Frapanti *et al.*
Journal of Engineering and Applied Science (2024) 71:143
https://doi.org/10.1186/s44147-024-00479-7

Journal of Engineering and Applied Science

RESEARCH Open Access

Comparison of physical and mechanical properties of traditional bricks in Deli Serdang with no-burn bricks using rice husk ash

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Abstract

Population growth has increased, causing more and more housing needs; Indonesia is one of the countries where bricks are still used as the primary material in building walls. It has resulted in increased demand for bricks. One of Indonesia's regions, Deli Serdang Regency, produces traditional bricks that burn a lot, but the process of making traditional bricks can cause environmental pollution. This research aims to find a way to reduce the effects of environmental pollution by making pressed bricks without burning and utilizing agricultural waste, namely rice husk ash (RHA). After that, a comparison was made between traditional burnt bricks from 15 sub-districts in Deli Serdang Regency and unburnt bricks made from rice husk ash (RHA). This study uses two methods, namely the method of sampling burned bricks and the method of making bricks without burning, both of which are tested for physical and mechanical properties. The results of this study use the requirements of SNI 15-2094-2000, where the test of physical properties of fuel bricks obtained a value of 76%, which meets the requirements, while bricks without burning obtained a value of 87.5%, which meets the requirements. For the results of the size of fuel bricks obtained, 66.6% of the value meets the requirements, while for bricks without burning, 100% meet the requirements. Mechanical properties test for absorption testing on fuel bricks obtained 0.135% while unburned bricks 0.130%, where the value meets the SNI requirements of a maximum absorption of 20%. Salt content testing obtained a value of 0.15% for burned bricks and 0.002% for unburned bricks, where the value meets the SNI requirements that are below 50%. Testing the compressive strength of bricks with a standard value of 5 MPa from the test results of the compressive strength of fuel bricks 3.01 MPa decreased by 39.8%, while the test of compressive strength of unburned bricks 5.17 MPa increased by 3.45%, but unburned bricks with added rice husk ash 1.98 MPa decreased by 60.4%. Based on the study's results, the absorption and salt content parameters follow the standard. At the same time, the strength test of firebricks and unburned bricks with added rice husk ash does not meet the SNI 15-2094-2000 standard, but the results of the compressive strength test of unburned bricks meet the SNI 15-2094-2000 standard.

Keywords: Bricks, Unburnt, Rice husk ash, Compressive strength

Introduction

Indonesia is one of the developing countries and is experiencing a growth phase in all fields. The field that is more rapidly developing is the field of development, along with the increasing number and rate of population development, it requires infrastructure in the form of a place to live or a house. The brick production industry is an industry that utilizes raw materials in the form of clay with a combustion process and is processed with a simple processing process [1]. Deli Serdang is an area in North Sumatra, Indonesia that produces many traditional unburned red brick production businesses which became the sampling location for the study [2] and also areas that are given education and socialization of bricks with SNI standards [3] and also check the stiffness value of bricks for building structures [4]. Bricks are commonly used as the main material component in the manufacture of walls of houses or buildings, bricks are chosen because the price is relatively cheap, easy to obtain, have a fairly high strength, are resistant to weather because of the way it is made is burned with a temperature of 800 °C [5].

The burning process on bricks aims to accelerate the drying process so that the bricks that are obtained harden perfectly and in a fairly short time [6]. This burning activity is considered faster but has several disadvantages because it produces air pollution for the surrounding environment, the fuel needed is quite a lot, and the results of the stone burning process cannot all be used because some of the bricks are damaged, cracked, broken or not burned at all perfectly [7]. Bricks can harden without burning, either by drying in the sun or letting them dry in the open air but it takes a long time compared to the combustion process. Thus, it is necessary to do a formulation by adding some special ingredients from agricultural waste which aims to minimise drying time and can even increase compressive strength if possible. Thus, it is necessary to conduct research in developing knowledge and making brick material updates to reduce the problems that occur and can produce bricks that are of standard quality, environmentally friendly, cheap and practical. One of them is the innovation of making traditional bricks without burning without added ingredients [8, 9] or unburned bricks with added agricultural waste rice husk ash [10, 11]. The physical and mechanical properties of bricks from burnt bricks and unburnt bricks were tested and a comparison was made between the two [12, 13].

Study literature

Materials that make bricks

Clay

Clay is the basic material in making burnt and dried bricks. The clay that is processed comes from the weathering of rocks such as basalt, andesite, granite and others which contain lots of feldspar, feldspar is a compound of silica-calcium-aluminium, silicate-sodium-aluminium, silicate-calcium-aluminium [14]. Judging from chemistry, clay is an aluminium hydrosilicate and in its pure state has the formula: Al_2O_3, $2SiO_2$, $2H_2O$ with a weight ratio of the elements: 47% silicon oxide (SiO_2), 39% aluminium oxide (Al_2O_3), and 14% water (H_2O). Generally, these additional elements consist of quartz in various sizes, feldspar, iron and so on. The amount of these additional elements together with other organic elements determines the distinctive properties of various clays and their use for certain purposes. These properties, such as the possibility of melting, the colour after being fired, and the level of the solidity of a type of clay, are greatly influenced by the mineral elements present in it. Meanwhile, organic elements usually make the soil plastic if it has not been burned [15, 16]. So, all clay, however, has plastic properties, when it is dry it will become hard, while when it is fired it will become dense and strong [17]. Usually, the iron oxide content is around 2–5%. Darker-coloured soil usually matures at lower temperatures, the opposite is lighter-colored or white soil [18]. The following are the results of the SAM (scanning electron microscope) test for clay soil in Fig. 1.

Then the plasticity index test was carried out on the soil. Before the test was carried out, the soil was first filtered using sieve number 50, and the plasticity index value of the clay soil was obtained. The Liquid Limit value of the red soil was 50.11% while the Plastic Limit value was 21.49%, then the plasticity index of red soil was 28.62%. From the results of clay grain analysis tests according to SNI standards, and procedures for classifying soil for engineering purposes, the soil is coarse-grained and passes filter number 200 less than 50%, namely 0.67%.

Red soil

The clay mineral composition of red soil is generally dominated by the clay mineral kaolinite. Kaolinite minerals generally form in environments with intensive alkaline leaching, acidic soil reactions, and relatively good soil drainage [19]. Land dominated by Kaolinite clay minerals will have a low negative charge (*low CEC*) because isomorphic substitution in this type of mineral rarely occurs. The dominance of the mineral kaolinite also indicates a state of high levels of weathering and leaching of bases in an acidic

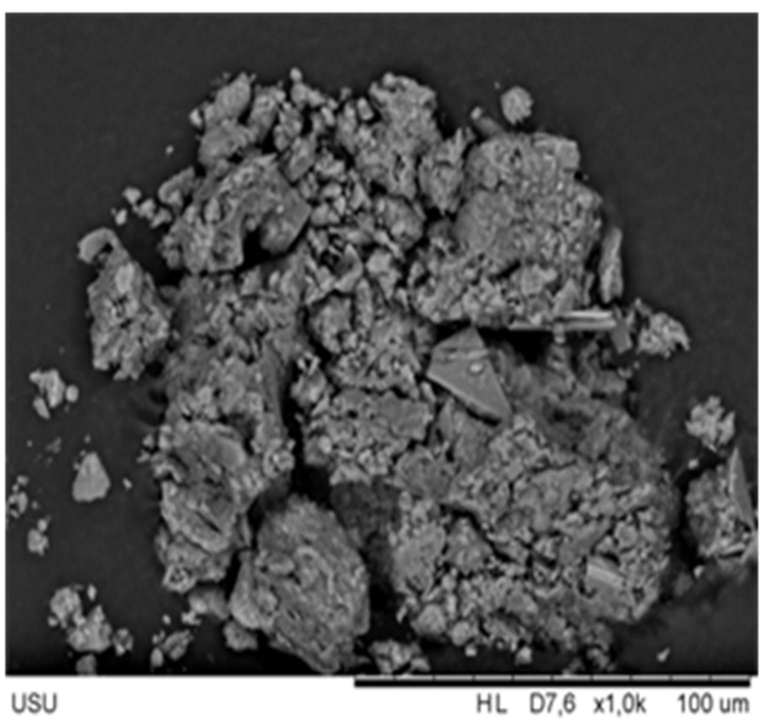

Fig. 1 Scanning electron microscope test of clay soil

and well-drained environment [20]. Other clay minerals that are often found in red soil in not too large quantities are iron oxide minerals such as goethite and hematite [21]. Iron oxide minerals are the most abundant type of oxide mineral found in the soil and are formed from Fe released by primary minerals during the weathering process. This mineral can be found distributed throughout the soil horizon, concentrated in one soil horizon, or only in rust and nodules of iron hydroxides in soils [22]. The following are the results of the red soil SEM (scanning electron microscope) test in Fig. 2. From the results of analysis tests on red soil granules according to the SNI standard for classifying soil for engineering purposes, the soil is coarse-grained and passes filter number 200 at less than 50%, namely 0.67%.

Lime

Limestone is a sedimentary rock that comes from dead marine organisms that have turned into calcium carbonate ($CaCO_3$) [23]. The formation of limestone in nature mostly occurs organically, where carbonate elements in marine organisms such as shellfish and oysters are degraded into smaller elements by microscopic microorganisms such as foraminifera to form carbonate sand or carbonate mud which will continuously settle and harden to form limestone mountains [24]. Limestone can be white, yellowish-white, or grey to black depending on the mineral impurities. Lime is a component of the mortar material obtained from burning limestone at a certain temperature and then extinguishing it with water. Lime ($CaCo_3$) in species/mortar functions as a white-binding material [25]. Calcium carbonate is the main component of limestone with a Ca content of 92.1%. Limestone also consists of other components such as Fe (2.38%), Mg (0.8%), Si (3%), In (1.4%), Ti (0.14%), Mn (0.03%), and Lu (0.14%) Calcium has high levels compared to other components in limestone, so processing is needed to obtain

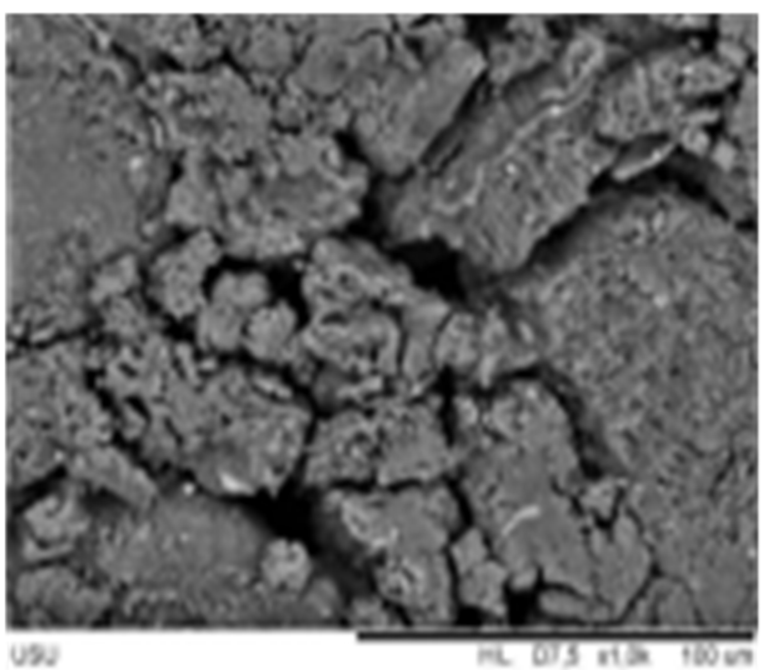

Fig. 2 Scanning electron microscope test of red soil

pure calcium. Calcium from limestone processing can be used as a building material, in the rubber industry, tyres, paper, filters for paint, soap and toothpaste [26]. Meanwhile, other components are found in limestone at low levels, if there are excessive levels it will cause toxic effects by Fe and Mn compounds, as well as carcinogenic effects by Si compounds [27].

Rice husk ash (RHA)

Rice husk ash is the result of burning rice husks [28]. Rice husk ash is a material that has the potential to be used because of its high production and wide distribution. Rice husk is a lignocellulosic material like other biomass but contains high levels of silica [29]. The chemical content of rice husk consists of 50% cellulose, 25–30% lignin, and 15–20% silica [30], The main composition of rice husk ash raw material and composition of rice husk ash [31] can be seen in Table 1.

Rice husk has now been developed as a raw material for producing ash which is known in the world as RHA (rice husk ask) [32]. Rice husk ash produced from burning rice husks at a temperature of 400–500 °C will become amorphous silica and at temperatures greater than 1000 °C it will become crystalline silica [33]. The following are the results of the SEM (scanning electron microscope) test for rice husk ash [34] in Fig. 3.

Examination of physical and mechanical properties of brick

Physical properties of bricks

Physical properties are the properties found in bricks without any load or treatment according to the SNI-15-2094-2000 standard [35]. The physical properties of bricks include

Visible

Bricks according to the SNI standard must be in the shape of a long rectangular prism, have sharp edges and angles, the remaining areas must be flat, not show cracks, not break easily, have a uniform colour and make a loud sound.

Table 1 Chemical composition of the main ingredients of rice husk ash

Substance	Clay	Risk husk Ash
SiO_2	60,67	93,59
Al_2O_3	15,18	0,54
Fe_2O_3	7,61	0,82
K_2O	3,12	1,94
MgO	1,15	0,15
TiO_2	1,18	0,07
CaO	0,79	1,45
Na_2O	0,56	0,01
SO_3	0,55	1,94
MnO_2	0,22	0,19
BaO	0,11	0,01
ZnO	0,01	0,04
ZrO	0,01	0,01

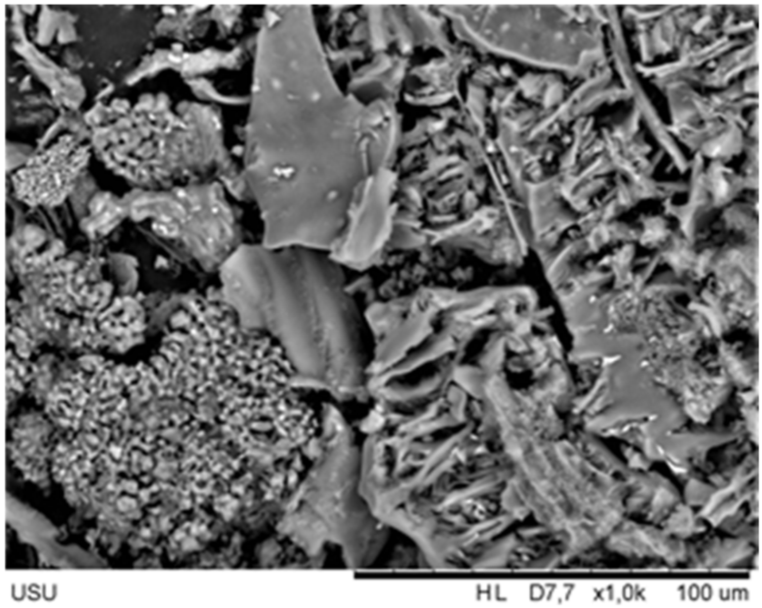

Fig. 3 SAM (scanning electron microscope) test for rice husk ash

Table 2 Sizes of red bricks according to SNI 15-2094-2000

No	Module	Thickness (mm)	Width (mm)	Length (mm)
1.	M5-a	65±2	90±3	190±4
2.	M5-b	65±2	100±3	190±4
3.	M6-a	52±3	110±4	230±4
4.	M6-b	55±3	110±6	230±5
5.	M6-c	70±3	110±6	230±5
6.	M6-d	80±3	110±6	230±5

Size and tolerance

The sizes of red bricks according to the Indonesian National Standard (SNI) 15-2094-2000 are shown in Table 2.

Mechanical properties of bricks

Mechanical properties of bricks are the properties of bricks when they are loaded or influenced by certain behaviors, the following are the physical and mechanical properties of bricks [9].

Compressive strength

The ability of the material to withstand loads or mechanical forces until failure occurs. The compressive strength of red brick is the compressive strength value when the first crack occurs in red brick. The average compressive strength and permitted coefficient of variation for red brick are grouped into several classes which can be seen in Table 3 [36].

Tabel 3 Test Results of Physical Properties of Traditional Brick in 15 Districts of Deli Serdang

No	Subdistrict	Cross-sectional dimensions			Visible Properties				
		Length (mm)	Wide (mm)	Height (m)	Right Angle	Flat	Not Cracked	Uniform Color	Loud when hit
1	Percut	186	95	50	NS	NS	S	NS	S
2	Patumbak	196	100	45	S	S	NS	S	S
3	Deli Tua	177	95	50	S	S	NS	NS	NS
4	Hamparan Perak	184	97	50	NS	NS	S	S	S
5	Sunggal	186	95	45	S	S	S	S	S
6	Labuhan Deli	177	98	44	S	S	S	S	NS
7	Sibiru-biru	186	97	50	S	S	S	S	S
8	Galang	178	99	50	S	S	S	S	S
9	Batang Kuis	180	94	45	S	S	S	S	NS
10	Pantai Labu	187	95	50	NS	S	S	S	S
11	Lubuk Pakam	182	95	50	S	S	S	NS	S
12	Pagar Merbau	184	97	50	NS	S	S	S	S
13	Tanjung Morawa	183	96	45	S	S	S	NS	NS
14	Beringin	180	92	46	NS	S	S	S	S
15	Bangun Purba	185	96	50	S	S	NS	S	S

Compressive strength can be calculated using the formula below:

$$f_m = \frac{P_{maks}}{A} \tag{1}$$

Information:
f_m = Compressive strength of red brick (MPa)
P_{maks} = Maximum compressive force (N)
A = Area of compression area (mm^2)

Salt content

The salt content in the bricks can be caused by surrounding environmental factors, namely, the source material (clay) is contaminated with sea water (close to the beach) so the finished bricks can cause salt crystals on the surface of the bricks. Calculate the amount of salt content, depending on the area of the brick containing the salt, divided by the area of the brick multiplied by 100%.

$$\text{Salt content}(G) = \frac{A_g}{A} \times 100\ \% \tag{2}$$

With:
G= salt content (%)
Ag= Area of salt content (cm^2)
A= Brick area (cm^2)

Easily soluble and harmful salts such as magnesium sulphate ($MgSO_4$), sodium sulphate (Na_2SO_4), and potassium sulphate (K_2SO_4), and maximum salt content of 1.0%, must not cause more than 50% of the brick surface to be thickly covered due to salt crystallization.

Water content

In the research, the results of the Brick Absorption Value Test that were tested were the Absorbency Value of bricks from each sub-district and bricks without burning. The absorption capacity of the brick is the amount of water the brick absorbs. The amount of absorption capacity is formulated as follows:

$$\text{Brick absorption capacity (Ds)} = \frac{A - B}{B} \text{x } 100\ \% \tag{3}$$

With

Ds= Absorption capacity of the brick (%)

A= Weight of wet brick (g)

B= Weight of oven-dry brick (g)

Water absorption is an important factor because it is one of the properties of bricks that greatly influences the strength of a brickwork. The absorption capacity of the bricks is controlled to prevent loss of water when used. The maximum water absorption of red brick is a maximum of 20%.

Methods

Research type

The research method encompasses two approaches:

1) Collecting traditional burn-brick that was collected from 15 sub-districts in Deli Serdang,
2) and producing unburnt bricks, partially supplemented with rice husk ash.

Research procedure

1. Traditional bricks with firing:

The study collected bricks from building stores across 15 sub-districts regency, with 3 bricks sampled from 4 stores in each sub-district. They are Percut, Patumbak, Deli Tua, Hamparan Perak, Sunggal, Labuhan Deli, Sibiru Biru, Galang, Batang Kuis, Pantai labu, Lubuk pakam, Pagar Merbau, Beringin, Tanjung Morawa, Bangun Purba.

2. No burn bricks.

a. Materials were prepared by procuring red soil, clay, cement, lime and rice husk ash, with subsequent quality checks.
b. Make a mixed composition with 8 mix variations.

– Variation 1 = Cement: Red Soil: Sand, with a ratio of 1: 8:2
– Variation 2 = Cement: Galong soil: Sand, with a ratio of 1:8:2
– Variation 3 = Lime: Red Earth: Sand, in the ratio of 1:8:2
– Variation 4 = Lime: Galong soil: Sand, in a ratio of 1:8:2
– Variation 5 = Cement: Red Soil: Sand: Rice Husk Ash, in the ratio of 1:8:2:2.
– Variation 6 = Cement: Galong soil: Sand: Rice Husk Ash, in the ratio of 1:8:2:2.
– Variation 7 = Lime: Red Earth: Sand: Rice Husk Ash, in the ratio of 1:8:2:2
– Variation 8 = Lime: Galong soil: Sand: Rice Husk Ash, in the ratio of 1:8:2:2

In this research, the author made 96 brick moulds with different variations, as explained above, then arranged them on racks and left them to dry at room temperature, drying time for 7 days. This drying is done so the bricks are strong and do not break easily.

iii. Making brick prints

– Preparing material mixtures with several composition variations
– Making Molding Tools

iv. Dried at ambient temperature.

Bricks were left to dry at room temperature for 7 days after moulding [37, 38].

The brick moulding tool is made of steel which is divided into 2 parts with the first part for printing bricks adjusted to SNI standards, namely 220 mm long, 120 mm wide and 60 mm thick. and a moulding tool to push material from a hydraulic pump with a size of 220 mm long, 120 mm wide and 40 mm thick is distinguished from the brick moulding tool from previous research with a manual mechanical machine [37, 39]. The working process of the moulding tool with a hydraulic pump can be seen in Fig. 4a–d.

3. Testing the physical properties and mechanical properties of bricks on traditional bricks with combustion collected from samples of 15 sub-districts in Deli Serdang district with unburned bricks that are moulded and then taking the results of its comparison.

a. Physical properties test

   Appearance properties: observing the flat side plane, no cracks, uniform colour, right angle, and loud when hit. Size and tolerance, namely checking the size and tolerance by using a vernier calliper measuring the brick's height, length, and width.
b. Mechanical properties test
c. Salt content test is testing salt content by soaking half of the bricks made upright with water for 1 h and then observing the white layer that coats the surface of the bricks.
e. Testing water absorption by doing bricks before being oven and then after being in the oven for 24 h again so that the amount of brick absorption of water can be obtained.

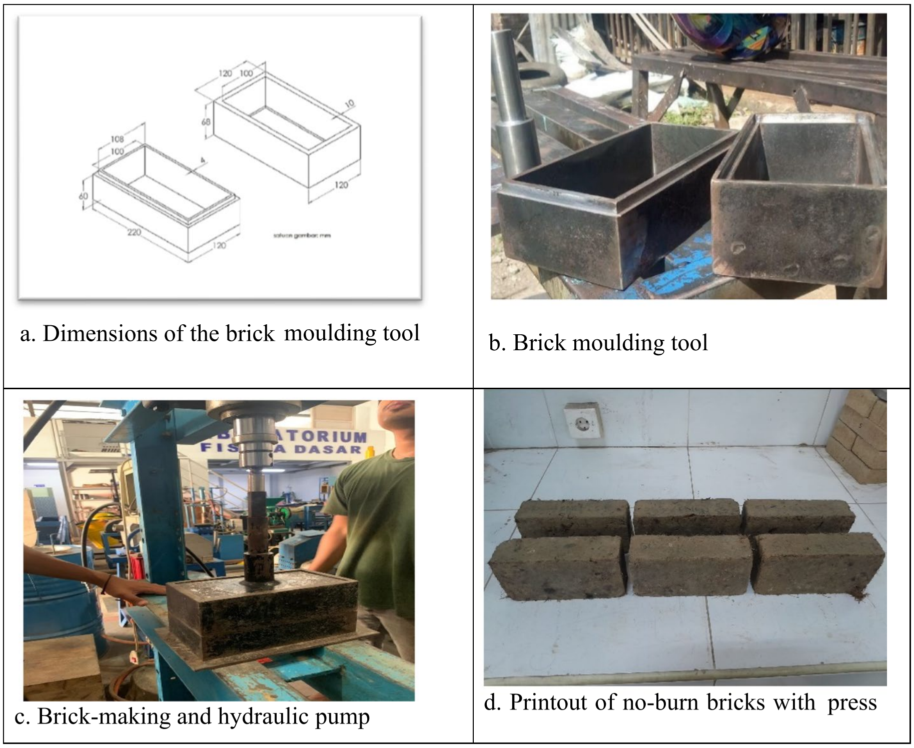

Fig. 4 a–d The working process of the moulding tool

f. The compressive strength test is to take a brick and put it under a press machine and see the results of the digital numbers that show the results of the force/load until the brick cracks.

The summarized research method scheme can be seen in the flow chart in Fig. 5.

Results and discussion

In the study conducted on traditional bricks within Deli Serdang Regency, the examination process adhered to the standards set by SNI 15-2094-2000, drawing in data from prior investigations. This analysis was juxtaposed against the characteristic of unburned pressed bricks, which incorporate rice husk ash (RHA), an agricultural by-product, in their composition. These alternative bricks were crafted using eight distinct blends of clay, red soil, cement, and sand, maintaining a proportional ratio of 1:8:2: The findings and data garnered from laboratory experiments and observations provided insightful comparisons between the two types of bricks.

Traditional brick

Physical test (size and apparent properties)

a. The physical properties examination of traditional bricks sourced from 15 sub-districts within the Deli Serdang District, featuring a total of 96 brick specimens, is detailed in Table 4.

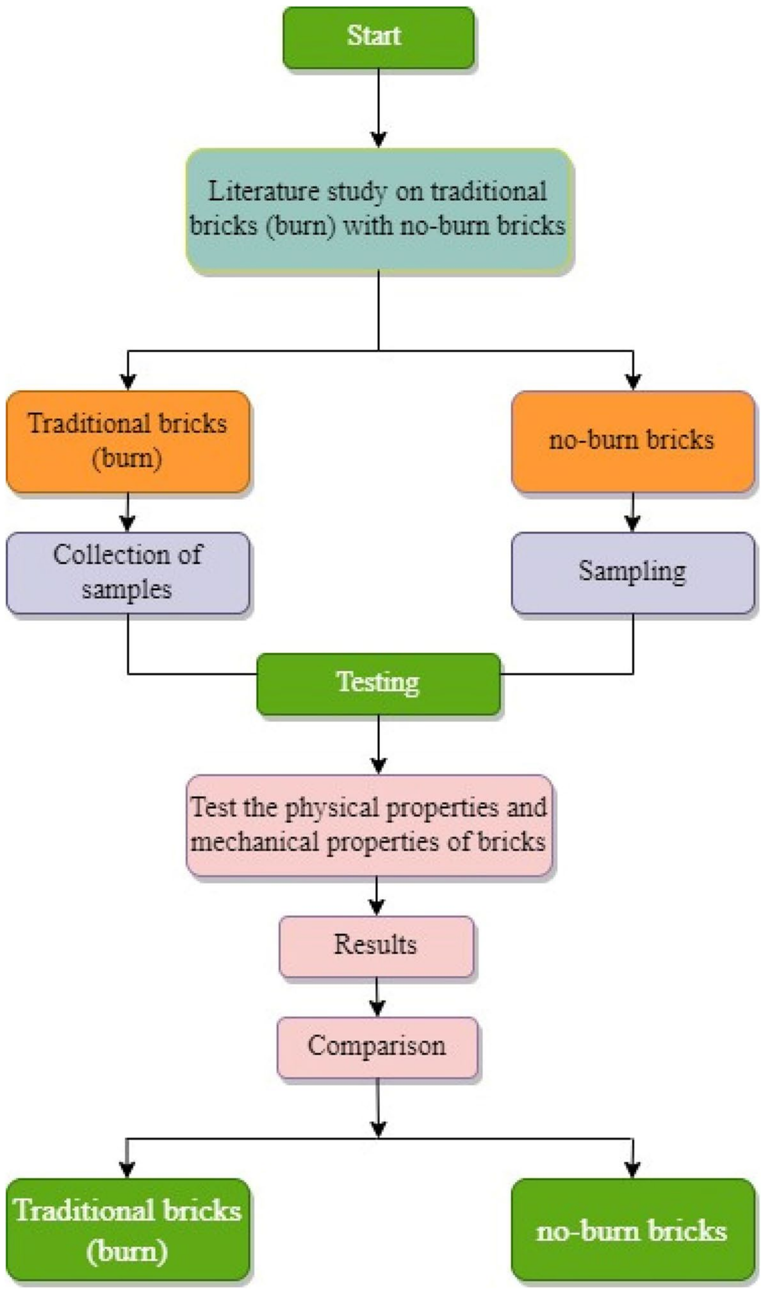

Fig. 5 Flow chart

In compliance with SNI standards, the physical test results for the dimensions of bricks reveal that for the M5-a module, a brick's length must be 190 ± 4 mm, translating to a minimum of 186 mm and a maximum of 194 mm. Analysis from 15 districts indicates that only 50% of the samples adhere to the SNI criteria for length. As for width, which is mandated to be 90 ± 3 mm, implying a range between 87 mm and 93 mm, samples from all 15 districts successfully meet the SNI standards. Regarding height, with a required specification of 65 ± 2 mm, meaning it should fall between 63 mm and 67 mm,

Tabel 4 Brick Mechanical Test Results (Moisture Content, Salt Content, Compressive Strength) Traditional Brick with Firing

No.	Brick Sample Code	Water content (%)	Salt Content (%)	Compressive Strength (Mpa)
1	Percut	0.142	0.150	2.49
2	Patumbak	0.082	0.125	4.89
3	Deli Tua	0.071	0.025	2.63
4	Hamparan Perak	0.082	0.030	3.30
5	Sunggal	0.168	0,000	2.93
6	Labuhan Deli	0.089	0,000	3.39
7	Sibiru-biru	0.143	0.020	2.48
8	Galang	0.167	0.040	3.34
9	Batang Kuis	0.227	0.010	2.60
10	Hamparan Perak	0.208	0.055	2.49
11	Lubuk Pakam	0.240	0.105	2.98
12	Pagar Merbau	0.102	0.015	2.47
13	Beringin	0.239	0.285	2.66
14	Tanjung Morawa	0.117	0.210	2.30
15	Bangun Purba	0.193	0.180	4.14
Average		**0.135**	**0.150**	**3.01**

none of the bricks from the 15 districts conform to the SNI requirements. Consequently, considering the dimensions and tolerances, 75% of the criteria specified by SNI are met [40]. Regarding the visible properties of the bricks, classified under “T” for those that do not meet the standards and “S” for those following SNI, there were 15 samples that did not comply and 60 samples that were consistent with SNI 15-2094-2000 criteria. Out of a total of 75 samples evaluated for their visible characteristics, 80% were found to meet the specifications set forth by SNI 15-2094-2000.

Mechanical test (moisture content, salt content, compressive strength)

a. The water content test aims to investigate and ascertain the moisture level in brick samples previously analyzed, sourced from 15 sub-districts across Deli Serdang. Detailed findings of this examination are presented in Table 5 below:

The analysis of water content in traditional bricks revealed an average of 0.135%, which is below the 20% threshold, thereby complying with the SNI 15-2094-2000 standard. Additionally, the assessment of salt content in these bricks showed an average of 0.15%, also below the 50% limit, aligning with the SNI 15-2094-2000 standard. However, the examination of the compressive strength of traditional bricks yielded an average of 3.01 MPa, falling short of the SNI 15-2094-2000 standard requirement of a minimum of 5 MPa, indicating non-compliance with the standard. These findings on the compressive strength of traditional bricks are depicted in Fig. 6, the compressive strength test diagram.

Table 5 Physical Test Results on Non-Fired Pressed Bricks

No	Sample Code	Cross-sectional dimensions			Visible Properties				
		Length (mm)	width (mm)	Height (mm)	Right Angle	Flat	Not Cracked	Uniform Color	Loud when hit
1	CCR	200	100	50	S	S	S	S	S
2	CCC	200	100	50	S	S	NS	S	S
3	CLR	200	100	50	S	S	NS	S	NS
4	CLC	200	100	50	S	NS	S	S	S
5	CRRHA	200	100	50	S	S	S	S	S
6	CCRHA	200	100	50	S	S	S	S	NS
7	LRRHA	200	100	50	S	S	S	S	S
8	LCRHA	200	100	50	S	S	S	S	S

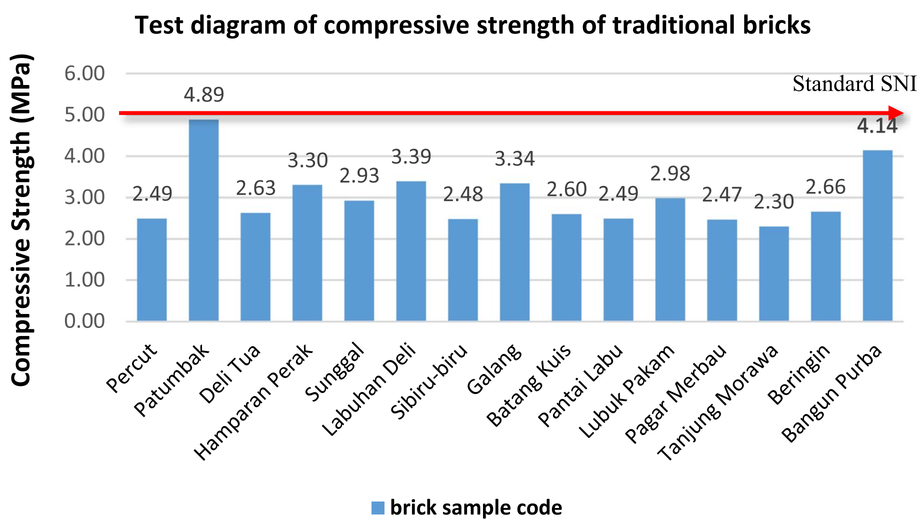

Fig. 6 Graph of the results of the traditional brick compressive strength test

No-burn bricks

Physical test (size and apparent properties)

The physical test outcomes, encompassing both size and tolerance as well as appearance properties, for 8 different mixture variations utilized in brick fabrication, involve the use of a moulding apparatus. These bricks were formed by applying pressure through a hydraulic pump, subsequently shaped with a hydraulic pump tool exerting a force of 5 MPa. The composition of eight different variations of pressed, non-burned bricks includes

1. CCR = control cement red soil
2. CCC = control cement clay
3. CLR = control lime red soil
4. CLC = control lime clay
5. CRRHA = cement red soil rush husk ash
6. CCRHA = cement clay rush husk ash

7. LRRHA = lime red soil rush husk ash
8. LCRHA = lime clay rush husk ash

Observations and measurements about eight variations of non-fired pressed bricks incorporating rice husk ash are detailed in Table 5. The examination of the physical properties of these non-fired pressed bricks, across all eight variations, revealed that their dimensions and tolerances fully comply with the SNI standards, achieving a 100% conformity rate. This is attributed to the employment of a steel brick mould, precisely engineered and fabricated to match the standard dimensions specified by SNI 15-2094-2000. Such an approach proves to be more efficient than utilizing diesel-engine-operated moulding tools or those that operate via levers.

Mechanical test (moisture content, salt content, compressive strength)

The outcomes of the mechanical tests conducted on the production of non-fired pressed bricks, featuring eight different compositional variations, are summarized in Table 6.

The analysis of the water content in these bricks revealed an average value of 0.13%, which is significantly lower than 20%, thereby adhering to the SNI 15-2094-2000 standards. Additionally, the average salt content in traditional bricks was found to be 0.002%, well below the 50% threshold and in compliance with the SNI 15-2094-2000 standards. Notably, the salt content in the non-fired pressed bricks is less than that found in conventional fired bricks Li, Yang [41] and Pela [42].

The average compressive strength of non-burn bricks without rice husk ash is 5,17 MPa, which satisfies the SNI standard requirements. In contrast, the average compressive strength of non-burned bricks incorporating rice husk ash is 1.98 MPa, falling below the 5 MPa threshold and thus not meeting the established standard.

a. Comparison between traditional bricks and no-burn bricks: results from physical properties tests (size and appearance). The comparison of the physical properties, specifically size and appearance, between traditional bricks and no-burn bricks reveals distinct differences. The comparison of size tests between traditional bricks and no-burn bricks indicates that no-burn bricks demonstrate superior conformity,

Tabel 6. Brick Mechanical Test Results (Water Content, Salt Content, Compressive Strength) of Pressed Bricks Without Burning

No.	Sample of brick collection area	Water content (%)	Salt Content (%)	Compressive Strength (Mpa)
1	CCR	0.127	0.0012	5.37
2	CCC	0.103	0	6.64
3	CLR	0.195	0	5.22
4	CLC	0.094	0.0025	3.46
5	CRRHA	0.149	0	1.50
6	CCRHA	0.124	0	2.01
7	LRRHA	0.159	0	2.13
8	LCRHA	0.807	0	2.28
Average		**0.130**	**0.002**	**3.58**

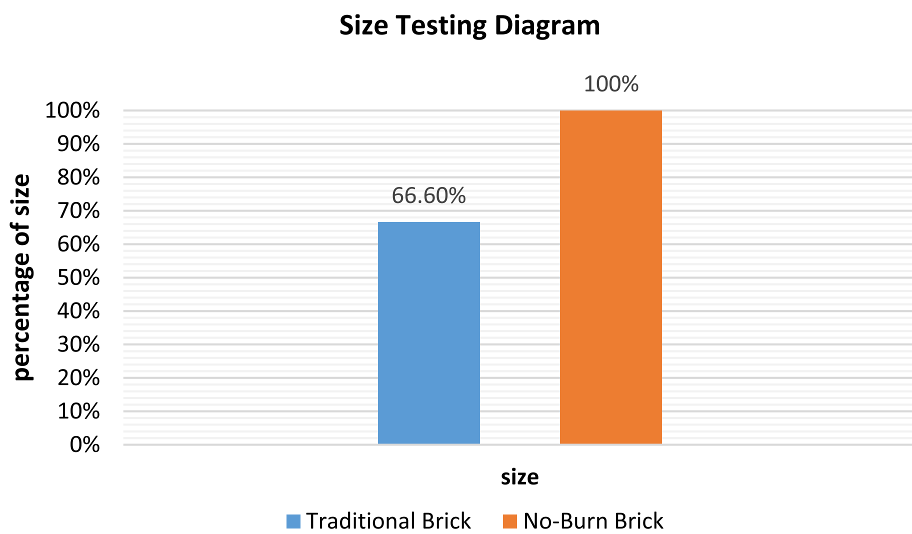

Fig. 7 Size comparison of traditional and no-burn bricks

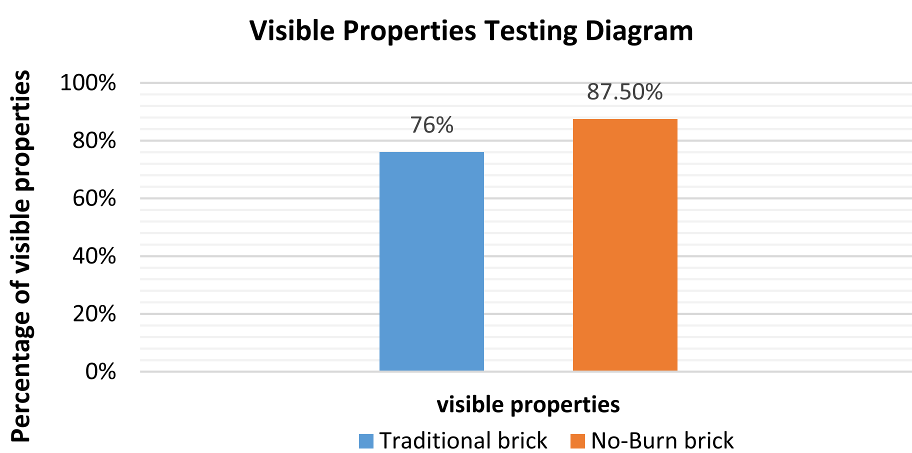

Fig. 8 Comparison of the visible properties of traditional bricks with no-burn bricks

with 100% of no-burn bricks meeting the specified criteria, compared to 66.60% for traditional bricks. This superiority in size conformity of no-burn bricks over traditional ones is illustrated in Fig. 7.

b. Comparison of visible properties between traditional bricks and no-burn bricks

The visible properties of traditional bricks versus no-burn bricks exhibit noticeable distinctions. The appearance, texture, and colour uniformity are key aspects where these two types of bricks can be compared, reflecting their respective manufacturing processes and material compositions. The comparison of physical properties between traditional bricks and no-burn bricks shows that 76% of traditional bricks and 87,50% of no-burn bricks perform better in the visible properties test for unburnt bricks [43]. This information is illustrated in the provided Fig. 8.

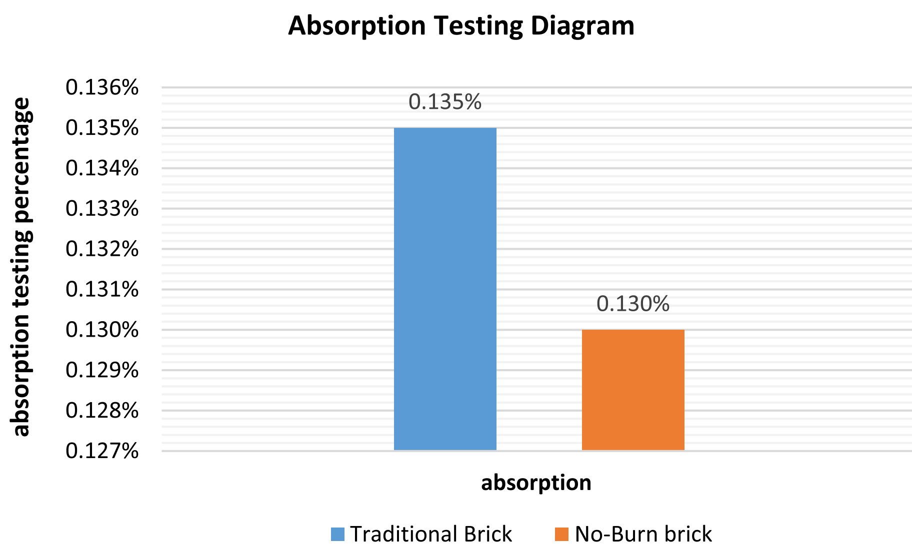

Fig. 9 Comparison of moisture content of burnt bricks/traditional bricks with no-burn bricks

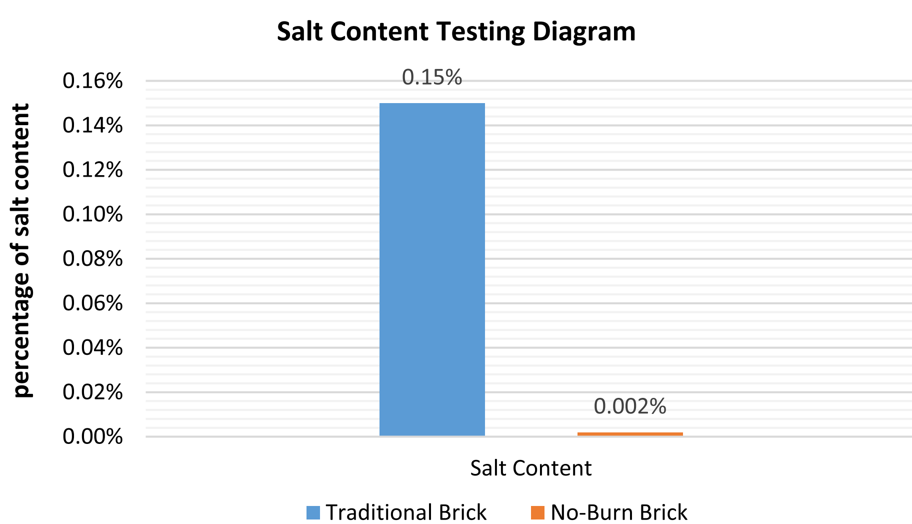

Fig. 10 Comparison of salt content of burnt/traditional bricks with no-burn bricks

Comparison of mechanical test results (moisture content, salt content, compressive strength)

The moisture content of traditional bricks and no-burn bricks.

The comparison of mechanical properties between traditional bricks and no-burn bricks indicates that the water content is 0.135% for traditional bricks and 0.130% for no-burn bricks, meeting SNI standards that require levels below 20%. This data is available in Fig. 9.

The salt content of traditional bricks and no-burn bricks.

The mechanical properties test comparing traditional bricks and no-burn bricks reveals a salt content of 0.15% for traditional bricks and 0.002% for no-burn bricks, meeting SNI standards that require levels below 50%. This information is displayed in the provided Fig. 10.

Compressive strength of traditional bricks and no-burn bricks

In comparing mechanical properties between traditional bricks and no-burn bricks, the compressive strength test results show that conventional bricks at 3,01 MPa decreased by 39.8%. In contrast, no-burn bricks at 5.17 MPa increased by 3.45%. However, no-burn bricks with added husk ash at 1.98 MPa decreased by 60.4%. This data is illustrated in Fig. 11.

The reduction in compressive strength of no-burn bricks with added rice husk ash is attributed to the decreased density caused by the high porosity of rice husk. This elevated porosity leads to an excess of pore cavities within the bricks, ultimately resulting in decreased compressive strength [44]. Excessive rice husk ash addition reduces the plasticity of the brick-forming material, weakening the bond between clay and rice husk ash. Another factor could be insufficient moisture content during the moulding process [45]. The high porosity of rice husk ash allows it to absorb water easily. Therefore, using a large amount of rice husk ash in a mixture can lead to water deficiency during the pozzolanic reaction process [46]. Insufficient moisture content during the pozzolanic process will decrease the compressive strength of the bricks.

Conclusions

From the results of the tests and research that have been carried out, several conclusions can be drawn, including

1. Results comparison of physical and mechanical properties of traditional bricks with no-burn bricks. There are differences in the influence of mixing materials and the manufacturing process. However, they can still be used for non-structural buildings such as walls.
2. In comparing the physical properties of traditional and no-burn bricks, visible properties scored 76% for no-burn bricks and 87% for conventional bricks. Traditional

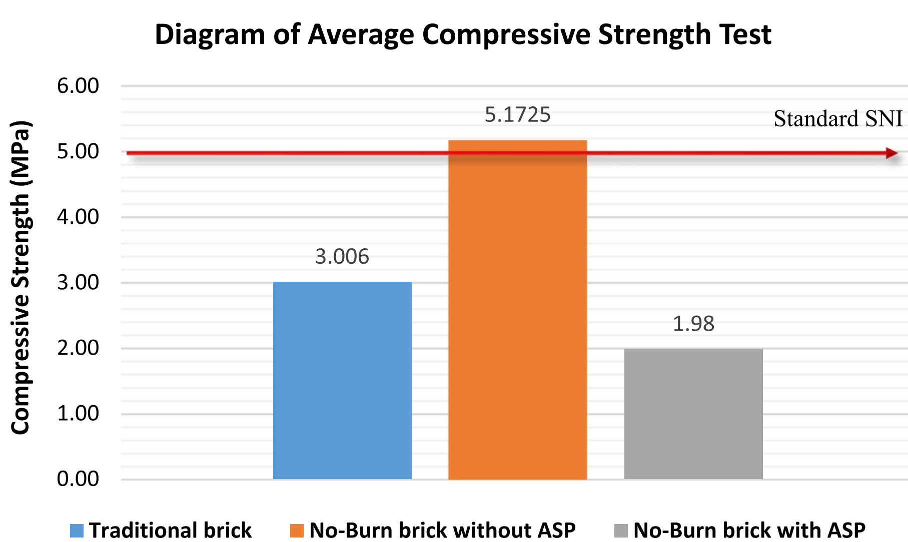

Fig. 11 Comparison of the compressive strength of bricks in fired bricks traditional bricks with no-burn bricks and no-burn bricks with rice husk ash

bricks scored 66.60% in size, while no-burn bricks scored 100%, attributed to a printing process that complies with SNI standards.

3. The average water absorption of unburnt compressed brick is 0.13%, lower than 0.135% for traditional burnt bricks, both within the safe threshold of 20%. Regarding salt content, unburnt compressed bricks have 0.002% compared to 0.5% in conventional burnt bricks, meeting SNI standards and posing no harm.
4. The comparison of compressive strength shows traditional bricks at 3.01 MPa and no-burn bricks at 5.17 MPa. Additionally, no-burn bricks with rice husk ash recorded 1,98 MPa, marking a 39.8% decrease for traditional bricks, a 3.45% increase for no-burn bricks, and a 60.4% decrease for no-burn bricks with rice husk ash.
5. The enhancement of compressive strength in non-fired bricks through the addition of rice husk ash with lime material resulted in a notable decrease compared to regular bricks. This decline can be attributed to imprecise material proportions, especially with the inclusion of rice husk ash and lime.
6. This research contributes to science and the environment by utilizing non-burning bricks made from rice husk ash, effectively repurposing agricultural waste and reducing environmental pollution. This innovation promotes the development of environmentally friendly building materials.

Abbreviations

RHA	Rush husk ash
SEM	Scanning electron microscope
S	According to SNI
NS	Does not accord to SNI
CCR	Control cement red soil
CCC	Control cement clay
CLR	Control lime red soil
CLC	Control lime clay
CRRHA	Cement red soil rush husk ash
CCRHA	Cement clay rush husk ash
LRRHA	Lime red soil rush husk ash
LCRHA	Lime clay rush husk ash

Acknowledgements
Thank you to the University of Muhammadiyah North Sumatera, the Faculty of Engineering and LP2M UMSU for facilitating this research.

Human/animal rights
This article does not need ethical standards on human and animal experimentation from any authority level.

Authors' contributions
All authors contributed significantly to the study in the areas of conceptualization, data curation, optimization, validation, funding acquisition, formal analysis, methodology, original draft, software, and manuscript writing. SF: conceptualization, data curation, formal analysis, methodology, software, writing of original draft. LET: project administration, resources, supervision, formal analysis. FVR: project administration, resources. ARN: writing—review and editing. FZ: writing—review and editing. All the authors jointly conducted a formal analysis of the laboratory outcome the final manuscript was read and approved by all authors.

Funding
Comparison of Physical and Mechanical Properties of Traditional Bricks in Deli Serdang with No-Burn Bricks Using Rice Husk Ash.
This work is supported by a 2021 and 2022 Universitas Muhammadiyah Sumatera Utara LPPM Research Grant, 2022 and 2022 LPPM UMSU Grants (104/II.3-AU/UMSU-LPPM/C/2022), Applied research programs and APB research and community service institutions.

Availability of data and materials
Data can be shared upon request as a basic requirement dictated by Springer rules.

Declarations

Ethics approval and consent to participate
This work is supported by a 2021 and 2022 Universitas Muhammadiyah Sumatera Utara LPPM Research Grant, 2022 and 2022 LPPM UMSU Grants (104/II.3-AU/UMSU-LPPM/C/2022), Applied research programs and APB research and community service institutions.

Competing interests
This research is supported by a 2021 and 2022 LPPM-Universitas Muhammadiyah Sumatera Utara Research Grant, 2022 and 2022 LPPM UMSU Grants (104/II.3-AU/UMSU-LPPM/C/2022). The authors whose names are listed immediately below certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Received: 28 December 2023 Accepted: 14 June 2024
Published online: 02 July 2024

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