Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 9, September : 2023

A STUDY ON RUBBER PIECES AS REPLACEMENT OF COARSE AGGREGATE IN CONCRETE

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ABSTRACT
Modifications of construction materials have an important bearing on the building sector. Several attempts have been therefore made in the building material industry to put to use waste material products, e.g., worn-outtyres, into useful and cos effective items. This Waste - Tyre rubber is the significant environmental problems worldwide. With the increase in the automobile production, large amounts of waste tyre need to be disposed. Due the rapid depletion of available sites for waste disposal, many countries banned the disposal of waste tyre rubber in landfills. Research had been in progress for long time to find alternatives to the waste tyre disposal. Among these alternatives is the recycling of waste-tyre rubber. Recycled waste tyre rubber is a most widely used method. Recycle wasted Tyre Rubber is a promising material in the construction industry due to its light weight, elasticity energy absorption, sound and heat insulating properties. Success in this regard will contribute to the reduction of waste material dumping problems by utilizing the waste materials as raw material for other products. The present proposal involves a comprehensive laboratory study for the newer application of this waste material in the preparation of fibrous concrete. The primary objective of investigation is to study the strength behaviour i.e. compressive and flexural strength, of rubberized concrete with different volume of waste- Tyre rubber. Parameter to be varied in Investigation: I. Volume variation of waste rubber. In this the density and compressive strength of concrete utilizing waste tyre rubber has been investigated. The proposed work is aimed to study the effect of volume variation of waste-Tyre rubber on the compressive strength, flexural strength, Slump test &The relationship between stress and strain of the concrete. Recycled waste tyre rubber has been used in this study to replace the coarse aggregate by weight of 15%. The results shows that although, there was a significant reduction in the compressive strength of concrete utilizing waste tyre rubber than normal concrete, concrete utilizing waste tyre rubber demonstrated a ductile, plastic failure rather than brittle failure. In this study we use to find out the compressive strength &flexural strength of concrete by the replacement of coarse aggregate by wasteTyre rubber in normal concrete in grade of M30.

Key Words: Waste tyre rubber, Compressive Strength, Flexural Strength, Workability.

I. INTRODUCTION

1.1 Background of the Study

Cement and aggregate, which are the most important constituents used in concrete production, are the vital materials needed for the construction industry. This necessity led to a continuous and increasing demand of natural materials used for their production. Parallel to the need for the utilization of the natural resources emerges a growing concern for protecting the environment and a need to preserve natural resources, such as aggregate, by using alternative materials that are either recycled or discarded as a waste.

Concrete strength is greatly affected by the properties of its constituents and the mix design parameters. Because aggregates are the major constituents of the bulk of a concrete mixture, its properties affect the properties of the final product. An aggregate has been normally treated as inert filler in concrete. However, due to the increasing awareness of the role played by aggregates in determining many important properties of concrete, the traditional view of the aggregate as an inert filler is being seriously questioned. Aggregate was initially viewed as a material dispersed throughout the cement paste largely for economic reasons. It is possible, however, to take an opposite view and to look on aggregate as a building material connected into a cohesive whole by means of the cement paste, in a manner similar to masonry construction. In fact aggregate is not truly inert and its physical, thermal, and sometimes chemical properties influence the performance of concrete.

Aggregate is cheaper than cement and it is, consequently, economical to put into the mix much of the former and as little of the soon as possible. Nevertheless, economy is not the only reason for using aggregate: it confers considerable technical advantages on concrete, which has a higher volume stability and better durability than hydrated cement paste alone.

According toward Kumaran S.G. et al, the goal of sustainability is that life on the planet can be sustained for the foreseeable future and there are three components of sustainability: environment, economy, and society. To meet its goal, sustainable development must ensure that these three components remain healthy and balanced. Moreover, it must do so simultaneously and right through the entire planet, both now and in the future. At the moment, the environment is most likely the most important factor and an engineer or architect uses sustainability to mean having no net unhelpful impact on the environment.

Among the many threats that affect the environment are the wastes which are generated in the production process or discarded after a specific material ends its life time or the intended use. The wastages are divided as solid waste, liquid waste and gaseous wastes. There are many ways for disposal of liquid and gaseous waste materials. Some solid waste materials such as plastic bottles, papers, steel, etc can be recycled without affecting the environment. However, studies on how to dispose some solid wastes such as waste tyres in the most beneficial ways are not yet fully exhausted.

Tyre is a thermo set material that contains cross-linked molecules of sulphur and supplementary chemicals. The process of mixing rubber with supplementary chemicals to form this thermoset material is generally known as vulcanization. This makes postconsumer tyres very stable and nearly not possible to degrade under ambient conditions. Consequently, it has resulted in a growing disposal problem that has led to changes in legislation and significant researches worldwide. On the other hand, disposal of the waste tyres all around the world is becoming higher and higher through time. This keeps on increasing every year with the number of vehicles, as do the future problems relating to the crucial environmental issues.

If the tyre is burned, the toxic product from the tyre will damage the environment and thus creating air pollution. Since it is not a biodegradable material, this may influence the fertility of the soil and vegetation. Sometimes it may generate uncontrolled fire. Similarly, the other test to the human society is in the form of carbon dioxide secretion and green house secretion. These emissions are considered as highly aggressive wastes to the universe.

Since 1990, it has been the policy of the State of Arizona that the recycling and reuse of waste tyres are given the highest priority. The Arizona Department of Transportation (ADOT) has lengthy support to the use of recycled waste tyre rubber in asphalt rubber hot mix.

A Co-operative work between ADOT and Arizona State University (ASU) was conducted to extend the use of crumb rubber in Portland cement concrete mixes. The intent was to use such mixes on urban improvement related projects. A list of reasonable projects was identified. Examples are roadways or else road intersections, sidewalks, recreational courts and pathways, and wheel chair ramps for improved skid resistance. This collaboration has also extended to include members from industry associations, concrete suppliers and consultants. Several crumb rubber in concrete test sections were built right through the state of Arizona and are being monitored for performance.Figure 1.1 below shows the stockpiles of waste tyres.

Fig. 1.1 Stockpiles of Waste tyres

Hence, all the above studies suggest that there is a strong need to use recycled materials in concrete and specifically waste tyres should be used in an environmental friendly way. For this, concrete construction can be considered as a very reasonable and suitable area of application.

1.2 Statement of the problem

Concrete has been a major construction material for centuries. Moreover, it would even be of high application with the increase in industrialization and the growth of urbanization. Yet concrete construction so far is mainly based on the use of virgin normal resources. Meanwhile the conservation concepts of natural resources are worth identification and it is very essential to have a look at the dissimilar alternatives. Among them lies the recyclingmechanism. This is a double advantage. One is that it can prevent the depletion of the scarce natural resources and the other will be the anticipation of different used materials from their severe intimidation to the environment.

It has been well reported that about 1 billion of used automobile tyres are produced each year globally. Specifically, 275 million of used rubber tyres gather in the United States and about 180 million in European Union. In Ethiopia, the amount of waste tyres is estimated to increase with the increase of vehicles. In addition to that, the usual ways of recycling tyres in our country like as a shoe making material and other tools is decreasing nowadays. This is consider as one of the main environmental challenges facing municipalities around the world because waste rubber is not easily biodegradable even after a long period of landfill treatment. The best management plan for scrap tyres that are worn out beyond hope for reuse is recycling. Utilization of scrap tyres should minimize environmental impact and maximize protection of natural resources. The regulatory practices consist of landfill bans and scrap tyre fees. Because rubber waste does not biodegrade eagerly, even after long periods of landfill treatment, there is changedconcentration in developing alternatives to disposal. One possible clarification for this problem is to incorporate rubber particles into cement-based materials. Scrap tyres know how to be shredded into raw materials for use in hundreds of crumb rubber products.

The other part of the problem is that aggregate production for construction purpose is continuously leading to the reduction of natural resources. Moreover, some countries are depending on imported aggregate and it is definitely very costly. For example, the Netherlands does not have its own aggregate and has to import. This concern leads to a highly growing interest for the use of substitute materials that can restore the natural aggregates.

Therefore, the use of recycled waste tyres as an aggregate can provide the solution for two major problems: the environmental problem created by waste tyres and the depletion of natural resources by aggregate production therefore the shortage of natural aggregates in some countries.

II. OBJECTIVES, SCOPE AND METHODOLOGY OFTHE STUDY

2.1 Objectives of the study

2.1.1 General Objective

Most of the time, used tyre rubber is not noticed to be applied in a useful way. It is slightly becoming a potential waste and pollutant to the environment. Moreover, the collecting process of waste tyres is not very costly as compared to the extraction or production of mineral aggregates used in normal concrete. Hence, this study is intended to show the possibility of using crumb rubber concrete in Ethiopia as a partial replacement for coarse aggregate in concrete. The general objective of this research is to evaluate the fresh and hardened properties of the concrete produced by replacing part of the natural coarse aggregate with an aggregate produced from locally available recycled tyre rubber.

2.1.2 Specific Objectives

The specific objectives of the research are listed as follows:

1) With the increase in urbanization in Ethiopia, the number of cars and consequently the amount of used tyre is going to increase significantly in the near future. Hence, the non-environmental nature of these wastes is going to be a potential hazard. This study can show an another way of recycling tyres by incorporating them into concrete construction. Of course, the concept that the problem emerges from urbanization and the solution goes along with it can also be respected. Therefore, it is the aim of this study to introduce an environmental friendly technology, which can promote the society and the nation.
2) Application of used tyres in concrete construction is a new technology and a well-developed mix design for material proportioning is not available. Through this study, it is intended to arrive at a suitable mix proportion and percent replacement using locally available materials by partial replacement of the natural coarse aggregates with recycled coarse rubber aggregates. Hence the opportunity of using waste tyres as an alternative building material will be investigated.
3) By conducting different laboratory tests on prepared specimens, it is proposed to analyze the results. Additionally, from the properties of the concrete the advantages and disadvantages of using it will be figured out.

2.2 Scope of the study

1) This study concentrated on the performance of a single gradation of crumb rubber. The waste tyres are collected from local sources and manually cut into pieces to attain a uniform size of 20 mm, which is the maximum aggregate size in the mix design.
2) The influence of dissimilar gradations of the rubber aggregate on concrete properties was not evaluated in this study but it should be considered in upcoming researches.
3) All the waste tyres collected were chosen from local area Tirupathi to avoid any inconsistent properties that may arise by mixing materials from different sources. The properties of waste tyres from other tyre manufacturers were not incorporated in this study.
4) The study was done on two grades of concrete (M20, M30). The percentage replacements were restricted to three categories i.e. 10, 25 and 50% replacement of the normal coarse aggregate. The different effects, which can be observed in different percentages of replacements, were not included in the present study.

2.3 Methodology of the study

The different methods utilized in this research include the following:

i) Background study

Literature survey was carried out to review previous studies related to this thesis.

ii) Collection of raw Materials

All the required materials were collected and delivered to the laboratory. These are; Cement, fine aggregate and coarse aggregate, used rubber tyres and also admixtures.

iii) Material Tests

Tests were conducted on the raw materials to determine their properties and suitability for the experiment.

iv) Mix Proportioning (Mix Design)

Concrete mix designs were prepared using the Department of Experiment (DOE) method. A total of 8 mixes with two types of concrete grades (M20, M30)were produced. They were prepared with coarse aggregate replacements by 10, 25 and 50 % of the rubber aggregates. A control mix with no rubber aggregate substitute was created to make a comparative analysis.

v) Specimen preparation

The concrete specimens were prepared in the Siddhartha institute of engineering and technology, Civil Engineering Department Material Testing laboratory. The prepared samples consist of concrete cubes and cylinders.

vi) Testing of Specimens

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 9, September : 2023

Laboratory tests were carried out on the prepared concrete samples. The tests conducted were slump, unit weight, compressive strength, splitting tensile strength.

vii) Data collection

The data gathering was mainly based on the tests conducted on the prepared specimens in the laboratory.

viii) Data Analysis and Evaluation

The test results of the samples were compared with the respective control concrete properties and the results were presented using tables, pictures and graphs. Conclusions and recommendations were lastly forwarded based on the findings and observations.

III. LITERATURE REVIEW

3.1 General Characteristics and Constituents of Concrete

3.1.1 Characteristics of Concrete

Concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in a hard matrix of material (the cement or binder) that fills the space between the aggregate particles and glues them together. In its simplest appearance, concrete is a mixture of paste and aggregates. The paste, collected of Portland cement and water, coats the surface of the fine and coarse aggregates. Through a chemical reaction called hydration, the paste hardens and gains strength to appearance the rock-like mass known as concrete.

Concrete is the world's most essential construction material. The quality and performance of concrete plays a key role for most of the infrastructures together with commercial, industrial, residential and military structures, dams, power plants and transportation systems. Concrete is the single largest man-made material in the world and accounts for more than 6 billion metric tons of materials annually. In the United States, federal, state, and local governments have nearly $1.5 trillion dollars in venture in the U.S. civil infrastructure. The worldwide use of concrete materials accounts for nearly 780 billion dollars in yearlyexpenditure.

Types of Portland Cements

Different types of Portland cement are manufactured to meet different physical and chemical requirements for specific purposes. The American Society for Testing and Materials (ASTM) description C 150 provides for eight types of Portland cements.

TYPE I

Type I is a general-purpose Portland cement suitable for all uses where the special properties of other types are not required. It is used where cement or concrete is not subject to specific exposures, such as sulfate attack from soil or water, or to an objectionable temperature rise due to heat generated by hydration. Its uses include pavements and sidewalks, reinforcedconcrete buildings, bridges, railway structures, tanks, reservoirs, culverts, sewers, water pipes and masonry units.

TYPE II

Type II Portland cement is used where precaution against moderate sulfate attack is important, as in drainage structures where sulfate concentrations in ground waters are higher than normal but not unusually severe. Type II cement will usually create less heat at a slower rate than Type I. With this moderate heat of hydration (an optional requirement), Type II cement can be used in structures of significant mass, such as large piers, heavy abutments, and heavy retaining walls. Its use will reduce temperature rise which is particularly important when the concrete is placed in warm weather.

TYPE III

Type III is a high-early strength Portland cement that provides high strengths at an early period, usually a week or less. It is used when forms are to be detached as soon as possible, or when the structure must be put into service rapidly. In cold weather, its use permits a decrease in the controlled curing period. Although richer mixtures of Type I cement can be used to grow high early strength, Type III, high early- strength Portland cement, may give it more agreeably and more economically.

Table 3.1 Typical solid wastes that have been measured as aggregate for Concrete.

Material	Composition	Industry
Mineral wastes	Natural rocks	Mining and Mineral processing
Blast furnace slags	Silicates or alumina silicates of calcium and magnesium silicate Glasses	Iron and Steel
Metallurgical slags	Silicates, aluminosilicates and glasses	Metal refining
Bottom ash	Silica glasses	Electric power
Fly ash	Silica glasses	Electric power
Municipal wastes	Paper, glass, plastics, metals	Commercial and Household wastes
Incinerator residues	Container glass and metal and silica Glasses	Municipal and Industrial wastes
Building rubble	Brick, concrete, reinforcing steel	Demolition

3.1.2.3 Water

Water is a key ingredient in the manufacture of concrete. Attention be supposed to be given to the quality of water used in concrete. The time-honored rule of thumb for water value is “If you can drink it, you can make concrete with it.” A large quantity of concrete is made using municipal water supplies. However, good quality concrete can be made with water that would not pass normal standard for drinking water.

Mixing water can cause problems by introducing impurities that have a harmful effect on concrete quality. Although satisfactory strength development is of primary concern, impurities restricted in the mix water may also affect setting times, drying shrinkage, or durability or they may cause efflorescence. Water should be avoided if it contains large amounts of dissolved solids, or considerable amounts of organic materials.

3.2 The Use of Recycled Materials in Concrete Construction

3.2.1 General

Waste materials are common problems in modern living. Waste accumulates from a number of sources including domestic, industrial, commercial and construction. These waste materials have to be eventually disposed of in ways that do not endanger human health. In light of this, waste minimization is increasingly seen as an ecologically sustainable strategy for alleviating the need for the disposal of waste materials, which is often costly, time and space consuming, and can also have significant detrimental impacts on the natural environment. Nowadays governments and organizations have been concerned with developing policies and programs to bring about successful outcomes to waste minimization. This is seen as being essential to reduce the total amount of waste materials going into landfill, especially in the urban areas where land is very scarce. The use of recycled materials is often cheaper for the consumers of the end product. Hence, there is also an economic justification for promoting its use.

The use of recycled materials generated from transportation, industrial, municipal and mining processes in transportation facilities is an issue of great importance. Recycled concrete aggregates and slag aggregates are being used where suitable. As the useable sources for natural aggregates for concrete are depleted, utilization of these products will increase. Utilization of fly ash and ground granulated blast furnace slag (ggbs) in concrete addressesthis issue in addition to improving concrete properties. The replacement of Portland cement by fly ash or GGBS reduces the volume of cement utilized which is a major benefit since cement manufacturing is a significant source of carbon dioxide emissions worldwide. Silica fume is a comparatively expensive product and it is added in smaller quantities in concrete mixture rather than as a cement replacement.

All of these applications greatly highlight the different attempts of using recycled materials in concrete and their respective reward achieved so far. One of today’s major problems and which will continue to do so for the foreseeable future is the environmental pollution resulting from industrial wastes and waste living materials. Particularly among the waste materials in the progression of civilization are discarded waste tyres. The main reason for this is that the amount of waste tyres is growing at an alarming rate due to the large number of cars and trucks.

Table 3.2 Percentage Composition of Materials for a Passenger and a Truck car.

Material	passenger car	Truck car
Natural rubber	14 %	27 %
Synthetic rubber	27 %	14 %
Carbon black	28 %	28 %
Steel	14-15 %	14-15 %
Fabric, fillers, accelerators, antiozonants etc.	16-17 %	16-17 %

3.3.2 Rubber Aggregate

Rubber aggregates are obtained by reduction of scrap tyres to aggregate sizes using two general processing technologies: mechanical grinding or cryogenic grinding. Mechanicalgrinding is the most common process. This method consists of using a variety of grinding techniques such as ‘cracker mills’ and ‘granulators’ to mechanically break down the rubber shred into small particle sizes ranging from several centimeters to fractions of a centimeter. The steel bead and wire mesh in the tyres is magnetically separated from the crumb during the various stages of granulation, and sieve shakers separate the fiber in the tyre.

Shredded tyres can be used as filler material for soils, foundations and pavements. Crumbed or pulverized tyre rubber can be combined with other polymeric material to form mats, playground tiles, or road barriers among others. By itself, it can be used as an aggregate for asphalt pavements or concrete mixes. Similar to the recycling of polymers, a solution is to substitute part of the aggregate in concrete mixes with pulverized tyre rubber or shredded tyres. The idea of using tyres as aggregates initially emerged from the reason that they have physical properties that can be substituted for existing materials, or because their properties provide an advantage over existing materials. These include; Durability, low unit weight, high hydraulic conductivity, low horizontal stress, flexibility for construction and thermal resistivity.

Fig. 3.1 Samples of Coarse granules of Waste Tyre

Ling T.C. and Hasanan M.N. conducted a research using crumb rubber produced by mechanical shredding as a fine material with the gradation close to that of natural sand. In this study, two particle sizes of crumb rubber were used: 1-3 mm and 3-5 mm as a partial substitute for sand in the production of concrete paving block. Figure 3.2 below shows the mechanically shredded fine tyres.

Fig. 3.2 Mechanically Shredded Fine Tyres

A research by Yunping Xi et al used two types of rubber particles of different sizes (large and small to study the size effect on mechanical properties of rubberized concrete. The average size of large particles was 4.12 mm, and the average size of small particles was 1.85 mm. The test results indicated that the particle size used in this study has no significant effect on compressive strength, brittleness and toughness of the concrete produced. Figure 3.3 below shows rubber cuts of 4.12 mm.

Fig. 3.3 Tyre Rubber Cuts of 4.12 mm

In a quite different manner**,** a study by Prakash P. et al has used crumb rubber to replace cement. The focus of the experimental program was to investigate the performance of Cement Stabilized Soil Blocks with treated crumb rubber as a partial replacement of cementto produce cement stabilized soil blocks. By using cement as a binder and conventional soil cement stabilized blocks production process, the treated crumb rubber cement stabilized soil blocks were more durable and absorbed higher energy under impact.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 9, September : 2023

IV. MATERIAL PROPERTIES AND MIX DESIGN

4.1 General

Concrete mixtures with and without rubber aggregates for different compressive strength values were prepared in this research work. The materials used to develop the concrete mixes in this study were fine aggregate, coarse aggregate, rubber aggregate, cement, water and admixture. A total of 8 mixes were prepared consisting of two types of concrete grades (M20,M30) with partial replacements of the coarse aggregate by 10, 25 and 50% of the rubber aggregate. Moreover, a control mix with no replacement of the coarse aggregate was produced to make a comparative analysis. In the subsequent parts, the different materials used in this study are discussed.

4.2 Cement

The cement type used in this research was OPC grade 53 cement manufactured in India. The main reason for using Ordinary Portland Cement (Type I) in this study is that, this is by far the most common cement in use and is highly suitable for use in general concrete construction when there is no exposure to sulphates in the soil or groundwater. The choice of OPC from PPC also avoids any uncertainties in the results of the test.

4.3 Aggregates

The relevant tests to identify the properties of the aggregates that were intended to be used in this research were carried out. After that, corrective measures were taken in advance before proceeding to the mix proportioning. In general, aggregates should be hard and strong, free of undesirable impurities, and chemically stable. Soft, porous rock can limit strength and wear resistance; it may also break down during mixing and adversely affect workability by increasing the amount of fines. Aggregates should also be free from impurities: silt, clay, dirt or organic matter. If these materials coat the surfaces of the aggregate, they will isolate the aggregate particles from the surrounding concrete, causing a reduction in strength. Silt, clay, and other fine materials will also increase the water requirements of the concrete, and organic matter may interfere with cement hydration. To proportion suitable concrete mixes, certain properties of the aggregate must be known. These are; shape and texture, size gradation, moisture content, specific gravity and bulk unit weight.

4.3.1 Properties of the Fine Aggregate

The fine aggregate sample used in this experiment was purchased from local sand suppliers at Addis Ababa around ‘*Legehar area*’. To investigate its properties and suitability for the intended application, the following tests were carried out.

- sieve analysis for fine aggregate and fineness modulus
- Specific gravity and absorption capacity for fine aggregate
- Moisture content for fine aggregate Silt content for fine aggregate -Unit weight of fine aggregate

4.3.1.0 Sieve Analysis for Fine Aggregate and Fineness Modulus

Sieve analysis is a procedure for the determination of the particle size distribution of aggregates using a series of square or round meshes starting with the largest. It is used to determine the grading, fineness modulus, an index to the fineness, coarseness and uniformity of aggregates. The quality of concrete to be produced is very much influenced by the properties of its aggregates. Aggregate grain size distribution or gradation is one among these properties and should be given due consideration.

Sieve Size (mm)	Wt. of Sieve (gm)	Wt. of Sieve and Retained (gm)	Wt. Retained (gm)	% age Retained	Cumul. Retained	% passing	Lower Limit	Upper Limit
9.5	586	586	0	0.00	0.00	100.00	100.00	100
4.75	567	576	9	1.80	1.80	98.20	95.00	100.00
2.36	521	535	14	2.80	4.60	95.40	80.00	100.00
1.18	529	584	55	11.00	15.60	84.40	50.00	85.00
0.06	506	719	213	42.60	58.20	41.80	25.00	60.00
0.03	478	627	149	29.80	88.00	12.00	10.00	30.00
0.015	462	512	50	10.00	98.00	2.00	2.00	10.00
Pan	423	431	8	1.60	99.60	0.40		

Industrial Engineering Journal

ISSN: 0970-2555

Volume : 52, Issue 9, September : 2023

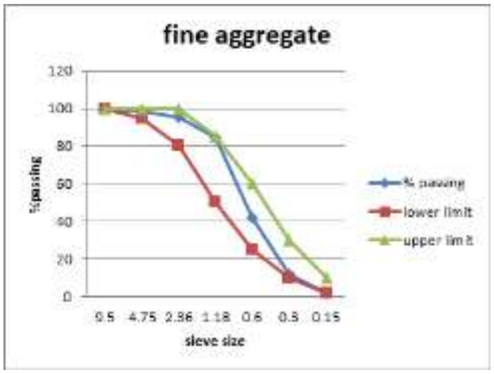

Fig. 4.1 Graph for Sieve analysis of Fine aggregate

Fineness modulus (F.M) = ∑cumulative coarser (%) ………………..[38] 100

F.M. = 266.2/100 =2.66

4.3.1.2 Specific gravity and absorption capacity of fine aggregate

The specific gravity of an aggregate is considered to be a measure of strength or quality of the material. The specific gravity of a substance is the ratio between the weight of the substance and that of the same volume of water. This definition assumes that the substance is solid throughout. Aggregates, however, have pores that are both permeable and impermeable. The structure of the aggregate (size, number, and continuity pattern) affects water absorption, permeability, and specific gravity.

4.3.1.3 Moisture content of fine aggregate

A design water cement ratio is usually specified based on the assumption that aggregates are inert (neither absorb nor give water to the mixture). But in most cases aggregates from different sources do not comply with this i.e. wet aggregates give water to the mix and drier aggregates take water from the mix affecting in both cases, the design water cement ratio and therefore workability and strength of the mix. In order to correct for these discrepancies, the moisture content of aggregates has to be determined.

4.3.1.4 Silt content of fine aggregate

Sand is a product of natural or artificial disintegration of rocks and minerals. Sand is obtained from glacial, river, lake, marine, residual and wind-blown deposits. These deposits however do not provide pure sand. They often contain other materials such as dust, loam and clay that are finer than sand. The presence of such materials in sand used to make concrete or mortar decreases the bond between the materials to be bound together and hence the strength of the mixture. The finer particles do not only decrease the strength but also the quality of the mixture produced resulting in fast deterioration. Therefore, it is necessary that one make a test on the silt content and check against permissible limits.

4.3.2 Properties of the coarse aggregate

Coarse aggregate for concrete shall consist of natural gravel or crushed rock or a mixture of natural gravel and crushed rock. Coarse aggregate used in this research was purchasedfrom*TikurAbay* Construction Company.

In a similar manner like the fine aggregate, laboratory tests were carried out to identify the physical properties of the coarse aggregate and the results are shown in Table 4.2 below. Table 4.3 shows the sieve analysis test results and figure 4.2 shows thecorresponding graph.

Table 4.2 Physical Properties of the Coarse Aggregate.

Description	Test Result
Moisture content	1.37 %
Unit weight of coarse aggregate	1533.25 kg/m^3
Bulk Specific gravity	2.79
Bulk specific gravity(SSD basis)	2.84
Apparent specific gravity	2.93
Absorption capacity	1.72 %
Crushing value of aggregate	17.83 %
Los Angeles Abrasion Test	14.9 %

Table 4.3 Sieve Analysis for the Coarse Aggregate.

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ISSN: 0970-2555
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Sieve Size (mm)	Wt. of Sieve (gm)	Wt. of Sieve and Retained (gm)	Wt. of Retained (gm)	% Retain.	Cum. Retain.	% Pass.	Lower Limit	Upper Limit
37.5	1188	1188	0	0.00	0.00	100.00	100.00	
19	1419	1419	0	0.00	0.00	100.00	90.00	100.00
12.5	1166	3645	2479	48.36	48.36	51.64	40.00	80.00
9.5	1171	2682	1511	29.48	77.84	22.16	20.00	55.00
4.75	1194	2222	1028	20.05	97.89	0.35	0.00	10.00
Pan	1060	1150	90	1.76	99.65	0.35	0.00	5.00

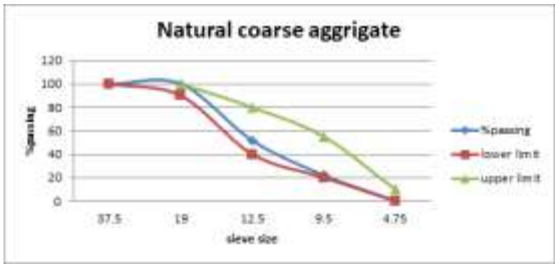


Fig. 4.2 Graph for Sieve analysis of Coarse aggregate

4.3.3 Rubber aggregate

The source of the rubber aggregate was recycled tyres which were collected from the local market commonly known as *'GomaTera'* around *Merkato* area, Addis Ababa. For uniformity of the concrete production and convenience, all the tyres collected were from those which were originally produced from Matador Addis Tyre factory and the type was a medium truck tyre as shown in figure 4.3. The reason for this is that the factory is the only tyre producing company in the country as the other tyres in the market are imported ones and the reason for choosing medium truck tyres is that they can give the required shape and size which is similar to the common natural gravel.

This study has concentrated on the performance of a single gradation of crumb rubber prepared by manual cutting. The maximum size of the rubber aggregate was 20 mm as shown in figure 4.4. Specific gravity test was conducted on the rubber aggregate chips and found to be 1.123. The rubber aggregates used in the present investigation were made by manually cutting the tyre in to the required sizes. It was very laborious, time consuming and was not easy to handle at the initial stages. However, all this complications can be easily sorted out if a large scale production is devised and proper cutting tools and machineries are made for this particular usage.


Fig. 4.3 Used medium truck tyres
Fig. 4.4 20 mm size Rubber aggregate

To come up with a rough cohesive surface of the rubber aggregate, surface treatment was done using cement paste. Rubber aggregates coated with cement paste were produced as follows:

- After thoroughly washing the sample to remove dusts and impurities from the surface of the particles, the rubber aggregates were then immersed in
water for 24 hours until all particles were fully saturated (wetted both inside and on the surface).
- The plain rubber aggregates were then taken to the saturated surface dry (SSD) condition by spreading them in a thin layer on a clean surface free from dust and rolled in a towel until all visible films of water are removed. In this condition, the rubber aggregate reached the saturated surface dry condition and thus requiring no alteration to the quantity of mixing water.

All the cement paste coating had an effect on the hydrophilicity of the rubber allowing it to adhere better to the cement paste that surrounded it as per the previous experience discussed in the literature review part of this research section 3.3.2.1. The rubber aggregate particles coated with cement paste are shown in figure 4.5 below.

4.5 (a)**4.5**(b)**Fig. 4.**5 **Rubber aggregates coated**

with Cement paste

V. TEST RESULTS AND DISCUSSIONS

5.1 General

This section describes the results of the tests carried out to investigate the various properties of the rubberized concrete mixes prepared in contrast with the control mixes. In the succeeding parts, the results for workability, unit weight, compressive strength, splitting tensile strength tests are presented. Analysis and discussions are also made on the findings.

Fig. 5.1 Slump Test

The mould for the slump test is in the form of a frustum of a cone, which is placed on top of a metal plate. The mould is filled in three equal layers and each layer is tamped 25 times with a tamping rod. Surplus concrete above the top edge of the mould is struck off with the tamping rod. The cone is immediately lifted vertically and the amount by which the concrete sample slumps is measured. The value of the slump is obtained from the distance between the underside of the round tamping bar and the highest point on the surface of the slumped concrete sample. The types of slump i.e. zero, true, shear or collapsed are then recorded. Table 5.1 shows the results of the slump test for the control concretes and the rubberized concretes.

Table 5.1 Slump Test Results

No.	Specimen	Grade	% rubber	w/c ratio	Slump (mm)
1	AM1	M20	0.00	0.65	21
2	AM2	M20	10.00	0.65	27
3	AM3	M20	25.00	0.65	32
4	AM4	M20	50.00	0.65	38
5	BM1	M30	0.00	0.53	9
6	BM2	M30	10.00	0.53	17
7	BM3	M30	25.00	0.53	22
8	BM4	M30	50.00	0.53	30

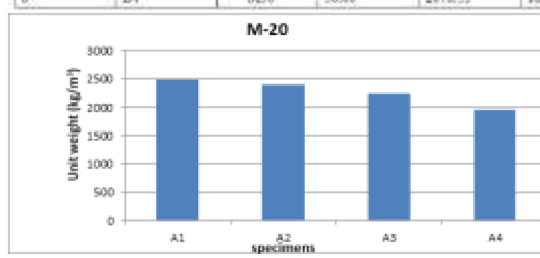
The introduction of recycled rubber tyres to concrete significantly increased the slump and workability. All concrete mixes were designed to have a slump of 10-30 mm. As can be seen from the results above, the control concretes BM1 had a slump of less than10 mm which is below the designed value whereas the result for AM1 (21 mm) is close to the designed range.

5.3 Hardened Concrete Properties

The different tests that have been carried out to establish the hardened properties of the concrete samples produced were; determination of unit weight, compressive strength, splitting tensile strength, impact resistance and flexural strength tests.

Table 5.2 Unit weights of the control concretes and rubberized concrete.

No.	Specimen	Grade	% rubber	Unit wt. (kg/m^3)	% Reduction
1	A1	M20	0.00	2479.85	0.00
2	A2	M20	10.00	2392.29	3.53
3	A3	M20	25.00	2253.34	9.13
4	A4	M20	50.00	1959.57	20.98
5	B1	M30	0.00	2485.93	0.00
6	B2	M30	10.00	2392.27	3.76
7	B3	M30	25.00	2335.21	6.06
8	B4	M30	50.00	2078.53	16.38



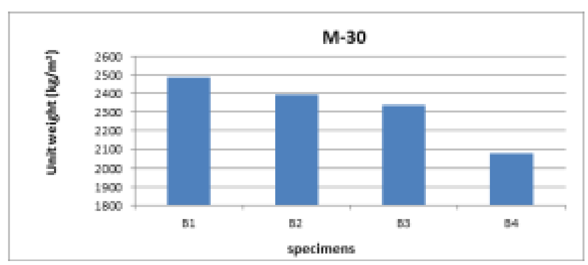


Fig .2 Graphical comparison of unit weight values

Using concrete with a lower density can result in significant benefits in terms of load bearing elements of smaller cross-section and a corresponding reduction in the size of foundations. Occasionally, the use of concrete with a lower density permits construction on

Industrial Engineering Journal

ISSN: 0970-2555

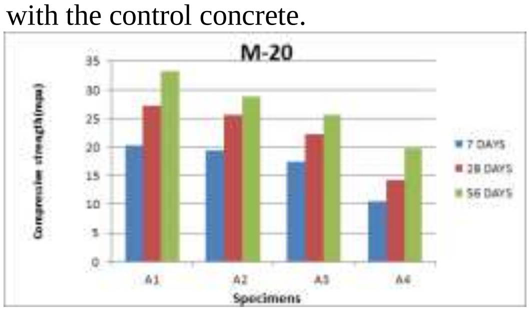
Volume : 52, Issue 9, September : 2023

ground with a low load-bearing capacity. Furthermore, with lighter concrete, the formwork need withstand a lower pressure than would be in case with normal weight concrete, and also the total mass of materials to be handled is reduced with a consequent increase in productivity. Concrete that has a lower density also gives better thermal insulation than ordinary concrete. Therefore, the reduced density of concrete containing rubbers aggregates can provide with all the benefits mentioned which are associated with a lower density.

Table 3 compressive strength test results

				Compressive strength (mpa)			% strength loss		
No	Specimen	Grade	% rubber	7 Days	28 days	56 days	7 Days	28 days	56 days
1	A1	M20	0	20.21	27.15	33.14	0.00	0.00	0.00
2	A2	M20	10	19.3	25.60	28.75	4.50	5.70	13.24
3	A3	M20	25	17.50	22.30	25.63	13.40	17.86	22.66
4	A4	M20	50	10.43	14.30	19.70	48.39	47.32	40.55
5	B1	M30	0	33.70	44.28	52.72	0.00	0.00	0.00
6	B2	M30	10	31.50	36.28	48.36	6.52	17.91	8.27
7	B3	M30	25	20.78	31.23	37.29	38.33	29.34	29.26
8	B4	M30	50	15.60	24.78	22.54	53.70	43.93	57.24

Figure 5.3 below illustrates the trend of strength development in the different concrete specimens prepared and Figure 5.4 shows the comparison of the strength achieved in contrast with the control concrete.



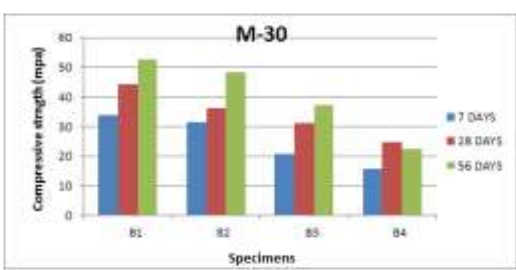
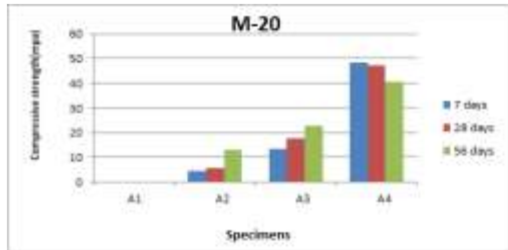


FIG 3 Compressive strength development



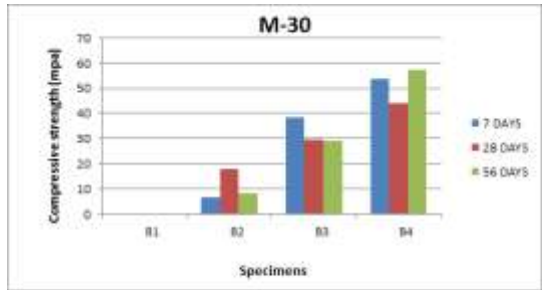


Fig.4percentage loss of compressive strength

The reason for the compressive strength reductions could be attributed both to a reduction of quantity of the solid load carrying material and to the lack of adhesion at the boundaries of the rubber aggregate. Soft rubber particles behave as voids in the concrete matrix. Considering the very different mechanical properties of mineral aggregates and rubber aggregates, mineral aggregates usually have high crushing strength and they are relatively incompressible, whereas rubber aggregates are ductile, compressible and resilient. Rubber has a very low modulus of elasticity of about 7MPa and a Poisson's ratio of 0.5. Therefore, rubber aggregates tend to behave like weak inclusions or voids in the concrete, resulting in a reduction in compressive strength. It is well known that the presence of voids in concrete greatly reduces its strength. The existence of 5 % of voids can lower strength by as much as 30 % and even 2 % voids can result in a drop of strength of more than 10%.

VI. CONCLUSIONS AND RECOMMENDATIONS

The general objective of this research was to evaluate the fresh and hardened properties of a concrete produced by replacing part of the natural coarse aggregates with an aggregate produced from locally available recycled waste tyre and subjected to local conditions. From the test results of the samples, as compared to the respective conventional concrete properties, the following conclusions and recommendations are drawn out.

6.1 Conclusions

1. The introduction of recycled rubber tyres into concrete significantly increased the slump and workability. It was noted that the slump has increased as the percentage of rubber was increased in all samples by using 50% replacement of rubber aggregates for the natural coarse aggregates.
2. A reduction in unit weight of up to 21% was observed when 50% by volume of the coarse aggregate was replaced by rubber aggregate in sample AM4 which is with a targeted compressive strength of 20 MPa. A much similar trend of reduction in unit weight of the rubberized concrete was observed in all the other samples containing rubber aggregates. The low specific gravity of the rubber chips as compared to the mineral coarse aggregates produced a decrease in the unit weight of the rubberized concrete. Crumb rubber is nearly two and half times lighter than the conventional mineral coarse aggregate and hence it can be expected that the mass density of the mix would be relatively lower.
3. Rubberized concrete can be used in non load bearing members such as lightweight concrete walls, building facades, or other light architectural units, thus the rubberized concrete mixes could give a viable alternative to the normal weight concrete.
4. For rubberized concrete, the test results show that the addition of rubber aggregate resulted in a significant reduction in concrete compressive strength compared with the control concrete. This reduction increased with increasing percentage of rubber aggregate. Losses in compressive strength ranging from 5.70% to 47.32% were observed. The reason for the strength reduction could be attributed both to a reduction of quantity of the solid load carrying material and lack of adhesion at the boundaries of the rubber aggregate, soft rubber particles behave as voids in the concrete matrix. Therefore, rubber aggregate tends to behave like weak inclusions or voids in the concrete resulting in a reduction in compressive strength. Although the compressive strength values have considerably decreased with the addition of waste tyre pieces, their values are still in the reasonable range for a 10 % and 25 % replacement values because the intended compressive strengths of 20 and 30 MPa were achieved in this categories.
4. The results of the splitting tensile strength tests show that, there is a decrease in strength with increasing rubber aggregate content like the reduction observed in the compressive strength tests. However, there was a smaller reduction in splitting tensile strength as compared to the reduction in the compressive strength.

   One of the reasons that splitting tensile strength of the rubberized concrete is lower than the conventional concrete is that bond strength between cement paste and rubber tyre particles is poor. Besides, pore structures in rubberized concretes are much more than conventional concrete.
5. The visual observation of the patterns of failure mode revealed that the rubberized concrete does not exhibit typical compression failure behavior. The control concrete shows a clean split of the sample into two halves, whereas the rubber aggregate tends to produce a less well defined failure. Moreover, the mode of failure was a gradual type rather than the brittle failure in the control concretes. This may be an indication more ductility in rubberized concrete than the control concrete. However, it has to be clearly investigated by carrying out ductility tests.
8. A reduced compressive strength of concrete due to the inclusion of rubber aggregates limits its use in some structural applications. Nevertheless, it has few desirable characteristics such as lower density, higher impact and toughness resistance, enhanced ductilityand slight increase flexural strength in the lower compressive strength concretes.

9. The use of rubber aggregates from recycled tyres addresses many issues. These include; reduction of the environmental threats caused by waste tyres, introduction of an alternative source to aggregates in concrete, enhancing of the weak properties of concrete by the introduction of different ingredients other than the conventionally used natural aggregates and ultimately leading to the conservation of natural resources. In addition to meeting recycling and sustainability objectives, it aims is to produce products with enhanced properties in specific applications.
10. In some applications of concrete, it is demanded that concrete should have low unit weight, Medium strength, high toughness and high impact resistance. Although concrete is the most commonly used construction material, it does not always fulfill these requirements. One of the ways to improve these properties can be the addition of the rubber into concrete as an aggregate. The overall results of this study show that it is possible to use recycled rubber tyres in concrete construction as a partial replacement for coarse aggregates.
11. However, the percentage replacement should be limited to specified amounts as discussed above and the application should be restricted to particular cases where the improved properties due to the rubber aggregates outweigh the corresponding demerits that may occur due to them.

6.2 Recommendations

1. Even though the use of waste tyres for various applications by traditional recyclers has been a common practice in Ethiopia so far, with the increase in urbanization and the change in the living conditions of the society, the old ways cannot continue with time. Hence, there will be a potential accumulation of waste tyres especially in the larger cities of the country. So far, the Government has made an attempt by declaring the solid waste management proclamation on the *Negarit gazette* prohibiting the import of waste tyres. Moreover, the country should also enforce laws regarding the management of waste tyres before the problem expands and reaches to an uncontrollable level.
2. Since the use of rubber aggregates in concrete construction is not a common trend in our country, more studies and research works need to be done in this area and academic institutions should play a great role.
3. Tyre manufacturers and importers in the country should be aware of the environmental consequences of waste tyres and they should have research centers that promote an environmental friendly way of tyre reprocessing.
4. Most of the time, it is observed that designers and contractors go to a high strength and expensive concrete to get few improved properties such as impact resistance in parking areas and light weight structures for particular applications. Nevertheless, these properties can be achieved through the application of rubberized concrete by first conducting laboratory tests regarding the desired properties. Therefore, the use of rubberized concrete as an alternative concrete making material needs an attention.
5. Since the long-term performance of these mixes was not investigated in the present study, the use of such mixes is recommended in places where high strength of concrete is not as important as the other properties.
6. Future studies should be continued in the following areas as part of the extension of this research work.
   i) In this research, a constant dosage of admixture was used for a particular mix category. It will be more helpful if the effects of various dosages of admixtures are investigated.
   ii) The effect of using de-airing agents to decrease the entrapped air in rubberized concrete should be studied. Consequently, a considerable increase in compressive strength can be achieved.
   iii) The existence of any chemical reactions between the rubber

aggregate and other constituents of the rubberized concrete to make sure that there is no undesirable effects that are similar to alkali-silica and alkali-carbonate reactions in natural aggregates needs to be investigated.

iv) This research was done by preparing single graded rubber aggregates of size 20 mm. The effect of different sizes should be studied in the future. Besides to this, the effects in different percentage replacements other than those made in this research needs to be investigated.

v) The test results in this study are based on results taken after 7th, 28th and 56th days of standard curing of the test samples. The long-term effects of rubberized concrete needs to be studied to find out the relevant properties associated with the age of the concrete.

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