A STUDY ON WASTE TYRE RUBBER PIECES IN THE PRODUCTION OF LIGHT WEIGHT CONCRETE

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ABSTRACT

With increase in urbanisation and industrialisation disposal of rubber tyre waste has creates a lot of problems to the society. The International Rubber Study Group (IRSG) 2017 report revealed 12.9 million tonnes of global rubber production as increased from 12.4 million tonnes in 2016. The objective of this research is to investigate the use of used rubber tyre waste pieces of three different dimensions used as coarse aggregate in the concrete consecutively searching an alternate method for disposal of non-biodegradable solid tyre wastes. This research mainly focus on the performance of concrete strength parameters by incorporating relatively lower percentages i.e. 0.5%, 1% and 2% of discarded tyre rubber pieces of coarse aggregate as compared to percentages taken in previous studies compiled in literature and ultimately finding a replacement for cement results in reducing cost of construction. Compressive strength test, split tensile strength test and workability test are conducted on concrete specimens and results are compared and discussed along with advantages and disadvantages.

1. INTRODUCTION

1.1 Background of the Study

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

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

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

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

1.2 Statement of the problem

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

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

2. OBJECTIVES, SCOPE AND METHODOLOGY OFTHE STUDY

2.1 Objectives of the study

2.1.1 General Objective

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

2.1.2 Specific Objectives

The specific objectives of the research are listed as follows:

1) With the increase in urbanization in Ethiopia, the number of cars and consequently the amount of used tyre is going to increase significantly in the near future. Hence, the non-environmental nature of these wastes is going to be a potential hazard. This study can show an another way of recycling tyres by incorporating them into concrete construction. Of course, the concept that the problem emerges from urbanization and the solution goes along with it can also be respected. Therefore, it is the aim of this study to introduce an environmental friendly technology, which can promote the society and the nation.

2) Application of used tyres in concrete construction is a new technology and a well-developed mix design for material proportioning is not available. Through this study, it is intended to arrive at a suitable mix proportion and percent replacement using locally available materials by partial replacement of the natural coarse aggregates with recycled coarse rubber aggregates. Hence the opportunity of using waste tyres as an alternative building material will be investigated.

By conducting different laboratory tests on prepared specimens, it is proposed to analyze the results. Additionally, from the properties of the concrete the advantages and disadvantages of using it will be figured out.

2.2 Scope of the study

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

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

3) All the waste tyres collected were chosen from local area Tirupathi to avoid any inconsistent properties that may arise by mixing materials from different sources. The properties of waste tyres from other tyre manufacturers were not incorporated in this study.

4) The study was done on two grades of concrete (M20, M30). The percentage replacements were restricted to three categories i.e. 10, 25 and 50% replacement of the normal coarse aggregate. The different effects, which can be observed in different percentages of replacements, were not included in the present study.

2.3 Methodology of the study

The different methods utilized in this research include the following:

i) Background study

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

ii) Collection of raw Materials

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

iii) Material Tests

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

iv) Mix Proportioning (Mix Design)

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

v) Specimen preparation

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

vi) Testing of Specimens

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

vii) Data collection

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

viii) Data Analysis and Evaluation

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

3. LITERATURE REVIEW

3.1 General Characteristics and Constituents of Concrete

3.1.1 Characteristics of Concrete

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

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

The ability of concrete to be cast to any preferred shape and pattern is an important feature that can offset other shortcomings. Good excellence concrete is a very durable material and should remain maintenance free for many years when it has been correctly designed for the service environment and properly placed. Of course, proper use of the structure for the intended function can have a significant role. Through choice of aggregate or control of paste chemistry and microstructure, concrete can be made inherently resistant to physical attack, such as from cycles of freezing and thawing or from abrasion and from chemical attack such as from dissolved sulfates or acids attacking the paste matrix or from highly alkaline pore solutions attacking the aggregates. Judicious use of mineral admixtures greatly enhances the stability of concrete. The main advantages of concrete as a construction material are the ability to be cast, being economical, durability, fire resistance, energy efficiency, on-site fabrication and its aesthetic properties. Whereas the disadvantages are low tensile strength, low ductility, volume instability and low strength to weight ratio.

Numerous advances in all areas of concrete technology including materials, mixture proportioning, recycling, structural design, durability requirements, testing and specificationshavebeen made. inventive contracting mechanisms have been considered, explored and tried. Various progresses have been made in utilizing some of these technology innovations. The major concrete making materials are discussed below.

3.1.2 Constituents of Concrete

3.1.2.1 Cement

Cement is a generic name that can apply to all binders. The chemical composition of the cements can be quite diverse but by far the greatest amount of concrete used today is made with Portland cement. For this cause, the discussion of cement in this thesis is mostly about the Portland cement.

Portland cement, the basic ingredient of concrete, is a closely controlled chemical combination of calcium, silicon, aluminum, iron and small amounts of other ingredients to which gypsum is added in the final grinding process to regulate the setting time of the concrete. Lime and silica compose up about 85% of the mass. Common among the materials used in its produce are limestone, shells, and chalk or marl combine with shale, clay, slate or blast furnace slag, silica sand, and iron ore. Each step in the manufacturing of Portland cement is checked by regular chemical and physical tests in plant laboratories. The finished product is also analyzed and tested to create sure that it complies with all stipulations.

The name "Portland" in Portland cement originated in 1824 when an English mason obtained a rights for his product. This was since his cement blend formed concrete that resembled the color of the usual limestone quarried on the Isle of Portland in the English Channel.

4. MATERIAL PROPERTIES AND MIX DESIGN

4.1 General

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

4.2 Cement

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

4.3 Aggregates

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

4.3.1 Properties of the Fine Aggregate

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

- sieve analysis for fine aggregate and fineness modulus
- Specific gravity and absorption capacity

for fine aggregate - Moisture content for fine aggregate - Silt content for fine aggregate - Unit weight of fine aggregate

4.3.1.1 Sieve Analysis for Fine Aggregate and Fineness Modulus

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

The original test sample was not meeting the gradation requirement and therefore blending of the fine aggregate passing the 1.18 mm sieve was done with the original sample in a proportion of 60%:40%. Table 4.1 below shows the percentage passing each sieve size and Figure 4.1 shows the corresponding graph.

5. TEST RESULTS AND DISCUSSIONS

5.1 General

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

5.2 Fresh Concrete Properties

5.2.1 Workability Test

A concrete mix must be made of the right amount of cement, aggregates and water to make the concrete workable enough for easy compaction and placing and strong enough for good performance in resisting stresses after hardening. If the mix is too dry, then its compaction will be too difficult and if it is too wet, then the concrete is likely to be weak.

During mixing, the mix might vary without the change very noticeable at first. For instance, a load of aggregate may be wetter or drier than what is expected or there may be variations in the amount of water added to the mix. These all necessitate a check on the workability and strength of concrete after producing. Slump test is the simplest test for workability and are most widely used on construction sites. In the slump test, the distance that a cone full of concrete slumps down is measured when the cone is lifted from around the concrete. The slump can vary from nil on dry mixes to complete collapse on very wet ones. One drawback with the test is that it is not helpful for very dry mixes. The slump test carried out was done using the apparatus shown in Figure 5.1 below.

Fig. 5.1 Slump Test

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

Table 5.1 Slump Test Results

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

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

CONCLUSIONS

The introduction of recycled rubber tyres into concrete significantly increased the slump and workability. It was noted that the slump has increased as the percentage of rubber was increased in all samples by using 50% replacement of rubber aggregates for the natural coarse aggregates.

A reduction in unit weight of up to 21% was observed when 50% by volume of the coarse aggregate was replaced by rubber aggregate in sample AM4 which is with a targeted compressive strength of 20 MPa. A much similar trend of reduction in unit weight of the rubberized concrete was observed in all the other samples containing rubber aggregates. The low specific gravity of the rubber chips as compared to the mineral coarse aggregates produced a decrease in the unit weight of the rubberized concrete. Crumb rubber is nearly two and half times lighter than the conventional mineral coarse aggregate and hence it can be expected that the mass density of the mix would be relatively lower.

Rubberized concrete can be used in non load bearing members such as lightweight concretewalls, building facades, or other light architectural units, thus the rubberized concrete mixes could give a viable alternative to the normal weight concrete.

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