain points, leading to the formation of tiny cracks, called microcracks, which can weaken the rubbercrete [18]. According to a study, replacing a certain percentage of concrete with crumb rubber showed a decreasing trend in compressive strength. The greatest decrease was seen when the replacement percentage was highest [22]. Compression testing (CT) is a crucial test that is carried out on hardened concrete as it is easy to perform and most of the desired concrete features are linked to its compressive strength.

Table-2: Mechanical properties of rubberized concrete

Sr No	Concrete Mix	CR %	Slump (mm)	Compaction Factor	Density (Kg/m^3)	Reference
1	1 : 1.85 : 2.75	0	36.44	-	-	[23]
		10	33.87	-	-	
		15	27.03	-	-	
		20	25.59	-	-	
2	1: 1.51: 2.56	0	30.8	3.1	3.0	[24]
		5	25.6	1.36	7.61	
		10	23.4	1.34	6.9	
		15	15.2	1.35	7.8	
3	1 : 1.77 : 2.66	0	48.50	5.1	5.4	[25]
		5	46.10	4.25	4.3	
		10	40.49	3.75	3.6	
		15	35.75	3.1	3.0	
		20	31.82	2.5	2.45	
4	1 : 1.9 : 2.3	0	37.0	4.20	6.2	[26]
		10	39.1	4.25	6.5	
		20	39.0	4.37	6.8	
		30	36.5	3.90	6.1	
		40	34.9	3.75	6.0	

The tensile strength of concrete can be measured through various methods, one of which is flexural strength. It determines the ability of a plain concrete beam to resist bending failure [26]. Flexural properties provide crucial information about the tensile properties of the concrete and play a vital role in the design of crumb rubber concrete bending members [27]. Many researchers have conducted experimental studies by varying crumb rubber percentages in concrete mix [23,24,25,26]. If we compare the results of previous researchers, increase in crumb rubber percentage showed a prominent change in compressive strength, split tensile strength and flexural strength as shown in as shown in Table 2. Moreover, the trend for compressive strength, split tensile strength and flexural strength of rubberized concrete decreases as the fractional amount of crumb rubber increases as shown in Table 2.

4. POTENTIAL OF CRC IN CONSTRUCTION

The implementation of waste utilization in developing countries is still in its infancy. The construction industry must overcome challenges and show courage to incorporate recycled waste materials into concrete mixes. The buildup of hazardous waste, including chemicals, toxins, and persistent materials like rubber and plastic, poses a growing environmental threat. However, repurposing non-decaying waste in concrete can provide a positive solution and help reduce harm to the environment. Worldwide, recycling efforts are being advanced and many have proven successful in preserving the environment and preserving natural resources [35].

Utilizing and recycling discarded tyre rubber in concrete can lower the consumption of raw resources, improving the construction industry's economic efficiency and promoting sustainable growth. In various earlier research, the characteristics of freshly mixed and hardened concrete containing CR particles have been examined. According to a number of experimental studies, adding CR to concrete mixtures usually causes a reduction in the material's compressive strength, flexural strength, splitting tensile strength, and elastic modulus [28,29]. Concrete containing crumb rubber (CR) has a low stiffness and good flexibility, and the characteristics of CR concrete (CRC) are determined by the CR's surface finish quality, content, shape, and particle size [30,31,32,33,34].

The utilization of CR in the construction industry gives robust performance and minimize the land pollution. It has been observed that the incorporation of untreated CR has prominent malignant effects on the performance of concrete. This is due to the weak bond between the weak interfacial zone (ITZ) and thus, does not make bond with the adjacent matrix. Whereas the treated crumb rubber has enhanced the performance of concrete due to strong ITZ. For constructional purpose, treated crumb rubber has shown positive results towards concrete properties. This reveals that there is possibility to use crumb rubber in concrete to make it eco-friendly and sustainable.

5. CONCLUSION

Following conclusions can be drawn:

- The use of crumb rubber as a substitute for natural fine aggregate in concrete can help address the issue of waste tire disposal and making sustainable concrete.

- The intrusion of crumb rubber in concrete showed malignant effect on the fresh and mechanical properties of concrete unless an admixture is inculcated to enhance its properties.

- The utilization of crumb rubber along with admixture has revealed positive results due to which it can be incorporated in concrete construction.

Crumb rubber being a waste material, has the ability to alter the properties of concrete in negative manner when used in concrete composites. The incorporation of crumb rubber with admixture in concrete indicated positive results towards the enhancement of concrete properties. Hence crumb rubber has the ability to be utilized in concrete construction.

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