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Experimental Study on Compressive Strength and Type Classification of Industrially Produced Mortar

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ABSTRACT

The bond between masonry and concrete units is provided by mortar, and its effectiveness is affected by the mix composition, water ratio, and curing process. This study aims to analyse the compressive strength of mortar produced by PT Beton Elemen Persada using two water ratios, namely 8.2 liters and 9 liters per 50 kg of cement, and to classify its quality according to SNI 03-6825-2002 and SNI 6882:2014/ASTM C270 standards. Cube specimens measuring 5 x 5 x 5 cm were used in laboratory experiments and tested at curing ages of 3, 7, 14, 21, and 28 days. The mortar's strength was determined by the compressive strength test as a standard procedure in construction, while flow table tests were used to evaluate its workability. The research showed that curing age has a significant impact on compressive strength, reaching an average of 13-14 MPa at 28 days.This value is acceptable for exterior walls and medium-load structures due to its compliance with the requirements for Type S Mortar (≥ 12.4 MPa). Furthermore, mortar properties were found to be influenced by the water ratio, with 8.2 liters producing denser mortar with higher strength, and 9 liters improving workability while reducing compressive strength. To sum up, the findings highlight the importance of regulating the water ratio to produce mortar that meets national and international construction standards with balanced compressive strength and workability.

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1. INTRODUCTION

Mortar is an essential component of building construction, particularly as it bonds concrete elements and masonry units. In addition to its function as a binder, mortar also contributes to the aesthetics of buildings, while good-quality mortar helps protect against damage. The primary causes of such damage are environmental factors, such as climate change and extreme weather, as well as human factors, including the lack of awareness of the importance of building maintenance (Rahma et al., 2025). In construction work, the mortar used must have properties such as ease of application, water resistance, good adhesion, quick drying, durability, and no cracking after installation. An important mechanical property of mortar is its compressive strength (Supriyadi et al, 2022).

One of the main parameters in assessing mortar quality is compressive strength, which is an indicator of mortar's resistance to compressive loads and also determines its quality classification according to applicable construction standards. Mortar serves as a binding matrix for both structural and non-structural components in a construction. Currently, there are many mortar modifications aimed at achieving maximum compressive strength and mortar quality. The addition of glass powder as a partial replacement for sand can affect the compressive strength of mortar, where replacing a certain amount of sand can increase or decrease the compressive strength of mortar (Muhedin & Ibrahim, 2023). To provide a clear theoretical foundation, this study refers to the classification of mortar as stated in SNI 6882:2014, which adopts ASTM C270. The comparison between these two standards is important to demonstrate the alignment between national and international regulations, while also serving as a reference in determining the research variables related to mortar compressive strength and function. Therefore, **Table 1** presents a comparison of mortar types based on both standards.

Table 1. Comparison of Mortar Types (SNI 6882:2014 & ASTM C270)

Mortar Type	Average Compressive Strength	Main Use	Notes
M	≥ 17.2 MPa	Foundations, retaining walls, structures with heavy loads	Strongest, resistant to high loads and extreme conditions
S	≥ 12.4 MPa	External walls, structures with moderate loads	Combination of strength and workability
N	≥ 5.2 MPa	Interior and exterior walls with light loads	Multi-purpose mortar, most commonly used
O	≥ 2.4 MPa	Non-structural work, light repairs	Low strength, easy to work with

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Mortar Type	Average Compressive Strength	Main Use	Notes
K	≥ 0.7 MPa	Restoration of historic buildings, decorative work	Very weak, used for conservation to avoid damaging old materials

According to SNI (03-6825-2002) , mortar is a mixture of cement, fine sand, and water that has several important properties. It must have cohesion, which is the ability of cement paste to bind sand particles so that they do not crack easily. The result of water absorption on the mortar by adding the amount of sand will result in a greater decrease in the compressive strength of each mortar variation. So that the mixture of plaster walls or specimens to adhere the recommended flooring and mortar walls of simple mortar is a mixture composition with the ratio of cement: sand 1: 5 for Semen Gresik and 1: 4 and 1: 5 for Holcim Cement (Sujatmiko, 2024). Meanwhile, the study (Sadir et al., 2025) explains that the addition of activated charcoal does not have a significant effect on the characteristics of composite mortar, (Lado et al, 2018) explains that the mixture composition and curing age show the average compressive strength value of mortar using Noeleke River Sand is higher.

The study by (Gue et al., 2025) explains that the variation of geothermal and water ratio mud as a partial substitute for cement has a very low effect on the compressive strength of mortar. Meanwhile (Maryenttry, et al., 2024) in their research explain that the addition of lime and fly ash affected by the water ratio significantly affects the compressive strength at 28 days, while fly ash addition at 4% did not meet the requirements because the setting time became faster compared to additions at 1% and 2%. Adding 25% silica fume by weight of lime produces the most optimal mortar performance, both in terms of compressive strength and tensile strength, so this composition is recommended for mortar applications with higher strength requirements. The use of Lapindo mud as a base material for geopolymer has not yet been able to compressive strength geopolymer mortar (Tsaqif et al., 2024). The highest increase in the compressive strength value of mortar with the addition of coconut shell charcoal occurred at the 7.5% variation, amounting to 7.51% (Sihombing et al., 2018).

The mixture with PVC and PP showed an increase in flow diameter and slump flow because round plastic particles reduce friction and water requirements. Compressive strength decreased as the plastic content increased due to weak bonds between plastic aggregates and cement paste, as well as the hydrophobic properties of plastic that inhibit cement hydration (Al-Kerttani et al., 2024). Meanwhile, in mortar with 10% and 15% microsilica replacement, the addition of silt was found to reduce compressive strength.

However, in variations of microsilica replacement of 5%, 20%, 25%, and 30%, the presence of silt did not have a significant effect on the compressive strength of the mortar (Dananjaya & Herdiawan, 2021) . The shrinkage of wet mortar can cause cracking. In this study, mortar shrinkage is influenced by temperature, water-cement ratio, and humidity.

Moreover, f.a.s values of 0.4 to 0.5 were used. The results of the study showed that an f.a.s value of 0.4 provided better mortar strength quality (Li et al., 2022) . Another study from (Martínez-García et al., 2021) stated that the water-to-cement ratio for mortar mixtures is determined based on consistent consistency. Mechanical and physical properties such as density, compressive strength, and flexural strength were studied at various curing periods, and the results showed that the optimal use of FRCA was 25% based on a 90-day curing period. Additionally, in the study (Wang et al., 2025) regarding the replacement of ash powder, f.a.s and cement ratio in slag mortar mixtures, it was found that the best f.a.s ratio to use is 0.44.

This study analyzes the compressive strength of mortar with varying water ratios produced by PT Beton Elemen Persada and classifies mortar types based on laboratory tests following SNI 03-6825-2002. The main issue addressed is the company's recommendation to use 9–10 liters of water, which in practice produces overly thin mixtures and raises concerns about product quality and consistency. Moreover, the classification of the mortar produced remains unclear in relation to national and international standards. To address this, the study systematically examines the most appropriate water ratio for achieving good consistency, evaluates compressive strength across ratio variations, and classifies mortar types based on laboratory results, including flow tests often overlooked in previous research. This approach provides a comprehensive assessment of mortar quality, compliance with standards, and recommendations for product development.

The novelty of this study lies in its dual focus: not only evaluating mortar performance in terms of compressive strength but also emphasizing systematic classification based on laboratory testing. This distinguishes it from prior studies that mainly explore alternative materials or additives while paying less attention to fundamental mortar properties and standard compliance. Thus, this study is expected to provide a new contribution to the literature and enhance the understanding of academics in designing materials to address construction competencies and the challenges of an increasingly irrelevant labor market (Tauhid et al., 2022) in relation to mortar, particularly within the context of evaluating the quality of industrial concrete products in Indonesia, as well as serving as a practical reference for the development of quality standards and product innovation in the construction sector.

2. METHOD

This research method uses a laboratory experimental approach to determine the compressive strength of mortar and classify it based on its water concentration ratio. The material used is mortar produced by PT Beton Elemen Persada under the trademark LB-PP / LB-PP-R adhesive and brick plaster. 9 liters per 50 kg and 8.2 liters per 50 kg were the water ratio variations tested. The test specimens were made in the form of 5 × 5 × 5 cm cubes in accordance with the testing procedures specified in SNI 03-6825-2002.

A total of 15 test specimens were used, divided according to the water ratio variation. After the moulding and curing process, the test specimens were tested using a compression testing machine to obtain the compressive strength value of the mortar. Compressive strength testing of mortar was carried out at 3, 7, 14, 21 and 28 days of age, with 3 test specimens representing 2 different mixtures. The compressive strength testing procedure was based on SNI 03-6825-2002. Mortar compressive strength testing was conducted using a compression testing machine available at the Construction Materials Testing Laboratory of the Bandung State Polytechnic. The compression testing machine used can provide direct mortar compressive strength values in kilonewtons (kN). To calculate the compressive strength using the formula below.

$$\mathbf{fc} = \frac{P}{A} \times 100$$

(SNI 03-6825-2002)

Where:

fc = mortar compressive strength (MPa)

P = maximum load received by the test specimen during testing (N)

A = cross-sectional area of the test specimen (mm^2)

In addition to compressive strength testing, a mortar flow test was also conducted to determine the workability of the mortar mixture. The mortar flow test was carried out using a flow table: the mortar mixture was placed on a cone-shaped test table, then dropped (dropped 25 times in 15 seconds according to the standard). The diameter of the mortar spread after dropping is measured, and the results indicate the workability and ease of application of the mortar. To calculate using the formula

$$\textbf{Flow (\%)} = \frac{D2-D1}{D1} \times 100\%$$

(SNI 6882:2014/ASTM C270)

Where:

D1 = initial diameter of the mortar mixture before being pounded (mm)

D2 = average diameter of the mortar mixture after 25 drops on the flow table (mm)

In addition, the mean value is calculated to represent the central tendency of the test results at each specimen age, using the formula:

$$\bar{x} = \frac{\sum x}{n}$$

Where x is the compressive strength value of each specimen, and n is the number of specimens.

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3. RESULT AND DISCUSSION

To evaluate the workability and consistency of mortar mixtures, a flow test was conducted with different water ratios. This test conducted in the laboratory by testing two water ratio comparisons, namely 8.2 and 9, the mortar flow results were obtained as showed in the **Table 2** provides insight into how variations in water content affect the spread and flow characteristics of mortar.

Table 2. Mortar Flow Test Results

Mortar	Water Ratio (l)	D1	D2
1	9	100	280
2	8.2	100	230

As presented in **Table 2,** the results of the mortar flow test show that for mixture 1 with a water ratio of 9 liters, the flow value was calculated using the formula Flow (%) of mixture 1 $=\frac{280-100}{100}$ x 100% resulting in 180%. Meanwhile, for mixture 2 with a water ratio of 8.2 liters, the flow value was obtained from the calculation Flow (%) of mixture 2 $=\frac{230-100}{100}$ x 100% which yielded 130%. These results illustrate how variations in water content influence the spread and flow characteristics of mortar. Flow mortar testing showed that variations in the water ratio have a significant effect on the workability of mortar. At a water ratio of 8.2 litres per 50 kg, the flow mortar test result is 23 cm. This value falls within the range of 21–23 cm (110–130%), which according to ASTM/SNI is the standard range for laboratory testing. It means that mortar with a water ratio of 8.2 litres has a relatively thick consistency but still meets the standard, making it denser and potentially producing higher compressive strength, although it is slightly more difficult to work with in field applications. **Figure 1** showed how the mortar flow test.

Figure 1. Mortar Flow Test

Meanwhile, at a water ratio of 9 litres per 50 kg, the mortar flow test result was 28 cm. This value falls within the range of 23–28 cm (130–180%), which is categorised as the practical range for brick/plaster mortar. This indicated that mortar with a water ratio of 9

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litres is more fluid and has higher workability, making it easier to apply in the field. However, overly plastic properties can reduce density and risk reducing compressive strength if not properly controlled. In general, these test results confirm that < 21 cm (≤ 110%) → Mortar is too thick, difficult to apply, and at risk of cracking due to insufficient workability, 21–23 cm (110–130%) → Standard range for laboratory testing (ASTM/SNI), 23–28 cm (130–180%) → Practical range for brick/plaster mortar, considered to still have normal workability, 28 cm (> 180%) → Mortar is too thin, easy to apply but at risk of segregation and reduced compressive strength. Thus, a water ratio of 8.2 litres is more suitable for laboratory testing and quality research because it produces dense mortar, while a water ratio of 9 litres is more suitable for field applications that require ease of workability, although the potential for a decrease in compressive strength must be taken into account. Results showed that compressive strength and split tensile strength of cement mortar decreased with an increase in the *w/c* ratio. It is observed that minimum *w/c* ratio required to make the cement mortar workable is 0.5 (Ayanlere et al., 2025). The mortar test conducted in the laboratory with a water ratio of 9 liters yielded compressive strength data, which are presented in **Table 3.**

Table 3. Mortar Mix with a Water-to-Cement Ratio of 9 Litres

Test Specimen Code	Age (days)	Cross-sectional Area (A)	Compressive Load (P)	Compressive Strength (MPa)	Note
C1	3	26.13	22.60	8.65	Good
E3	3	25.64	11.00	4.29	Porous
E1	7	25.81	27.20	10.54	Good
C2	7	25.83	28.50	11.03	Good
D2	14	25.78	26.90	10.26	Good
E2	14	25.89	27.80	10.85	Good
C3	21	25.84	31.70	12.15	Good
D3	21	25.02	33.80	13.23	Good
D1	28	25.62	33.80	13.18	Good

As presented in **Table 3**, Compressive strength testing of mortar was conducted on test specimens with ages of 3, 7, 14, 21, and 28 days. To obtain the compressive strength, the following formula was used Fc-C1 $=\frac{P}{A}\times 100 = \frac{22.60}{26.13}\times 100 = 8.65$ MPa, to calculate the mean according to the specimen age example age 14 x- = $\frac{10,26+10,85}{2}$ = 10,56 MPa. The data obtained was then averaged for each age, with the exception of sample E3, which was not used due to its porous condition. The average compressive strength values of the mortar are as follows for age 3 days obtained a compressive strength of 8.65 MPa, 7 days old: 10.78 MPa, 14 days: 10.56 MPa, 21 days: 12.69 MPa, 28 days old: 13.18 Mpa.

The test results show an increase in compressive strength as the test specimen ages, which is consistent with the Portland cement hydration process. At 3 days of age, the compressive strength is still relatively low because the hydration reaction has not yet developed optimally. At 7 days of age, there is a significant increase to an average of 10.78 MPa. At 14 days of age, the compressive strength value was relatively stable (10.56 MPa), indicating a transition phase before further increase. An increase is again observed at 21 days with an average of 12.69 MPa, reaching a maximum value at 28 days of 13.18 MPa. This is consistent with the characteristics of Portland cement mortar, which generally achieves its design strength at 28 days.

In addition, the flow mortar test results show that the water ratio affects workability. Mortar with a water ratio of 8.2 liters/50 kg of c e produced a flow of 23 cm, which is within the laboratory standard range (21–23 cm, 110–130%). Mortar with a water ratio of 9 liters/50 kg produced a flow of 28 cm, which is within the practical range (23–28 cm, 130–180%) for brickwork/plastering. This confirms that a higher water ratio increases workability but has the potential to reduce compressive strength if not controlled as presented in **Figure 2.**

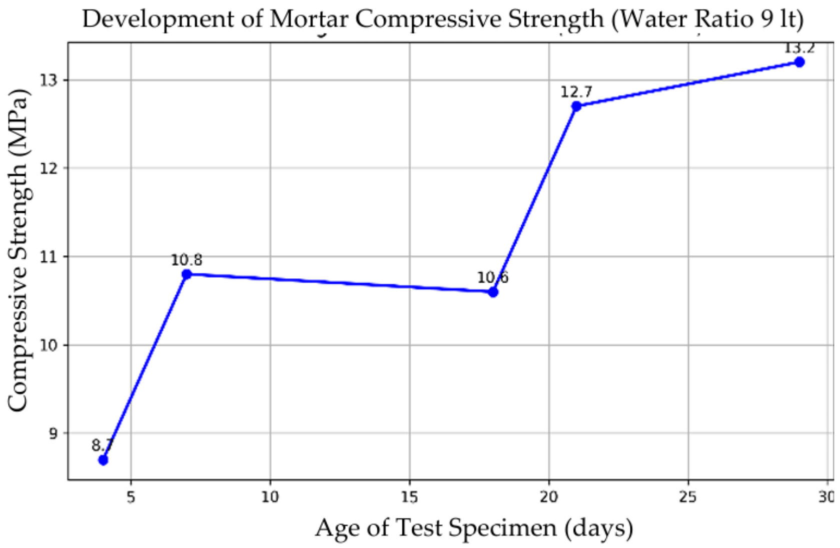

Figure 2. Compressive Strength Graph for a Water Concentration Ratio of 9 Litres

The mortar test conducted in the laboratory with a water ratio of 8.2 liters yielded compressive strength data, which are presented in **Table 4.**

Table 4. Mortar Mix with Water Concentration Ratio of 8.2 Litres

Test Specimen Code	Age (days)	Cross-sectional Area (A)	Compressive Load (P)	Compressive Strength (MPa)	Note
A1	3	26.29	24.10	9.17	Good

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Test Specimen Code	Age (days)	Cross-sectional Area (A)	Compressive Load (P)	Compressive Strength (MPa)	Note
B1	7	24.98	27.30	10.93	Good
A2	14	24.91	28.60	11.26	Good
B2	21	25.67	33.20	12.88	Good
A3	28	26.32	37.50	14.35	Good
B3	28	26.06	33.60	12.97	Good

Mortar test data with a water ratio of 8.2 litres/50 kg shows an increasing trend in compressive strength from 3 to 28 days, with the highest average at 28 days being 13.66 MPa. Average Compressive Strength per Age 3 days obtained a compressive strength of 9.17 MPa, 7 days 10.93 MPa, 14 days 11.26 MPa21 days 12.88 MPa and 28 days 13.66 MPa. The test results showed that the compressive strength of mortar increases with the age of the test specimen, in accordance with the hydration characteristics of Portland cement. At 3 days of age, the compressive strength is still low (9.17 MPa) because the hydration reaction is not yet optimal. At 7–14 days of age, there is a significant increase to 11.26 MPa. At 21 days, the average compressive strength increased to 12.88 MPa, reaching a maximum value of 13.66 MPa at 28 days. It is confirmed that mortar with a water ratio of 8.2 liters/50 kg has good density and strength, and it increases consistently until the standard age of 28 days. Next, **Figure 3** presented the Compressive Strength Graph for Water Concentration Ratio of 8.2 liters.

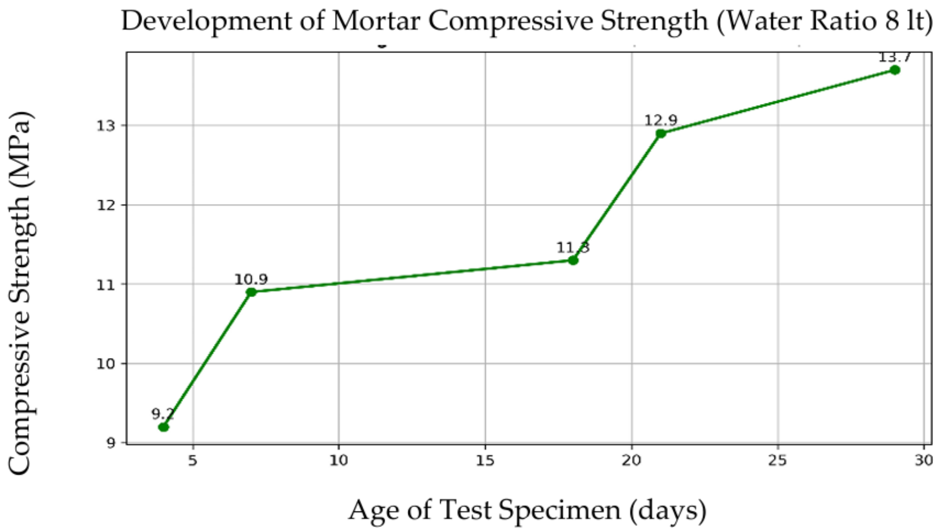

Figure 3. Compressive Strength Graph for Water Concentration Ratio of 8.2 Litres

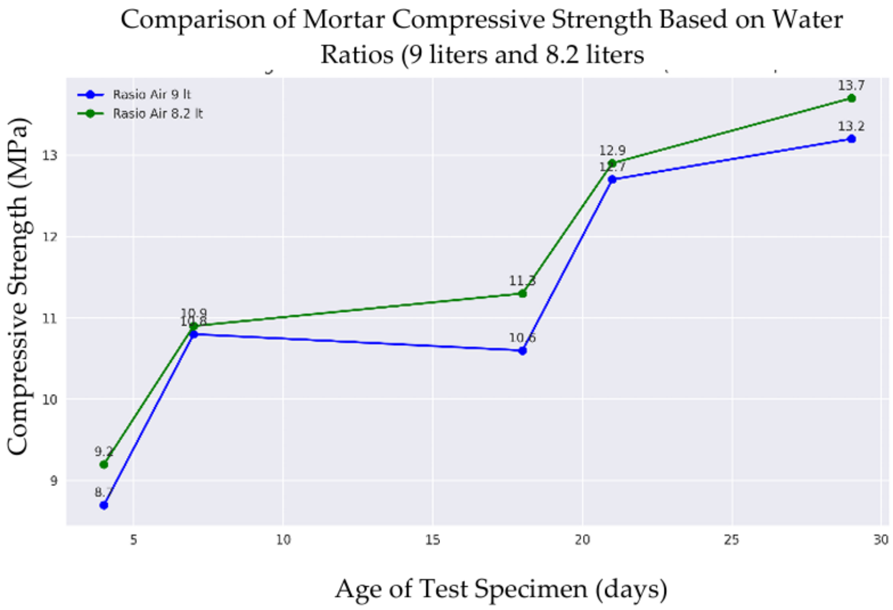

Figure 4. Comparison of Compressive Strength Graphs for Water Concentration Ratios of 9 and 8.2 Litres

Figure 4 showed the compressive strength development curve of mortar based on two variations of water-to-cement ratios, namely 8.2 L/50 kg and 9.0 L/50 kg, tested at ages of 3, 7, 14, 21, and 28 days. In general, both curves show an increasing trend in compressive strength as the age of the test specimen increases, which is consistent with the cement hydration mechanism and the formation of a denser microstructure over time. At a water ratio of 8.2 L/50 kg, the initial compressive strength (day 3) was higher than that of the 9.0 L/50 kg ratio, and this advantage persisted until day 28. This indicates that a lower water ratio produces a denser mortar mix with lower porosity, enabling it to withstand greater compressive loads. Conversely, a higher water ratio (9.0 L/50 kg) tends to produce mortar with lower compressive strength, presumably due to an increase in free water volume that contributes to the formation of capillary voids in the mortar structure.

The difference in compressive strength between the two water ratios became more apparent at 14 to 28 days, indicating that the effect of the water ratio on mortar strength is not only significant in the early stages, but also affects long-term strength. This phenomenon is in line with the principle that a lower water-cement ratio supports the formation of more efficient hydration products and better structures. The following are test specimens in the form of mortar cubes that have undergone compressive strength testing. Several concrete cubes with crack patterns marked with symbols and letters (A3, B3, D1) at 28 days of concrete age. The A3 mortar cube shows a more controlled or smaller crack pattern, indicating better resistance to loads. The compressive strength value for the A3 cube is the highest at 14.35 MPa as showed in **Figure 5.**

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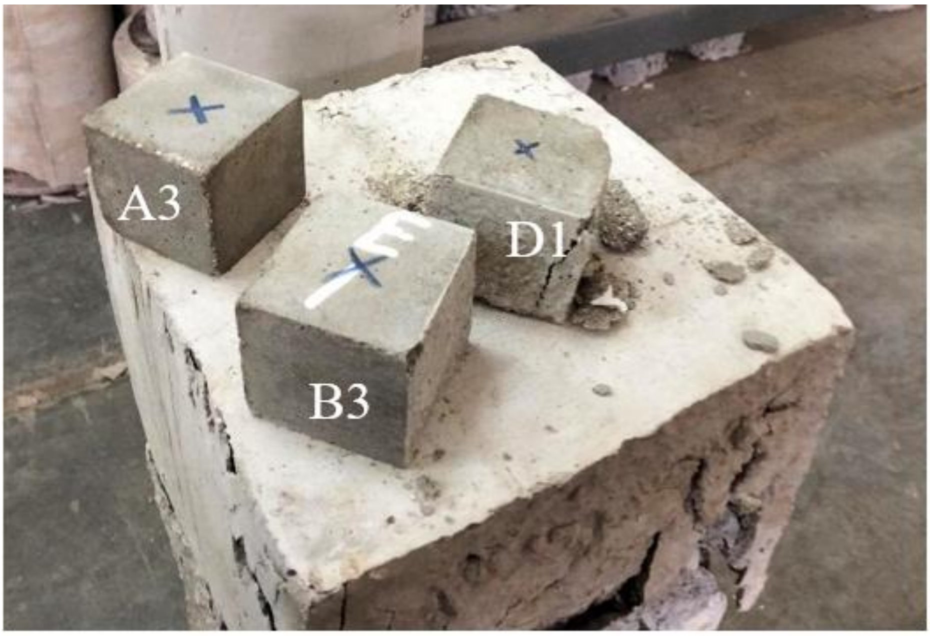

Figure 5. Crack Patterns in Concrete Compressive Strength Test Results at 28 Days

Thus, this study is expected to provide a new contribution to the literature and enhance the understanding of academics in designing materials to address construction competencies and the challenges of an increasingly irrelevant labor market (Tauhid et al., 2022) in relation to mortar, particularly within the context of evaluating the quality of industrial concrete products in Indonesia, as well as serving as a practical reference for the development of quality standards and product innovation in the construction sector. The quality of mortar is affected by the water content in the mortar mixture. The aggregate's water content (in the field) must be known to determine the amount of water required for the mortar mixture and determine the aggregate's unit weight. The water requirement in mortar mixes is usually based on the aggregate being in a dry saturated state. Therefore, if the site is dry, the mortar mix will absorb water, but if the aggregate is wet, it will add water (Muhammad & Priambodo, 2020). The amount of water added affects the hydration process: excessive water will cause numerous air bubbles after hydration is complete, while insufficient water will prevent complete hydration (Ali & Walujodjati, 2023; Wei & Maeda, 2023) .

Furthermore, recent studies emphasize that water content plays a fundamental role in controlling the microstructural evolution and mechanical performance of cement-based materials, particularly through its influence on the water–cement ratio. Variations in this ratio significantly affect pore structure development, where higher water content leads to increased capillary porosity, which in turn reduces compressive strength and structural integrity (Zheng et al., 2021). This finding is reinforced by more recent experimental studies demonstrating that although higher water content improves fluidity and workability, it simultaneously weakens mechanical performance due to the formation of a more porous internal structure (Jierula et al., 2024). Therefore, careful control and

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accurate estimation of water content especially under variable field conditions—are essential to ensure the reliability, performance, and sustainability of mortar and concrete products in modern construction practices.

4. CONCLUSION

The test has showed that the compressive strength of mortar increases with the age of the test specimen, in accordance with the Portland cement hydration process. At an early age (3 days), the compressive strength is still low because the hydration reaction is not yet optimal. At 7–14 days of age, there is a significant increase, which continues to increase until it reaches its maximum value at 28 days of age. The average compressive strength value at 28 days is in the range of 13–14 MPa, which falls into the Type S Mortar category according to SNI 6882:2014/ASTM C270 (≥ 12.4 MPa). This type of mortar is suitable for use in exterior walls or structures with moderate loads. In addition, the mortar flow test results showed that the water ratio affected workability. A lower water ratio (8.2 L/50 kg) produced mortar with better density and strength, while a higher water ratio (9.0 L/50 kg) improved workability but reduced compressive strength. Overall, this study confirms that controlling the water ratio is crucial to obtaining mortar with a balance between compressive strength and workability, thereby meeting technical requirements and construction standards.

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