
UTILIZATION OF CONCRETE WASTE AS A SUBSTITUTE FOR COARSE AGGREGATE IN CONCRETE

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ABSTRACT

The use of concrete waste as a substitute for coarse aggregate in concrete mixtures is one alternative for utilizing construction waste that cannot be used. Concrete waste is used as a substitute for split stone, with variable usage rates of 0%, 25%, 50%, 75%, and 100%. The tests in this study were conducted on the 7th, 14th, 21st, and 28th days of the concrete sample age and were tested using a concrete compressive strength tester. This study aims to find safe values, utilization, and innovations regarding the utilization of construction waste so that it can be reused. This study refers to K-300 concrete as a reference for the composition of the test results. This study found that all variables met the K-300 requirements at 28 days of testing. At 7 and 14 days of testing, the 100%, 75%, and 50% concrete waste mixture variables did not meet the requirements because the compressive strength test values did not meet the 65% strength requirement. Thus, the substitution of 25% concrete waste was deemed to meet the requirements because the test on day 7 yielded a value of 16.9 MPa, on day 14 a value of 19.91 MPa, and on days 21 and 28 values of 22.33 MPa and 25.99 MPa, respectively. The 25% concrete waste sample from four tests produced values that met the requirements and were considered suitable for use based on the results of this study.

Keywords: Coarse aggregate, concrete waste, concrete mix.

Introduction

Concrete is a widely used building material. Concrete is made by mixing cement, water, and aggregate in specific proportions, and it hardens within a certain period of time. According to SNI 15-1990-03, concrete is a mixture of cement, water, and aggregate, with or without additional ingredients, that forms a solid mass. Population growth and economic improvement in Indonesia have made infrastructure development, such as buildings, bridges, roads, and various other public facilities, one of the top priorities [1]. With the rapid development and numerous changes caused by increasingly dense human activity, the methods and quality of buildings and materials produced have also

developed [2] [3].

Natural resources (NR), which are very limited in quantity as a form of concrete construction material, pose a problem in terms of the availability of concrete material, for which a solution is urgently needed [4]. A construction technology is very important to reduce the use of natural materials and can have a positive impact on new concrete innovations [5]. One way to reduce the use of natural materials is to reuse concrete waste for new concrete [6] [7] [8]. This process is an effective method of processing concrete waste, particularly through crushing to produce coarse aggregates that can serve as a substitute for natural crushed stone [9]. The development of recycling is a profitable alternative for

concrete materials, because the aggregates used are discarded aggregates. The utilization of concrete waste can reduce the waste produced from unused building debris, which can be used as a substitute for coarse aggregates. Recycled aggregates have several qualities, physical and chemical properties [10] [11]. These qualities result in differences in the properties of the concrete material produced and tend to reduce the compressive strength of the concrete [12]. Concrete waste is taken from the demolition of buildings and broken into small pieces like the size of split stones to replace coarse aggregates in concrete.

This study was conducted to test the feasibility of using concrete waste as a substitute for coarse aggregate in concrete mixtures using K-300 concrete quality as a reference. The mix design process for normal K-300 concrete with a volume of 1m³ used the SNI 7394-2002 method with a mixture of 215L of water, 413kg of cement, 681kg of fine aggregate, and 1021kg of coarse aggregate. The composition value of the K-300 concrete mixture will be converted based on the requirements for each concrete compressive strength test sample, namely, cylinders. When making concrete cylinder samples, the author conducted tests on the samples using the Slump Test based on SNI 03-1972-1990 and concrete compressive strength tests based on SNI 03-1974-1990. This study required four types of samples consisting of 25%, 50%, 75%, and 100% of concrete waste. Each type of sample had four pieces so that each sample had a multiple of one week. The samples were tested on the 7th, 14th, 21st, and 28th days of the immersion period.

Method

The research used an experimental method conducted in a laboratory. The variables used in this study were K-300 concrete quality with concrete waste mixtures of 0%, 25%, 50%, 75%, and 100%. The basic materials used in this study were as follows:

1. PCC type 1 Cement
2. Fine aggregate in the form of mundu sand
3. Coarse aggregate in the form of natural stone from

Sukabumi

4. Clean water
5. Concrete waste originating from PT. Lautan Mustika Indonesia. This concrete waste is the result of stripping long poles with K-400 concrete quality with a concrete age of 128 days.

The initial stage of this research involved collecting the necessary raw materials in accordance with the *mix design* results. If the raw materials used to make concrete are of good quality and the concrete mixture is prepared in accordance with *the mix design*, then the resulting concrete will be of good quality [13]. After that, all the raw materials for concrete that have been adjusted to the *mix design* composition are mixed. Then, all samples are molded using a cylindrical molding tool. After the *mixing* and molding processes are complete, the concrete *curing* process continues. Concrete curing is the treatment of concrete after it has been cast and the mold has been removed to prevent the concrete from losing water too quickly. In other words, it is a measure to maintain the moisture and temperature of the concrete so that the hydration process can run perfectly and cracks on the concrete surface can be avoided [14]. After the concrete curing process is complete, sample testing was carried out using a concrete compressive strength tester. Compressive strength testing of concrete samples was conducted after the concrete had aged for 7, 14, 21, and 28 days [15]. Samples that had not yet reached the testing age were checked periodically during soaking or curing to ensure that the concrete samples were completely submerged. After all samples were tested, a comparison of the concrete compressive strength test results was carried out to obtain the results of the effectiveness of concrete waste substitution that is suitable for use. The calculated effectiveness value is how strong the tested concrete is based on the age of the concrete sample.

Results

A total of 20 samples were made in this study with 4 types of samples calculated based on concrete waste substitution of 0%, 25%, 50%, 75% and 100% and concrete age of 7, 14, 21 and 28 days. Before conducting concrete quality tests on all samples, the materials used were first examined. The following are the results of the inspection of the materials used for this study.

Table 1. Results of coarse aggregate testing

No	Type of Inspection	Results
1	Specific Gravity (g/cm^3)	
	a. Apparent Specific Gravity	3.4155
	b. Bulk Specific Gravity (dry)	3.3353
	c. Bulk Specific Gravity (ssd)	3.3588
	d. Absorption (%)	0.7139
2	Moisture Content (%)	2.1568
3	Volume Weight (g/cm^3)	
	a. Loose Condition	1.4076
	b. Compact Condition	1.5430
4	Wear (Los Angeles machine)	5,500

Table 2. Results of fine aggregate testing

No	Type of Test	Results
1	Silt Content	0.2255
2	Specific Gravity (g/cm^3)	
	a. Apparent Specific Gravity	2.5023
	b. Bulk Specific Gravity (Dry)	2.4977
	c. Bulk Specific Gravity (ssd)	2.4997
	d. Absorption (%)	0.0206
2	Moisture Content (%)	0.4667
3	Fineness Modulus	4.0527
4	Bulk Density (g/cm^3)	
	a. Loose Condition	1.2235
	b. Compact Condition	1.4306

After examining the materials used in this study, they were mixed with concrete waste for several samples. As a reference, one sample was designed with K-300

concrete quality with a volume of $1m^3$, which had the following composition:

Table 3. Composition of K-300 concrete

No	Material	Qty	Volume
1	Coarse Aggregate	1021 kg	$0.75 m^3$
2	Fine Aggregate	681 kg	$0.48 m^3$
3	Cement	413 kg	8.3 bags @50 kg
4	Water	215 L	215 L

Then, the composition in Table 1 was converted based on the volume of the concrete cylinder, with a diameter of 15 cm and a height of 30 cm, resulting in the following concrete volume:

$$0.25 \times \pi \times \phi^2 \times t = 0,25 \times \pi \times 15^2 \times 30 = 5301.4376 \text{ cm}^3 \quad (1)$$

For One Cylinder in $1 m^3 = 0.005301 m^3$

From the conversion calculation of one cylinder above, the material requirements for one cylinder of concrete mix can be determined as follows:

Table 4. Conversion volume of K-300 concrete composition

No	Material	Qty	Volume	Conversion Volume
1	Crushed Stone	1021 kg	0.75 m ³	5.4 kg
2	Sand	681 kg	0.48 m ³	3.6 kg
3	Cement	413 kg	8.3 bags @50 kg	2.1 kg
4	Water	215 L	215 L	1.1 L

After determining the volume of each material used, the mix design calculation process was carried out with or without concrete waste substitution used as a coarse aggregate replacement of 25%, 50%, 75%, and 100% of the concrete volume. The mix design calculations for each sample are as follows:

Table 5. Mix design

Sample	Material Volume Based on K-300 Quality Concrete						
	Coarse Aggregate		Concrete Waste		Water (Liters)	Cement (kg)	Fine Aggregate (kg)
1 ^{*)}	100%	5.40 kg	0	0.00 kg	1.1	2.1	3.6
2	75%	4.05 kg	25	1.35 kg	1.1	2.1	3.6
3	50	2.70 kg	50	2.70 kg	1.1	2.1	3.6
4	25	1.35 kg	75%	4.05 kg	1.1	2.1	3.6
5	0	0.00 kg	100	5.40 kg	1.1	2.1	3.6

Note: *) Sample 1 is the reference sample for the other samples.

After obtaining the mix design for each sample, the process of mixing materials, casting concrete samples, curing/maintaining each specified concrete age was conducted. The final stage was testing the samples. The results of testing the compressive strength of concrete with 0% concrete waste substitution can be seen in Table 6 and Fig. 1 below:

Table 6. Results of concrete sample testing with 0% concrete waste

Test Specimen No.	Concrete Code	Production Date	Test Date	Concrete Age (Days)	Weight (kg)	Cross-sectional Area (cm ²)	Test Results	
							K (Kg/cm ²)	MPa (N/mm ²)
1	L. concrete (0%)	12/20/2023	12/19/2023	7	11.19	17.63	204.86	17.01
2	L. concrete (0%)	12/20/2023	12/26/2023	14	11.21	17.63	240.96	20.12
3	L. concrete (0%)	12/20/2023	01/02/2024	21	11.25	17.63	270.21	22.48
4	Concrete (0%)	12/20/2023	01/09/2024	28	11.27	17.63	315.11	26.17

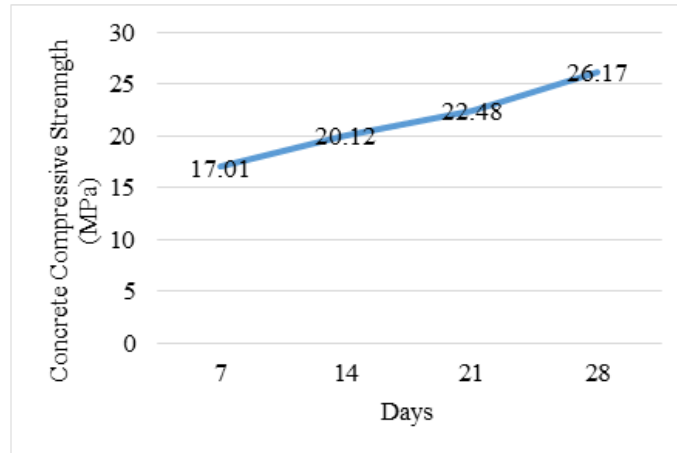


Fig. 1. Compressive strength of concrete with 0% concrete waste

The results of the concrete compressive strength test can be seen in Table 7 and Fig. 2 below: with the substitution of 25% concrete waste mixture

Table 7. Test results of concrete samples with 25% concrete waste

Test Specimen No.	Concrete Code	Date of Manufacture	Test Date	Concrete Age (Days)	Weight (kg)	Cross-sectional Area (cm ²)	Test Results	
							K (Kg/cm ²)	MPa (N/mm ²)
1	L. concrete (25%)	May 25, 2024	06/01/2024	7	11.09	17.63	204.10	16.95
2	L. concrete (25%)	May 25, 2024	06/08/2024	14	11.12	17.63	239.75	19.91
3	L. concrete (25%)	May 25, 2024	06/15/2024	21	11.13	17.63	268.33	22.33
4	Concrete (25%)	May 25, 2024	06/22/2024	28	11.17	17.63	312.97	24.56

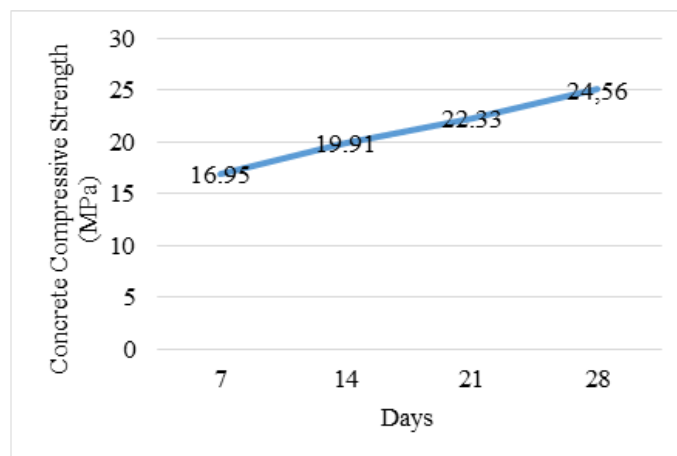


Fig. 2. Compressive strength of concrete with 25% concrete waste

The results of the concrete compressive strength test with the substitution of 50% concrete waste mixture

can be seen in Table 8 and Fig. 3 below:

Table 8. Test results of concrete samples with 50% concrete waste

Test Specimen No.	Concrete Code	Production Date	Test Date	Concrete Age (Days)	Weight (kg)	Cross-sectional Area (cm ²)	Test Results	
							K (Kg/cm ²)	MPa (N/mm ²)
1	L. concrete (50%)	May 25, 2024	06/01/2024	7	11.06	17.63	193.47	16.06
2	Concrete (50%)	May 25, 2024	06/08/2024	14	11.09	17.63	219.11	18.19
3	L. concrete (50%)	May 25, 2024	06/15/2024	21	11.12	17.63	262.33	21.78
4	L. concrete (50%)	May 25, 2024	06/22/2024	28	11.17	17.63	302.13	24.37

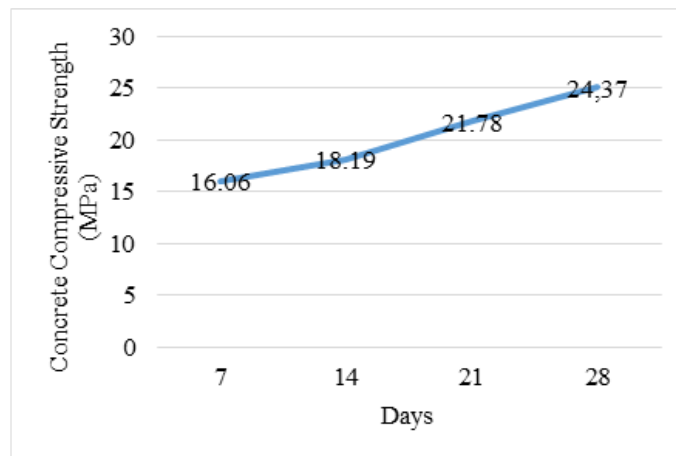


Fig. 3. Compressive strength of concrete with 50% concrete waste

The results of the concrete compressive strength test can be seen in Table 9 and Fig. 4 below: with the substitution of 75% concrete waste mixture

Table 9. Results of testing concrete samples with 75% concrete waste

No. Test Object	Concrete Code	Production Date	Test Date	Concrete Age (Days)	Weight (kg)	Cross-sectional Area (cm ²)	Test Results	
							K (Kg/cm ²)	MPa (N/mm ²)
1	L. concrete (75%)	May 25, 2024	06/01/2024	7	11.07	17.63	139.92	11.62
2	Concrete (75%)	May 25, 2024	06/08/2024	14	11.10	17.63	184.01	15.28
3	Concrete (75%)	May 25, 2024	06/15/2024	21	11.11	17.63	250.94	19.55
4	Concrete (75%)	May 25, 2024	06/22/2024	28	11:15	17.63	302.13	24.13

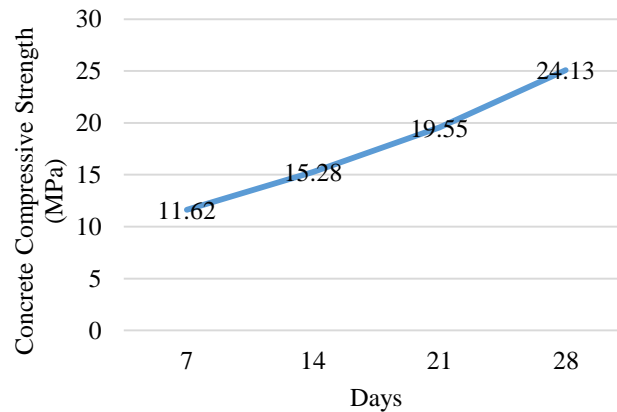


Fig. 4. Compressive strength of concrete with 75% concrete waste

The results of concrete compressive strength testing can be seen in Table 10 and Fig. 5 below: with the substitution of 100% concrete waste mixture

Table 10. Test results for concrete samples with 100% concrete waste

Test Specimen No.	Concrete Code	Date of Production	Test Date	Concrete Age (Days)	Weight (kg)	Cross-sectional Area (cm ²)	Test Results	
							K (Kg/cm ²)	MPa (N/mm ²)
1	L. concrete (100%)	02/20/2023	09/12/2023	7	11.09	17.63	125.21	10.39
2	Concrete (100%)	02/20/2023	12/16/2023	14	11.22	17.63	149.55	12.42
3	L. concrete (100%)	02/20/2023	12/23/2024	21	11.25	17.63	250.10	20.77
4	L. concrete (100%)	02/20/2023	12/30/2024	28	11.29	17.63	300.05	24.02

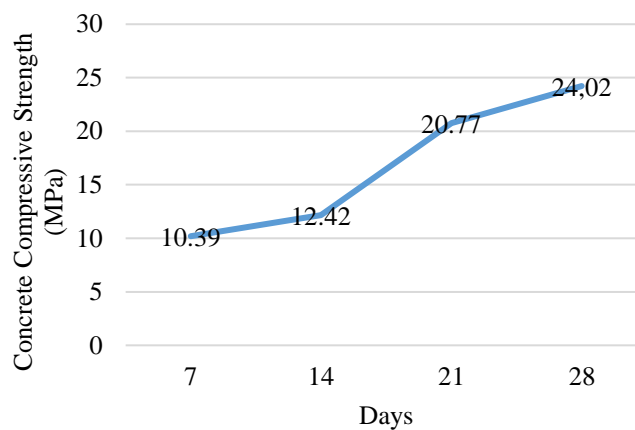


Fig. 5. Compressive strength of concrete with 100% concrete waste

Discussion

Based on the results of the concrete compressive strength test above, it can be seen that the more concrete waste substitution used as the substitution for coarse aggregate, the lower the hardness level of the concrete

sample. On the 7th, 14th, and 21st days of sample age, there was a significant reduction in the hardness level of the concrete samples. However, on the 28 days of age, the concrete samples with 25%, 50%, 75%, and 100% concrete waste substitution achieved the

compressive strength required by SNI for K-300 concrete quality. The following is a comparison graph of concrete samples based on age and substitution.

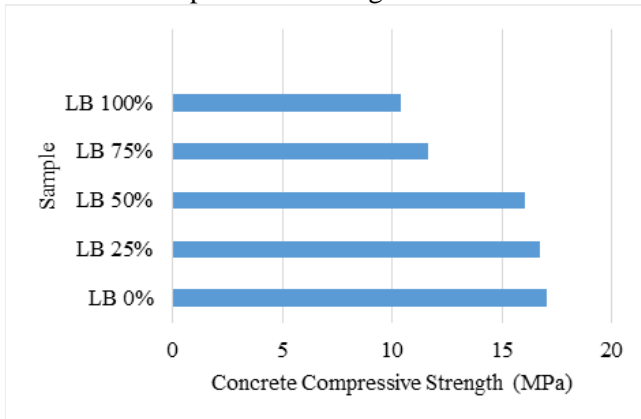


Fig. 6. Concrete compressive strength test on day 7

Compressive strength test of concrete on day 7 shows that concrete with 100% and 75% concrete waste substitution has a lower hardness level compared to concrete with 50%, 25%, and 0% substitution. Therefore, concrete samples with 100% and 75% substitution do not meet the K-300 concrete standard at 7 days of age, which should have a minimum strength of 65% or 15.6MPa.

Table 7 below shows that the concrete compressive strength test on day 14 indicates that concrete with 100% and 75% concrete waste substitution had the lowest compressive strength values of 12.42 MPa and 15.28 MPa, which are still far from the compressive strength of the 0% concrete waste sample, which is 20.12 MPa.

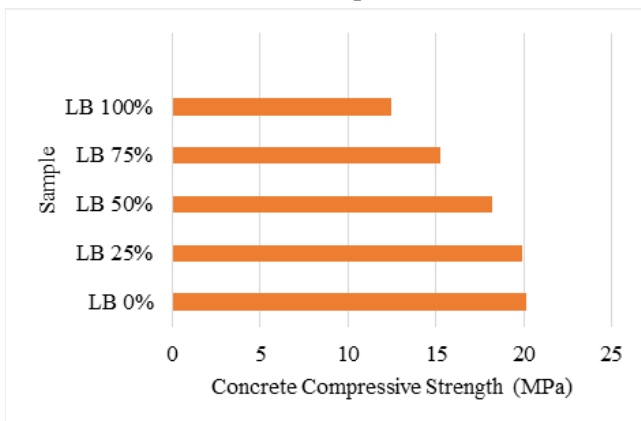


Fig. 7. Compressive Strength test of concrete on day 14

On the 21st day of testing, all sample types produced compressive strength values that were still relatively far from the standard strength value for K-300 concrete, which is 24.9MPa. Fig. 8 shows a comparison of concrete strength on the 21st day.

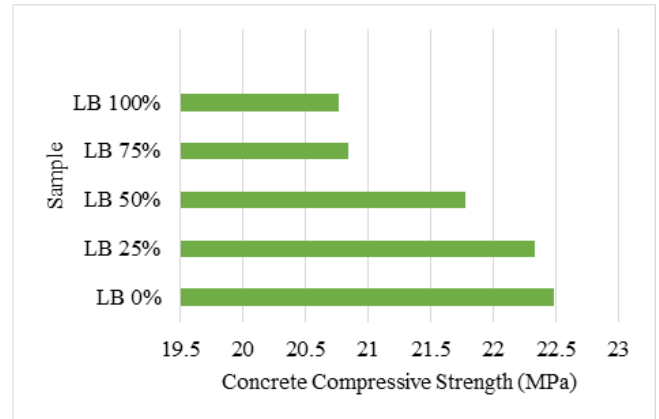


Fig. 8. Concrete compressive strength test on day 21

Fig. 9 shows that the results of testing concrete samples on day 28 indicate that only concrete samples with 0% concrete waste obtained compressive strength values exceeding the K-300 concrete standard. Samples with 100% concrete waste substitution obtained a compressive strength value of 24.02MPa, 75% concrete waste substitution obtained 24.13MPa, 50% concrete waste substitution obtained 24.37MPa, 25% concrete waste substitution obtained 24.56MPa, and 0% concrete waste substitution obtained 26.17MPa.

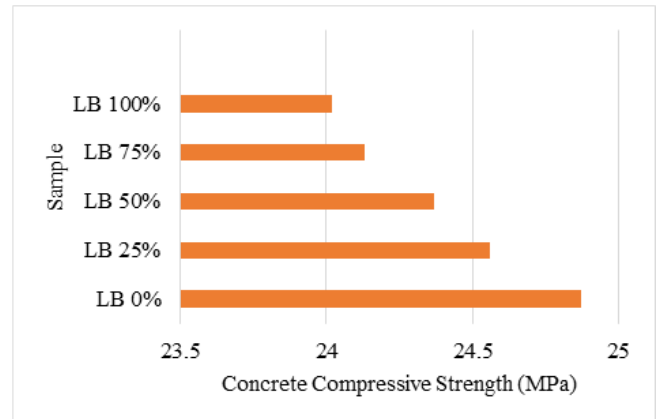


Fig. 9. Compressive strength test of concrete on day 28

From the comparison of concrete compressive strength test results with 0%, 25%, 50%, 75%, and 100% substitution tested on days 7, 14, 21, and 28 in Fig. 10 below, it can be seen that concrete samples with concrete waste substitution show a decrease in strength in compressive strength test.

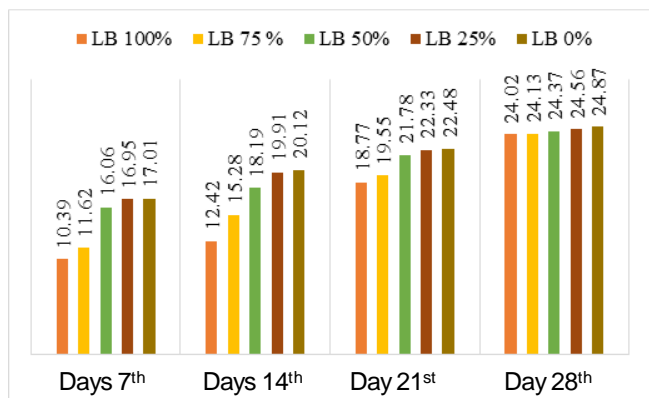


Figure 10. Concrete compressive strength test on days 7, 14, 21, and 28

Conclusion

From the results of the study, it can be concluded that:

1. Based on the results of the concrete compressive strength test, concrete using concrete waste as a coarse aggregate substitute can result in a decrease in strength because concrete waste contains other elements such as sand, stone, and cement. The presence of these elements decreases the compressive strength.
2. Based on the values of concrete compressive strength obtained, substituting 25% concrete waste is still a viable option because the strength level on day 28 is 24.56 MPa, which is close to the compressive strength of K-300 concrete (24.90 MPa).
3. Based on the values of concrete compressive strength obtained, samples with 50%, 75%, and 100% concrete waste substitution can be considered for use as a concrete mixture below K-300.
4. The use of concrete waste as a substitution for coarse aggregate can reduce the use of natural stone as a construction raw material and can reduce the cost of purchasing natural stone. This happens because currently, the price of concrete waste per truck is only around Rp. 375,000.

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