



A RESEARCH PAPER ON PARTIAL REPLACEMENT OF COARSE AGGREGATE BY WASTE TIRES IN CEMENT CONCRETE

Devendra Kumar Sharma

Assistant Professor,
Aryabhata College of Engineering and
Research Center,
Ajmer.

Niraj Kumar

Assistant Professor,
Aryabhata College of Engineering and Research
Center,
Ajmer.

Ritesh Kumar

Assistant Professor,
Aryabhata College of Engineering and Research Center,
Ajmer.

ABSTRACT

Solid waste management has gained a lot of attention to the research community now-a-days. Out of the various solid waste, accumulated waste tyres, has become a problem of interest because of its non- biodegradable nature. Most of the waste tyre 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. Thus, 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 .

KEYWORDS: Rubberised Concrete (Rc); Scrap-Tyre-Rubber; Coarse Aggregate; Concrete Mix

1. INTRODUCTION

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(14). In its simplest form, concrete is a mixture of paste and aggregates. The paste, composed 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 form the rock-like mass known as concrete.

Concrete is the world's most important construction material. The quality and performance of concrete plays a key role for most of the infrastructures

including commercial, industrial, residential and military structures, dams, power plants and transportation systems. Concrete is the single largest manufactured 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 investment in the U.S. civil infrastructure. The worldwide use of concrete materials accounts for nearly 780 billion dollars in annual spending.

Yet concrete construction so far is mainly based on the use of virgin natural resources. Meanwhile the conservation concepts of natural resources are worth remembering and it is very essential to have a look at



the different alternatives. Among them lies the recycling mechanism. This is a twofold advantage. One is that it can prevent the depletion of the scarce natural resources and the other will be the prevention of different used materials from their severe threats to the environment. It has been well reported that about 1 billion of used automobile tires are generated each year globally. In addition to that, the traditional ways of recycling tires in our country like as a shoe making material and other tools is decreasing nowadays. This is considered as one of the major 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 strategy for scrap tires that are worn out beyond hope for reuse is recycling. Utilization of scrap tires should minimize environmental impact and maximize conservation of natural resources. One possible solution for this problem is to incorporate rubber particles into cement-based materials. Scrap tires can 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 depletion of natural resources. Moreover, some countries are depending on imported aggregate and it is definitely very expensive. For example, the Netherlands does not possess its own aggregate and has to import. This concern leads to a highly growing interest for the use of alternative materials that can replace the natural aggregates.

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

2. PROBLEM STATEMENT

Concrete has been a major construction material for centuries. Moreover, it would even be of high application with the increase in industrialization and the development of urbanization. Yet concrete construction so far is mainly based on the use of virgin natural resources. Meanwhile the conservation concepts of natural resources are worth remembering and it is very essential to have a look at the different alternatives. Among them lies the recycling mechanism. This is a twofold advantage. One is that it can prevent the depletion of the scarce natural resources and the other will be the prevention of different used materials from their severe threats to the environment. It has been well reported that about 1 billion of used automobile tires are generated each year globally. In addition to that, the traditional ways of

recycling tires in our country like as a shoe making material and other tools is decreasing nowadays. This is considered as one of the major 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 strategy for scrap tires that are worn out beyond hope for reuse is recycling. Utilization of scrap tires should minimize environmental impact and maximize conservation of natural resources. One possible solution for this problem is to incorporate rubber particles into cement-based materials. Scrap tires can 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 depletion of natural resources. Moreover, some countries are depending on imported aggregate and it is definitely very expensive. For example, the Netherlands does not possess its own aggregate and has to import. This concern leads to a highly growing interest for the use of alternative materials that can replace the natural aggregates. Therefore, the use of recycled waste tires as an aggregate can provide the solution for two major problems: the environmental problem created by waste tires and the depletion of natural resources by aggregate production consequently the shortage of natural aggregates in some countries

3. IMPORTANCE OF THE STUDY

1) This study concentrated on the performance of a single gradation of crumb rubber. The waste tires are collected from local sources and manually cut into pieces to achieve a uniform size of 20 mm, which is the maximum aggregate size in the mix design.

2) The influence of different gradations of the rubber aggregate on concrete properties was not evaluated in this study but it should be considered in future researches.

3) The study was done on three grades of concrete (M15, M20, and M25). The influence of using recycled tires in high strength concrete was not covered in the present study. The percentage replacements were limited to three categories i.e. 10, 25 and 50% replacement of the natural coarse aggregate. The different effects, which can be observed in different percentages of replacements, were not included in the present study.

4. MATERIAL SELECTION

Materials Used

The basic material of concrete e.g. cement, sand, aggregate and scrap tyre rubber are used. Portland-pozzolana cement can be produced either by integrating



the predetermined quantities of Portland cement clinker and pozzolana (15 to 35% by mass of Portland–pozzolana cement) together with small amount of gypsum, or by intimately and uniformly blending Portland cement having predetermined fineness and fine pozzolana. 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. The cement used for the present investigation was Portland-Pozzolana Cement. It is conformed to the requirement of Indian Standard specification IS: 455 (1989). The results are given in Table 1. The tests on cement were carried out as per IS: 4031(1988). Blaine's apparatus and Le-Chaterlier flasks were used to find out fineness and specific gravity of cement respectively. The physical properties of Portland-pozzolana cement were determined according to IS: 455(1989), tested according to IS: 4031(1999) and compared with the requirements of IS: 455(1989). The physical properties of Portland pozzolana cement

Scrap Tyre Rubber

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). Usually three main categories of discarded tyre rubber have been considered such as chipped, crumb and ground rubber. Chipped or shredded rubber is used to replace the gravel. To produce this rubber, in first stage the rubber has length of 300 – 430 mm long and width of 100 -230 mm wide. In the second stage its dimension changes to 100 -150 mm by cutting. If the shredding is further continued particles of about 13 – 76 mm in dimension are produced. Crumb rubber is used to replace the sand. This rubber is manufactured by special mills where big rubbers change into smaller particles. In this procedure particles of about 0.425 - 4.75 mm in dimension are produced.

Ground rubber is used to replace the cement. In this category particles of about 0.075 – 0.475 mm in dimension are used. 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.

Cement

The cement type used in this research Ordinary Portland Cement. The main reason for using Ordinary Portland Cement 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 (Naville A.M,1996).

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 (Sidney Mindess and David Darwin,2003).

5. PROPERTIES OF THE FINE AGGREGATE

To investigate the properties and suitability of the fine aggregate for the intended application, the following tests were carried out.

- Crushing value test
- Specific gravity and absorption capacity for fine aggregate
- Impact Resistance test
- Unit weight of fine aggregate

Aggregate crushing test

The strength of coarse aggregate may be assessed by aggregate crushing test. The aggregate crushing value provide a relative measure of resistance of crushing under gradually applied compressive load. To achieve a high quality of construction work, aggregate possessing high resistances to crushing or low value of crushing value are preferred. The apparatus for the standard test consists of a steel cylinder 15.2 cm diameter with a base plate and a



plunger, compression testing machine, cylindrical measure of diameter 11.5 cm and height 18 cm, tamping rod and sieves.

Dry aggregate passing 12.5 mm IS sieve and retained on 10 mm sieve is filled in the cylindrical measure in three equal layer, each layer being rapped 25 times by the tamper. The test sample is weighted (equal to W_1 g) and placed in the test cylinder in three equal layer, tamping each layer 25 times. The plunger is placed on the top of the specimen and a load of 40 tonnes is applied at a rate of 4 tonnes per minute by the compression machine. The crushed aggregate is removed and sieve on 2.36 mm IS sieve. The crushed material which passes this sieve is weighted equal to W_2 g. the aggregate crushing value is the percentage of crushing material passing 2.36 mm sieve in terms of original weight of the specimen.

$$\begin{aligned} &\text{Aggregate crushing value} \\ &= 100 W_2/W_1 \text{ percent} \\ &\text{Weight of cylinder with sample} \\ &= 3.148 \text{ kg} \\ &\text{Weight of empty cylinder} \\ &= 2.657 \text{ kg} \\ &\text{Weight of sample } (W_1) \\ &= 3.148 - 2.657 = 0.491 \text{ kg} \\ &\text{Weight of pan with crushed sample} \\ &= 0.419 \text{ kg} \\ &\text{Weight of empty pan} \\ &= 0.281 \text{ kg} \\ &\text{Weight of crushed sample } (W_2) \\ &= 0.419 - 0.281 = 0.138 \text{ kg} \\ &\text{Aggregate crushing value} \\ &= 100 W_2/W_1 \text{ percent} \\ &= 0.138/0.491 * 100 \\ &= 28.10 \% \end{aligned}$$

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 (Abebe Dinku,2002).

The following results were found for the fine aggregate sample.

Bulk Specific gravity = 2.41

Impact test

A test designed to evaluate the toughness of stone or the resistance of the aggregates to fracture under repeated impacts is called impact test. The aggregate impact test is commonly carried out to evaluate the resistance to impact of aggregate and has been standardized by ISI. The aggregate impact value indicates a relative measure of resistance of aggregate to the impact, which has a different effect than the resistance to gradually increasing compressive stress. The aggregate impact testing machine consists of a metal base and a cylindrical steel cup of internal diameter 10.2 cm and depth 5 cm in which the aggregate specimen is placed. A metal hammer a weight of 13.5 – 14.0 kg having a free fall from a height 38 cm is arranged to drop through vertical guides.

Aggregate specimen passing 12.5 mm sieve and retained on 10 mm sieve is filled in the cylindrical measure in 3 layers by tamping each layer by 25 blows. The sample is transferred from the measure to the cup of the aggregate impact testing machine and compacted by tamping 25 times. The hammer is raised to a height of 38 cm above the upper surface of the aggregate in the cup and is allowed to fall freely on the specimen. After subjecting the test specimen to 15 blows, the crushed aggregate to sieved on 2.36 mm sieve. The aggregate impact value is expressed as percentage of fine formed in term of total weight of the sample.

The aggregate impact value should not normally exceed 30 percent for aggregate to be used.

$$\begin{aligned} &\text{Weight of cylinder with sample} \\ &= 2.595 \text{ kg} \\ &\text{Weight of empty cylinder} \\ &= 1.967 \text{ kg} \\ &\text{Weight of sample } (W_1) \\ &= 2.595 - 1.967 = 0.628 \text{ kg} \\ &\text{Weight of pan with sample passes through 2.36 mm sieve} \\ &= 0.398 \text{ kg} \\ &\text{Weight of empty pan} \\ &= 0.281 \text{ kg} \\ &\text{Weight of sample passes through 2.36 mm sieve } (W_2) \\ &= 0.398 - 0.281 = 0.117 \text{ kg} \\ &\text{Aggregate impact value} \\ &= 100 W_2/W_1 \text{ percent} \end{aligned}$$

Unit weight of fine aggregate

Unit weight can be defined as the weight of a given volume of graded aggregate. It is thus a density measurement and is also known as bulk density. But this alternative term is similar to bulk specific gravity, which is quite a different quantity, and perhaps is not a good choice. The unit weight effectively measures the volume that the graded aggregate will occupy in



concrete and includes both the solid aggregate particles and the voids between them. The unit weight is simply measured by filling a container of known volume and weighing it. Clearly, however, the degree of compaction will change the amount of void space, and hence the value of the unit weight. Since the weight of the aggregate is dependent on the moisture content of the aggregate, a constant moisture content is required. Oven dried aggregate sample is used in this test. The unit weight of the fine aggregate sample used was found to be 1480 kg/m³.

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. 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 5.1 below.

Table 1 Physical Properties of the Coarse Aggregate.

Description	Test Result
Moisture content	1.37 %
Unit weight of coarse aggregate	1503.25 kg/m ³
Bulk Specific gravity	2.67
Absorption capacity	1.72 %
Crushing value of aggregate	22.83 %
Los Angeles Abrasion Test	18.9 %

Rubber Aggregate

The source of the rubber aggregate was recycled tires which were collected from the local market. For uniformity of the concrete production and convenience, all the tires collected were from those which were originally produced and the type was a medium truck tire. The reason for choosing medium truck tires 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. The rubber aggregates used in the present investigation were made by manually cutting the tire 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.

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.
- 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.

- The next step was the surface treatment of the rubber aggregates. For this the rubber aggregates were coating with cement paste. The rubber aggregates were thoroughly coated with a thin layer of cement paste, a mixture of cement powder and water. The coated rubber aggregates were then air dried by spreading them on a clean surface for about 24 hours. 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.

Water

The quality of the water plays a significant role in concrete production. Impurities in water may interfere with the setting of the cement, may adversely affect the strength of the concrete or cause staining of its surface, and may also lead to corrosion of the reinforcement. For these reasons, the suitability of water for mixing and curing purposes should be considered. In this research pure filtered water is used.

6. SELECTION OF CONCRETE MIX PROPORTIONS (MIX DESIGN)

General

The selection of mix proportions is a process of choosing suitable ingredients of concrete and determining their relative quantities with the object of producing as economically as possible concrete of certain minimum properties, notably strength, durability and a required consistency. The key to achieving a strong, durable concrete rests in the careful proportioning and mixing of the ingredients. A concrete mixture that has no enough paste to fill all the voids between the aggregates will be difficult to place and will produce rough, honeycombed surfaces and porous concrete. A mixture with an excess of cement paste will

be easy to place and will produce a smooth surface; however, the resulting concrete is likely to shrink more and be uneconomical. A properly designed concrete mix will possess the desired workability for the fresh concrete and the required durability and strength for the hardened concrete. Cement and water form a paste that coats each particle of stone and sand. Through a chemical reaction called hydration, the cement paste hardens and gains strength. The character of the concrete is determined by the quality of the paste. The strength of the paste, in turn, depends on the ratio of water to cement. High-quality concrete is produced by lowering the water-cement ratio as much as possible without sacrificing the workability of fresh concrete (The Portland Cement Association, 2009). Generally, using less water produces a higher quality concrete provided the concrete is properly placed, consolidated, and cured and fulfills any durability requirements requested.

7. TESTING ARRANGEMENT

In this study, many mixes consisting of three types of concrete grades (M15, M20 and M25) were produced 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. The mixture proportions of the basic ingredients i.e. cement, water, and fine aggregate, were the same for the control concrete and rubberized concrete. However, a certain amount of the coarse aggregate was replaced by an equal volume of rubber aggregate to form rubberized concrete. Three control mix designs, M15, M20 and M25 were prepared for this investigation. The main reason for selecting this concrete grades is that these are by far the most commonly used concrete grades for most of the concrete construction works and hence application of the research can be more feasible.

The following tests were performed on the different concrete samples produced in this study.

- 1) Slump test for workability
- 2) Determination of unit weight of hardened concrete
- 3) Compressive strength test
- 4) Flexural strength test, and
- 5) Impact Resistance test

8. Batching of Materials

Saturated Surface dry aggregates were used for the concrete mixes under research. Cement and aggregates were batched by weight while water and chemical admixtures were batched by volume. Chemical admixtures in the form of solutions were mixed with water and used in the preparation of

concrete mixes. All the replacement for the coarse aggregate was done on a volume basis.

9. Mixing and Test Sample Preparation

It is essential that the mix ingredients are properly mixed so as to produce fresh concrete in which the surface of all aggregate particles is coated with cement paste and which is homogeneous on the macro-scale and therefore possessing uniform properties. Thorough mixing is essential for the complete blending of the materials that are required for the production of homogeneous, uniform concrete (Sidney Mindess and David Darwin, 2003). The type of mixer used in the laboratory for this research is a pan type



Fig.5.3: Pan Mixer

Pan mixers offer the possibility of observing the concrete in them, and therefore of adjusting the mix in some cases. They are particularly efficient with stiff and cohesive mixes. They are also suitable for mixing very small quantities of concrete hence they are mostly used in the laboratory (Neville A.M, 1996). All the dry ingredients were blended together prior to adding water. All batches were then wet-mixed by adding the required water.

Table 2: Composition of Tires

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 %

**Table 3: Slump Test Results**

No.	Specimen	Grade	% rubber	Slump (mm)
1	15M1	M15	0	30
2	15M2	M15	10	35
3	15M3	M15	25	41
4	15M4	M15	50	47
5	20M1	M20	0	10
6	20M2	M20	10	20
7	20M3	M20	25	33
8	20M4	M20	50	47
9	25M1	M25	0	7
10	25M2	M25	10	14
11	25M3	M25	25	23
12	25M4	M25	50	43

HERE

15M1 – stands for the mix of M15 concrete with no rubber aggregate replacement.

15M2 – stands for the mix of M15 concrete with 10 % volume of the coarse aggregate of the control mix replaced by an equivalent volume of rubber aggregate.

15M3 – stands for the mix of M15 concrete with 25 % volume of the coarse aggregate of the control mix replaced by an equivalent volume of rubber aggregate.

15M4 – stands for the mix of M15 concrete with 50 % volume of the coarse aggregate of the control mix replaced by an equivalent volume of rubber aggregate.

20M1 – stands for the mix of M20 concrete with no rubber aggregate replacement.

20M2 – stands for the mix of M20 concrete with 10 % volume of the coarse aggregate of the control mix replaced by an equivalent volume of rubber aggregate.

20M3 – stands for the mix of M20 concrete with 25 % volume of the coarse aggregate of the control mix replaced by an equivalent volume of rubber aggregate.

20M4 – stands for the mix of M20 concrete with 50 % volume of the coarse aggregate of the control mix replaced by an equivalent volume of rubber aggregate.

25M1 – stands for the mix of M25 concrete with no rubber aggregate replacement.

25M2 – stands for the mix of M25 concrete with 10 % volume of the coarse aggregate of the control mix replaced by an equivalent volume of rubber aggregate.

25M3 – stands for the mix of M25 concrete with 25 % volume of the coarse aggregate of the control mix replaced by an equivalent volume of rubber aggregate.

25M4 – stands for the mix of M25 concrete with 50 % volume of the coarse aggregate of the control mix replaced by an equivalent volume of rubber aggregate.

The introduction of recycled rubber tires to concrete significantly increased the slump and workability. It was noted that the slump has increased as the percentage of rubber aggregate was increased in all samples. This test shows that the workability decreases as the strength of the concrete increases for a given amount of w/c ratio in rubberized concrete. A different observation which was noticed while casting the rubberized concrete was that the rubber aggregates have a high tendency to come out to the top surface when vibrated by a table vibrator. This is due to the low specific gravity of the rubber aggregate. In general, rubberized concrete mixes did not pose any difficulties in terms of finishing, casting, or placement and can be finished to the same standard as plain concrete.

**Table-4 : Unit Weight Results**

No.	Specimen	Grade	% rubber	Unit wt. (kg/m ³)	% Reduction
1	15M1	M15	0	2460	0
2	15M2	M15	10	2361.6	4
3	15M3	M15	25	2214	10
4	15M4	M15	50	1918.8	22
5	20M1	M20	0	2515	0
6	20M2	M20	10	2389.25	5
7	20M3	M20	25	2313.8	8
8	20M4	M20	50	2012	20
9	25M1	M25	0	2502	0
10	25M2	M25	10	2401.92	4
11	25M3	M25	25	2351.88	6
12	25M4	M25	50	2101.68	16

Table-6 : Flexural strength Test Results

No.	Spec.	Grade	% rubber	Failure Load (KN)	Flexural Strength (MPa)	% Strength Loss
1	15M1	M15	0	9.4	9.40	0
2	15M2	M15	10	9.75	9.75	-3.72
3	15M3	M15	25	6.70	6.70	28.72
4	15M4	M15	50	7.10	7.10	24.47
5	20M1	M20	0	12	12.00	0
6	20M2	M20	10	12.45	12.45	-3.75
7	20M3	M20	25	11.1	11.10	7.5
8	20M4	M20	50	7	7.00	41.67
9	25M1	M25	0	12.70	12.70	0
10	25M2	M25	10	11.75	11.75	7.48
11	25M3	M25	25	9.8	9.80	22.83
12	25M4	M25	50	6.6	6.60	48.03

Table-5: Compressive Test Result

No.	Spec.	Grade	% Rubber	Compressive Strength (N/mm ²)	% Strength loss
				28 Days	28 Days
1	15M1	M15	0	21.25	0
2	15M2	M15	10	19.55	8
3	15M3	M15	25	15.16	28.66
4	15M4	M15	50	9.82	53.79
5	20M1	M20	0	40.60	0
6	20M2	M20	10	35	13.79
7	20M3	M20	25	29.20	28.08
8	20M4	M20	50	15.10	62.81
9	25M1	M25	0	50.15	0
10	25M2	M25	10	40.80	18.64
11	25M3	M25	25	32.57	35.05
12	25M4	M25	50	20.83	58.46

Table-7: Drop Weight Test Results

No.	Spec.	Grade	% Rubber	No. of Blows for Ultimate Failure
1	15M1	M15	0	21
2	15M2	M15	10	144
3	15M3	M15	25	201
4	15M4	M15	50	72
5	20M1	M20	0	70.50
6	20M2	M20	10	155
7	20M3	M20	25	200.50
8	20M4	M20	50	50
9	25M1	M25	0	523
10	25M2	M25	10	620.50
11	25M3	M25	25	670.50
12	25M4	M25	50	130

CONCLUSION

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 tire and subjected to local conditions. From the test results of the samples, as compared to the respective conventional concrete properties, the following conclusions are drawn out.

1. The introduction of recycled rubber tires 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.



2. From the results, it was found out that a reduction of unit weight up to 22 % was observed when 50 % by volume of the coarse aggregate was replaced by rubber aggregate in sample 15M4. Whereas 4 and 10 % reductions were observed for 10 and 25 % rubber aggregate replacement in samples 15M2 and 15M3 respectively. In the second category (M20) a reduction in unit weight of 5 %, 8 and 20 % was noted for 10, 25 and 50 % of the coarse aggregate replacement by rubber aggregate. In samples of third category (M25) the reduction in unit weight was 4, 6 and 16 % for 10, 25 and 50 % of the replacement of coarse aggregate with the rubber aggregate respectively.

So from the results it is found that use of rubber in cement concrete reduces the weight of concrete.

3. For rubberized concrete, the 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 of 8 % (15M2), 13.79 % (20M2), 18.64 % (25M2) were observed when 10% of the coarse aggregate was replaced by an equivalent volume of rubber aggregate. The observed losses of strength when 25 % of the coarse aggregate was replaced by rubber aggregate were 28.66 % (15M3), 28 % (20M3), 35.05 % (25M3). For rubberized concrete containing 50% by volume of rubber aggregate replacement, losses of 53.79 % (15M4), 62.81 % (20M4), 58.46 % (25M4) were noticed. Although the compressive strength values have considerably decreased with the addition of waste tire pieces, their values are still in the reasonable range for a 10 % and 25 % replacement values because the intended compressive strengths of 15, 25, 30 and 40 MPa were achieved in this categories.

4. The results show that the flexural strength increased compared to the control mix for rubber aggregate content of 10 % and for the low strength concrete classes (i.e. 15M2 and 20M2). In these two categories of concretes, for rubber aggregate content of 25% and 50% a flexural strength reduction was observed as compared to the control mix. This indicates that

improvements in flexural strength are limited to a relatively small rubber aggregate contents. On the other part for mix (M25) a reduction in flexural strength is seen in all concrete samples containing the rubber aggregate. The observed percentage losses in mix M25 are 7.48, 22.83 and 48.03 % for a rubber content of 10, 25 and 50 percents respectively.

From the results obtained, it can be concluded that as the amount of rubber content increases, the reduction in the flexural strength also increases with a concrete of medium and high strength compressive values. Nevertheless, a good advantage of increase in flexural strength can be achieved with a lower strength concretes M15 and M20 and by limiting the replacement value to only 10 % of the coarse aggregate.

5. The test results shows that the addition of rubber aggregate to concrete at a lower percentages of 10 and 25 % enhanced the impact resistance of the concrete greatly and hence the application of rubberized concrete can be of great help in structures which are exposed to vibrations and impact loads.

6. 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 ductility, and a slight increase in flexural strength in the lower strength concretes.

7. The use of rubber aggregates from recycled tires addresses many issues. These include; reduction of the environmental threats caused by waste tires, 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.

REFERENCES

1. Ahirwar, K. (2009). *Waste tyre rubber as coarse aggregate replacement in cement concrete*. Master thesis in Structural Engineering, Civil engineering Department, and IIT Kharagpur.
2. Bakri, A. M. M. A., Fadli, S. A. S. N., Bakar, M. D. A., and Leong, K. W. (2007). *Comparison of rubber as aggregate and rubber as filler in concrete*, First International Conference on Sustainable Materials 2007, Penang.
3. Ganjian, E., Khorami, M., Maghsoudi, A. K. (2008). *Scrap-tyre rubber replacement for aggregate and filler in concrete*, Construction and Building Materials.
4. Huang, B., Li, G., Pang, S., and Eggers, J. (2004) *Investigation in to waste tyre rubber-filled concrete*. *Journal of Materials in Civil Engineering*, 16(3), 187-194.
5. Hernandez-Olivares, F., Barluenga, G., Bollati, M., and Witoszek, B. (2002). *Static and dynamic behavior of recycled tyre rubber- filled concrete*. *Cement Concrete Research*, 32, 1587-1596.
6. IS: 456 (2000). *Indian Standard Plain and Reinforced Concrete Code of Practice*. Bureau of Indian Standards, New Delhi.



7. IS: 383 (1970). *Indian Standard Specification for Coarse and Fine aggregates from Natural Sources for Concrete (Second Revision)*. Bureau of Indian Standards, New Delhi.
8. IS: 10262 (1982). *Recommended Guidelines for Concrete Mix Design*. Bureau of Indian standards, New Delhi.
9. IS: 516 (1959). *Indian Standard Method of Tests for Strength of Concrete*. Bureau of Indian Standards, New Delhi.
10. IS: 5816 (1999). *Indian Standard Splitting Tensile Strength of Concrete-Methods of Test*. Bureau of Indian Standards, New Delhi.
11. IS: 2386 (1963). *Indian Standard Methods of Test for Aggregates for Concrete*. Bureau of Indian Standards, New Delhi.
12. IS: 455 (1989). *Indian Standard Specification for Portland Slag Cement*. Bureau of Indian Standards, New Delhi.
13. IS: 4031(1996). *Indian Standard Method of Physical Tests for Hydraulic Cement*. Bureau of Indian Standards, New Delhi.
14. Khaloo, A. R., Dehestani, M., and Rahamatabadi, P. (2008). *Mechanical properties of concrete containing a high volume of tire-rubber particles*. *Waste Management*, 28, 2472-2482.
15. Khatib, Z. K., and Bayomy, F. M. (1999). *Rubberised Portland cement concrete*. *Journal of Materials in Civil Engineering*, 11(3), 206-213.
16. Li, G., Stubblefield, M. A., Garrick, G., Eggers, J., Abadie, C., Huang, B., (2004). *Development of waste tire modified concrete*. *Cement Concrete Research*, 34(12), 2283-2291.
17. Malladi, K. S. (2004). *Studies on rubberized cement concrete*. *Master Thesis in Structural Engineering, Civil Engineering Department, IIT Kharagpur*.
18. Reda Taha, M. M., EI-Dieb, A. S., EI-Wahab, M. A. A., and Abdel-Hameed, M. E. (2008). *Mechanical, Fracture, and Microstructural Investigations of Rubber concrete*, *Journals of Materials in Civil Engineering*, 20(10), 640-649.
19. Siddique, R., and Naik, T. R. (2004). *Properties of concrete containing scrap-tire rubber- an overview*. *Waste Management*, 24, 563-569.
20. Topcu, I. B., and Demir, A. (2004). *Durability of rubberized mortar and concrete*. *Journal of Materials in Civil Engineering*, 19(2), 173-178.