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ADOPTION OF CRUSHED OLD TYRES IN CONCRETE CONSTRUCTION TO ATTAIN SUSTAINABLE DEVELOPMENT

Juma Dash Harry[*1] Cyprian Kemboi Kipchumba[*2] Dr. Daniel Siringi[*3]
Dr. Eng. Clement Kiptum[*4]

[*1]Undergraduate, Department of Civil &Structural Engineering University of Eldoret
[*2]Undergraduate, Department of Civil &Structural Engineering University of Eldoret
[*3]Guide and. Dr. Department of Civil &Structural Engineering University of Eldoret
[*4]Guide and. Dean School of Engineering University of Eldoret
University of Eldoret, Eldoret, Kenya

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Abstract: **Recent years have been shadowed by an increase in the adoption of recycled transportation and building materials, focusing on the adoption of damped waste materials. Numerous waste materials, including glass, plastic, and tire rubber, have been adopted in conjunction with standard resources as recycled aggregates or a binder improvement, depending on the application. Rubber from powdered tires may be added as a flexible aggregate in a concrete block, reducing the likelihood of brittle failure and increasing the concrete's capacity to absorb more significant amounts of energy before failure. Due to the high elastic modulus of rubber particles, the substitute of coarse aggregate for crumb rubber may significantly impact the strength characteristics of concrete, resulting in concentrated stress, strain, and bonds between the rubber particles and the cement. Rubber granules are an acceptable substitute for coarse aggregate in developing responsive concrete.**

On the contrary, the use of finely graded rubber may result in a tensile behavior with substantial deformations before the complete disintegration of the concrete. It may have a more negligible impact on the loss of strength of the concrete. According to the experiment, despite the experimental concern on safety, it aims to assess rubberized concrete's performance and thus potential use in the concrete making to aid in environmental conservation.

Keywords: **recycled aggregates, rubber particles, concrete, stress, strain and compression, tension, and flexural strength.**

I. INTRODUCTION

Tires have become an indispensable component of daily life due to the advancement of the automobile industry in recent years. It is practically impossible for us to get by without them, whether we are driving a passenger vehicle or riding public transit, such as a bus or train. However, they are also frequently utilized in air transportation, and they play a significant part in the movement of freight. Because of societal progress around the globe, tires demand has significantly risen, and as a consequence, the creation of waste tires is increasing in proportion to this growth. Waste tires are not biodegradable and are usually kept and disposed of unhygienically; the end of the tire's usable life is predicted to occur in over 1,000 million units every year, with more than half of them being trashed without being reused. Every year, around 1.4 billion tires are sold worldwide, with an equal number finally falling into the group of end-of-life tires. Because of their significant volume and endurance, these tires are among the largest and most effective forms of garbage. Furthermore, hundreds of millions of used tires have been discarded or hoarded illegally. Improper tire disposal poses a possible hazard to human health and could enhance environmental problems in some situations. Numerous market opportunities for discarded tires have emerged as landfills reduce their acceptance of complete tires, and the health and ecological concerns of hoarding tires

II. RESEARCH QUESTIONS AND HYPOTHESIS

The primary query regarding this research is the performance of rubber in concrete blocks and how it can help improve the pavement's concrete stability, flexibility, and general strength. As an often -overlooked aspect of substantial development, this research aims to identify the specific impacts of recycled waste rubber use, identifying the most appropriate mix between the rubber and the coarse aggregate to achieve the most productive, flexible, cheaper, and long-lasting concrete blocks. Therefore, the central question is to understand the impact of recycled waste rubber used in the new development of the concrete block. At the same time, the research hypothesizes on establishing the best mix design that can replace the 100% use of course and fine aggregates in concrete block production.

III. STATEMENT OF THE PROBLEM

- Developments keep changing with complexities year by year; with this increase in demand for natural resources, virtual construction materials are being depleted, posing future development – challenges

- At the same time, the disparity in tons of tires placed on the market versus reclaimed is increasing. It may be concluded that the need for waste tire management would keep growing due to the wear and tear of current tires, which are not permitted to be disposed of in landfills as they cause environmental -adverse effects.

IV. OBJECTIVES

Main objectives

➨ This research's primary purpose is to help find the most appropriate, cost-effective, and environmentally-friendly solution for adopting old tires in concrete construction as aggregates.

Specific objectives

➨ To examine the flexural strength of rubber with concrete in creating a rubber-concrete block.

➨ To check on particle sizes distribution of aggregates (sand, coarse, and crushed rubber).

➨ To check on the workability of concrete when crushed rubber is used as aggregates.

➨ To check the strength properties of concrete when rubber is used and compare it with standard concrete strength properties (similar concrete class).

V. LITERATURE REVIEW

Methods and possibilities of using waste tires

Recyclable tires may be used to get rare materials, as well as to conserve energy as compared to the manufacture of new tires, and to minimize the quantity of waste produced by manufacturing new tires. Recycled rubber from used tires accounts for the lion's percentage of the overall amount of rubber products now in use [10]. Because it includes many compounds with potential energy storage, it also acts as raw material, and tires are constructed of a flexible rubber substance that has been strengthened with textile and metal components to make them more durable [1]. To recycle tires, you need to take the following steps: facilitating the reduction of risks associated with contamination due to temporary storage of used tires [8]. Reduce consumption of non-renewable resources. Service used tires as a secondary ingredient (instead of new tires). It has resulted in the development of three product categories due to the utilization of tires as raw material sources [5]. Rubber granules, steel wires, nylon, and textile fibers are just a few of the materials that have been used. Modern technology makes it possible to separate these elements from rubber crumbs. The rubber crumb itself may be recycled or used once separated from the other materials.

Application of waste tires in concrete and performance

Utilization of 3D digital image correlation to create a three-dimensional model to evaluate concrete produced from recycled tire crumbs revealed that the concrete was very successful in its application [8]. Various natural (coarse) aggregate percentages were substituted with recycled rubber in the finished product, ranging from 10 percent to 50 percent of its total volume. It has been discovered, for example, that increasing the number of rubber products in concrete (from 10 percent to 50%) enhances the deformation characteristics of the concrete. However, using rubber products instead of natural aggregate would substantially improve the material's flexibility while reducing its compressive strength [8]. It is possible to achieve a damping ratio of up to 90 percent when using concrete containing 25 percent rubber crumb, making it appropriate for usage in regions subjected to dynamic solid loads [1]. Through experimentation, it was investigated how to improve the characteristic performance of the contact zone between cement and the rubberized [8]. The study revealed that dust inclusion from the aggregate treatment might increase the performance of zones of contact involving rubber flakes and the cemented product, which would be a significant advancement in cementing. This theory is supported by the strength characteristics, which display an increment in compressive strength after seven days and 28 days following the experiment [5]. During the experimental investigation of re-adopted rubber for use in the form of granules and dust to substitute present aggregate in cement mixers, It was discovered that: Crumbed dust within the mixture plays a vital role in aiding internal compaction and further ensures no propagation of cracks within the concrete [4]

The existence of rubber particles and crumbs in the mixture diminishes the absorption ability of the concrete [7]. Rubber crumb was utilized instead of fine aggregate in proportions ranging from 10 percent to 20 percent, depending on the application percentage; it aimed to reduce the cost [3]. The researchers found that rubberized granules induced the ultimate strength properties into concrete components, with the portion of crumbs used as a variable based on the amount of rubber incorporated. When the coarse aggregate is substituted with the recycled waste rubber, the compression capability and concrete modulus of elasticity decreased by approximately 14 percent and 19 percent, respectively, after 28 days. When natural aggregate is replaced with waste rubber, the modulus of elasticity and strength decreases by approximately 10 percent and 16 percent. In a study published in the journal Concrete Research, authors described the practical design of self-compacting concrete that has its basis on rubberized granules from tire recycling and further published their findings, aiding further experimentation [4]. The recipes were developed using tiny natural aggregate (sand) and coarse mining crushed aggregate as the building blocks to construct the structure. Rubber crumb was employed as a sand replacement in this experiment, with percentages of 10 percent, 20 percent, and 30 percent rubber crumb being used.

In-depth, most authors have reported a considerable decrease in segregation resistance, passing ability, viscosity, and flowability as the rubber component of the material gains [3]. Regardless of the rubber replacement amount, rubber type, rubber size, or substitute material utilized in the production of the SCC [8]. Researchers observed increased flowability while claiming a reduction in viscosity. It's observed that increasing the degree of rubberized aggregate replacement increased the capacity to pass the test [2].

Porosity/Air Content

Through experimentations, it has been discovered that using recycled crumbed rubber (size 1–4 mm) as a rationed substitute for fine aggregate in self-consolidating mortar mixes enhanced the regarded porosity present in the mortar mixtures [1]. By substituting coarse and fine aggregates with rubberized totals (size-mm 0–3) by volume, researchers have discovered a possible increment of the existing air content in the SCC mixtures [7]. Substitution of rubberized granules (size 0–4.75 mm) for fine particles in SCC mixes resulted in a more cohesive combination when fine particles were used [2]. Most researchers discovered that partial substitution of fine and coarse aggregates rubberized granules (max size 4.75 mm) at varying percentages of the total volume of SCC mixes increased the amount of air in the mix. When the rubber aggregate content was lowered from 30% to zero percent, the air content decreased from 5% to 1.5 percent, resulting in a net reduction of 1.5 percent

According to recent research, crumbed tire aggregates in concrete have been demonstrated to minimize the extraction of coarse and fine aggregates and the negative effect produced by tires discarded at landfills [3]. Rubber concrete has several advantages, including cheaper cost due to decreased density, hardness and impact tolerance enhancement, and increased durability [9].

The inclusion of rubber granules into concrete modifies the qualities of the finished product. Through experimentations, it has been observed that the inclusion of rubberized aggregates, with their uneven form and jagged edges, may help to reduce slump [5]. Rubber aggregates may, however, be made more workable by soaking them in water for 24 hours before using them. Because of the poor interfacial connection between the rubberized aggregates and the concrete mixtures, the compression and tension strengths substantially decrease as the rubber aggregate in the concrete rises. The strength of recycled tire aggregates decreases more because the grain size of the aggregates rises [11].

Benefits of Using Recycled Tires in Concrete

To increase the durability and resilience of concrete, researchers have tried incorporating reclaimed rubber into concrete mixtures to enhance their performance [4]. The outcome has been beneficial, with the researchers noting that this mixture may increase the lifetime of concrete buildings, roads, and bridges and reduce landfill trash from automobile tire disposal. Rubber tire polymer fibers operate as a binding agent, preventing cracking from developing significantly [3]. The tires are carefully shredded and used in the concrete mix as a fine aggregate. The optimal tire fiber blend contains 0.35 percent of the tire fibers [5]. Although rubber fibers have been utilized in asphalt roads, rubber fibers provide a more durable and longer-lasting concrete when employed in the concrete mix.

The most significant advantage of using more resilient concrete is reducing cracking in concrete buildings, roadways, and bridges. It is essential to highlight the usage of recycled tires in building structures to increase their long-term durability [6]. A landfill would otherwise be the final destination for most discarded tires. According to some estimates, approximately three billion kilos of tires are recycled each year, compared to almost six billion cubic meters of concrete utilized annually [1]. Then polymer fibers derived from recycled tires may be used in any concrete mix, regardless of its composition.

VI. METHODOLOGY

Sample collection

In this research, sample materials were collected by picking worn-out tires, crushing them, cleaning them, taking them to laboratories, and conducting tests.

Data collection

This test assesses the proportion of different grain sizes present within sand (fine), coarse aggregates, and recycled waste rubber. The distribution of various grain sizes influences aggregate engineering qualities. Grain size analysis offers the grain size distribution necessary for categorizing aggregate sizes, affecting the concrete block bond.

Workability was not explicitly tested; instead, concrete consistency was measured, which provides a broad indication of the mix's workability condition. A thorough literature search was conducted by investigating various databases that include construction manuals databases and other concrete construction-related journals published online. This is to identify and capture the relevant standards to aid the research process. Notably, the research prioritized conducting experiments on the topic.

After determining the ratio used on the concrete, and blocks made, compressive, tensile, and flexural tests were done using universal test machine cubes to determine if the rubber used in concrete could meet desired specifications. The blocks made were cast into test cubes and then cured for 28 days, and then the test was done on the cubes at an interval of 7 days. Adopting relevant software such as strata and excel to analyze and compare the data sets was pivotal. The study utilized a descriptive statistic approach to illustrate and summarize the relationship between various study constructs. This study's list of constructs includes the most probable mix designs that result in high stability, durability, and the same time economic aspect in the production aspect

VII. EXPERIMENT AND ANALYSIS

Material and methods

The materials utilized in the research were cement, natural aggregates (fine and coarse), and recycled waste rubber aggregates with diameters ranging (from 10 to 20mm). Heavy vehicle scrap tire rubber was shredded to make the rubbers aggregate depicted in Fig. 1. Rubber concrete is made from M25-grade concrete. Replacement percentages are computed based on the volume of the old system. Following 28 days of curing, three specimens of 150x150x150 mm cubes are cast and examined for each percentage.

Fig.1 (from the University of Eldoret Lab)

Experimental data analysis

Sieve analysis.

This testing was conducted to evaluate the proportion of various grain sizes. Sieve analysis was carried out to identify the final product's coarse aggregates and nanostructure mix. The distribution of different grain sizes in soil (engineering materials) impacts the engineering qualities of that particular material. When doing a particle sizes analysis, it is necessary to know the grain size distribution to categorize the material.

Coarse aggregates.

Table A1

Size of Sieve (MM)	Total Weight retained	% retained	Cumulative % retained	Weight filtered through	% filtered through
20.0	0.0	0.0	0.0	3000	100
14.0	1551.0	51.7	51.7	1449.0	48.3
10.0	998.0	68.9	120.6	451.0	15.03
6.3	344.0	76.3	196.9	107.0	3.57
5.0	107.0	100	296.9	0.0	0.0
TOTAL	3000.0	296.9	666.0	-	-

GRADATION CURVE COARSE AGGREGATES

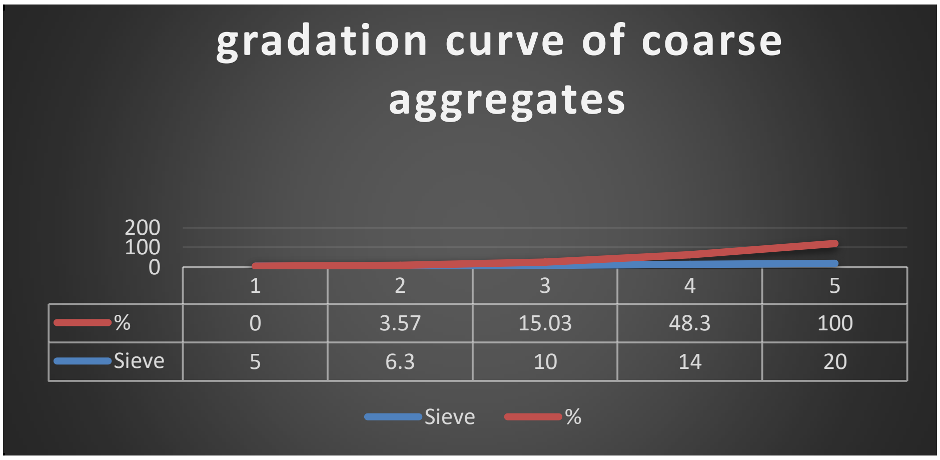


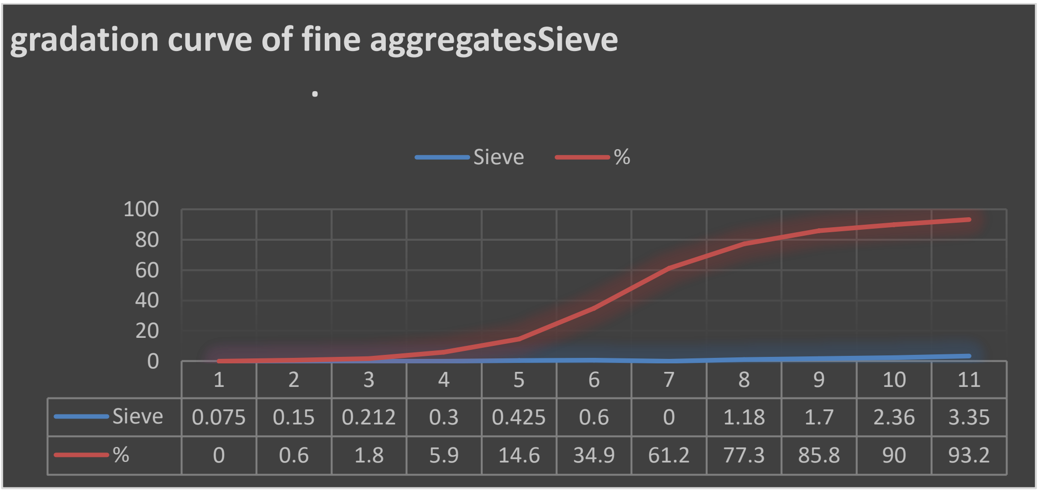
Fig.2

Fine aggregates

Table A2

Size of Sieve (MM)	Total Weight retained	% retained	Cumulative % retained	Weight filtered through	% filtered through
3.35	68.0	6.8	6.8	932.0	93.2
2.36	32.0	3.2	10.0	900.0	90.0
1.7	42.0	4.2	14.2	858.0	85.8
1.18	85.0	8.5	22.7	773.0	77.3
0.85	161.0	16.1	38.8	612.0	61.2
0.6	263.0	26.3	65.1	349.0	34.9
0.425	203.0	20.3	85.4	146.0	14.6
0.3	87.0	8.7	94.1	59.0	5.9
0.212	41.0	4.1	98.2	18.0	1.8
0.15	12.0	1.2	99.4	6.0	0.6
0.075	6.0	0.6	100.0	0.0	-
TOTAL	1000	100	-	-	-

GRADATION CURVE OF FINE AGGREGATES

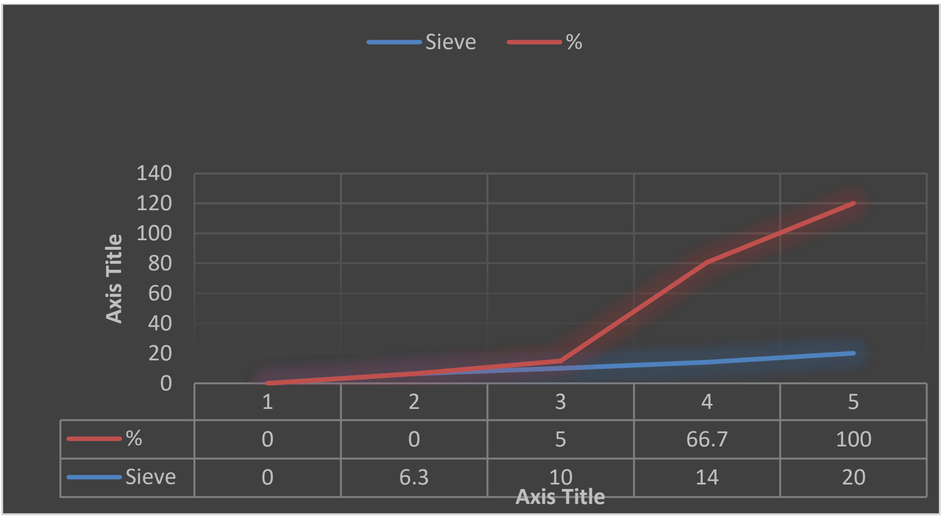


Crushed tire rubber

Table A3

Size of Sieve (MM)	Total Weight retained	% retained	Cumulative % retained	Weight filtered through	% filtered through
20.0	0.0	0	0	3000	100.0
14.0	1000	33.33	1000	2000	66.67
10.0	1850	61.67	2850	150	5.0
6.3	150	5.0	3000	-	0.0
TOTAL	3000	100	-	-	-

GRADATION CURVE CRUSHED RUBBER TIRE.



VIII. MIX DESIGN

According to the trial mix findings, a concrete block of class 25 was prepared per IS 10262:2009. The standard concrete ratios are shown in Table A4. Table A4

Table A4.

Mix proportionalities			
class	expected mean strength (N/mm2)	Water/Cement ratios	ratios
M25	31. 60	0.46	1:2.2:2.72

Test Specimens

Cubes with dimensions of 150mm x 150mm x 150specimens were cast in standard steel molds with dimensions of 150mm x 150mm. Table A5 contains information on the test specimens, including their characteristics.

Table A5

	specimen	% replaced (rubber)	water	Cement	CA	FA	Rubber
	G1	0	2.88	5.7	15.5	6.8	0
	G2	8	2.88	5.7	14.4	6.8	0.8
	G3	12	2.88	5.7	13.7	6.8	1.6
	G4	18	2.88	5.7	13.2	6.8	2.42

Tests for properties

Slump test

The slump test and compaction factor rates are used to measure the workability of concrete. Results are shown in Table A6. Figure 3 depicts the variation in the Compaction factor caused by multiple degrees of rubber.

Fig. 3. Slump testing

Table A6

sample	% replaced (rubber)	Slump results (mm)	Compacting factor
G1	0	85	0.82
G2	8	62	0.7
G3	12	0	0.65
G4	18	0	0.65

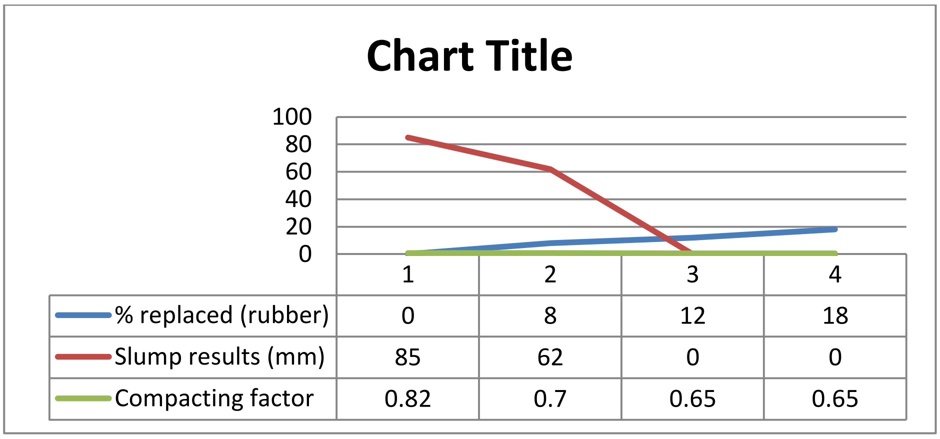


Fig.4 Workability test graph

Compression strength.

The compressional strength of the samples is assessed using a universal testing machine, and the findings are described in Tables A7and Fig. 5

Table A7

Compressive strength (MPa)				
sample	% replaced (rubber)	Strength -7days	Strength -21days	Strength -28days
G1	0	20	25	30.41
G2	8	16.88	21	27.95
G3	12	14.3	17	25.3
G4	18	12.2	16	22

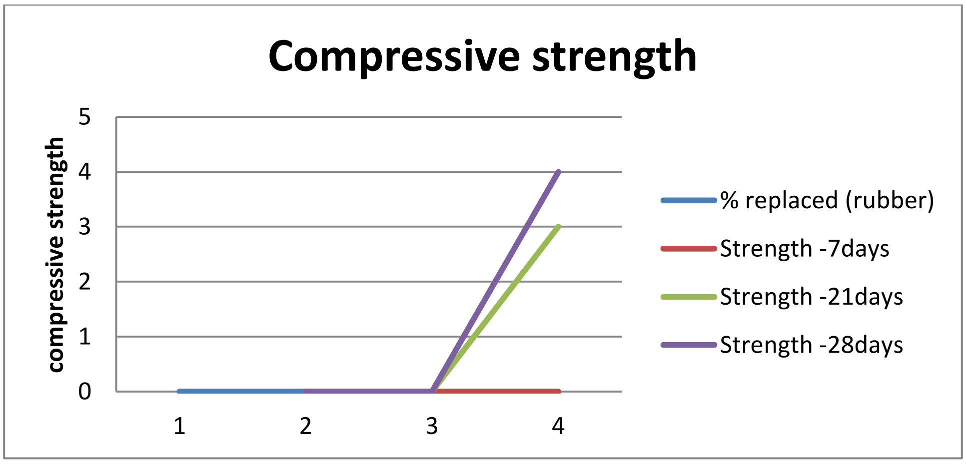


Fig. 5 Compressive strength graph

Fig 6. Universal testing machine.

Flexural strength.

Table: A 8

tensile strength (MPa)				
sample	% replaced (rubber)	Strength – 7 days	Strength - 21 days	Strength – 28 days
G1	0	3	4.0	5.1
G2	8	2.71	3	3.55
G3	12	1.5	1.89	2.39
G4	18	1.33	1.5	2.3

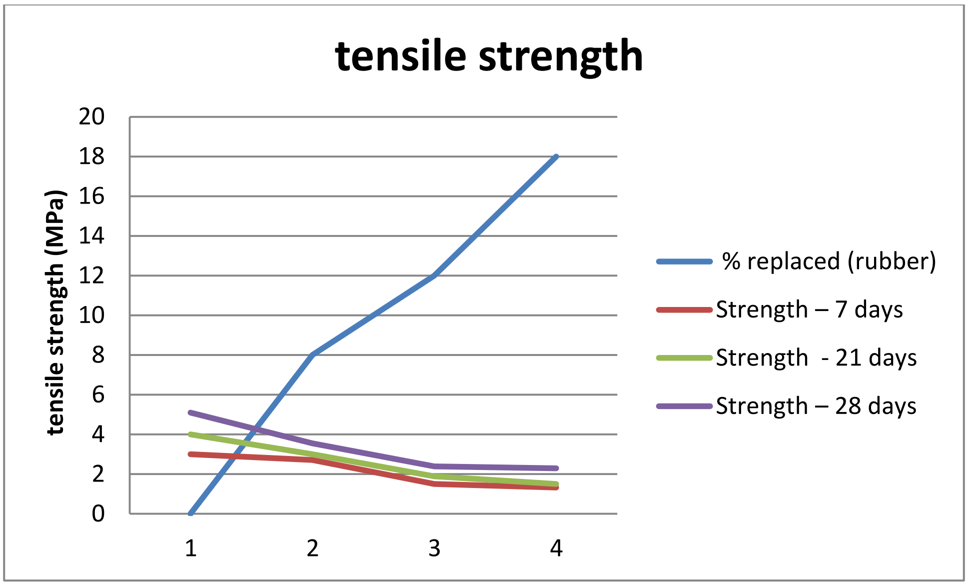


Fig 7 tensile strength graph

IX. RESULTS AND DISCUSSION

Concrete slump and workability were considerably improved when recycled rubber tires were added. All concrete mixtures were supposed to have a 5-inch slump; however, they all had significantly smaller recessions. The slump was found to be lessened as the rubber content was raised. According to IS 456-2000, the slump requirement for the concrete construction works ranges from 50 mm to 100 mm; this is adequately captured in the experimentations. In general, the quantity of energy required to cast specimens grew significantly as the percentage of rubber increased. The strength of concrete under tension, flexure, and compression increases along with the paste aggregate bond strength. As a general rule, the stress-strain curve (not shown) for each test reveals a rise in plastic deformation, which corresponds to an increase in toughness with a progressive failure. The pieces of cement tested usually stay intact, connected through the rubber particles.

Compression

There was a decrease in compressive strength in all conditions, and the reduction of compressive strength is much more pronounced with a more significant percentage of rubber substitution (Tables A7and Fig. 5). Compressive strength changes are shown in portions in Tables A7 for each mix and age combination. Low rubber elastic modulus in comparison to natural aggregates and more air trapped in rubber voids and cement grains are all variables that contribute to the reduction. It has been claimed that the compressive strength can be improved by using supplemental cementing materials (SCMs). With this information in mind, waste tire rubber can complement natural fine or coarse aggregate while maintaining compressive strength (Fc) values lower than the limit for structural purposes, namely 17 MPa or above. However, the appropriate replacement level is first determined based on test results.

Critically pavements require the minor compressive strength of 26.7Mpa, to ensure adequate durability and to serve the purpose of load-bearing. The required characteristics are achieved after 28 days and thus prove satisfactory for installation in many areas such as footpaths.

Flexural Strength.

Waste tire rubber has been found to reduce the flexural strength of SCC by a significant margin, according to many studies. The drop in flexural strength was the same regardless of rubber particle diameter for the rubber replacement at the same level. Compressive strength is further reduced by air trapped between rubber and cement particles, which is assumed to be caused by the voids and pore spaces on the rubber surface. The elastic behavior of rubber particles, on the other hand, may have prevented a quick collapse in some test specimens containing rubber. However, the incorporation of scrap tire rubber resulted in increased flexural strength because of the rubber aggregate's more extraordinary load-carrying ability. Representatives (recycled rubber) significantly facilitate the decline in flexure of concrete.

Tensile Strength.

Tensile strength decreases as rubber quantity in test specimens increases: the capability gaps or the replacement material. Up to 18% rubber substitution was evaluated. The most remarkable drop in splitting tensile strength occurred at this replacement stage; rubber pre-treatment procedures might improve this mechanical attribute after pre-coating the rubber granules using a mortar pre-treatment method. To increase the tensile strength, it is possible to add longer fibers, which have a beneficial effect on the values.

X. CONCLUSIONS

The rise in tenacity and ductility suggests that any other test method is essential to improve strength while retaining flexibility. However, at this point, recycled rubber tires used as aggregate might be effective in operating as a concrete mixture in non-structural applications, so it represents a feasible alternative to reusing tires helping in the environment preservation.

Despite the rubber concrete mixtures having a lower compressive strength than standard concrete, this study shows a considerable market for structural concrete that includes rubber aggregates and uses discarded rubber tires, whose disposal is a significant source of pollution.

- It is possible to strengthen the binding characteristics of rubber particles when used in concrete to increase their strength.
- It is possible to use rubberized concrete in architectural applications, road curbs, footpaths, false facades, stone baking, inner construction, and construction as an earthquake sonic boom absorbing material. Where resonance dampers are needed, such as in base pads for machines and equipment rail stations, it's also of advantage in use. Load impact resistance or blast is required, including barrier, rail line buffers, bunkers, and trench filling of its lightweight unit.
- The use of rub created in rendering top rooftop surfaces for insulating could be one of its potential applications.

XI. RECOMMENDATIONS

Rubber aggregates for concrete buildings are not widespread in Kenya. An enormous amount of effort must be made, and institutions of higher learning alongside reserved engineering research institutions should play a significant role in ensuring experimentations and research works are furthered to layout standards on the usage of the tire in partial substitution of aggregates. Research institutes that encourage environmentally friendly tire recycling should be available to tire makers and importers concerned about the environmental impact of waste tires.

Designers and constructors often resort to high-strength concrete to gain additional features, including impact resistance for parking facilities and lightweight constructions for specific uses. It is still possible to attain these features by applying rubberized concrete after first conducting testing to determine what properties are wanted. It should be examined because rubberized concrete can be used as an alternative to traditional concrete.

Despite the lack of long-term testing, these mixtures are advised in areas where high concrete strength is less significant than other attributes. To further this investigation, it is recommended that future experiments be carried out in the following areas:

- This study used a consistent admixture dose for a specific mix category.
- Investigating the effects of different admixture dosages is a good idea.
- De-airing products should be tested to see if they reduce the amount of air trapped in rubberized concrete. As a result, compressive strength could be significantly improved.
- Whether or not any alkali-silica or alkali-carbonate reactions occur between the rubber aggregate and other rubberized concrete elements should be explored to rule out any unwanted consequences.
- Rubber aggregates of size 14 mm were prepared for this study by manufacturing single graded rubber aggregates. There is a need to investigate the impact of different sizes in the future.

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