Effect of Tyre Rubber Pieces on Strength of Ordinary Concrete

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Abstract- *The use of scrap tyre rubber in the preparation of concrete has been thought as an alternative disposal Solid waste management has gained a lot of attention to the research community now-a- days. Out of the various solid waste, accumulated waste tires, has become a problem of interest because of its non- biodegradable nature. Most of the waste tire rubbers are used as a fuel in many of the industries such as thermal power plant, cement kilns and brick kilns etc. Unfortunately, this kind of usage is not environment friendly and requires high cost. It can't be released off effortlessly in nature as its deterioration takes much time and furthermore creates ecological contamination of such waste to ensure the earth.*

In this context a part of 20% of cement is replaced with silica fume and varying amounts of 5, 10, 15, and 20% of coarse aggregate is replaced by pre-treated scrap tyre pieces. The concrete is molded to desired shape, solidified, and cured. The variations in the rubber content show variations in the mechanical properties of the concrete specimen, which are recorded. Its different properties like compressive strength, split tensile strength and flexural strength will be investigated and compared with ordinary concrete.

The results show that increase in rubber content in the concrete mixture decreases the strength, the strength of the concrete when compared to rubber concrete increases due to addition of silica fume.15% of rubber replacement provides strength to concrete, increase in percent decreases the strength of concrete.

Keywords- Silica Fume, Waste Tyre Rubber, Compressive Strength, Split Tensile Strength, Flexural Strength.

I. INTRODUCTION

Concrete is a composite material made up of coarse aggregate held together in cement and fine aggregate matrix. In a concrete mix, cement and water forms a paste called matrix which fills the voids of the fine aggregate, coats the surface of fine and coarse aggregates, and binds them together. The scarcity and availability at reasonable rates of sand and aggregate are now giving anxiety to the construction industry. Rubber aggregates from discarded tyre rubber in sizes 20-10 mm, 10-4.75 mm and 4.75 mm down can be partially replaced natural aggregates in cement concrete construction

1.1.1 Tyre waste management

Accumulation of solid waste management has become a major environmental problem. Out of the various solid waste, accumulated waste tires is non- biodegradable in nature. Scrap tires are discarded when they are of no use. These waste rubber tires are generally called black pollution, as they take much time to deform, posing a potential threat to environment and also to the living beings.

This process generally is more harmful to the environment and requires high cost. The scrap tires must be reused in the most effective way possible. The use of scrap tire rubber in the preparation of concrete is an alternative way to dispose tire waste to protect the environment. This kind of concrete may be used where elasticity, tensile strength should be achieved. This study is an attempt to identify the various properties of concrete mix with the coarse tire rubber chips as a coarse aggregate.

In this experimental study, a part of coarse aggregate is replaced with chopped waste car tire pieces and a part of cement is replaced with silica fume.

Figure 1.2 Accumulated Scrap tyres

1.1.2 Source of silica fume

Silica fume is a powdered material of light to dark in color and composed of at least 85% ultra-fine, non-crystalline SiO_2 particles. It is an outcome during the manufacture of silicon metal or ferrosilicon alloys in an electric furnace.

1.1.3 Caustic soda

Caustic Soda, also known as sodium hydroxide (NaOH) is an inorganic compound. It is a white solid which is generally in pellet or powdered or flaky form. It is manufactured by the electrolysis of sodium chloride solution using one of three cell types which are mercury, diaphragm, and membrane cells. Caustic soda is produced in various forms such as powdered and flaky forms. The rubberized concrete has lesser compressive strength and hence treated with caustic soda. The scrap tyre pieces are soaked for 24 hours in the caustic soda solution in order to increase the compressive strength of the concrete.

Figure 1.3 Caustic soda

1.3 MATERIALS AND PROPERTIES

The materials used for the concrete mix in this study are coarse and fine aggregates, chopped scrap tyres, cement, micro silica, caustic soda and water.

1.1.3 Aggregates

Aggregates form the body of the concrete and reduce the shrinkage. They are the materials used as filler with binding material in the production of concrete. They are also the raw materials that are an essential ingredient in concrete.

Figure 1.4 Coarse aggregate

Figure 1.5 Fine aggregate

1.1.4 Scrap tyre Pieces

Car tyres are chopped to 20mm size are used as a part of coarse aggregate. In this experimental study rubber aggregates are partially replaced natural aggregates in cement concrete. Rubber tyres are shredded into pieces, which are present in desired shapes and sizes. The rubber tyre chips are of angular in shape and 20mm in size.

Figure 1.6 Tyre pieces

1.1.5 Properties of rubber tyres

Since rubber tires are used as coarse aggregates, it is essential to study the properties of tires. Its physical, thermal and mechanical properties are listed below

General Characteristics

- Durometer range (Shore A) : 20-95
- Tensile Range (PSI) : 500-3000
- Compression Set : Good
- Resilience/ Rebound : Excellent

Resistance

- Abrasion resistance : Excellent
- Tear resistance : Good
- Solvent resistance : Fair
- Oil resistance : Fair

- Aging Weather/ Sunlight : Good

Temperature Range

- Low Temperature Usage : 10^0 to -50^0 F or -12^0 to -46^0 C
- High Temperature Usage : Up to 250^0 F or up to 121^0 C

Cement

Cement is binding material which is used for making any type of concrete. Among the various types of cement available in the market, Ordinary Portland Cement of 53 grade confirming to IS 269-1976, whose compressive strength at the end of 28^{th} day is 54 N/mm2 when tested as per IS 4031-1988, from Jay Pee Company is used in this project work.

Table 1.1 PHYSICAL PROPERTIES OF CEMENT

S.NO:	PHYSICAL PROPERTIES	RESULTS
1	Fineness of cement	5%
2	Specific gravity of cement	3.13
3	Normal consistency	32%
4	Initial setting time(minutes)	30
5	Final setting time(minutes)	600
6	Compressive strength	$54N/mm^2$

1.1.1 Micro Silica

The micro silica that is used for the concrete mix is of pellet form and grey in color. Silica fume is a byproduct in the carbo-thermic reduction of high-purity quartz with carbonaceous materials like coal, coke, wood-chips, in electric arc furnaces in the production of silicon and ferrosilicon alloys.

It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. It is acquired at the price of Rs.12 per kg from **G.R.R. Associates, Visakhapatnam**. 20% of cement is replaced by silica fumes, in this concrete mix. Micro silica increases the compressive strength of the mix.

Figure 1.9 Micro silica

Table 1.3 PROPERTIES OF SILICA FUME

Property	Value
Particle size (μm)	1
Bulk density (kg/m^3)	130-430 (as produced); 480-720 (densified)
Specific Gravity	2.2
Specific surface (m^2/kg)	15,000 – 30,000

1.1.1 Caustic Soda

Diluted caustic soda is used to treat the tire pieces by soaking them in the solution for 24 hours. Sodium hydroxide is used in some cement mix plasticizers. This helps Homogenize cement mix, preventing segregation of sands and cement, decreases the amount of water required in a mix and increases workability of the cement product, be it mortar, render or concrete. In this experimental study, caustic soda of white solid flaky form is acquired from **Sri Lakshmi Chemicals, Kakinada** at the price of Rs.60/- per kg.

Figure 1.10 Caustic soda

II. LITERATURE REVIEW

There is renewed interest in finding ways to recycle the used tires. Therefore, over the past few years, many researchers focused on the use of waste tires in different shapes and sizes in concrete. Russell J. Schnormeier in 1988 mentioned that the scrap tires can be used in concrete products. These materials are economical, and have many ecological advantages.

2.1 EXPERIMENTS ON THE USAGE OF SCRAP TYRES IN CONCRETE

T Senthil Vadivel, RThenmozhi and M. Doddurani (2014), et al., studied the behavior of waste tire rubber aggregate concrete cylindrical specimen under. It was concluded that the mixture has reduction in compressive strength and density and has higher toughness, higher impact resistance and enhanced ductility than the conventional concrete. Mix was prepared to get M20 concrete with 6% of truck tire chips. The result of this experimental study showed that the concrete mix had 29.84 MPa of compressive strength and 2.4 MPa of tensile strength for 28 days of curing.

Mavroulido M and Figueiredo J (2010), et al., "Discarded tire rubber as concrete aggregate: a possible outlet for used tires" it can be concluded that despite the observed lower values of the mechanical properties of concrete there is a potential large market for concrete products in which inclusion of rubber aggregate would be feasible. Even if the rubber tyre aggregate was used at relatively low percentages in concrete, the amount of waste tyre rubber could be greatly reduced due to the very large market for concrete products worldwide. Therefore the use of discarded tyre rubber aggregates in concrete shows promise for developing an additional route for used.

Zheng L, X Sharon Huo and Y Yuan (2008), et al.,carried out an experiment on concrete with untreated rubber chips of size 15mm to 40mm by replacing the coarse aggregate by 15%, 30% and 45% by the volume. The experiment was based on **ASTM 2005**.

EXPERIMENTS ON THE EFFECT OF CAUSTIC SODA FOR THE TREATMENT OF TYRE PIECES

Research on the properties of the tire rubber in concrete showed that the tire and cement paste bond is weak, due to its soft surface. Research work has been carried out by engineers, on surface treatment of the chopped rubber tyres in order to increase the strength and adhesive property. A few chemical admixtures such as caustic soda, latex admixture cleaner, carbon tetra chloride solvent are used for surface treatment of chopped tyre aggregates. In this context, caustic soda has been chosen, to treat the tire pieces. The use of caustic soda for surface treatment has been reviewed below.

Ganjianin, E., Khorami, M., and Maghsoudi, A.A., (2009), et al., confirmed the decrease in compressive strength for increase rubber content. However, they obtained a slight increase in compressive strength when 5% of chipped rubber replaced the coarse aggregates due to better grading of the mixture.

Albano,Camacho N, Reyes J(2005), et al., found an improvement in the compressive and splitting tensile strengths of rubberized concrete containing NaOH and saline pre-treated scrap tire waste as a fine aggregate replacement material.

2.3 EFFECT OF SILICA FUME IN CONCRETE

Some studies proved that usage of pozzolanic materials such as fly ash, silica fume, and met kaolin may achieve the mechanical strength in rubberized Portland Cement Concrete. Researchers have tried to gain different advantages from the use of waste tire in concrete.

Erhan Guneyisi, Mehmet Gesolu and TuranOzturan, (2004), et al., said that the, rubberized concrete mixtures with silica fume appears to be workable. The test results indicate that there is a reduction in the compressive and splitting tensile strength, and modulus of elasticity with the increase in rubber content from 0% to 50%.

However, the addition of silica fume has resulted in a strength increment as high as 43% and 27% depending on the variation in the water cement ratio and the amounts of silica fume and rubber used. On the other hand, the elastic modulus of the rubberized concretes slightly increased up to 15% with the use of silica fume. The effect of using silica fume in concrete of 20% weight of powder and 50%, respectively, increases the mechanical properties and reduced the rate of strength loss.

Philippe Lawrence, Martin Cyr and Erick Ringot(2003), used some powders to decrease the hydration rate, which could lead to setting delay and affect the development of short-term compressive strength. This effect is mainly in the case of silica fume. These enhancements or delays of cement hydration are the consequences of various physical and chemical phenomena, which are difficult to dissociate most of the time.

III. EXPERIMENTAL PROGRAM

This chapter comprises the experimental program and the properties constituent materials to study fresh and hardened properties of concrete. Concrete mix with a compressive of 25 MPa is used. The materials used to develop the concrete mixes in this study are fine aggregate, coarse aggregate, shredded rubber, cement, micro silica, sodium hydroxide (NaOH) and water. Concrete is tested to know whether the concrete has attained a sufficient strength or concrete has set sufficiently for stripping, stressing, de-propping, opening etc., and also to determine whether the concrete has gained sufficient strength for the intended purpose. There are so many tests available for testing different qualities of concrete. Different tests give results for their respective quality of concrete.

The properties of several constituent materials used in this work are also discussed such as moisture content and specific gravity. The laboratory investigation consisted of tests for both fresh and hardened concrete properties. Fresh concrete is tested for slump flow. The tests for hardened concrete includes tests for compressive strength and tensile Strength. The test procedures are illustrated in the following sections. The necessary tests are conducted in the laboratory in accordance with IS specifications. The experimental program consists of grading of coarse aggregates used in the concrete, calculating the mix design, sampling, batching, mixing of concrete, slump test to determine the workability of fresh concrete, casting, curing and testing the hardened properties of concrete such as tensile and compression strength. In this chapter the procedures adopted, the reason to adopt a certain procedure, IS specifications used, apparatus etc., are explained in an elaborate manner.

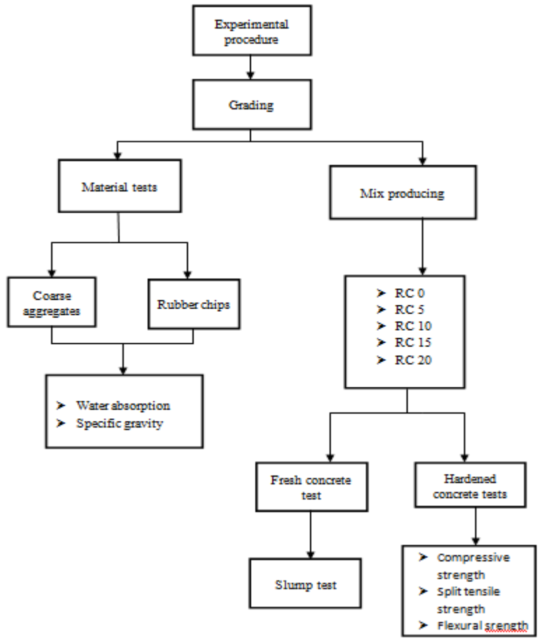


Figure 4.1 Flow chart of Experimental program

IV. GRADING OF COARSE AGGREGATES

The objective of grading aggregates is to determine the particle size of the aggregates to achieve the higher strength of the resultant mix. Grading of coarse aggregates and rubber chips is done by adopting the method of sieve analysis. Sieves of sizes conforming to IS 456 specifications are used. Various apparatus required for the sieve analysis are sieves of different sizes. This is done by sieving the aggregates as per IS: 2386 (Part I) – 1963. A set of IS Sieves of sizes – 80mm, 63mm, 50mm, 40mm,31.5mm, 25mm, 20mm, 16mm, 12.5mm, 10mm, 6.3mm,4.75mm, 3.35mm, 2.36mm, 1.18mm, 600µm, 300µm, 150µm and 75µm. The sieves are arranged in such a way that a sieve of greater size is placed at the top and a sieve of smaller size is placed at the bottom. The aggregates are sieved by hand or by using a sieve shaker to attain accuracy. In this context aggregate of grade 20 are used in order to attain higher workability. The aggregates must pass through 25mm sieve and retain at 20 mm sieve.

Figure 4.2 Graded rubber aggregates

Treating of rubber with NaOH

Rubber aggregates are treated with caustic soda, to increase the workability of rubber aggregates. By treating the rubber with caustic soda the strength of the rubber increases. By treating, it will also increase binding property of rubber with concrete mixture. The rubber chips are treated with NaOH for 24 hours. 1M NaOH is used to treat the rubber. It is more convenient to prepare an appropriate NaOH for approximately 1M solution. The treated NaOH is dried and used in concrete. 1 molar of NaOH indicates 40gms of NaOH mixed with 1 liter water. 1 kg of rubber aggregates are treated using the prepared solution.

Figure 4.3 NaOH treatment on rubber tyres

Figure 1.14 Casting

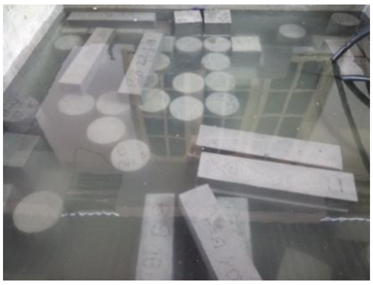


Figure 1.15 Curing

V. MIX DESIGN FOR M25 CONCRETE

5.4.1 Stipulations for proportioning

a) Grade designation: M25
b) Type of cement : OPC 53grade, IS 8112
c) Type of mineral admixture:silica fume conforming to IS 3812
d) Maximum nominal size of aggregate : 20mm
e) Minimum cement content : 320 kg/m^3
f) Maximum water-cement ratio : 0.5
g) Workability : 50 mm
h) Exposure condition : mild
i) Degree of supervision : good
j) Type of aggregate : crushed angular aggregate
k) Maximum cement (OPC) content : 450 kg/m^3
l) Chemical admixture : NaOH

5.4.2 Test data for materials

a) Cement used : OPC 53 grade conforming to IS 8112
b) Specific gravity of cement :3.15
c) Silica fume :Conforming to IS 3812 (Part I)
d) Specific gravity of silica fume : 2.6
e) Chemical admixture : NaOH
f) Specific gravity of
   1) Coarse aggregate : 2.84
   2) Fine aggregate : 2.6
g) Water absorption
   1) Coarse aggregate : 0.97%
   2) Fine aggregate : 1.23%
h) Sieve analysis
   1) Coarse aggregate : confirming to table 2 of IS 383
   2) Fine aggregate : conforming to grading Zone II of Table 4 IS383.

5.4.3 Target strength for mix proportioning

f'_{ck} = f_{ck} + 1.65 s

Where f'_{ck} is target average compressive strength at 28 days,

$f_{ck}$is characteristic strength for 28 days, and

s is standard deviation

From IS 10262:2009 Table I, page 2,

Standard deviation, s=4 N/mm^2

Therefore, Target strength = 25+1.65 x 4

= 31.6 N/mm^2.

5.4.4 Selection of water-cement ratio

From Table 5 of IS 456, page 20,
Maximum water-cement ratio = 0.5.
Based on experience, adopt water-cement ratio as 0.44.
$0.44 < 0.5$
Hence it is allowable water content.

5.4.5 Selection of water content

From IS 10262:2009 Table 2, page 3,
For 20 mm aggregate
Maximum water content = 186 liter (for 25 to 50 mm slump range)

5.4.6 Calculation of cement content

Water-cement ratio = 0.44

Cement content = $\frac{186}{0.44}$ = 420 kg/m^3

From Table 5 of IS 456, page 20,
Minimum cement content = 320 Kg/m^3
420 kg/m3 > 320 kg/m3,
Hence, it is the allowable cement content.

5.4.7 Proportion of volume of coarse aggregate and fine aggregate content

From Table 3, IS10262: 2009, page 3,
Volume of coarse aggregate corresponding to 20 mm size and fine aggregate (Zone II)
Water cement ratio= 0.50 to 0.60.
In the present case water-cement ratio is 0.44. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.06. The proportion of volume of coarse aggregate is increased by 0.012 (at the rate of -/+ 0.01 for every ± 0.05 change in water-cement ratio).
Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.40 = 0.612.
Therefore, volume of coarse aggregate = 0.612
Volume of fine aggregate content =I - 0.612 = 0.388.

5.4.8 Mix calculations

The mix calculations per unit volume of concrete shall be as follows:

Volume of concrete = 1m^3

Volume of cement = $\frac{\text{mass of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000}$

$= \frac{420}{3.15} \times \frac{1}{1000} = 0.133\text{m}^3$

Volume of water = $\frac{\text{mass of water}}{\text{specific gravity of water}} \times \frac{1}{1000}$

$= \frac{186}{1} \times \frac{1}{1000} = 0.186\text{m}^3$

Volume of all in aggregate=1-[b+c]= 1-[0.133+0.186] =0.681
Mass of coarse aggregate = d × Volume of coarse aggregate × Specific Gravity of coarseaggregate ×1000
= 0.681×0.612 × 2.84 × 1000
= 1183.63 kg ≈ 1190 kg
Mass of fine aggregate = d × volume of fine aggregate ×Specific gravity of fine aggregate× 1000
= 0.681× 0.388 × 2.6 × 1000
= 686.99 kg
≈ 690 kg

5.4.9 Mix proportions for trial mix

Cement	= 420 Kg/m^3
Water	= 186 Kg/m^3
Fine aggregate	= 690 Kg/m^3
Coarse aggregate	= 1190 Kg/m^3
Water-cement ratio	= 0.44

Therefore, Mix proportions for concrete mix of M25 grade is

Water : cement : F.A : C.A
186 kg : 420 kg : 690 kg : 1190 kg
0.44 : 1 : 1.64 : 2.83

VI. TESTS AND RESULTS

6.1 Water absorption and specific gravity results

Table 6.1 Water absorption and specific gravity test results

Rubber content in Concrete	Water absorption	Specific gravity
0%	2.62	2.84
5%	2.66	2.24
10%	2.68	2.45
15%	3.26	2.33
20%	3.32	2.25

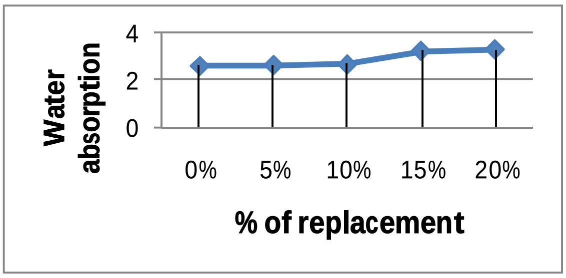


Figure 6.1 Water absorption test

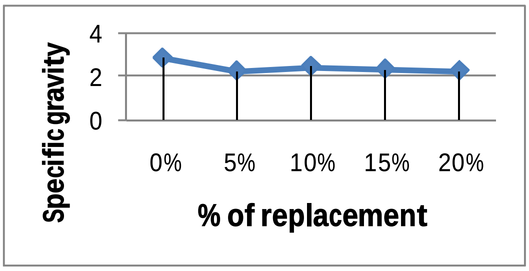


Figure 6.2 Specific gravity test

6.2 Slump test results

Mix	Slump (mm)
0%	46
5%	54
10%	61
15%	75
20%	87

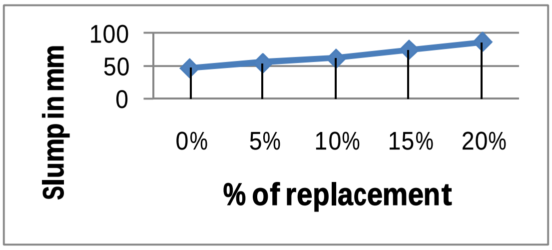


Figure 6.3 Slump cone test

6.3.1 COMPRESSIVE STRENGTH RESULTS FOR 7 AND 28 DAYS CURING

% of replacement	Compressive strength (N/mm2)	
	7 Days	28 Days
Nominal mix	27	33
0%	31	38
5%	26	35
10%	24	32
15%	23	31
20%	21	26

% of replacement	Compressive strength (N/mm2)	
	7 Days	28 Days
Nominal mix	27	33
0%	31	38
5%	26	35
10%	24	32
15%	23	31
20%	21	26

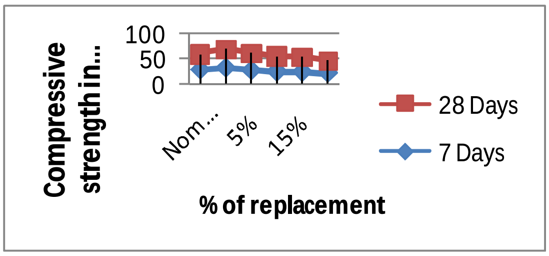
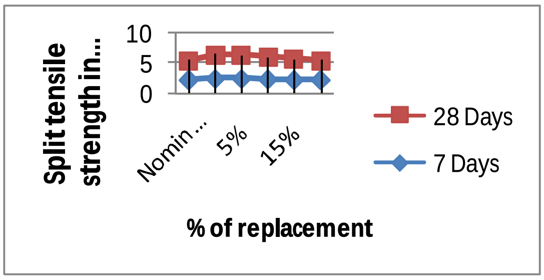


Figure 6.4

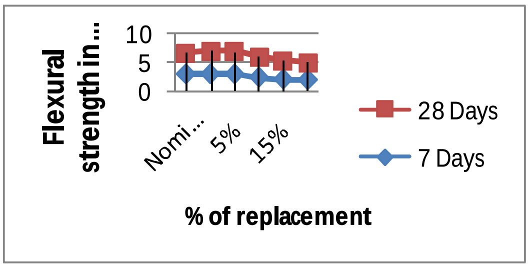
6.3.2 SPLIT TENSILE STRENGTH RESULTS FOR 7 AND 28 DAYS CURING

% of replacement	Split tensile strength (N/mm2)	
	7 Days	28 Days
Nominal mix	2.3	3.2
0%	2.5	3.9
5%	2.5	3.8
10%	2.4	3.6
15%	2.3	3.3
20%	2.3	3.1



6.3.3 FLEXURAL STRENGTH TEST RESULTS FOR 7 AND 28 DAYS

% of replacement	Flexural strength (N/mm2)	
	7 Days	28 Days
Nominal mix	2.97	3.75
0%	3.01	3.92
5%	2.99	3.86
10%	2.46	3.46
15%	2.11	3.15
20%	1.98	2.96



VII. CONCLUSION

This thesis aims to investigate the behavior of fresh and hardened properties of concrete mixes and the effect of utilizing pre-treated rubber tires in these mixes. Based on the limited experimental work carried out in the current study, the following conclusions may be drawn out.

1) Slump test results showed that the slump has increased as the percentage of rubber was increased in all mixes of pre-treated rubber.
2) Compressive strength decreases as the percentage of waste tire replacement increases for all mixes of pre-treated rubber.
3) The results of the splitting tensile strength tests showed that, there is a decrease in strength with increasing rubber aggregate content similar to the reduction observed in the compressive strength tests due to the weak bond strength between cement paste and tire rubber.
4) More concrete properties depend on properties of materials those used in mixes, and the cohesion between those materials and cement baste, so the pre-treatment of rubber particles by using different methodologies can improve those properties of concrete
5) Using of mortar with bonding agent pre-treatment for rubber particles give the best values of compressive strength and splitting tensile strength with respect to untreated rubber.
6) The test results show that the compression and tensile strength has been increased 5% when compared to normal rubber concrete.
7) Rubber replacement up to 15% shows adoptable results, 20% results shows decrease in strength.
8) Rubber concrete acts as good noise barriers and it can be used for slabs, pavements to reduce sound pollution.

VIII. SCOPE FOR FUTURE WORK

The following recommendations are proposed for further research

- Since the addition of scrap tires decreases compressive strength, it is recommended to use waste tires for non-structural elements in buildings such as underground slabs, behind building stones and in partitions etc.,
- It is recommended to study the effect of larger sizes of shredded tires on normal rubber concrete.
- It is recommended to further test the physical characteristics of normal rubber concrete through shrinkage limit, permeability, abrasion, thermal and noise insulation etc.,
- It is recommended to explore the effect of other raw materials in these mixes and study the changes in physical characteristics of normal rubber concrete. Further extensive research is needed to investigate the durability, toughness and impact resistance of the mix and to optimize the mix with the aim of reducing the levels of entrapped air and water absorption.
- There is a need for future studies to investigate energy absorption of RUBCRETE concrete under dynamic loading, and also the durability of tyre rubber concrete under adverse weathering conditions.
- There is a scope for carrying study regarding the fire resistance of rubberized concrete with respect to higher temperatures that can occur in the event of a fire accident.

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