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UTILIISATION OF CRUMB RUBBER AS PARTIAL REPLACEMENT FOR SAND TO PRODUCE LIGHTWEIGHT CONCRETE

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ABSTRACT

The development of crumb rubber concrete for lightweight concrete production has gained significant attention in recent years due to its potential environmental and structural benefits. Disposal of condemned tyre continues to constitute serious problem to the environment, hence there is need for further research on effective use of crumb rubber in concrete. The crumb rubber possess the capability as a sustainable and environmentally friendly material. This study therefore, focuses on developing crumb rubber concrete for practical use in light weight concrete construction. Concrete mix design was done, followed by processing of crumb rubber concrete in the laboratory and the performance of the concrete was evaluated. This process included three stages namely; selecting effective rubber particle size, designing and adjusting concrete mixes, and testing recommended mixes for practical applications. The compressive strength, tensile strength and flexural strength were measured. The results showed that within the crumb rubber size range used (0.075–5.00 mm), increasing the rubber particle size decreases the compressive strength. Compared to conventional concrete, the presence of 16% rubber as sand volume replacement decreased the 7-day/28-day strength ratio by values that ranged between 9% and 20%.

Key Words: Compressive strength, Crumb rubber, Lightweight concrete, Sustainability of environment, Tensile strength.

1.0 Introduction

Waste tyres cause tremendous pressure and ecological issues for the entire tyre industry when accumulated in cultivated land or combusted (Syed *et al*. 2021; Fengming *et al*. 2022) Crumb rubber which mean small piece or the powdered form of tire (used in vehicle) which is being made after removing thin steel wire from the tire. As the use and production of rubber is increasing day by day with the increase of population. With the coming generation there is rapid increase in the production of vehicle so there is chance of increase in crumb rubber. But still there is very less use of vehicle tire. In most of the parts of the world the use of vehicle tire as crumb rubber is very less, so very often they are normally burn or just buried in landfills. Due to this i.e., landfill and burning there are many issue rising which are harmful to environment and causes Global Warming too. So nowadays many techniques have been coming into work. There are also many recycling methods for the tire according to our needs. So it is not easy to decompose tire under environment conditions and thus leads to serious issue. Based on the above investigation tire as crumb rubber are used in concrete.

A significant number of used tires are discarded each year after their natural lifetime of use. A number of approaches have been explored to recycle used tires. In several instances, tire derived aggregates, which are typically large aggregates, have been used as raw materials for civil engineering projects. However, a significant fraction of used tires still finds their way into landfills,

resulting in public health and environmental hazard. Landfill facilities require tires to be shredded in order to minimize the extent of floating tires; the cost of shredding is dependent on the final particle size of the rubber, with finer particles being more expensive. A number of studies have been conducted exploring the use of tire-derived particles as a substitute for fine aggregates, with varying degrees of success.

The management of waste tire has been a source of major concern in many countries of the world (Khaloo et al. 2008). Accumulation of this waste is found to be very dangerous, not only due to a potential negative environmental impact, but also because it presents a fire hazard and provides a breeding ground for rodents. (Guneyisi *et al.* 2004; Gha-ly and Cahill 2005; Selvakumar and Venkatakrishnaiah 2015; Barris *et al.* 1994; Hammer and Gray 2004; Ganjian *et al*, 2009).

The importance of recycling of waste tires have motivated a significant body of research pertaining to rubberized concrete, Khaloo *et al.* (2008), concluded that the incorporation in concrete of rubber aggregates, obtained from waste tires, is a suitable solution to decrease weight in some engineering manufactures, but could not conclude on some mechanical properties of the concrete such as durability, the toughness and impact resistance of the mix. In the investigation of the shrinkage properties of rubberized concrete pavement, results obtained showed that samples prepared with 20% and 25% rubber in concrete gave a good performance at water cement ratio 0.45 and 0.40 respectively (Mohammadi, Khabbaz 2015). It has also been found out that waste material could be a source of advantage in the production of lightweight concrete (Aamer and Hussain, 2015).

2.0 Materials and Methods

2.1 Materials

Materials used in this study include Ordinary Portland cement (OPC), Crumb rubber, Coarse Aggregates and Water.

2.2 Mix Proportioning for Concrete

This study consisted of one plain concrete as the control and crumb rubber concretes. All of the concretes were designed at a constant water-cement ratio of 0.42. Crumb rubber was used as the replacement for an equal part of fine aggregate and mixture. Considering the different specific gravities of crumb rubber and mineral materials, the replacement with crumb rubber was conducted based on the volume other than weight. The replacement levels of crumb rubber varied from 5% to 20% by volume for fine aggregate and from 1% to 10% for the concrete mixture.

Concrete specimens were produced as mixing of the mixture was conducted by a power-driven revolving pan mixer. In order to achieve a more homogenous distribution of rubber particles in the mixture with less entrapped air, the pre-treatment of crumb rubber was performed for 5 min before being added into the mixer. The mixing procedure was started with 2 min of pre-mixing of cement, aggregates and crumb rubber. Then, an additional 2 min of mixing were conducted

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after adding the water. After mixing, the mixture was poured into the molds with three layers. A vibration for five seconds was performed after rodding 25 times for each layer. All specimens were removed from the molds after 24 hrs and cured in the conditions of 95% relative humidity.

2.2 Testing of materials

2.3.1 Sieve analysis

The sieve sizes in general used for particle size distribution of fine aggregates are 10 mm, 4.75 mm, 2.36 mm, 1.18 mm and 600 µm, 300 µm, 150 µm, and 75 µm. This test consist of dividing up and separating by means of a series of test sieves named above, a material into several particle size classifications of decreasing sizes. The mass of the particles retained on the various sieves were then related to the initial mass of the material. Figure 1 shows the sieve analysis of sand while Figure 2 shows the sieve analysis for crumb rubber.

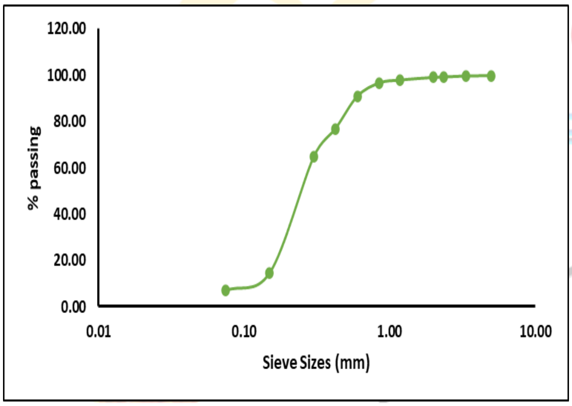

Figure 1: Particle size distribution (sieve analysis) of sand

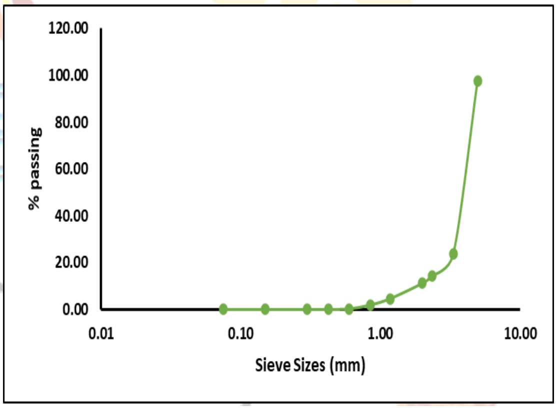

Figure 2: Particle size distribution (sieve analysis) of crumb rubber

2.3.2 Curing

Curing of concrete cubes was done with clean and colourless water with total immersion method at a normal temperature to promote the hydration of cement, and thus, the development of strength of concrete and to keep concrete saturated.

2.3.3 Slump test

The slump test is used to determine variations in the uniformity of mix of given proportions. The objective of the test is to determine slump of fresh concrete mix. The procedure of the test involved cleaning and oiling the inside surfaces of the cone mould to prevent sticking of fresh concrete on the surfaces of the mould. The mould is then filled with fresh concrete in three layers with each layer compacted with 25 strokes of the tamping rod. When filled, the top surface was struck off using a straight blade, and the cone slowly lifted and removed, leaving the molded concrete unsupported. Then its height duly measured. The difference between that height and that of the cone was therefore recorded as the slump.

2.3.4 Compressive strength

The compressive strength for all the concrete cubes was determined in accordance with South African standard, SANS 5863 (2006) and BS 12390 parts 3 (2009). Each concrete was prepared in accordance with the percentage mixes been investigated in this work. Three samples for each curing age and for the percentage replacement were replicated, a total of 70 cubes were cast.

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The compressive strength of each cube was determined from a compressive testing machine at a load rate of 180 kN/min. All the samples were tested to failure by crushing and the maximum load recorded, the maximum load divided by the area of each cube gives the compressive strength of the samples. The test was conducted on compression testing machine of capacity

Figure 3: Compressive test of concrete cube

2000 kN as shown in Figure 3.

2.3.5 Split Tensile strength

Testing for split tensile strength of concrete is done as per ASTM C 496–96 (2004). The test is conducted on compression testing machine of capacity 2000 kN as shown in Figure 4. The cylinder is placed horizontally between the loading surfaces of compression testing machine and the load is applied at the rate of 100 kN/minute until the failure of the cylinder.

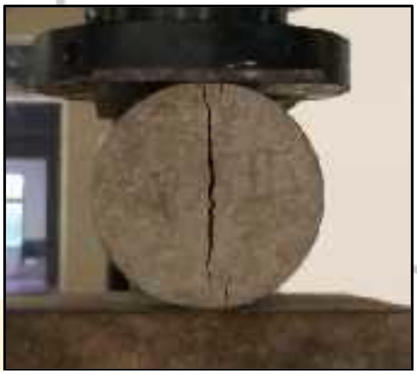

Figure 4: Split Tensile strength of concrete

3.0 Results and Discussion

3.1 The slump test result

The slump test is the most commonly used method of measuring the consistency or workability of concrete which can be employed either in the laboratory or onsite. It was observed that all the concrete sample slumps evenly, which can also be referred to as a true slump during the test period and this can be said that the entire sample have good consistency properties. The slump value decreases as the percentage of rubber increases in the concrete mix, similar finding was reported by Fengming *et al*. (2022). The implication of this is that if the concrete is to be transported to a distance site, the water cement/ratio will have to be increased in order to increase its slump and workability before pouring, but in general, the rubberized concrete specimens have acceptable workability in terms of ease of handling, placement, and finishing. The very low slump especially in all the rubberized samples can be attributed to the absorption of water by the rubber particles in the concrete mixture; since the rubber crumb was dry, it affinity with water was high within the concrete environment. The slump test results for

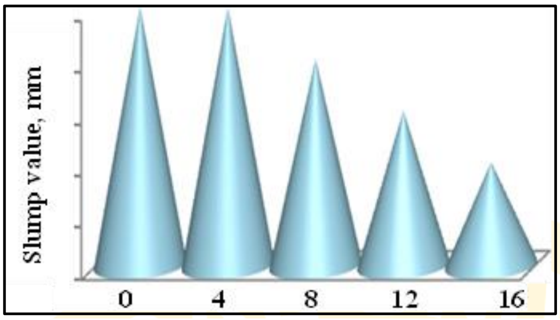

Figure 5: Slump of concrete samples

concrete samples is shown in Figure 5.

3.2 Compressive test result

The compressive strength test results shows that the compressive strength reduces as the percentage of rubber crumb increases in the concrete mix. The ultimate strength for Control specimen is more than that of crumb rubber specimens by over 23%. Although there is reduction of ultimate strength in tire rubber concrete, they can still be used for low strength structural applications. The reduction in compressive strength can be attributed to the decrease in adhesive strength between the surface of the waste plastic and the cement paste. Since the aim of this work is to use rubber crumb in lightweight concrete, ACI 213 (2003) recommended a minimum 28 days compressive strength of 7 N/mm2 for light weight concrete (LWC), while BS 8110 (1997) required a minimum 28 days compressive strength of 15 N/mm^2 for concrete to be used as reinforced concrete, and a minimum 7 N/mm2 for plain concrete. The results from the entire test specimen showed that rubber crumb can be used to replace fine aggregate in light weight concrete up to 12% optimum level since the least 28 days compressive strength obtained is 19.40 N/mm^2, which is greater than the recommended values. The compressive strength test results for concrete samples is shown in Figure 6.

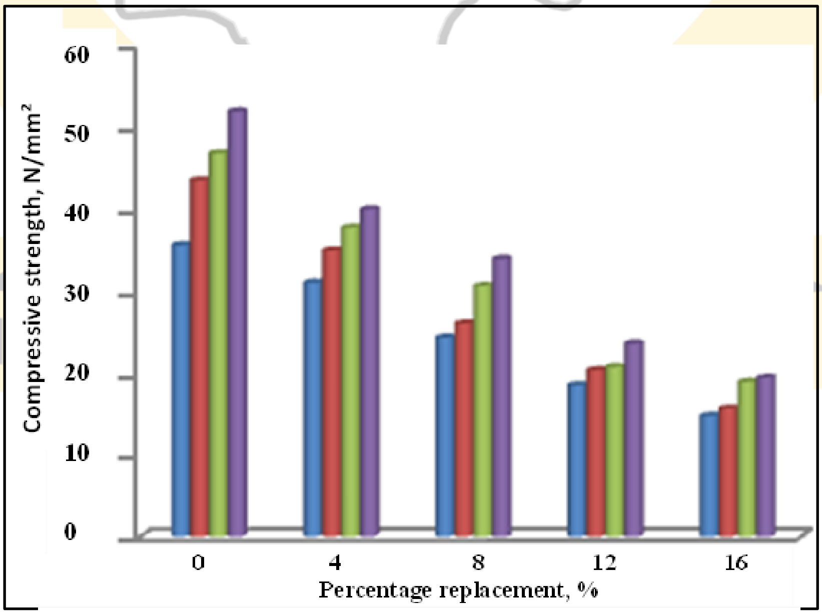

Figure 6: Compressive strength of concrete samples

3.3 Tensile test result.

The 14 and 28 days tensile test result for all the samples recorded that as more rubber crumbs were added to the concrete samples, the tensile strength also reduces. The results showed the tensile strength for the control to be 2.76 and 3.11 N/mm^2 for the 14 and 28 days test respectively. These reduced by 39 and 41% at 14 and 28 days respectively for the M4 sample. The phenomenon continued for the entire concrete samples as M16 gave1.15 and 1.33 N/mm^2 at 14 and 28 days respectively. The reduction in tensile strength can also be attributed to the weak interfacial adhesive force between the cement paste and the elongated surface of the rubber crumb which encourages micro voids within the concrete material; these voids are potential weak points for the tensile stresses generated during the application of tensile forces on the concrete samples, the more voids within the concrete samples the less the compressive strength. The split tensile strength test results for concrete samples is shown in Figure 7.

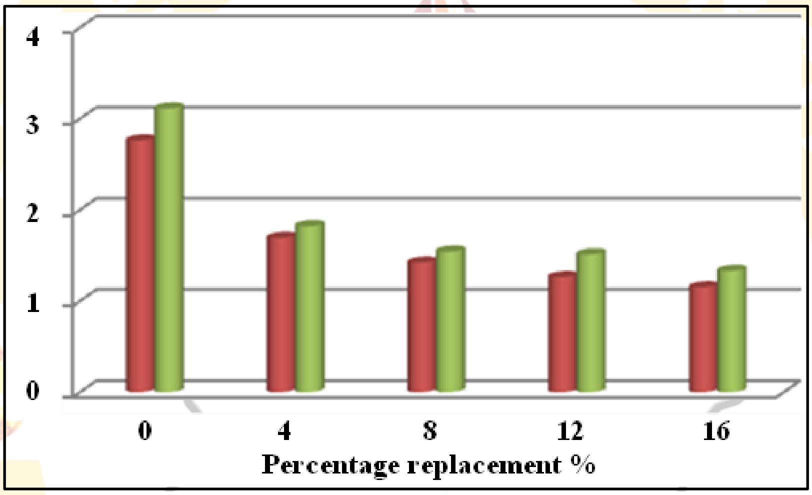

Figure 7: Split tensile strength of concrete samples

3.4 Rubber crumb distribution in concrete

The presence of rubber crumbs in concrete allowed for the formation of voids or spacing between the interface of the cement paste and the rubber crumbs, these voids accommodate water molecules when the concrete was wet, but by the time the concrete becomes hardened, these voids are left behind and it eventually contributed to the reduction in compressive strength of the concrete. The more rubber crumb present in a sample, the more voids formed and hence the increases in weak adhesive force (van der Waals forces of attraction). Naturally, capillary and air voids are present in concrete cement paste; Capillary voids represent the space not filled by the solid components of the hydrated cement paste, but the presence of external impurities like the rubber crumb increases the amount of these voids in concrete and hence the low density and compressive strength experienced from the samples where fine aggregates were replaced by rubber crumbs.

4.0 Conclusion

From the investigation carried out on the use of rubber crumb in lightweight concrete, it can be concluded that the presence of rubber crumb reduces both compressive and tensile strengths of concrete, this is because the rubber crumb allowed the increase in water demand, reduction in bond between aggregate and cement paste, leading to increase in drying shrinkage and lower strength. The result obtained for the compressive strength gave a positive side of the research work because the 28 days compressive strength for crumb rubber concrete mix is higher than the recommended compressive strength of 15 N/mm2 for reinforced light weight concrete. Hence rubber crumb can conveniently replace fine aggregate in concrete up to 16% optimum replacement level for light weight concrete. Additionally, the rubber crumbs in concrete encourage the formation of voids within the concrete interface and thus lead to the lightweight characteristics of the rubberized concrete.

Conflict of Interest

The Authors declares no conflict of interest in this study.

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