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The Effect of Firing Position in a Furnace on Mechanical Properties of Bricks in Lubuk Alung District, Padang Pariaman

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ABSTRACT

Brick is one of the materials used in building house walls. The demand for red bricks in construction and business growth in the property sector is increasing. Lubuk Alung District, precisely in Jorong, Kampung Ladang, is one of the West Sumatra areas producing conventional bricks. The process of firing brick in this sub-district is still carried out using a conventional furnace, using wood as an energy source. The quality of the red bricks produced is different due to the different positions of the bricks in the kiln. This research aims to determine whether the red bricks produced in Jorong Kampung Ladang, Lubuk Alung District, meet the quality classification of red bricks according to SNI 15-2094-2000. From the results, the bricks in the upper, middle, and lower firing positions meet the quality requirements for the physical properties of red bricks. However, red bricks in the upper, middle, and lower firing positions do not meet the SNI 15-2094-2000 quality standards regarding dimensions or sizes. Meanwhile, the results of mechanical properties testing for specific gravity and compressive strength showed that none of the test object samples met the standards required according to SNI 15-2094-2000.

Keywords: *Bricks; Furnace; Mechanical properties; Compressive strength; Water absorption.*

INTRODUCTION

The development of the construction industry in the modern era, such as at this time, is relatively rapid, especially in the construction of buildings, luxury housing, and simple houses in urban areas to remote areas. One of the materials used to construct house walls is red brick. SNI 15-2094-2000 [1] explains that red brick is one of the building materials in the form of a long rectangular prism with a maximum volume of 15%, used in making building construction made from clay or clay with or without a mixture of other materials, then printed And burned with high hot temperatures, so it cannot be destroyed when soaked in water. In general, red brick functions as a non-structured and structural material. As a structural function, it is used as a buffer or a load above it, while the function as a non-structural function can be used as a boundary wall and aesthetic enhancer without carrying the burden on it [2].

The construction industry is experiencing a rise in demand for red bricks due to growing business in the property sector. Despite the availability of alternative materials, such as lightweight brick and concrete blocks, red brick remains a popular choice among the public. This is evident from the numerous conventional brick-making enterprises that have sustained their operations despite economic pressures. One reason for bricks' continued appeal is their affordability and accessibility. Moreover, from an aesthetic standpoint, it is often perceived to possess more excellent artistic value than its counterparts.

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The Jorong neighborhood in the Lubuk Alung District of West Sumatra is a hub for traditional red brick production. This longstanding industry provides a vital source of income for the surrounding community, with each brick-making operation typically employing at least five workers. However, despite the area's rich history of brick production, the traditional method of firing bricks using wood fuel in a conventional stove is still widely practiced. This process involves stacking the bricks in layers, creating a tunnel at the bottom for the firewood, and covering the sides of the brick structure with half-baked bricks, with the top covered with clay mud.

When setting up bricks in a traditional stove, it is important to leave space between them to allow for even distribution of heat from the bottom to the top [3]. If bricks are placed too close together, it can impede the flow of small combustion gases and ultimately reduce the efficiency of the flame. Burning bricks in a conventional kiln can take anywhere from 2-3 days, depending on the quantity being burned. The ideal temperature range for combustion is between 800-900℃. However, the temperature in the top layer of the furnace typically only reaches around 400-600℃, while the bottom layer can reach temperatures of up to 1100-1200℃ due to its proximity to the fire source or fire bag.

When using wood fuel in a traditional stove for brick-making, the resulting brick quality can vary. Unfortunately, the general public is often unaware of the quality of red bricks, and their purchasing decisions are based purely on habit or preference for certain producers without any knowledge of the actual quality. However, with the implementation of SNI 15-2094-2000 quality requirements and traditional red brick testing methods, researchers have become interested in analyzing the bricks' compressive strength. This measurement defines the maximum pressure a red brick can withstand per unit surface area under load. Maintaining the strength of a building can be enhanced by using bricks that have a high compressive strength value. This can lead to a stronger building overall.

This study evaluates the compressive strength of red bricks sourced from a conventional brick industry in Jorong Kampung Ladang, Lubuk Alung District, Padang Pariaman Regency. The research will focus on analyzing the effects of the firing process in a conventional kiln on the strength of these bricks in various positions. By conducting this study, the public can receive reliable information on the quality of these bricks, ensuring their confidence in using them for construction purposes, including residential and civil engineering buildings.

MATERIAL AND METHODS

Physical Properties of Bricks

Brick, commonly referred to as red brick, is one of the building elements used in the manufacture of building construction made of clay or without a mixture of other materials, then molded and burned at high temperatures so that it cannot be destroyed when immersed in water [1]. Bricks are a fundamental building material in construction, created through a multi-stage process that involves soil and water, sometimes with additional mixtures. This process includes digging, processing, molding, drying, and burning at high temperatures until the bricks change color and harden, becoming impervious to water damage [4].

Red brick, on the other hand, is a man-made material designed to mimic the properties of natural stone. This can only be achieved through either heating (burning) or chemical processes

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[4]. Red brick is a popular choice for wall construction due to its fire-resistant properties. Additionally, the larger size of red bricks makes them relatively easy for masons to handle and install in various patterns. Key properties to consider when selecting red bricks include their compressive strength, surface quality, salt content, sharpness of edges, and water absorption capabilities, which must meet specific requirements [5].

Bricks are composed of different materials such as clay, silt, sand, and water. According to Bowles [6], clay or loam is a deposit with a particle size of 0.002 mm or smaller, and it is formed from the weathering of rock chemical elements. Elianora et al. [7] state that clay or loam is the primary ingredient used in making burnt and dried bricks. To ensure that the clay used to make bricks is suitable, it must possess plastic and cohesive properties, which allow it to be easily molded. However, if the clay has a high plasticity value, the formed bricks may crack or break during the firing process. The clay used to make bricks should have a plasticity level of 25%-30% from the plasticity index. The burnt clay must also resist water seepage, not rot over time, and be red. Finally, it should not contain any lime or gravel grains more significant than 5 mm.

The physical properties of bricks are carried out without changing the shape or giving weight to the bricks. The brick requirements in SNI 15-2094-2000 for the physical properties of bricks include the brick's appearance, size, and salt content. The apparent nature of bricks is a condition of bricks visually for wall masonry, where bricks must be in the form of long rectangular prisms, have brownish-orange color standards, have elbow ribs and flat plane surfaces, and do not show cracks. The dimensions of red brick vary greatly. This is adjusted to the need for building capital. Another consideration is the installation process during construction. Several regions in Indonesia have bricks of different sizes and different mixtures of materials, including the quality. The brick sizes specified in SNI 15-2094-2000 regulations can be seen in Table 1 below.

Table 1 Size and tolerance of bricks for wall pair SNI

Mould	Height	Width	Length
M-5a	65 ± 2	92 ± 2	190 ± 4
M-5b	65 ± 2	100 ± 5	190 ± 4
M-6a	52 ± 3	110 ± 2	230 ± 5
M-6b	55 ± 3	110 ± 2	230 ± 5
M-6c	70 ± 3	110 ± 2	230 ± 5
M-6d	80 ± 3	110 ± 2	230 ± 5

Mechanical Properties of Bricks

The study of mechanical properties of red bricks is an essential area of research in the field of civil engineering. Various treatments and loads are applied to the bricks in order to determine their mechanical behavior and characteristics. As outlined in SNI 15-2094-2000, the mechanical properties of bricks can be evaluated through several factors, including their apparent density, water absorption, specific gravity, and compressive strength. This information is crucial in understanding the performance and durability of red bricks in the construction industry.

Conventional Furnace

The image displayed in Figure 1 showcases a traditional stove utilized by a small industry

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located in the Lubuk Alung sub-district. The kiln utilized to create red bricks is a conventional model, constructed entirely of brick. Semi-finished bricks are arranged to form a furnace at the base, providing a space to insert firewood. This is then continued with more brick arrangement at the top. The brick serving as the furnace is colloquially known as a tooth brick, while the outermost brick is referred to as a skin brick. The stove itself possesses dimensions of 3x3x3 meters, with a 50 cm hole designated for placing firewood as fuel. The process of burning the bricks continuously takes three days until they no longer emit smoke.

Fig. 1 Conventional Furnace

Research Methodology

The bricks were put under examination to assess their appearance, including surface flatness, angle rib, and cracks. Additionally, their size, tolerance, water absorption, and compressive strength were evaluated and compared to the SNI standard. This research was carried out by taking samples in the form of bricks obtained from brick producer in Lubuk Alung sub-district. The brick samples taken were 51 bricks with 17 bricks each at the top, middle and bottom firing positions. Other materials used in this research were sand, portland cement, and water.

RESULTS AND DISCUSSION

Physical Properties of Red Brick

1. Apparent Density

The results of observations of the visible properties of red bricks can be seen in the table 2.

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Table 2. Visible Properties

No	Position	Colors	Defenition
1	Top		Reddish orange color ±70%, has a loud sound, has a flat shape ±80%, and angular segments.
2	Middle		The color is reddish orange ±80%, has a loud sound, has a flat shape ±70%, and has right-angled segments.
3	Bottom		Reddish orange color ±85%, slightly blackish brown at the edges of the brick, sounds loud, has a flat shape ±80%, and has right-angled segments.

2. Red Brick Dimensions

Red brick measurements are in the form of length, width, and height. The results of the red brick measurement can be seen in the following table 3. The average measurements of the red bricks in the upper firing position were found to be 18.14 cm in length, 9.22 cm in width, and 4.82 cm in height. It appears that each brick has almost the same size in terms of length, width, and height. The measurements obtained for the bricks in the middle and bottom firing positions were also consistent with these results.

Table 3 Average Red Brick Dimensions

Position	Length	Width	Height
Upper	18.14	9.22	4.82
Middle	18.05	9.12	4.76
Lower	17.68	8.8	4.71
Average	17.9567	9.0467	4.7633

3. Salt Content

The results of observing salt content show that red brick does not contain harmful salt on average. Because, from the observations, no white powders are attached to the red brick. To ensure that the salt content test results on red bricks are safe to use in accordance with SNI 15-2094-2000, it is necessary to ensure that the salt content of bricks is less than 1.0%.

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Brick Mechanical Properties

1. Apparent Density of Bricks

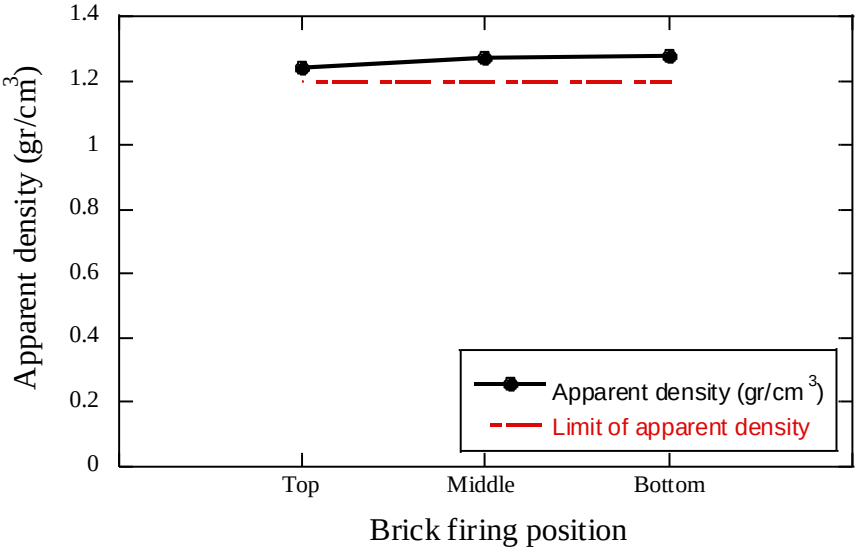

Fig. 2 Apparent Density of Bricks

From the Figure 2, it can be seen that the overall average value of the apparent density of red brick meets the established standards. Based on SNI 15-2094-2000, the minimum apparent density of masonry brick is 1.2 gr/cm³.

2. Specific Gravity

Figure 3 shows that the average value of the specific gravity of red brick does not meet the established standards. Based on SII-0021-1978, it is explained that the specific gravity of red brick ranges from 1.8-2.6 gr/cm³. Thus, the red brick used does not meet the specific gravity requirements of red brick.

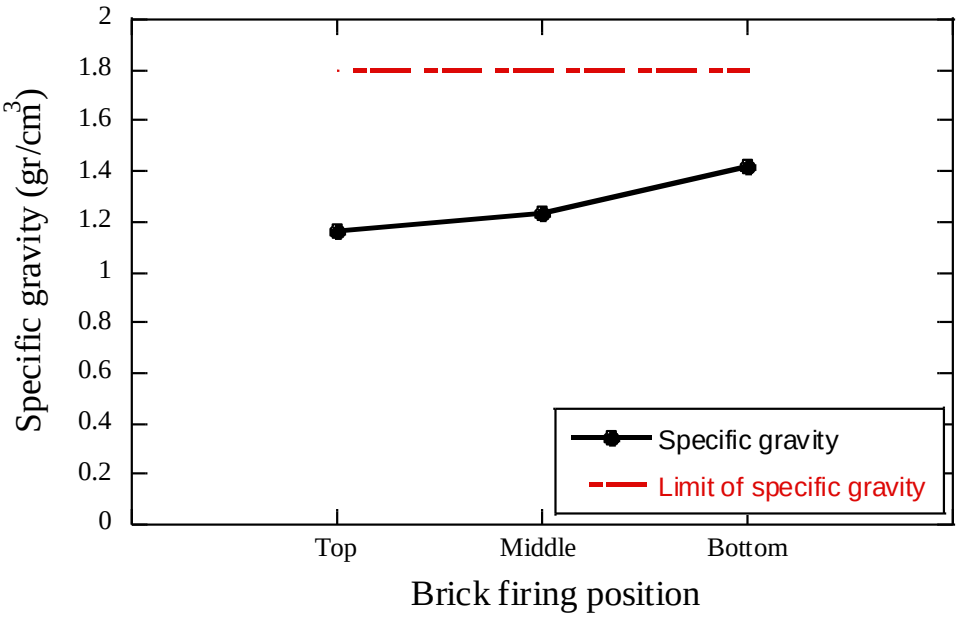

Fig 3. Specific Gravity of Bricks

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3. Water Absorption

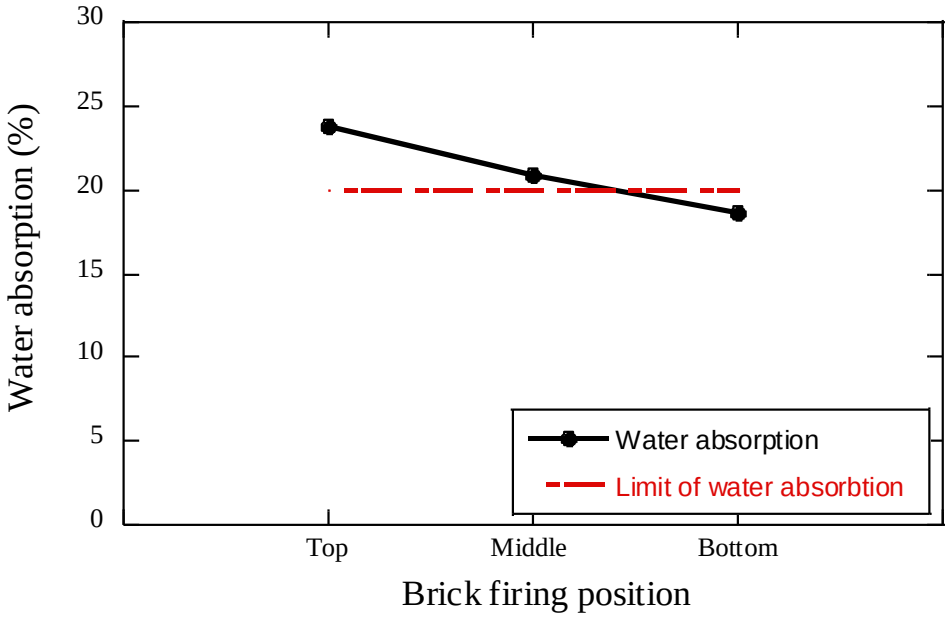

Fig. 4 Water Absorption

Figure 4 shows the results of water absorption in the upper and middle combustion positions exceed the maximum limit of water absorption. Hence, the red brick of the upper and middle burning positions is unsuitable because it does not meet water absorption standards. In contrast, the red brick of the lower burning position is suitable for use because water absorption is below the maximum limit of the water absorption set.

4. Compressive Strength

The highest compressive strength value is in the lower combustion position with a compressive strength value of 23.26 kg/cm² as can be seen in figure 5, while the lowest compressive strength value is in the lower combustion position with a compressive strength value of 11.85 kg/cm². These results have not met SNI 15-2094-2000 standards with a minimum compressive strength of 50 kg/cm².

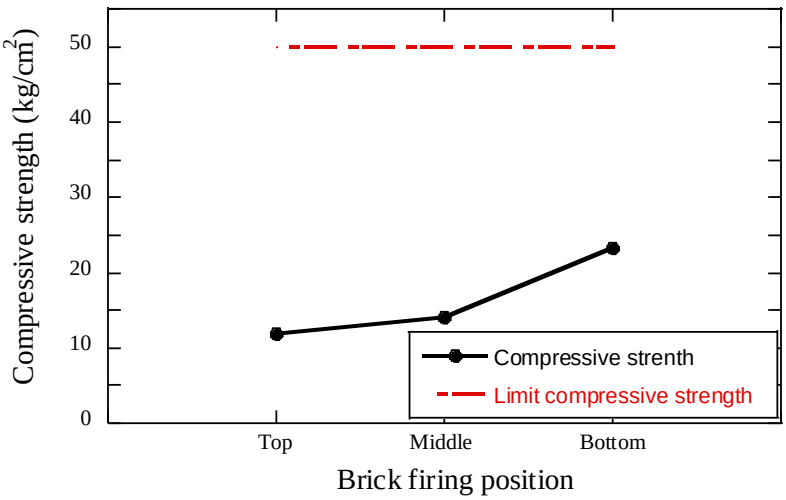

Fig. 5 Compressive Strength

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Discussion

Based on the results of physical properties testing of red bricks that have been carried out, it is found that the characteristics of the average appearance are elbowed, reddish-orange in color, flat shape, and loud sound. From the measurement results, red brick has not met SNI 15-2094-2000 standards, and this is because the dimensions of brick molds at the production site are not appropriate or do not meet the standards. The apparent density value at SNI 15-2094-2000 red brick wall masonry is at least 1.2 gr/cm^3. The relationship between water absorption and apparent density can be seen in the Fig. 6. It explains that the greater the water absorption, the less it will affect the apparent density of red bricks.

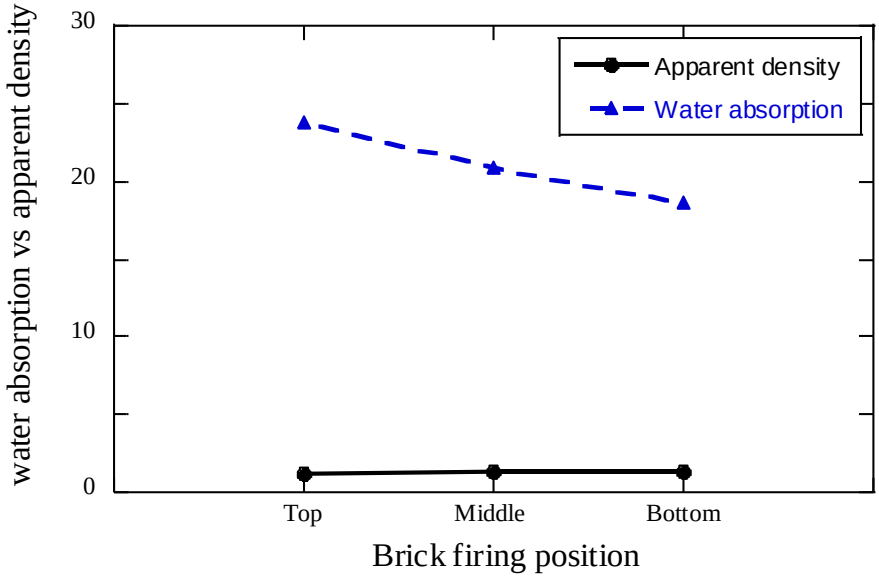

Fig. 6 Water absorption vs apparent density

The relationship between average specific gravity and average water absorption can be seen in Figure 7. It shows that the greater the water absorption, the less it will affect the specific gravity of the red brick.

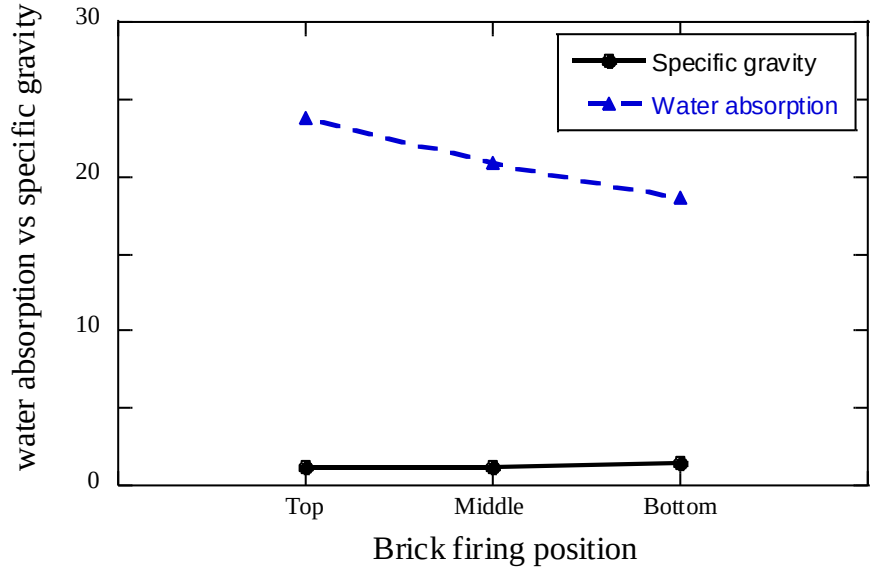

Fig. 7 Specific gravity vs water absorption

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The relationship of compressive strength of red brick with apparent density can be seen in the Figure 8. It can be concluded that to increase the compressive strength of red brick, an apparent density of red brick is required.

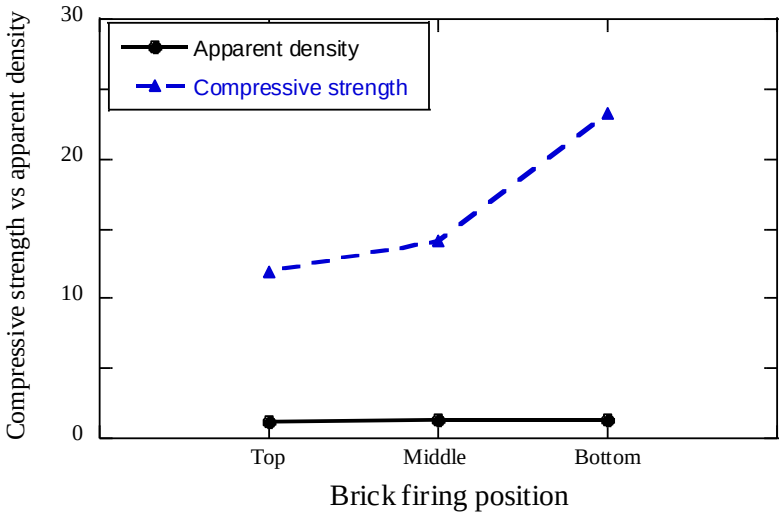

Fig. 8 Compressive strength vs apparent density

The relationship between the compressive strength of red brick and the specific gravity of red brick can be seen in Figure 9. It can be concluded that the greater the specific gravity value, the no effect on the compressive strength value of red brick.

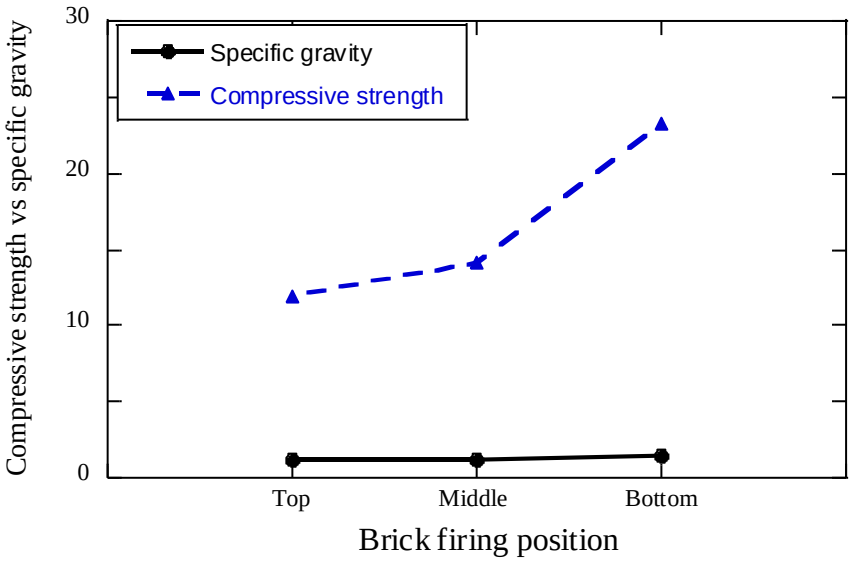

Fig. 9 The compressive strength vs the specific gravity

The average value of each brick position was obtained from the compressive strength and absorption testing. The result data obtained was that the upper position brick had a high-water absorption of 23.76%, the compressive strength value of the red brick was 11.85 kg/cm², the red brick of the middle burning position had a water absorption of 20.91%, and a compressive strength value of 14.12 kg/cm². The bottom combustion position has water absorption of 18.66% and a compressive strength value of 23.26 kg/cm².

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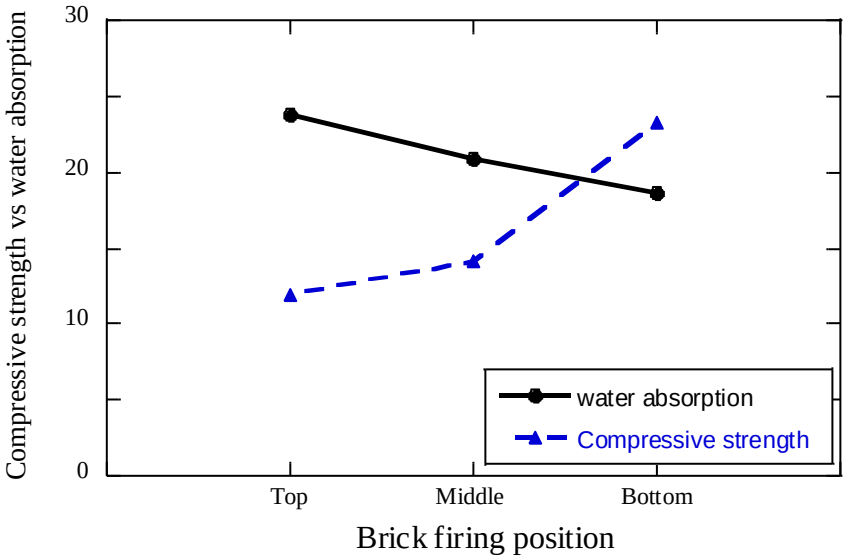

Fig. 10 Compressive strength vs water absorption

The figure 10 shows that the firing position affects the value of compressive strength and water absorption at the time of combustion in conventional furnaces. Bricks that are burned in the upper and middle positions have a lower compressive strength value than those burned in the lower position. This happens because of the temperature difference during the combustion process.

CONCLUSION

Based on the results of the research that has been obtained, it can be concluded as follows:

1. The results of physical properties tests that have been carried out, or the top, middle, and bottom combustion positions, have met the quality of the red brick visible properties requirements based on SNI 15-2094-2000, but not for the dimensions or size of red brick
2. The results of mechanical properties tests that have been carried out, all red brick test objects of the top, middle, and bottom combustion positions meet the quality requirements of pseudo-density bricks, while for water absorption testing, only the lower combustion test objects meet the requirements based on SNI 15-2094-2000.
3. There is a significant influence of the position laying during the combustion process on the compressive strength of red brick.
4. The compressive strength value of red brick in each position is the average compressive strength value of the upper burning position of 11.85 kg/cm², the middle burning position with an average compressive strength value of 14.12 kg/cm², and the lower burning position with the average compressive strength value of 23.26 kg/cm². Red brick that has the optimum compressive strength value is in the lower combustion position close to the fire bag with an average compressive strength value of 23.26 kg/cm².
5. The water factor in red brick determines the strength of the brick.

Suggestions that can be given based on the discussion and drawing conclusions in this study are as follows:

1. There is a need for socialization with red brick makers about SNI 15-2094-2000, especially the Jorong Kampung Ladang, Lubuk Alung District, and Padang Pariaman Regency community.

2. Test specimens for red masonry and mortar are expected to have a flat surface to maximize compressive strength results.
3. Mortar mixture for brick compressive strength test is recommended to be done in a place such as mortar so that the mortar can be mixed well.
4. Modify the combustion chamber to produce even heat for each brick produced by separating the fire directly in the combustion chamber and the brick stacking chamber by creating a partition and channeling hot air using a blower to the brick stacking.
5. Add a temperature measuring indicator (thermometer temperature gauge) to maintain the combustion process at the desired temperature.
6. It is necessary to create a molding tool equipped with a press so that the density of the brick-making material is more substantial.

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