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The Use of Rubber Damaged Tires in the Concrete : A Review

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Abstract : Rubber is produced excessively worldwide every year. It cannot be discharge off easily in the environment as its decomposition takes much time and also produces environmental pollution. In such a case the reuse of rubber would be a better choice. In order to reuse rubber wastes, it was added to concrete as coarse aggregate and its different properties like compressive strength, Tensile strength, ductility etc. The aim of this paper is to compare and study the effect of rubber content on compressive strength of concrete. Rubber concrete has some known shortcomings in mechanical performance compared to conventional concrete, particularly with respect to compressive strength. Many previous researchers have tried to overcome the material deficiencies using different methods such as pre-treatment. The bond between rubber and matrix could be improved, a degree of load transfer to the rubber could be achieved and the reduction in strength compressive mitigated. This has been the driving force for investigation by a number of workers for applying surface pretreatments to rubber. for The effectiveness increase of using rubber in concrete, the chemical pre-treatment of rubber particles using sodium hydroxide (NaOH) solution. some of results reported less positive or contradictory from these approaches.

Keywords : Tires, recycled, concrete, NaOH,

1- Introduction

The management of worn tires poses a major problem for all world countries. Although waste tyres are difficult to ignite this risk is always present. Some research has already been conducted on the used of waste tyre as aggregate replacement in concrete showing that a concrete with enhanced toughness and sound insulation properties can be achieved. Rubber aggregates are obtained from waste tyres using two different technologies: mechanical grinding at ambient temperature or cryogenic grinding at a temperature below the glass transition temperature. The first method generates chipped rubber to replace coarse aggregates. As for the second method it usually produce crumb rubber to replace fine aggregates. Since the cement market demand is expected to have a twofold increase **[1].** Several studies have indicated that the presence of crumb rubber in concrete lowers the mechanical properties (compressive and flexural strength) compared to those of conventional concrete. The lower strength is due to the lack of bonding between the rubber crumb and Portland cement. This decrease in strength was found to be directly proportional to the rubber content. The sizes of the rubber crumbs also appear to have influence on the strength. The coarse grading of rubber crumbs lowers the compressive strength in comparison with finer grades. Apart from reliability and constructability, advantages such as the elimination of noise in processing plants and a reduction in construction time and labor costs have been cited as benefits of self-compacting concrete. On site, delivery delays are frequent and ambient temperatures have been found to influence the workability of the concrete **[2].** However, it reduced its compressive strength, tensile strength, and modulus of elasticity compared to conventional concrete. Some of the main reasons for this strength reduction are the low hydraulic conductivity and the smooth surface of rubber particles, which both result in poor rubber/cement interface adhesion. This poor adhesion is also attributed to the existence of zinc stearate which is used in tyre formulation during manufacturing. This zinc stearate migrates and diffuses to the rubber surface creating a soap layer that repels water. In this context, the sustainability criteria is emphasized and applied to concrete (and structural concrete). Concrete is the most widely used building material because of factors, such as versatility, ease of raw materials obtainment, low cost, ease of fabrication, high mechanical strength, impermeability to water and great durability Thus, rubberized concrete can support construction sustainability and contribute to the development of the civil engineering area by using industrial waste, minimize the consumption of natural resources and produce a more efficient material **[3].**

Samar Raffoul 2016 [4] Mineral aggregates were replaced with rubber particles of roughly similar size distribution to minimise the impact on the packing of the concrete mix constituents. Nevertheless, RuC fresh properties were slightly inferior at high levels of fine aggregate replacement. The combined replacement of fine and coarse aggregates helps achieve high rubber contents with minimal influence on strength and workability. Mix optimisation minimises the adverse effects of rubber on the concrete fresh and hardened mechanical properties. SF and PFA had a filling effect (thus improving packing) and a pozzolanic reaction with the cement hydration products. Pre-washing rubber with water or pre-coating with SF did not improve RuC performance. SEM analysis revealed a gap between rubber and the rubber cement paste ITZ, particularly for larger rubber particles. The use of SF and PFA reduced this gap.

Nahla Naji Hilal 2017 [5] The effect of crumb rubber size and content on hardened characteristics of self-compacting concrete. The highest splitting tensile strength result was obtained from control mixture, and the systematical decreasing of splitting tensile strength was observed as rubber content increased. The static elastic modulus decreased with increasing rubber size and content in a fashion similar to that observed in both compressive and splitting tensile strengths. The net flexural strength of control mix is highest value. While the significant improvement was achieved with addition of all tire wastes types, the best value for ductility was obtained with 25% mixed crumb rubber. The maximum displacement corresponds to the maximum load, the highest maximum load for the control mix and decreases gradually according to the amount and size of crumb rubber respectively. Decreasing of bond strength with increasing the crumb rubber size and content.

Nelson Flores Medina 2016 [6] There is a high reduction of compressive strength in series with FCR and CR. In series containing between 20% and 80% in volume of CR, a higher reduction of compressive strength than for those with FCR occurred. A flexural strength reduction takes place with the increase of recycled rubber in all the mixture series. This reduction of flexural strength is more evident in series with CR than in those with FCR. The sound absorption coefficient of rubberized concrete with CR obtained in this research work is lower than the coefficient obtained in rubberized concrete with FCR aggregates. Only concrete mixtures, with bulk porosity over 15%, have reached sound absorption coefficients over 0.25. Concrete with 80–100% of FCR have obtained porosities over 15% and can also be considered as EPC, with high open and tortuous porosity, which increases the sound absorption. Fibers partially coated with crumb rubber provide better sound properties to concrete than the usually crumb rubber in the market used as aggregate

Omid Rezaifar 2016 [7] Compressive strength of the concrete decreased with increased rubber content. using MK in conjunction with CR has lowered the loss of compressive strength in rubberized concrete by about 22% for optimum MK. The water absorption decreased with increased CR content up to about 9 vol.% replacement but increased when CR content exceeded this ratio. The results showed that use of MK was very effective in reducing water absorption. using MK in conjunction with CR has improved water absorption by about 18% for optimum MK. The unit weight of the concrete is decreased by the addition of CR as partial replacement for sand. The utilization of MK slightly increased the unit weight of the concrete but was not statistically significant.

Priyanka Asutkar 2016 [8] It is observed that the specific gravity and bulk density of rubber aggregates are less as compared to natural coarse aggregates. The density of concrete decreases when use of rubber aggregates in concrete increases. Due to this the lightweight concrete is obtained which helps to reduce the weight of structure. But the compressive strength decreases and toughness of concrete increases if use of rubber aggregates increases. It is found that optimum percentage of replacement of rubber aggregates can be up to 15%. It is concluded that such type of concrete cannot be used in structural elements where high strength is required. It can be used in other construction elements like partition walls, road barriers, pavements, sidewalks, etc. which has high demand in construction industries.

Agampodi S.M Mendis 2017 [9] From the experiments this study found that by changing other mixing parameters, similar compressive strength can be achieved from different CRCs with different level of rubber content. Similarly, CRCs of similar rubber content can have very different compressive strength due to different proportion of other constituents of the mix. Also regardless of rubber content, similar strength CRCs exhibit similar splitting tensile strength, modulus of rupture, modulus of elasticity and stress strain behaviour. The variations of these properties between one mixes to other mix of similar strength are well within the range of variation observed for normal concrete. The experiments also showed that after 14 days of concrete casting, the strength developments of different mixes of similar strengths are very similar. This is true for both compressive and splitting tensile strength of the CRCs tested. The effect of rubber content to the strength gain rate was not clearly evident from the experimental results. This study also demonstrates that existing design guidelines for normal concrete can be used to predict the splitting tensile strength and modulus of elasticity of CRCs with similar level of accuracy of normal concrete.

Giedrius Girskas 2017 [10] The test results revealed that rubber admixture reduces the ultrasonic pulse velocity in concrete specimens. The ultrasonic pulse velocity in concrete specimens containing coarser rubber granules was slightly higher than in specimens containing finer rubber granules. It can be stated that ultrasonic pulse velocity depends only on the rubber admixture content and the rubber particle size is irrelevant. The test results revealed that with higher content of rubber admixture in concrete specimens the relative pore and capillary wall thickens and the spare pore space decreased. With higher content of rubber admixture in concrete specimens the spatial inhomogeneity indicator increased steadily because coarse rubber particles and their bigger amount caused uneven distribution of pores and capillaries by their length.

Shuaicheng Guo 2017 [11] The compressive strength of the concrete samples prepared with NaOH-treated and cement coated Na_2SiO_3-treated rubber concrete samples were higher than the results of other type rubber concrete samples. And the strength declination of these two samples was also limited (< 4%) compared to the control sample. The compressive strength of the concrete samples with NaOH solution treated rubber aggregate increase by 23.4% compared to the results of samples with as received rubber aggregate. The electrical resistivity of the concrete samples increases with the added rubber aggregate. The ultrasonic transmission speed was also to evaluate the stiffness change with added rubber aggregate. The speed decreases with the added rubber material and the samples with same replacement ratio had a similar transmission speed. The decreasing on transmission speed is caused by the lower stiffness of rubber aggregate compared to normal aggregate. The study demonstrates the surface treatment and coating methods can improve the mechanical performance and long-time durability of rubber concrete.

Liang He 2016 [12] After the rubber surface modification, the adhesion strength of the rubber and cement paste was increased . It was also found in the mechanical tests that the rubber surface modification was quite useful to enhance the compressive strength and impact strength of rubber-cement concrete. The surface modification of crumb rubber by oxidation and sulphonation introduced a large number of hydroxyl, carbonyl and sulfonate groups on the rubber surface. This surface modification greatly reduced the contact angel of the rubber with water and the rubber surface turned to be hydrophilic, which can improve the interface reaction between crumb rubber and cement matrix materials. The adhesive property of the rubber and cement paste is improved obviously after the rubber surface modification.

Li-Jeng Hunag 2016 [13] Shrinkage increases with the rubber particle replacement percentage and with age, but is still below the specified limit of 0.025%. Sulfate resistance increases with the rubber particle replacement percentage. The effects of the rubber particle replacement percentage and high porosity on electrical resistance are inconsistent. At a rubber particle replacement percentage of 40%, moisture begins to leak out because of the excess of pores, so the permeability ratio cannot be measured correctly. The absorption rate increases with the rubber particle replacement percentage.

Alessandro P. Fantilli 2016 [14] Rubber granulates exert a sort of passive confinement in compressed elements, and prevent the rapid growth of cracks in the tensile zones of beams and plates. when compressive strength is the functional unit of the analyses, Traditional lightweight concrete(TLC) performs better than rubber lightweight concrete (RLC). Conversely, fiber-reinforced RLC is the best solution when flexural strength and structural ductility are the required performances.

Zeno Ghizdaˇveț 2016 [15] Materials made of concrete with added SBR were obtained and it was found that the sound absorption coefficient was above 0.5 (the limit defining sound absorbing materials) for all samples containing rubber, in contrast to the control samples (without SBR). SBR addition in concrete brought a significant decrease in compressive strength at all ages. Apparent density decreased with the amount of added rubber while the apparent porosity experienced an increase.

Fig. 1. Types of tire rubber recycled

Effect of rubber pre-treatment

The NaOH solution is using as a pre-treatment of rubber particles aiming to improve the rubber/cement adhesion and then the concrete strength. For concrete durability protection, the NaOH solution is totally removing by washing the rubber particles at the end of the pre-treatment process. The effect of rubber pre-treatment using NaOH solution on concrete slump, compressive strength, tensile strength, and modulus of elasticity is determining. This is attributing to the relatively rough surface of pre-treated rubber compared to non-treated rubber that resulte in relatively slow movement of rubber particles in the concrete matrix.

Conclusions

The following conclusions have been drawn from research on using rubber as aggregate in concrete

- The using rubber instead of aggregates in concrete it shows less compressive strength when compared with ordinary concrete.
- Rubberized concrete shows reduction in density of concrete when compared with control concrete specimen.
- Concrete made of crumb rubber as fine aggregate shows much strength when compared with concrete made of chipped rubber as coarse aggregate.
- No appreciable increment in the compressive strength of concrete density by using different percentage of rubber as fine aggregates in concrete.
- The use silica fume in rubberized concrete to increase its compressive strength.
- Fibers partially coated with crumb rubber, with a low energy recycling manufacture, provide better sound properties to concrete than the usually crumb rubber in the market used as aggregate.
- The using of crumb rubber in self- compacting concrete manufacturing resulting in systematical decreasing of the compressive strength. The coarse crumb rubber utilization decreasing the compressive strength of self-compacting concrete more than the using of fine crumb rubber.
- The systematical decreasing of splitting tensile strength was observed as rubber content increased.

- The static elastic modulus decreasing with increasing rubber size
- The using rubber in concrete it shows less flexural strength when compared with ordinary concrete.
- The systematical decreasing of fracture energy (GF) is observing as rubber content increased.
- The characteristic length,(which is a measure of ductility of the concrete), is increasing significantly by the increasing the crumb rubber volume fraction.
- The maximum displacement corresponds to the maximum load, the highest maximum load for the control mix and decreases gradually according to the amount and size of crumb rubber respectively.
- Decreasing of bond strength with increasing the crumb rubber size and content.

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