

ANALYSIS OF THE USE OF RUBBER SANDAL WASTE AS A SUBSTITUTE FOR SOME OF THE COARSE AGGREGATE IN CONCRETE

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ABSTRACT

Based on SNI 1974: 2023, concrete is a composite material that hardens over time and has compressive strength at 28 days. Concrete is widely used because of its advantages, despite its disadvantages such as weight, cracking, and high formwork costs. This study reviews rubber sandal waste as a substitute for coarse aggregate at 15% and 30% to reduce the weaknesses of concrete. The background is the growth of industry, particularly the rubber sandal industry, which produces large amounts of waste. The test results show that concrete without waste (0%) achieved a compressive strength of 18.94 MPa (7 days) and 34.74 MPa (14 days), exceeding the SNI 1974: 2023 limit. With a rubber sandal waste composition of 15%, the compressive strength was 16.65 MPa (7 days) and 21.24 MPa (14 days), only meeting the 7-day requirement. The 30% composition showed similar results. This means that the use of rubber sandal waste up to 30% reduces compressive strength performance at 14 days.

Keywords: Concrete, Compressive Strength, Rubber Sandal Waste, Coarse Aggregate Substitution, Testing

INTRODUCTION

Based on SNI 2847:2013, concrete is a composite material consisting of a mixture of water, fine aggregate, coarse aggregate, and Portland cement or other hydraulic cement, without additives or supplements. Concrete hardens over time and reaches its characteristic compressive strength (f'_c) at 28 days of age. Concrete is widely used in construction such as buildings, roads, bridges, and dams, due to its advantages such as high compressive strength, fire resistance, long service life, and low maintenance costs. However, concrete has disadvantages, including: high formwork costs, potential cracking due to live loads and shrinkage, and a heavier structure compared to steel. Further research is needed to find concrete substitute materials that can reduce the disadvantages of concrete. Improvements in the economic and industrial sectors, especially those related to urbanization, have increased the demand for industrial products. The manufacturing industry contributes significantly to the national GDP, with this sector contributing 18.52% in the second quarter of 2024. One of the rapidly growing industries is the rubber sandal industry, which produces a lot of waste. Therefore, the author is interested in researching the use of rubber sandal waste as a substitute for some of the coarse aggregate in concrete, with waste levels of 15% and 30%. These levels were chosen in order to find a balance between concrete quality and waste utilization, as well as to obtain results that can be analyzed effectively.

METHODS

The number of test specimens used in this study was determined based on the variation in concrete mix and test age. There were three mix variations used, namely normal concrete without the addition of rubber sandal waste, concrete with the addition of 15% rubber sandal waste, and concrete with the addition of 30% rubber sandal waste. For each mixture variation, concrete compressive strength testing was carried out at three different ages, namely at 7 days, 14 days, and 28 days.

Table 1. Determination of the Number of Research Samples

No.	Test Object Sample	Age (Days)			number of test items
		7	14	28	
1.	Normal Concrete Variations	3	3	3	9
2.	Variations in Rubber Sandal Waste 15%	3	3	3	9
3.	Variations in Rubber Sandal Waste 30%	3	3	3	9
Number					27

Source: Research Data Processing, 2025.

Research on the compressive strength of concrete using rubber sandal waste as a substitute for some of the coarse aggregate was conducted at the Karawang Batching Plant Laboratory. In this study, rubber sandal waste will be used as a substitute for some of the coarse aggregate and will be conducted from May to June 2025.



Figure 2 Pioneer Batching Plant, East Karawang, West Java



Figure 3 Research Flow Chart

Preparation of tools and materials consists of sieves, scales, measuring cups, ovens, cement spoons, concrete mixers, cylinder molds, concrete compressive strength testing machines, wheelbarrows, and slump test equipment. The stages of test specimen production consist of the mix design stage, the mixing stage, the slump test stage, the test specimen curing stage, and the concrete compressive strength test.

RESULTS AND DISCUSSION

The mix design used in this study was designed with the aim of achieving a slump value of 12 ± 2 cm, which indicates the workability of fresh concrete mix. This slump value was chosen so that the concrete would be easy to work with in the field without compromising structural quality. In addition, the specified planned compressive strength is $f'_c = 25$ MPa, which is known as K-300 in concrete quality units. This value indicates that the concrete is designed to withstand compressive loads of up to 25 MPa at 28 days after curing, which is the general standard for medium structural construction such as floors, columns, and building beams. The mix design planning includes the proportions of all the main components that make up porous concrete, namely cement, coarse aggregate (gravel or crushed stone), and water. The composition of these materials has been carefully calculated to achieve a balance between strength, durability, ease of workmanship, and material efficiency. The details of the concrete mix composition based on the mix design with the target slump and compressive strength can be seen in the table below:

Table 2 Total Number of Samples

No.	Material	Description	Volume	Unit
1.	Cement	Indocement	330	Kg
2.	Coarse aggregate, maximum 2.5 cm	Rumpin	1334	Kg
3.	Water		165	Liter

From the results of the mix design calculations that have been carried out previously, the theoretical mixture proportions for each 1 m³ of concrete were obtained. These proportions include the measurements of each constituent material of the concrete, namely cement, coarse aggregate, and water, which are calculated carefully in order to produce concrete with the planned quality, namely f_c = 25 MPa or equivalent to K-300 quality. The results of this mix design were then used as a reference in determining the material requirements for the volume of concrete to be used in making the test specimens. The volume of concrete mix required in this study was adjusted to the number and size of the test specimens to be made. The number of test specimens planned included 27 cylindrical test specimens with dimensions of 15 cm in diameter and 30 cm in height. All test specimen sizes have been converted into meters to facilitate the calculation of the total volume of concrete required. Referring to these dimensions, the volume of each cylindrical test specimen is calculated using the cylinder volume formula, namely $\pi \times r^2 \times t$, while the volume of the block test specimen is calculated using the formula length $\times$ width $\times$ height. After obtaining the individual volumes of each test specimen, the total volume of all test specimens was added up and then compared to the proportion of concrete mix per cubic meter. This step was intended to determine the exact amount of materials that had to be prepared on a laboratory scale, so that there would be no shortage or waste of materials during the mixing and molding process of the test specimens. The calculation of the volume of normal porous concrete, variation 1, and variation 2 for cylindrical test specimens is as follows:

$$\begin{aligned}
 \text{Volume} &= 9 \text{ pieces} \times \text{cylinder volume} \\
 &= 9 \text{ pieces} \times (\text{circle area} \times \text{height}) \\
 &= 9 \text{ pieces} \times (1/4 \times \pi \times d^2 \times t) \\
 &= 9 \text{ pieces} \times (1/4 \times 3.14 \times 0.152 \times 0.3) \\
 &= 0.0477 \text{ m}^3
 \end{aligned}$$

Thus, the test mixture proportion is 0.0477 m³

Table 3 Mix Design for 1 m³

No.	Material	Description	Volume	Unit
1.	Cement	Indocement	312	Kg
2.	Coarse aggregate, maximum 2.5 cm	Rumpin	810	Kg
3.	Fine Aggregate	black sand	346	Kg
4.	Stone Dust	Purwakarta	642	Kg
5.	Water		165	Liter

Table 4 Mix Design for Normal Concrete Cylinder Test Specimens

Description	Water	Cement	Aggregate		stone dust
			Fine	Coarse	
Every 1 m ³	165 liter	312 kg	346 kg	810 kg	642 kg
Every 0,0477 m ³	0,0477 m ³ x 165 liter = 7,8705 liter	0,0477 m ³ x 312 kg = 14,8824 kg	0,0477 m ³ x 346 kg = 16,5042 kg	0,0477 m ³ x 810 kg = 38,6370 kg	0,0477 m ³ x 642 kg = 30,6234 kg

Table 5 Mix Design for Cylindrical Concrete Test Specimens Variation 1

Description	Water	Cement	Aggregate			stone dust
			Fine	Coarse		
				Rubber Sandal Waste (15%)	Split (85%)	
Every 1 m ³	165 liter	312 kg	346 kg	121,5 kg	688,5 kg	642 kg
Every 0,0477 m ³	0,0477 m ³ x 165 liter = 7,8705 liter	0,0477 m ³ x 312 kg = 14,8824 kg	0,0477 m ³ x 346 kg = 16,5042 kg	0,0477 m ³ x 121,5 kg = 5,7956 kg	0,0477 m ³ x 688,5 kg = 32,8415 kg	0,0477 m ³ x 642 kg = 30,6234 kg

Table 6 Mix Design for Cylindrical Concrete Test Specimens Variation 2

Description	Water	Cement	Aggregate			stone dust
			Fine	K Coarse		
				Rubber Sandal Waste (30%)	Split (70%)	
Every 1 m ³	165 liter	312 kg	346 kg	243 kg	567 kg	642 kg
Every 0,0477 m ³	0,0477 m ³ x 165 liter = 7,8705 liter	0,0477 m ³ x 312 kg = 14,8824 kg	0,0477 m ³ x 346 kg = 16,5042 kg	0,0477 m ³ x 243 kg = 11,5911 kg	0,0477 m ³ x 567 kg = 27,0459 kg	0,0477 m ³ x 642 kg = 30,6234 kg

The results of the cylinder-shaped normal concrete compressive strength test can be seen in Table 7 below.

Table 7 Normal Concrete Compressive Strength

No.	Date		Age	Weight	Load	C. Strength	Remark	Rata-rata
	Casting	Test	(Days)	(Gram)	(kN)	(MPa)	%	(MPa)
1.	24 Jun 25	01 Juli 2025	7	12220	334,3	18,92	75,7	18,94
2.	24 Jun 25	01 Juli 2025	7	12260	339,5	19,22	76,9	
3.	24 Jun 25	01 Juli 2025	7	12220	330,0	18,68	74,7	
4.	24 Jun 25	08 Juli 2025	14	12340	406,0	22,98	91,9	23,16
5.	24 Jun 25	08 Juli 2025	14	12380	409,0	23,15	92,6	
6.	24 Jun 25	08 Juli 2025	14	12340	412,5	23,35	93,4	
7.	23 Jun 25	22 Juli 2025	28	12360	501,3	28,38	113,5	27,86
8.	23 Jun 25	22 Juli 2025	28	12320	483,7	27,38	109,5	
9.	23 Jun 25	22 Juli 2025	28	12400	491,4	27,82	111,3	

The results of the cylinder-shaped concrete compressive strength test for variation 1 can be seen in Table 8 below.

Table 8 Concrete Compressive Strength for Variation 1

No.	Date		Age	Weight	Load	C. Strength	Remark	Rata-rata
	Casting	Test	(Days)	(Gram)	(kN)	(MPa)	%	(MPa)
1.	24 Jun 25	01 Juli 2025	7	12320	303,0	17,15	68,6	16,65
2.	24 Jun 25	01 Juli 2025	7	12220	283,2	16,03	64,1	
3.	24 Jun 25	01 Juli 2025	7	12300	296,6	16,79	67,2	
4.	24 Jun 25	08 Juli 2025	14	12400	374,3	21,19	84,8	21,24
5.	24 Jun 25	08 Juli 2025	14	12240	384,1	21,74	87,0	
6.	24 Jun 25	08 Juli 2025	14	12340	367,4	20,80	83,2	

7.	23 Jun 25	22 Juli 2025	28	12600	396,6	22,45	89,8	22,34
8.	23 Jun 25	22 Juli 2025	28	12420	388,9	22,01	88,1	
9.	23 Jun 25	22 Juli 2025	28	12340	398,3	22,55	90,2	

The results of the cylinder-shaped concrete compressive strength test for variation 2 can be seen in Table 9 below.

Table 9 Concrete Compressive Strength for Variation 2

No.	Date		Age	Weight	Load	C. Strength	Remark	Rata-rata
	Casting	Test	(Days)	(Gram)	(kN)	(MPa)	%	(MPa)
1.	24 Jun 25	01 Juli 2025	7	12240	276,8	15,67	62,7	16,57
2.	24 Jun 25	01 Juli 2025	7	12260	292,3	16,55	66,2	
3.	24 Jun 25	01 Juli 2025	7	12340	309,0	17,49	70,0	
4.	24 Jun 25	08 Juli 2025	14	12380	385,4	21,82	87,3	21,15
5.	24 Jun 25	08 Juli 2025	14	12380	367,8	20,82	83,3	
6.	24 Jun 25	08 Juli 2025	14	12300	367,4	20,80	83,2	
7.	23 Jun 25	21 Juli 2025	28	12380	402,2	22,77	91,1	22,43
8.	23 Jun 25	21 Juli 2025	28	12420	391,4	22,16	88,6	
9.	23 Jun 25	21 Juli 2025	28	12340	394,9	22,35	89,4	

The results of testing the compressive strength of normal concrete with f'_c 25 MPa and the compressive strength of concrete containing rubber sandal waste with a quality of f'_c 25 MPa can be seen in Figure 4 below.

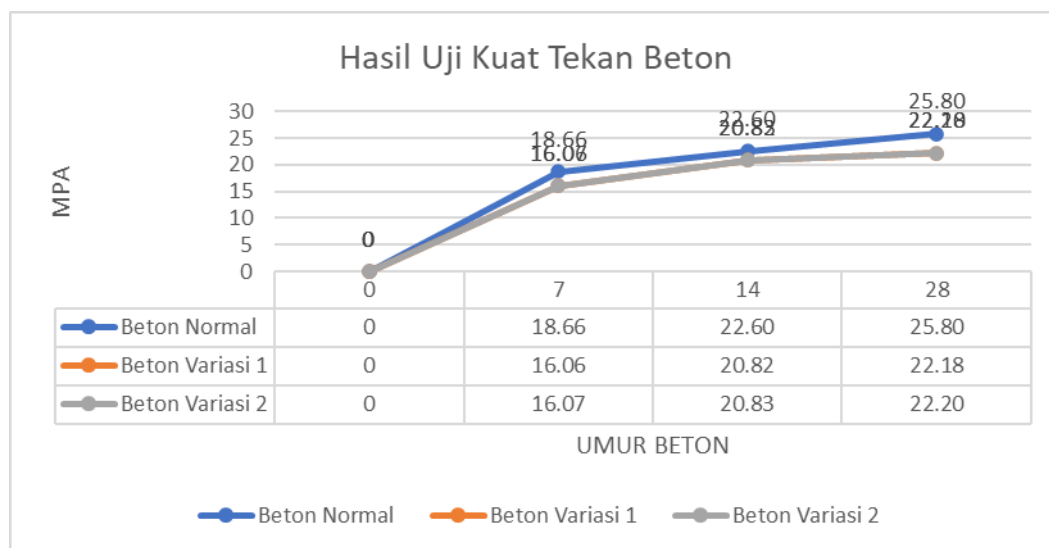


Figure 4. Results of Normal Concrete Strength Test, Variation 1 and Variation 2

When comparing the compressive strength of normal concrete with concrete that uses rubber sandal waste mixture as a substitute for part of the aggregate at 28 days of age, there is a decrease of:

- Concrete using 15% rubber sandal waste + 85% coarse aggregate
28 days = $\frac{25-22,34}{25} \cdot 100\% = 10.64\%$ (Decrease)
- Concrete using 30% rubber sandal waste + 70% coarse aggregate
28 days = $\frac{25-22,43}{25} \cdot 100\% = 10.28\%$ (Decrease)

The average compressive strength of normal concrete at 28 days is 27.86 MPa, exceeding the planned compressive strength of 25 MPa, while the average compressive strength of concrete using 15-30% rubber sandal waste at 28 days is 22.34 MPa and 22.43 MPa, it can be concluded that the addition of rubber sandal waste as a substitute for some of the coarse aggregate affects the decrease in the planned concrete quality.

CONCLUSIONS

Based on the research that has been conducted, several conclusions have been drawn, including the following:

- 1) Based on the table of concrete compressive strength tests and rubber sandal waste as a substitute for coarse aggregate for a composition of 0%, the average concrete compressive strength for 7 days was 18.94 MPa, for 14 days was 23.16 MPa, and for 28 days was 27.86 MPa. From these data, the percentage increase in concrete compressive strength using rubber sandal waste for a composition of 0% was obtained, starting from 7 days of age with an average value of 75.76%, 14 days of age with an average value of 92.83%, and 28 days of age with an average value of 111.43%. where these data results have exceeded the concrete compressive strength requirements according to SNI 2847: 2019, namely 7 days of age with a minimum limit of 65%, 14 days of age with a minimum limit of 88%, and 28 days of age with a minimum limit of 100%.
- 2) Based on the table of concrete compressive strength tests and rubber sandal waste as a substitute for coarse aggregate for a composition of 15%, the average concrete compressive strength for 7 days was 16.65 MPa, for 14 days it was 21.24 MPa, and for 28 days it was 22.34 MPa. From these data, the percentage increase in concrete compressive strength using rubber sandal waste for a composition of 15% at 7 days was obtained with an average value of 66.63%, at 14 days, the average value was 85%, and at 28 days, the average value was 89.7%. From these data, it can be concluded that at 7 days, the concrete compressive strength exceeded the compressive strength requirements according to SNI 2847: 2019, which stipulates a minimum limit of 65% for 7 days. However, at 14 days, the average concrete compressive strength was 85%, and at 28 days, the average concrete compressive strength was 89.37%, which did not meet the minimum requirements of 88% and 100%.
- 3) Based on the table of concrete compressive strength tests and rubber sandal waste as a substitute for coarse aggregate for a composition of 30%, the average concrete compressive strength value for 7 days is 16.57 MPa, for 14 days is 21.15 MPa, and for 28 days is 22.43 MPa. From the data above, the percentage increase in concrete compressive strength using rubber sandal waste for a composition of 30% at 7 days was found to be 66.3% on average, and at 14 days, the average value is 84.6%. These data show that at 7 days, the concrete compressive strength has exceeded the concrete compressive strength requirement according to SNI 2847: 2019 for 7 days with a minimum limit of 65%, but at 14 days, the average average compressive strength of concrete obtained was 84.6%, which did not reach the minimum limit required, which is 88%. At 28 days of age, the average compressive strength of concrete obtained was 89.70%, which also did not reach the minimum limit required, which is 100%.
- 4) When comparing the compressive strength of normal concrete with concrete that uses rubber sandal waste as a substitute for some of the coarse aggregate at 28 days of age, there is a decrease of:
 - Concrete using 15% rubber sandal waste + 85 coarse aggregate
28 days = $(25-22.34)/25 \cdot 100\% = 10.64\%$ (Decrease)
 - Concrete using 30% rubber sandal waste + 70 coarse aggregate
28 days old = $(25-22.43)/25 \cdot 100\% = 10.28\%$ (Decrease)
- 5) The average compressive strength of normal concrete at 28 days is 27.86 MPa, exceeding the planned compressive strength of 25 MPa, while the average compressive strength of concrete using 15-30% rubber sandal waste at 28 days is 22.34 MPa and 22.43 MPa, respectively. Therefore, it can be concluded that the addition of rubber

sandal waste as a partial replacement for coarse aggregate affects the decrease in the planned concrete quality.

- 6) From the results of testing the compressive strength of normal concrete with a quality of f'_c 30 MPa and the compressive strength of concrete with 15% and 30% rubber sandal waste with a quality of f'_c 30 MPa, it is known that when comparing the compressive strength of normal concrete with concrete that uses a mixture of rubber sandal waste as a substitute for part of the coarse aggregate at 7 days of age, there is a decrease of:

- Concrete using 15% rubber sandal waste + 85% coarse aggregate
Age 7 days = $(30-16.54)/30 \cdot 100\% = 44.87\%$ (Decrease)
- Concrete using 30% rubber sandal waste + 70% coarse aggregate
7 days old = $(30-16.17)/30 \cdot 100\% = 46.10\%$ (Decrease)

The average compressive strength of normal concrete at 7 days is 18.37 MPa, which does not exceed the planned compressive strength of 30 MPa, while the average compressive strength of concrete using 15-30% rubber sandal waste at 28 days is 16.54 MPa and 16.17 MPa, it can be concluded that both f'_c 25 MPa and f'_c 30 MPa with the addition of rubber sandal waste as a partial replacement for coarse aggregate still affect the decrease in the planned concrete quality.

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