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ANALYSIS OF THE EFFECT OF BRICK WASTE ON CONCRETE COMPRESSIVE STRENGTH

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ABSTRACT
The construction industry generates significant red brick waste, often left unused and posing environmental challenges. Utilizing this waste as a substitute for fine aggregate in concrete can reduce reliance on natural materials and enhance concrete performance. Both red bricks and sand share a common silica (SiO_2) content, making bricks a viable alternative material. This study evaluates the compressive strength of concrete incorporating red brick waste and identifies the optimal substitution percentage for maximum strength. Concrete samples (15x15x15 cm^3) of K250 quality were tested with red brick waste replacing 0%, 6%, 8%, 10%, 12%, and 14% fine aggregate by weight. Compressive strength tests were conducted after curing periods of 7, 14, 21, and 28 days. Results indicate that adding brick waste significantly influences concrete strength. Concrete with 12% brick waste substitution achieved the highest compressive strength of 274.09 kg/cm^2, surpassing the strength of 6% substitution at 260.61 kg/cm^2. The findings demonstrate that red brick waste is a sustainable and effective alternative aggregate, contributing to environmental conservation and improved concrete performance. However, substitution proportions must be optimized to maintain desired structural properties.

Keywords: aggregate; concrete compressive strength; red brick

INTRODUCTION

Concrete is a widely used construction material important in developing modern infrastructure. Its compressive strength is a key factor determining its suitability for a wide range of applications (Danché et al., 2024; Guan et al., 2024; Muguda & Wyndham, 2024; Pinchi et al., 2020; Wang et al., 2024). Researchers have been exploring alternative materials to replace conventional aggregates in concrete to reduce environmental impact and improve sustainability (Giri & Priyadarshini, 2022; Zamora-Castro et al., 2021).

One alternative material is brick waste, which is generated in large quantities from the demolition process and construction activities. Several studies have investigated whether brick waste can be used as a substitute for natural aggregate in the manufacture of concrete. The inclusion of waste bricks in concrete has been found to significantly impact its compressive strength. Research shows that concrete made with waste bricks can have durability, low permeability, and acceptable compressive strength (Lestari et al., 2023; Varona et al., 2020).

A study using brick waste as a substitute for fine aggregate in concrete shows that this approach leads to a greener environment (Ahmed et al., 2024; Moujoud et al., 2023; Xu et al., 2024). In addition, it has been proven that combining waste bricks can improve the compressive, tensile, and flexural strength of concrete and its elastic modulus. The behavior of high-temperature concrete as aggregate waste bearings, including those containing brick, mixed, and concrete waste, has also been studied, where it is revealed that these materials can retain their compressive strength even after exposure to high temperatures of 500^{o}C (Amakye et al., 2021; Varona et al., 2020).

One promising approach is using brick waste as a partial substitute for fine aggregate in concrete (Ahmed et al., 2024; Khitas et al., 2025). Brick waste is a by-product of the demolition and construction process, and its utilization in concrete can contribute to the efficient management of construction and demolition waste. Several studies have investigated the potential use of waste bricks in concrete, focusing on understanding its impact on the mechanical properties of the resulting materials (Wang et al., 2024; Zhu & Zhu, 2020).

In the research, Santoso et al. (2020) analyzed the influence of concrete compressive strength with brick additives as a substitute for fine aggregate. Experiments were carried out using brick waste (0%, 3%, 5%, and 7%), and the results obtained at the age of 28 days that met the quality of K250 concrete were percentages (5% and 7%). Furthermore, the research of Zhu & Zhu (2020) analyzed the effect of brick waste on the compressive strength of concrete as a substitute for fine aggregate. An experiment was carried out using brick waste (0%, 13%, 14%, 15%, 16%, and 17%), and the results obtained at the age of 28 days that met the quality of K250 concrete were percentages (13% and 14%).

By reviewing the literature study in the previous study, this study will analyze the compressive strength of concrete with the addition of red brick waste as a substitute for fine aggregate with variations of 0%, 6%, 8%, 10%, 12%, and 14%.

Concrete is a widely used construction material that is crucial to developing modern infrastructure. Its compressive strength is a key factor determining its suitability for various applications. To reduce environmental impact and enhance sustainability, researchers have been exploring alternative materials to replace conventional aggregates in concrete.

This study focuses on utilizing red brick waste, a by-product of demolition and construction, as a partial substitute for fine aggregate in concrete. Research has shown that incorporating brick waste can improve concrete's mechanical properties, such as compressive strength, durability, and low permeability. However, existing literature has not clearly established the optimal substitution rate for achieving maximum compressive strength. The primary objective of this study is to evaluate the compressive strength of concrete incorporating varying percentages of red brick waste as a substitute for fine aggregate. Specifically, it aims to identify the optimal substitution percentage that maximizes strength while maintaining the desired structural properties.

This research contributes to the field by providing empirical data on the effects of red brick waste on concrete's mechanical properties. It addresses gaps in the current literature regarding the optimal use of brick waste in concrete mixtures, promoting sustainable practices in the construction industry. The findings will serve as a reference for future studies and practical applications in utilizing construction waste effectively.

METHOD

Location and Object of Research

The research was located at the Civil Engineering Laboratory, Gunung Jati Independent University Cirebon, Indonesia.

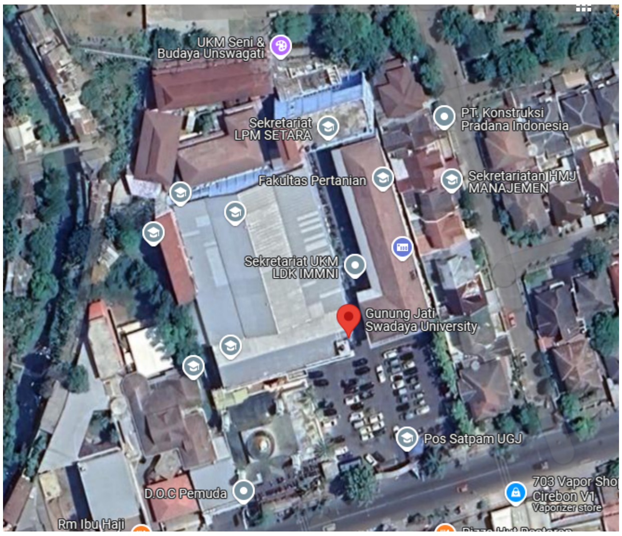


Figure 1.
Research Location Map

Retrieval Techniques and Data Sources

The research began by collecting and studying the literature on concrete research using the influence of brick waste. Research design allows the creation of procedures and steps to direct and optimize the time and results achieved.

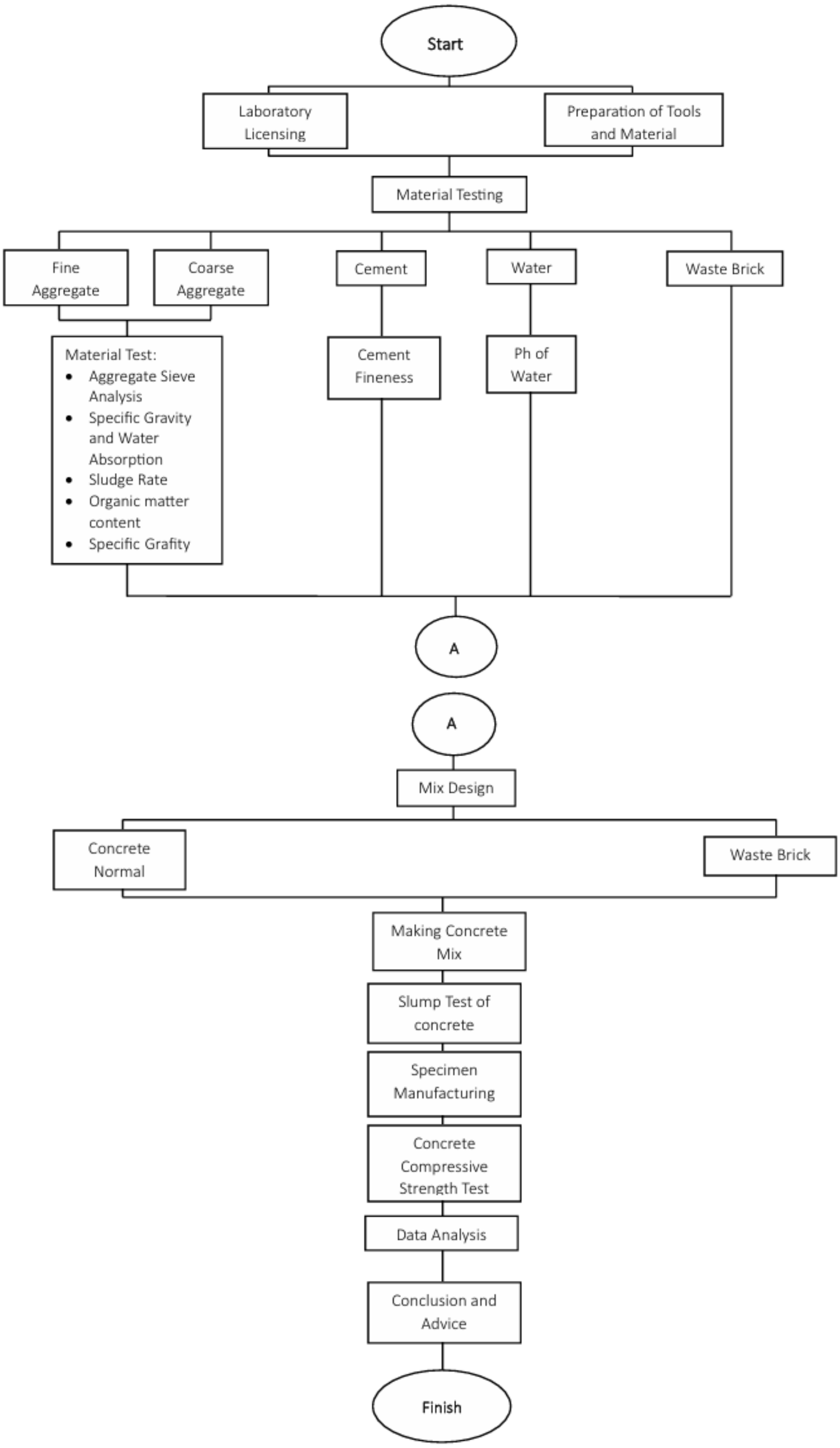


Figure 2.
Research Flow

This research employs an experimental method, focusing on analyzing the compressive strength of concrete using red brick waste as a partial substitute for fine aggregate. The study aims to evaluate the impact of varying percentages of brick waste (0%, 6%, 8%, 10%, 12%, and 14%) on the concrete's performance. The experimental approach allows for a systematic investigation of the properties of concrete mixtures, emphasizing the relationship between the substitution of fine aggregate and the resulting compressive strength. By conducting controlled laboratory tests, this research seeks to provide empirical data that supports the effective use of brick waste in concrete production. (Syarif, 2016)(Badan Standarisasi Nasional, 2008)

This research is based on regulations or requirements, such as crude aggregate testing. The research is carried out based on the SNI 03-1969-2008 standard. The OK aggregate and red brick waste testing is based on the SNI 03-1968-1990 standard, the organic content test is SNI 03-2816-1992, the sludge content test is SNI 03-1750-1990, the specific gravity test is based on the SNI 03-1970-1990 standard, the moisture content test is SNI 03-1971-1990, cement fineness testing, namely SNI 03-2530-1991, water pH testing, namely SNI 3553-2015, and slump testing, namely SNI 7394-2008. The research began by reviewing and looking at previous research, preparing materials for laboratory tests, and making cube-shaped test objects with a size of 15x15x15cm^3.

RESULTS AND DISCUSSION

Fine Aggregate Testing

Fine aggregate testing is carried out twice in each experiment to obtain accurate research data. The results of these tests, which were carried out in accordance with the requirements of SNI 03-1968-1990 (Badan Standarisasi Nasional, 1990), are shown in Table 1 below.

Table 1. Fine Aggregate Testing Recapitulation

Description	Test Results (Sand)	Test Results (Brick Waste)	Testing Standards	Mark	Standard Requirements	Information (Sand)	Information (Brick Waste)
Grading zone	I	I	-	-	-	-	-
Fineness modulus	3.61	3.4	SNI 03-1968-1990	1.5-3.8	SNI 03-1750-1990	Qualify	Qualify
Bulk specific gravity	2.53	2.4	SNI 1969:2008	2.50-2.70	SK SNI T-15-1990-03	Qualify	Qualify
Bulk specific gravity (SSD)	2.63	2.5	SNI 1969:2008	2.50-2.70	SK SNI T-15-1990-03	Qualify	Qualify

Apparent specific gravity	2.82	2.52	-	-	-	Qualify	Qualify
Absorption	0.042	0.3	-	-	-	-	-
Silt and Clay Content	7.98%	4.92%	SNI 03-4142-1996	-	SNI 03-1750-1990	Qualify	Qualify
Organic Matter Content	No. 4	No. 5	SNI 03-2816-1992	No. 1, 2, or 3	-	Qualify	Qualify
Water content	4.71%	5.82%	SNI 03-1971-1990	-	SK SNI-15-1990-30	Qualify	Qualify

The test results in the table above show that the data obtained meets the test standards, including testing grading zones, fineness modulus, bulk specific gravity, absorption, and other test data.

Coarse Aggregate Testing

Poor aggregate quality does not affect the strength and durability of the resulting concrete. Coarse aggregate testing is carried out according to the requirements of SNI 03-1969-2008. The results of the coarse aggregate test are presented in the table (Badan Standarisasi Nasional, 2008).

Table 2. Recapitulation of Coarse Aggregate Testing

Description	Test Results (Gravel)	Testing Standards	Mark	Standard Requirements	Information (Gravel)
Grading zone	III	-	-	-	Qualify
Fineness modulus	4.47	SNI 03-1969-2008	4.75-40	-	Qualify
Bulk specific gravity	2.75	-	-	-	Qualify
Bulk specific gravity (SSD)	2.78	SNI 1969:2008	2.50-2.80	SK SNI T-15-1990-03	Qualify
Apparent specific gravity	2.83	-	-	-	Qualify
Absorption	0.01	-	-	-	-

After experiments and calculations on the coarse aggregate gradation, the gravel's fineness modulus was 4.47 mm, which met the requirements. These values indicate that the coarse aggregate is already suitable for concrete mixtures.

Cement Fineness Testing

The cement fineness test, which refers to ASTM C184-66, determines the size of the cement grains. This affects the speed of the hydration reaction and the strength of the concrete. This test refers to ASTM C184-66 (ASTM International, 1966).

Table 3. Cement Fineness Testing

Description	Test Results (Mark)	Test Results (Standard Requirements)	Condition (Mark)	Condition (Standard Requirements)
Specific gravity (%)	3.15	3.15	3.15	3.15
Cement Fineness:				
F1	0%	ASTM C184-66	0	ASTM C184-66
F2	21%		22	

The results of the cement fineness experiment showed that 0% of cement was retained in the No. 100 sieve, and 21% in No. 200. Thus, cement is considered to meet the fineness requirement if it is held in the No.100 filter by 0% and No.200 by 22%.

Water pH Testing

Water pH testing is essential to ensure that the water used in concrete mixing has the right level of acidity. This study used groundwater from the civil engineering laboratory on the main campus of Gunung Jati Swadaya University. The results showed that water was used for the concrete mixture (Badan Standarisasi Nasional, 2015).

Table 4. Water Test Recapitulation

No	Description	Test Results (Mark)	Test Results (Standard Requirements)	Condition (Mark)	Condition (Standard Requirements)	Information
1	Water conditions	Clear	-	Clear	-	Qualify
2	Water taste	Bid	SNI 3553-2015	Bid	SNI 3553-2015	Qualify
3	Smell of water	Odorless	-	Odorless	-	Qualify
4	pH of water	6.000	SNI 3553-2015	4.5-8.5	Construction and Building Manual, Book 4	Qualify

The pH test of water is done manually using litmus paper. After the test was completed and the litmus paper's color matched, the value was 6, which indicates that the water is slightly acidic, with a light acidity level.

Mix Design

The purpose of the red brick concrete mix design is to utilize each of the two classic construction materials, namely concrete and red brick. This study observed changes in concrete characteristics caused by cement substitution, coarse aggregate, and fine aggregate. Therefore, a mixture of concrete quality with K-250 with a cement water factor of 0.52% is used. The sample needs for angry brick waste are 1.85 in 6% variation, 2.47 in 8% variation, 3.08 in 10% variation, 3.70 in 12% variation, and 4.32 in 14% variation. The table below shows the output of the Mix Design work.

The calculation of Table 5 provides results to determine the need for materials. The design mix refers to SNI-7394-2008 to produce 1 m^3 of quality concrete Fc' = 25 MPa (K-250) Slump (12+2/- 14) CM, W/C = 0.52. Namely, it is in the form of sand with a coefficient of 692 kg, cement with a coefficient of 384 kg, gravel with a coefficient of 1039 kg, and water with a coefficient of 215 liters. From a total of 72 samples to determine the material, the results were obtained for cement of 17.1 kg, sand of 30.8 kg, gravel of 46.3 kg, and water of 9.6 liters with a cube mold measuring 15 x 15 x 15 cm^3.

Table 5. Sample Needs for Concrete Research

Sample	Material	Number of Needs Material	Unit	Variations	Age	Number of Samples	Total Samples
Concrete Normal	Sand	30.8	Kg	0%	7, 14, 21, and 28 days	3	12
	Cement	17.1	Kg				
	Gravel	46.3	Kg				
	Water	9.6	Liter				
Concrete Variations	Sand	28.98	Kg	6%	7, 14, 21, and 28 days	3	12
	Cement	17.1	Kg				
	Gravel	46.3	Kg				
	Water	9.6	Liter				
	Red Brick	1.85	Kg				
	Sand	28.36	Kg	8%	7, 14, 21, and 28 days	3	12
	Cement	17.1	Kg				
	Gravel	46.3	Kg				
	Water	9.6	Liter				
	Red Brick	2.47	Kg				

	Sand	27.75	Kg	10%	7, 14, 21, and 28 days	3	12
	Cement	17.1	Kg				
	Gravel	46.3	Kg				
	Water	9.6	Liter				
	Red Brick	3.08	Kg				
	Sand	27.13	Kg	12%	7, 14, 21, and 28 days	3	12
	Cement	17.1	Kg				
	Gravel	46.3	Kg				
	Water	9.6	Liter				
	Red Brick	3.7	Kg				
	Sand	26.51	Kg	14%	7, 14, 21, and 28 days	3	12
	Cement	17.1	Kg				
	Gravel	46.3	Kg				
	Water	9.6	Liter				
	Red Brick	4.32	Kg				

Specimen Manufacturing and Maintenance

The test results show that the concrete must be made correctly and meet the SNI 2493:2011 standard. Concrete stirring must be done correctly to avoid air bubbles weakening the concrete structure. In this practice, the concrete curing treatment method is used. This means the concrete is immersed in water for 7, 14, 21, and 28 days before being tested for compressive strength.(Badan Standarisasi Nasional, 2011)

Slump Test Concrete

A slump test is essential to ensure the concrete mixture has properties that suit the project's requirements. Its main purpose is ensuring the concrete can be worked easily without compromising its final strength.

Table 6. Recapitulation of Concrete Slump Test Results

Red Brick Percentage (%)	T1 (cm)	T2 (cm)	T3 (cm)	T4 (cm)	T average (cm)
0	12	11.7	12.2	14	12.25
6%	12.5	14	12	12	13
8%	14	13	11	14.2	13.05

10%	12.3	12	14	11.8	12.5
12%	14	12	12.5	12	12.6
14%	12.7	11.7	14	14	13.1

In this study, the test standard uses SNI 7394-2008 with a slump height between 12 and 14 cm. The highest slump value is 14%, with a height of 13.1 cm, and the lowest slump value is 0%, with a height of 12.25 cm. This slump value is suitable for testing the compressive strength of concrete in this study.

Concrete Fill Weight Test

The concrete content weight test determines the unit weight of fresh or hard concrete per unit volume. It is essential to ensure that the concrete mixture has the right composition because the strength, stability, and durability of the concrete after hardening depends on its composition.

Table 7. Recapitulation of Concrete Fill Weight Testing

No	Mixed Variations	7 days (Kg)	14 days (Kg)	21 days (Kg)	28 days (Kg)
1	Concrete Normal	7.6	7.7	7.7	7.9
2	Concrete 6% Red Brick	7.5	7.6	7.7	7.7
3	Concrete 8% Red Brick	7.5	7.6	7.7	7.8
4	Concrete 10% Red Brick	7.5	7.7	7.7	7.7
5	Concrete 12% Red Brick	7.5	7.6	7.6	7.7
6	Concrete 14% Red Brick	7.5	7.5	7.7	7.7

After 7 days, normal concrete has an average fill weight of 7.6 kg/cm3; on days 14 and 21, it is 7.7 kg/cm3, and on day 28, it is 7.9 kg/^{cm3}. With a variation of 6% to 14%, the average fill weight at 7 days was 6.3 kg/cm3, 6.3 kg/cm3 at 14 days, 6.4 kg/cm3 at 21 days, and 6.4 kg/cm3 at 28 days. These values are a preliminary reference for comparing the fill weight between normal concrete and average variation concrete.

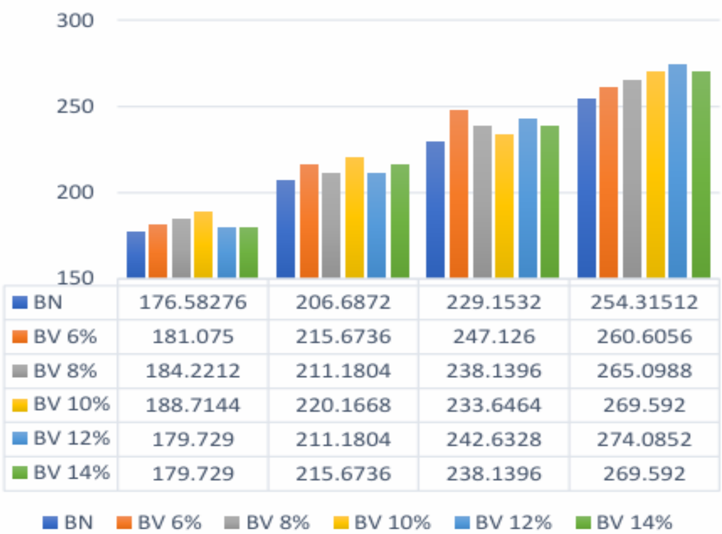
Analysis of Concrete Compressive Strength Results

After the test piece has been curing for 7, 14, 21, and 28 days, the concrete is tested for compressive strength. The following table shows the average compressive strength values for various mixture variations.

Table 8. Results of Concrete Compressive Strength

Concrete Age	Variations Test Specimen	Compressive Strength of Concrete (kg/Cm²)	Increased %

7 Days	BN	176.58276	0
	BV 6%	181.075	2.54
	BV 8%	184.2212	4.33
	BV 10%	188.7144	6.87
	BV 12%	179.729	1.78
	BV 14%	179.729	1.78
14 Days	BN	206.6872	0
	BV 6%	215.6736	7.84
	BV 8%	211.1804	2.16
	BV 10%	220.1668	1.96
	BV 12%	211.1804	5.88
	BV 14%	215.6736	3.92
21 Days	BN	229.1532	0
	BV 6%	247.126	7.84
	BV 8%	238.1396	3.92
	BV 10%	233.6464	1.96
	BV 12%	242.6328	5.88
	BV 14%	238.1396	3.92
28 Days	BN	254.3151	0
	BV 6%	260.6056	2.47
	BV 8%	265.0988	4.24
	BV 10%	269.592	6.01
	BV 12%	274.0852	7.77
	BV 14%	269.592	6.01



Graph 1.

Relationship of Compressive Strength with Mixed Variations

The study results show that using a combination of red bricks in concrete can increase its compressive strength from a variation of 6% to 14%. The concrete tested for 28 days had the highest compressive strength, which was at a variation of 12% with a compressive strength of 274.0852 k

g/cm2, higher than the compressive strength of normal concrete of 254.31512 kg/cm2, and the smallest compressive strength is in the variation of 6% with a compressive strength of 260.6056 kg/cm2.

CONCLUSION

This study looks at how the use of red brick waste as an addition to fine aggregate affects the compressive strength of concrete. So, the following conclusions are drawn:

1. Variations in the optimum and minimum concrete compressive strength values, the results of the study show that using a combination of red bricks can increase the compressive strength of concrete from a variation of 6% to 14%. The highest compressive strength was recorded at 28 days with a 12% variation of 274.0852 kg/cm2, while the lowest compressive strength occurred at a variation of 6% with a concrete compressive strength of 260.6056 Kg/cm2.
2. Correlation between additive materials and concrete strength: The analysis results show a significant correlation between the compressive strength of concrete and the proportion of certain additives. In some cases, the right proportion of red bricks in the mixture can increase the compressive strength of concrete.
3. The practical implication is that if there is the right proportion of red bricks in the concrete mixture, the compressive strength can be better and more environmentally friendly. The compressive strength value of red brick, with a variation of 12%, reached a compressive strength of 274.0852 kg/cm2 for 28 days.

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