บทความวิจัย

อิฐมวลเบาจากเถ้าแกลบผสมปูนซีเมนต์: แนวทางการประยุกต์เป็นวัสดุก่อสร้างทางเลือก

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บทคัดย่อ

ประเทศไทยเป็นพื้นที่เกษตรกรรมปลูกข้าวที่มีการใช้แกลบเป็นเชื้อเพลิงชีวมวล ซึ่งทำให้ได้เถ้าแกลบเหลือทิ้งเป็นผลพลอยได้จำนวนมาก ดังนั้นงานวิจัยนี้ขอเสนอแนวทางการผลิตอิฐมวลเบาชนิดใหม่โดยใช้เถ้าแกลบที่ได้จากการเผาอิฐของโรงงานในจังหวัดพระนครศรีอยุธยาผสมกับปูนซีเมนต์เพื่อศึกษาความเป็นไปได้ในการนำมาใช้เป็นวัสดุก่อสร้างทางเลือก สำหรับการทดลองลักษณะสัณฐานและองค์ประกอบของเถ้าแกลบได้ถูกวิเคราะห์ด้วย SEM-EDS จากนั้นทดสอบสมบัติทางกายภาพและสมบัติเชิงกลของอิฐที่ผลิตจากเถ้าแกลบผสมปูนซีเมนต์ (5–30% โดยน้ำหนัก) ได้แก่ ความหนาแน่น การดูดซึมน้ำ และความต้านทานแรงอัด ตาม มอก. 2601-2556 (คอนกรีตบล็อกมวลเบาแบบเติมฟองอากาศ) จากผลการวิจัยพบว่า เถ้าแกลบที่ได้หลังจากคัดแยกเพื่อลดขนาดอนุภาคนั้นมีรูปร่างหลายเหลี่ยม มีขนาดอนุภาคเฉลี่ย 14.66 ไมโครเมตร และมีซิลิกอนไดออกไซด์สูงถึงร้อยละ 83.45 ทั้งนี้ อิฐมวลเบาที่ผลิตจากเถ้าแกลบในอัตราส่วนร้อยละ 25–30 โดยน้ำหนักผสมกับปูนซีเมนต์ มีค่าความหนาแน่นอยู่ในช่วง 979–1,000 กิโลกรัมต่อลูกบาศก์เมตร และมีค่าความต้านทานแรงอัด 48.5–58.3 กิโลกรัมต่อตารางเซนติเมตร แสดงให้เห็นว่าอิฐมวลเบาที่ผลิตได้มีน้ำหนักเบาและมีสมบัติเชิงกลอยู่ในเกณฑ์ที่ยอมรับได้สำหรับวัสดุก่อสร้างประเภทอิฐมวลเบาแบบเติมฟองอากาศ (มอก. 2601-2556 ชนิด C10) ยกเว้นค่าการดูดซึมน้ำที่สูงกว่าเกณฑ์ มอก. 2601-2556 กำหนดเพียงเล็กน้อย ผลลัพธ์ดังกล่าวแสดงให้เห็นว่าอิฐมวลเบาที่ผลิตจากเถ้าแกลบผสมปูนซีเมนต์มากกว่าร้อยละ 25 โดยน้ำหนักของเถ้าแกลบมีสมบัติเชิงกลที่นำไปใช้งานได้จริง มีศักยภาพและความเป็นไปได้ในการพัฒนาและประยุกต์ใช้เป็นคอนกรีตบล็อกมวลเบาแบบเติมฟองอากาศ ชนิด C10 ได้อย่างมีประสิทธิภาพ ด้วยสารก่อฟองเพื่อปรับสมบัติการดูดซึมน้ำให้เป็นไปตามข้อกำหนดของอุตสาหกรรมก่อสร้าง นอกจากนี้งานวิจัยยังสะท้อนถึงการส่งเสริมการใช้ประโยชน์จากของเสียทางการเกษตรให้มีมูลค่าเพิ่ม พร้อมทั้งสนับสนุนแนวทางการพัฒนาอุตสาหกรรมอย่างยั่งยืน

คำสำคัญ: อิฐมวลเบา เถ้าแกลบ ปูนซีเมนต์

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Research Article

Lightweight Bricks from Rice Husk Ash Mixed with Cement: A Possibility for Use as Alternative Construction Materials

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Abstract

Thailand is an agricultural country where rice husks are widely used as biomass fuel, resulting in a large quantity of rice husk ash as a byproduct. Therefore, this research proposes the production of novel lightweight bricks using rice husk ash obtained from brick firing at factories in Phra Nakhon Si Ayutthaya Province, mixed with cement, to evaluate its feasibility as an alternative construction material. For the experiment, the morphology and composition of rice husk ash were analyzed by SEM-EDS. The physical and mechanical properties of the bricks produced from rice husk ash (5–30% by weight) mixed with cement, including density, water absorption, and compressive strength, were then tested according to TIS 2601-2556 (Cellular lightweight concrete blocks using preformed foam). From the results, it was found that the rice husk ash after sieving for particle size reduction has a polygonal shape, an average particle size of 14.66 µm, and a high silicon dioxide (SiO_2) content of 83.45%. The lightweight bricks produced from rice husk ash mixed with cement at 25–30% by weight have a density in the range of 979–1,000 kg/m^3, and a compressive strength of 48.5–58.3 kg/cm^2. This indicates that the bricks are lightweight and have acceptable mechanical properties for aerated lightweight concrete block materials (TIS 2601-2556, C10), except for water absorption, which slightly exceeds the limit specified in the TIS 2601-2556 standard. These results show that lightweight bricks produced from rice husk ash mixed with cement containing more than 25% by weight of rice husk ash have adequate mechanical properties and the potential to be effectively developed and applied as aerated lightweight concrete blocks (C10 standard), with the addition of a foaming agent to adjust water absorption properties to meet the requirements of the construction industry. In addition, this research promotes the utilization of agricultural waste for value addition and supports the development of sustainable practices in the industry.

Keywords: Lightweight Brick, Rice Husk Ash, Cement

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1. Introduction

In Thailand, the agricultural sector grows paddy for domestic consumption and export in the amount of more than 24.0 million tons per year [1], generating approximately 8 million tons of rice husk per year [1]. The rice husk can also be used as raw material for energy production by pyrolysis [2]. However, Rice Husk Ash (RHA) after burning is a large quantity of low-value agricultural waste that needs to be disposed of without proper management [2], [3]. Therefore, research on recycling rice husk ash for further use is an important approach for the management system of the agricultural industry. Agricultural ash after the burning process is a solid residue consisting of silicon dioxide (SiO_2), also known as silica, with approximately >60% [4]. Silica has many important properties, such as chemical resistance, thermal stability, hardness, and insulation. These properties make it useful in various applications, especially construction [5].

From the literature review, it was found that waste materials containing silica act as pozzolans that enhance the strength properties of concrete and cement; therefore, they can be further utilized in the production of materials for building and construction [6], [7]. Pozzolanic properties measure the extent to which chemical reactions occur between the key components of pozzolanic materials, calcium hydroxide and water. This property is important because it indicates their ability to contribute to reactions leading to strength development in concrete [8]. Zain *et al.* [9] and Antiohos *et al.* [10] demonstrated that rice husk ash exhibits high pozzolanic activity due to its amorphous silica, fineness, and high specific surface area. However, rice husk ash with a high carbon content was found to have low pozzolanic activity [11].

Several investigators have reported on the production of concrete from agricultural ash and industrial waste for use as alternative materials in the construction field [12]–[14]. For example, concrete mixed with fly ash has been used to produce non-load-bearing concrete, and geopolymers mixed with bagasse ash and aluminum waste have been developed to produce lightweight concrete blocks [15], [16]. The use of ash as a partial replacement for cement in an appropriate proportion can result in adequate compressive strength [16].

Several researchers [17]–[19] have investigated the hydration mechanisms of cement blended with rice husk ash. The general conclusion is that rice husk ash with a high SiO_2 content reacts with $Ca(OH)_2$ to form Calcium Silicate Hydrate (CSH) gel. Since the pozzolanic reaction consumes calcium hydroxide, cement paste containing rice husk ash exhibits a lower $Ca(OH)_2$ content compared to pure Portland cement paste. However, there are conflicting conclusions regarding the effect of rice husk ash on the early rate of hydration. The investigation conducted by Feng *et al.* [18] showed that the addition of rice husk ash stimulates the early hydration of cement, resulting in increased heat generation and a higher amount of CH contents in the rice husk ash–blended cement paste. However, Nguyen *et al.* [20] argued that the incorporation of rice husk ash slows down the initial hydration of cement. The discrepancy between these results may be attributed to the use of different water-to-binder (w/b) ratios, as this ratio can influence the early hydration rate of paste containing rice husk ash. In addition, it has been found that rice husk ash exhibits both hydraulic and pozzolanic properties; therefore, its reaction with water can also lead to the formation of CSH [21]. The optimal level of cement replacement with rice husk ash depends on several factors, including the desired concrete properties, project requirements, and relevant standards. Generally, the level of rice husk ash replacement is between 10–30% by weight of cement [22]–[24]. However, researchers have studied higher levels of replacement to assess their impact on concrete performance [25], [26]. Thorough testing and evaluation are essential in determining the optimal level of replacement for specific applications.

Lightweight concrete bricks are popular construction materials because they have many advantageous properties such as low density, thermal resistance, and sound insulation [27], [28]. They also have lower production and transportation costs compared to commercial lightweight concrete [28], [29]. Based on the chemical composition of commercial concrete, it was found that the main component is silica [30], which facilitates compatibility with rice-husk ash. Therefore, it is possible to develop lightweight bricks mixed with rice-husk ash, which helps reduce environmental pollution and manage agricultural waste to be beneficial according to the principles of sustainable development of the sufficiency economy [31].

For the above reason, this research investigated the properties of lightweight bricks made from rice husk ash as the main ingredient, mixed with cement as a binder. The focus was on differentiating this research from previous studies by using rice husk ash, a waste product from burning rice husks as fuel in community brick factories, as the primary ingredient, and cement as a binder and reinforcing material at a ratio of 5–30% by weight of rice husk ash. The study examined the effect of this on the physical and mechanical properties of the resulting lightweight bricks, which meet the standards of TIS 2601-2556 (Cellular lightweight concrete blocks using preformed foam) [32]. This refers to concrete blocks that are lighter than blocks of the same size, with small air bubbles evenly distributed throughout the concrete matrix. These air bubbles are generated using a foaming agent. Furthermore, the study proposed optimal mix ratios that achieve properties conforming to TIS 2601-2556, providing guidelines for their application as an alternative material in the construction industry.

2. Materials and Methods

2.1 Materials and Instruments

Rice husk ash was obtained as a byproduct of biomass energy production in a brick kiln (high-temperature furnace for firing clay bricks) in Phra Nakhon Si Ayutthaya province. Rice husk was used as fuel for firing bricks at temperatures of approximately 800–900 °C for about 7 days per firing cycle in an open firing process. The resulting ash was a fine, dark gray powder. The particle of rice-husk ash was ground using the Los Angeles Abrasion (Matest, A075N) and particle size was controlled by sieving at 100 μm. Although the variations in the elements of the rice husk ash were not significant [33], the morphology and composition were dependent on the temperature and burning time. Therefore, the actual size and elemental composition of the

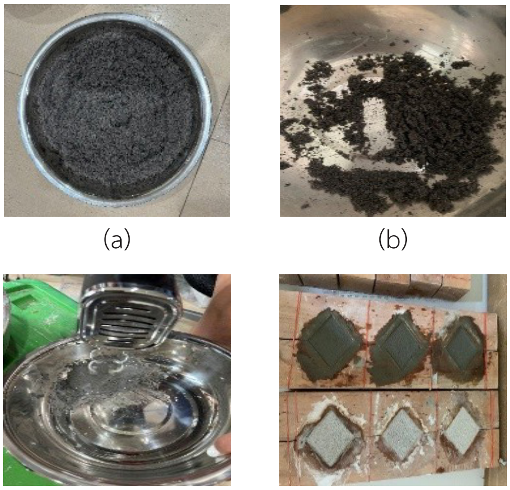

(a) (b)
(c) (d)

Figure 1 Steps of lightweight concrete preparation: (a) rice husk ash after sieving, (b) cement mixing, (c) stirring, and (d) molding process.

obtained rice husk ash were analyzed by the scanning electron microscope with energy dispersive X-ray (SEM–EDS, Hitachi, TM 4000 plusII).

An Ordinary Portland Cement (OPC) type 1 was complied with TIS 15-2562 for construction. The 2-decimal digital balance (Abam, NBL-4602) was used to weigh the raw materials and the obtained specimens. The specimens were dried in an oven (Memmert, UF 110). The dimensions of the specimens were measured using a vernier caliper (Mitutoyo, CD-6 CSX). The compressive strength of the specimen was tested using a universal testing machine (Humboldt, MH-4156).

2.2 Preparation of Lightweight Concrete Bricks

The rice-husk ash was sieved to control the particle size up to 100 µm and mixed with the cement and water (Figure 1 (a)–(c)) in the specified proportions as shown in Table 1. The water-cement ratio was maintained at 0.55, while the rice husk ash–cement ratios were set at 20.0, 10.0, 6.7, 5.0, 4.0, and 3.3, respectively. The pre-mixtures from all 7 formulas contained rice-husk ash mixed with cement in different amounts, namely AC0, AC5, AC10, AC15, AC20, AC25 AC30, respectively.

After that, the pre-mixed specimens were stirred to combine until they formed a viscous substance, and then poured into a mold with a size of $5.0 \times 5.0 \times 5.0$ cm^3 as shown in Figure 1 (d). All specimens were dried in the mold for 24 h, then the mold was removed, and the specimens were cured for 28 days, respectively.

Table 1 Composition of raw materials

Specimens	Weight (g)			Rice husk ash : Cement
	Rice husk ash : Water	Cement : Water	Total Water	
AC0	200 : 200	0	200.0	-
AC5	200 : 200	10 : 5.5	205.5	20.0
AC10	200 : 200	20 : 11.0	211.0	10.0
AC15	200 : 200	30 : 16.5	216.5	6.7
AC20	200 : 200	40 : 22.0	222.0	5.0
AC25	200 : 200	50 : 27.5	227.5	4.0
AC30	200 : 200	60 : 33.0	233.0	3.3

2.3 Physical and Mechanical Properties

The obtained lightweight bricks were tested for the physical properties, including density and water absorption, according to TIS 2601-2556 (Cellular lightweight concrete blocks using preformed foam) [32], and further tested for the mechanical property by the UTM to analyze the compression strength. The test is repeated on 3 specimens to average the testing results.

2.3.1 Density and Water Absorption

After curing for 28 days, the obtained lightweight concrete bricks were re-dried at 100 °C for 24 h and then cooled in an oven to room temperature. The specimen was weighed (M_D) with a balance and its dimensions measured with a Vernier caliper (Figure 2 (a)) to calculate its volume (V). After that, the density (D) was calculated as in Equation (1).

For testing the water absorption (W_A), the dried specimens were weighed and immersed in water for 24 h. The mass of specimens after water immersion was measured within 3 min. The water absorption was calculated from the mass of dried (M_D) and wet specimens (M_w) as Equation (2).

$$D = \frac{M_D}{V} \tag{1}$$

$$W_A = \frac{M_W - M_D}{M_D} \times 100 \tag{2}$$

2.3.2 Compressive Test

Lightweight brick specimens were tested for compression using the UTM machine (Figure 2 (b)), according to ASTM C109 [34]. In the testing procedure, the load was applied at a constant rate until the specimens failed and could not withstand the compressive force. The compressive strength (CS) was then calculated from compressive force (F) and specimen area (A) as in Equation (3).

$$CS = F/A \tag{3}$$

2.3.3 Sound Velocity

The measurement of sound velocity according to ASTM C597 [35] using a 54 kHz high-frequency pulsed instrument was a non-destructive testing method for determining the quality and integrity of concrete. Ultrasonic waves are transmitted through a 54 kHz transmitter, and the time it takes for the waves to travel through the concrete between the transmitter and receiver is measured. This time is then used to calculate the wave velocity, allowing for the determination of concrete quality.

(a) (b)

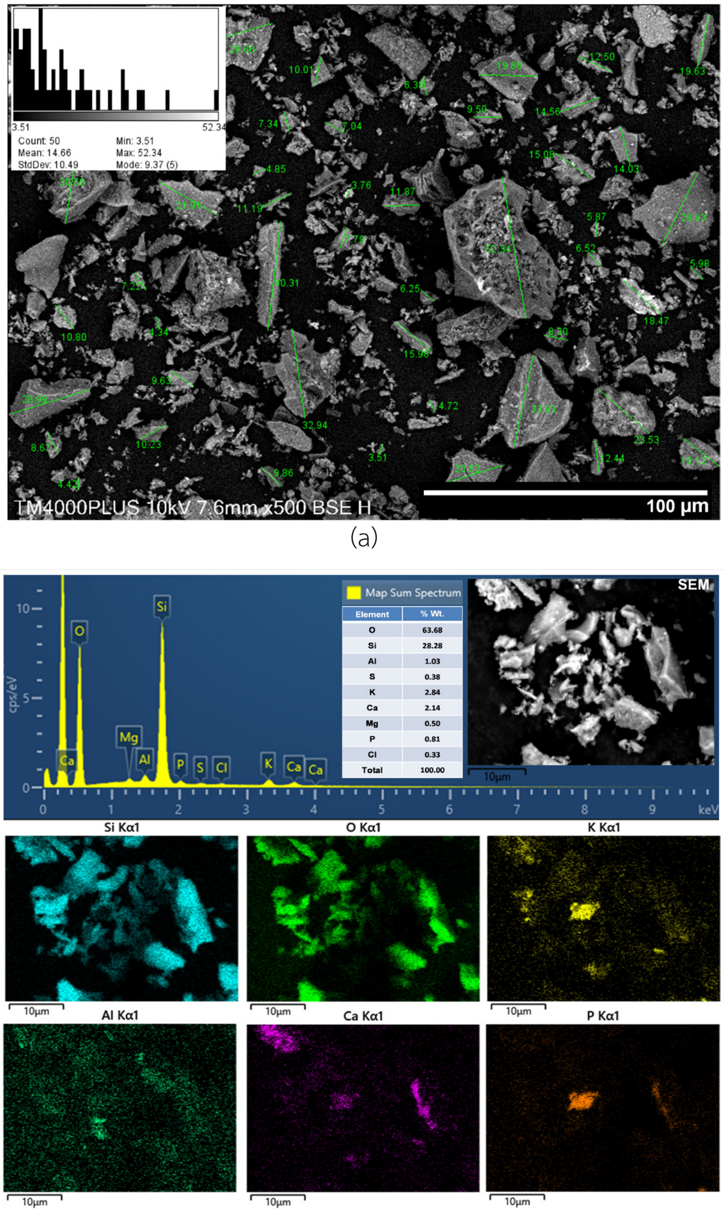
Figure 2 (a) Dimensional measurement and (b) compressive testing of the brick.

3. Results and Discussions

3.1 Characterization of Rice Husk Ash

The morphology and elemental composition of rice husk ash after sieving were analyzed by SEM-EDS as shown in Figure 3. The observed particles were found to have a small polygonal structure (Figure 3 (a)) with an average particle size of 14.66 µm (n = 50, SD = 10.48, mode = 9.37, min-max = 3.51–52.34 µm), which resulted from the size reduction by the sieving process.

From SEM-EDS mapping (Figure 3 (b)), it was found that the primary elements of the rice husk ash were oxygen (O, 63.68 wt.%) and silicon (Si, 28.28 wt.%) along with others elements. This result indicated that the main component of rice husk ash was silicon oxide, likely in the form of SiO_2. In addition, other elements could form common oxides such as SiO_2, Al_2O_3, CaO, and K_2O. Based on possible structure, the percentages of normalized oxide



Element	% Wt.
O	63.68
Si	28.28
Al	1.03
S	0.38
K	2.84
Ca	2.14
Mg	0.50
P	0.81
Cl	0.33
Total	100.00

(a)

(b)

Figure 3 Characterization of rice husk ash by (a) SEM and (b) SEM-EDS mapping technique.

could calculate as Equation (4) and (5). Where the MW and the AW represented molecular weight and atomic weight, respectively, while normalized oxide referred to adjust the total content of metal oxide (72.49 wt.%) to 100%, as oxygen and non-oxidizing elements are not included calculations.

$$\%\,Oxide = Element_{wt\%} \times (MW_{oxide} / AW_{element}) \quad (4)$$

$$\%\,Normalized\ oxide = Oxide_{wt} / Total\ Oxide \quad (5)$$

Table 2 Composition of rice husk ash

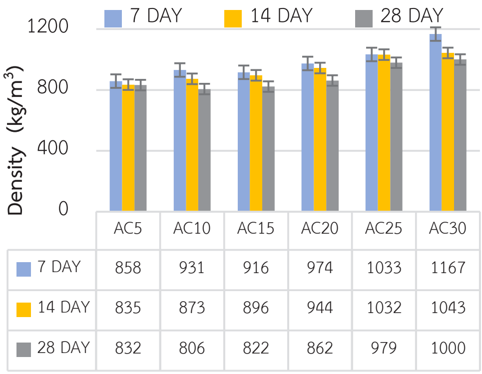
Element	wt.%	Oxide	Ratio of MW / AW	% Normalized Oxide
Si	28.28	SiO_2	2.139	83.45
Al	1.03	Al_2O_3	1.889	2.69
Ca	2.14	CaO	1.399	4.13
Mg	0.5	MgO	1.659	1.14
K	2.84	K_2O	1.204	4.72
P	0.81	P_2O_5	2.291	2.57
S	0.38	SO_3	2.497	1.31
Total	-	-	-	100

The calculated result was summarized in Table 2. It was found that the normalized SiO_2 content was as high as 83.45 wt.%, indicating a silica-rich material that was suitable for producing concrete brick and using in various applications.

3.2 Preparation and Testing of Lightweights Concrete Bricks

From the preparation of bricks obtained from rice husk ash mixed with cement at 0, 5, 10, 15, 20, 25, and 30% by weight of rice husk ash, it was found that the AC0 specimens were fractured and could not be formed. All specimens (AC5 – AC30) exhibited similar external characteristics, such as a cubic shape (size 5 × 5 × 5 cm^3), light gray color, smooth surfaces, and small pores. This result indicated that cement acted as a binder of rice-husk ash, and the proportion of rice-husk ash mixed with cement in the aforementioned range did not affect the appearance of the bricks, as shown in Figure 4.

Figure 4 The obtained bricks from rice-husk ash mixed with cement.



	AC5	AC10	AC15	AC20	AC25	AC30
7 DAY	858	931	916	974	1033	1167
14 DAY	835	873	896	944	1032	1043
28 DAY	832	806	822	862	979	1000

Figure 5 Density of obtained bricks from rice-husk ash mixed with cement.

3.2.1 Density Test

The density of bricks made from rice-husk ash mixed with cement was shown in Figure 5. It was found that the density of the bricks tended to increase (832–1000 kg/m^3) with the increasing amount of cement (5–30%). This could be explained by the cement being inserted into the spaces between the rice husk ash and causing the shrinkage of the bricks to increase, resulting in an increase in mass per volume. Therefore, when more cement was used, the volume decreased and the density increased. This result was consistent with the findings reported by Rokiah Othman *et al.* [36]. In addition, it could be seen that as time increased, the bricks underwent a significant hydration reaction, but it misstates the outcome: hydration added water to form new, denser compounds (like CSH gel) that increase strength, while leaching or dehydration issues could cause water loss, leading to increased porosity and reduced density/strength. Proper hydration increased strength and density over time, but improper conditions could reverse some benefits [37].

From the testing results, it was found that all of the brick specimens produced from rice husk ash mixed with cement had the density consistent with the density of lightweight bricks of C9 and C10 according to the TIS 2601 standard, which specifies an average density of 801–900 and 901–1000 kg/m^3, respectively. Therefore, it was concluded that rice husk ash mixed with cement could be developed into lightweight bricks.

3.2.2 Water absorption test

Figure 6 presents the water absorption of lightweight bricks. It was found that the water absorption tended to increase with increasing amounts of cement mixed with rice husk ash from 5, 10, and 15%, respectively. The water absorption of lightweight bricks decreased slightly and became stable with the addition of 20–30% cement. It could explain that the addition of cement, 5–15% resulted in an increase in the pore structure of lightweight bricks, causing them to adsorb more water. In the case of mixing cement with 20–30% by weight of rice husk ash, the addition of cement enhanced the hydration and pozzolanic reactions with rice husk ash, resulting in a closed pore structure with reduced pore size, thereby decreasing water absorption capacity and stabilization, respectively. This is consistent with the research findings of Barbhuiya *et al.* [38] which showed that adding cement to rice husk ash enhanced the hydration and pozzolanic reactions, resulting in denser concrete, less porosity, reduced water absorption, and increased durability (stability). This was achieved through the formation of more CSH gel, filling voids, and improving the porous structure. This combination results in a finer and more tightly closed porous system, effectively reducing permeability and improving the overall performance of the concrete.

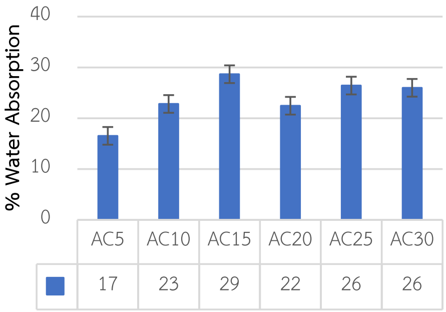
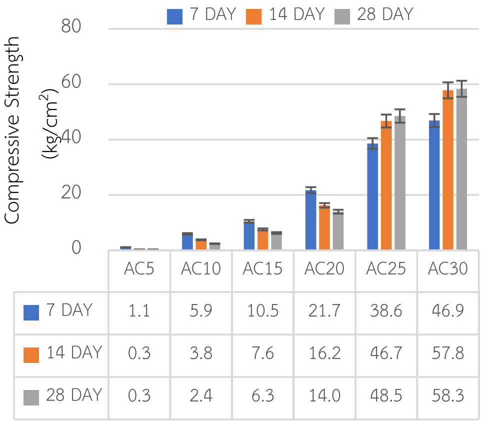


Figure 6 Water absorption of obtained bricks from rice husk ash mixed with cement.

The results showed that the AC5, AC10, and AC20 specimens had water absorption that met the TIS 2601-2556 criteria for C9, C10, and C12 lightweight bricks, which specified maximum water absorption of 23%. However, the AC15, AC25, and AC30 specimens did not comply with the TIS 2601-2556. The AC25 and AC30 specimens exhibited water absorption values slightly higher than the criteria of TIS 2601-2556, which was due to differences in production methods and the water adsorption capacity of the rice husk ash. Rice husk ash had high water solubility, especially if the silica within it was in an amorphous form, which was achieved with specific burning (Calcination) temperatures and durations,



	AC5	AC10	AC15	AC20	AC25	AC30
🟦 7 DAY	1.1	5.9	10.5	21.7	38.6	46.9
🟧 14 DAY	0.3	3.8	7.6	16.2	46.7	57.8
⬜ 28 DAY	0.3	2.4	6.3	14.0	48.5	58.3

Figure 7 Compressive strength of bricks produced from rice husk ash mixed cement.

making it useful as a pozzolan in concrete, though its high silica content also made it less soluble in pure water than other biomass ashes. The solubility was highly dependent on processing, with high temperatures and short times often yielding more soluble (Amorphous) silica, while very high temperatures could lead to less soluble, crystalline silica [39].

3.2.3 Compressive strength

Figure 7 shows the compression strength of lightweight bricks developed from rice husk ash mixed with cement. It was found that the compressive strength of lightweight bricks tended to increase depending on the amount of cement mixed with rice husk ash. The specimens with higher compressive strength (≥25.5 kg/cm^2) must contain more than 25% cement. It could be explained that the cement had a high compressive strength, which allowed it to withstand compressive load. In addition, the amount of cement could reduce the pore between the rice-husk ash in the lightweight brick, resulting in a dense structure (related to the density result), resulting in a high area to withstand compressive stress [38].

From the testing results, it was found that the compressive strength of AC5, AC10, AC15, and AC20 tended to decrease as the curing time increased. This indicated that the cement content (5–20%) was insufficient for the hydration and pozzolanic reactions, resulting in a weak structure with compressive strength lower than the requirement specified in TIS 2601-2556 (25.5 kg/cm^2). Furthermore, the unreacted rice husk ash exhibited unbalanced expansion and contraction during the curing reaction, creating more voids and further reducing strength. In the case of 25% and 30% cement, the strength was found to be increased due to a suitable balance of cement and rice husk ash for hydration and pozzolanic reactions, resulting in a dense structure and high strength with curing time [38]. The AC25 and AC30 specimens from rice husk ash mixed with 25–30% cement at a curing time of 28 days had the highest compressive strength of 48.5 and 58.3 kg/cm^2, respectively.

Although the compressive strength results met the C9-C16 criteria according to TIS 2601-2556, which specifies the compressive strength of lightweight bricks C not less than 25.5 (C9, C10 and C12) – 51.0 (C14 and C16) kg/cm^2, the density properties were within the C9 (801–900 kg/m^2) and C10 (901–1,000 kg/m^2) range, and the water absorption properties did not meet the C9 requirement (not more than 23%) of TIS 2601-2556. In this case, it might be due to the direct mixing method did not use the aeration technique according to TIS 2601-2556, resulting in some properties differing from the specified criteria. Therefore, it was necessary to improve the properties with a foaming agent to meet the TIS standard.

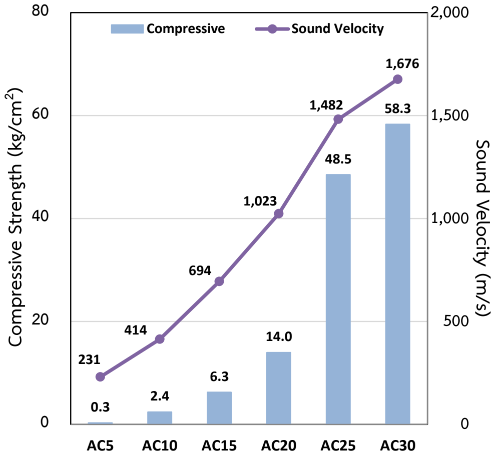


Figure 8 Comparison of sound velocity and compressive strength of lightweight bricks produced from rice husk ash mixed cement.

Figure 8 shows the comparative results of sound velocity and compressive strength of bricks from rice-husk ash mixed with cement. The result showed that the sound velocity transferring through the specimens tends to increase with increasing cement content. It was found that at a curing time of 28 days, lightweight bricks from rice-husk ash mixed with cement ratios of 5, 10, 15, 20, 25, and 30% tended to increase in sound velocity values of 230, 414, 694, 1023, 1482, and 1676 m/s, respectively. It was found that higher cement content resulted in better adhesion bonding of bricks and a finer distribution of rice-husk ash, which allowed sound waves to travel through lightweight bricks more rapidly. It was also found that the mixture with the highest cement content (AC30) exhibited the highest compressive strength, with a compressive strength value of 58.3 kg/cm^2. In addition, it was found that cement reactions were found to contribute to increased compressive strength. However, if a small amount of cement is used, a gel is formed that slows down the reaction, resulting in a lower compressive strength [38].

4. Conclusion

This research presented the lightweight brick produced from rice husk ash (average size 14.66 µm and 83.45% SiO_2) mixed with cement in proportions of 5–30% by weight of rice husk ash. The physical and mechanical properties of the brick were investigated, and the results were concluded as follows.

1) The density of all specimens (806–1000 kg/m^2) met the criteria for TIS 2601-2556 lightweight bricks (C9 and C10).

2) The water absorption values of AC25 and AC30 lightweight bricks prepared from rice husk ash mixed with cement (25-30% by weight of rice husk ash) were slightly higher than the C9-C12 standard of TIS 2601-2556 (≤23%). It was due to the reference standard that was used for preparing lightweight bricks using the aeration technique. However, the research finding indicated that this property could be further improved by adding foaming agents or designing a porous structure.

3) The compressive strength of lightweight bricks was improved with higher cement content, with the highest values achieved at 25–30% cement (48.5–58.3 kg/cm^2). Low-cement mixes (≤25%) showed strength loss over curing time due to insufficient binder and unstable pore structure, whereas mixes with ≥25% cement maintained or increased strength over time. As a result, lightweight bricks formulated with AC5-AC20 had compressive strength lower than that specified by TIS 2601-2556 (25.5 kg/cm^2). This indicated that sustainable production of

lightweight bricks from rice husk ash required more than 25% cement to achieve the necessary mechanical properties for practical use. Therefore, it was concluded that the lightweight bricks from rice husk ash mixed with cement could be used as an alternative material in construction.

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