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# STUDY OF RUBBER AGGREGATES IN CONCRETE AN EXPERIMENTAL INVESTIGATION

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**Abstract:** The use of scrap tyre rubber in the preparation of concrete has been thought as an alternative disposal of such waste to protect the environment. In this study an attempt has been made to identify the various properties necessary for the design of concrete mix with the coarse tyre rubber chips as aggregate in a systematic manner. In the present experimental investigation, the M20 grade concrete has been chosen as the reference concrete specimen. Scrap tyre rubber chips, has been used as coarse aggregate with the replacement of conventional coarse aggregate Concrete is one of the most popular building materials. The construction industry is always increases its uses and applications. Therefore, it is required to find alternative materials to reduce the cost of concrete. On the other hand, Non-biodegradable waste i.e. water bottles, cool drink bottles and disposable glasses, shredded or crumbed rubber etc., is creating a lot of problems in the environment and its disposal becoming a great difficulty. The objective of this paper is to investigate the use of rubber pieces as coarse aggregate in the concrete. Concrete tested with varying percentages of rubber from 0 to 15% of normal aggregates. Compressive strength, of concrete is measured and comparative analysis is made.

## 1. Introduction

During the last three decades, there have been dramatic changes in the way of thinking about industrial processes and the approach and evaluation of new and innovative materials. Concrete, in its most basic form, is one of the world's oldest building materials. Concrete is a substance composed of only a few simple and commonly available ingredients that when properly mixed and cured, may last for centuries. Concrete is an evolving material as well. New techniques and methods for selecting the right quantities of those simple components are continually being presented to the design community. New ingredients to include in concrete mixes are also constantly being researched and developed.

In general, concrete has low tensile strength, low ductility, and low energy absorption. Concrete also tends to shrink and crack during the hardening and curing process. These limitations are constantly being tested with hopes of improvement by the introduction of new admixtures and aggregates used in the mix. One such method may be the introduction of rubber to the concrete mix. Shredded or crumbed rubber is waste being of non-biodegradable and poses severe fire, environmental and health risks.

### 1.1 Objectives

The objective of this study is to test the properties of concrete when shredded or crumbed rubber used as aggregate by partial replacement of natural aggregates. The parameters of this investigation include the compressive strength of concrete specimens. Cubes of 150 X 150 X 150mm size for compressive strength, cubes are casted for the testing of concrete. The concrete having compressive strength of 20N/mm$^2$ ($M_{20}$) is used and percentages of rubber aggregates are 0, 5, 10, and 15% of normal aggregates. The natural aggregates are replaced by rubber aggregates on volume basis. The strength performance of modified concrete specimens was compared with the conventional concrete.

### 1.2 Use of old tyre

Rubber from discarded tyres use in, floor mats, belts, gaskets, shoe soles, dock bumpers, seal, muffler hangers, shims and washers. 3 to 5% Rubber crumbs and upto 10% reclaimed rubber is particularly used in automobile tyres. Tyre pieces are used as fuel in cement and brick kiln. However, various local authorities are now banning the tyre burning due to atmosphere pollution. Whole tyres also used as highway crash barriers, furniture, boat bumpers on marine docks, etc. Land filling or burning tyres for energy have limited prospects as environmental authorities are acknowledging the need for its greener alternatives.

It has been observed that the rubberized concrete may be used in places where desired deformability or toughness is more important than strength like the road foundations and bridge barriers. Apart from these the rubberized concrete having the reversible elasticity properties may also be used as a material with tolerable damping properties to reduce or to minimize the structural vibration under impact effects

The difficulties associated to the theoretical investigations to identify the mechanical properties of the rubberized concrete have necessitated the need for the experimental investigations on rubberized concrete. Therefore, in this study an attempt has been made to identify the various properties necessary for the design of concrete mix with the coarse tyre rubber chips as aggregate in a systematic manner.

**1.3 Production**

The majority of India's car manufacturing industry is based around three clusters in the south, west and north. The southern cluster consisting of Chennai is the biggest with 35% of the revenue share. The western hub near Mumbai and Pune contributes up to 33% of the market and the northern cluster around the National Capital Region contributes 32%. Chennai, houses the India operations of Ford, Hyundai, Renault, Mitsubishi, Nissan, BMW, Hindustan Motors, Daimler, Caparo, Mini, and Datsun. Chennai accounts for 60% of the country's automotive exports. Gurgaon and Manesar in Haryana form the northern cluster where the country's largest car manufacturer, Maruti Suzuki, is based. The Chakan corridor near Pune, Maharashtra is the western cluster with companies like General Motors, Volkswagen, Skoda, Mahindra and Mahindra, Tata Motors, Mercedes Benz, Land Rover, Jaguar Cars, Fiat and Force Motors having assembly plants in the area. Nashik has a major base of Mahindra and Mahindra with a SUV assembly unit and an Engine assembly unit. Aurangabad with Audi, Skoda and Volkswagen also forms part of the western cluster. Another emerging cluster is in the state of Gujarat with manufacturing facility of General Motors in Halol and further planned for Tata Nano at their plant in Sanand. Ford, Maruti Suzuki and Peugeot-Citroen plants are also set to come up in Gujarat. Kolkata with Hindustan Motors, Noida with Honda and Bangalore with Toyota are some of the other automotive manufacturing regions around the country.

About one crore 10 lakhs all types of new vehicles are added each year to the Indian roads. The increase of about three crores discarded tyres each year poses a potential threat to the environment. New tyre is made of natural rubber (also called virgin rubber), styrene-Butadien Rubber (SBR), Polybutadienc Rubber (PBR), Carbon black, Nylon tyre cord, rubber chemicals, steel tyre card and Butyl rubber.

In 2011, there were 3,695 factories producing automotive parts in all of India. There are different types of rubber waste generated around the world each year as by product materials. Probably the biggest environmental concern of rubber waste is the disposal of scrap tires. Scrap tires pose three environmental threats as follows:

**TABLE 1.1: Indian tyres industry general detail**

| | |
|---|---|
| Consumption world ranking | 4$^{th}$ |
| Total number of Tyre Companies | 36 |
| Total number of Tyre Factories | 51 |
| Tyre Production 2012-13 (Estimated) | 110 Million |
| Industry Turnover (Estimated) | Rs.31000 crores |
| Capacity Utilization (Estimated) | 84% |
| Growth in Truck & Bus tyre production | 15% |

## 2. Materials Used

The basic materials for mixing Concrete are required such as

- Cement
- Fine aggregate
- Coarse aggregate
- Tyre rubber aggregate
- Water

**2.1 Cement**

The cement used for the present investigation was ordinary Portland cement.53 Grade Cement is a Bharathi brand cement with a remarkably high C3S (Tri Calcium Silicate) providing long-lasting durability to concrete structures.

This grade was introduced in the country by BIS in the year 1987 and commercial production started from 1991. Advent of this grade in the country owes it to the improved technology adopted by modern cement plants. OPC 53 Grade cement is required to conform to BIS specification IS:12269-1987 with a designed strength for 28 days being a minimum of 53 MPa or 530 kg/sqcm.

53 Grade OPC provides high strength and durability to structures because of its optimum particle size distribution and superior crystallized structure. Being a high strength cement, it provides numerous advantages wherever concrete for special high strength application is required, such as in the construction of skyscrapers, bridges, flyovers, chimneys, runways, concrete roads and other heavy load bearing structures. Not only is this grade of cement stronger than other grades / types, it is also more durable. Further, by substituting lower grade cement with OPC 53, overall savings can be obtained through reduced quantity of cement that would be required to be used. A savings of 8-10% can be achieved with the use of 53 Grade OPC in place of any other grade.The most important use of cement is the production of mortar and concrete, which is a combination of cement and an aggregate to form a strong building material that is durable in the face of normal environmental effects


Fig 2.1: OPC 53 Grade cement

**2.1.1 Cement Properties and Strength Analysis**

The physical properties of cement are Setting Time, Soundness, Fineness, and Strength.

**2.1.2 Setting Time**

- Cement paste setting time is affected by a number of items including: cement fineness, water-cement ratio, chemical content (especially gypsum content) and admixtures. Setting tests are used to characterize how a particular cement paste sets.
- For construction purposes, the initial set must not be too soon and the final set must not be too late.
- Initial set. Occurs when the paste begins to stiffen considerably
- Final set. Occurs when the cement has hardened to the point at which it can sustain some load.
- Setting is mainly caused by $C_3A$ and $C_3S$ and results in temperature rise in the cement paste.
- False set :No heat is evolved in a false set and the concrete can be re-mixed without adding water
- Occurs due to the conversion of unhydreous /semihydrous gypsum to hydrous gypsum ($CaSO_4.2H_2O$)
- Flash Set: is due to absence of Gypsum. Specifically used for under water repair

**2.1.3 Soundness**

- When referring to Portland cement, "soundness" refers to the ability of a hardened Cement paste to retain its volume after setting without delayed expansion. This Expansion is caused by excessive amounts of free lime (CaO) or magnesia (MgO). Most Portland cement specifications limit magnesia content and expansion.
- The cement paste should not undergo large changes in volume after it has set. However when excessive amounts of free CaO or MgO are present in the cement, these oxides can slowly hydrate and cause expansion of the hardened cement paste.
- Soundness is defined as the volume stability of the cement paste.

**2.1.4 Fineness**

- Fineness or particle size of Portland cement affects Hydration rate and thus the rate of strength gain. The

smaller the particle size, the greater the surface area-to volume ratio, and thus, the more area available for water-cement interaction per unit volume. The effects of greater fineness on strength are generally seen during the first seven days.

- When the cement particles are coarser, hydration starts on the surface of the particles. So the coarser particles may not be completely hydrated. This causes low strength and low durability.
- For a rapid development of strength a high fineness is necessary.

**2.1.5 Strength**

- Cement paste strength is typically defined in three ways: compressive, tensile and flexural. These strengths can be affected by a number of items including: water cement ratio, cement-fine aggregate ratio, type and grading of fine aggregate, curing conditions, size and shape of specimen, loading conditions and age.

**2.1.6 Duration of Testing**

Typically, Durations of testing are:
1 day (for high early strength cement)

- 3 days, 7 days, 28 days and 90 days (for monitoring strength progress)
- 28 days strength is recognized as a basis for control in most codes.
- When considering cement paste strength tests, there are two items to consider:
- Cement mortar strength is not directly related to concrete strength. Strength tests are done on cement mortars (cement + water + sand) and not on cement pastes

**TABLE 2.1: Properties of OPC cement**

| **Properties a)Physical** | **Requirements as per IS12269-1987** | **Cement values** |
|---|---|---|
| Fineness (sqm/kg) | 225 (min) | 325 |
| Soundness (mm) | | |
| Lechatlier method | 10mm (max) | 1 |
| Autoclave (%) | 0.8 (max) | 0.03 |
| Setting time | | |
| Initial (min) | 30 minutes | 150 |
| Final (max) | 600 minutes | 260 |
| Compressive Strength (MPa) | | |
| 1 day | | 20 |
| 3 day | 27 | 39 |
| 7 day | 37 | 49 |
| 28 day | 53 | 70 |
| b) Chemical | | |
| 1)Lime saturation factor | 0.8-1.0-2 | 0.9 |
| 2)Alumina Modulus | 0.66(min) | 1.23 |
| 3) Insoluble residue (%) | 4(max) | 0.25 |
| 4) Magnesia (%) | 6(max) | 1.1 |
| 5) Sulphuric anhydrideS03 (%) | 3(max) | 1.5 |
| 6) Loss on ignition (%) | 4(max) | 0.8 |
| 7)Alkalies | | |
| 8) Chloride (%) | 0.1 (max) | 0.002 |
| 9)C34 Content | | 7 |
| 10)Temperature during Testing | 27± 2 | 27± 2 |
| 11) Humidity (%) | 65± 5 | 65± 5 |

**2.2 Fine aggregate**

The locally available river sand from Karimnagar, Andhra Pradesh, India, is used as fine aggregate in the concrete design mix. The specific gravity, water absorption and fineness modulus are 2.62, 0.3% and 2.78 respectively. Sand is of Zone-II as per IS: 383-1970.

The physical properties of aggregate were considered according IS: 2386(1963).

Aggregate most of which pass through 4.75 mm IS sieve is known as fine aggregate. Fine aggregate shall consists of natural sand, crushed stone sand, crushed gravel sand stone dust or arable dust, fly ash and broken brick (burnt clay). It shall be hard, durable, chemically inert, clean and free from adherent coatings, organic matter etc. and shall not contain any appreciable amount of clay balls or pellets and harmful impurities e.g. iron pyrites, alkalies, salts, coal, mica, shale or similar laminated materials in such form or in such quantities as to cause corrosion of metal or affect adversely the strength, the durability or the appearance of mortar, plaster or concrete.

**2.3 Coarse Aggregate**

Aggregates are the most mined material in the world. Aggregates are a component of composite materials such as concrete and asphalt concrete; the aggregate serves as reinforcement to add strength to the overall composite material. Coarse aggregate of size 20mm is sieved and used

**2.4 Tyre rubber aggregate**

The basic material of concrete e.g. cement, sand, aggregate and scrap tyre rubber are used. Ordinary Portland cement can be produced either by integrating the predetermined quantities of Portland cement. This cement produces less heat of hydration and offers greater resistance to the sulphate attack and chloride-ion penetration due to impurities in water than normal Portland cement. It is particularly useful in marine and hydraulic construction, and other mass concrete structures like dam, bridge piers and thick foundations

Tyre rubber aggregate. About 30 cm long waste tyre rubber pieces are obtained from local market; the pieces were cleaned with soap water and rinse with clean water. After drying under sun at open place, both faces of the tyre pieces were rubbed with hard wire brush to make surfaces as rough as can be done by hand.

Tyre may be divided into two types – car and truck tyres. Car tyres are different from truck tyres with regard to constituent materials (e.g. natural and synthetic rubber)

In the present study the old rubber from heavy vehicles, such as truck tyre was used. The chipped rubber samples were obtained by cutting the tyre manually. The scrap tyre rubber chips passing through the 20 mm sieve size were used in the study. The physical property (specific gravity) of rubber was found to be 1.114 from the tyre company's website. Rubber samples before cutting are as shown in Fig. 1.

Fig 2.2: Rubber Samples (Before Cutting)

Fig 2.3: Chipped Rubber Samples

**2.5 Classification of scrap tires**

**2.5.1 Scrap tires**

They can be managed as a whole tire, as slit tire, as shredded or chopped tire, as ground rubber or as a crumb rubber product. A typical automobile tire weighs 20 lb, whereas a truck tire weighs around 100 lb. Table 3 gives the typical composition by weight of automobile and truck tires.

**TABLE 2.2: Typical Materials Used in Manufacturing Tire**

| |
|---|
| **a) Synthetic Rubber**<br>**b) Natural Rubber**<br>**c) Sulphur and sulphur compounds**<br>**d) Phenolic resin**<br>**e) Oil**<br>1. Aromatic<br>2. Naphthenic<br>3. Paraffinic<br>**f) Fabric**<br>4. Polyester<br>5. Nylon etc.<br>**g) Petroleum waxes**<br>**h) Pigments**<br>6. Zinc oxide<br>7. Titanium dioxide etc.<br>**i) Carbon black**<br>**j) Fatty acids**<br>**k) Inert materials**<br>**l) Steel wires** |

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**2.5.2 Slit Tires:**

These are produced in tire cutting machines. These machines can slit the tire into two halves or can separate the sidewalls from the tread of the tires.

**2.5.3 Shredded or Chipped Tires:**

Tire shreds or chips involve primary and secondary shredding. The size of the tire shreds produced in the primary shredding process can vary from as large as 300 to 460mm long by 100 to 230 mm (4 to 9 inch) wide, down to as small as 100 to 150 mm in length, depending on the manufacturer's model and condition of the cutting edges, normally sized from 76 mm (3 inch) to 13 mm (0.5 inch), requires both primary and secondary shredding to achieve adequate size reduction.

**TABLE 2.3: Typical Composition by Weight**

| Composition by percent weight | Automobile tire | Truck tire |
|---|---|---|
| Natural rubber | 14 | 27 |
| Synthetic Rubber | 27 | 14 |
| Carbon black | 28 | 28 |
| Steel | 14 to 15 | 14 to 15 |
| Fabric, filler, accelerators, antiozonants | 16 to 17 | 16 to 17 |

**2.5 Water:**

Water used in concrete is free from sewage, oil, acid, strong alkalies or vegetable matter, clay and loam. The water used is potable, and is satisfactory to use in concrete. Water sample collected from bore well and its properties are shown in Table 3.5

**TABLE 2.5: Properties of water sample**

| S.No. | Parameter | Results | Limits as per IS 456 – 2000 |
|---|---|---|---|
| 1 | pH | 6.3 | 6.5 – 8.5 |
| 2 | Chlorides (mg/l) | 45 | 2000 (PCC) 500 (RCC) |
| 3 | Alkalinity (ml) | 6 | < 25 |
| 4 | Sulphates (mg/l) | 105 | 400 |
| 5 | Florides (mg/l) | 0.04 | 1.5 |
| 6 | Organic Solids (mg/l) | 43 | 200 |
| 7 | Inorganic Solids (mg/l) | 115 | 3000 |

## 3. Experimental Investigation

### 3.1 Objective:

Study the feasibility of incorporating scrap tyre rubber chips as coarse aggregate in concrete mixes and determine the change in the properties after the incorporation of the rubber into the concrete mix.

Investigation on the influence of the rubber content on the mechanical properties of rubberized concrete starting with the 0% rubber content (i.e., without rubber) and up to 15% rubber content in the M20 grade concrete (i.e., with a partial replacement of the coarse aggregate by 0%, 5%, 10% and 15% by volume of the total coarse aggregate). For convenience, the mix design for M20 grade concrete has been done according to IS: 10262 (1982).

A total of 24 cubes are casted of M20 grade by replacing 0, 5, 10 and 15 percent of tyre aggregate with coarse aggregate and compared with regular M20 grade concrete And the cubes were tested under 200 ton compression testing machine to study the compressive strength of the cubes, the details of the experimental program for cubes are mentioned in the table below.

### 3.2 Tests on cement

#### 3.2.1 Cement

The cement used in this study is bharati OPC 53 grade the specific gravity of cement is 3.15.

#### 3.2.2 Specific gravity of cement:

Specific gravity of cement is generally required for calculations in connection with cement concrete design work, for determination of moisture content and for calculation of volume yield of concrete.

**TABLE: 3.1: specific gravity of cement**

| | | | | | |
|---|---|---|---|---|---|
| 1. | Weight of empty bottle, | $W_1$ gm | 69.8 | 69.8 | 69.8 |
| 2. | Weight of bottle+ water, | $W_2$ gm | 193 | 190 | 192 |
| 3. | Weight of bottle+ kerosene, | $W_3$ gm | 172 | 171 | 173 |
| 4. | Weight of bottle+ cement+ kerosene, | $W_4$ gm | 216.2 | 215 | 217.5 |
| 5. | Wt of cement, | $W_5$ gm | 25 | 25 | 25 |
| 6. | Sp. gravity of kerosene, | $S=(W_3-W_1)/(w_2-w_1)$ | 0.84 | 0.84 | 0.83 |
| 7. | Sp. Gravity of cement, $S=W_5\ (W_3-W_1)/((W_5+W_3-W_4)(W_2-W1)$ | | 3.15 | 3.14 | 3.15 |
| Average specific gravity of cement = 3.15 | | | | | |

#### 3.2.3 Standard consistency test:

For finding out initial setting time, final setting time and soundness of cement, and strength a parameter known as standard consistency has to be used. It is pertinent at this stage to describe the procedure of conducting standard consistency test. The standard consistency of a cement paste is defined as that consistency which will permit a vicat plunger having 10 mm diameter and 50 mm length to penetrate to a depth of 33-35 mm from the top of the mould. The apparatus is called vicat apparatus. This apparatus is used to find out the percentage of water required to produce a cement paste of standard consistency. The standard consistency of the cement paste is some time called normal consistency (CPNC)

**TABLE: 3.2: Consistency test**

| Trails | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| % of Water | | 24% | 26% | 28% | 30% |
| Initial Reading | Mm | 41 | 41 | 41 | 41 |
| Final Reading | Mm | 37 | 27 | 15 | 6 |
| Difference (height penetrated) 'mm' | | 4 | 14 | 26 | **35** |

**3.2.4 Initial and final setting time of cement**

In order that the concrete may be placed in position conveniently, it is necessary that the initial setting time of cement is not too quick and after it has been laid, hardening should be rapid so that the structure can be made use of as early as possible.

Initial Setting Time**:**

- Lower the needle gently and bring it in contact with the surface of test block and quickly release. Allow it to penetrate into the test block.
- In the beginning, needle will completely pierce through the test block. But after some time when the paste starts losing its plasticity, the needle may penetrate only to a depth of (33-35mm from top). Now stop the clock.

Final Setting time**:**

- For the determination of final setting time replace the needle of vicat apparatus by the needle with an annular attachment. The cement is considered finally set when, upon applying the needle gently to the surface of test block; the needle makes an impression thereon, while the attachment fails to do so.

**3.2.5 Observation and calculation:**

Weight of cement = 400gm.
(Size of cement particle passing µ800size)
Needle area dimension of 50mm=1mmlong.
Gauging time =2-3min
P = 30%
Quantity of water = 0.85P x weight of cement
= [(0.85 x 30)/100]x 400g
= 102 ml.

**TABLE: 3.3 Initial and final setting time of cement**

| Trails | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | min | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| Initial Reading | mm | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| Final Reading | mm | 0 | 0 | 0 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 6 |
| Difference (might not penetrated) 'mm' | | 0 | 0 | 0 | 39 | 38 | 38 | 37 | 37 | 36 | 35 | 34 |

Result: Initial setting time of cement = 60min.

Final setting time of cement = 5 Hrs.

### 3.3 Fine aggregates

#### 3.3.1 Specific gravity test and water absorptions:

Specific gravity for an aggregate is defined as the ratio of the weight of a given volume of sample to the weight of equal volume of water at the same tense temperature. Specific gravity of fine aggregate is generally required for calculations in connection with cement concrete design work, for determination of moisture content and for calculation of volume yield of concrete.

**TABLE: 3.4 Specific gravity test of fine aggregate**

| **Specific gravity:** | Trail 1 | Trail 2 | Trail 3 |
|---|---|---|---|
| Weight of empty pycnometer ($W_1$g) | 600 | 600 | 600 |
| Weight of pycnometer + water ($W_2$g) | 1463 | 1463 | 1463 |
| Weight of saturated surface dry ($W_3$g) | 1127 | 1124 | 1126 |
| Weight of pycnometer + water + Fine aggregate($W_4$g) | 1788 | 1786 | 1788 |
| Bulk specific gravity= $(W_3-W_1) / [(W_2-W_1)-(W_4-W_3)]$ | 2.61 | 2.60 | 2.61 |

**TABLE: 3.5 Water absorptions of fine aggregate**

| **Water Absorption:** | Trail 1 | Trail 2 | Trail 3 |
|---|---|---|---|
| Weight of tray +saturated surface dry F A (W5)g | 1605 | 1589 | 1602 |
| Weight of tray + oven dry Fine Aggregate (W6)g | 1600 | 1585 | 1598 |
| Weight of empty try | 1070 | 1065 | 1068 |
| Percentage of water absorption | 0.94 | 0.76 | 0.75 |

Bulk specific gravity = $W_3/(W_3-(W_4-W_2))$ = Average value= 2.61.
Percentage of water absorption = $(W_5-W_6/W_6-W_7)$ X100 = Average value = 0.82%.
Result: specific gravity of fine aggregate is 2.64 and percentage of water absorption is 0.82%.

#### 3.3.2 Fineness Modulus Of Fine Aggregate:

Fineness modulus (FM) is only a numerical index of fineness, giving some idea of the mean size of particular in the entire body of aggregate. Determination of fineness modulus may be considered as a method of standardization of the grading of the aggregates.

#### 3.3.3 Observation and Calculations:

Weight of fine aggregate (W) = 1000gms.
Weight of fine aggregate retained on sieve (Wi).
Percentage of fine aggregate retained on sieve = $(W_i/W)$ X 100

**TABLE: 3.6: Fineness modulus of fine aggregate**

| Sieve No. | Weight of FA retained (Wi) | % of retained (Wi/W) X100 | Cumulative % of retained ( f ) | % of passing F = 100-f |
|---|---|---|---|---|
| 10mm | 0 | 0 | 0 | 100 |
| 4.75mm | 9.0 | 0.9 | 0.9 | 99.1 |

| | | | | |
|---|---|---|---|---|
| 2.36mm | 42.0 | 4.2 | 5.1 | 94.9 |
| 1.18mm | 119 | 11.9 | 17 | 83 |
| 600µ | 345 | 34.5 | 51.5 | 48.5 |
| 300µ | 289 | 28.9 | 80.4 | 19.6 |
| 150µ | 169 | 16.9 | 97.3 | 2.7 |
| PAN | 21 | 2.1 | 0 | 0 |

Result: As per IS 383-1970 Table no 4.6, sand confirms ZONE II

**3.3.4 Grading of sand:**

On the basis of particle size, fine aggregate is graded into four zones. Where the grading falls outside the limits of any particular grading zone of sieves, other than 600 micron IS sieve, by a total amount not exceeding 5 percent, it shall be regarded as falling within that grading zone.

**TABLE 3.7: Grading of fine aggregate**

| **IS Sieve** | **Percentage passing for** | | | |
|---|---|---|---|---|
| | **Grading Zone I** | **Grading Zone II** | **Grading Zone III** | **Grading Zone IV** |
| 10mm | 100 | 100 | 100 | 100 |
| 4.75mm | 90 – 100 | 90 – 100 | 90 – 100 | 90 – 100 |
| 2.36mm | 60 – 95 | 75 – 100 | 85 – 100 | 95 – 100 |
| 1.18 mm | 30 – 70 | 55 – 90 | 75 – 100 | 90 – 100 |
| 600 micron | 15 – 34 | 35 – 59 | 60 – 79 | 80 – 100 |
| 300 microns | 5 – 20 | 8 – 30 | 12 – 40 | 15 – 50 |
| 150 microns | 0 – 10 | 0 – 10 | 0 – 10 | 0 – 15 |

**3.4 Coarse aggregates**

**3.4.1 Specific gravity and water absorption:**

Specific gravity for an aggregate is defined as the ratio of the weight of a given volume of sample to the weight of equal volume of water at the same tense temperature. It is important in determination of moisture content and in many concrete mix design calculation. It is also required for the calculation of volume yield of concrete.

**TABLE: 3.8: Specific gravity and water absorption**

| **Specific gravity:** | Trail 1 | Trail 2 | Trail 3 |
|---|---|---|---|
| Wt,,of saturated agg..suspended in water+wire basket ($W_1$g) | 3290 | 3293 | 3291 |
| Weight of empty wire basket while keeping in water ($W_2$g) | 1882 | 1880 | 1881 |
| Weight of saturated surface dry aggregate ($W_3$g) | 2080 | 2082 | 2082 |
| Weight of oven dry aggregate ($W_4$g) | 2040 | 2040 | 2040 |
| specific gravity = $W_4/W_3$-($W_1$-$W_2$) | 2.67 | 2.65 | 2.65 |
| Average specific gravity | 2.65 | | |
| Percentage of water absorption = ($W_3$-$W_4/W_4$) X100 | 0.19 | 0.2 | 0.2 |

Its value lies between 2.6-2.8.

Result: specific gravity of Coarse Aggregate = 2.65 and

Percentage of water absorption is 0.19.

**3.4.2 Fineness modulus of course aggregate:**

Fineness modulus is only a numerical index of fineness, giving some idea of the mean size of particular in the entire body of aggregate. Determination of fineness modulus may be considered as a method of standardization of the grading of the aggregates.

Weight of aggregate taken = W = 2000g

**TABLE 3.9: Fineness modulus of course aggregate**

| Sieve No. | Weight retained (Wi) | % retained. (Wi/W) X100 | Percentage retained. ( C ) | Cumulate% passing. (F) |
|---|---|---|---|---|
| 20mm | 267 | 13.35 | 13.35 | 86.65 |
| 10mm | 1698 | 84.90 | 98.25 | 1.75 |
| 4.5mm | 35 | 1.75 | 100 | 0 |
| 2.36mm | 0 | 0 | 0 | 0 |

Fineness Modulus of Coarse Aggregate = $\sum C$ /100 = 211.6/100= 2.12

Result: Fineness Modulus of Coarse Aggregate = 2.74

**3.5 Properties of rubber**

The physical properties of shredded or crumbed rubber are given in Table 3.10

**TABLE 3.10: Properties of rubber**

| | |
|---|---|
| Compacted density | 2.3 to 4.8kN/cum |
| Compacted unit weight | 1/3 of soil |
| Compressibility | 3 times more compressible than soil |
| Density | 1/3 to 1/2 less dense than the granular fill |
| Durability | Non-biodegradable |
| Modulus of Elasticity | 1/10 of sand |
| Permeability | Less than 10cm/sec |

| | |
|---|---|
| Poisson's Ratio | 0.2 to 0.3 |
| Specific gravity | 1.14 to 1.27 |
| Thermal insulation | 8 times more effective than the gravel |
| Unit weight | Half the unit weight of gravel |

**3.6 Mix proportion**

- In this study four different types of mixes or combination is being considered and designed as per Indian Standard Specification IS: 10262(2009)
- Water cement ratio- The water cement ratio must be optimum according to the grade of concrete chosen and mix design has to be done
- Quality aggregates –The quality of aggregates must be high.
- The other three concrete mixes were made by replacing the coarse aggregates with 0%, 5% 10% and 15% of discarded tyre rubber by weight.

In the present study we are designing a Concrete Mix for M20 Grade concrete is (1:1.5:3) and the water cement ratio is 0.55 below the different percentage of rubber aggregate is replaced by coarse aggregate and cubes were tested for compressive strength for 7 days and 28 days

**TABLE 3.11: Mix proportion of M20 grade concrete**

| **Percentage %** | **Cement** | **Fine aggregate** | **Coarse aggregate** | **Rubber aggregate** |
|---|---|---|---|---|
| | **%** | **%** | **%** | **%** |
| **0%** | 100% | 100% | 100% | 0% |
| **5%** | 100% | 100% | 95% | 5% |
| **10%** | 100% | 100% | 90% | 10% |
| **15%** | 100% | 100% | 85% | 15% |
| **Water** | W/C Ratio = 0.55 | | | |

## 4. Tests And Results

**4.1 Hardened Concrete Properties**

Compression test according to IS: 516(1959) is carried out on these cubes. The specimens were loaded at a constant strain rate until failure. The compressive strength is decreased with an increase in the percentage of the tyre rubber chips. The results of compressive strength of cubes for 7 days and 28 days are as follows.

**4.2 Fresh Concrete Properties:**

**4.2.1 Workability:**

The replacement of coarse aggregate by scrap tyre rubber effects on the workability of the concrete. The workability of rubberized concrete shows an increase in slump with increase of waste tyre rubber content of total aggregate volume. The result of the normal concrete mix showed an increase in workability, but it can be summarized that the workability is adversely affected by the incorporation of chipped tyre rubber. The results of the slump test are as shown.

**4.3 Discarded tyre as concrete aggregates**

Early studies in the use of worn-out tyres in asphalt mixes were very promising, They showed that rubberized asphalt had better skid resistance, reduced fatigue cracking, and achieved longer pavement life than conventional asphalt. So far very little work has been done in the use of rubber from scrap tyres in Portland Cement Concrete (PCC) mixture. The work done so far in the use of tyre rubber as aggregates in concrete is given below:

**4.4 Density**

The general density reduction was to be expected due to the low specific gravity of the rubber aggregates with respect to that of the natural aggregates. The reduction in density can be a desirable feature in a number of application, including architectural application such as nailing concrete, false facades, stone backing and interior construction as well as precast concrete, light weight hollow and solid blocks, slabs etc.

**4.5 Effect of texture of rubber particle surface**

Various studies show that the rougher the rubber particles used in concrete mixtures the better the bonding they develop with the surrounding matrix and, therefore, the higher the compressive strength of rubcrete concrete may be obtained by improving the bond between rubber particles and the surrounding cement paste.

Aggregates vary from merely washing them with water to acid etching. About 57% improvement in compressive strength was obtained when rubber aggregates before use treated with carbon tetrachloride (CCl4). The treatment increase in surface roughness of the rubber, which improves its attachment to the cement paste. Upon loading weak bonding of rubber aggregates to surrounding cement paste is one of the main causes of lower compressive strength of rubcrete concrete. There are various methods by which rubber aggregates bonds may be improved. The waste rubber recycling factories should supply the rubber aggregates in pretreated and specified grading for their better performance. This will build confidence to users and improve the mass sale of rubber aggregates as a new construction material of cement concrete construction. Quality rubber aggregates should be manufactured and supplied by waste rubber recycling factories in grading 20-10 mm, 10-4.75 mm and 4.75 mm down sizes.

**4.6 Toughness impact resistance heat and sound insulation**

Rubberized concrete did not exhibit brittle failure when specimens loaded in compression. It is due to its ability to with stand large tensile deformations, the rubber particles act as springs, delaying the widening of cracks and preventing full disintegration of the concrete mass. Rubberized concrete will give better performance than conventional concrete where vibration damping is required, such as in building as an earthquakes shock-wave absorber, in foundation pads for machinery, and in Railway stations.

When rubber aggregates were added to the mixture, the impact resistance of concrete is increased, Rubber aggregates in concreter also make the material a better thermal insulator, which could be very useful especially.

in the wake of energy conservation requirements. From fire test it was observed that flammability of rubber in rubcrete mixture was much reduced by the presence of cement and aggregates. It is believed that fire resistance of rubcrete mixture is satisfactory. In this connection more testing is needed.

**4.7 Durability**

Since rubber waste concrete has lower compressive strength than reference concrete it is expected that is behavior under fast mechanical degradation actions could also be lower. Topçu & Demir mentioned that a high volume replacement of sand by rubber waste has lower durability performance assessed by freeze-thaw exposure, seawater immersion and high temperature cycles. According to them the use of a 10% replacement is feasible for regions without harsh environmental conditions. Ganjian et al. studied the durability of concrete containing scrap-tyre wastes assessed by water absorption and water permeability revealing that a percentage replacement of just 5% is associated with a more permeable concrete (36% increase) but not a more porous one..

**4.8 Uses of rubber concrete (rubcrete)**

Fattuhi and Clark have suggested that rubcrete could possibly be used in the following areas:

- Where vibrations damping is needed, such as in foundation pad for machinery, and in railway stations.
- For trench filling and pipe bedding, pile heads and paving slabs
- Where resistance to impact or blast is required such as in railway buffers, jersey barriers and bunkers.
- Rubcrete because of its light unit weight may be suitable for architectural applications like
- Nailing concrete
- False facades

- Stone backing
- Interior construction.

Topcu and Avcular have suggested that it may be used in highway construction as

- shock absorber, in sound barriers,
- as a sound boaster, and
- Also in buildings as an earthquake shock-wave absorber.

However, more significant research is needed before strong recommendations can be made..

**4.9 Slump test**

Ingredients of mixes are properly mixed so as to produce homogeneous and uniform fresh concrete in macro-scale in order to know its workability using slump test as shown in figure 3. The results of same test for the conventional concrete and various rubberized concrete are shown in table 1.

Fig 4.1: Process of Concrete Mixing and Slump Test

**TABLE 4.1: Slump Test**

| Specimen | % rubber | slump (mm) |
|---|---|---|
| **A** | 0 | 92 |
| **$A_1$** | 5 | 60 |
| **$A_2$** | 10 | 29 |
| **$A_3$** | 15 | 5 |

It is noted that slump has been decreased due to increase in percentage of rubber aggregates in all samples of concrete mix. In normal concrete mix, slump is seen to 92 mm and when the coarse aggregates are replaced with 15% tyre chips then the slump is about 5 mm which becomes nearly zero slump value.

**4.10 Unit weight**

From the test, specific gravity of rubber tyre aggregates and mineral coarse aggregates are of 1.18 and 2.70 respectively. From the observation, it is noted that unit weight of rubberized concrete decreases due to increase in rubber tyre aggregates as shown in Table 2.

**TABLE 4.2: Unit weight of conventional concrete and various rubberized concrete mix**

| Specimen | % rubber | Unit wt. in Kg |
|---|---|---|
| **A** | 0 | 8.541 |
| **$A_1$** | 5 | 8.345 |
| **$A_2$** | 10 | 7.979 |
| **$A_3$** | 15 | 7.317 |

**4.11 Compressive strength**

Compressive strength test on cubes were carried out using the Universal Testing Machine (UTM). Compressive test were carried out on cubes of dimensions 150 × 150 × 150 mm after 7 days and 28 days. For each test and for each mix three specimens were tested. The compressive strength was computed using the expression $F_c$= P/A for cubes, Where, $F_c$ is the compressive stress in MPa. P is the maximum load applied in Newton and A is the cross sectional area in $mm^2$.

Standard cast iron moulds of size 150x150x150mm for cubes are used in the preparation of specimens. The experimental setup is shown in below figures.

Fig 4.2: compressive test machine

Fig 4.3: specimen after failure

Fig 4.4: Compressive Strength Test Set Up for Cubes

Compression test according to IS: 516(1959) is carried out on these cubes. The specimens were loaded at a constant strain rate until failure. The compressive strength is decreased with an increase in the percentage of the tyre rubber chips. The results of compressive strength of cubes for 7 days and 28 days are as follows. The concrete mix was prepared with water-cement ratio of 0.55 then accordingly. The concrete cubes are casted.
The same cubes are cured in water curing tank in laboratory at normal room temperature and are tested at 7th and 28th days with the help of Compression Testing Machine which is shown in figure 5.5. The results of crushing strength of conventional and rubberized concrete mix of same concrete grade are shown in Table 4.3.


Fig 4.6: water curing tank

**TABLE 4.3: Compressive strength of various concrete mixes**

| Specimen | % age Rubber aggregates | Actual Comp. Strength (MPa) | | Av.Compressive Strength (MPa) | |
|---|---|---|---|---|---|
| | | 7 days | 28 days | 7 days | 28 days |
| A | 0 | 17.778 | 25.778 | 17.48 | 27.11 |
| | | 16.889 | 26.667 | | |
| | | 17.779 | 28.889 | | |
| $A_1$ | 5 | 16.000 | 17.333 | 16.15 | 19.26 |
| | | 16.889 | 19.556 | | |
| | | 15.556 | 20.889 | | |
| $A_2$ | 10 | 13.333 | 14.667 | 13.62 | 15.48 |
| | | 14.222 | 16.000 | | |
| | | 13.333 | 15.778 | | |
| $A_3$ | 15 | 10.000 | 12.667 | 10.37 | 12.14 |
| | | 10.667 | 11.556 | | |
| | | 10.444 | 12.222 | | |

The test results show that addition of rubber aggregates resulting to significant reduction in compressive strength compared to conventional concrete at $7^{th}$ and $28^{th}$ days. Figure 6 illustrates the trend of strength development in different concrete specimens at $7^{th}$ and $28^{th}$ days whereas figure 7 shows the comparison of compressive strength of subsequent concrete mix at $7^{th}$ and $28^{th}$ days in comparison to conventional concrete. Further, gain of compressive strength of various prepared concrete mix with respect to the days from the stage of its curing is shown in figure 8. From the scenario of this graph, one can conclude that rapid in strength gain takes place up to its 7 days of curing later on its gaining rate becomes slower.

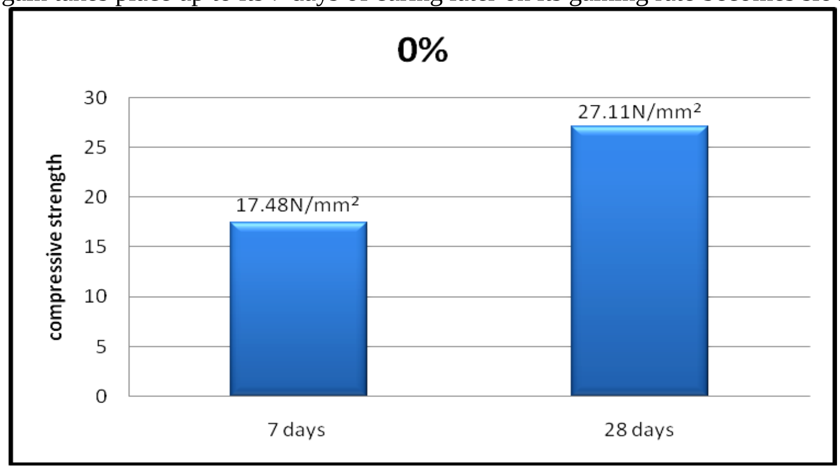


Fig 4.7: Comparison of Compressive Strength of Cubes for 0% replacement of coarse aggregate

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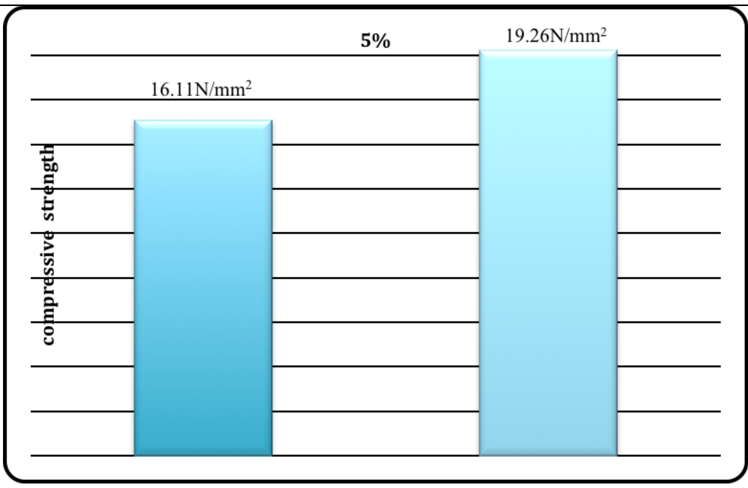


Fig 4.8: Comparison of Compressive Strength of Cubes for 5% replacement of coarse aggregate

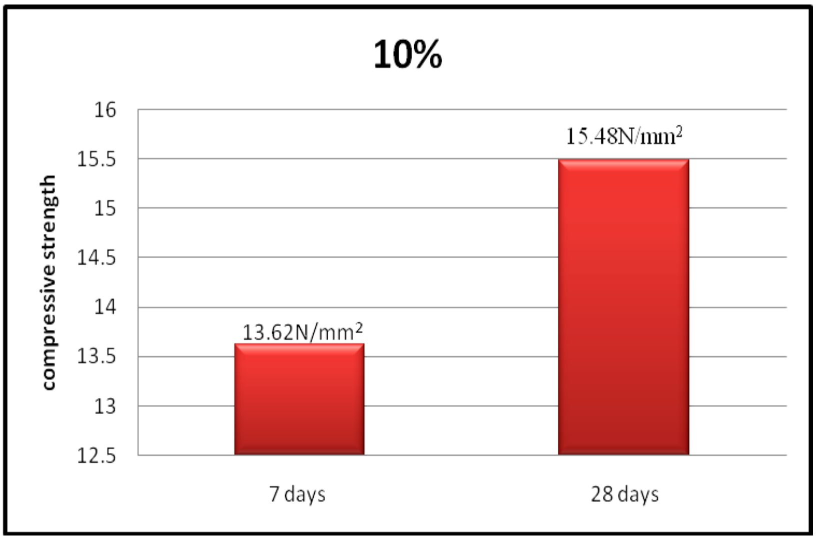


Fig 4.9: Comparison of Compressive Strength of Cubes for 10% replacement of coarse aggregate

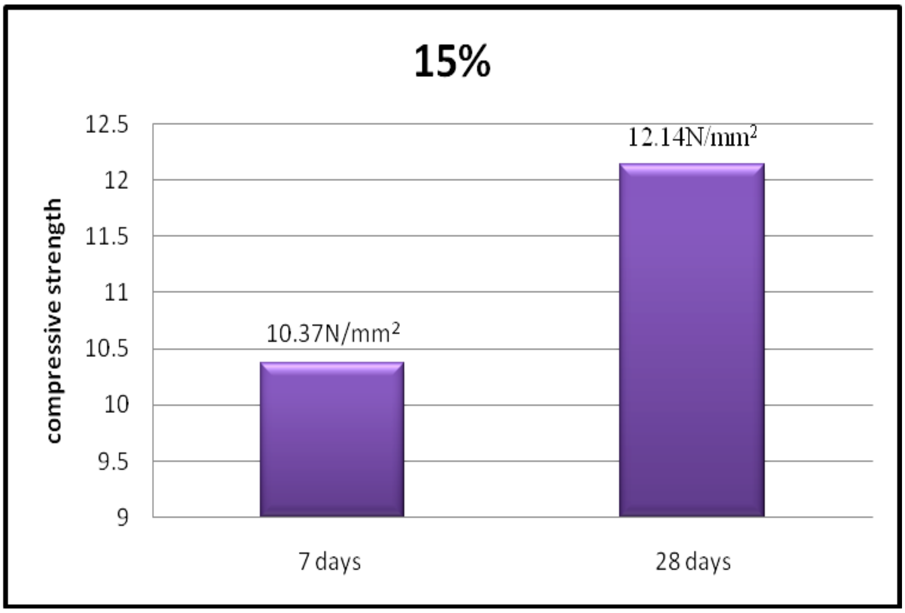


Fig 4.10: Comparison of Compressive Strength of Cubes for 15% replacement of coarse aggregate

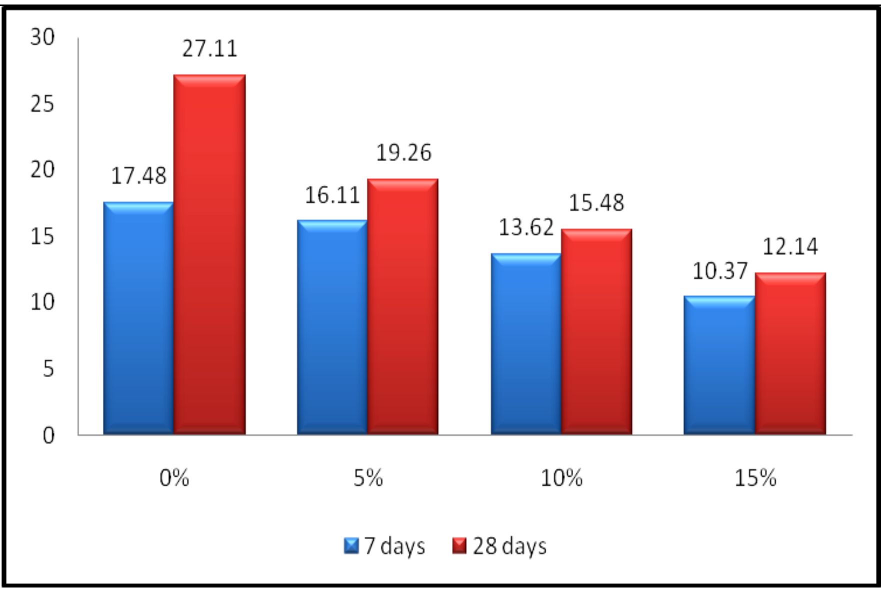


Fig 4.11: Comparison of Compressive Strength of Cubes in 7 and 28 Days

## Discussions

The reasons for reduction in the strength of concrete when rubber was used are as follows:-

- The addition of rubber aggregate in concrete mixes reduces the concrete density, which can be utilized in light weight concrete. Rubcrete concrete reduces the concrete strength, however, this may be used where M-10 and M- 15 grade concrete is needed. Further researches are needy for its use in RCC Work. Other properties as obtained by various researches are given elsewhere in the paper
- Lack of proper bonding between rubber particles & the cement Paste
- Due to replacement of the aggregates by rubber particles, the weight was reduced.
- High concentration of rubber particles at the top layer of specimen due to lower specific gravity of the rubber particles.
- Due to non-uniform distribution of rubber particles in the concrete, non- homogenous samples are produced, which in turn results in reduction in concrete strength.
- The stiffness of rubber is lower as compared to stiffness of coarse aggregate, the presence of rubber
- Particles in concrete reduce the concrete mass stiffness and also decreases load bearing capacity of concrete.
- Despite the reduced compressive strength of rubberized concrete in comparison to conventional concrete, there is a potential large market for concrete products in which inclusion of rubber aggregates would be feasible which will utilize the discarded rubber tyres the disposal of which, is a big problem for environment pollution.
- .Rubberized concrete strength may be improved by improving the bond properties of rubber aggregates. In India, out of 36 tyre manufacturers the tyre recyclers are around 20, the major contribution is only by four or five among these M/S Gujarat reclaim has annual turnover of over Rs 15 crores from its Haridwar (uttarakhand , india ) tyre recycling plants.
- With a production of 20 tons of reclaim rubber per day. The tyre recycling factories should supply quality rubber aggregates in 20-10mm, 10-4.75mm and 4.75mm down sizes to be used as cement concrete aggregate.
- The light unit weight qualities of rubberized concrete may be suitable for architectural application, false facdes, stone baking, interior construction, in building as an earthquake shock wave absorber, where vibration damping is required such as in foundation pads for machinery railway station, where resistance to impact or explosion is required, such as in jersey barrier, railway buffers, bunkers and for trench filling.
- one of the possible applications of **rubcrete** may be its application in rendering of roof top surfaces for insulation.
- Slump value is decreased as the percentage of replacement of scrap tyre rubber increased. So decrease in workability.
- The compressive strength is decreased as the percentage of replacement increased, but rubber (MCR-03) concrete developed slightly higher compressive strength than those of without rubber (MC-00) concrete.

The split tensile strength is increased with decreased percentage of scrap tyre rubber.

- Decrease in compressive strength, split tensile strength and flexural strength of the specimen.
- Lack of proper bonding between rubber and cement paste matrix.
- In the rubberized concrete the loss of strength was 45% with 15% replacement of coarse aggregate by rubber particles.

## Recommendations

- It is not recommended to use rubber or leather in production of concrete structural members. Rubber waste can be used with non structural concrete such as light weight concrete or fill concrete. Leather will increase the workability and decrease concrete strength dramatically,
- Even though the use of waste tires 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 conventional ways cannot continue with time. Hence, there will be a potential accumulation of waste tires , especially in the larger cities of the country.
- The Government so far has made an attempt by declaring the solid waste management proclamation on the *Negarit gazette* prohibiting the import of waste tires. Moreover, the country should also enforce laws regarding the management of waste tires before the problem expands and reaches to an uncontrollable level.
- Since the use of rubber aggregates in concrete construction is not a common trend in country like India. Many studies and research works need to be carried out in this area and academic institutions should play a major role.
- Tyre manufacturers and importers should be aware of the environmental consequences of waste tires and they should have research centers that promote an environmental friendly way of tire reprocessing.
- 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.

- 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.
- Future studies should be continued in the following areas as part of the extension of this research work.
- 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.
- 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.
- 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

## Conclusion

From the test results of various mix samples, the following conclusions are drawn

- Introduction of recycled rubber tyres into concrete mix leads to decrease in slump and workability for the various mix samples.
- Reduction in unit weight of 14.33 % was observed corresponding to 15% by volume of coarse aggregates was replaced by rubber aggregate in sample $A_3$ which is with a targeted compressive strength of 12.14 Mpa. A much similar trend of reduction in unit weight of rubberized concrete were observed in all other samples containing rubber aggregates.
- For rubberized concrete, test results show that addition of rubber aggregates resulting to significant reduction in compressive strength compared to conventional concrete which is in the range of 28.95 % to 55.21%. Although the compressive strength is still in the reasonable range for the 5% replacement.
- Rubberized concrete can be used in non-load bearing members i.e. lightweight concrete walls, other light architectural units, thus rubberized concrete mixes could give a viable alternative to where the requirements of normal loads, low unit weight, Medium strength, high toughness etc.

- The overall results of this study show that it is possible to use recycled rubber tyre aggregates in concrete construction as partial replacement to mineral coarse aggregates
- Fine and coarse aggregates of rubber increased workability of fresh concrete. .
- The compressive strength of concrete with rubber decreased with increase of curing time.

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