The Effect of Various Sizes of Waste Tyre Rubber Shred on Concrete Strength

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Abstract. Concrete is one of the most important building materials and usually used in a construction project. The construction activity is increased and could result in a reduction of conventional coarse granite in the market due to the use of 60-75% of the aggregate in the concrete. The world is facing the problem of excessive disposal of excess rubber tyres and it is alarming. This study was conducted to find alternative to reduce the increase number of waste rubber tyres from time to time by leveraging the use of the rubber tyres and can also reduce the use of coarse aggregate. A total of 24 concrete cubes were made to assess the impact of the strength of concrete mixed with various size of rubber tyre. This study consists of a control sample of concrete (C30) and three (3) experiment samples that consisting of 10% tyre rubber sheets and divided into three (3) different sizes of 10mm (R10), 20mm (R20) and 30mm (R30) to replace coarse aggregate 20mm. The results of the experiment samples R10, R20 and R30 are compared with the control sample C30. Each sample was tested for slump, density and compression test. The increase of size of the tyre rubber has led to the workability of concrete reduced from 20% to 56% compared to control concrete. The larger pieces of tyre rubber cause the density of concrete decreased. The design compressive strength of the control sample of concrete on the 28-day was 30 N/mm^2. The experiment sample R10 past the target design compressive strength of the control sample of concrete with the degradation of only 6.6%. The increase of the size of the rubber tyre causes the decrease of the compressive strength from 6.6% to 27.98%. This study showed that the concrete mixes containing pieces of rubber tyre with the size of 10mm can be considered as an alternative to the future construction.

Introduction

Recently, concrete use is becoming prevalent in line with economic growth. Aggregate is one of the most important components used in the manufacture of concrete. In order to protect natural resources, the use of aggregate in concrete production can be reduced by using alternative material such as recycled waste. Tyre rubber wastes represent a major environmental problem. According to Thomas et al. [1], millions of waste tyres discarded and cultivated throughout a serious threat to the ecological environment. In the world perspective, it is estimated that each year 1,000 million waste tyres in 2030 and is expected to increase to 1200 million and could reach up to 5000 million annually [1]. In Malaysia, an estimated 8.2 million or approximately 57,391 tonnes tyres reach the end of their useful lives every year [2]. Management of waste-tyre rubber is difficult to handle because the waste tyre rubber is not easily biodegradable [3]. However, recycling of waste tyre rubber is an alternative. Recycling waste tyre rubber providing and environmentally friendly solution to save these tyres from going to landfills [4]. Previously, research had been performed to investigate the availability of using waste tyre rubber in concrete mixes [5]. Previous studies have also already been conducted on the use of waste tyre as aggregate replacement in concrete showing that a concrete with enhanced toughness and sound insulation properties can be achieved [6].

As mention by El-Gammal et al [5], recycled waste tyre is a promising material in the construction industry because its lightweight, elasticity, energy absorption, sound and heat insulating properties. Tyre rubber is durable material and has a strong resistance to the environment. Therefore, research on the use of waste tyre rubber need to be done from time to time to increase the awareness of environmental conservation and sustainable development [7]. In this paper, the compressive strength of concrete utilizing waste tyre rubber has been investigated. Recycled waste tyre rubber has been used in this study to replace the fine and coarse aggregate based on different size of the tyre rubber. In this study, waste tyre rubbers have been cut in different size of 10mm, 20mm and 30mm that used in the concrete mix.

Aim and Objectives of the Study

The aims of this study is to investigate the effect of various size of waste tyre rubber shred on concrete strength. In more specific, the objectives of this study are:

i. To assess the strength of concrete by different size pieces of tyre rubber.
ii. To compare the compressive strength of concrete according to the different size of tyre rubber in the same percentage.
iii. To determine the size of the pieces of concrete design tyres that have the highest strength in this study.
iv. To investigate the properties of concrete with rubber tyres.

Scope of the Study

In this study, the effect of different size of tyre rubber on concrete strength was investigated. The scope of this study are to investigate the strength of concrete mixed with tyre rubber. For the purpose of this study, the concrete Grade 30 was used. The compressive strength of the concrete is tested on the seventh (7th) and 28th days. There are 24 concrete cubes were made to study the effects of various size pieces of tyre rubber on concrete strength. The study used 10% of the pieces of tyre rubber, which comprises three (3) different sizes of 10mm, 20mm and 30mm to replace the 20mm aggregate in each of the concrete mix. For the experimental samples, each size tyre rubber is made of six (6) concrete cube. While the control sample, a total of six (6) ordinary concrete cube made without the mixture of shred rubber.

Literature Review

Numerous researchers investigated the effect of waste tyre rubber on concrete strength. For example, a study by Kotresh and Belachew [6] on waste tyre rubber as concrete aggregates. This study found that the slump was increased with increase of waste tyre rubber content of total aggregate volume. This study showed that the workability is increased when increasing the percentage of tyre rubber that is used to replace the coarse aggregate.

Another study conducted by El-Gammal et al. [5] on the effect of waste tyre rubber as replacement to aggregate in concrete mixtures on the compressive strength of concrete. The researchers used recycle tyre rubber to replace the fine and coarse aggregate by weight using different percentages. They found that the compressive strength was significantly increased when using crumb rubber instead of chipped rubber. This study showed that there was a significant reduction in the compressive strength of concrete using waste tyre rubber than normal concrete. However, concrete utilizing waste tyre rubber demonstrated a significant ductility.

Isa et al. [2] also investigated the use of rubber manufacturing waste as concrete additive. In this study, the researchers used different percentages of rubber tyres by weight 1%, 3% and 5%. This study showed that when rubber tyre is added to the concrete mix with increasing percentage, the workability of concrete is increased up to a certain level, which is by 2.5% addition.

Based on the literature review, it can be concluded that recycled waste tyre rubber is a promising material in the construction industry. Most of the prior research investigated the effect of waste tyre rubber on concrete strength by different percentages of tyre rubber. More research is warranted to investigate the use of tyre rubber in concrete mixture as a replacement of coarse aggregate. Hence, the current study aims to extend the literature by investigating the effect of various size waste tyre rubber on concrete strength.

Methodology

Materials

The material used to develop the concrete mixtures in this study were cement, water, fine aggregate (sand), coarse aggregate, and shred tyres rubber. The cement used was Ordinary Portland Cement (OPC). Natural sand was used as fine aggregate and the type of coarse aggregate was crushed. This study used the shred of the waste tyre rubber of motorcycle. Shredded tyre rubber is used to replace the coarse aggregate. There are three different size of the tyre rubber, which is (a) 10mm, (b) 20mm and (c) 30mm as shown in Figure 1.

(a) 10mm (b) 20mm (c) 30mm

Figure 1: Shred tyre rubber used in the concrete mix

Experiment Procedures

The experimental procedure was listed in Figure 2. During the lab phase, the timeline was much important to be noticed. In this study, the experiment concrete took 28-days to reach the target compressive strength of 30 N/mm^2. The compressive strength of which is monitored on the 7-days and the 28-days. Target compressive strength in this study was 22.5 N/mm^2 on the 7-days and 30 N/mm^2 on the 28-days. Each sample was tested for slump, density and compression test.

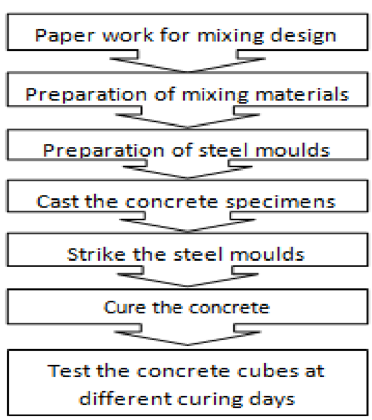

Figure 2: Experiment procedures

Concrete Mixtures

A total of 24 concrete cubes were made. Six (6) ordinary concrete cube made without the mixture of shred rubber as the control group. For the experimental group, 10% of the pieces of tyre rubber, which comprises three (3) different sizes of 10mm, 20mm and 30mm to replace the 20mm aggregate in each of the concrete mix. Each size of the shred tyre rubber is made of six (6) concrete cube. Table 1 shows the details of the concrete mixtures used in this study.

Table 1: Details of the concrete mix proportions

Component (Kg)	Control Group (C30)	Experimental Group		
		Shred Tyre Rubber sized 10mm (R10)	Shred Tyre Rubber sized 20mm (R20)	Shred Tyre Rubber sized 30mm (R30)
Cements	11.34	11.34	11.34	11.34
Water/Cement ratio	0.45	0.45	0.45	0.45
Water	5.10	5.10	5.10	5.10
Sand	15.48	15.48	15.48	15.48
10mm Coarse Aggregate	13.95	13.95	13.95	13.95
20mm Coarse Aggregate	27.93	25.13	25.13	25.13
Shred Tyre Rubber	0.00	2.80	2.80	2.80

Preparation of Test Specimens

Mixing was done in a small drum mixer as shown in Figure 3. Coarse aggregate, sand, rubber aggregate, cement, and water was added to the mixer respectively. After the addition of each material, the mixer continue to mix until the mixture became homogenous. Oiled steel molds of dimensions 150mm x 150mm x 150mm as shown in Figure 4 were filled in approximately three equal layers and compacted manually. After 24 hours of casting, the specimens were cured by soaking in to water until the age of testing. It was noticed that the compaction of the shred rubber group was very difficult because of the rubber property.

Figure 3: Rotary drum concrete mixer

Figure 4: Oiled steel moulds for concrete casting

Results and Discussions

In this section, the results of the slump test, bulk density and compressive strength of the concrete were discussed.

Slump Test Analysis

The results of the slump test analysis for control and rubber tyre concrete specimens are shown in Table 2 and Figure 5.

Table 2: Slump test for the different sizes of tyre rubber in concrete mix

Group	Size of Shred Tyre Rubber	Percentage of Shred Tyre Rubber (%)	Slump (mm)
Control (C30)	-	-	25
Specimen R10	10mm x 10mm	10	20
Specimen R20	20mm x 20mm	10	15
Specimen R30	30mm x 30mm	10	11

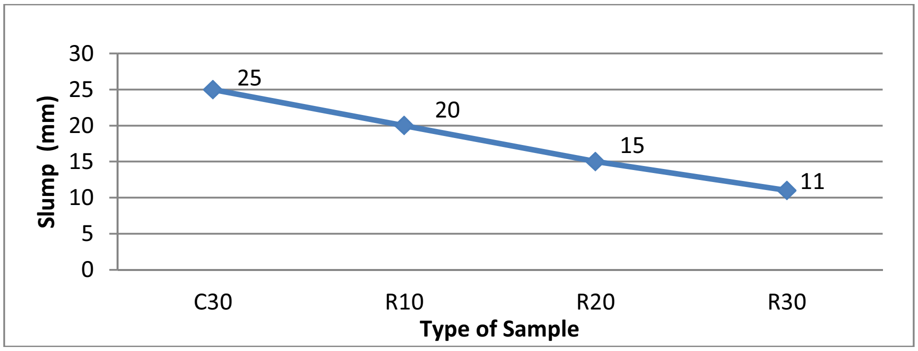

Figure 5: Graph slump test for the different size of tyre rubber in concrete mix

It could be seen from the above table and figure that the slump value for the control group (C30) is greater compared to the three specimens, which is the concrete that having 10% of shred rubber tyre that replace the 20mm coarse aggregate. The results also showed that the lowest slump value of the concrete is the sample R30, followed by R20 and R10. This is indicated that the greater the size of the pieces of tyre rubber that is mixed into the concrete, the workability properties of the concrete is decreased. The lower slump value for the big size of the tyre rubber is due to the rough texture and the angular shape of the shred tyre rubber aggregate.

Concrete Density

The density of a concrete is a measure of mass per unit volume. This experiment is performed to determine the density of the concrete for the control sample and three specimens sample that mixed rubber tyres with sized 10 mm (R10), 20 mm (R20) and 30 mm (R30). The results of the density of concrete in 7-days are presented in Table 3 and Figure 6 and the density of concrete in 28-days are presented in Table 4 and Figure 7.

Table 3: Bulk Density of the Concrete in 7-days

Type of Sample	Weight (kg)	Volume (m^3)	Density (kg/m^3)	Average of Density (kg/m^3)
C30 No. 1	8.10	0.0033	2,400.00	
C30 No. 2	8.20	0.0033	2,429.63	2,409.88
C30 No. 3	8.10	0.0033	2,400.00	
R10 No. 1	7.80	0.0033	2,311.11	
R10 No. 2	7.80	0.0033	2,311.11	2,320.99
R10 No. 3	7.90	0.0033	2,340.74	
R20 No. 1	7.60	0.0033	2,251.85	
R20 No. 2	7.60	0.0033	2,251.85	2,241.97
R20 No. 3	7.50	0.0033	2,222.22	
R30 No. 1	7.40	0.0033	2,192.59	
R30 No. 2	7.30	0.0033	2,162.96	2,182.71
R30 No. 3	7.40	0.0033	2,192.59	

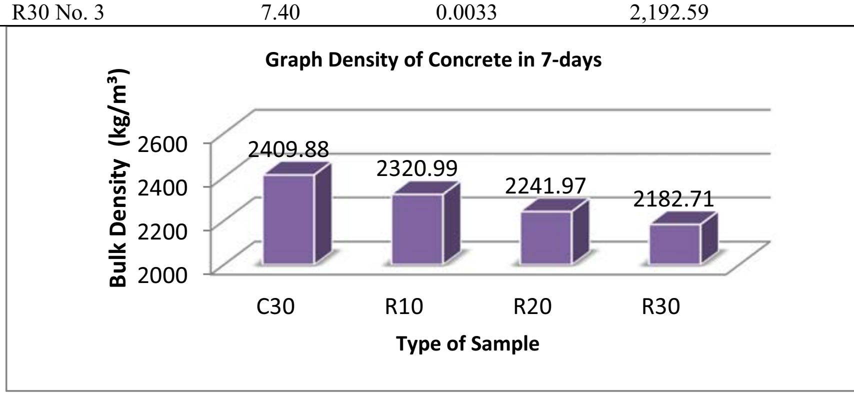

Figure 6: Graph density of concrete in 7-days

Table 4: Concrete density in 28-days

Type of Sample	Weight (kg)	Volume (m^3)	Density (kg/m^3)	Average of Density (kg/m^3)
C30 No. 1	8.20	0.0033	2429.63	
C30 No. 2	8.30	0.0033	2459.26	2419.75
C30 No. 3	8.00	0.0033	2370.37	
R10 No. 1	7.50	0.0033	2222.22	
R10 No. 2	7.60	0.0033	2251.85	2291.36
R10 No. 3	8.10	0.0033	2400.00	
R20 No. 1	7.40	0.0033	2192.59	
R20 No. 2	7.40	0.0033	2192.59	2212.34
R20 No. 3	7.60	0.0033	2251.85	
R30 No. 1	7.10	0.0033	2103.70	
R30 No. 2	7.30	0.0033	2162.96	2133.33
R30 No. 3	7.20	0.0033	2133.33	

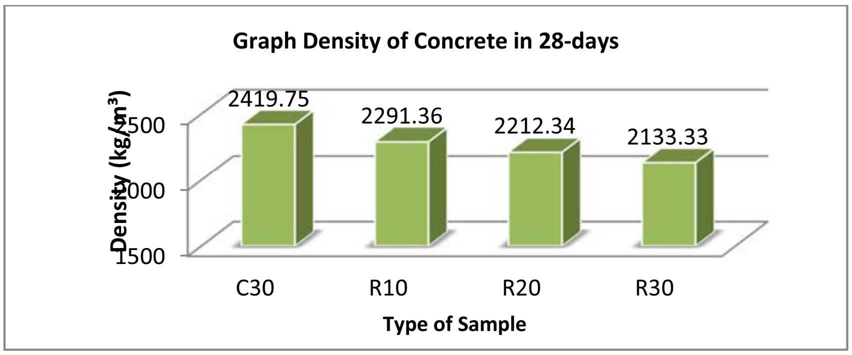

Figure 7: Graph of concrete density in 28-days

From the tables and figures above, it could be seen that concrete casted using the largest size of the shred tyre rubber, which is the sized 30 mm gave the lowest density compared to the other groups. This result indicated that the increase of the size of tyre rubber in the concrete mix the density decrease. The density of different size pieces of rubber tyres affects the density of concrete. The larger pieces of rubber tyre and angular shape makes the resulting space between the aggregate and rubber tyres. Thus, the decrease is due to the density of concrete rubber tyres that are smaller than the density of coarse aggregate.

Compressive Strength Test Analysis

The results of 7-days compressive strength tests for concrete mixture are shown in Table 5 and Figure 8. Meanwhile, the results of 28-days compressive strength test for the concrete mixture are shown in Table 6 and Figure

Table 5: Compressive strength of concrete in 7-days

Type of Sample	Load (kN)	Area (mm^2)	Compressive Strength (N/mm^2)	Average of Compressive Strength (N/mm^2)
C30 No. 1	560	22,500	24.89	
C30 No. 2	620	22,500	27.56	27.26
C30 No. 3	660	22,500	29.33	
R10 No. 1	520	22,500	23.11	
R10 No. 2	480	22,500	21.33	22.22
R10 No. 3	500	22,500	22.22	
R20 No. 1	335	22,500	14.89	
R20 No. 2	365	22,500	16.22	15.33
R20 No. 3	335	22,500	14.89	
R30 No. 1	230	22,500	10.22	
R30 No. 2	420	22,500	18.67	14.07
R30 No. 3	300	22,500	13.33	

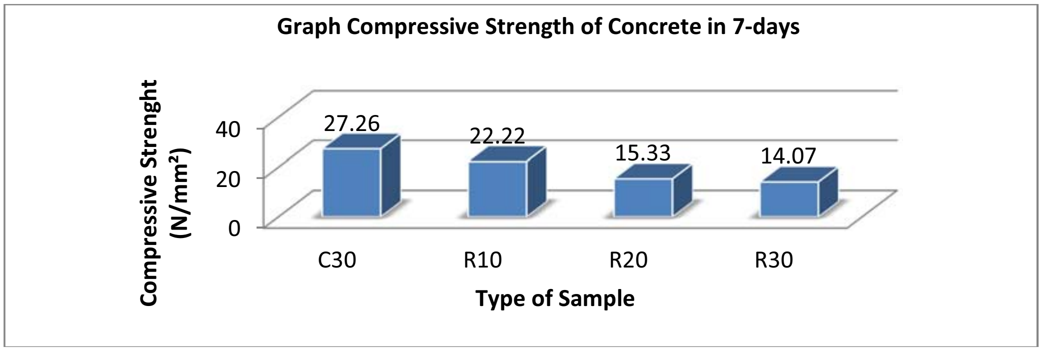

Figure 8: Graph of compressive strength of concrete in 7-days

Table 5 and Figure 8 above show that there was a significant reduction in the compressive strength of concrete when the different size of tyre rubber was used to replace the 20mm coarse aggregate in the concrete mixtures for the test of 7-days. The results also showed that only the control group exceed the target mean strength, which is 27.26 N/mm^2. The results also indicated that the largest size of the shred tyre rubber used in the concrete mixtures, the compressive strength of the concrete decrease.

Table 6: Compressive strength of concrete in 28-days.

Type of Sample	Load (kN)	Area (mm^2)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm²)
C30 No. 1	800	22500	35.56	
C30 No. 2	690	22500	30.67	33.63
C30 No. 3	780	22500	34.67	
R10 No. 1	690	22500	30.67	
R10 No. 2	710	22500	31.56	31.41
R10 No. 3	720	22500	32.00	
R20 No. 1	680	22500	30.22	
R20 No. 2	690	22500	30.67	29.85
R20 No. 3	645	22500	28.67	
R30 No. 1	530	22500	23.56	
R30 No. 2	595	22500	26.44	24.22
R30 No. 3	510	22500	22.67	

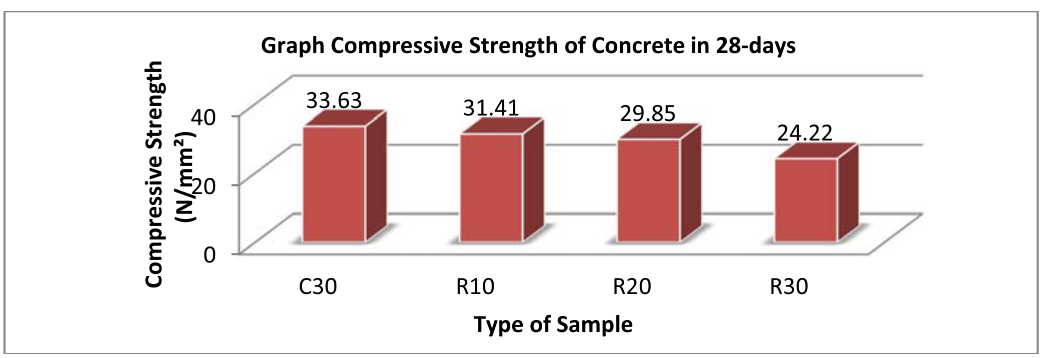

Figure 9: Graph compressive strength of concrete in 28-days

Table 6 and Figure 9 above show that there was only slight reduction of the compressive strength between the control group (C30) and the three specimen of different size of the tyre rubber (i.e. R10, R20 and R30) in 28-days. Interestingly, the results also show that both control group (C30) and the specimen with the tyre rubber sized 10 mm (R10) in 28-days exceed the target mean strength, which is 33.63 N/mm^2 for control group and 31.41 N/mm^2 for specimen R10. The statistical T-test analysis as shown in Table 7 also proves that there is no significant different between the control group (C30) and the specimen R10 with the t value = 1.4308, p value > 0.05.

This result indicated that the shred tyre rubber with sized 10 mm can be used to replace the coarse aggregate in the concrete mixtures.

Table 7: T-Test Analysis of Comparison Between Control Group (C30) and R10

	C30	*R10*
Mean	33.6333	31.4100
Variance	6.7840	0.4591
Observations	3.0000	3.0000
Pooled Variance	3.6215	
df	4.0000	
t Stat	**1.4308**	
P(T<=t) one-tail	**0.1128**	

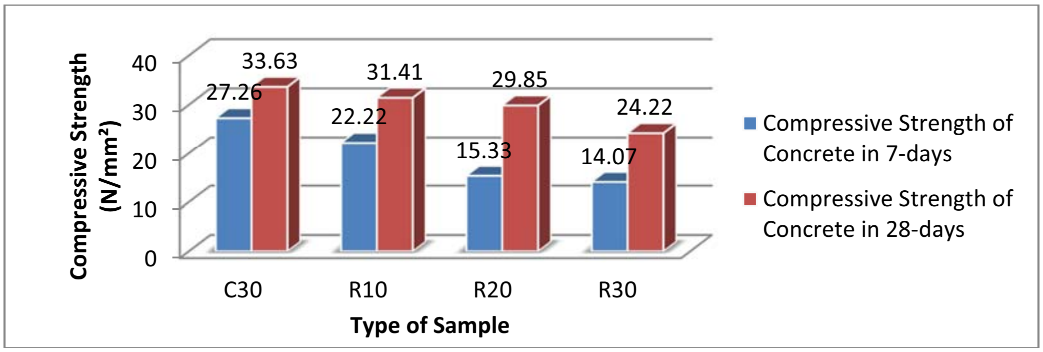

Figure 10: Graph comparison of compressive strength between 7-days and 28-days

Figure 10 shows the comparison of compressive strength of concrete mixtures between 7-days and 28-days for control group (C30) and the three types of specimens group (i.e. R10, R20 and R30). The results indicated that the compressive strength of the samples in 28-days is highest compared to the samples in 7-days. This means that the timeline is also affect the compressive strength, which is the more age of the concrete, the compressive strength increase.

Conclusion and Recommendation

Conclusion

This study investigated the effect of waste tyre rubber as a replacement to aggregate in concrete mixtures on the density and compressive strength of concrete. From the results of this study, the following conclusions are drawn:

1. The larger pieces of tyre rubber that is used to replace aggregate in the concrete mixtures, the workability of the experimental concrete sample shows a significant reduction in the concrete strength from 20% to 50% compared to the control concrete sample.
2. The density value of the experimental concrete samples is reduced when use the larger size of tyre rubber in the concrete mixture. Concrete containing shred rubber has a lower density compared to the control concrete sample. It is due to the density of the rubber tyre is lower as compared to coarse aggregate.
3. The compressive strength of the concrete containing shred rubber is reduced approximately 7% to 28% compared to the control concrete sample.
4. The concrete mixture that use a small size rubber tyres R10 has a higher compressive strength compared to concrete R20 and R30, which is use a larger size rubber tyres.
5. Normal concrete cracks easily and fragile compared to concrete containing shred tyre rubber, which is more elasticity.

Recommendation

1. To ensure the sample results are accurate, way of mixing concrete should be done properly in order to spread the rubber tyres randomly in the concrete mixtures. Thus, the experimental sample was mixed more accurately and not interfere the results.
2. It is recommended to test the strength of concrete with different type of rubber tyre vehicles such as bicycles, cars, and trucks.
3. It is recommended to add durability testing in the experiments.
4. It is recommended to use small pieces of rubber tyres (crumb) in the concrete mixture.
5. It is recommended to use additives in concrete mixture to see the effectiveness and performance of concrete mixed use tyre rubber sheets.
6. It is recommended to apply different curing method on samples such as wet curing, dry curing, pickling salt water and others to know the effect of curing method on strength of concrete.
7. The increase of the percentage of rubber tyres will cause the lower of the density ≤ 1800 kg/m^3 of concrete and allow the concrete to be a lightweight concrete.

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