

Study on Mechanical Properties of Concrete Containing Rubber Fine Aggregate as a Replacement Material in Concrete Mix

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Abstract

This research involved the production of Rubber waste material as a replacement material for natural fine aggregates in the concrete mix. The first objectives of this study were to determine the compressive strength and density of concrete containing Rubber Fine Aggregate (RFA). The second objective is to evaluate the effectiveness of Rubber Fine Aggregate (RFA) needed as replacement materials in concrete mix. Due to the disposal of waste tires which had problems because tires do not biodegrade landfill sites become overcrowded and the prices of natural aggregate begin to increase due to the limited resources. This research was made to reduce of dependence on raw materials and reduce pollution caused by the waste of tires. In methodology, the waste tires were cut into smaller pieces during the shredding process. The design of the concrete mix was calculated using the Design of Normal Concrete Mix and the percentage of concrete containing RFA was set at 0%, 3%, 6%, and 9%. Compressive strength and density test will be conducted where 24 concrete cubes were tested at the age 7 and 28 days after curing process. Based on data analysis and result shows that 3% of the percentage containing Rubber Fine Aggregate gives minimum density and maximum compressive strength compared with 6% and 9%. However, objective of this research not achieve because there have two error which are wrong type of cement and calculation of design of the concrete mix during material preparation.

1. Introduction

Manufacturers produce tires locally to meet regional demand, but once these tires reach the end of their useful life, they often end up stockpiled, leading to serious health risks, environmental hazards, and aesthetic issues. There are not enough landfills to accommodate the vast number of waste tires, which take an incredibly long time to biodegrade. A stark reminder of the dangers posed by tire dumps is the 1999 incident in Westley, California, where a lightning strike ignited a massive tire dump. The resulting fire burned for 36 days, releasing pyrolytic oil that contaminated nearby streams and water bodies, causing significant environmental damage [1]. By using the method of recycling a large amount of tire rubber waste can produce a new type of concrete containing RFA. The uses RFA in concrete mix has lower compressive strength, elastic modulus, splitting tensile

and flexural strengths than normal concrete, which also found that adding rubber to normal aggregates reduces structural strength properties for structural applications [2].

This research focuses on RFA has been used to replaced natural fine aggregate in concrete mix. RFA is made from waste material which is rubber tires from vehicles including cars and lorry. The research is focused on the use of RFA in residential construction applications which are foundation, beam, column and slabs for grade 30. The dimension of the cube test that was used is 100mm × 100mm × 100mm for 24 cubes. The Recycle Rubber was acquired from the rubber and tire recycling with size 1-3mm at factory in Parit Sulong, Johor. All the sample preparations and testing have been done are at the Concrete Technology Workshop at FTK, UTHM Pagoh Campus.

2. Methodology

Flow chart of methodology was prepared as shown in Figure 1. Preparing a flow chart is important to make this research run smoothly.

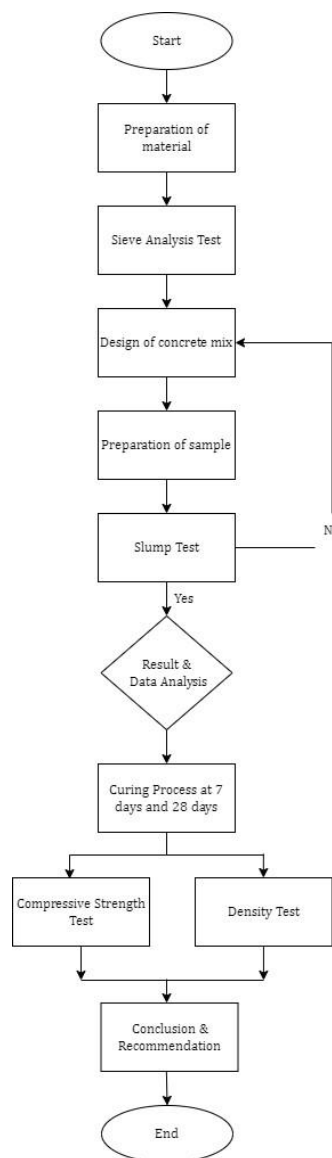


Fig. 1 Flowchart of methodology

2.1 Material

This research required several key materials to produce concrete cubes, including cement, fine aggregate, coarse aggregate, and water. Two types of fine aggregate were used: natural fine aggregate and rubber fine aggregate, with the latter made from vehicle tires to replace the former in the concrete mix. These materials were prepared to ensure the experiment proceeded smoothly. The first phase is preparation of materials before concrete mix to determine the suitable and standardized materials.

2.1.1 Rubber Fine Aggregate

RFA used as replacement material for natural fine aggregate in concrete mix and also can reduce the use of river sand. RFA produced from waste tires at factory with size 1-3mm. Rubber is naturally less dense than most traditional construction aggregates such as sand and contributing to its lightweight properties [3]. However, excessive use of RFA in concrete mix can reduce the strength of concrete compared to normal concrete.



Fig. 2 Rubber Fine Aggregate

2.2 Design of Concrete Mix (DOE Method)

Mix design is the process of selecting suitable materials and determining their proportions of RFA containing in concrete mix. The dimension of concrete cube is 100mm × 100mm × 100mm for 24 cubes. Each cube mixture will contain an additional 20%, for each proportion it must be done to ensure that the possibility of a lack of mixture does not occur when performing the concrete cube.

Table 1 The quantity of the material used in concrete mix design (DOE Method)

Quantities	Cement (kg)	Water (kg or liter)	Fine Aggregate (kg)	Coarse Aggregate (kg) 20 mm
Per m ³ to nearest 5 kg	390	210	685	1115
Per trial mix of 28.8 × 10 ⁻³ m ³	11.23	6.05	19.73	32.11

Table 2 The total weight of Rubber Fine Aggregate in natural fine aggregate for per trial mix for 28.8 × 10⁻³ m³ for Cube

Percentage of RFA (%)	Total weight of RFA (kg)	Total weight of Natural Fine Aggregate (kg)
0	0	4.93

3	0.15	4.78
6	0.30	4.63
9	0.44	4.49

2.3 Laboratory Test

This research focuses on RFA as replacement material containing in concrete mix. This research focuses on RFA as replacement material containing in concrete mix. The total cubes have been prepared is 24 concrete cubes for compressive strength test and density test. Every testing using same sample which is 24 cubes. Each sample will be testing after curing process at age 7 days and 28 days.

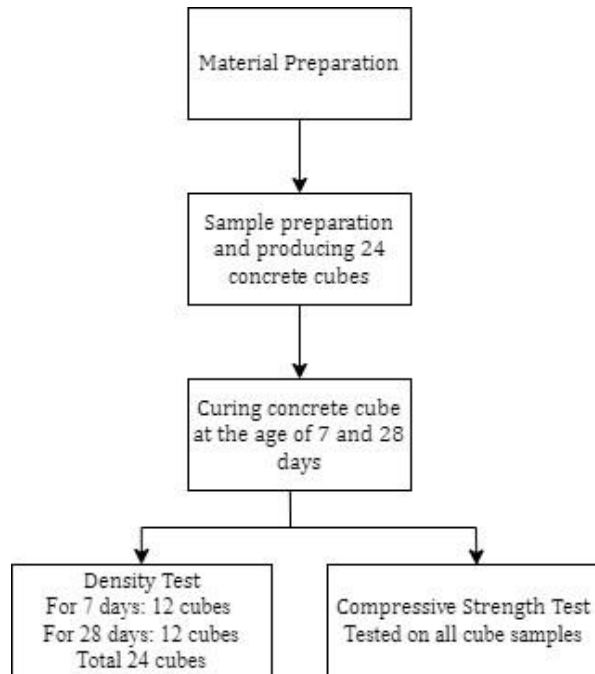


Fig. 3 Flowchart of laboratory test

3. Results and Discussion

3.1 Slump Test

Table 3 shows that 0%, 3%, 6% and 9% of the percentages containing rubber fine aggregate were within the range proposed in the concrete mix design, which is 30 mm to 60 mm. The slump value decreases with an increase in the percentage of RFA. This is because RFA not absorb water like sand [4]. This leads to a reduction in the water available for lubrication in the concrete mix, making it harder and less workable.

Table 3 Result of slump test

Percentage of RFA	Collapse Height (mm)	Type of Collapse	Degree of Workability
0%	55	True slump	Medium
3%	45	True slump	Medium
6%	43	True slump	Medium
9%	41	True slump	Medium

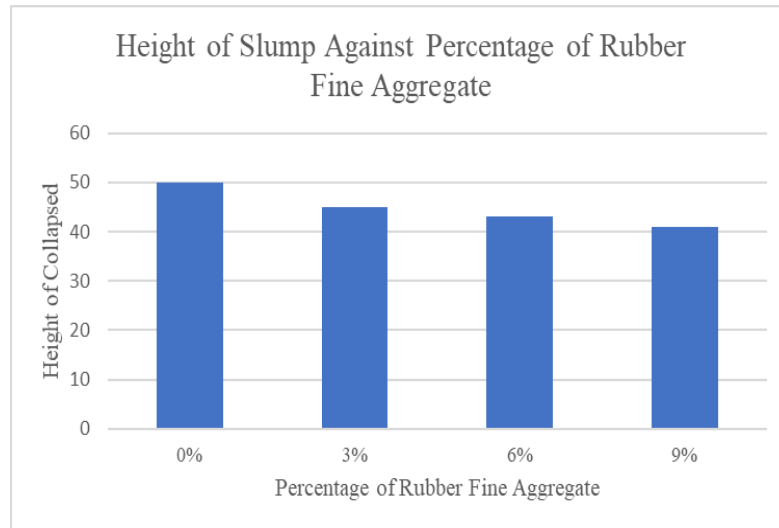


Fig.4 Graph of height of slump against percentage of rubber fine aggregate

3.2 Compressive Strength Test

Table 4 shows that 3% of RFA containing in concrete mix have maximum compressive strength which is 25.35 MPa compare to 6% and 9% of RFA. Control has 27.5 MPa less than 30 MPa as shown in design of concrete mix calculation for Ordinary Portland Cement (OPC). This result fail because the error using type of cement which is composite cement, has compressive strength 32.5 MPa at age of 28 days [5].

Table 4 Result of compressive strength test with different percentage of Rubber Fine Aggregate at the age 7 & 28 days

Percentage of RFA	Average Strength of Concrete Cube (MPa)	
	7 days	28 days
0%	27.52	26.88
3%	25.35	23.43
6%	18.73	19.85
9%	14.41	15.47

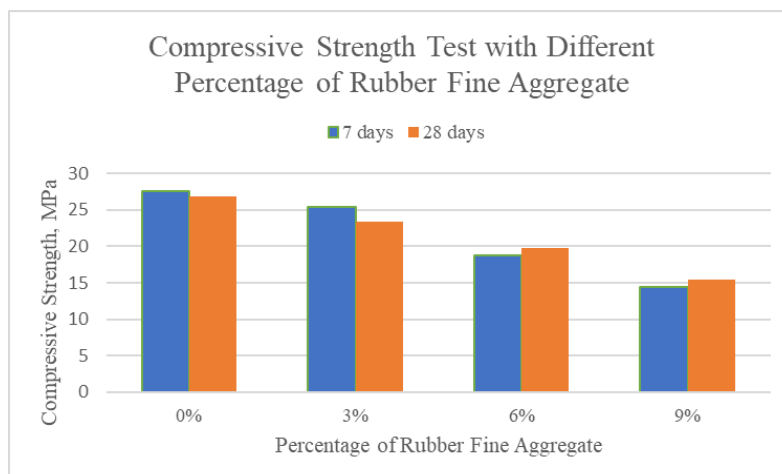


Fig. 5 Graph of compressive strength test with different percentage of ESP and POBA at the age 7 and 28 days

3.3 Density Test

Based on Table 5 shows the result of density failed because normal concrete has a density of roughly 2400 kg/m³ if using Ordinary Portland Cement (OPC). The uses of composite cement in concrete mix reduce the density of concrete compare than normal concrete. Density of concrete containing RFA decreases when the percentage of RFA increases, due to RFA have a much lower density depending on particle size and moisture content. This considerable difference in density can have implications for the overall density of the concrete mixture when rubber fine aggregate is used as a replacement for natural fine aggregate.

Table 5 Density data

Percentage of RFA	Average Density (kg/m ³)	
	7	28 days
	days	
0%	2203.33	2220.00
3%	2210.00	2236.67
6%	2160.00	2186.67
9%	2103.33	2133.33

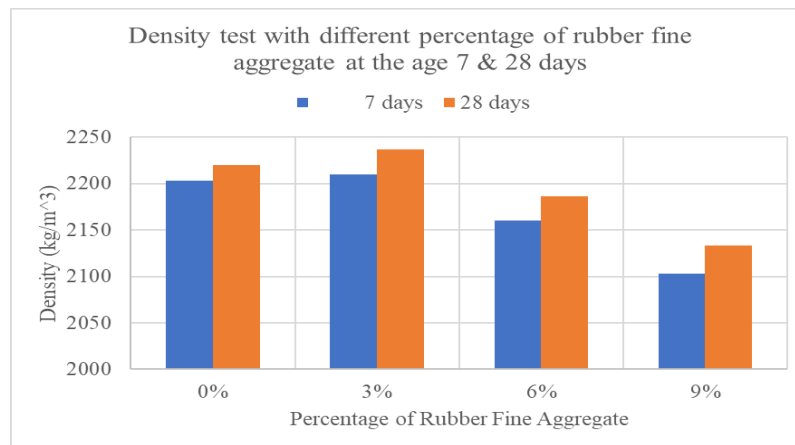


Fig. 6 Graph of density test with different percentage of RFA at the age 7 and 28 days

4. Conclusion

Conclusion, the objective of this study not achieve because of wrong use of cement and calculation for design of concrete mix for OPC. The result of compressive strength less than 30 MPa as calculate DOE for OPC, while result of density below 2400 kg/m³ for normal concrete compressive strength. However, the use of rubber fine aggregate in concrete mixes is an innovative approach with several potential benefits. Firstly, it contributes to sustainability by recycling used tires, thus reducing waste and the environmental impact associated with tire disposal. Additionally, incorporating rubber aggregate can make concrete lighter, which is advantageous in applications where weight reduction is important. Rubber particles also enhance the flexibility and impact resistance of concrete, potentially leading to fewer cracks and improved durability. Furthermore, concrete with rubber aggregate can offer better sound insulation, making it useful for noise reduction in construction. The rubber particles act as a cushion, which can reduce the likelihood of cracks forming in the concrete, contributing to its overall resilience. Among recommendation for this study are the correct selection of cement and the correct calculation of design of concrete mix according to the grade to be designed.

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