Mesopotamian Journal of Civil Engineering
Vol.2023, **pp**. 1–9
DOI: https://doi.org/10.58496/MJCE/2023/001; ISSN: 3006-1148
https://mesopotamian.press/journals/index.php/MJCE

Research Article

Experimental Investigation of Waste Rubber Admixtures in Concrete

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ARTICLE INFO

Article History

Received 03 Nov 2022
Accepted 02 Jan 2023
Published 26 Jan 2023

Keywords

Tyre rubber
non-biodegradable
coarse aggregate
M25 grade concrete

ABSTRACT

In this experimental study, coarse aggregate is partially substituted with tyre rubber to examine the behavior and failure properties of rubberized concrete. Due to this waste's inability to biodegrade, there are significant fire, environmental, and health dangers. Concrete's characteristics could be greatly improved by using used tire rubber as a partial aggregate in a variety of ways. Currently, one of the world's biggest waste management issues is how to get rid of used tires. About 1.2 billion trash tires are produced annually worldwide. Therefore, efforts have been made to determine how discarded tires might be applied in construction projects. The purpose of this research is to look into the best way to use used rubber tires into concrete mix as coarse aggregate. Concrete is made by substituting 20%, 30%, and 40% of coarse aggregate with tires and the outcomes are compared to those of standard M25 grade concrete. The durability of newly laid and cured concrete were determined. The findings showed that rubberized concrete can be used to successfully counteract a loss of strength while maintaining the benefits of greater ductility. This suggests great prospects for uses in seismic zones, notably for structural columns. The main goal of this research is to identify an effective strategy for reusing rubber waste for improved ecological circumstances and the building sector.

1. INTRODUCTION

The characteristics of concrete's components and the mix design factors have a significant impact on the material's strength. Aggregates comprise the majority of a concrete mixture, their characteristics have an impact on the end product's characteristics. In concrete, an aggregate has traditionally been used as an inert filler. Actually, aggregate is not completely inert, and the functioning of concrete is affected by its physical, thermal, and occasionally chemical qualities. The growing discard tire stacks will result in a buildup of scrap tires at disposal locations, pose a risk of spontaneous explosions, and create a complex cocktail of chemicals that will damage the ecosystem and pollute soil and plants. The tyre rubber also called as polymeric waste causes many environmental problems of raising relevance [1]. Each year, there is a rise in the volume of disposed rubber. Now a days, As a result, tyres are currently stockpiled or landfilled, with 3000 million in the EU and 1000 million in the US [2]. by 2030, the number of discarded tyres from motor vehicles is expected to reach 1200 million, causing ecological threats due to reduced biodiversity and toxic components in waste disposal areas. Tyre landfilling poses a significant ecological threat [3]. waste tyres pose a risk of burning due to accidental high temperatures, generating toxic fumes and melting, causing oil contamination of soil and water. high temperatures can lead to tyre melting and contaminating soil and water[4][5]. It adds to atmospheric contamination because it is difficult to disintegrate and because it is unknown how long it will take for it to biodegrade. Repurposing discarded rubber products as building components looks to be an acceptable remedy to both the environmental issue and the issue of cost-effective construction design. The demand for more creative and adaptable compounds grows as the use of ecologically sound, inexpensive, and very light building supplies in the construction field becomes more and more popular. Due to this, there will be higher expectations for new building goods that incorporate diverse used and waste rubbers, both in terms of their mechanical and thermal performance.

The mechanical strength, Young's modulus, creep and shrinkage behavior, and stress-strain diagrams of GRC specimens were then determined experimentally. The experimental studies required to take into account cementitious form with different simple mortar creations, with different kinds of fibre glasses or with metal components because the material characteristics were highly reliant on the manufacturing techniques. These tests helped characterize the production conditions to provide material qualities that were optimized.While the second approach often creates crumb rubber to replace fine particles, the first technique produces crushed rubber to substitute coarse aggregates. The most pertinent information regarding the durability and qualities of concrete incorporating rubber wastes will be reviewed in this paper. It also covers how waste treatments, waste particle size, and waste replacement volume affect the properties of fresh and hardened concrete.

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According to investigations so far, rubber scrap concrete is specifically advised for concrete constructions situated in high risk of earthquakes as well as for areas subjected to extremely demanding dynamic actions, such as sleepers for railroads. Additionally, this substance can be utilized for non-load-bearing applications like noise mitigation barriers.

2. SCOPES AND OBJECTIVES

- Investigating the use of waste tyres as an alternative construction material, aiming to find a suitable mix proportion and percent replacement for natural coarse aggregates with recycled rubber aggregates.
- To determine the properties of the each and every construction material used in this investigation.
- To investigate the compressive strength, split tensile strength, and flexural strength of the rubber concrete.

3. BACKGROUND

There is a significant environmental issue with the disposal of non-biodegradable waste tires. In general, there is a resurgence of interest in creating solutions to the problem of disposing of used tires. As a result, numerous studies have been conducted in the past few years on the use of old tires of various sizes and shapes in concrete. In 1988, Russell J. Schnormeier[6] noted that recycled tires may be disposed of by being used to make concrete products. These materials are economical and have both technological and environmental benefits

Eldin N. N. and Senouci A. B. studied the performance of the rubberized concrete using tire flake and crumbled rubber as an alternative to aggregate in dimensions 38, 25 and 19 mm. They found that the material's compressive strength was reduced by 85% and its tensile strength by 50%, but that it could soak up a substantial quantity of plastic energy under the tensile and compressive force[7-10].

Schimizze et al. created 2 rubberized mortar mixtures, one with very fine rubber granular and the other with coarse rubber granular. According to their findings, the compressive strength was around 50% lower than the standard mix. While the mixture including the fine rubber particles exhibited a decline in the modulus of elasticity of around 47% of the standard mixture, the mix comprising the coarse rubbery particles showed a drop of approximately 72 percent of the standard mixture When rubberized plain cement concrete mix are employed as fixed foundation in flexible pavements, the drop in modulus of elasticity suggests better flexibility, which can be considered as gain.

Akkurt, I., and Akyldrm, H., investigated the radiation-shielding capabilities of pumice concrete. It was determined that adding pumice stone as concrete aggregate does not improve the material's gamma radiation protecting characteristics.

Ahmed S. Eisa et al (2020) [11] The effect of crumb rubber and steel fibres on the behaviour of reinforced concrete beams under static stresses was examined. Tyre crumbs were used into plain concrete and steel fibre concrete mixes, partially substituting fine particles at various weight percentages. The volume percentage of steel fibre was held constant at 1%. In two stages, a large experimental programme with 130 samples was carried out. To evaluate the mechanical characteristics of the concrete mixes, the first step included compressive, splitting tensile, and flexural testing. The second stage investigated the static behaviour of reinforced concrete beams under four-point flexural tests using the prescribed concrete mixes. The results demonstrated that employing crumb rubber as a 5% or 10% substitute for fine particles resulted in satisfactory behaviour for RC beams.

D.S. Vijayan et al (2020) [12] were conducted leading test on rubber materials to determine their characteristics. Mix proportions of these concrete were prepared using Indian standards for M30 grade of concrete. Sample specimens were replaced with shredded rubber at different rates 5%,10%,15%,20%, with varying rates of replacement. A control concrete mix was created without shredded rubber in the M30 grade. Fresh concrete properties and harden properties were tested with control concrete and varying percentages of shredded rubber as aggregate.

P.Jeevana et al (2023) [13] analysed the behavior characteristics of rubberized concrete, where tire rubber is partially replaced with coarse aggregate. India handles over 270 million scrap tires annually, which pose fire, environmental, and health risks. Tyres was utilized in engineering applications like artificial reefs, erosion control, and asphalt and concrete aggregates, with recycling rubber was improve concrete characteristics. M30 grade concrete particularly used as a specimen, and scrap tire rubber chips are used as coarse aggregate. This sustainable use of aggregates and effective mass management of rubber tire waste are achieved. The study evaluates the workability and compressive properties of rubberized concrete to investigate the optimal use of crumb rubber as coarse aggregate in concrete.

Mr.Jaydeo Phadtare et al (2020) [14] investigated the impact of utilizing unwanted tyre rubbers as a substitute material for the coarse aggregate in untreated concrete without pre-surface treatment. The concrete was tested under the compression strength test, tensile strength test, flexural strength test and slump cone test. The primary goal is to incorporate discarded tyre rubber into concrete without compromising its qualities. The study looked at partially replaced concrete at different strengths after seven and twenty-eight days of curing process.

Devendra Kumar et al (2021) [15] studied aims to identify the properties needed for designing concrete mixes with coarse tyre rubber aggregate. The reference specimen in the investigation is M20 grade concrete, and the coarse aggregate is scrap tyre rubber waste.

K.Paul Sibiyone et al (2017)[16] were aimed to use waste rubber as a partial replacement of coarse aggregate in M20 mix to manufacture the rubberized concrete. Partial replacement of flap rubber (10, 20, 30, and 40%) were tested for three basic test for harden concrete like split tensile compressive and flexural strength test. Results showed a reduction in strength for the waste rubber mixure, but slump values increased as the flap rubber content increased from zero to twenty percentage. This makes the flap rubber mixture more workable and lightweight, making it suitable for non-structural and structural applications.

T.Ishwarya (2018)[17] studied use recycled waste tyre rubber to replace for coarse aggregate 20%. Results show compressive strength reduction, but concrete with recycled rubber exhibited ductile plastic failure instead of brittle failure. The study compared the normal concrete compressive strength in grades M25 and M30 and compared the conventional beam to the rubcrete beam.

A.Chandran (2017) [18]investigate the use of waste tyre rubber as chips in concrete to enhance strength and protect the environment. It discusses the suitability of rubberized concrete with the both structural and non-structural members, its uses, barriers, and benefits for future research.

4. MATERIALS AND EXPERIMENTAL PROCEDURE

4.1 Cement

For casting all the Specimens, OPC (Ordinary Portland Cement), 53 Grade complying to IS: 269 - 1976, was utilized. The material properties as tabulated in table 1.

TABLE I. PHYSICAL CHARACTERISTICS OF CEMENT

Property	Value
Fineness of cement	2%
Specific gravity	3.15
Initial setting time	30 mins
Ultimate setting time	110 mins
Normal consistency	31%

4.2 Fine Aggregate

All of the specimens were cast using clean, dry river sand that had passed through an IS 4.75mm sieve. The properties of FA as represented in table 2.

TABLE II. PHYSICAL CHARACTERISTICS OF FINE AGGREGATE

Property	Value
Fineness modulus	2.25
Water Absorption	1.5%
Sp.gravity	2.65

4.3 Coarse Aggregate

20mm downsized crushed granite aggregate was used. Properties of CA as shown in table 3.

TABLE III. PHYSICAL CHARACTERISTICS OF COARSE AGGREGATE

Property	Value
Sp. gravity	2.65
Bulk Density	1642.45
Surface moisture	0.08
Water absorption	1%
Finess Modulus	6.98

4.4 Rubber

Rubber has a remarkable gripping ability and a very high coefficient of friction. These characteristics have a great deal of value in numerous engineering applications. Water functions as a lubricant for rubber since it considerably reduces friction when it is moist, which is another crucial property of rubber. With the passage of time, rubber ages similar to many other organic materials. Loss of strength, extensibility, and other mechanical qualities are some effects of rubber's aging process. If the rubber is not carefully engineered to resist this action, even the little amount of ozone in typical outside air (approximately one part in 100 million) might cause small cracking. Table 4 shows the characteristics of rubber.

TABLE IV. PHYSICAL CHARACTERISTICS OF RUBBER

Property	Value
Specific gravity	0.73
Water Absorption	0%
Bulk Density (g/cc)	0.5283

4.5 Water

Using potable water, specimens were cast and preserved**.**

4.6 Mix Design

Table 5 & 6 shows the quantity of material & percentage replacement of rubber.

TABLE V. MIX PROPORTION

Materials	Quantity
Cement	330 kg/m^3
Fine aggregate	452.61 kg/m^3
Coarse aggregate	1322.13 kg/m^3
Water	165 liter

TABLE VI. REPLACMENT OF COARSE AGGREGATE BY RUBBER

Replacement (%)	Quantity (kg/m^3)
20	264.4 kg/m^3
30	396.6 kg/m^3
40	528.8 kg/m^3

5. EXPERIMENTAL WORK

5.1 Compressive Strength Test

Compressive strength is a term used to describe a material or structure's ability to endure stresses that have an ability to shrink it in size. Plotting the applied force vs the deflection in a testing apparatus will yield the measurement. The maximum capacity for compressive load can be thought of as a specific amount of cracking since some materials crack persistently at their limit of compressive strength while others break at that point. Structures are designed with compressive strength as a key factor. Each specimen is required to remain in the compressive testing equipment during the testing process. A concrete block's breaking point maximum stress will be recorded. By applying the following formula to the data stated, the compressive strength can be determined.

$$\textit{Compressive Strength}=\textit{Load}/\textit{Area} \quad (1)$$

Specimen Size=150mm x150mmx150mm

The amount of strength increases at different levels of waste rubber replacement on days 7, 14, and 28 as shown in table 7, 8 & 9 respectively. It is evident that there is a strength drop at the 10% replacement. SiO_2 reacts chemically with cement's alkalis when waste rubber is ground to an extremely fine powder, creating cementitious products that aid in the development of strength. Additionally, it can be because the waste rubber efficiently filled the gaps and created dense concrete. It is able to observed that there is an increase in strength even with 10% Waste Rubber substitution while compares the strength improvement against the cement mortar's strength. This must be because the strength starts to wane as the dilution effect takes hold. As a result of the alkali silicate reaction, extra waste rubber presents that don't react with calcium cause weak spots to appear in the concrete, reducing its strength.

TABLE VII. COMPRESSIVE STRENGTH OF CUBE FOR SEVEN DAYS

Mix ID	**% of waste rubber replacement**	**Compressive strength (N/mm^2)**
CC	0%	10.2
20WR	20%	13.7
30WR	30%	12.6
40WR	40%	11.9

TABLE VIII. COMPRESSIVE STRENGTH OF CUBE FOR FOURTEEN DAYS

Mix ID	**% of waste rubber replacement**	**Compressive strength (N/mm^2)**
CC	0%	12.8
20WR	20%	18.43
30WR	30%	17.92
40WR	40%	17.15

TABLE IX. COMPRESSIVE STRENGTH OF CUBE FOR 28 DAYS

Mix ID	**% of waste rubber replacement**	**Compressive strength (N/mm^2)**
CC	0%	13.4
20WR	20%	22.9
30WR	30%	22.15
40WR	40%	21.80

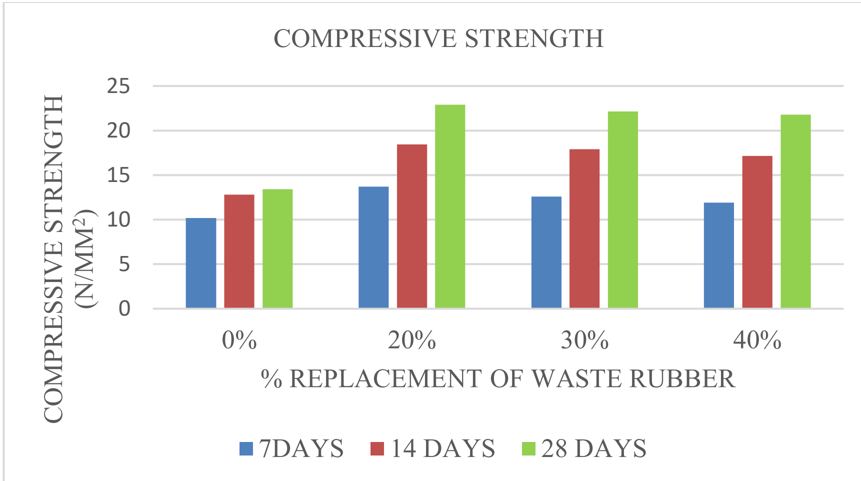

Fig.1. Compressive Strength

Concrete's compressive strength was tested for 7, 14, and 28 days with waste rubber replacement at 0, 20, 30, and 40% replacement. In comparison to concrete with different percentages of replacement, the 20% replacement concrete offers a higher strength of 13.7 N/mm2, 18.43 N/mm2, and 22.9 N/mm2 at seven, fourteen and twenty-eight days, respectively & shows in figure 1.

5.2 Flexural Strength Test

The beam specimens with dimensions of 700 mm x 150 mm x 150 mm were used for the testing. After, seven days of curing, specimens were dried in the open air and put through a flexural strength test using a flexural testing apparatus. Applying the stress at a pace that causes the maximum stress to rise steadily until rupture occurs. Within the middle third of the span length, a fracture is indicated in the tension surface. Using the formula (R), the flexural strength was calculated & tabulated in table 10, 11 & 12.

$$R = Pl / bd2 \qquad (2)$$

TABLE X. COMPRESSIVE STRENGTH OF CUBE FOR 28 DAYS

Mix ID	% of waste rubber replacement	Flexural strength (N/mm^2)
CC	0%	1.8
20WR	20%	2.2
30WR	30%	2.04
40WR	40%	1.96

TABLE XI. COMPRESSIVE STRENGTH OF CUBE FOR 28 DAYS

Mix ID	% of waste rubber replacement	Flexural strength (N/mm^2)
CC	0%	3.4
20WR	20%	3.52
30WR	30%	3.02
40WR	40%	2.4

TABLE XII. COMPRESSIVE STRENGTH OF CUBE FOR 28 DAYS

Mix ID	% of waste rubber replacement	Flexural strength (N/mm^2)
CC	0%	2.95
20WR	20%	3.32
30WR	30%	3.25
40WR	40%	2.02

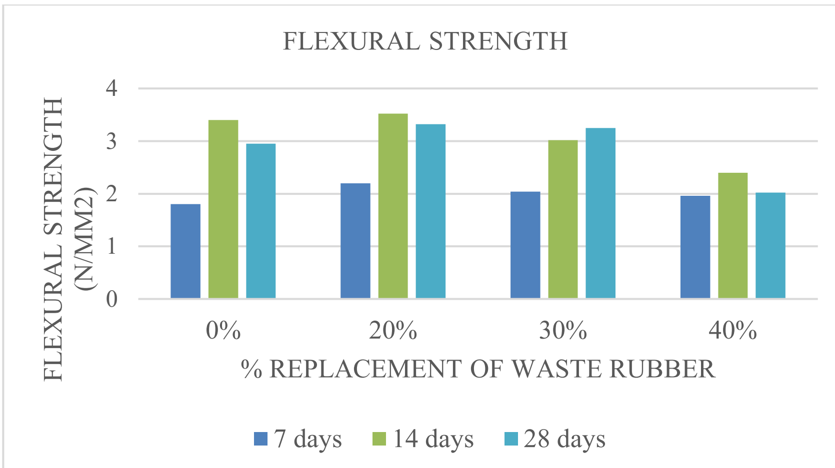

Fig.2. Flexural Strength

All beam specimens are put through two-point flexural strength testing & the results are shown in Figure 2. The findings demonstrate that 20% replacement gives the strongest outcomes, with strengths of 2.2 N/mm2 at day 7, 3.52 N/mm2 at day 14, and 3.32 N/mm2 at day 28.

5.3 SPLIT TENSILE STRENGTH

The 300 mm length and 150mm diameter cylindrical specimen was casted and used for this investigation. When the cylinder specimen placed in the machine and the load was applied till the specimen breaks.the test results were tabulated in table 13,14,15.

$$\textit{Split tensile strength} = 2P/\mu dl \quad (3)$$

TABLE XIII. SPLIT TENSILE STREGTH FOR 7 DAYS

Mix ID	% of waste rubber replacement	Tensile strength (N/mm^2)
CC	0%	1.12
20WR	20%	1.81
30WR	30%	1.6
40WR	40%	1.5

TABLE XIV. SPLIT TENSILE STREGTH FOR 14 DAYS

Mix ID	% of waste rubber replacement	Tensile strength (N/mm^2)
CC	0%	1.9
20WR	20%	2.3
30WR	30%	2.1
40WR	40%	1.86

TABLE XV. SPLIT TENSILE STREGTH FOR 28 DAYS

Mix ID	% of waste rubber replacement	Tensile strength (N/mm^2)
CC	0%	2.5
20WR	20%	2.7
30WR	30%	2.4
40WR	40%	1.92

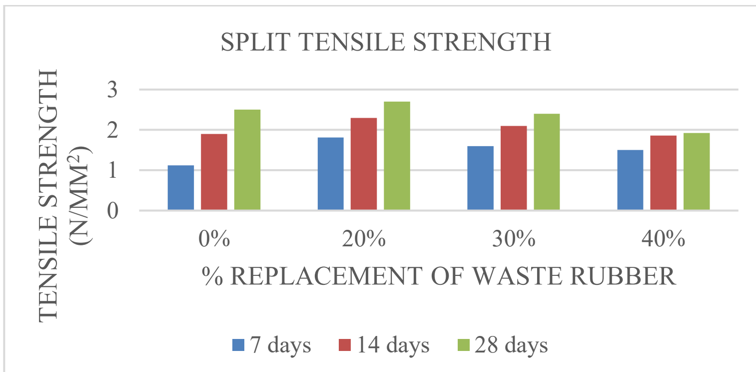

Fig.3. Split Tensile Strength

The result of tensile strength after 7, 14 and 28 days are recorded. Result indicates that as we increase percentage of waste Tyre Rubber from 0% to 20 % its tensile strength increases after further increment in percentage of waste Tyre Rubber there is loss in tensile strength. At 20% replacement, it offers 1.81 N/mm2, 2.3 N/mm2, 2.7 N/mm2 strengths at days 7, 14, and 28 days as shown in figure 3. That means we can replace up to 20% natural coarse aggregate by waste Tyre Rubber.

6. CONCLUSION

The test findings from this study show that using used waste rubber in concrete has a lot of promise. It has been determined from the results of the current investigation that a 20% substitution of rubber waste for coarse aggregate results in the maximum strength. At day 28, concrete had higher compressive, tensile, and flexural strengths of 22.9N/mm2, 2.7 N/mm2 and 3.32 N/ mm2, respectively. Additionally, it is advised to use this concrete composite for ribs, floor slabs, and lintel beams in situations where load carrying capacity does not dictate the design. Because rubberized concrete has a lower compressive strength than conventional concrete, there is a potential large market for concrete products incorporating rubber aggregates, which will use discarded rubber tyres, the disposal of which is a major source of pollution in the environment. Rubberized concrete's light unit weight qualities may make it perfect for architectural applications, fake facades, stone baking, interior construction, seismic shock wave absorbers in structures, and vibration dampening in foundation pads for mechanical railway stations.

Funding

None

Conflicts Of Interest

None

Acknowledgment

None

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