



Impact of Incorporating Rattan Cane in Red Brick Unit Interlocking Systems on Compression and Shear Strength Properties

Eka Juliafad ^{1*}; Fajri Yusmar¹; Nevy Sandra ¹; Lisyana Junelin Restu ¹; Fauzan¹

1. Civil Engineering Department, Faculty of Engineering, Universitas Negeri Padang, Padang, Indonesia

* Corresponding author: ekajuliafad@ft.unp.ac.id

ARTICLE INFO

Article history:

Received: 17 March 2025

Revised: 04 August 2025

Accepted: 17 August 2025

Keywords:

Masonry;

Interlocking Bricks;

Rattan;

Shear Strength;

Compressive Strength.

ABSTRACT

The interlocking mechanism enhances the material's shear strength by increasing its resistance to shear forces and reducing the likelihood of brittle failure. In this study, rattan was employed as the interlocking material due to its inherent ductility, which is anticipated to improve the shear performance of masonry walls. This system was applied to locally produced red brick units in West Sumatra, Indonesia. The proposed interlocking system introduces a lightweight, affordable, and environmentally friendly alternative to conventional strengthening techniques. The home industry usually makes red bricks in Indonesia with minimal supervision; hence, the compression and shear strength are inadequate. The test objects were red bricks available in West Sumatra, Indonesia. Rattan interlocked these bricks at penetration depths of 0.5 cm, 1 cm, and 1.5 cm. Compressive and shear strengths were tested on the masonry with these interlocking configurations. The results showed that the bricks with 1.5 cm interlocking had the best performance; their compressive strength of 11.74 Kg/cm² decreased by only 13% compared to bricks without an interlocking system of 13.44 Kg/cm². The shear strength was 5.988 Kg/cm², which increased by 63% compared to the brick unit without an interlocking system, which was 3.599 Kg/cm².

E-ISSN: 2345-4423

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How to cite this article:

Juliafad, E., Yusmar, F., Sandra, N., Restu, L. Junelin and Fauzan, F. (2026). Impact of Incorporating Rattan Cane in Red Brick Unit Interlocking Systems on Compression and Shear Strength Properties. Journal of Rehabilitation in Civil Engineering, 14(2), 2290 <https://doi.org/10.22075/jrce.2025.2290>

1. Introduction

Masonry serves as a vertical structural component in buildings, functioning both as a support for the ceiling and as a partition between different areas, while also contributing to the overall rigidity of the structure. Various materials are commonly used in masonry construction, including red brick, natural stone, hollow bricks, wood or board, plywood, cubicle panels, concrete, asbestos, and others [1–4]. In Indonesia, red brick is the most frequently utilized masonry material. It is produced by shaping clay and subsequently firing it. This is regulated under SNI 15-2094-2000 [5] titled "Solid Red Brick for Wall Pairs."

Interlocking bricks refer to a system in which bricks are designed to mechanically lock or hook into each other [6–10]. The concept of interlocking bricks dates back to the early 1900s and was inspired by the design of children's construction toys. These toys were initially created to demonstrate principles of creativity and to facilitate learning in science, engineering, and architecture. Materials such as tin, metal, wood, and clay were initially used for these toys. Since the 1970s, interlocking bricks made from a mixture of red earth, sand, and cement, which were then fired, have been implemented in regions like Africa, Canada, the Middle East, and India. One notable development in the use of interlocking red bricks is the incorporation of rattan material [2,6,11].

In both low-rise and high-rise structures, red brick walls influence the building's structural behavior. During an earthquake, lateral forces are transmitted from the wall frame (portal) to the structure, which may cause cracks in the walls [12–15]. However, the response of brick-walled frames to lateral loads has been extensively researched. Brick walls possess adequate strength and stiffness to resist such forces. Globally, various techniques have been developed to reinforce masonry, including PP-Band Mesh, fiber-reinforced paints, wire mesh systems, and the use of polypropylene fiber mortar [16–21]. Despite their effectiveness, these reinforcement methods are applied to the exterior surface of the masonry, which many architects or building owners find undesirable due to the visual alteration. In contrast, the interlocking brick method offers an alternative reinforcement solution that maintains the architectural integrity of the masonry [9].

The use of bamboo as a substitute for steel reinforcement in RC structures was reviewed by Das et al. One of the largest sources of greenhouse gas emissions worldwide, especially carbon dioxide (CO₂), is the building industry. High CO₂ emissions and energy consumption, which account for 36–40% of world emissions in industrialized nations, highlight the necessity of changing the way building materials are used. Conventional materials such as cement, steel, and glass are known to have high carbon intensity both during the production stage and during the construction process. Bamboo was selected because of its renewable, eco-friendly, and reasonably priced qualities. The approach used is a systematic literature review based on the PRISMA 2020 method. *Bambusa balcoa*, *Bambusa vulgaris*, *Dendrocalamus asper*, and *Bambusa bamboo* are the species that have been examined the most; they have an average tensile strength of 118.578 MPa and an elastic modulus of 15.529 GPa. According to these numbers, bamboo can mechanically replace steel in light to medium structural applications and has a tensile strength that is on par with some hardwoods. In addition to its strength, the use of bamboo has also been reported to save construction costs by up to 36.78% and significantly reduce carbon emissions, making it a potential solution in supporting environmentally friendly development. [22].

Soleymani et al.'s studies provide a comprehensive comparison of their benefits and limitations. It also identifies key knowledge gaps, offers best-practice recommendations, and emphasizes the need for continued research to enhance the preservation of culturally significant masonry structures [23]. Rashid et al. explored an innovative and modern concept known as smart bricks. Experimental results confirm that even a few well-placed smart bricks can identify cracks and monitor strain effectively, making them a practical and innovative solution for preserving and safeguarding built heritage and modern masonry structures [24].

Jahangir and Eshafani have been researching to enhance the brick construction of ancient and historical buildings. They experimentally investigated the bond behavior of steel-reinforced grout (SRG) applied to masonry structures, focusing on factors such as bond length, width, loading rate, and test setup. The results reveal that Mode-II failure predominates across all specimens, and an effective bond length exceeds 150 mm. For bond lengths shorter than this threshold, failure occurs through detachment of the composite's top matrix layer. These findings contribute valuable insights into the bond performance of SRG systems, which are essential for designing effective reinforcement strategies in masonry structures [25]. Eka et al. investigated the use of fiberglass paint to increase the strength of masonry. The study showed that brick masonry strengthening with a fiberglass paint coating increased its compressive and shear strengths. The compressive strength of bricks with fiber paint coating at thicknesses of 1 mm, 2 mm, and 3 mm was 30.1 Kg/cm², 31.22 Kg/cm², and 53.31 Kg/cm², respectively, with an increase percentage of 16.26%, 20.59%, and 105.91% compared to the brick without fiber paint. The shear strength of bricks with fiber paint coating at thicknesses of 1 mm, 2 mm, and 3 mm was 3.77 Kg/cm², 5.35 Kg/cm², and 5.05 kg/cm², respectively, with an increase of 1.34%, 43.82%, and 35.75% compared to bricks without fiber paint coating [21].

One of the most advanced methods for strengthening masonry structures is Textile Reinforced Mortar (TRM). Sangeetha et al.'s investigated the behavior of both unreinforced and TRM-strengthened masonry wallets under diagonal compression. Five types of clay brick specimens (700 × 700 × 115 mm) were tested: unplastered, plastered, GFRP strip wrapped, TRM full plastered, and TRM strip plastered. The unreinforced specimens exhibited brittle failure with diagonal cracking and joint displacement, while TRM-reinforced ones showed improved ductility, distributed cracking, and increased shear strength. TRM strip and full plastering improved strength by 1.13 and 1.68 times, respectively, while GFRP wrapping increased capacity by 44%. Finite element analysis (FEA) using ANSYS accurately predicted the failure modes with less than 8% deviation, confirming TRM as an effective retrofitting solution under diagonal compression. [26]

Afzali et al.'s have also studied the use of waste materials. The study aimed to evaluate the effect of various types and percentages of waste, such as crumb rubber, tire scrap fibers, palm fibers, polymer bag fibers, palm ash, and polypropylene fibers, on the compaction behavior and compressive strength of clayey sandy soil stabilized with cement. Their study's findings demonstrated that, of all the waste materials examined, palm fiber had the greatest impact on the soil's strength and compaction characteristics because of its uniform distribution and stronger inter-particle connections. The combination of 6% cement and 1% polypropylene fiber produced the best sample in terms of ductility behavior. [27]

Fakharian et al.'s study shows that artificial intelligence models can adequately estimate the compressive strength of hollow concrete block masonry prisms. These findings demonstrate the value of AI-based technologies as alternatives to standard empirical models in structural analysis. In a different research, Soleymani et al. demonstrated that calibrating an existing empirical model using machine learning, particularly genetic algorithms, significantly improves the accuracy of textile-reinforced mortar bond strength prediction. The calibrated equation increases the R-value from 0.83 to 0.84 and reduces the mean absolute percentage error from 25.64% to 12.18% [28,29].

This study used the interlocking method. The provision of interlocking on the masonry is expected to increase the material's shear strength, preventing it from being easily damaged by shear forces and undergoing brittle fracture. Brittle fracture is the fracture of a material that begins with rapid cracking in a short time. Ductility properties can limit the seismic forces acting on the structure. The greater the shear strength of the material used in the structure, the greater the level of energy dispersion possessed by the structural system, so that the forces acting or entering the structure will be smaller and reduce the brittle fracture rate of the material [30].

1.1. Research gap and novelty

Most previous research has concentrated on earth bricks or mortar-based bricks where the interlocking features are formed from the same material as the brick itself [2,31–34]. These components typically display the same brittle characteristics. In response to this limitation, the current study introduces a different approach by using rattan as the interlocking element. This alternative material is expected to provide improved tensile properties and potentially increase the shear strength of the brick unit [35].

One of the advantages of using the interlocking system in this study is that interlocking is an internal reinforcement, so it does not change the architectural form of the masonry [1]. We chose rattan as an interlocking material because rattan is ductile or tough, which is expected to increase the shear strength of the wall. Besides its ductility, rattan is a lightweight material, possesses high tensile strength, can withstand compression, is sustainable because it can be found everywhere, and is simple to cultivate [35]. Hence, in this study, we introduce the novel application of rattan cane, one of the renewable materials that support the agenda of sustainable development goals in environmentally friendly alternatives in construction techniques.

2. Materials and methods

2.1. Masonry

Masonry is a solid structure that can limit or even protect an area. There are three main types of structural walls: building walls, boundary walls, and retaining walls [36]. When the wall is subjected to earthquake loads, it will experience some damage, such as shear and flexural damage. Shear failure (Fig. 1) is damage to the wall that, when subjected to an earthquake in the longitudinal direction of the wall (the direction of wall length/x-axis), can cause shear cracks if the wall cannot withstand the earthquake. Flexural damage (Fig. 2) refers to the damage inflicted on the wall when an earthquake occurs in the axial direction (short axis of the wall/z-axis) of the wall's cross-section. Brick walls have a flexural force capacity much smaller than the shear force capacity, so the walls are very easy to collapse or detach if they are not tied to the column, which can cause them to burst [14,37]. Red brick, according to SNI-10 (Indonesia Standard for Red Brick), is defined as a building element used for building construction and is a material made from clay with or without a mixture of other materials and then burned at a high enough temperature so that it cannot be destroyed again when immersed in water [10,38].



Fig. 1. Masonry shear failure source: cendana news [39].



Fig. 2. Masonry flexural failure.

The use of rattan in products is largely based on its strength and durability, with its value primarily assessed by how well it performs under load. Several experimental tests have been conducted to evaluate rattan's flexural toughness, including measurements of flexural strength (modulus of elasticity/MOE) and flexural fracture strength or ultimate load (modulus of rupture/MOR). These tests are typically performed by applying a load at the midpoint of a 28 cm span using a Universal Testing Machine (UTM) with a load capacity of fifteen tons and a testing speed of 10 Kg per minute [40–42]. According to Murdi Harjoko (1994) [43], tree-type rattan demonstrates a bending stress at its lowest elastic limit of 202.56 Kg/cm², while canoe rattan shows a torsional stress at its lowest elastic limit of 98.67 Kg/cm². In contrast, Manau rattan reaches a stress level of 19983.44 Kg/cm² at its highest elasticity limit, classifying it as a high-quality (standard) rattan.

2.2. Research methods

The test objects in this study were normal red bricks sold in Padang, aged 7 days. Rattan material interlocked the test object with penetrations of 0.5 cm, 1 cm, and 1.5 cm. Next, we tested the interlocking masonry's compressive strength and shear strength. The flowchart (Fig. 3) illustrates the steps of this research.

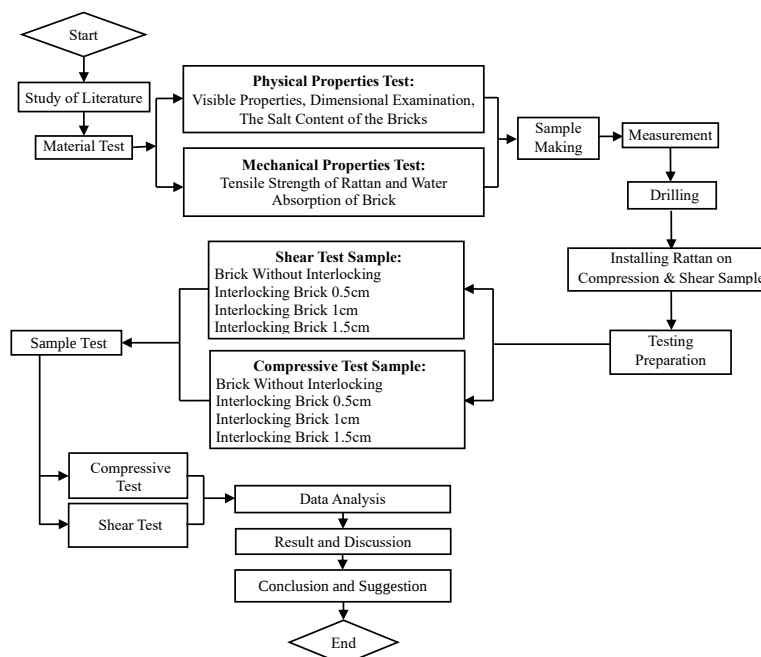


Fig. 3. Research flowchart.

The research began by reviewing existing studies on brick testing. After that, an examination of the bricks' physical and mechanical properties and the rattan's tensile strength was conducted. The brick samples were then prepared for testing. The bricks are measured and drilled, after which they are reinforced with rattan with several types of samples, namely bricks without interlocking and with interlocking of 0.5 cm, 1 cm, and 1.5 cm. In this study, compressive and shear tests were conducted. After the tests, the results were analyzed, the findings were discussed, and conclusions were drawn, including suggestions for future improvements.

Table 1. Rattan details used in the red brick unit for each specimen type.

Name	Mortar Thickness	Penetration Depth	Rattan Length
	(tm)	(dp)	(2lp + tm)
	(cm)	(cm)	(cm)
Brick without Interlocking	2	0	0
Interlocking 0,5 cm	2	0.5	3
Interlocking 1 cm	2	1	4
Interlocking 1,5 cm	2	1.5	5

We obtained the Saga rattan for this study from a rattan-woven shop in Lubuk Begalung, Padang City, Indonesia. The rattan used as interlocking bricks in this study is first measured in diameter to determine the size of the hole drilled in the brick. The diameter of the rattan used is between 0.7 cm and 1 cm. The tensile strength of Saga Rattan was obtained by conducting a tensile strength test using a Universal Testing Machine (Fig. 4.a and Fig. 4.b). The tensile strength of Saga Rattan, on average, is 5.15 MPa. The length of the rattan used is twice the penetration length plus the thickness of the mortar used. Penetration is defined as the depth of interlocking material injected into the brick. Table 1 and Fig. 4.c provide details about the used rattan.

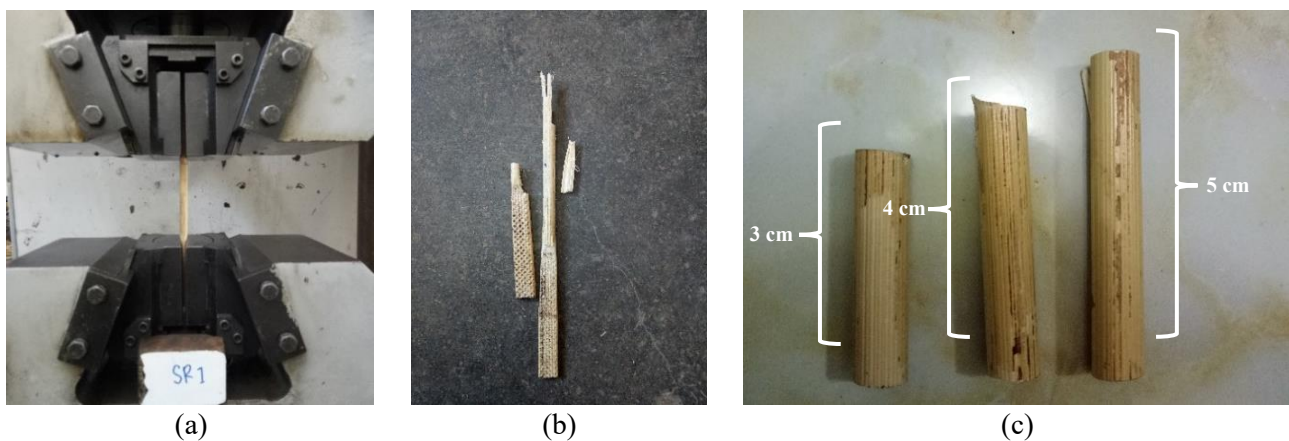


Fig. 4. Saga rattan; (a) Tensile strength of Saga rattan, (b) Saga rattan failure pattern after testing, and (c) Saga rattan as an interlocking.

2.3. Fabricated samples

Fabricated samples consist of compressive strength and shear strength specimens, with details of the shape that can be seen in the following sketch images, Fig. 6 and Fig. 7. Each sample type is made into five units. Fig. 5 illustrates the sample preparation steps.

2.3.1. Brick compression test sample

The design of the compressive brick unit (Fig. 6) involves cutting red brick in half and joining each half with mortar. We used one part Portland cement to three parts fine aggregate for the mortar mix proportion

(Fig. 6(a)). For the brick unit compressive tests, we applied three different types of interlocking rattan with penetration depths of 0.5 cm (Fig. 6(b)), 1 cm (Fig. 6(c)), and 1.5 cm (Fig. 6(d)).

2.3.2. Brick shear test sample

Shear sample types consist of units without interlocking material (Fig. 7(a)) and 3 types with interlocking material for rattan (Fig 7(b), 7(c), and 7(d)). The shear brick sample consists of 5 red bricks united with 2 cm mortar, and each side with the area indicated in green indicates interlock material from rattan.



Samples measurement



Samples drilling



Installing rattan on brick



Installing rattan on the compression test object



Installing rattan on the shear test object



Samples preparation

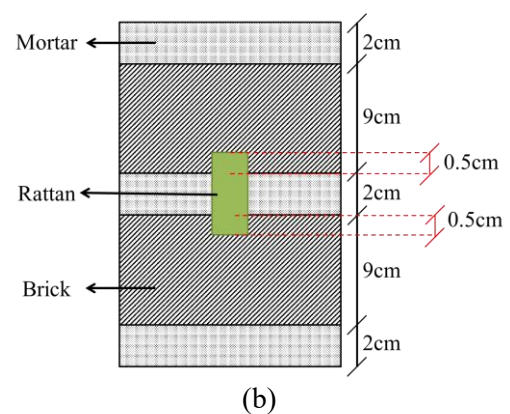
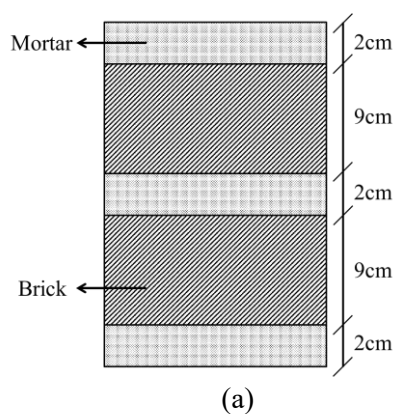


Compression test objects



Shear test objects

Fig. 5. Samples Preparation Process.



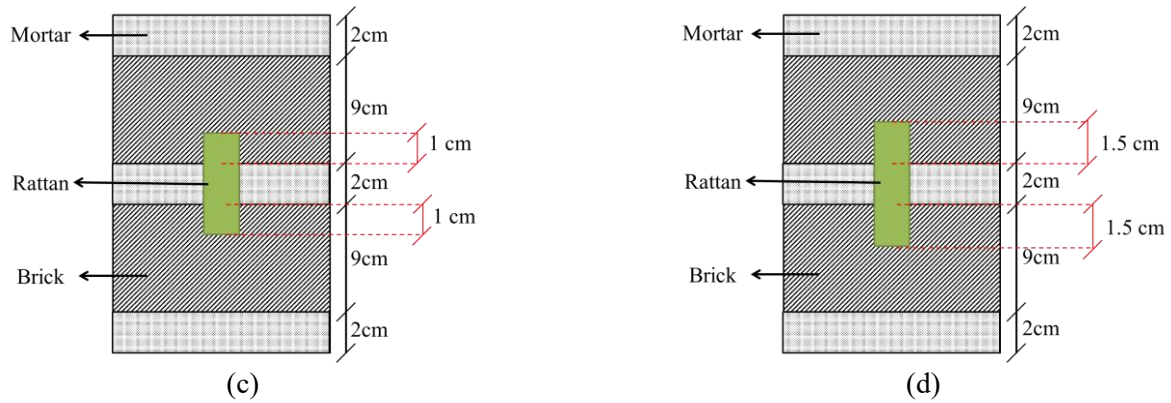


Fig. 6. Fabricated Samples for Compressive Strength Test; (a) Brick without Interlocking, (b) Brick with 0.5mm rattan interlocking, (c) Brick with 1mm rattan interlocking, and (d) Brick with 1.5mm rattan interlocking.

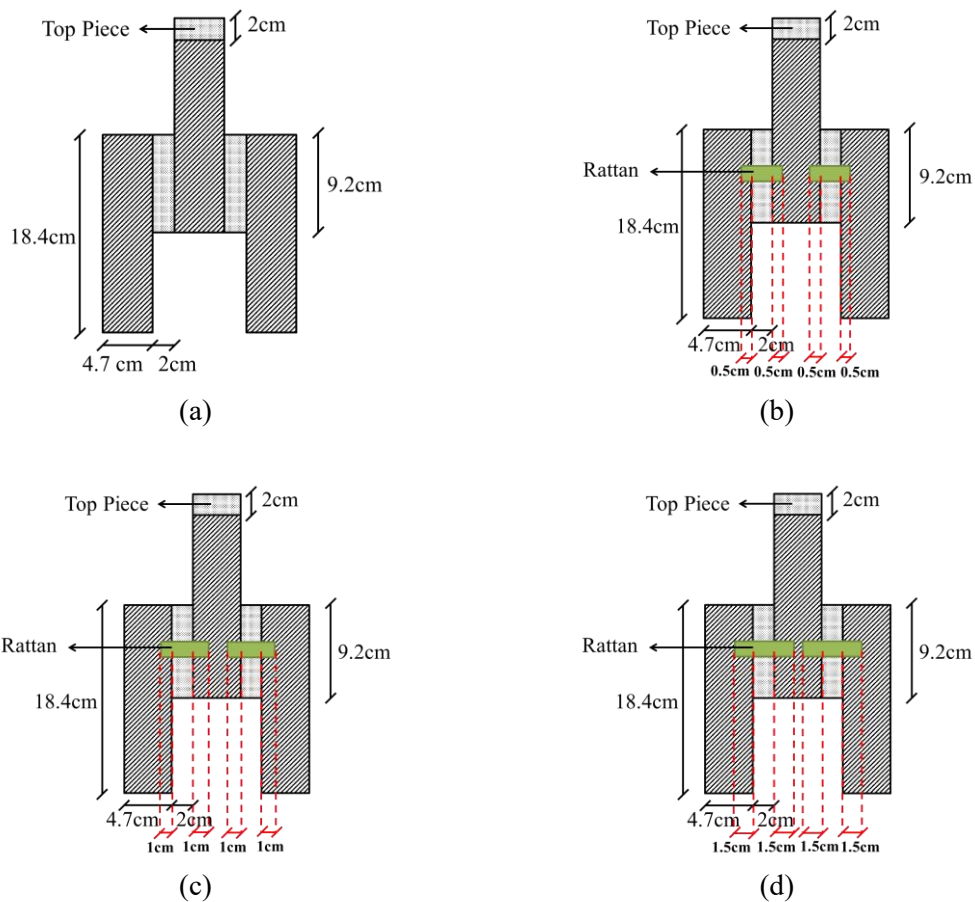


Fig. 7. Fabricated Samples for Shear Strength Test; (a) Brick without Interlocking, (b) Brick with 0.5mm rattan interlocking, (c) Brick with 1mm rattan interlocking, and (d) Brick with 1.5mm rattan interlocking.

The design of the Fabricated Sample for compression and shear, as seen in Fig.6 and Fig.7, was inspired by the anchorage system in reinforced concrete hollow brick [32] and the area of reinforced concrete building joint.

2.4. Experimental set-up

The test was conducted at the Structural Laboratory of the Department of Civil Engineering, Faculty of Engineering, Universitas Negeri Padang.

2.4.1. Compressive strength test of masonry

The compressive strength test (Fig. 8) of the brick is a test of the maximum limit of the compressive strength of the unit surface area of the loaded test object. For the testing process that refers to SNI, the test object's surface is given a load until it reaches the maximum load at a speed of 2 Kg/cm²/second [1,44]. This test aims to determine the maximum compressive strength of bricks per unit surface area loaded. The formula for calculating the compressive strength of bricks is (Eq. 1):

$$f'_c = \frac{P}{A} \quad (1)$$

Where P is the Maximum Load (Kg), and A is the Area of Pressure (cm²).

2.4.2. Shear strength test of masonry

We performed the masonry shear strength test (Fig. 8) using a specimen made up of three whole bricks. The shear strength value was calculated based on the maximum load applied, the width of the bonded area, and the height of the shear plane. This test aims to evaluate the mortar's ability to resist shear forces on the wall, particularly under earthquake loads or forces acting along the wall's lengthwise direction. The shear strength testing of the red brick mortar was carried out in accordance with ASTM 155207 (Standard Practice for Capping Concrete Masonry Units).

The purpose of testing the shear strength of this brick is to determine the bonding power of the brick to the mortar and the effect of loading. Equation 2 for calculating the shear strength of bricks:

$$f_v = \frac{P + w}{2(b \times h')} \quad (2)$$

Where f_v is shear strength, P is Maximum Load (Kg), b is Brick Width (cm), h' is shear plane length (cm) = $\frac{1}{2} h$, and w is Sample Weight (Kg).

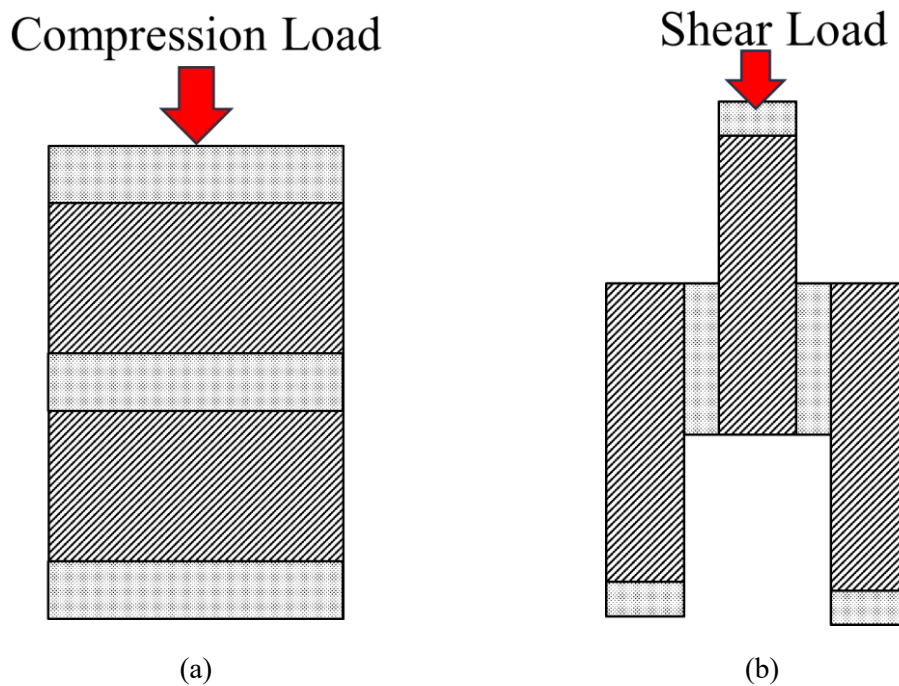


Fig. 8. Loading setup; (a) compression test, and (b) shear test.

3. Results and discussion

3.1. Fine aggregate test (sand)

This study uses sand as the fine aggregate. We tested the sand to determine its silt content, water content, specific gravity, and organic matter content.

3.1.1. Sand silt content

The silt content in sand is determined by measuring the difference between the original weight of the sand and its constant dry weight after washing, then dividing the result by 100 and multiplying by 100%. From the mud content test, the silt content was found to be 3.67%. According to SII.005 and ASTM C.33 standards, the maximum allowable silt content in sand is 5%, which means the sand used in this study meets the required standard (Table 2).

Table 2. Sand silt content.

No.	Treatment Type	Testing			Average silt content
		1	2	3	
1	Fixed dry weight (gr)	100	100	100	
2	Fixed weight after washing and oven (gr)	96.8	96.1	96.1	
3	Silt Content	3.20%	3.90%	3.90%	3.67%

3.1.2. Sand real moisture content and sand saturated-surface-dry moisture content

Sand's real moisture content is the water content contained in the sand in real conditions calculated by reducing the original sand weight by a fixed dry weight, dividing by a fixed dry weight, and multiplying by 100%. The water content of Saturated-Surface-Dry is the water content contained in the sand in a dry saturated condition by reducing the weight of the original sand by a fixed dry weight and dividing by a fixed dry weight, then multiplying by 100% (Table 3).

Table 3. Real sand moisture content.

no.	treatment type	testing			average moisture content
		i	ii	iii	
1	initial weight (gr)	100	100	100	
2	fixed dry weight (gr)	97.1	96.2	98	
3	real moisture content	2.98%	3.95%	2.04%	2.99%

Table 4. Sand saturated-surface-dry moisture content.

No.	Treatment Type	Testing			Average Moisture Content
		I	II	III	
1	Initial weight (gr)	100	100	100	
2	Fixed dry weight (gr)	96,1	96,1	96,3	
3	Saturated-Surface-Dry Moisture Content	4.05%	4.05%	3.84%	3.98%

According to the results of the test data analysis (Table 4), the real water content of the sand used to manufacture mortar is 2.99%. Based on SNI 03-1737-1989 [45], the standard water content of sand is a maximum of 3%; thus, the sand used meets the requirements of real sand moisture content standards. The water content of Saturated-Surface-Dry sand for mortar making was tested at 3.98%. Based on SNI 03-1737-1989 [45], the standard water content of sand is a maximum of 3%; thus, the sand used does not meet the Saturated-Surface-Dry sand water standard requirements. To ensure the water content of the sand will be acceptable, we dry the sand in the oven until the water contents meet the Saturated-Surface-Dry requirements.

3.1.3. Sand real density and sand saturated-surface-dry density

We obtain the real density of sand (Table 5) by dividing its weight by volume. By dividing the weight of the sand in its Saturated-Surface-Dry condition by its volume, we may get its specific gravity. The real density of the sand is 2.43, based on the test data analysis. According to SNI 1970-2008 [46], sand has a minimum real density of 2.3. As a result, the utilized sand meets the real density specifications. Sand has a Saturated-Surface-Dry density of 2.58 (Table 6). The sand utilized satisfies the sand Saturated-Surface-Dry density standard criteria since, according to SNI-1970-2008 [46], the minimum density of sand Saturated-Surface-Dry is 2.3.

Table 5. Real sand density.

No.	Treatment Type	Testing			Average Density
		I	II	III	
1	Sand weight (gr)	100	100	100	
2	Measuring glass weight (gr) (A)	201	201	200.4	
3	Measuring glass and full water weight (gr) (B)	748.5	75.3	753.6	
4	Measuring glass, water, and sand weight (gr) (C)	809.2	806.3	815.7	
5	Volume (3 + 1) - 4	39.3	47	37.9	
6	Real density	2.53	2.12	2.64	2.43

Table 6. Sand saturated-surface-dry density.

No.	Treatment Type	Testing			Average Density
		I	II	III	
1	Sand weight (gr)	100	100	100	
2	Measuring glass weight (gr) (A)	200.4	201	201	
3	Measuring glass and full water weight (gr) (B)	754.5	759.5	753.4	
4	Measuring glass, water, and sand weight (gr) (C)	818.4	819.2	813.3	
5	Volume (3 + 1) - 4	45.3	53.1	40.1	
6	Real density	2.2	1.88	2.49	2.58

3.1.4. Sand organic substance

The presence of organic substances in sand is assessed through the Sand Organic Substance test, which evaluates the color of the sand to determine its suitability for construction use. Based on the test results (Fig. 9) the sand is considered appropriate, as the color of the solution does not exceed the No. 3 standard.



Fig. 9. Sand organic substance test results.

3.2. Physical properties of brick test

Bricks undergo tests to evaluate their physical and mechanical properties.

3.2.1. Physical properties of bricks

Testing of the physical properties of bricks includes visual inspection of the visible properties, dimensional examination, and salt content. The visible properties of bricks include color, sound, flat shape, uncracked shape, and right-angled segments. We can express the imperfection of the five test objects as a percent (%). The research on bricks (Table 7) that meet the requirements of SNI 15-2094-2000 [5] reveals that the surface is flat, does not crack, and has an angled shape when knocked. We used squared bricks for this study, which are reddish yellow, produce a loud sound when tapped, have a flat surface, and are free from cracks. Table 7 displays the results of the examination of visible properties.

Five brick samples also underwent the salt content test. The salt content observations indicate that the average brick contains no harmful salt. Observations reveal that the bricks do not have any white powder attached to them, so that the results of testing the salt content in bricks are safe to use and follow SNI 15-2094-2000 [5], where the salt content of bricks is less than 1.0%.

Table 7. Inspection of the visible properties of bricks.

No.	Bricks Color	Definition
1		70% reddish-orange color, 90% loud sound, 80% flat shape, 5% cracked shape, and right-angled segments.
2		80% reddish-orange color, 90% loud sound, 85 flat shapes, 10% cracked shape, and right-angled segments.
3		60% reddish-orange color, 90% loud sound, 80% flat shape, 5% cracked shape, and right-angled segments.
4		80% reddish-orange color, 85% loud sound, 90 flat shapes, 5% cracked shape, and right-angled segments.
5		85% reddish-orange color, 85% loud sound, 90 flat shapes, 5% cracked shape, and right-angled segments.

3.2.2. Mechanical properties of bricks

Testing of the mechanical properties of bricks includes brick water absorption, compressive strength, and shear strength tests. Water absorption of bricks is the ability to absorb water by immersing them in a container in the form of a basin filled with water until the bricks are saturated. The absorption of bricks can be obtained from the measurement of the dry mass and wet mass of bricks.

According to the standard SNI 15-2094-2000 [5], a brick's maximum water absorption value is 20%. From Table 8, the results of the absorption of bricks are 16.48%, indicating that the bricks already meet the standards and are suitable for use in making samples (Fig. 10).

Table 8. Brick absorption.

Brick Code	Saturated Bricks Weight (gr)	Oven Dry Brick Weight (gr)	Bricks Water Absorption (%)
1	1371.64	1154.30	18.83
2	1365.36	1185.03	15.22
3	1351.86	1161.27	16.41
4	1362.18	1172.10	16.22
5	1328.18	1147.81	15.71
Average			16.48

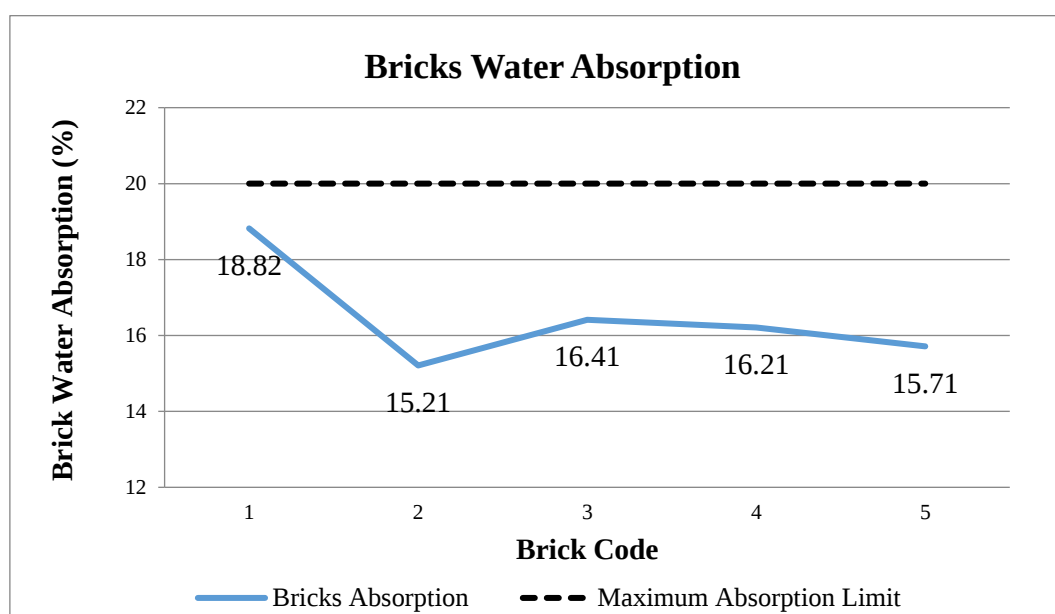


Fig. 10. Brick water absorption.

3.3. Bricks compressive strength test results

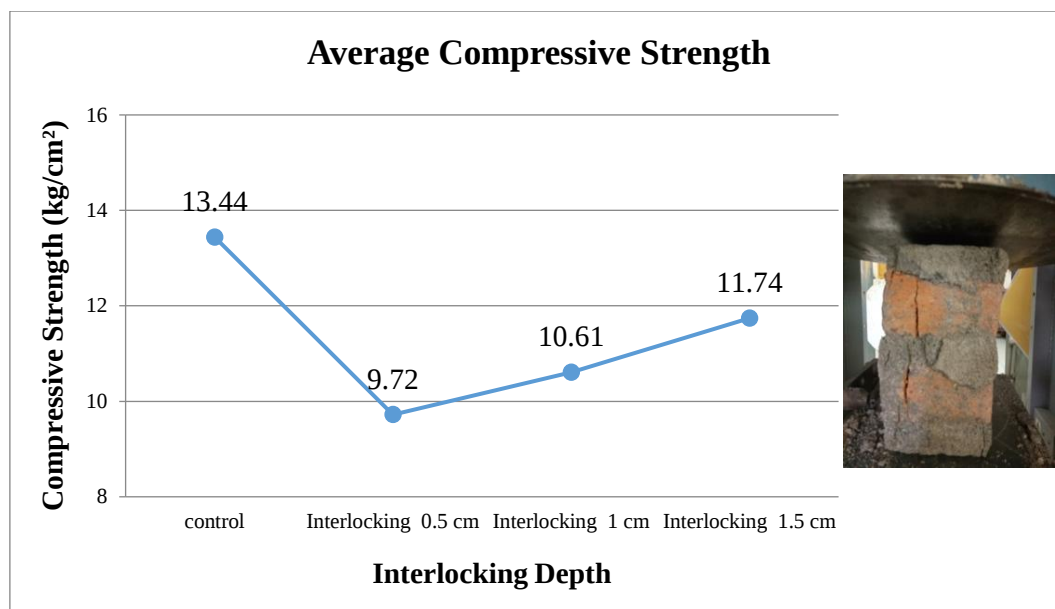
We conducted compressive strength tests on a total of 20 brick samples, divided into four groups: five control bricks (normal type), and five each of interlocking bricks with penetration depths of 0.5 cm, 1 cm, and 1.5 cm. The compressive strength results are presented in Table 9.

As shown in Table 9, the interlocking bricks exhibited lower compressive strength compared to the control bricks. Fig. 11 illustrates that compressive strength initially drops at a penetration depth of 0.5 cm, then increases as the depth grows, although it still does not match the strength of the control bricks. The percentage reduction in compressive strength for the rattan interlocking bricks at depths of 0.5 cm, 1 cm, and 1.5 cm is 28%, 21%, and 13%, respectively. Figure 12 shows the crack patterns observed in the test specimens.

When compared with the compressive strength results of fiberglass-painted bricks from a study by Eka et al., the highest strength was achieved at a 3 mm fiber paint thickness, reaching 53.31 Kg/cm² [21]. In contrast, the highest strength in this study was 11.74 Kg/cm² at an interlocking depth of 1.5 cm. Based on these findings, bricks reinforced with fiberglass paint demonstrate higher compressive strength than those using rattan interlocking.

Table 9. Bricks compressive strength.

No.	Sample	Average Compressive Strength kg/cm ²
1	Control	13.44
2	Interlocking 0.5 cm	9.72
3	Interlocking 1 cm	10.61
4	Interlocking 1.5 cm	11.74

**Fig. 11.** Average compressive strength of brick.

Test results indicate that increasing the interlocking depth improves compressive strength, indicating that rattan interlocking holds strong potential as an alternative form of reinforcement, even though bricks with rattan interlocking exhibit lower compressive strength when compared to control bricks. One major factor contributing to the decreased strength is vibration from the hole-drilling tool, which can jeopardize the bricks' structural integrity. If the holes were created during the brick-molding procedure, which is thought to improve compressive strength, the result might be different.

Furthermore, because the hole was made marginally larger than the diameter of the rattan, a tiny space still exists between the two. The interlocking bricks' decreased compressive strength could also be attributed to this gap.

**Fig. 12.** Crack pattern of compression test specimens.

3.4. Bricks shear strength test results

The Civil Engineering Building Structural Laboratory at UNP conducted the brick shear strength test using the Universal Testing Machine (UTM). The shear test consisted of four specimen types, with five samples for each type. The tested bricks included: normal bricks as control specimens, and interlocking bricks with penetration depths of 0.5 cm, 1.0 cm, and 1.5 cm. In total, the shear strength test involved 60 brick specimens. The results of the shear strength tests are presented in Table 10.

Table 10. Bricks shear strength.

No.	Sample	Average Shear Strength kg/cm ²
1	Control	3.599
2	Interlocking 0.5 cm	3.300
3	Interlocking 1 cm	4.578
4	Interlocking 1.5 cm	5.988

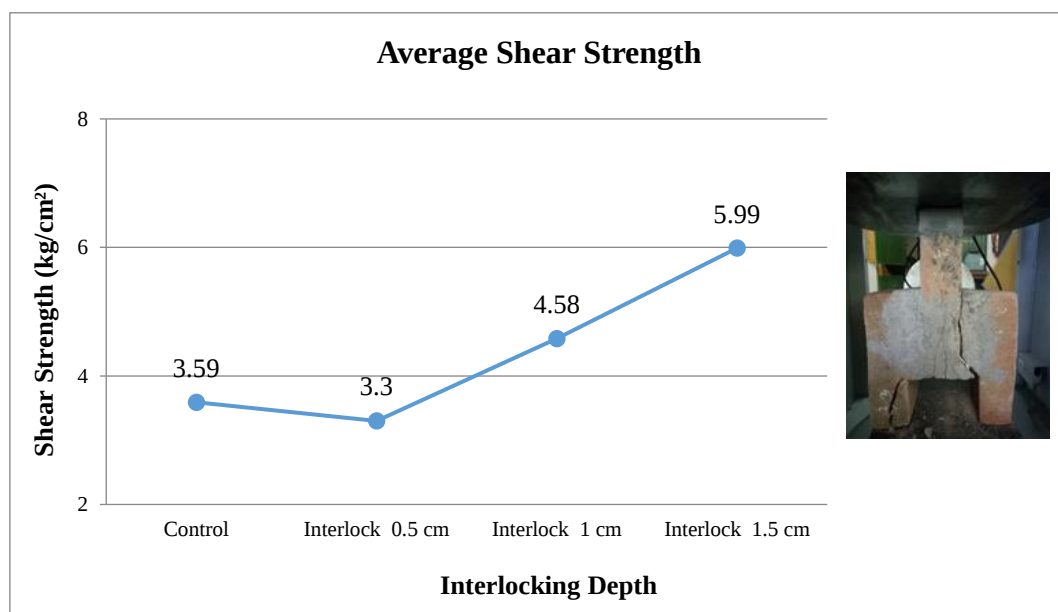


Fig. 13. Average shear strength of bricks.

Based on the results shown in Table 10, the average shear strength values for the control sample, as well as the interlocking bricks with depths of 0.5 cm, 1 cm, and 1.5 cm, are all recorded as 3.59 Kg/cm². However, the graph in Fig. 13 illustrates that while the shear strength drops at the 0.5 cm interlock, it rises significantly at the 1 cm and 1.5 cm depths. Specifically, the shear strength increases by 26% and 63% at 1 cm and 1.5 cm interlocks, respectively, while it decreases by 11% at the 0.5 cm interlock. The decline in shear strength at the 0.5 cm depth is attributed to the shallow penetration of the rattan, which causes it to become dislodged under pressure, as shown in Fig. 14(b). Because the rattan does not penetrate deeply enough to resist shear forces effectively, and because the interlocking section has a smaller shear area due to the oversized hole relative to the rattan diameter, the sample has a lower shear strength than the control. In contrast, although the bricks with 1 cm and 1.5 cm interlocks also have reduced shear cross-sections compared to the control, the greater penetration depth allows them to better withstand shear forces.

Eka et al. found that the maximum shear strength of bricks coated with fiberglass paint is 5.31 Kg/cm² at a thickness of 2 mm [21]. In this investigation, the maximum shear strength is 5.988 Kg/cm² at a 1.5 cm interlocking depth. When comparing the two research outcomes, bricks with rattan interlocking had higher shear strength than bricks with fiberglass paint.



Fig. 14. Damage pattern of shear test specimens; (a) Crack pattern, and (b) Rattan separated from the brick.

Figure 12 and Figure 14 shows the damage of compression and shear test specimens.

The resistance of a building under seismic loads depends on its weight. The vulnerability will be higher when the building is heavier, and vice versa. Fig. 15 illustrates how the interlocking rattan material in the brick red unit contributes positively to the masonry wall strength and the building's overall weight.

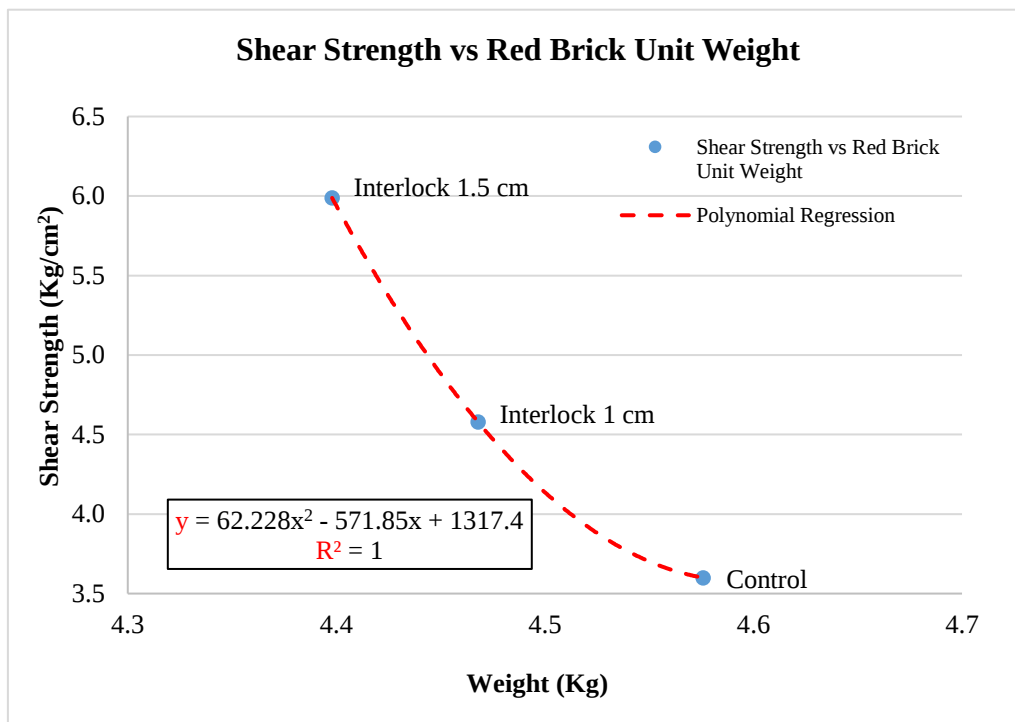


Fig. 15. Relationship of weight to shear strength of brick unit.

4. Conclusions

Based on the brick test research results with the provision of interlocking rattan, the following conclusions can be drawn.

- The compressive strength of interlocking bricks of 0.5 cm, 1 cm, and 1.5 cm are 9.72 Kg/cm², 10.61 Kg/cm², and 11.74 Kg/cm², respectively. The compressive strength results decreased from the

control brick sample, which was 13.44 Kg/cm². The percentage decrease in compressive strength is 28%, 21%, and 13%, respectively.

- The shear strength of 1 cm and 1.5 cm interlocking bricks are 4.58 Kg/cm² and 5.99 Kg/cm², respectively. This result has increased from the control brick sample, which is 3.59 Kg/cm². The shear strength of the 0.5 cm interlocking brick is 3.3; this result is lower than that of the control sample. The percentage increase in shear strength of 1 cm and 1.5 cm interlocking bricks is 26% and 63%, respectively. In 0.5 cm interlocking brick, the percentage of shear strength decreased by 11%.

From the results, the 1.5 cm interlocking bricks obtained optimal quality compared to the 0.5 cm and 1 cm interlocking bricks because the 1.5 cm interlocking bricks increased the shear strength by 63%. However, there is a decrease in compressive strength of 13%, so based on the research conducted, it can be concluded that interlocking bricks using rattan cannot increase the compressive strength of bricks. The decrease in compressive strength of interlocking bricks compared to control bricks can be attributed to the vibrations generated during the hole-making process and the gap between the rattan and the hole wall. Therefore, further research can be done by making holes in the bricks during the brick-making process or filling the gap with other materials.

Funding

Our research was financed by Universitas Negeri Padang, under contract number 1773/UN35.15/LT/2024.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Authors contribution statement

Eka Juliafad: Conceptualization; Formal analysis; Investigation; Methodology; Project administration; Writing – original draft; Writing – review & editing.

Fajri Yusmar: Formal analysis; Investigation; Resources; Writing – review & editing.

Nevy Sandra: Formal analysis; Investigation; Resources; Writing – review & editing.

Lisyana Junelin Restu: Data curation; Resources; Software; Writing – original draft, Writing – review & editing.

Fauzan: Resources; Writing – review & editing.

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