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Research Paper

Fly Ash and Rice Husk Ash Utilization to Enlarge Clay Brick Dimension

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Abstract

Burnt clay bricks, mostly used as non-structural wall unit materials in Indonesia, contain only clay in Bengkulu Province. A large amount of clay is used during clay brick production as a shrinkage effect of burning, while clay is a limited natural resource. Available non-plastic materials that can withstand combustion contraction are required to reduce the use of clay. Ash materials like fly ash and rice husk ash are non-plastic materials. The purposes of this research are to reduce clay usage, enlarge dimensions, and improve brick performance at the same time by adding coal fly ash (FA) and rice husk ash (RHA). This research is an experimental study of FA clay brick (FCB) and a combination of 50% FA and 50% RHA clay brick (FRCB). The ash was added to the mixture at weights of 10%, 20%, and 30% of clay. The factory-specified production method was used to create bricks. After the materials and water meltdown process to produce plastic material, bricks were molded, dried, and burned. Green and burnt brick measurements and weights were gathered. The Brick Indonesian Standard Code (SNI 15-2094-2000) was used while determining the bricks' compression strength and absorption. The mean values of the quantitative data were used after being analyzed through coefficient of variation values less than 10%. The result shows that the compressive strengths and absorption of 10% and 20% of the ash content of FCB meet the Indonesian code. Both brick volumes expand as the ash content increases. FRCB volume weight is 11%, 7.8%, and 8.1% lighter than FCB for 10%, 20%, and 30% ash content, respectively. Both brick varieties meet the ASTM code for nonload-bearing concrete masonry units. The use of FA and a mixture of FA and RHA enhances shrinkage, increases brick dimensions, and simultaneously lowers brick weight. Using lighter and larger bricks for the walls helps to recycle waste, reduce the mass of the building, and reduce the use of clay resources. Application 10% and 20% fly ash is recommended for increasing the size of clay bricks in Bengkulu Province, Indonesia.

Keywords: *Burnt Clay Brick, Coal Fly Ash, Rice Husk Ash, Shrinkage*

INTRODUCTION

The most common type of brick used in masonry construction globally is fired clay because of its strength, flexibility, and longevity (ASTM C216-10, 2010; Ukwatta and Mohajerani, 2017; Al-fakih *et al.*, 2019; Akinyele, Igba and Adigun, 2020; Alkhaly *et al.*, 2022). According to Aboul's estimate (Bautista-Marín, Esguerra-Arce and Esguerra-Arce, 2021), over 62% of homes in Southeast Asia are built with burnt clay brick. Burned clay brick, as one of the traditional local building materials, is frequently utilized as a non-structural wall material in Indonesian homes and buildings, particularly in the province of Bengkulu.

Burning is recognized as the most widely utilized technique for producing clay bricks in the nations having substantial quantities of clay (Elhusna, Wahyuni and Gunawan, 2014; Joglekar *et al.*, 2018; Silva and Perera, 2018). The fired process reduces brick dimensions and even becomes smaller ones when the brick contains only clay. Bengkulu clay bricks have a volume shrinkage larger than 42% which means the ratio of burnt brick and green brick is about 68% (Elhusna, Wahyuni and Gunawan, 2014).

Numerous studies have documented the utilize of various kinds of industrial and agricultural wastes in clay bricks production. The goal of the studies are to use less clay while simultaneously increasing brick performance. Coal fly ash and rice husk ash are industrial and agricultural wastes, whose volume continues to increase nowadays (Kadir and Sarani, 2012; Çiçek and Çinçin, 2015; Abbas et al., 2017; Eliche-Quesada et al., 2018; Joglekar et al., 2018; Hossain et al., 2019; Akinyele, Igba and Adigun, 2020; Josiah Marut, Alaezi and Obeka, 2020; Ketov et al., 2021; Tjaronge and Caronge, 2021). Silica is found in clay, fly ash, and rice husk ash as their greatest chemical ingredient (Abbas *et al.*, 2017; Huynh *et al.*, 2018; Silva and Perera, 2018; Alkhaly *et al.*, 2022; Rief and Hasan, 2022).

One of the ways to reduce the use of clay in bricks is to use available waste materials that can increase the volume of fired bricks. However, research on the dimensional changes due to the addition of fly ash and rice husk ash is still limited. This research purpose deals with brick contraction and enlarges its dimensions by adding FA and RHA to clay during brick production. This article shows the results of a study on changes in the dimensions, volume, and weight of clay bricks due to the variation in the addition of both of the ashes, as well as their changes between green bricks and burnt ones. The reported mechanical properties of clay bricks in this research are compressive strength and absorption.

LITERATURE REVIEW

Clay Brick Characterization

Clay brick characteristics (ASTM C216-10, 2010) can be distinguished based on its durability and mechanical properties. The bricks after firing can be characterized by examining their dimensions, absorption, and compressive strength (Gavali *et al.*, 2019) (Bautista-Marín, Esguerra-Arce and Esguerra-Arce, 2021). American standard material testing provides a minimum compressive strength limit for nonload-bearing concrete masonry units of 3.45 MPa and no limit for water absorption (Al-fakih *et al.*, 2019). Meanwhile, SNI 15-2094-2000, the Indonesian code, limits water absorption to a maximum of 20% and a minimum compressive strength of 5 MPa, with a variation coefficient of 22% or 3.9 MPa for solid clay bricks for wall pairs.

Clay Brick and Coal Fly Ash

Clay and coal fly ash (FA) are similar in texture and oxidation components. FA can substitute a part of clay as a raw material for clay bricks because of these similarities [18]. Fly ash particles, a by-product of coal-fired thermal power plants, frequently resemble small, spherical powders [23]. FA components are mostly Al, Ca, Mg, Fe, Na, and Si [22], [13], [20], [21]. It is essentially composed of SiO2, CaO, and Al2O3 with small quantities of oxides of iron, sulfur, and magnesium.

Clay bricks with 5% FA can be used as bricks that can withstand severe weather (Abbas *et al.*, 2017). Replacement 25% clay with fly ash reduces the clay brick weight by 18% (Abbas *et al.*, 2017). Fired bricks made of clay and FA up to 20 wt% are reported to have similar physical and mechanical properties to bricks without FA and decrease in bricks with greater FA content (Eliche-Quesada *et al.*, 2018). The burnt clay bricks' compressive strength rises by 17.36% with 4% FA addition (Kumar *et al.*, 2021).

Rice Husk Ash and Clay Brick.

The largest compound content of clay and rice husk ash is SiO2 (Muntohar, 2011; Huynh *et al.*, 2018; Silva and Perera, 2018; Loetchantharangkun and Wangrakdiskul, 2021). The bricks produced by combining clay with 4% waste RHA by weight have a water absorption rate of 19%, and the compressive strength is 32.7% higher than that of the usual bricks manufactured in the factory (Silva and Perera, 2018).

MATERIALS AND METHODS

Clay Brick Materials

Materials were prepared in 2 stages, namely collecting and testing their physicals properties. The materials used for the brick production were clay, fly ash, rice husk ash, and water. The materials were taken from nearby locations on the Sumatra island, Indonesia. The clay and water were available in the brick factory site in Selebar regency. The rice husk ash was collected from the combustion in Arga Makmur regency. Both regencies are located in Bengkulu Province. The fly ash was collected from Keban Agung, located in Lahat regency, South Sumatra Province.

Both ashes used (Figure 1) have passed through sieve number 100. Physical properties of the ashes and clay (Table 1) were carried out according to the Indonesian National Standard code

Figure 1. Fly ash and rice husk ash

The physical properties of the materials (Table 1) were collected based on Indonesian National Standards. The amount of materials used for each combination (Table 2) varied between fly ash clay brick (FCB) and fly ash and rice husk ash clay brick (FRCB). The second variation used a weight combination of 50% fly ash and 50% rice husk ash for each ash percentage.

Table 1. Materials Physical Properties

Description	**Clay**	**Fly Ash**	**Rice husk ash**	**Codes**
Bulk density (gr.cm-3)	1,27	0,99	0,3	(SNI-03-3637-1994, 1994)
water content (%)	46,20	2,88	3,81	(SNI-03-1971-1990, 1990)
Density (gr.cm-3)	2,76	2,13	1,78	(SNI-1970-2008, 2008)
Liquid limit (%)	61,82			(SNI-1965-2008, 2008)
Plastic limit (%)	47,17			(SNI-1966-2008, 2008)
Plastic index (%)	14,65			(SNI-1966-2008, 2008)

Table 2. Clay and Ash Amounts of a Brick Unit Mixture

Ashes (%)	FCB variation (kg)		FRCB variation (kg)		
	Clay	Fly Ash	Clay	Fly Ash	Rice husk ash
10	2,2	0,22	2,2	0,11	0,11
20	2,2	0,44	2,2	0,22	0,22
30	2,2	0,66	2,2	0,33	0,33

Notes: fly ash clay brick (FCB); fly ash and rice husk ash clay brick (FRCB)

Bricks Manufacturing

Brick production was carried out according to the factory method. Clay and each ash variation (Table 2) were mixed evenly. Water was poured into the clay mixture and stirred with pressure until the mortar was plastic enough to be cast into the mold. The length, width, and height of the mold are 215mm, 105mm, and 50mm, respectively. The drying process of the green bricks under the sun was done until they were dry and hard. The bricks were then arranged in the kiln and fired for 48 hours. The bricks were removed from the kiln after the next 48 hours due to the brick cooling process.

Collecting Dimensions and Weight

Dimensions and weight of the bricks were measured in accordance with codes of Indonesian national standard and American standard testing materials.

Compressive Strength and Absorption Testing

The brick specimens for the test compressive strength and absorption of were made according to the Indonesian code of solid clay bricks for wall masonry (SNI 15-2094-2000, 2000).

FINDINGS AND DISCUSSION

Brick Properties.

The length, width, and unit weight of fly ash bricks (FCB) extend as the fly ash content increases (Figure 2a). Meanwhile the brick height and unit weight appear to be unaffected by the ash content of more than 10%. They have the same values for 20% and 30% ash content.

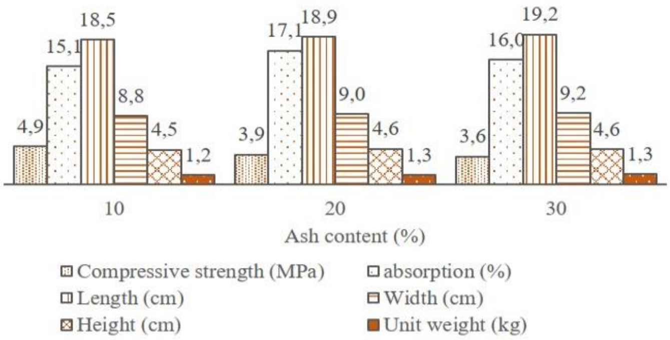

Figure 2. Fly ash clay bricks (FCB) [Properties of clay brick spesimens]

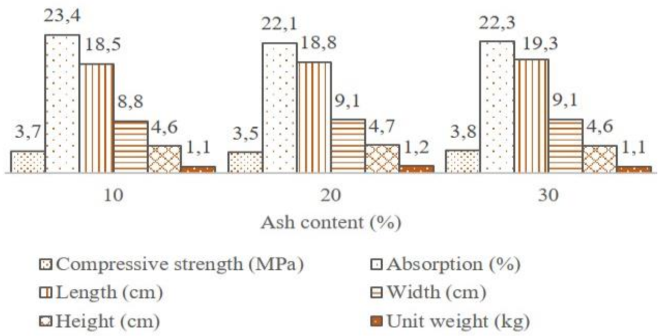

Figure 3. Fly ash and rice husk ash clay bricks (FRCB) [Properties of clay brick spesimens]

Fly ash and rice husk ash clay brick (FRCB) length rises as the amount of ash rises, but the width rises when the ash content is greater than 10% and has the same value at a higher ash content (Figure 2b). FRCB height and unit weight have their own trend. They increase at 20% ash content but have the same value at 10% and 30% ash contents. The result (Figure 2) exhibits that FRCB dimensions are slightly bigger than FCB ones when the weight unit is lighter. Bigger and lighter bricks are produced when 50% of the FA by weight is replaced with lighter RHA.

The highest FCB compressive strength is 4,9 MPa at 10% FA, and then it decreases as the ash content rises. Despite a reduction in clay brick strength by the addition of 20% FA to clay bricks, it is still in line with the codes in Indonesia. This situation is contrary to the one mentioned before (Hossain *et al.*, 2019), where the brick strength decreases when it contains more than 20% fly ash. It is also shown that the strength and the absorption reduce at 30% FA, whereas generally, absorption increases when compressive strength decreases and vice versa. This study exhibits that the compressive strength of burnt clay bricks with the addition of 10% to 30% FA is greater than 3.55 N/mm2, a burnt clay brick with 4% FA (Silva and Perera, 2018).

The brick with 30% ash content as the highest strength of FRCB is 26% higher than the 10% one and 5.6% higher than the FCB with the same ash content. While the 10% FCB compressive strength is the highest between the brick types, it is 32.4% higher than the FRCB one. The important thing is that all the strength of FCB and FRCB still meets the ASTM code since they are higher than 3 MPa.

Compressive strength and absorption of brick. The compressive strength of FCB (Figure 2a) decreases as the ash content rises but the absorption rises at 20% ash content. and then decreases 1.1% at 30% ash content. The possibility is that the presence of 30% fly ash causes the brick melting process to be better during combustion so that the adhesion between the particles is better and produces smaller pores.

The compressive strength for 10% and 20% ash content of FCB is higher than FRCB ones, and vice versa for FRCB with 30% ash content. The absorption value of FCB is smaller than that of FRCB. The interesting thing is that the compressive strength and absorption values decrease at 30% ash content of FCB and while for FRCB, compressive strength and absorption decrease at 20% ash content and increase at 30% ash content. In accordance with the Indonesian code (SNI 15-2094-2000, 2000), the utilization of 10% and 20% fly ash can increase the size of burnt clay bricks in Bengkulu Province.

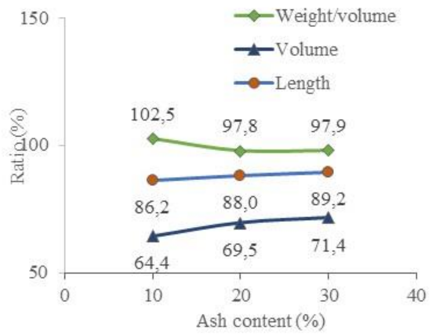

Figure 4. Fly ash clay bricks (FCB) [Properties ratio of burnt and green clay bricks]

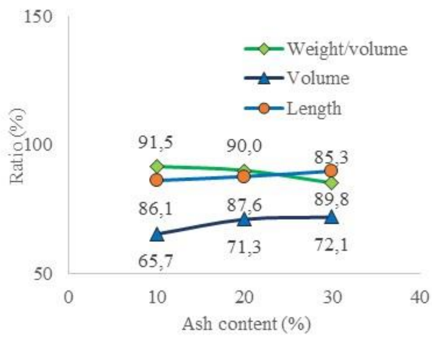

Figure 5. Fly ash, rice husk ash clay bricks (FRCB) [Properties ratio of burnt and green clay bricks]

Properties Ratio of The Green and Burnt Bricks

The properties ratio of the green and burnt bricks (Figure 3) show that FRCB expand the volume greater than FCB one. FRCB weight volumes are also lighter than FCB. It might prove that the combination of fly ash and rice husk ash successfully filled the clay bricks during the firing process. Since the RHA has a small bulk density, FRCB becomes lighter than FCB, whose ash bulk density is heavier.

The presence of fly ash produces bricks with better compressive strength compared to the presence of fly ash and rice husk ash. The strength of these two types of bricks decreases when the amount of ash increases but still meet ASTM for nonload-bearing concrete masonry units. Only the strength and the absorption of FCB up to 20% fly ash addition, meet the Indonesian code.

The volume of the bricks expands as the amount of ash increases since it is mentioned before that the minimum shrinkage of clay brick volume in Bengkulu is 42% (Elhusna, Wahyuni and Gunawan, 2014), where it's equivalent to 58% of the burnt and green clay brick ratio, However, the volume weight of FRCB is 11%, 7,8%, and 8,1% lighter than FCB for 10%, 20%, and 30% ash content, respectively. This is because the volume of FRCB is slightly larger than FCB. The use of fly ash or a combination of fly ash and rice husk ash for clay bricks can increase dimensions, improve shrinkage, and at the same time reduce the weight of clay bricks.

CONCLUSIONS AND FURTHER RESEARCH

The best fly ash clay brick occurs in bricks with 10% fly ash, while bricks with a mixture of clay and fly ash and rice husk ash produce the highest compressive strength in 30% ash clay bricks. The volume of the bricks expands as the amount of ash increases, but the volume weights of fly ash and rice husk ash brick (FRCB) are 11%, 7,8%, and 8,1% lighter than fly ash brick (FCB) for 10%, 20%, and 30% ash content, respectively. This is because the volume of FRCB is slightly larger than FCB. Based on compressive strength and absorption values, FCB with up to 20% ash content meets the Indonesian code for brick. Both brick types meet ASTM requirements for nonload-bearing concrete masonry units. The use of fly ash or a combination of fly ash and rice husk ash for clay bricks increase dimensions, improve shrinkage, and at the same time reduce the weight of clay bricks. larger and lighter bricks as wall material contribute to reducing the building's mass, the use of limited clay resources, and recycling the waste whose volume.

Following the Indonesian code (SNI 15-2094-2000, 2000), the use of 10% and 20% fly ash is recommended to increase the size of clay bricks in Bengkulu Province. Despite a reduction in clay brick strength by the addition of 20% FA to clay bricks, it is still in line with the codes in Indonesia. This study's findings are limited to the attributes covered previously. Research on the additional characteristics of bricks as a wall material could be explored. Further research on reducing the utilization of clay in brick production should also be done by combining other waste materials.

LIMITATION & FURTHER RESEARCH

The limitations of the study are those characteristics of design or methodology that impacted or influenced the interpretation of the findings from your research. Further research should suggest the number of gaps in our knowledge that follow from our findings or to extend and further test of the research.

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