

A Review on Innovative Reuse of End-Of-Life Tyre Components in Concrete Construction

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Abstract— With rapid increase in the number of vehicles every day, the amount of scrap tire generated keeps proliferating as it is estimated to reach 1.2 billion tonnes annually by 2030. To attain economically viable and environmentally friendly tyre recycling, it is necessary to develop new applications and products, which will use tyre by-products as raw materials. Due limitation in the recycling of scrap tires, one of the most feasible solution is to use crumb rubber from scrap tire as partial replacement to fine aggregate in concrete industry. This paper presents a review of the recent researches carried out on investigating the fresh and hardened properties of rubbercrete.

Key words: Waste Tire, Crumb Rubber, Recycling Materials, Rubbercrete

I. INTRODUCTION

Concrete is a composite material made up of coarse aggregate held together in cement – fine aggregate matrix. The coarse aggregates used in manufacturing concrete are either naturally occurring or crushed rock and the fine aggregate is sand. As concrete is the most commonly used construction material, the natural resources are being utilized at a rapid rate. On the other hand, waste tires pose a serious environmental problem all over the world. A tire can be defined as complex elastomeric formulations composite combined with steel and fiber cords while a waste tire can simply be defined as a type of solid waste generated from used, unwanted or discarded tires, irrespective of its size or type and has been removed from its original usage. In the developed countries, it was estimated that the rate of generation of waste tires stands in the ratio of one passenger tire per person, with an estimate of 1 billion waste tires generated annually, with an expectation that the waste tire generation will reach 1.2 billion by 2030. Waste tire management continues to pose serious environmental, health and aesthetic problems and therefore need to be solved. Several attempts have been made for the proper utilization and management of waste tires. One of the advantages of the use of rubber as a replacement for some of the aggregate is the reduction in the density of concrete mix, because the density of rubber is much lower than the density of river aggregate or crushed aggregate. The density of fresh concrete made with natural aggregate amounts to ~2400 kg/m³, while the density of fresh concrete made with recycled rubber is lower and amounts to 1800-2100 kg/m³. This means that the density of concrete can be reduced by 20 to 30 percent if rubber is used instead of some of the aggregate, depending of course on the proportion of rubber in the concrete mix.

II. SCRAP TYRE

Discarded end-of-life tires are the main source of rubber aggregates. Waste rubber tires are known as black pollution since they do not decompose and disintegrate in the nature and pose a potential fire hazard to the environment at their storage locations. Waste tire is a solid waste and its disposal and management poses environmental concern among several countries. This is mainly due to its non-biodegradable nature as a result of presence of stabilizers, additives and the cross-linked structure of the elastomeric polymer material. These scrap tires are dangerous not only due to potential environmental threat, but also from fire hazards and provide breeding grounds for rats, mice, vermines and mosquitoes. Over the years, disposal of tires has become one of the serious problems in environments. Landfilling is becoming unacceptable because of the rapid depletion of available sites for waste disposal.

III. PROBABLE KEYS TO END OF LIFE TYRE DISPOSAL

Waste tire management continues to pose serious environmental, health and aesthetic problems and therefore need to be solved. Several attempts have been made for the proper utilization and management of waste tires. To this end, different methods have been proposed in order to dispose the scrap tires. Including use of rubber particles in petroleum industry as a last circulating material, use of tires as fuel, ground rubber applications for play-ground or sports surfacing or use in new rubber products, also in asphaltic pavement and recently in Portland cement concrete. Scrap-tires have been used as a fuel for cement kiln, as feedstock for making carbon black, and as artificial reefs in marine environment. Because of high capital investment involved in it, using tires as a fuel is technically feasible but economically not very attractive. The waste tires are used in the pyrolysis of tire derived fuel, but the use of tires for fuel is economically less advantage compared to fuel derived from petroleum products, and it involves pollution of environment by releasing toxic gases to the surrounding environment. The use of rubber-tires in making carbon black eliminates shredding and grinding costs, but carbon black from tire pyrolysis is more expensive and has lower quality than that from petroleum oils.

In addition, one of the new directions that has been studied over the past several years is the use of waste tyres and their components in the concrete manufacturing technology. The total of 1.5 billion tons of cement, 900 million litres of water, and 9 billion tons of sand and stone, are consumed each year for the production of concrete. In keeping with sustainability postulates, the main objective is to find alternative sources of raw products in concrete technology, as this would reduce an adverse environmental

impact of production of concrete components, while at the same time preserving natural resources.

IV. CRUMB RUBBER

Crumb rubber is a waste tire in which the size of the whole tire is reduced and grinded into smaller particle ranging from 4.75 mm to 75 μ m. It is produced in a special mill through grinding of the waste tire to granular sizes between 0.425 mm to 4.75 mm, with different sizes produced based on the properties and temperature of the milling machine generated. It can be used as a partial replacement of fine aggregate in concrete or mortar. Crumb rubber is hydrophobic and non-polar material which repels water and entraps air into its surface. In comparison to fine aggregate it has lower specific gravity ranging from 0.51 to 1.2, bulk density ranging from 524 kg/m³ to 1273 kg/m³, lower water adsorption, strength and stiffness.

V. LITERATURE REVIEW

A. Muhammad B. Waris, Nehal N. Ali, and Khalifa S. Al-Jabri,

“Use of Recycled Tire in Concrete for Partial Aggregate Replacement”-This study investigate possible use of recycled tire in concrete for partial fine aggregate replacement to provide possible solution for tire waste management as well as aggregate resource conservation. Commercially produced tire crumbs of size ranging between 0.80 to 4.0 mm were used for partial replacement of fine aggregates in concrete. Three fractions of 20%, 40% and 60% replacement were considered in addition to a control mix. A lean mix proportion of 1:2:4 with water-cement ratio of 0.50 was used in this study. In the fresh state, workability improved with increase in replacement percentage of tire crumbs. In hardened concrete, the compressive strength, tensile strength and flexural strength decreased with increase in fraction of tire crumbs. The apparent density was only slight changed while voids and water absorption decreased because of increase in workability.^[1]

B. Toutanji, H.A., 1996.

The use of rubber tyre particles in concrete to replace mineral aggregates investigated the effect of replacement of mineral coarse aggregate by rubber tyre aggregate. Shredded rubber tyres used had a maximum size of 12.7mm and a specific gravity of about 0.61. The effect of the replacement of mineral coarse aggregate by rubber tyre aggregate is investigated in this paper. Four different volume contents of rubber tyre chips were used: 25, 50, 75 and 100%. The incorporation of these rubber tyre chips in concrete exhibited a reduction in compressive and flexural strengths, the reduction in compressive strength was approximately twice the reduction of the flexural strength. The specimens which contained rubber tyre aggregate exhibited ductile failure and underwent significant displacement before fracture. The toughness of flexural specimens was evaluated for plain and rubber tyre concrete specimens. The test revealed that high toughness was displayed by specimens containing rubber tyre chips as compared to control specimens.^[2]

C. G. Nagesh Kumar¹, V. Sandeep², Ch. Sudharani,

“using tyres wastes as aggregates in concrete to form rubcrete – mix for engineering applications” – This paper presents the results, obtained after replacement of fine and coarse aggregates, in concrete mix, with tyre rubber. The tyre rubber, which has been used in the present study, is obtained after the mechanical trituration process of post – consumed tyres from trucks. Researchers have investigated, over the years, the use of recycled tyre rubber waste as a replacement for aggregate in concrete and its effectiveness. “Rubcrete-Mix” which would result from such replacement is found to have many engineering applications and holds promise in future. Rubcrete also possesses good mechanical properties and is considered to be one of the best and economical ways of recycling the used tyres. The present experimental study has the aim of arriving at the optimum quantity of the replacement material for the aggregates in concrete mixtures, for various engineering applications. For achieving a proper bond with the surrounding concrete paste, the recycled aggregates have been designed with respect to their size, shape and gradation. In preparing the concrete, Portland slag cement has been used along with super plasticizer less than 1% by weight of cement to achieve required workability of the resulting concrete. Furthermore, durability studies have been conducted and mixes have been designed for M30 grade concrete. It was observed that the 40% of Compression Strength was reduced with increase of replacement of fine aggregate with tyre rubber powder by 40%. Also 36% reduction of strength was observed when both coarse aggregate and fine aggregate was replaced with Chipped Rubber 2.5% and Rubber Powder 20%.^[3]

D. M.A Aiello , F.Leuzzi

“Waste Tyre Rubberised Concrete : properties at fresh and hardened state” investigate the properties of various concrete mixtures at fresh and hardened state, obtained by a partial substitution of coarse and fine aggregate with different volume percentages of waste tyres rubber particles, having the same dimensions of the replaced aggregate. Workability, unit weight, compressive and flexural strength and post-cracking behaviour were evaluated and a comparison of the results for the different rubcrete mixtures were proposed in order to define the better mix proportions in terms of mechanical properties of the rubberized concrete. Results showed in this paper were also compared to data reported in literature. Moreover, a preliminary geometrical, physical and mechanical characterization on scrap tyre rubber shreds was made. The rubberized concrete mixtures showed lower unit weight compared to plain concrete and good workability. The results of compressive and flexural tests indicated a larger reduction of mechanical properties of rubcrete when replacing coarse aggregate rather than fine aggregate. On the other hand, the post-cracking behaviour of rubberized concrete was positively affected by the substitution of coarse aggregate with rubber shreds, showing a good energy absorption and ductility indexes in the range observed for fibrous concrete, as suggested by standard (ASTM C1018-97, 1997).^[4]

E. Eldin and Senouci (1993)

reported that concrete mixtures with tire chips and crumb rubber aggregates exhibited lower compressive and splitting tensile strengths than regular portland cement concrete. There was approximately 85% reduction in compressive strength and 50% reduction in splitting tensile strength when coarse aggregate was fully replaced by coarse crumb rubber chips. However, a reduction of about 65% in compressive strength and up to 50% in splitting tensile strength was observed when fine aggregate was fully replaced by fine crumb rubber. Both of these mixtures demonstrated a ductile failure and had the ability to absorb a large amount of energy under compressive and tensile loads.^[5]

F. Biel and Lee (1996)

reported that the type of cement noticeably affects the compressive strength of rubcrete. They used two types of cement, magnesium oxychloride cement and portland cement, in making rubcrete. The percentage of fine aggregate substitution varied from 0% to 90% by weight. It was observed that 90% loss in compressive strength occurred for both portland cement rubber concrete (PCRC) and magnesium oxychloride cement rubber concrete (MOCRC) when aggregates (90% of fine aggregate and 25% of total aggregate) were replaced by untreated rubber. Magnesium oxychloride cement concrete exhibited approximately 2.5 times the compressive strength of portland cement concrete for both inclusion of rubber and without inclusion of rubber in the concrete. In terms of splitting tensile strength, portland cement concrete specimens made with 25% of rubber by total aggregate volume retained 20% of their splitting tensile strength after initial failure, whereas the magnesium oxychloride cement concrete specimens with the same rubber content retained 34% of their splitting tensile strength. They further noted that use of magnesium oxychloride cement may provide high strength and better bonding characteristics to rubber concrete, and rubber concrete made with magnesium oxychloride cement could possibly be used in structural applications if rubber content is limited to 17% of the total volume of the aggregate.^[6]

G. Malek K. Batayneh, Iqbal Marie, Ibrahim Asi (2007)

This paper addresses the recycling of rubber tires accumulated every year in Jordan to be used in concrete mixes. The main objectives of this research were to provide more scientific evidence to support the use of legislation or incentive-based schemes to promote the reuse of accumulated waste tires. This research focused on using crumb tires as a replacement for a percentage of the local fine aggregates used in the concrete mixes in Jordan. Different concrete specimens were prepared and tested in terms of uniaxial compression and splitting tension. The main variable in the mixture was the volumetric percentage of crumb tires used in the mix. The test results showed that even though the compressive strength is reduced when using the crumb tires, it can meet the strength requirements of light weight concrete. In addition, test results and observations indicated that the addition of crumb rubber to the mix has a limited effect toward reducing the workability of the mixtures. The mechanical test results demonstrated that the tested specimens of the crumb rubber concrete

remained relatively intact after failure compared to the conventional concrete specimens.

H. Trilok Gupta, Sandeep Chaudhary, Ravi K. Sharma (2015),

In this paper, a systematic experimental investigation is carried out on concrete with rubber fibers (obtained by grinding waste rubber tyres) as partial replacement of fine aggregates, to evaluate the compressive strength, density, water permeability, static modulus of elasticity, dynamic modulus of elasticity and chloride diffusion. Rubber fibers have been used with three different water/cement ratios (0.35, 0.45 and 0.55). Six levels of rubber fibers contents (0, 5, 10, 15, 20 and 25%) as partial replacement of sand and three levels of silica fume (0, 5 and 10%) as partial replacement of cement have been considered. Microstructure analysis of rubber fiber sample by scanning electron microscope and Energy dispersive X-ray analyzer has been carried out. Compressive strength, static and dynamic modulus of elasticity of waste rubber tyre fiber concrete are found to decrease with the increase in the replacement level of fine aggregates by rubber fibers.^[9]

I. A. Sofi (2016)

This paper reviews the tests performed to determine the compressive strength, flexural tensile strength, water absorption and water penetration of using rubber tyre waste concrete samples. It was observed that the compressive strength, flexural tensile strength and depth of water penetration of the rubberized concrete were less than that of the control mix, while the abrasion resistance and water absorption (up to 10% substitution) exhibited better results than that of the control mix concrete. This paper also reviews the performance of concrete mixtures incorporating 5%, 7.5% and 10% of discarded tyre rubber as aggregate and cement replacements.^[10]

J. Kunal Bisht, P.V. Ramana (2017)

Experimental work has been conducted to evaluate compressive strength, flexural strength, density and durability properties like water absorption and abrasion resistance for the different proportions (0%, 4%, 4.5%, 5% and 5.5%) of crumb rubber in concrete. It has been observed that with an increment of crumb rubber, workability of concrete decreases. The output of compressive and flexural strength show slight decrease with 4% replacement of fine aggregates by crumb rubber. Water absorption and abrasion resistance were also marginally affected at the same substitution level of crumb rubber in concrete. Hence, it can be concluded that 4% of fine aggregates can be replaced by crumb rubber to manufacture concrete for non-structural elements.^[11]

VI. SUMMARY & DISCUSSION

- 1) Compressive strength of waste rubber tyre fiber concrete decreases with the increase in the replacement level of fine aggregates by crumb rubber.
- 2) The reduction in compressive strength of concrete manufactured with rubber aggregates may limit its use in some structural applications, but rubberized concrete also has some desirable characteristics such as lower density, higher impact and toughness resistance,

enhanced ductility and better sound insulation. If tire-rubber could be used in applications that demand concrete characteristics associated with rubberized concrete, then disposal of used tires could be reduced to a large extent.

- 3) 3. It is also possible to make high-strength rubber concrete using magnesium oxychloride cement, which gives better bonding characteristics to rubber and significantly improves the performance of rubber concrete. Moreover, adhesion between rubber particles and other constituent materials can be improved by pre-treating the rubber aggregates with magnesium oxychloride.
- 4) 4. More research is required to optimize the particle size, percentage of rubber, type of cement, use of chemical and mineral admixtures, and methods of pretreatment of rubber particles on the characteristics of concrete.
- 5) 5. Ash from rubber obtained from combustion tires could be used in mortar and concrete. However, significant
- 6) research is needed in this direction.
- 7) 6. Scrap-tire rubber could be successfully used in flowable fill.
- 8) 7. It seems that there is still a need for future studies to optimize the size, shape, grading, density, amount, and methods of pre-treatment of rubber particles on the properties of rubber concrete.

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