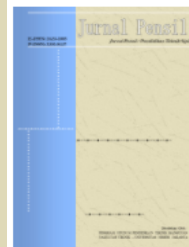


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## STUDY OF THE CORRELATION BETWEEN SPECIFIC GRAVITY AND COMPRESSIVE STRENGTH OF CONVENTIONAL BRICKS, BRICKS MIXED WITH ACACIA ASH, AND CARBIDE LIME ASH BRICKS

Marlia Adriana<sup>1\*</sup>, Norminawati Dewi<sup>2</sup>, Budi Kurniawan<sup>3</sup>, Intan Safitri<sup>4</sup>, Tekad Budiantoro<sup>5</sup>  
<sup>1,2,3,4,5</sup> Road and Bridge Engineering Technology Study Program, Department of Industrial Engineering, Tanah Laut State Polytechnic  
Jalan A. Yani KM 6, Pelahari, Tanah Laut, South Kalimantan Province, 70812, Indonesia  
<sup>\*1</sup>[marlia@politala.ac.id](mailto:marlia@politala.ac.id), <sup>2</sup>[norminadewi@politala.ac.id](mailto:norminadewi@politala.ac.id), <sup>3</sup>[budikurniawan@politala.ac.id](mailto:budikurniawan@politala.ac.id),  
<sup>4</sup>[tekad@politala.ac.id](mailto:tekad@politala.ac.id), <sup>5</sup>[intan@politala.ac.id](mailto:intan@politala.ac.id)

### Abstract

This study aims to analyze the correlation between specific gravity and compressive strength of conventional bricks and those mixed with acacia wood ash and carbide lime ash as environmentally friendly additives. The research program involved preparing brick specimens with a composition of 85% clay and 15% additive, combined with water contents of 20 ml, 25 ml, and 35 ml. The specimens were molded, air-dried for 7 and 14 days, and subsequently tested for specific gravity and compressive strength. The results indicate that bricks incorporating acacia wood ash exhibited the highest specific gravity and compressive strength compared to conventional bricks and bricks mixed with carbide lime ash. The maximum specific gravity of 5.967 g/cm<sup>3</sup> and the highest compressive strength of 12.603 MPa were achieved by acacia ash bricks at 14 days of curing. A positive correlation was observed between specific gravity and compressive strength, indicating that increased density significantly enhances mechanical performance. A positive correlation between density and compressive strength suggests that higher density is associated with greater mechanical strength. This study demonstrates the potential of using acacia ash waste as a filler to enhance brick strength without requiring combustion. The application of acacia ash not only enhances mechanical properties but also reduces energy consumption and production time, supporting the development of sustainable and environmentally friendly brick manufacturing technologies.

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**Keywords:** Brick, Specific Gravity, Compressive Strength, Acacia Ash, Carbide Lime Ash

## Introduction

Bricks are widely used construction materials, but conventional production methods often involve high energy consumption and environmental impacts (Dabaieh et al., 2020; Kucukdogan, 2025). In response to global sustainability challenges, recent studies have focused on utilizing industrial and biomass waste as eco-friendly additives in brick manufacturing (Chin et al., 2022; Lachheb et al., 2026; Wang & Abuel-Naga, 2025). Acacia wood ash and carbide welding ash are promising alternatives that can reduce waste disposal while improving material properties. Previous research indicates that acacia wood ash enhances moisture behaviour and material compactness, supporting the development of unfired, energy-efficient, and sustainable brick materials (Abbass et al., 2025; Adriana et al., 2023; Amin & Abadir, 2025; Hossain & Islam, 2026)

As one of the most commonly used building materials in construction, the quality of bricks is greatly influenced by various factors, including specific gravity and compressive strength. The specific gravity of bricks ranges from 1.8 to 2.6 g/cm<sup>3</sup>, with significant variations depending on the material composition and manufacturing process (Bakiroglu & Yaras, 2025; Syahland, 2016; Wang et al., 2026). Based on research by (Ayat, 2020), the use of rice husk ash and carbide waste in brick mixtures can also significantly increase compressive strength. In one study, a mixture with a ratio of 60% clay, 25% rice husk ash, and 15% carbide waste produced the highest average compressive strength of 7,75 MPa. Based on previous research (Forest et al., 2017), the addition of fly ash has been shown to reduce the specific gravity of bricks by 0.98 to 1.35 g/cm<sup>3</sup>, which has implications for changes in compressive strength.

In another study (Sihombing et al., 2020) The physical characteristics of red bricks showed that their dry density was around 1,5 g/cm<sup>3</sup>, which is equivalent to 1.5 g/cm<sup>3</sup>. This shows that red bricks have varying densities depending on the composition and manufacturing process. This study highlights the importance of material composition in achieving optimal brick performance and shows that the addition of carbide waste can increase the compressive strength to a certain limit before it decreases (Jwaida, 2025; Xie et al., 2025; Zeng et al., 2026). On the other hand, research on acacia wood ash as an additive also shows a specific gravity (Souza et al., 2022; Subanndi et al., 2020).

The specific gravity of bricks is influenced by various factors related to the material, manufacturing process, and environmental conditions. Some of these factors include the moisture content of the brick, which can affect its specific gravity. Bricks that absorb water will have a higher density, thus affecting the calculation of specific gravity (Prayuda et al., 2018). The apparent density of bricks is directly related to specific gravity. The greater the apparent density, the higher the specific gravity of the brick (Shrestha, 2019). This also affects the compressive strength of the brick (Al-Yasiri et al., 2026; Dini et al., 2021). The type and quality of raw materials used in brick making, such as clay or aggregate, also affect specific gravity. Denser raw materials will produce bricks with a higher specific gravity. The molding and drying processes of bricks can affect their density. Pressure during molding and temperature during drying are important factors that can change the internal structure of the brick (Sutcu et al., 2024). The age or storage time of bricks after production can affect their specific gravity. Older bricks may experience changes in their physical properties due to environmental exposure. In some types of lightweight bricks, air trapped during the manufacturing process can reduce the overall specific gravity (Ahmad et al., 2022).

However, most existing studies focus on single additives, and limited research has examined the comparative performance of acacia wood ash and carbide lime ash within the same experimental framework (Mydin, 2023; Torabi-Kaveh et al., 2026). In particular, the correlation between specific gravity and compressive strength in unfired bricks incorporating these two waste materials has not been sufficiently explored. Therefore, this study aims to investigate the effect of acacia wood ash and carbide lime ash on the specific gravity and compressive strength of unfired bricks and to analyze the correlation between these properties at different curing ages. The findings are expected to contribute to the development of sustainable, energy-efficient brick materials that utilize waste resources while maintaining adequate structural performance.

## Research Methods

The specific gravity of bricks incorporating acacia wood ash and carbide welding ash was determined through a series of laboratory procedures. Clay was used as the primary raw material, while acacia wood ash was obtained from charcoal combustion residues in Ranggung Village, and carbide welding ash was collected from welding workshops and motorcycle repair facilities near the Tanah Laut State Polytechnic. All materials were air-dried, cleaned of impurities, and sieved through a 160  $\mu\text{m}$  sieve to ensure uniform particle size.

Prior to compressive strength testing, a mortar mixture consisting of cement, sand, and water was prepared and passed through a 200  $\mu\text{m}$  sieve to produce a homogeneous paste for specimen assembly. The required measuring equipment included a digital balance for mass determination, volumetric measuring tools, measuring cups, tape measures, basins, and mixing implements (Tiwari et al., 2025).

Brick specimens were produced by mixing clay with acacia wood ash and carbide welding ash at a proportion of 85% clay and 15% additive. Water contents of 20 mL, 25 mL, and 35 mL were applied to each mixture variation. The materials were thoroughly mixed until a homogeneous consistency was achieved. The resulting mixtures were then placed into brick molds and compacted to minimize air voids and ensure uniform density.

After molding, the brick specimens were air-dried at room temperature for 7 and 14 days to reduce moisture content prior to testing. Once dried, each specimen was weighed using a digital balance to obtain its mass. The dimensions of each brick, including length, width, and height, were measured using a precision measuring tool. The volume of each specimen was calculated using the following equation:

$$V = L \times W \times H$$

The specific gravity of each brick specimen was subsequently determined by dividing its mass by its calculated volume (Thaickavil & Thomas, 2018). Specific Gravity Calculation. Calculate specific gravity using the formula:

$$\rho = \frac{m}{v}$$

Where:

$\rho$ = specific gravity ( $\text{kg}/\text{m}^3 \approx 0,001 \text{ g}/\text{cm}^3$ )

m= brick mass (kg)

v= volume of bricks ( $\text{m}^3$ )

After determining the specific gravity of each brick specimen based on its measured mass and calculated volume, the mechanical performance of the bricks was further evaluated through compressive strength testing (Lile et al., 2025). Compression Strength such as :

$$\tau = \frac{P}{L}$$

Where:

$\tau$ = Compression Strength (MPa)

P= Maximum Load (N)

L= Cross-section area ( $\text{mm}^2$ )

## Research Results and Discussion

Conduct a correlation analysis between the specific gravity values obtained from various mixture proportions to determine the compressive strength of conventional bricks, bricks with acacia ash mixture, and carbide welding ash. This process aims to ensure that the two types of ash

used in the study have consistent physical characteristics, so that they can provide optimal results in making bricks.

### **Brick making**

In this study, 2100 grams of clay were mixed with 600 ml of water to produce bricks. Based on previous test results (Adriana et al., 2023), there are three types of mixtures that will be tested: first, bricks without additives with three samples having water concentrations of 20 ml, 25 ml, and 35 ml, respectively; second, bricks with the addition of additives in the form of carbide welding ash with a ratio of 85% clay and 15% carbide welding ash, also with water concentrations of 20 ml, 25 ml, and 35 ml; third, bricks with the addition of acacia wood ash with the same ratio and the same water concentration. In addition, a brick mixture combining both additives will also be made with similar proportions.

After the dough is moulded, the drying process is carried out in stages at room temperature, with an average temperature of 30-32°C. After one day of drying, the bricks are turned over to expose all sides to air. Once dry enough, they are stacked crosswise to ensure good air circulation. This method is expected to produce high-quality bricks without the need for firing, making them more environmentally friendly and resource-efficient (Wang & Abuel-naga, 2025).

### **Brick compressive strength test**

Before testing, the bricks were assembled into cubes using mortar and paste, and the surface was leveled so that the pressure plate on the testing machine could adhere evenly to the entire sample (Bompa, 2020). After that, the length and width dimensions of the sample were re-measured to determine the cross-sectional area that would receive pressure from the testing machine (Sulistia, 2023). The compressive strength test was carried out after the bricks were dry and solid. This test used a Compression Test Machine (CTM) like such as experiment (Zebua & Sinulingga, 2018) at the PU Laboratory of Tanah Laut Regency, following the SNI 0021-1978.

Stones, the second layer is mortar, and the third layer is brick back. The coating of these 3 elements aims to facilitate the implementation of compressive strength testing against axial loading from the compressive strength tool to the brick test specimen. The types of brick test specimens made in this study were 3 types, namely conventional bricks made from original red soil (O), a mixture of red soil with acacia ash waste additives (A), and a mixture of red soil with carbide welding ash waste additives (K) derived from the combustion of charcoal that is no longer used.

### **Brick Dimension Measurement**

Measurement of brick dimensions significantly influences the specific gravity and compressive strength of bricks (Sulistia, 2023). This is because the specific gravity and compressive strength values of bricks are analysed based on formula calculations by entering the volume value of the brick by knowing the length, width, and thickness of the brick (Al-Yasiri et al., 2026; Hashem et al., 2026; Roca et al., 2022; Sarwar et al., 2025; Wang et al., 2026; Wang & Abuel-Naga, 2025). Measurements were carried out on 3 types of bricks, each type of brick consisting of 3 pieces, so that the test specimens totalled 9 pieces. When the test was carried out, the type of brick sample was given the code A.1-A.3 for the acacia ash mixture, the code K.1-K.3 for the carbide welding ash mixture, and the code O.1-O.3 for conventional bricks. The results of the brick dimension measurements indicated a brick length of 200-220 cm. Then the results of the brick width measurement between 98 mm and 105 mm, and the brick thickness between 45 mm and 55 mm. The results of the brick dimension measurements in this study meet the brick size standards in SNI 15-2094-2000. The results of the brick dimension measurements can be seen in Table 1.

Table 1. Results of Brick Dimension Measurements

<b>Brick Sample</b>	<b>Long (mm)</b>	<b>Wide (mm)</b>	<b>Thick (mm)</b>
A.1	210	100	52
A.2	207,5	98	52
A.3	207,5	100	52
K.1	220	105	52
K.2	220	105	52,5
K.3	220	105	52
O.1	207,5	102,5	52
O.2	207,5	100	52
O.3	207,5	100	52

(Source: Test data, 2024)

### Brick Specific Gravity Test Results

The specific gravity test on bricks aims to determine the density of the soil mass by comparing the weight of the brick to the volume of the brick. Each brick sample was tested based on the drying age of the brick. Each sample was tested based on the drying age of the brick, namely 7 days and 14 days. From the results of the study, the specific gravity value was obtained for the specific gravity of bricks with a mixture of acacia ash and carbide welding ash and conventional bricks in Table 2.

Table 2. Data on the Weight of Bricks Aged 7 and 14 Days

<b>Brick Sample</b>	<b>Bricks Density (gr/cm3)</b>	<b>Bricks Density (gr/cm3)</b>
	<b>Day-7</b>	<b>Day-14</b>
A.1	4,057	5,322
A.2	4,204	4,709
A.3	4,211	5,967
K.1	3,996	5,660
K.2	3,702	5,167
K.3	3,818	4,630
O.1	3,959	5,223
O.2	3,755	5,878
O.3	4,166	4,866

(Source: Test data, 2024)

Table 2 presents the results of the specific gravity test for each brick type. The results of the specific gravity test of bricks show that the maximum specific gravity is 5,967 gr/cm<sup>3</sup> obtained from the specific gravity test of brick samples with a mixture of acacia ash, while the minimum specific gravity value of 4,630 gr/cm<sup>3</sup> is obtained from the results of the test on the specific gravity with brick samples with a mixture of carbide welding ash. So it can be seen that the mass density of the soil in the mixture of bricks with carbide welding ash is smaller than the mass density of the soil in the mixture of bricks with acacia ash, which will affect the compressive strength value. The graphs of the results for the specific gravities at 7 days and 14 days are shown in Figure 1.

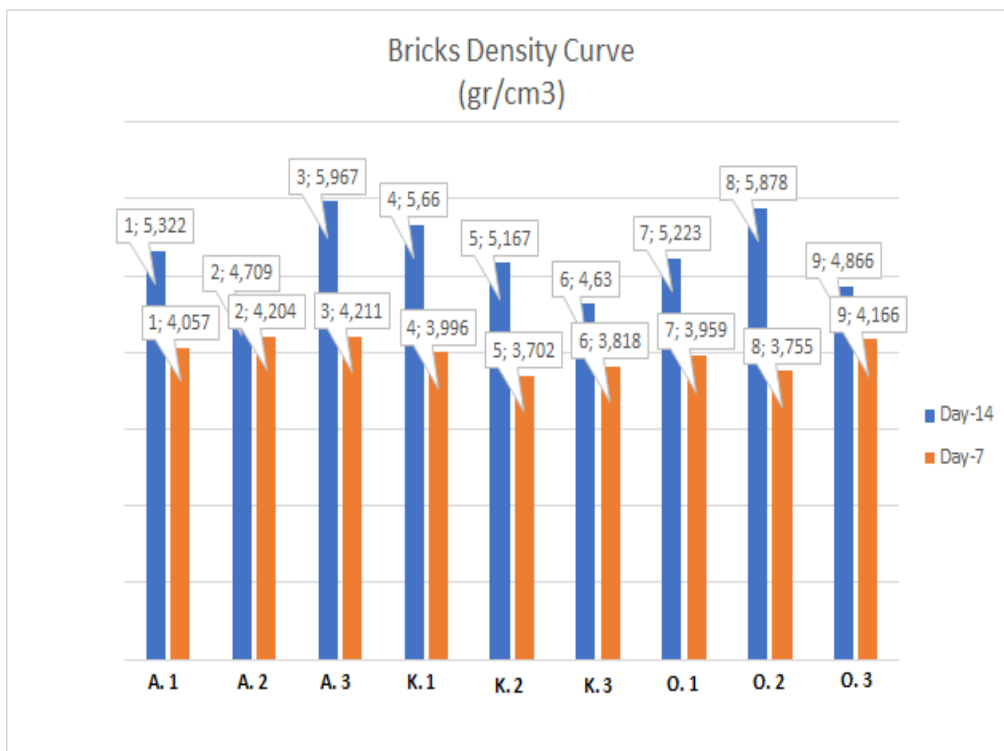


Figure 1. Brick Weight Graph

The compressive strength test of mixed bricks made of carbide welding ash, acacia ash and conventional bricks obtained from the compressive strength tester based on the maximum load value of the machine can be seen in Table 3.

Table 3. Results of Brick Compressive Strength Tests for 7 and 14 Days

Brick Sample	Maximum Load (gr)		Compressive Strength Bricks (MPa)			
	7 Days	14 Days	7 Days	Average	14 Days	Average
A.1	380.000	180.000	9,002	9,033	18,095	12,603
A.2	200.000	185.000	8,775		9,835	
A.3	205.000	175.000	9,322		9,880	
K.1	200.000	190.000	8,913	8,174	8,658	8,225
K.2	175.000	155.000	7,360		7,576	
K.3	195.000	175.000	8,249		8,442	
O.1	200.000	180.000	9,002	8,995	9,403	9,078

Brick Sample	Maximum Load (gr)		Compressive Strength Bricks (MPa)			
	7 Days	14 Days	7 Days	Average	14 Days	Average
O.2	195.000	175.000	9,298		9,398	
O.3	175.000	185.000	8,686		8,434	

(Source: Test data, 2024)

Table 3 is the result of the compressive strength of bricks with a mixture of carbide welding ash, acacia ash and conventional bricks based on the maximum load value on the machine in grams. From the test results, the highest average compressive strength value was obtained in brick samples with a mixture of acacia ash with a compressive strength value of 9.033 MPa, then continued with conventional bricks with an average compressive strength value of 8.995 MPa and the lowest average compressive strength value was found in bricks with a mixture of carbide welding ash with a value of 8.175 MPa at the age of 7 days, while the maximum average compressive strength at the age of 14 days was found in brick samples with a mixture of acacia ash with a compressive strength value of 12.603 MPa, followed by conventional bricks with a compressive strength value of 9.078 MPa and the lowest average compressive strength value was in bricks with a mixture of carbide welding ash with a compressive strength value of 8.225 MPa.

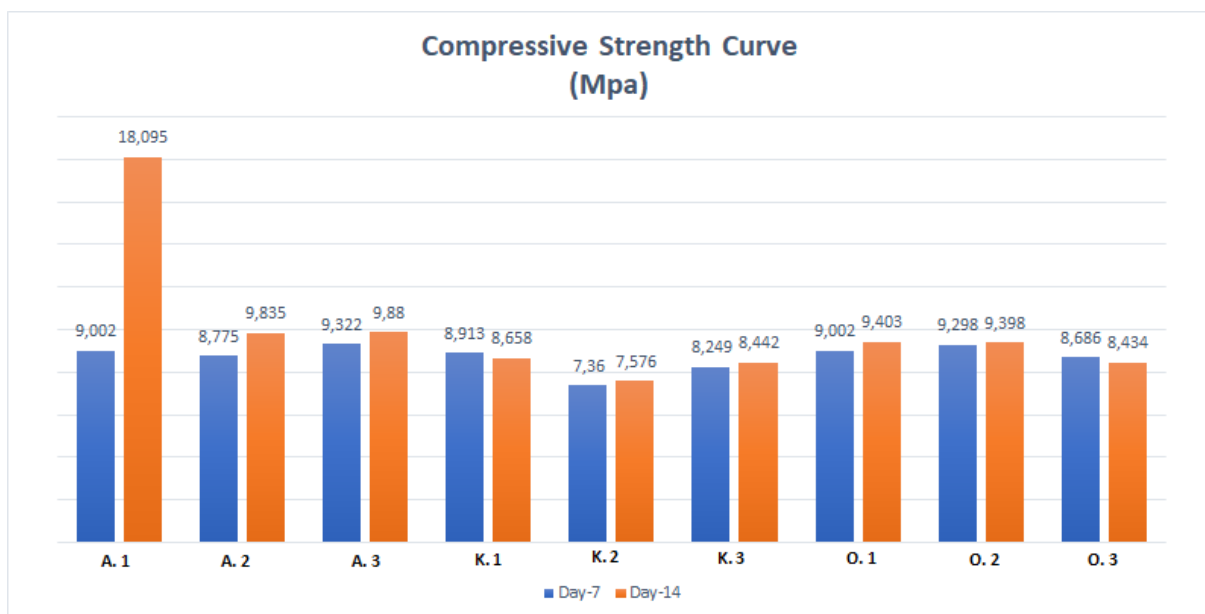


Figure 2. Graph of Brick Compressive Strength Results

Figure 2 shows a graph of the increase in the compressive strength of bricks, where the graph clearly shows that the compressive strength of bricks at the age of 14 days has increased compared to the compressive strength of bricks at the age of 7 days. Meanwhile, the comparison of the specific gravity and compressive strength values of bricks with a mixture of carbide welding ash, acacia ash, and conventional bricks is shown in Table 4.

Table 4. Specific Gravity and Compressive Strength Values of Bricks

Brick Sample	Specific Gravity Bricks (gr/cm <sup>3</sup> )				Compressive Strength Bricks (MPa)	
	7 Days	Average	14 Days	Average	7 Days	14 Days
A.1	4,057	4,157	5,322	5,332	9,002	18,095
A.2	4,204		4,709		8,775	9,835
A.3	4,211		5,967		9,322	9,880
K.1	3,996	3,838	5,660	5,152	8,913	8,658
K.2	3,702		5,167		7,360	7,576
K.3	3,818		4,630		8,249	8,442
O.1	3,959	3,96	5,223	5,322	9,002	9,403
O.2	3,755		5,878		9,298	9,398
O.3	4,166		4,866		8,686	8,434

Source: Test data, 2024)

Table 4 is a table of specific gravity values and compressive strength results of bricks at 7 and 14 days, in the specific gravity table it can be seen that the composition of unfired bricks at the age of 14 days is higher than that of unfired bricks at the age of 7 days. The minimum specific gravity of bricks is found in brick samples with a mixture of carbide welding ash with an average specific gravity value of 3.838 gr / cm<sup>3</sup> and for the maximum specific gravity value of bricks obtained from the test results on brick samples with a mixture of acacia ash with an average specific gravity value of 4.157 gr / cm<sup>3</sup> at the age of 14 days, the average maximum specific gravity value of 5.332 gr / cm<sup>2</sup> is found in brick samples with a mixture of acacia while the average minimum specific gravity value of 5.152 is found in brick samples with a mixture of carbide welding ash.

### Correlation of Specific Gravity Value to Compressive Strength of Bricks

Specific gravity value (*density*) is the mass of dry soil that fills the space within the soil layer within the brick sample (Prayuda et al., 2018). The specific gravity of the soil in the brick sample is the mass of the dry soil per unit volume. This volume, in this case, represents the space within the soil filled by the soil particles formed within the brick sample. A comparison can be illustrated by the correlation graph of specific gravity values against the compressive strength of bricks at 7 days old, shown in Figure 3.

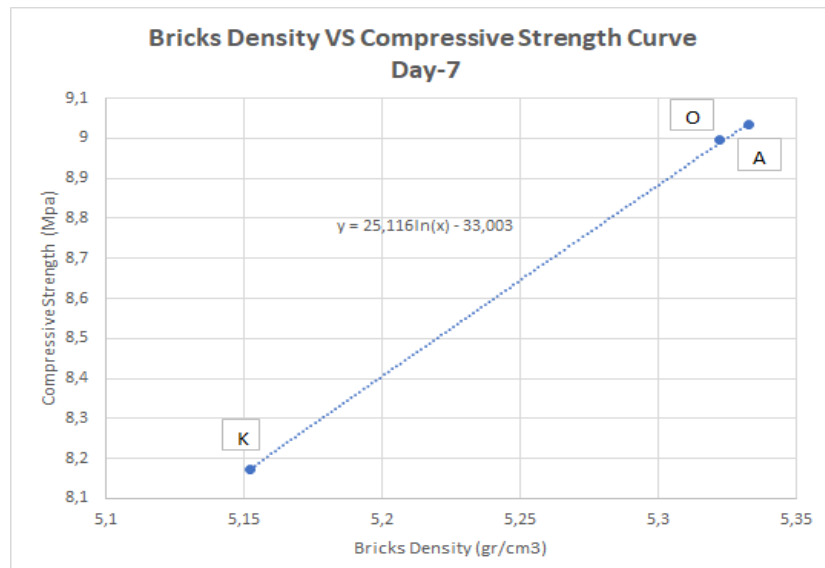


Figure 3. Graph of Brick Type Weight VS Press Strength 7 Day Drying Age

Figure 3 is a graph of the specific gravity of 7-day-old bricks against their compressive strength, showing that the greater the specific gravity, the greater the compressive strength. From the graph, it can be seen that the maximum specific gravity is in the brick sample with acacia ash mixture. The correlation graph of specific gravity and compressive strength shows a direct relationship, indicating that the brick sample with acacia ash mixture has a higher compressive strength than the brick samples mixed with carbide welding ash and conventional bricks. This shows that the brick with acacia ash mixture is stronger in resisting pressure, so that it lasts longer in resisting the load until it cracks and breaks. The analysis based on the correlation graph of specific gravity versus compressive strength at 14 days is shown in Figure 4.

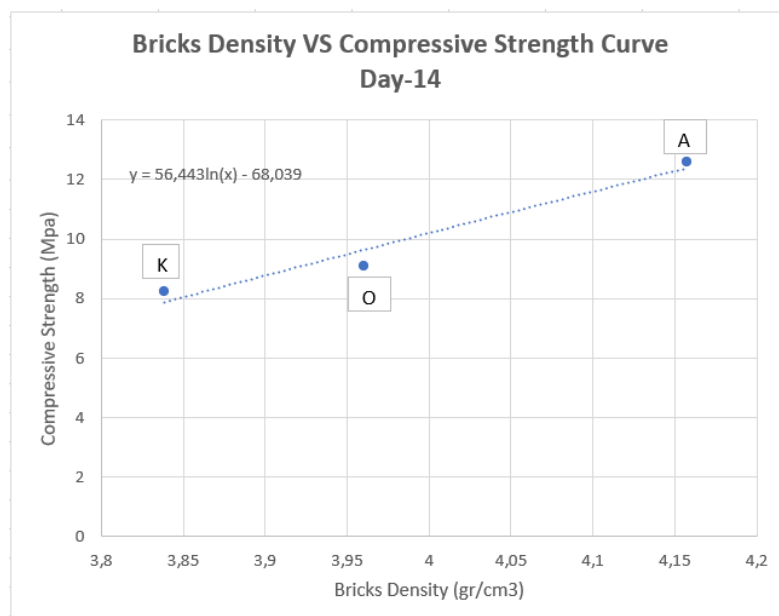


Figure 4. Graph of Brick Type Weight VS Compressive Strength at 14 Days of Age

The graph in Figure 4 also shows the same correlation between specific gravity and the compressive strength of bricks. At 14 days, the specific gravity shows that the higher the specific gravity, the greater the compressive strength of the bricks obtained. At the age of 14 days, the

maximum specific gravity value of the bricks was obtained from brick samples with acacia ash mixture, while the smallest specific gravity value was obtained from brick samples with a mixture of carbide welding ash, and these values are directly proportional to the graph that the higher the specific gravity value, the greater the compressive strength of the bricks.

Among the 3 compositions added to the brick mixture, it is known that the addition of acacia ash waste material has the highest specific gravity and the highest compressive strength of bricks compared to other types of mixture compositions. This is due to the nature of acacia ash which has characteristics such as fillers that fill the cavities of the brick elements (Prayuda et al., 2018) so that it makes bricks with acacia mixture denser and has higher compressive strength, while bricks with a mixture of carbide welding ash have water-soluble properties (Adriana et al., 2023) so that it causes the drying process to be faster than other bricks but has the lowest specific gravity and compressive strength of bricks because bricks with a mixture of carbide welding ash cause bricks to be brittle because they are hot so that the bricks are easily broken (Piqri, 2022).

Bricks made with acacia ash offer a manufacturing advantage: they don't require a 7-14-day firing. This process is faster and produces stronger bricks than conventional bricks. By eliminating the lengthy firing process, the time typically spent heating can be allocated to re-molding the bricks, resulting in a larger number of bricks. This has the potential to significantly increase productivity. The application of this research supports the development of an environmentally friendly technology-based brick industry, thereby promoting the industry's sustainability and progress.

## Conclusion

This study demonstrates a clear positive correlation between density or specific gravity and compressive strength of bricks, with higher density values producing greater compressive strength. Brick samples with an acacia wood ash mixture showed the highest compressive strength values compared to those mixed with carbide welding ash and other mixtures. Acacia wood ash acts as a filler, densifying and strengthening the brick structure, while carbide welding ash produces bricks with lower density and compressive strength, because its water-solubility and heat resistance make the bricks more brittle. The maximum density at 7 days was 3.838 gr/cm<sup>3</sup> for the acacia ash mixture, and at 14 days it reached 5.332 gr/cm<sup>3</sup>. For compressive strength, the maximum value at 7 days was 9.033 MPa, and at 14 days it reached 12.60 MPa. The enhanced performance is primarily attributed to the filler effect of acacia wood ash, which reduces internal porosity and improves particle packing within the brick matrix.

In contrast, bricks containing carbide lime ash showed lower density and compressive strength due to the brittle and water-soluble nature of the additive. Eliminating the firing process significantly reduces energy consumption and production time, making acacia wood ash-based bricks a promising alternative as sustainable construction materials. These findings support the utilization of biomass waste in eco-friendly brick manufacturing and provide practical insights for energy-efficient building material development.

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