EFFECT OF AGGREGATE REPLACEMENT WITH WASTE TIRE RUBBER ON PROPERTIES OF CONCRETE – AN OVERVIEW

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Abstract- Tire rubber never decomposes, hence it's a waste product. When tires are piled up at landfills, harmful chemicals are released into the air, ground, and water. Toxic black smoke may be emitted into the air when rubber tires catch fire. Many of the dangerous compounds typically utilized in tire manufacture may be found in this smoke. There are chemical substances in this Fire that are wiped away when water is sprayed. These pollutants then permeate the soil and contaminate lakes and ponds. In this situation, it is preferable to repurpose rubber. This paper focuses on the strategies adopted by researchers to utilize waste rubber as an additive in concrete. Studies have been conducted for the replacement of coarse and fine aggregate ranging from 0-100% and investigation of mechanical properties including flexural strength, tensile strength, compressive strength and physical properties including ductility, unit weight density, etc. have been part of the studies. Dynamic properties like impact resistance and energy absorption have been investigated at different ages and results were compared with normal concrete (NC). It has been discovered, as a result, that rubberized concrete (RC) is better in durability, ductility, lightweight, and has greater crack resistance but reduced mechanical properties. However, RC's capacity of energy absorption and impact resistance is higher than NC The mechanical properties of RC can be enhanced by adding different types of admixtures.

Keywords- Rubberized Concrete, Mechanical Properties, Dynamic Properties, Physical Properties, Energy Absorption.

1 Introduction

One of the causes of environmental pollution includes the decomposition of waste tire rubber. It is observed that a large amount of waste rubber requires a large area or site for deposition. Waste rubber produces harmful chemicals which are dangerous to the environment and soil. The world is facing a challenging problem because rubber is nondegradable. Rubber waste recycling is a considered option. Concrete is one of the most commonly used building materials in the world today. A portion of sand or coarse aggregate may be replaced with recycled rubber in concrete. The sustainability of natural resources, primarily aggregate, is a primary issue because concrete is the most widely used man-made construction material. Utilizing waste tires in the manufacturing of concrete efficiently addresses the issues related to waste tire disposal and a sustainable approach toward natural resources [1]. The RC's thermal insulation, electrical resistance, freezing resistance, ductility strain capacity, energy absorption, and impact energy can all be enhanced by the addition of rubber [2]. According to [3], 37 million truck tires are thrown away in the UK each year, and this number is expected to rise in the future. Rubber waste is a very long-lasting product [4]. Thus, the removal of non-usable tires is the main issue. The concrete mix in which rubber is added is known as rubber-treated concrete. Partial substitution of coarse or fine aggregates in concrete further enhances its characteristics like unit weight, high impact resistance, and impact resistance ability. Also, the addition of rubber shows high durability. RC shows better results where the above-mentioned properties are required. Three aspects, including slump, air void, and density, are examined in the physical characteristics of rubberized concrete. In a study, it was found that adding rubber crumbs to freshly laid concrete has a severe impact on the slump values [5]. In almost every type of structure, reinforced concrete and steel are the essential elements. These elements provide structural integrity to building structures. The lifecycle of concrete is affected by different factors which include: extreme weather conditions, higher temperatures, and climate change. These factors sometimes lead to premature deterioration. As the world is progressing towards sustainable energy and technology, the efforts for sustainable technologies can contribute greatly to the maintenance of infrastructures.

Figure 1: Crumb rubber particles

Figure 1 shows the crumb rubber generated from waste rubber tires. The findings demonstrate that using rubberized concrete will sustainably reuse waste material to assist in protecting the environment and save natural aggregates [6]. This paper reports a comprehensive comparison of mechanical, physical and dynamic properties of rubberized concrete with normal concrete. Role of rubber addition in modifying concrete's properties has been highlighted. Key parameters have been identified and recommendations are made for future research directions.

2 Mechanical Properties of RC

[4] evaluated the compressive load-bearing capacity of RC columns and found that the inclusion of rubber in the columns lowered their load-carrying capacity. This is due to the specific gravity of rubber which is much lower than fine aggregate [5] Used split Hopkinson pressure bar (SHPB) set up to find the compressive strength and the results showed a decrease in compressive strength from 50.12 MPa NC to 17.91 MPa RC at 50% replacement. Split tensile strength decreased from 4.60 MPa to 2.21 MPa at 50% replacement. [8] investigated compressive strength using the SHPB system, findings suggest that increasing rubber particles reduces compressive strength and flexural strength of rubber-treated concrete. Research also stated it is advised that replacement should not exceed 30%. Although, the compressive strength of RC starts decreasing after 7 and 28 days. The findings reveal that 0%, 1.75%, 3.25%, and 7.0% addition are equivalent to NC in terms of split tensile strength, which ranges from 4.46MPa to 4.48MPa [9]. When rubber is added to concrete, the tensile strength is somewhat improved [10]. The compressive and tensile strength of rubber-treated concrete was estimated at 7 and 28 days. The results show 10%, 20%, 30%, 40%, and 50% rubber content reduces the compressive strength by 17.7%, 39.9%, 54.1%, 62.0% and 72.2% at 7 days and 21.3%, 37.9%, 54.3%, 62.5% and 66.4% at 28 days, respectively [11]. RC's compressive strength can be enhanced by the addition of silica fume. Strength increased from 1.52MPa to 1.79MPa at 7 days and 1.66MPa to 1.93 MPa at 28 days when 5% silica and 40% rubber were added. These improvements result from pozzolanic reactions between silica fume and free calcium hydroxide in the paste, as well as mechanical improvements brought on by the addition of a very fine powder to the cement paste mixture [12]. When crumb rubber and steel fibers are added in various amounts of 5%, 15%, and 25% by volume of fine aggregate, compressive strength decreases by 12%, 24%, and 43% after 90 days [13]. Compressive strength decreased with increasing rubber concentration, whereas rubber particles containing ground granulated blast furnace slag (GGBFS) showed relatively less decrement in strength [14]. Pretreatment of rubber has positive impacts on compressive and split tensile properties of RC. The addition of rubber particles produces a negative impact on compressive strength [15]. Strength decrement in RC is caused due to poor bonding between rubber particles and concrete matrix [16,17].

Table 1: Mechanical properties of RC

References	Specimens		Properties Investigated	Output (RC Vs NC)	
[9]	Cylinder	100×200 mm	Compressive strength	-37%	Decreased
		50×300 mm	Split tensile strength	-8.7%	Decreased

[10]	Cylinder	150×300 mm 63.5×150 mm	Compressive strength Split tensile strength	-63% -56.48%	Decreased Unchanged
[12]	Cubes	100×100×100 mm 150×150×150 mm	Compressive strength Split tensile strength.	-70% 38.55%	Decreased Increased
[15]	Cylinder Beams	150×300 mm 150×150×600 mm	Compressive strength split tensile strength	-59.22% -31.93%	Decreased Decreased
[24]	Cylinder	150×300 mm	Compressive strength Split tensile strength	-51.12% -21.61%	Decreased Decreased

A Series of tests were conducted and obtained results show that compressive strength was reduced by 10%, 18%, and 20% for 5%, 10%, and 15% replacement, and flexural strength decreased up to 14% for 15% replacement [18]. [19] found that the mechanical properties of RC decreased as rubber content increased, much as the split and flexural strength inflection points between 40% and 60% rubber substitution. Untreated RC has shown lower compressive strength than treated RC, according to a study in [20]. The compressive strength of treated RC is 24% more than NC. Also, pretreated RC has a greater split tensile strength than untreated RC however, this only increases by 20% in the case of a 20% replacement. The compressive strength of pretreated RC was found to be 92.62% less than NC, however, flexural strength was found to be 130% greater in treated RC when 5% of the treated rubber was substituted for the NC [21].

In comparison to NC, the tensile strength of treated RC is 2.67 times greater. Rubber particles have low specific gravity, which reduces the compressive strength of concrete when they are substituted with coarse aggregate [22]. Concrete's compressive strength decreases with increasing rubber content. Replacement of rubber by 10% to 50% resulted in a 20% to 85% decrease in compressive strength [23]. When epoxy resins were added to RC as an additive, the compressive strength of the concrete increased for 28 days. The reason reported was that the epoxy is an adhesive material that facilitates the enhancement of bonding between cement matrix and rubber particles despite a progressive decline in the concrete's compressive strength over time. At 28 days, epoxy resin admixture improves the split tensile strength. flexural and compressive strength of RC with and without 1% superplasticizer addition as rubber content was increased, compressive strength decreased. However, mixing admixtures increased compressive strength a little. The RC's flexural strength improved, while the addition of mixing admixtures increased strength even more [25]. Compressive and split-tensile characteristics of RC have been studied, the findings showed that rubber inclusion lowered the strength of concrete, but a 25% substitution yielded substantial results [26].

3 Physical Properties of RC

[14] found that the slump and unit weight of RC was reduced as the percentage of rubber particles increased, with a decrease in a slump from 220 mm to 185 mm and an increase in air content. Rubber in concrete reduces concrete's workability owing to rubber's high-water absorption, hence as rubber percentage increases, so decrease RC's unit weight. As a result of its lower unit weight, RC contains a larger percentage of air. Due to rubber's elastic characteristics, RC has a greater modulus of elasticity than NC [17]. When rubber content was increased in RC, the unit weight decreased. With a 15% substitution of rubber aggregate, water absorption of RC increased by 8% during 28 days [18]. The low binding strength of the cement paste to the rubber reduces the workability of both treated and untreated RC [21]. RC's dry unit weight decreased as the rubber content increased, resulting in a 33% decrease in 25-mm aggregate density and a 46% decrease in 12.5-mm aggregate density with 50% replacement. Rubber content has a direct correlation to porosity in RC. The permeability of RC varies from 0.25 to 0.61 cm/s depending on the proportion of rubber in the concrete. There is no change in unit weight when 10% rubber, is added to concrete [11]. The water absorption of rubber-treated concrete increases with the addition of more rubber particles. Whereas the modulus of elasticity decreases when rubber content is raised by 10%, 20%, 30%, and 50%. Water absorption is not significantly altered by a 10% replacement.

Table 2: Physical properties of RC

References	Specimens		Properties	Replacement	Output (RC Vs NC)	
[17]	Column Specimens	240×1500 mm 400×400×1200 mm 350×350×350 mm	Unit weight Air content	25-100%	-12% +172%	Decreased Increased

[18]	Cylinder Beams	150×300 mm 150×150×762 mm	Unit weight. Water absorption	0-15%	-7% +8.6%	Decreased Increased
[22]	Cubes	150×150×150 mm	Unit weight	0-15%	-14.33%	Decreased
[23]	Cubes	150×150×150 mm	Porosity Permeability	0-50%	59%	Increased Increased
[29]	Cubes	150×150×150 mm	Density	5-20%	-92.213%	Decreased

4 Dynamic Properties and Impact Resistance of RC

Table 3: Dynamic properties and energy absorption of RC

References	Specimens		Properties Investigated	Output (RC Vs NC)	
[13]	Cube Beam	100×100×100 mm 100×100×500 mm	Impact energy absorption	+171%	Increased
[12]	Cubes	100×100×100 mm 150×150×150 mm	Impact resistance Energy absorption	+239% +9.46%	Increased Increased
[14]	Cube Prism	150×150×150 mm 70×70×100 mm	Energy absorption	+24%	Increased
[27]	Cylinder	150×300 mm	Impact resistance	+2%	Increased
[32]	Railway sleeper	63×250 mm	Impact resistance Impact strength	+50% +40-60%	Increased Increased

RC absorbs more energy than NC, as shown by a 0.5 kg steel ball drop test from a standard height of 1 m [14]. The higher the rubber content, the greater the energy absorption capacity. A 5%, 15%, and 25% rubber replacement yields 3.682, 4.083, and 4.586 kgm^2/sn^2 respectively. According to [27], a 65 kg mass was dropped from 650 mm height and the impact resistance of RC was better than that of NC, making it suitable for highway barriers. Using both computational and experimental data, [28] demonstrated that RC with steel reinforcement resists blast loading. [29] calculated the damping ratio of RC, results show that crumb RC dissipated energy about 2.6 times the energy dissipated by NC. Slightly reduction in crumb RC decreased energy dissipation by 1.8% compared to NC. The impact resistance of RC is higher than NC, this is because of the elastic nature of rubber [18]. It was noted that RC has a high dynamic compressive strength. RC has been studied for its dynamic properties, and the results reveal that it has stronger impact resistance and energy absorption than NC. RC offers a higher impact strength than NC [32]. Concrete's impact energy was improved by the addition of steel fibers to crumb rubber. Replacement of 5%, 15%, and 25% increased impact energy by 30.6%, 66.6%, and 70.6%, respectively [13].

5 Practical Application of Rubberized Concrete

Significant increment in dynamic properties makes rubberized concrete an efficient material for energy absorption and toughness relied applications. Structures, where strength requirement is not the primary objective and dissipation of stresses through energy absorption is desired, rubberized can play a vital role instead of normal concrete. In addition, structures subject to impulsive loading like bridge piers and roadside barriers can have enhanced toughness through utilization of rubberized concrete.

6 Conclusions

The following conclusions can be drawn from this study:

1 Greater rubber content results in decreased mechanical properties but increased dynamic and impact resistive properties of rubberized concrete. However, both positive and negative aspects have been discovered in response to physical properties.
2 The negative results have an obvious reason of poor bonding between rubber particles and cement paste but pretreatment of rubber enhances the mechanical properties of concrete.
3 Crumb rubber replacement with fine aggregates shows better results instead of coarse aggregate.

Admixtures like silica fume, epoxy resins, superplasticizer, etc. can be utilized for better mechanical properties by improving the bond strength of rubber particles and cement paste. A thorough study needs to be conducted to identify the most suitable admixture that could result be used for enhancement of mechanical properties. In addition, comparison of strength properties through different pretreatment techniques of rubber should be investigated.

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