ABSTRACT

Waste tyre rubber constitutes a large portion of solid waste which has turned into a worldwide environmental concern. The waste tyres represents a significant environmental human health, and aesthetic problem. The consumption of waste tyre rubber in concrete has gained more attention from the point of view of enhanced engineering properties. The objective of this study is to explore the effect of rubber types on mechanical properties of concrete. This study presents the results to the investigation of strength characteristics of concrete produced using waste tyres as substitutes for conventional coarse aggregate in replacement of 10%, 20%, 25%.56 cylinders were prepared using waste tyres for this study. It has been observed that compressive strength is decreased 11.5%, 47.9% for 10%, 20% replacement respectively. So tyre aggregate can use up to 10% replacement for proper strength. The use of tyre rubber particles provides a new type of concrete that inspire the use of waste tyres as a replacement of coarse aggregate.

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LIST OF SYMBOLS

γ_w	Water density, kg/m^3
γ_{bulk}	Unit weight, kg/m^3
C	Compressive strength, psi
G_s	Specific gravity
F.M	Fineness of Modulus
D	Diameter of the cylinder, mm
L	Length of the cylinder, mm
P	Load, kN

CHAPTER 1

INTRODUCTION

1.1 Research Background

Environmental pollution has been increased in developing country because of burning of waste tires. It is one of the biggest problem facing the human. Tire fires are extremely dangerous and the most difficult problems. As toxic gases are released, the air is polluted incredibly.

Recycling waste solid materials is one of the most challenging problems worldwide with the unprecedented growth of the world population. Tire rubber constitutes a large portion of that solid waste which has turned into a worldwide environmental concern. In several countries, tire rubber is being burned and used as fuel, which can result in serious hazards. Scrap tires dumped in sanitary landfills are a significant environmental hazard and result in possible contamination. Only small quantities of scrap tires are being used or recycled as construction materials. Rubber from scrap tires is one of the more recent waste materials investigated for its potential use in construction industry (Reda et al., 2008). Materials like waste tires can be used to replace aggregates in concrete. But these materials cannot replaced fully but they are partially replaced to about 0% to 25%. Studies are made on both fresh as well as hardened properties of rubberized concrete and compare with normal concrete.

Nowadays it is the best useful option to waste recycling and reuse, rather than to disposal. Effective management of waste tires is a highly challenge. Since the quantity of waste tires disposed into the environment in an uncontrolled manner has decreased considerably in recent years, their disposal at waste-disposal sites can also be the cause of environmental disasters such as long-term fires. This firing on waste tires is difficult to control and suppress, resulting in significantly toxic smoke rise. So various invented taken worldwide in an attempt to convert waste materials into new products (Ana et al., 2007).

Health impacts of open burning of used (scrap) tires: Air emissions from open tire fires have been shown to be more toxic (e.g., mutagenic) than those of a combustor, regardless of the fuel. Open tire fire emissions include "criteria" pollutants, such as particulates, carbon monoxide (CO), sulfur oxides (SO_2), oxides of nitrogen (NOx), and volatile organic compounds (VOCs). They also include "non-criteria" hazardous air pollutants (HAPs), such as polynuclear aromatic hydrocarbons (PAHs), dioxins, furans, hydrogen chloride, benzene, polychlorinated biphenyls (PCBs); and metals such as arsenic, cadmium, nickel, zinc, mercury, chromium, and vanadium. Both criteria and HAP emissions from an open tire fire can represent significant acute (short-term) and chronic (long-term) health hazards to firefighters and nearby residents. Depending on the length and degree of exposure, these health effects could include irritation of the skin, eyes, and mucous membranes, respiratory effects, central nervous system depression, and cancer. Firefighters and others working near a large tire fire should be equipped with respirators and dermal protection. Unprotected exposure to the visible smoke plume should be avoided (Environmental Law Alliance Worldwide).

Figure 1.1: Waste tyre firing (BESTON 2015)

In developing countries wastes are discharged, but we can use this wastes as potential material or replacement material in the construction industry. If this wastes are used in the construction, this will have the double advantage of reduction in the cost of construction material and also as a means of disposal of waste. In recent decades, increasing use of car as the main means of transport have the tremendously boosted tire production. About 1990s, many research projects were studied on how to use waste tires in different application. These tires are composed of elements that are non-degradable in nature at ambient temperature. They usually produce environmental bad-effects. Rubber Manufacture's association estimates that about 300 million tires were generated in the

USA in 2005 and the total number of waste tires consumed in end-use markets reached approximately 260 million tires. It also estimate that about 190 million waste tires remained in stockpile at the end of 2005 in the USA. Official Iranian statistics estimates that about 20 million tires were produced in the country in 2005 and estimate that about 10 million waste tires were added to the existing stockpile annually in Iran. To this effect in the last decade considerable research and development has been carried out (Eshmaiel et al., 2008).

The recovery of waste tires has normally grown in each year, for instance from 55% in the United States in 1994 and from 21% in Europe in 1994. The recovery of waste tires in Japan was already at 90% in 1994, and has kept steady at near that rate for approximately 20 years (Farhad 2015).

To decrease solid waste problems authority must have to focused at the reduction of waste production and recovery of usable materials from waste as well as utilization of waste. Partially replacing the coarse aggregate in concrete by waste tires, a concrete has been developed which possesses the potential of being used in building construction as floor, pavement, water barrier etc. Generally concrete as time goes on through a process of hydration of the cement paste, producing a require strength to withstand the load. So the use of waste tires as coarse aggregate in concrete has never been a usual practice among the average citizens, particularly in areas where light weight concrete is required for non-load bearing walls, non-structural floors, and strip footings (Cyr et al., 2004). About 50% of the overall self- weight of concrete is responsible for coarse aggregate. In this time, the main problem is the cost of construction which is increasing day by day because of high demand, scarcity of raw materials, and high price of energy. From the standpoint of energy saving and conservation of natural resources, the use of alternative constituents in construction materials is now a global concern. For this reason, the extensive research and development works towards exploring new ingredients are required for producing sustainable and environment friendly construction materials. The recycling of solid wastes in civil engineering applications has undergone considerable development over a very long time. The recycling of hazardous wastes for use in construction materials and the environmental impact of such practices have been studied for many years (Cyr et al., 2004).

Figure 1.2: Sustainable concrete with scrap tyres (Eldin and Senouci 1993)

Waste tires are not commonly used in the construction industry but are often dumped as disposal wastes. One of the suggestion in the forefront has been the sourcing, development and use of alternate, non-conventional local construction materials.

The possibility of using waste tires as an aggregate production has not been given any serious attention. It was concluded that the waste tires (WT) were more suitable as low strength-giving lightweight aggregate when used to replace common coarse aggregate in concrete production. WT being hard and having steel and not easily degrade material if crushed to size of sand can be a potential material to substitute sand. Here steel fibers are also having in tires and is collected from waste tires can be used as fiber reinforcement. In this research both steel and WT are used in the construction. Concrete is a composite material which composed of aggregates, cement and water. Production of concrete demand its constituents like aggregates, cement, water and admixtures. Sources of conventional aggregates occupy the major part of the concrete. The large scale production of concrete in construction activities using conventional coarse aggregate such as granite immoderately reduces the natural stone deposits and affecting the environmental hence causing ecology imbalance. Extraction and processing of aggregates is also a major concern for environment. Therefore consumption of alternate waste material in place of natural aggregate in concrete production not only protects environment but also makes a concrete a sustainable and environment friendly construction material. It also important that it reduces cost of construction using waste tires and helps to use some construction industry.

1.2 Objectives of the Study

The main objective of this research is to quantify the contribution of recycled tires fibers for use in the concrete industry. The result of the study carried out on the strength characteristics of concrete using waste tires as substitutes for conventional coarse aggregates. It is also expected to serve the purpose of encouraging in construction incorporating these material. Research on the use of waste as aggregate in concrete production, is relatively a new invention. This study is to introduce waste tires of the solid wastes that have been successfully used as aggregate for making concrete in experimental and practical environments. The specific objectives of this study are outlined below:

- To determine the physical and engineering properties of aggregate
- To investigate mechanical properties of concrete using waste tires as a replacement of coarse aggregate.

1.3 Significance of this Research

In this study to provide new knowledge to the contractors and developers on how to improve the construction industry methods and services by using waste tires and to sustain good product performance and meet recycling goals. In developing countries such as Bangladesh standard requirements in order to help contribute to the industry in saving the environment, to encourage the government to find solutions regarding the disposal to landfills of waste materials and save the environment. This study reduces in the environmental costs of landfilling and increase in landfill voids. It saves in the virgin materials used to make concrete by substituting tire rubber.

1.4 Organization of the Study

The thesis is categorized into five main chapters and references which will provide a clear conception and acknowledgement about the flexural behavior of reinforced concrete beam using waste tires. A brief description of these chapters is described below:

- **Chapter 1:** This chapter deals with the general brief about the bad impact of waste tire on environment, their uses in concrete and objectives of the thesis.
- **Chapter 2:** A literature review about the use of waste tires in concrete. It is a text of a scholarly paper, which includes the current knowledge including substantive findings, as well as theoretical and methodological contributes to a particular topic.
- **Chapter 3:** The chapter deals with the methodology, various laboratory testing and experiments, data collections that have conducted for this thesis.
- **Chapter 4:** This chapter includes the results of experiments and explanation of those results.
- **Chapter 5:** The chapter includes the outcome of the thesis, conclusions and recommendations.
- **References:** A list of journals, books and case reports are included here for further query.

1.5 Outline of Research

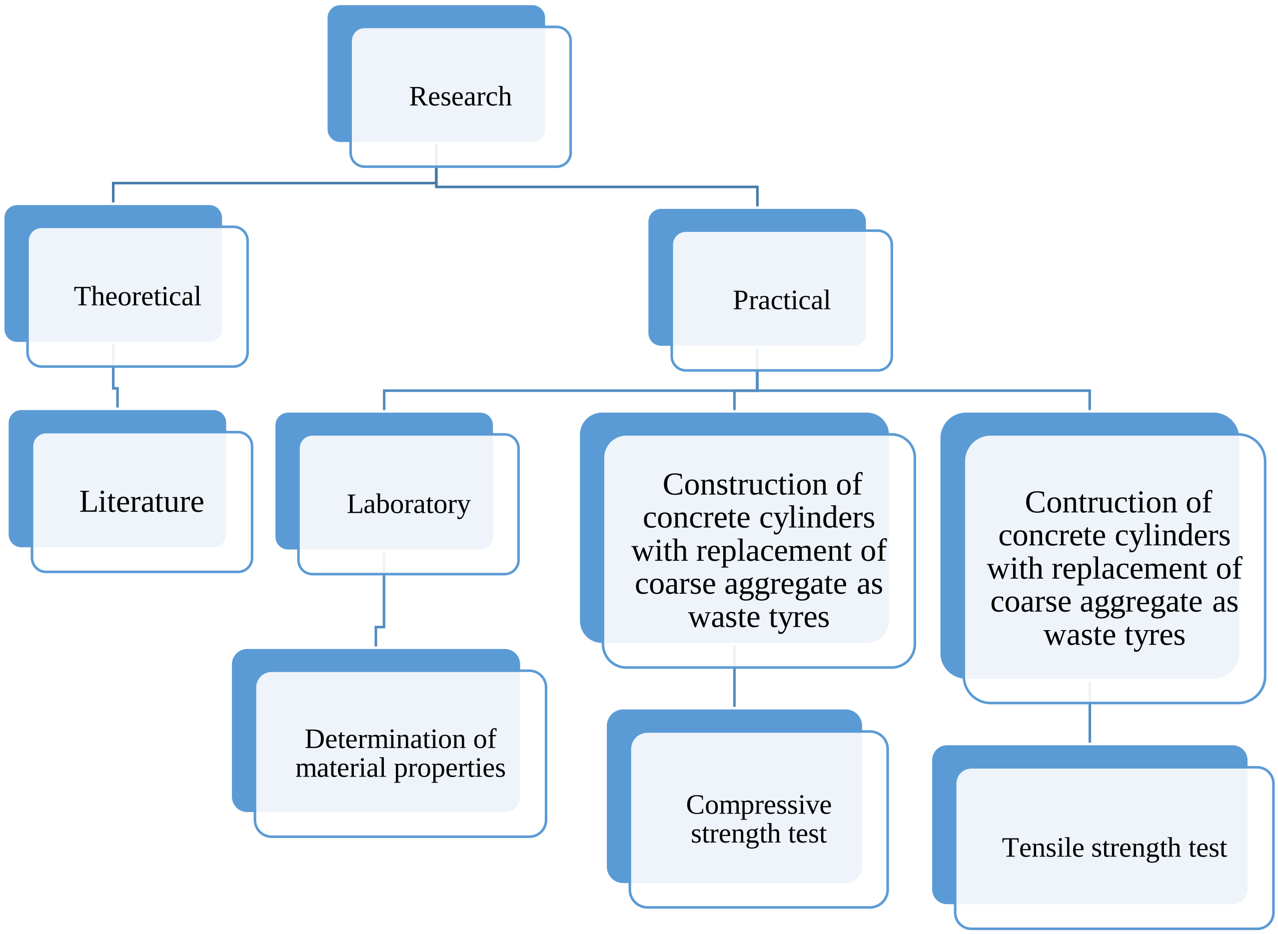

Figure 1.3: Outline of Research

CHAPTER 2

LITERATURE REVIEW

2.1 General

For better alternative option many research have been established for products containing recycled materials. Many authors have reported the properties of concrete with waste tires. During the last 2 decades researchers investigated the possible use of tire rubber particles in concrete and mortar. Most investigations focused on using tire rubber particles as coarse aggregate in concrete. This study has been undertaken to fully investigate the engineering characteristics of tires as coarse aggregate in concrete.

2.2 Previous Research Study

Eldin and Senouci (1993a) is the initial study to investigate WTR aggregates. In the study, fine aggregates replaced by crumb rubber (CR, 1 mm) and coarse aggregates replaced by tire chips (TC, 6–38 mm). Their results showed the RC had lower workability, and lower compressive and tensile strengths. The decrease in mechanical properties was related to loss of adherence between the surface of rubber particles and the cement matrix. Also, it was observed that the loss of compressive strength increased with the size of the WTR. Khatib and Bayomy (1999) established a characteristic role to qualify the deduction in strength because of the addition of WTR.

Segre and Joekes (2000) noted that the action of WTR particles with NaOH increased the adhesion of rubber to cement paste, improved the mechanical properties and abrasion resistance, and reduced the water absorption of the RC. Eldin and Senouci (1994) and Ling and Poon (2012) observed similar results. Hernandez et al., (2002) studied the static and dynamic behavior of RC. Li et al., (2004) applied a pretreatment to TC before mixing them into concrete for improving the strength of RC. Güneyisi et al., (2004) used silica fume to increase the strength of concrete containing CR. All of the surface treatments have shown varying degrees of success. However, none of the surface treatments so far have revealed conclusive evidence of an effective technique to recover the strength of concrete containing WTR (particularly at more than 10% volume).

Khaloo et al., (2008) have investigated ultrasonic analysis by the ultrasonic echo method in order to study sound absorption and the ultrasonic modulus of tire-rubber concrete. The results show that RC is an effective absorber of sound and shaking energy. Ganjian et al., (2009) performed tests of RC mixes including 5, 7.5, and 10% of WTR as aggregate and cement replacement. The results showed that adding WTR decreased the compressive, tensile, and flexural strengths, and modulus of elasticity. Moreover, the water permeability improved with increasing percentages of WTR as aggregates, but it was reduced when the WTR was used for cement replacement. Ho et al., (2012) considered the effect of partial replacements of sand and cement by WTR on the fracture characteristics of concrete. The study found that the addition of WTR in concrete improved the fracture properties, while both compressive and flexural strengths were reduced. Bravo and de Brito (2012) replaced natural aggregates in concrete with 5, 10 and 15% WTR aggregates and observed that the compressive strength decreased by 50 for 15% replacement. Also, the results showed that shrinkage and water absorption of RC increased, and carbonation resistance and chloride resistance were reduced with increased rubber content.

Reports in the literature also showed that a significant increase in the impact resistance toughness of concrete was reported when tire rubber particles were incorporated Toutanji (1996); Fattuhi and Clark (1996); Raghavan et al., (1998) showed that increasing the tire rubber particles content significantly enhanced the impact strength of rubber concrete. Topçu (1997) reported the increase of the brittleness index which indicates the ability to absorb energy with a chipped tire rubber content of 15%. Topçu and Avcular (1997) and Khatib and Bayomy (1999) showed that replacing aggregate with tire rubber particles resulted in increasing the strain capacity of concrete and thus the ability to absorb energy.

Topcu (1997) investigated the particle size and content of tire rubbers on the mechanical properties of concrete. He found that, although the strength was reduced, the plastic capacity was enhanced significantly.

Naik et al., (1995) studies concluded that among the surface treatments tested to enhance the hydrophilicity of the rubber surface, a sodium hydroxide (NaOH) solution gave the best result. The particles were surface-treated with NaOH saturated aqueous solutions for 20 min before using them in concrete. Then, scanning electron microscopy (SEM) and measurements of water absorption, density, flexural strength, compressive strength, abrasion resistance, modulus of elasticity, and fracture energy tests were performed, using test specimens (water-to-cementitious materials ratio of 0.36) containing 10% of powdered rubber or rubber treated with 10% NaOH. The test results showed that the NaOH treatment enhances the adhesion of tire-rubber particles to cement paste, and mechanical properties such as flexural strength and fracture energy were improved with the use of tire-rubber particles as addition instead of substitution for aggregate. Some reduction in the compressive strength (33%) was observed, which was lower than that reported in the literature.

Toutanji (1996) investigated the effect of replacement of mineral coarse aggregate by rubber tire aggregate. Shredded rubber tires used had a maximum size of 12.7mm and a specific gravity of about 0.61. The incorporation of these rubber tire chips in concrete exhibited a reduction in compressive and flexural strength. The specimens which contained rubber tire aggregate exhibited ductile failure and underwent significant displacement before fracture. The toughness of flexural specimens was evaluated for plain and rubber tire concrete specimens. The test revealed that high toughness was displayed by specimens containing rubber tire chips as compared to control specimens.

Khatib and Bayon (1999) has developed Rubberized Portland cement concrete to conduct experimental program in which two types of rubber fine Crumb Rubber and coarse tyre chips were used in Portland cement concrete (PCC) mixtures. Rubberized PCC mixes were developed by partially replacing the aggregate with rubber and tested for compressive and flexural strength in accordance to ASTM standards. Tyre chips were elongated particles that ranged in size from about 10 to 50mm. Results show that rubberized PCC mixes can be made and are workable to a certain degree with the tyre rubber content being as much as 57percentage of the total aggregate volume. However, strength results show that large reductions in strength would prohibit the use of such high rubber constant. It is suggested that rubber contents should not exceed 20percentage of the total aggregate volume.

Mavroulido and Figueiredo (2010) "Discarded tyre rubber as concrete aggregate" 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. These can also include nonprime structural applications of the medium to low strength requirements, benefiting from other features of this type of concrete. 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.

Humphrey (1999) investigated that some of the advantageous properties of tyre chips include low material density, high bulk permeability, high thermal insulation, high durability, and high bulk compressibility. In many cases, scrap tyre chips may also represent the least expensive alternative to other fill materials. Crumb rubber has been successfully used as an alternative aggregate source in both asphalt concrete and PCC. This waste material has been used in several engineering structures like highway base courses, embankments, etc.

Zheng et al., (2008) worked on rubberized concrete and replaced the coarse aggregate in normal concrete with ground and crushed scrap tyre in various volume ratios. Ground rubber powder and the crushed tyre chips particles range in size from about 15 to 4 mm were used. The effect of rubber type and rubber contention strength, modulus of elasticity were tested and studied. The stress – strain hysteresis loops were obtained by loading, unloading and reloading of specimens. Brittleness index values were calculated by hysteresis loops. Studies showed that compressive strength and modulus of elasticity of crushed rubberized concrete were lower than the ground rubberized concrete.

Khallo et al., (2008) determined the hardened properties of concrete using different types of tyre rubber particle as a replacement of aggregate in concrete. The different types of rubber particles used were tyre chips, crumb rubber and combination of tyre chips and crumb rubber. These particles were used to replace 12.5 percentage, 25 percentage, 37.5 percentage, and 50 percentage of the total mineral aggregate by volume not by weight. The results showed that the fresh rubberized concrete had lower unit weight and workability compared to plain concrete. Result showed large reduction in strength and modulus of elasticity in concrete when both tyre rubber chips and crumb rubber were used together as compared to that when these were used individually. It was found that the brittle behavior of concrete was decreased with increased rubber content. The maximum toughness index indicated the post failure strength of concrete with 25 percentage rubber content.

Ganjian et al., (2008) investigated the performance of concrete mixture incorporating 5 percentage, 7.5 percentage and 10 percentage tyre rubber by weight as a replacement of aggregate and cement. Two set of concrete mix were made. In the first set chipped rubber replaced the coarse aggregate and in the second set scrap tyre powder replaced cement. The durability and mechanical test were performed. The result showed that up to 5 percentage replacement in both sets no major changes occurred in concrete characteristic.

2.3 Waste Tires Growing

It is known that approximately 1.5 billion tires are produced each year. It is the main contributor to the nation's pollution problem as a solid waste tires. It also presents serious disposal problems for local environment. This will have the double advantage of reduction in the cost of construction material and also as a means of disposal of waste (Hyder 2012). The recycling volume of waste tires for each year are given below in Figure 2.1:

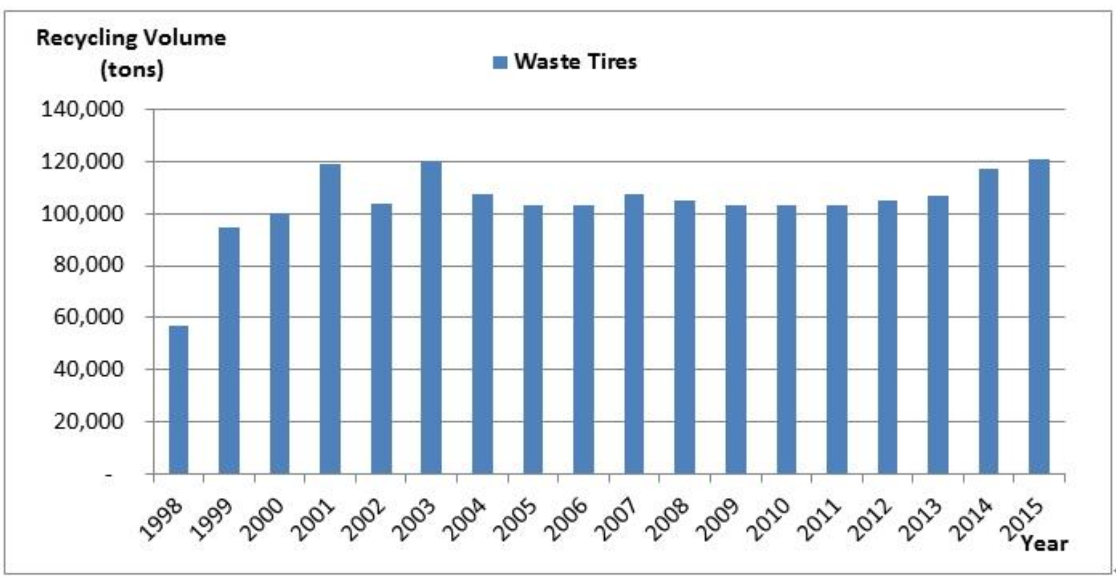

Figure 2.1: Recycling volume of waste tires per year (The Recycling, Disposal and Reuse, Recycling Volume and Collection rate of Different Materials, 6.1 articles)

2.4 Chemical Properties of Waste Tyre Rubber Ash

Chemical properties which have waste tyre rubber ash are given below in Table 2.1

Table 2.1: Chemical properties of waste tyres rubber ash (Mousavi et al., 2010)

Component	(%)
SiO_2	26.5
Fe_2O_3	9.3
Al_2O_3	8.7
CaO	12.9
MgO	6.4
SO_3	1.6
Na_2O	1.4
K_2O	1.1
TiO_2	1.0
Cl	0.1
Zn	20.2
Loss in ignition	10.6

2.5 Waste Tyre as Coarse Aggregate

Investigation for scrap tyre-rubber replacement for aggregate and cement in concrete may differ with changes in materials characteristics, mixture proportions of the ingredients, curing procedure, and use of admixture and additives (Ganjian et al.2008). It was concluded that

- Compressive strength of concrete depended on two factors: grain size of the replacing rubber and percentage added. In general, compressive strength was reduced with increased percentage of rubber replacement in concrete, through with 5% replacement of aggregate by rubber, decrease in compressive strength was low (less than 5%) without noticeable changes in other concrete properties. The highest reduction was related to 7.5% and 10% for rubber used. The reduction in compressive strength at 28 days of age was about 10-23% for aggregate.

- Modulus of elasticity of concrete was reduced with the replacement of rubber for aggregate. Reduction in modulus of elasticity was 17-25% in the case of 5-10% aggregate replacement by chipped rubber.
- Tensile strength of concrete was reduced with increased percentage of rubber replacement in concrete. The most important reason being lack of proper bonding between rubber and the paste matrix, as bonding plays the key role in reducing tensile strength. In the case of 5-10% aggregate replacement by chipped tyre rubber, the reduction in tensile strength was about 30-60%. Figure 2.2 is shown disposal of waste tyres

Figure 2.2: Waste tyre disposal (Holice, Pardubice District, Pardubice Region, The Czech Republic A dump of tyres)

Figure 2.3: Waste tyre as coarse aggregate (Engineering Science and Technology, an International Journal; February 2017)

Increase in percentage replacements by waste tyre reduced the strength and density of concrete. Waste tyre can be used as partial replacement of coarse aggregate in concrete.

2.6 Coarse Aggregate in Mix Portion

Coarse aggregate are materials retained on 5mm (3/16 inc) test sieve and containing only so much finer material as permitted from the various sizes as specific by ACI. Coarse aggregate may be described into three major part which are uncrushed gravel, crushed stone or crushed gravel and partially crushed gravel when it is the product of bending of uncrushed and crushed gravel. Stone having maximum size of 19 mm was used as coarse aggregate in this study.

2.7 Factor to be Considered for Mix Design

According to Yogesh and Chitte (2014), factor of mix design:

- The grade designation giving the characteristics requirement of concrete.
- The type of cement influences the rate of development of compressive strength of concrete.
- Maximum nominal size of aggregate to be used in concrete may be as large as possible within the limit.
- The cement content is to be limited from shrinkage, creeping and cracking

CHAPTER: 3
EXPERIMENTAL STUDY

3.1 Methodology

Concrete is an artificial stone manufactured from a mixture of binding materials and inert materials with water.

Concrete = Binding Materials (cement) + Inert Materials (coarse aggregate and fine aggregate) + Water.

Waste tyres is used as a replacement of coarse aggregate to invent a new type of concrete in civil engineering application.

3.1.1 Determination of Material Properties

Coarse Aggregate

Construction aggregate, or simply "aggregate", is a broad category of coarse to medium grained particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. Aggregates are the most mined materials in the world. Stone chips were used as coarse aggregate in this study.

Fine Aggregate

Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 3/8-inch sieve. Fine aggregate is natural sand which has been washed and sieved to remove particles larger than 5 mm. Coarse sand (Sylhet sand) was used as fine aggregate in this study.

Binder

Portland composite cement (PCC) was used as a binder material. Properties as normal consistency, initial setting time, final setting time of Portland cement composite were determined according to

ASTM C187, ASTM C191, ASTM C191 testing standards respectively and the values of these properties were found to be 28.5%, 145 minute and 270 minutes respectively.

Waste Tyres and Steel from Waste Tyres

Waste tyres replacing in coarse aggregate were cut in maximum size 19 mm and steel from waste tyres were cut in 40-50 mm. These are shown below in Figure 3.1, 3.2, 3.3

Figure 3.1: Cutting waste tyre

Figure 3.2: After cutting waste tyre

Figure 3.3: After cutting steel wire from waste tyres

3.1.2 Unit Weight of Aggregate

This method of test covers the procedure for determining the compacted or loose mass per cubic meter of both fine and coarse aggregates. This test method is used to determine unit weight, voids and moisture content in fine and coarse aggregate by method of ASTM C29 that are necessary for selecting proportions of concrete mixture.

Calculation

The unit weight of the aggregate from the following formula:

Unit weight per cubic meter $=\frac{G-T}{V}$………………. (1)

Where,

G= Mass of aggregate plus measure;

T=Mass of measure; and

V=Volume of measure.

3.1.3 Moisture Content of Coarse Aggregate

This method is used to determine the percentage of water in a sample by drying the sample to constant weight by method of ASTM C127. The water content is expressed as the percentage, by weight, of the dry sample.

Calculation

The moisture content of the sample is calculated using the following equation:

%W= (A-B)/B×100…………………….. (2)

Where:

%W= Percentage of moisture in the sample;

A=Weight of wet sample (grams); and

B= Weight of dry sample (grams).

3.1.4 Specific Gravity and Absorption

This method of test covers the procedures for determining the specific gravity and absorption of aggregates. Coarse aggregate represents aggregate retained on the No. 4 (4.75 mm) sieve. Fine aggregate is all aggregate passing the No. 4 (4.75 mm) sieve by method of ASTM C127.

Calculations

Determine calculations based on appropriate formula

A = Oven dry weight

B = SSD weight

C = Weight in water

Bulk Specific Gravity = A / (B-C) …………. (3)

Bulk SSD Specific Gravity = B / (B-C) ……………… (4)

Apparent Specific Gravity = A / (A-C) ………………………… (5)

Absorption= [(B-A)/A]×100 …………………………… (6)

3.1.5 Sieve Analysis

Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. This is done by sieving the aggregates as ASTM C29. In this we use different sieves as standardized and then pass aggregates through them and thus collect different sized particles left over different sieves.

3.1.6 Determination of Compressive Strength of Concrete

Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. These specimens are tested by compression testing machine after 7 days, 28 days curing.

Compressive force was applied to the specimen by using compression strength machine and failure load was measured. Compressive strength was calculated by using equation (7).

C=P/A ……………………. (7)

Where,

C = compressive strength;

P = failure load; and

A = contact area.

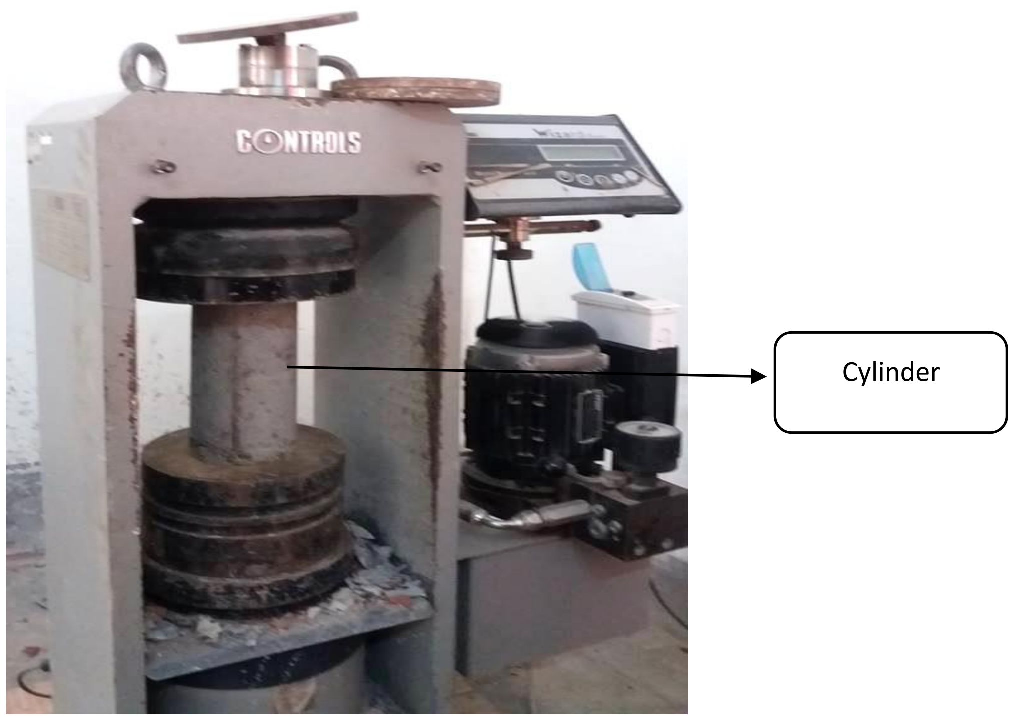

Figure 3.4: Equipment set-up of compressive strength test

3.1.7 Determination of Modulus of Elasticity

Elastic modulus (E) describes tensile elasticity, or the tendency of an object to deform along an axis when opposing forces are applied along that axis; it is defined as the ratio of tensile stress to tensile strain. It is often referred to simply as the elastic modulus. The modulus of elasticity denoted as E is defined as the ratio between normal stress to strain below the proportional limit of a material, according to ASTM E6-89, and it is used to measure instantaneous elastic deformation. The modulus of elasticity is one of the most important elastic properties of concrete science it impacts the serviceability and performance of concrete structures. The elastic modulus of concrete is closely related to the properties of the cement paste and stiffness of mix aggregate. ASTM C469 cautions that the modulus of elasticity values will usually be less than the modulus derived under rapid load application and usually greater than values obtained under slow load application when all other test conditions remain the same. Figure 3.5 shows the determination of modulus of elasticity

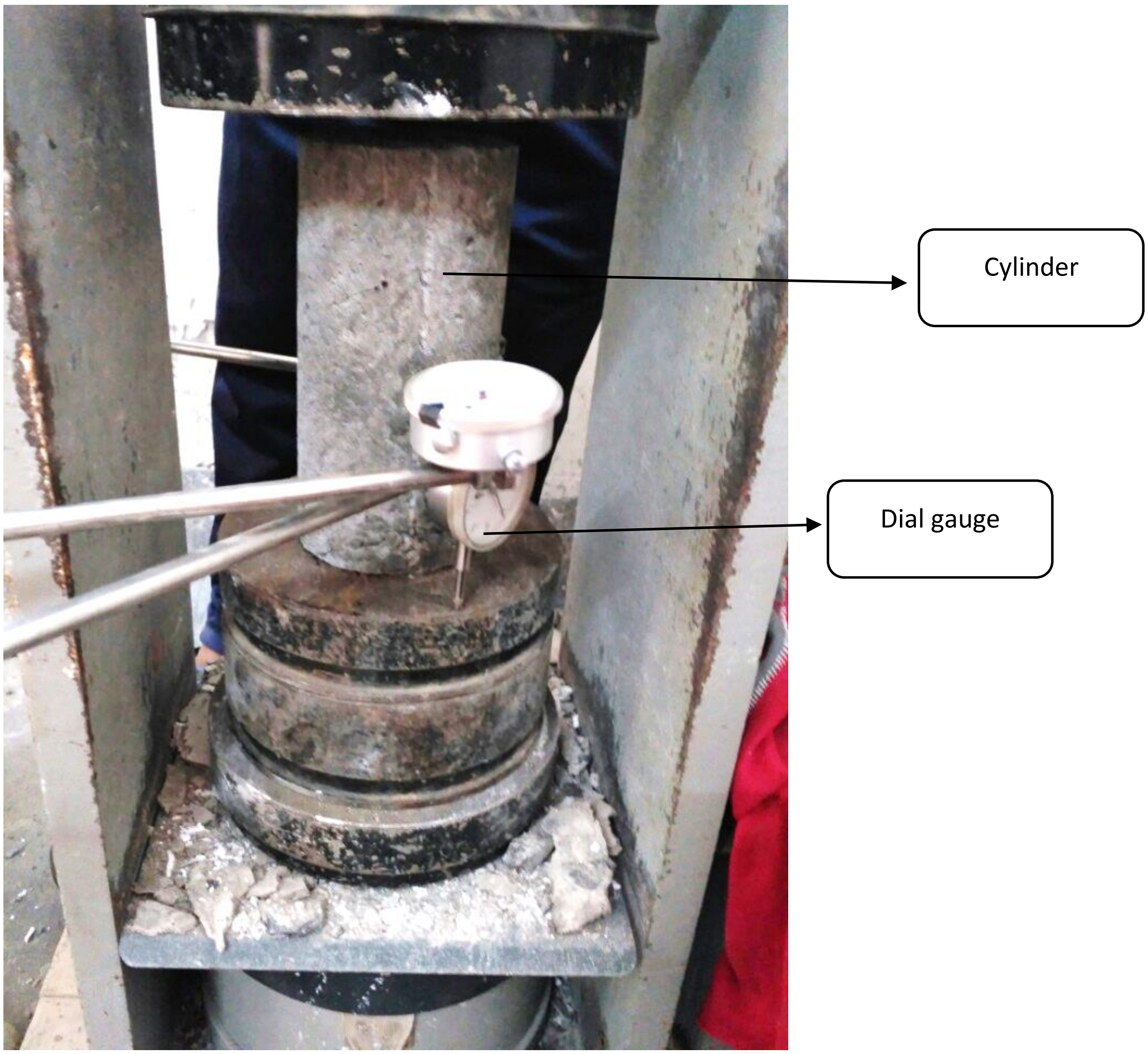

Figure 3.5: Equipment set-up for modulus of elasticity

3.1.8 Determination of Tensile Strength of concrete

Specimen was positioned into the compression strength machine according to Brazilian test method. Load was applied to the specimen and failure load was measured. Tensile strength was calculated by using equation (8).

T=2P/лDL………………………. (8)

Where,

T= tensile strength;

P= failure load;

D= diameter of the cylinder; and

L= length of the cylinder.

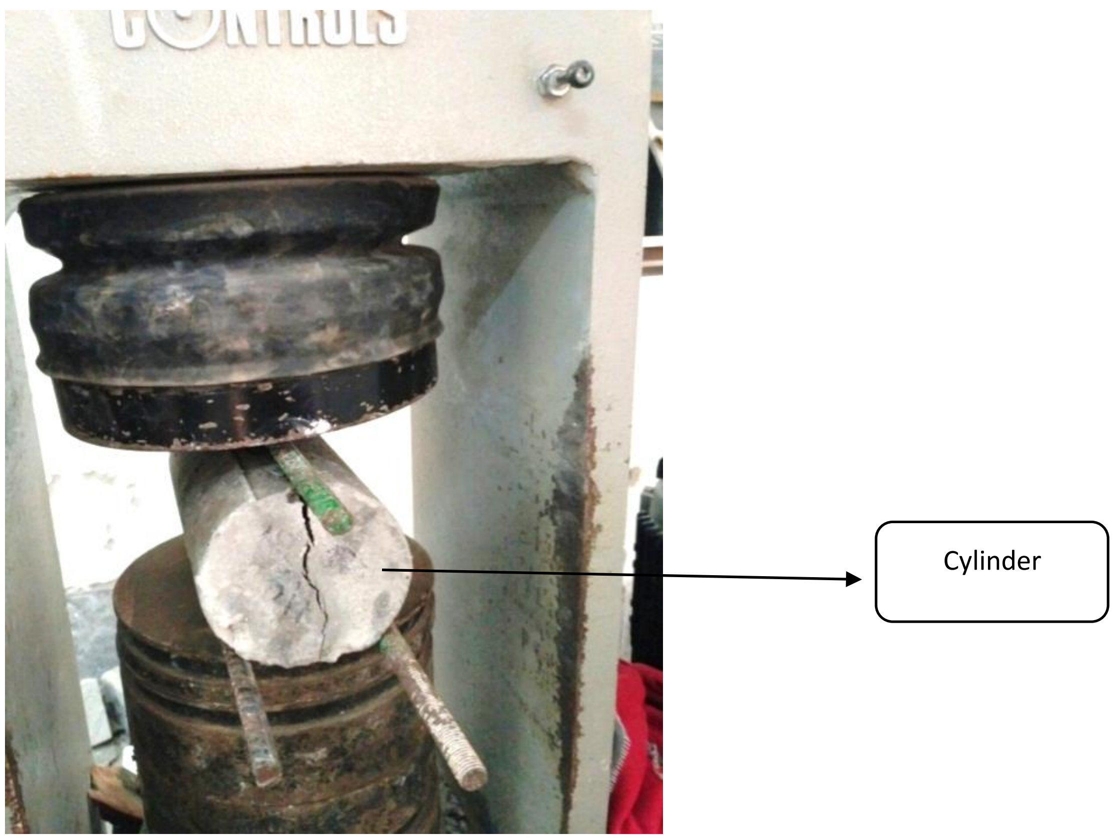

Figure 3.6: Equipment set-up of splitting tensile strength test

3.1.9 Slump Cone Test

Slump test is the most commonly used method of measuring workability of concrete which can be employed either in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete. It does not measure all factors contributing to workability, nor is it always representative of the playability of the concrete. However, it is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch. Repeated batches of the same mix, brought to the same slump, will have the same water content and water cement ratio; provided the weights of aggregate, cement and admixtures are uniform and aggregate grading is within acceptable limits. Additional information on workability and quality of concrete can be obtained by observing the manner in which concrete slumps. Quality of concrete can also be further assessed by giving a few tamping or blows by tamping rod to the base plate. The deformation shows the characteristics of concrete with respect to tendency for segregation. The size of slump cone mold is Bottom diameter: 20 cm, Top diameter: 10 cm and Height: 30 cm. In slump test of fresh concrete, the each layer of concrete was compacted 25 times with the help of steel rod 0.6m long and 16mm in diameter. The slump cone is removed carefully in the vertical direction without affecting the shape of concrete slump. Figure 3.7 shows the determination of slump value

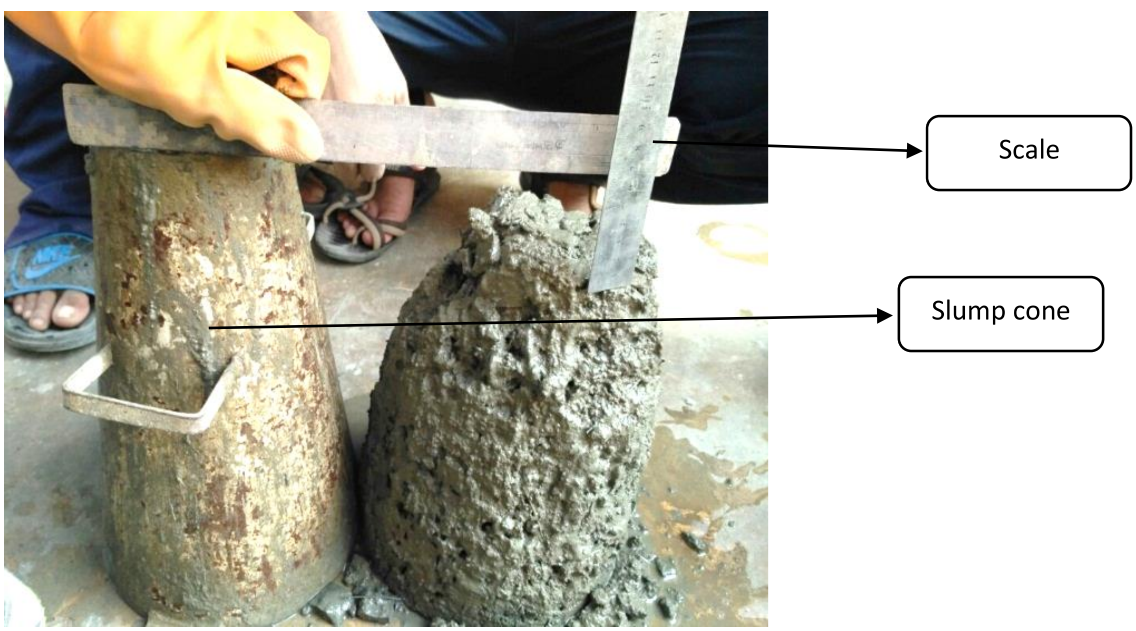

Figure 3.7: Slump value measurement

3.2 Mix Design Ratio

The concrete mix for every specimen was based on the weight of materials. The weight portion of the concrete mixture was 1 (cement): 2 (fine aggregate): 4 (coarse aggregate), giving a water to cement ratio of 0.45. Figure 3.8 shows mixture of concrete

Figure 3.8: Concrete mixer

3.3 Test Specimens

- 4 in x 8 in cylindrical specimen were used.
- Portland composite cement (PCC), Stone chips and Sylhet sand were used for mixing.
- As a replacement of coarse aggregate waste tyres were replaced of 0%, 10%, 20% and 25% in mixing.
- For each percentage 14 cylinders were prepared.

Figure 3.9, 3.10 and 3.11 are shown below the casting procedure

Figure 3.9: Tamping of cylindrical mold

Figure 3.10: Preparing cylindrical mold

Figure 3.11: Test specimens

3.4 Curing of Test Specimen

Fresh concrete gains strength most rapidly during the first few days and weeks. Structural design is generally based on the 28-day strength. Curing is the process of maintaining satisfactory moisture content in a favourable temperature in concrete during the hydration of the cementitious materials so that the desired properties of the concrete are developed. Curing is the procedure for promoting hydration of cement paste and controlling of concrete temperature and movement of moisture from and into the concrete. Figure 3.12 shows the curing of the specimen for 7 days and 28 days

Figure 3.12: Curing the specimen

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Unit Weight and Voids of Aggregate

Unit weight or bulk density is the weight in air of a unit volume of a permeable material (including both permeable and impermeable voids). Unit weight used to determine bulk density values used in selecting proportions for concrete mixes. Absorption and unit weight of stone chips were found 2.16% and 1563 kg/m^3 and for fine aggregate 2.46% and 1549.17 kg/m^3. The unit weight of concrete is primarily affected by the unit weight of the aggregate, which varies by geographical location and increases with concrete compressive strength depending on the added pozzolans. The unit weight of lightweight aggregate concretes may vary depending on the source of light weight aggregate materials.

4.2 Moisture Content of Aggregate

The moisture contents of coarse aggregate and fine aggregate were found to be 0.9% and 3.2% respectively. These were allowed for in the calculation of batched quantities and of the total water requirement of the concrete mix. Moisture may be present as adsorbed moisture at internal surfaces and as capillary condensed water in small pores.

4.3 Specific Gravity of Aggregate

The specific gravity of stone chips and sand were 2.92 and 2.61 respectively. These ranges between the 2.5–3.0 range of specific gravity for normal weight aggregates. The specific gravity of used cement was 3.02.

4.4 Workability

Slump was used to measure the workability of concrete. The measured slump values for the normal weight concrete and the 0%, 10%, 20% and 25% replacement of coarse aggregate with waste tyres were 83 mm, 73 mm, 55 mm and 42 mm respectively. It has been found that the slump value decreased with the use of waste tyre as coarse aggregate. Figure 4.1 shows workability results on slump.

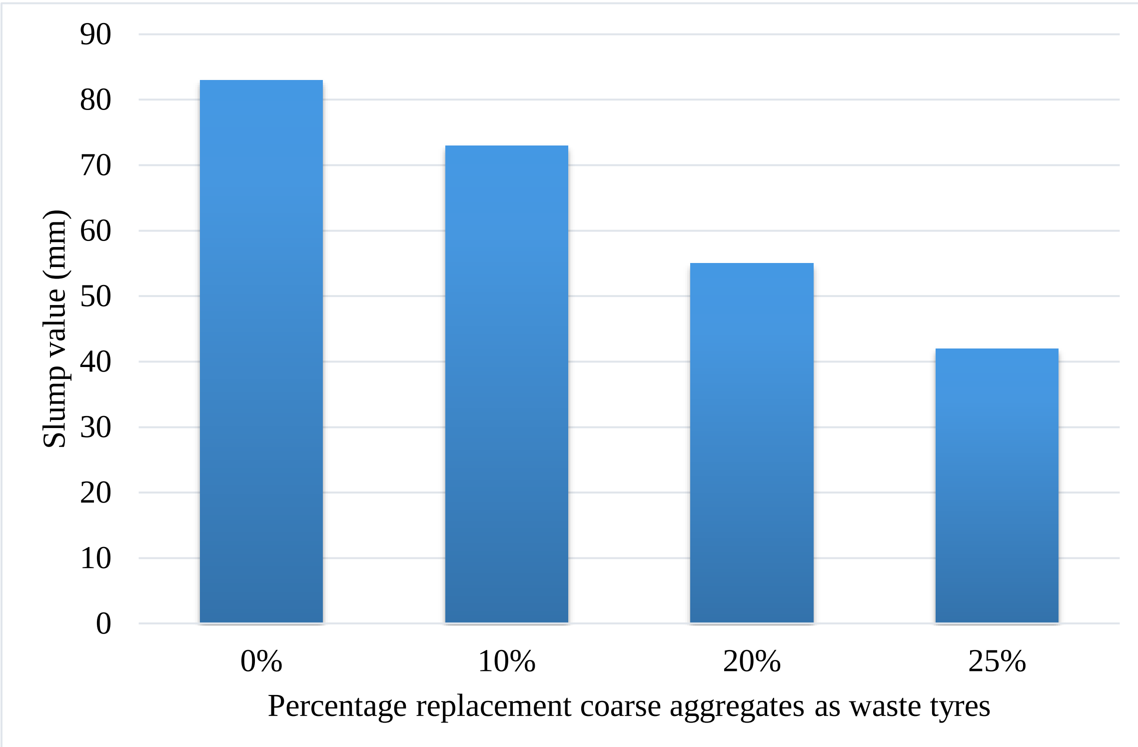

Figure 4.1: Comparison of slump value of different mixing

4.5 Sieve Analysis of Aggregate

Particle size determinations on large samples of aggregate are necessary to ensure that aggregates perform as intended for their specified use. A sieve analysis, or gradation test determines the distribution of aggregate particles by size within a given sample. Sieve (or mechanical) analysis consists of determining the proportionate amounts of particles retained on or passing through each of a set of sieves arranged in decreasing sizes. Using the percentage of weights retained on each sieve, a graph, called a particle size distribution curve. A uniform shape, like an escalator, shows uniform gradation. When a large part of the aggregate is made up of particles of one size, it is reflected in the graph as a near vertical drop. Table 4.1 is the fineness modulus of sand showing below

Table 4.1: Sieve analysis of fine aggregate

Sieve # (ASTM)	Weight retained (gm)	Cumulative weight retained (gm)	Cumulative % retained	F.M value
4	0	0	0	
8	61.8	61.8	12.61	
16	115.8	177.6	36.24	2.95
30	138.5	316.1	64.51	
50	97.9	414	84.89	
100	60.4	474.4	96.82	

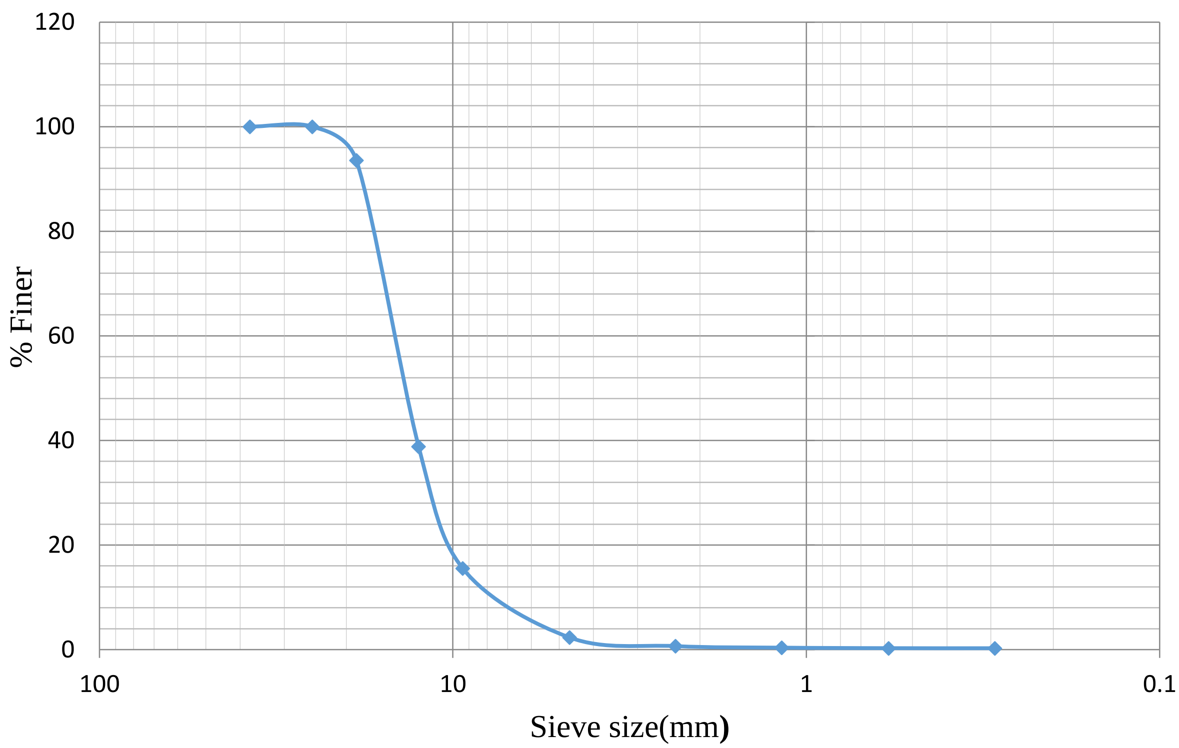

Figure 4.2: Sieve vs. % Finer (coarse aggregate)

4.6 Tensile strength of cylindrical specimen

Tensile strength is an important property of concrete because concrete structures are highly vulnerable to tensile cracking due to various kinds of effects and applied loading itself. However, tensile strength of concrete is very low in compared to its compressive strength. Test was performed according to ASTM C496. Figure 4.3 shows the failure pattern of the specimen after tensile strength test

Figure 4.3: Failure pattern

The results showed that the tensile strength of the concrete decreased as the percentage replacement of coarse aggregate. It was observed that the maximum tensile strength of 3.2 MPa attained at 0% replacement for 28 days. The tensile strength for 7 days and 28 days value are shown below:

Table 4.2: The tensile strength variation with various percentage of waste tyres

Sl. No.	Percentage of waste tyres	Tensile strength (MPa) at 7 days	% Variation	Tensile strength (MPa) at 28 days	% Variation
01	0%	2.7	-	3.2	-
02	10%	1.9	29.63	2.7	15.63
03	20%	1.6	40.7	2.2	31.25
04	25%	1.3	51.9	1.6	50

From tensile strength data we observed that the increasing in percentage of waste tyres in concrete then decreasing the tensile strength. 10% replacement then decreasing the tensile strength 29.6% at 7 days and 15.63% at 28 days. The Figure 4.4 are shown the variation of tensile strength at 7 days

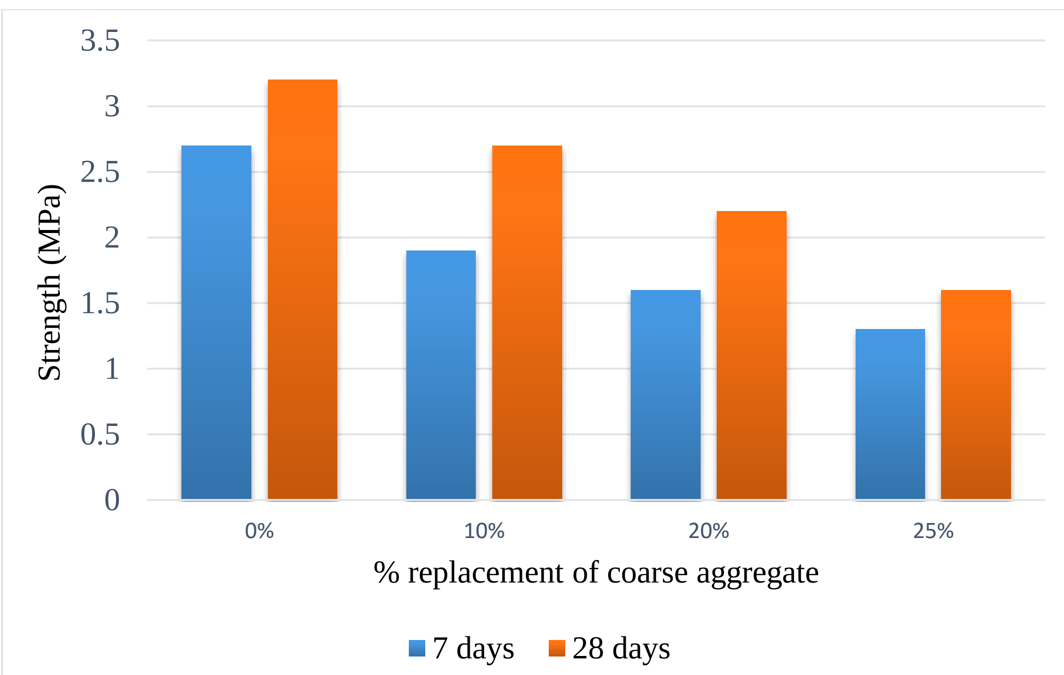

Figure 4.4: Tensile strength vs % replacement of coarse aggregate as waste tyres at 7 and 28 days

4.7 Compressive Strength of Cylindrical specimen

Compressive strength is defined as resistance of concrete to axial loading. Figure 4.3 shows the failure pattern of the specimen after compressive strength test

Figure 4.5: Failure pattern

The results showed that the compressive strength of the concrete decreased as waste tyres were used in concrete. It was observed that the maximum compressive strength of 16.5 MPa was attained at 0% replacement for 28 days curing, while the minimum strength of 4.6 MPa was attained at 25% coarse aggregate replacement for 7 days curing. The compressive strength for 7 days and 28 days value are shown below:

Table 4.3: The compressive strength variation with various percentage of waste tyres

Sl. No.	Percentage of waste tyres	Compressive strength (MPa) at 7 days	% Variation	Compressive strength (MPa) at 28 days	% Variation
01	0%	13.1	-	16.5	-
02	10%	9.1	30.5	14.6	11.5
03	20%	5.4	58.8	8.6	47.9
04	25%	4.6	64.9	5.6	66

Figure 4.6 are shown the variation of compressive strength at 7 and 28 days

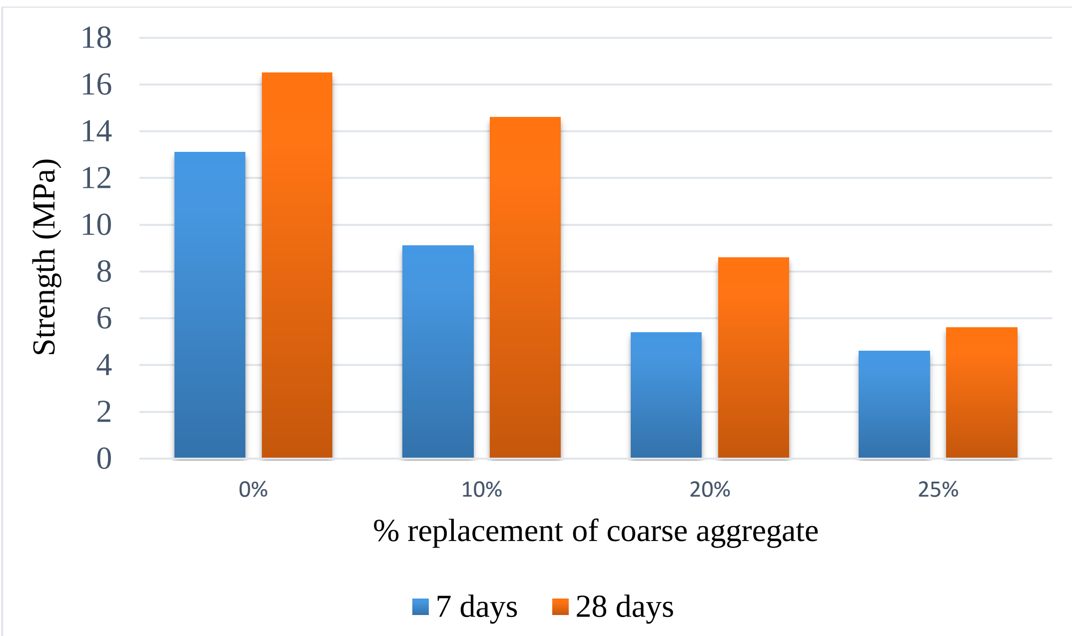

Figure 4.6: Compressive strength vs % replacement of coarse aggregate as waste tyres at 7 days and 28 days

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the experimental results of this study the following conclusions can be drawn:

- Waste tyres can be used as a replacement for the conventional stone aggregates in concrete production.
- Reduction of compressive strength and tensile strength were observed when the coarse aggregate was replaced by tyres.
- From this research it is observed that concrete with tyre aggregate can use up to 10% replacement for proper strength, however, 20% can be replaced in light-weight concrete applications.
- The 28-day splitting tensile strength of rubberized concrete for 10% and 20% were 2.7 MPa and 2.2 MPa respectively. These values are in the usual range for light weight concrete.
- This study suggests that concrete with rubber aggregate is perhaps suitable for: (1) Architectural applications such as nailing concrete, false facades, stone backing, and interior construction because of its light unit weight; (2) low-strength-concrete applications such as sidewalks, driveways, and selected road construction applications; and (3) crash barriers around bridges and similar structures because of its high toughness (high plastic energy absorption).

5.2 Recommendations

- Waste tyres concrete offers as a potential construction material and simultaneously solving the environmental problem of reduction in solid waste.
- Further study should be carried out, to find out fire performance.
- This study should be also carried out for flexural performance for beam.

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APPENDIX

Table A1: Specific gravity and absorption of coarse aggregate

Aggregate type	Coarse aggregate
Room temperature	28°C
Unit weight of water, γ_w (gm/cc)	995.99
Weight of SSD sample , B (gm)	5108.1
Weight of oven dry sample, A (gm)	5000
Weight of displaced water, w (gm)	1709.1
Specific gravity, G_s	2.92
% Absorption	2.16

Table A2: Unit weight and void of coarse aggregate

Aggregate type	Coarse aggregate (Loose)
Mass of measure , T (kg)	8.096
Mass of water , Mw (kg)	5.216
Water calibration temperature	28°C
Water density , γ_w (kg/m^3)	996.31
Volume of measure ,V (kg/m^3)	0.00522
Mass of aggregate + Measure , G (kg)	16.28
Unit weight , γ_{bulk} (kg/m^3)	1563
% Voids	43.5

Table A3: Moisture content of coarse aggregate

Aggregate type	Coarse aggregate
Weight of wet aggregate and tare (gm)	1000
Weight of oven dry aggregate and tare (gm)	991
Weight of water (gm)	9
Weight of tare (gm)	0
Weight of dry aggregate (gm)	991
Moisture content	0.9%

Table A4: Unit Weight and void in fine aggregate

Aggregate type	Coarse aggregate (Loose)
Mass of measure , T (kg)	8.096
Mass of water , Mw (kg)	5.216
Water calibration temperature	28°C
Water density , γ_w (kg/m^3)	996.31
Volume of measure ,V (kg/m^3)	0.00522
Mass of aggregate + Measure , G (kg)	16.6
Unit weight , γ_{bulk} (kg/m^3)	1549.17
% Voids	33.07

Table A5: Specific gravity and absorption of fine aggregate

Aggregate type	Fine aggregate
Room temperature	28°C
Weight of oven dry specimen, A(gm)	195.2
Weight of pycnometer filled with water, B (gm)	1369.8
Weight of SSD specimen, S (gm)	200
Weight of pycnometer with specimen and water, C (gm)	1495
Specific gravity , G_s	2.61
Absorption	2.46

Table A6: Moisture content of fine aggregate

Aggregate type	Fine aggregate
Weight of wet aggregate and tare (gm)	500
Weight of oven dry aggregate and tare (gm)	484.45
Weight of water (gm)	15.55
Weight of tare (gm)	0
Weight of dry aggregate (gm)	484.45
Moisture content	3.2%

Table A7: Sieve analysis of coarse aggregate

Sieve #	Weight retained (gm)	Cumulative weight retained (gm)	Cumulative % retained	%Finer
3/4”	0	0	0	100
1/2”	4760	4760	95.2	4.8
3/8	187	4947	98.94	1.06
#4	15	4962	99.24	0.76

Table A8: Sieve analysis of fine aggregate

Sieve # (ASTM)	Weight retained (gm)	Cumulative weight retained (gm)	Cumulative % retained	F.M value
4	0	0	0	
8	61.8	61.8	12.61	
16	115.8	177.6	36.24	2.95
30	138.5	316.1	64.51	
50	97.9	414	84.89	
100	60.4	474.4	96.82	

Table A9: Sieve analysis of tyre chips

Sieve #	Weight retained (gm)	Cumulative weight retained (gm)	Cumulative % retained	F.M value	%Finer
3”	0	0	0		100
1.5”	0	0	0		100
1”	0	0	0		100
3/4”	661	661	13.22	3.02	86.78
1/2”	3938	4504	90.08		9.92
3/8”	421	4925	98.5		1.5
#4	75	5000	100		0

Table A10: Compressive Strength of cylindrical specimen (0% coarse aggregate replace)

Sample no	Strength at 7 days (MPa)	Average	Strength at 28 days (MPa)	Average
1	14.7		16.7	
2	12.4	13.1	16.4	16.5
3	11.6		15.8	
4	13.8		17.1	

Table A11: Compressive Strength of cylindrical specimen (10% coarse aggregate replace)

Sample no	Strength at 7 days (MPa)	Average	Strength at 28 days (MPa)	Average
1	10.2		15.6	
2	9.5	9.1	13.4	14.6
3	7.1		14.2	
4	9.7		15.3	

Table A12: Compressive Strength of cylindrical specimen (20% coarse aggregate replace)

Sample no	Strength at 7 days (MPa)	Average	Strength at 28 days (MPa)	Average
1	5.6		7.4	
2	5.3	5.4	8.7	8.6
3	6.3		9.6	
4	4.4		8.8	

Table A13: Compressive Strength of cylindrical specimen (25% coarse aggregate replace)

Sample no	Strength at 7 days (MPa)	Average	Strength at 28 days (MPa)	Average
1	4.8		5.4	
2	4.1	4.6	5.2	5.6
3	4.6		6	
4	4.9		5.8	

Table A14: Tensile Strength of cylindrical specimen (0% coarse aggregate replace)

Sample no	Strength at 7 days (MPa)	Average	Strength at 28 days (MPa)	Average
1	2.7		3.4	
2	25	2.7	2.9	3.2
3	2.9		3.3	

Table A15: Tensile Strength of cylindrical specimen (10% coarse aggregate replace)

Sample no	Strength at 7 days (MPa)	Average	Strength at 28 days (MPa)	Average
1	2.2		2.3	
2	1.5	1.9	3.2	2.7
3	2		2.7	

Table A16: Tensile Strength of cylindrical specimen (20% coarse aggregate replace)

Sample no	Strength at 7 days (MPa)	Average	Strength at 28 days (MPa)	Average
1	1.3		2.2	
2	1.9	1.6	2.4	2.2
3	1.7		2.1	

Table A17: Tensile Strength of cylindrical specimen (25% coarse aggregate replace)

Sample no	Strength at 7 days (MPa)	Average	Strength at 28 days (MPa)	Average
1	1.1		2	
2	1.4	1.3	1.5	1.6
3	1.3		1.6	