

The durability of concrete containing recycled tyres as a partial replacement of fine aggregate

Mohamad Syamir Senin¹, Shahiron Shahidan^{1,*}, Alif Syazani Leman¹, Nurulain Othman¹, Shamrul-mar Shamsuddin¹, M. H.W. Ibrahim¹, S. S. Mohd Zuki¹

¹ Jamilus Research Center-Sustainable Construction, Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia.

*Corresponding author: shahiron@uthm.edu.my

Abstract. Nowadays, uncontrolled disposal of waste materials such as tyres can affect the environment. Therefore, careful management of waste disposal must be done in order to conserve the environment. Waste tyres can be use as a replacement for both fine aggregate and coarse aggregate in the production of concrete. This research was conducted to assess the durability of concrete containing recycled tyres which have been crushed into fine fragments to replace fine aggregate in the concrete mix. This study presents an overview of the use of waste rubber as a partial replacement of natural fine aggregate in a concrete mix. 36 concrete cubes measuring 100mm x 100mm x 100mm and 12 concrete cubes measuring 150mm x 150mm x 150mm were prepared and added with different percentages of rubber from recycled tyres (0%, 3%, 5% and 7%) as fine aggregate replacement. The results obtained show that the replacement of fine aggregate with 7% of rubber recorded a compressive strength of 43.7MPa while the addition of 3% of rubber in the concrete sample recorded a high compressive strength of 50.8MPa. This shows that there is a decrease in the strength and workability of concrete as the amount of rubber used a replacement for fine aggregate in concrete increases. On the other hand, the water absorption test indicated that concrete which contains rubber has better water absorption ability. In this study, 3% of rubber was found to be the optimal percentage as a partial replacement for fine aggregate in the production of concrete.

1. Introduction

Along with the demands of globalisation, the increasing demand for building materials as well as the increasing human population around the world have led to a shortage of construction materials [1-3]. Engineers have been challenged to convert industrial waste into useful construction materials [4-5]. This is because the construction sector is important in order to assist in the development of economic development in Malaysia to achieve the status of a developed nation. The use of rubber from waste tyres to replace fine aggregate may help to alleviate disposal problems [6]. Various studies have been conducted to replace the main components in concrete production with alternative materials in order to reduce cost and conserve the environment. In this research, rubber was used to replace fine aggregate in concrete. According to Blessen Skariah Thomas and Ramesh Chandra Gupta, by the year 2030, the number of discarded tyres would reach 1200 million tyres yearly (including the stockpiled tyres, there would be 5000 million tyres to be discarded on a regular basis) [7]. Besides that, 60% of the waste tyres are continuously being disposed at places which are categorised as hazardous [8]. The disposal of waste rubber is a threat the environment and there is no shortcut in solving this problem due to the



lack of management of waste rubber [9]. The build-up of old rubber tyres in landfills is commonly considered a major threat to the environment, and it is a burden on landfill space [10]. Therefore, in the process of making concrete, rubber particles originating from recycled tyres have been chosen to replace fine aggregate in concrete. There are some features in the rubberised concrete to be compared with ordinary concrete in terms of strength and durability. This is done to make sure that the rubber concrete is safe for use in the construction industry. Concrete is an important building material in the production of building structures [11]. Concrete is widely used because it has durability and optimum compressive strength. The shape, strength, ability and value of the regular concrete are different from those of rubberised concrete. Additional material or materials used in the production of concrete should be tested in terms of effectiveness according to the standards set. As such, this study makes use of recycled waste tyres as a partial replacement for fine aggregate in the production of concrete. The main objective of this paper is to evaluate the level of durability of concrete containing rubber from recycled tyres as fine aggregate replacement.

2. Literature review

2.1. Rubber tyres

In order to prevent environmental problems from worsening, recycling tyres is an innovative idea or way in this case [12-16]. Recycling tyres is the processes of recycling vehicle tyres that are no longer suitable for use on vehicles due to wear or irreparable damage (such as punctures) [17]. Previous studies have contributed greatly to the understanding of the behaviour of fibrous concrete, especially when tyre chips and waste plastic strips were used in concrete [18]. Early studies on the use of scrap tyres in asphalt mixes were very promising [19]. They showed that rubberised asphalt had better skid resistance, reduced fatigue cracking, and achieved longer pavement life than conventional asphalt. Large benefits can result from the use of scrap tyre rubber in Portland cement concrete (pcc) mixtures, especially in circumstances where properties like lower density, increased toughness and ductility, higher impact resistance, and more efficient heat and sound insulation are desired [20-23].

The use of waste tyres as a replacement for sand in concrete has great potential in the construction industry. Rubber is the principal element of tyres where both synthetic and natural rubbers may be used. Rubber consists of many polymeric repeated units (mainly polybutadiene) chained together [24]. Natural rubber is an elastic variety of plants. Synthetic rubber can be produced as a thermoset polymeric material in which individual monomer chains are chemically linked by covalent bonds during polymerisation [25]. The disposal of discarded tyres has been a major concern throughout the world because rubber is not easily biodegradable. The simplest way to get rid of waste tyres is by burning. However, this method generates toxic fumes that contaminate air, soil and water. The use of tyre rubber in the production of concrete is an alternative way to recycle this residue [26]. Most countries have to deal with the problem of waste rubber tyre disposal which greatly affects the environment [27]. Therefore, many research studies have been done to evaluate the influence of rubber tyres on cement. Many researchers have observed that the presence of rubber tyre in concrete reduces its mechanical properties.

3. Materials and methods

This part describes the methods used in this research. Basic materials such as cement, fine aggregate, coarse aggregate, water and rubber were used in this study.

3.1. Material preparation

3.1.1. Cement. Ordinary Portland cement with characteristic strength was used in accordance with BS EN 197-1. This cement was taken into account during the mix design process. It was stored in airtight packages before use.

3.1.2. Fine aggregate. Natural river sand with a maximum particle size of 4.75 mm was used as fine aggregates. The procedures for measuring the durability of sand were the same as those for measuring the durability of gravel. A sieve analysis test was carried out in accordance with BS EN 933-1. As shown in Figure 3.3, the sand used in this study presented continuous grading.

3.1.3. Coarse aggregate. Crushed gravel with a nominal maximum size of 20 mm was used as coarse aggregate. The water absorption of the coarse aggregate used in this study under SSD (saturated surface dry) condition was measured by immersing them in water for 24 hours followed by the removal of excess surface water with a wet cloth after they were taken out of the water. At the time when there is no free water on the surface, the aggregates were assumed to be under the SSD condition.

3.1.4. Water. Tap water that is reasonably free from contamination in the laboratory was used to hydrate the cement in the mixtures.

3.1.5. Rubber. In this study, rubber obtained from recycled tyres was used as a partial replacement of fine aggregate in concrete. In order to obtain a suitable size, raw rubber tyres were placed in a machine to produce rubber particles measuring 0.16mm. This is important to ensure that the size and shape of rubber particles are similar to sand. In addition, the rubber particles must be free from impurities.

3.2. Specimen preparation and testing

48 concrete cube specimens were prepared for three separate tests. For the compressive strength test, 24 concrete cubes measuring 100mm x 100mm x 100mm were used. For the water absorption test, 12 concrete cubes measuring 150mm x 150mm x 150mm were used whereas the carbonation test involved the use of 12 concrete cubes measuring 100mm x 100mm x 100mm. Table 1 show the mix proportion used in this study.

Table 1: Mix proportion.

Type of concrete	Cement (kg)	Sand (kg)	Coarse aggregate (kg)	Water/cement ratio	Rubber ash (kg)	Rubber crumb (kg)
0%	430.00	530.00	1240.00	0.45	0.00	0.00
3%	430.00	514.10	1240.00	0.45	0.00	4.56
5%	430.00	503.50	1240.00	0.45	0.00	7.60
7%	430.00	492.90	1240.00	0.45	0.00	10.64

4. Results and discussion

4.1. Compressive strength

This test was conducted using a compression machine as shown in figure 1. The machine was used to investigate the compressive strength of the composite concrete specimens shown in figure 2. Moreover, this test was done on composite concrete samples containing different compositions of rubber (0%, 3%, 5% and 7%). Recycled rubber particles were used to partially replace sand in the concrete samples. All samples including the control samples and the composite samples were tested after a curing period of 7 days and 28 days respectively.



Figure 1. Compression machine.



Figure 2. Cube specimens.

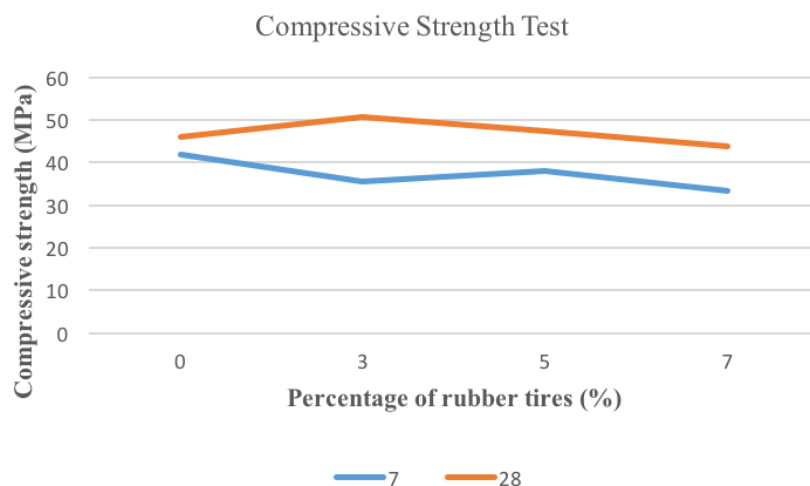


Figure 3. Compressive strength of cube specimens.

Figure 3 shows the compressive strength of the cube specimens after a curing period of 7 days and 28 days respectively. In the study, concrete samples containing 7% of rubber recorded the lowest compressive strength (43.7 MPa) while the highest compressive strength (50.8 MPa) was achieved by concrete samples containing 3% of rubber. Hence, it can be concluded that the optimum amount of rubber which should be used in concrete is 3%.

4.2. Water absorption

The purpose of this test was to investigate the water absorption ability of the concrete samples. The test was conducted on after a curing period of 28 days. The water absorption test was conducted on concrete samples containing 0%, 3%, 5% and 7% of rubber. All samples were then weighed before being submerged into a tub of water for 24 hours. The samples were weighed again after 24 hours. The data is shown in Figure 4.

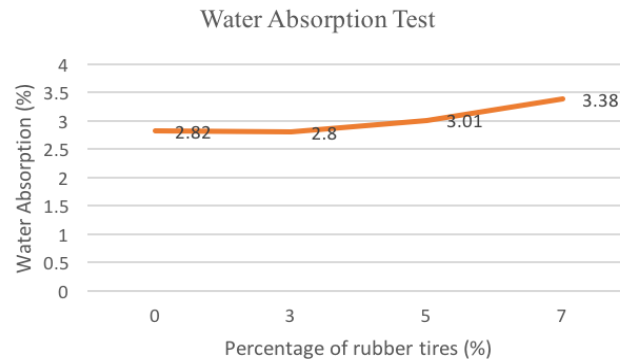


Figure 4. Water absorption (%) vs percentage of rubber (%) in concrete specimens.

It can be concluded that the percentage of rubber which should be used to replace fine aggregate is most suitable at 3% since it does not absorb too much water. Therefore, a high amount of rubber should not be used for building construction. A lower water absorption rate is not always an indicator of better frost resistance whilst a high one does not always mean poor frost resistance. Structural engineers can use materials with lower water absorption rates to improve the safety factors in their designs.

4.3. Carbonation

This test was carried out to determine the depth of concrete affected due to a combined attack of atmospheric carbon dioxide and moisture which can cause a reduction in the level of alkalinity of concrete. A solution containing 0.2% of phenolphthalein was used as the pH indicator of concrete. Figures 5,6,7 and 8 show the depth of carbonation for each of the concrete specimens (control, 3% rubber, 5% rubber and 7% rubber)



Figure 5. Control



Figure 6. 3%



Figure 7. 5%



Figure 8. 7%

The carbonation in the concrete samples which were exposed to air for two weeks was not more than 1mm. After a year or so, it may reach a depth of 1 mm for dense concrete of low permeability (low

water/cement ratio), or up to 5 mm or more for more porous and permeable concrete (high water/cement ratio).

5. Conclusion

The highest compressive strength of 50.8 MPa was achieved by concrete samples which contain 3% of rubber. The durability of concrete which can be assessed by testing the water absorption of the replacement tyre recycling as much as 3% low percentage compared to the other percentage of 2.8%. Meanwhile, the carbonation tests revealed that the carbonation of samples which were exposed to air for two weeks was not greater than 1mm.

6. References

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