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A Review on Construction Technologies that Enables Environmental Protection: Rubberized Concrete

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Abstract: Throughout the world, the disposal of used tires is a major environmental problem causing environmental hazards such as breeding ground for mosquitoes, producing uncontrolled fire and they are contaminating the soil and vegetation. Therefore, there is an urgent need to identify alternative outlets for these tyres, with the emphasis on recycling the waste tyre. Concrete is an excellent structural material and considered as essential for the modern civilization and human society. Now, the use of waste tires in concrete has become technically feasible and the concrete is being considered as light weight concrete. This study reviews the feasibility of using waste tires in the form of chips and fibers with different sizes in concrete to improve the strength as well as protecting the environment. Also it reviews the potential application in the field by exploiting its unique characteristics and properties. In this study, we outline the use of rubberized concrete in structural and non-structural members and show how it is suitable for the concrete, its uses, barriers and benefits and way to future study.

Keywords: used tires, rubberized concrete, environmental protection

INTRODUCTION

It is well known that the increasing piles of waste tires will create The accumulation of used tyres at landfill sites also presents the threat of uncontrolled fires, producing a complex mixture of chemicals harming the environment and contaminating soil and vegetation. It is estimated that in UK alone 37 million car and truck tyres are being discarded annually and this number is set to increase. This is considered as one of the major environmental challenge the world is facing because waste rubber is not easily biodegradable even after a long period of landfill treatment. One of the solutions suggested is the use of tire rubber as partial replacement of coarse aggregate in cement-based materials[1]. Although concrete is the most popular construction material, it has some limited properties: low tensile strength, low ductility, low energy absorption, and shrinkage and cracking associated with hardening and curing[2]. Several studies performed recently have shown that the application of the recycled tire rubber in concrete might improve these weak characteristics of concrete.

Rubberized concrete: The concrete mixed with waste rubber added in different volume proportions is called rubberized concrete and is an infant technology. Partially replacing the coarse or fine aggregate of concrete with some quantity of small waste tire cubes can improve qualities such as low unit weight, high resistance to abrasion, absorbing the shocks and vibrations, high ductility and brittleness and so on to the concrete. Moreover the inclusion of rubber into concrete results in higher resilience, durability and elasticity [3-9]. In constructions that are subject to impact effects the use of rubberized concrete will be beneficial due to the altered state of its properties.

Review on rubberized concrete: According to Eldin[10] tests conducted on rubberized Concrete behaviour, using tire chips and crumb rubber as aggregate substitute of sizes 38,25mm and 19mm exhibited reduction in compressive strength by 85% and tensile splitting strength by 50% but showed the ability to absorb a large amount of plastic energy under tensile and compressive loads.

In[11] Biel and Lee have used recycled tire rubber in concrete mixes made with magnesium oxychloride cement, where the aggregate was replaced by fine

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crumb rubber up to 25% by volume. The results of compressive and tensile strength tests indicated that there is better bonding when magnesium oxychloride cement is used. The researchers discovered that structural applications could be possible if the rubber content is limited to 17% by volume of the aggregate.

Schimizze[12] developed two rubberized concrete mixes using fine rubber granulars in one mix and coarse rubber granulars in the second. While these two mixes were not optimized and their design parameters were selected arbitrarily, their results indicate a reduction in compressive strength of about 50% with respect to the control mixture. The elastic modulus of the mix containing coarse rubber granular was reduced to about 72% of that of the control mixture, whereas the mix containing the fine rubber granular showed a reduction in the elastic modulus to about 47% of that of the control mixture. The reduction in elastic modulus indicates higher flexibility, which may be viewed as a positive gain in rubberized PCC (RPCC) mixtures used as stabilized base layers in flexible pavements.

I.B. TopÇu in [13] investigated the effect of particle size and content of tire rubbers on the mechanical properties of concrete. The researcher found that, although the strength was reduced, the plastic capacity was enhanced significantly.

Zaher *et al*[14] concluded that RPCC mixtures can be made using ground tire in partial replacement by volume of CA and FA. Based on the workability, an upper level of 50% of the total aggregate volume may be used. Strength data developed in their investigation (compressive and flexural) indicates a systematic reduction in the strength with the increase of rubber content. From a practical viewpoint, rubber content should not exceed 20% of the aggregate volume due to severe reduction in strength. Once the aggregate matrix contains nontraditional components such as polymer additives, fibers, iron slag, and other waste materials, special provisions would be required to design and produce these modified mixes. At present, there are no such guidelines on how to include scrap tire particles in PCC mixtures.

Serge *et al*.,[15] used saturated NaOH solution to treat waste tire rubber powders. They found that NaOH surface treatment increased rubber/cement paste interfacial bonding strength and resulted in an improvement in strength and toughness in waste tire powder modified cement mortar.

Hernandez-olivares *et al*.,[16] used crumbed waste tire fibres (average length 12.5 mm) and short polypropylene(pp) fibres (length from 12-10 mm) to modify concrete.

Gregory Garrick [17], shows the analysis of waste tire modified concrete used 15% by volume of coarse aggregate when replaced by waste tire as a two phase material as tire fiber and chips dispersed in concrete mix. The result is that there is an increase in toughness, plastic deformation, impact resistance and cracking esistance. But the strength and stiffness of the rubberised sample were reduced. The control concrete disintegrated when peak load was reached while the rubberized concrete had considerable deformation without disintegration due to the bridging caused by the tires. The stress concentration in the rubber fiber modified concrete is smaller than that in the rubber chip modified concrete. This means the rubber fiber modified concrete can bear a higher load than the rubber chip modified concrete before the concrete matrix breaks.

Kamil *et al*.,[18], analyzed the properties of Crumb Rubber Concrete, The unit weight of the CRC mix decreased approximately 6 pcf for every 50 lbs of crumb rubber added. The compressive strength decreased as the rubber content increased. Part of the strength reduction was contributed to the entrapped air, which increased with the rubber content. Investigative efforts showed that the strength reduction could be substantially reduced by adding a de-airing agent into the mixing truck just prior to the placement of the concrete.

Guoqiang Li,[19] conducted investigation on chips and fibers. The tire surfaces are treated by saturated NaOH solution and physical anchorage by drilling hole at the centre of the chips were also investigated and they concluded that fibers perform better than chips: NaOH surface treatment does not work for larger sized tire chips: using physical anchorage has some effect. Further efforts will be geared toward the enlarging he hole size and insuring that the hole be through the chip thickness entirely. Fibre length restricted to less than 50mm to avoid entangle: steel belt wires provide positive effect on increasing the strength of concrete.

From the above literature review it is seen that waste tire rubber modified concrete is characterized as having high toughness and low strength and stiffness. Various methods have been tried to improve the strength and stiffness of waste tire modified concrete. However preparing waste tire powders and thin tire fibres is time, effort and money consuming. Sometimes, the cost may be so high that it cannot be justified by its gain in performance. Because larger sized chips or fibres are very easy to produce, it is expected that the cost of larger sized chips or fibre modified concrete will be very low. However, it is not clear if larger sized fibres or NAOH treated chips work or not. Further experimental analyses are needed.

Challenges in environmental protection: The wastages are divided as Solid Waste Disposal, Liquid Waste Disposal and Gaseous Waste Disposal. There are lots of disposal ways for liquid and gaseous waste materials. Some solid waste materials such as PET bottles, papers, steel, etc can be recycled without affecting the environment. But there is no way to dispose the solid wastes such as waste tires. If the tire is burned, the toxic product from the tire will damage the environment and thus creating air pollution. Since it is not a bio degradable material, this may affect the fertility of the soil and vegetation. Sometimes they may produce uncontrolled fire. Similarly, there is an another challenge to the human society is in the form carbon dioxide emission and green house emission, which are considered as another type of waste, which is threatening the universe.

Need for further research: As seen in the above section the accumulation of used tyres at landfill sites presents the threat of uncontrolled fires, producing a complex mixture of chemicals harming the environment and contaminating soil and vegetation.

There is, therefore, an urgent need to identify alternative outlets for these tyres, with the emphasis on recycling in line with the policy of most countries.

One such possible outlet is to produce tire chips and fibres components for use in concrete as aggregate or filler. Indeed, waste tire chips and fibre is uniquely different to other waste materials, because its production method does not require any sophisticated machineries and easy to handle in economically. Hence, the successful use of waste tire chips and fibres in concrete could provide one of the environmentally responsible and economically viable ways of converting this waste into a valuable resource.

The principal objective is to develop ways of exploiting inherent stability, impact, crack and thermal resistance characteristics that waste tyre rubber can bring to concrete. Based on the number of conclusions that have been reached based on available literature, discussions and consultations with professionals from relevant engineering, research and scientific disciplines, the following three main issues were identified:

- There is growing evidence of the feasibility of substituting waste tyre rubber with a portion of natural aggregate in concrete manufacturing and also adding minerals and chemical admixtures in concrete production
- The need to examine the influence of waste tyre rubber on the fundamental mechanical and durability properties (strength, stiffness, fatigue, impact, thermal, crack and freeze/ thaw resistance) of concrete and concrete products and measure the performance
- The requirement to prepare a technical document that covers guidelines for incorporating waste tyre rubber in concrete; thereby, creating a disposal route for millions of used tyres around the world to improve the performance of Concrete, while reducing the environment impact

Applications and advantages of rubberized concrete over ordinary concrete: The rubberized concretes are affordable, cost effective and withstand for more pressure, impact and temperature when compare it with conventional concrete. It is observed that the Rubber Modified Concrete (RMC) are very weak in compressive and tensile strength. But they have good water resistance with low absorption, improved acid resistance, low shrinkage, high impact resistance, and excellent sound and thermal insulation. Studies shows the CRC (crumb rubber concrete) specimens remained intact after failure (did not shatter) compared to a conventional concrete mix. Such behavior may be beneficial for a structure that requires good impact resistance properties. The impact resistance of rubberized concrete was higher, and it was particularly evident in concrete samples aggregated with thick rubber [18].

Moreover the unique qualities of rubberized concrete will find new areas of usage in highway constructions as a shock absorber, in sound barriers as a sound absorber and also in buildings as an earthquake shock-wave absorber. It reduces plastic shrinkage cracking and reducing the vulnerability of concrete to catastrophic failure.

Currently, the waste tyre modified concrete is used in Precast sidewalk panel, non-load bearing walls in buildings and Precast roof for green buildings[20]. It can be widely used for development related projects such as roadways or road intersections, recreational courts and pathways, and skid resistant ramps[18]. With this new property it is projected that these concretes can be used in architectural applications such as nailing concrete, where high strength is not necessary, in wall panels that require low unit weight, in construction elements and Jersey barriers that are subject to impact, in rail roads to fix rails to the ground[13].

Rubberized concrete can also be used in non load bearing members such as lightweight concrete walls, building facades, or other light architectural units, thus the waste tyre modified concrete mixes could give a viable alternative to the normal weight concrete[14]. Rubberized mixes could be used in places where cement-stabilized aggregate bases are needed, particularly under flexible pavements. The other viable applications well suited for use in areas where repeated freezing and thawing occur, and can also be poured in larger sheets than conventional concrete.

The tennis courts can now be poured in a single slab, eliminating 'section' lines which must be smoothed after curing. Roofing tiles and other concrete products can now be made lighter with Rubberized concrete [21]. It may also used in runways and taxiways in the airport, industrial floorings and even as structural member.

Current research: Though rubberized concrete has proven its applications in various construction fields, still a lot of research has to be done to measure the elastic constants and mechanical properties of rubberized concretes by adding rubber in different volume proportions, water-cement ratios, aspect ratios and in different forms such as fiber chips, powder form, etc. so that the appropriate strength can be explored.

A research is underway using the grade of cement 53, to improve the strength, fine sand and coarse aggregate of a combination of 10mm and 20mm. The waste tyre rubber shall be used in the form of chips and fibers by partially replacing the coarse aggregate by 0, 5, 10, 20 and 25%.

The proposed concrete mixture shall be considered as high strength concrete with a ratio of 1:1:2.5. Figure 1 shows the waste tyre chips of size 10mm cubic with a central anchorage hole of 6mm diameter which is for the above research.

Figure 2 shows the proposed waste tyre fibre, which can be used as partial replacement of coarse aggregate in the concrete. The size of the waste tyre fibres shall be 25, 50 and 75mmX7mmX7mm with an anchorage hole of different diameters.

The water-cement ratio in the proposed research is taken as 0.4. It is recommended that to improve the strength characteristics and other mechanical properties of rubberized concrete, some ADMIXTURES (Chemical or Mineral) can be added as a partial replacement of cement. To get more workability and strength enhancement of waste tyre modified concrete, a required quantity of super plasticizer shall be added. The above concrete shall be mixed in a Pan mixer for uniform distribution of waste tyre rubbers in the concrete to avoid balling as well as accumulation of waste tyre rubbers in the concrete.

The proposed concrete will have higher strength, high resistant to acid attacks and high resistance against freezing & thawing. This is called as New Generation Concrete (NGC). No earlier research had explored the possible use of NGC as a structural member material. The scope of this work is limited to the development of the rubberized concrete mixes and evaluation of their basic engineering properties to be used as structural member.

Fig. 1: Waste tyre rubber chips with 6mm diameter hole

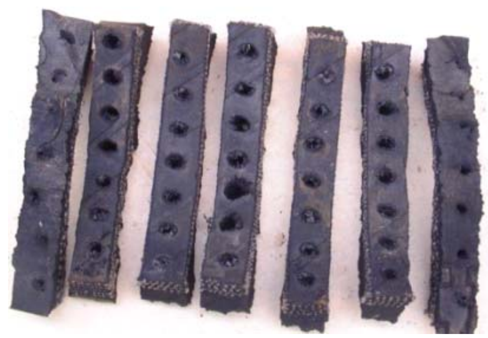

Fig. 2: Fiber Rubber of 75mmX7mmX7mm

CONCLUSION

Recycling technology for concrete has significantly developed in the recent years, making the material sufficiently recyclable [20]. It is evident that from the above discussion, the reduction of compressive and tensile strength can be increased by adding some super plasticizers and industrial wastes as partial replacement of cement will definitely increase the strength of waste tyre rubber modified concrete. Many studies reveal that there will be increase in strength enhancements as well as environmental advantages. The future NGC using waste tyre rubber could provide one of the environmental friendly and economically viable products. Though problems remain regarding the cost of production and awareness among the society the wastes can be converted into a valuable product. But further research is needed to increase performance against fire.

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