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Research article

Product of Hollow Concrete Blocks Mixed with Rice Husk Ash and Cassava Fermentation Waste

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Abstract: This research focuses on enhancing the properties of hollow concrete blocks by incorporating rice husk ash and cassava fermentation waste. The study replaces 15% of the cement with rice husk ash from a Bag Filter source and substitutes 0.5-10% of the stone dust by weight with cassava fermentation waste from Ajinomoto (Thailand) Co., Ltd. The hollow concrete blocks were formed using a cement-to-stone dust ratio of 1:10 and a water-to-binder ratio (W/B) of 0.625, with 7 x 19 x 39 cm dimensions. The test results indicate that the density of the hollow concrete blocks decreases with the addition of rice husk ash compared to control hollow concrete blocks. However, when a small amount of cassava fermentation waste is added, the weight and density of the hollow concrete blocks increase. Additionally, the moisture content of the rice husk ash mixed blocks is lower than that of the control hollow concrete blocks. Still, it increases proportionally with the inclusion of cassava fermentation waste. Combining rice husk ash and cassava fermentation waste leads to higher water absorption values in the hollow concrete blocks. Moreover, the compressive strength of the rice husk ash mixed hollow concrete blocks is greater than that of the control hollow concrete blocks. However, the addition of cassava fermentation waste reduces compressive strength.

Keywords: Cassava Fermentation; Cassava pulp; Hollow Concrete Blocks; Rice Husk;

1. Introduction

Hollow concrete blocks, often referred to in the market as "brick blocks," come in both load-bearing and non-load-bearing varieties. They are typically hollow in appearance and are popular due to their affordability and availability. These blocks are advantageous in construction because they allow for quick work and time savings due to their large size. Commercial brick blocks are made from a mixture of Portland cement, crushed stone, sand, and water, which are pressed into block forms using a high-frequency shaker [1]. Standard sizes for hollow concrete blocks include 0.07 x 0.19 x 0.39 meters, 0.09 x 0.19 x 0.39 meters, and 0.14 x 0.19 x 0.39 meters [2]. Cement is a key component in the production of hollow concrete blocks. It is produced by burning limestone at high temperatures of about 1,500 degrees Celsius, generating significant carbon dioxide emissions. Cement production accounts for approximately 8% of global greenhouse gas emissions annually. Reducing these emissions presents a challenge, prompting a global push to develop technologies that lower carbon output. This includes reducing the use of cement, a major contributor to emissions, and substituting it with alternative materials that provide similar properties. Embracing low-carbon concrete or alternative materials to replace traditional concrete is essential for achieving net-zero carbon emissions by 2050 [3].

Rice husk ash is a byproduct of paddy milling and the combustion of rice husks for energy, producing approximately 4.6 million tons annually [4]. This low-density material offers excellent heat insulation and reduces weight while enhancing properties when incorporated into building materials. Rice husk ash is a pozzolanic material, which, when mixed with cement, can increase the compressive strength of cement or concrete by more than 10% [5]. In hollow load-bearing concrete masonry, used for constructing exterior and interior walls and various structural applications, rice husk ash is particularly beneficial. [6]. According to a study by Kinkachon et al. [7]. rice husk ash can be used as a raw material for producing lightweight bricks, with a recommended proportion of 10% by weight. Additionally, using rice husk ash in concrete mixtures at up to 25% can significantly delay the onset of reinforcement corrosion within the concrete [8].

Tapioca starch production generates byproducts such as cassava peel and cassava pulp. Cassava pulp constitutes up to 10% of the fresh cassava tubers used in production [9]. This pulp has a high moisture content of about 70-80% by weight, making it difficult to utilize and an excellent food source for microorganisms. If left untreated, it can lead to microbial degradation in the environment, causing unpleasant odors that disturb surrounding communities [10]. Research by Boontositrakul, Suweero, and Weeranukul [11] found that replacing stone dust with 3% by weight of cassava tree chips in rice husk ash hollow concrete blocks can reduce the density or weight of the blocks and improve their heat insulation properties.

This research investigates the potential of using rice husk ash, sourced from the bag filter area, as a substitute for Portland cement and cassava starch fermentation residue to replace stone dust in producing hollow concrete blocks. This approach seeks to enhance the value of these waste materials by incorporating them into construction products, thereby reducing environmental pollution and lowering the costs associated with hollow concrete block production. Additionally, this strategy aims to develop new, cost-effective construction materials that can be effectively utilized in various building projects.

2. Materials and Methods

2.1 Research materials

This research utilizes Portland cement Type 1, which meets the standards of ASTM C-150 Type 1 [12]. Stone dust is sun-dried and then sifted through a No. 4 sieve. It has a specific gravity of 2.62, consistent with the research results of [13] as shown in Figure 1. It is used as a coarse aggregate. Rice husk ash (RHA), sourced from the bag filter area of Ajinomoto (Thailand) Co., Ltd., is sieved through No. 325 according to ASTM E11 [14], with a sieve opening size of 45 micrometers. This ash has a specific gravity of 2.07, which is consistent with the research results of [15], as determined by ASTM C188 [16] tests (see Figure 2), and is used to replace Portland cement Type 1 partially. The cassava fermentation waste (CFW), also obtained from Ajinomoto (Thailand) Co., Ltd. and shown in Figure 3, is used as an aggregate to replace stone dust partially. Tap water is used to facilitate the binder's reaction.

Figure 1. Stone Dust.

Figure 2. Rice husk ash.

Figure 3. Cassava fermentation waste.

2.2 Mixture design and sample preparation

The ratio for hollow concrete blocks mixed with rice husk ash is adopted from previous studies [11], using a cement-to-stone dust ratio of 1:10. A water-to-binder ratio (W/B) of 0.625 is used to develop hollow concrete blocks mixed with rice husk ash and cassava fermentation waste. Cement is partially replaced with rice husk ash from bag filter sources, and stone dust is partially replaced with cassava fermentation waste. The main ratio selected for mixing involves replacing 15% of the cement with rice husk ash (RHA15), as this ratio yields the highest compressive strength. Cassava fermentation waste is used to replace 0.5% to 10% of the stone dust by weight (CFW05-CFW10) to compare the properties of the developed hollow concrete blocks with control hollow concrete blocks. A total of 13 mixture ratios are used for forming hollow concrete blocks, as shown in Table 1.

Table 1 Hollow concrete blocks mixture rate by weight.

Mix	**Binder**		**Aggregates**		**W/B**
	Cement	**Rice husk ash**	**Stone dust**	CFW	
Control	1.00	0.00	10.00	0.00	0.625
RHA15	0.85	0.15	10.00	0.00	0.625
CFW05	0.85	0.15	9.95	0.05	0.625
CFW1	0.85	0.15	9.90	0.10	0.625
CFW2	0.85	0.15	9.80	0.20	0.625
CFW3	0.85	0.15	9.70	0.30	0.625
CFW4	0.85	0.15	9.60	0.40	0.625

Table 1. Hollow concrete blocks mixture rate by weight. (Continue)

Mix	Binder		Aggregates		W/B
	Cement	**Rice husk ash**	**Stone dust**	CFW	
CFW5	0.85	0.15	9.50	0.50	0.625
CFW6	0.85	0.15	9.40	0.60	0.625
CFW7	0.85	0.15	9.30	0.70	0.625
CFW8	0.85	0.15	9.20	0.80	0.625
CFW9	0.85	0.15	9.10	0.90	0.625
CFW10	0.85	0.15	9.00	1.00	0.625

Hollow concrete blocks mixed with rice husk ash are formed to a size of 0.07 x 0.19 x 0.39 meters using the designed ratios and a vibrating press, as shown in Figure 4. As depicted in Figure 5, the blocks are then cured or dried in a shaded and well-ventilated area for the specified test period.

Figure 4. Vibrating hollow concrete blocks compactor.

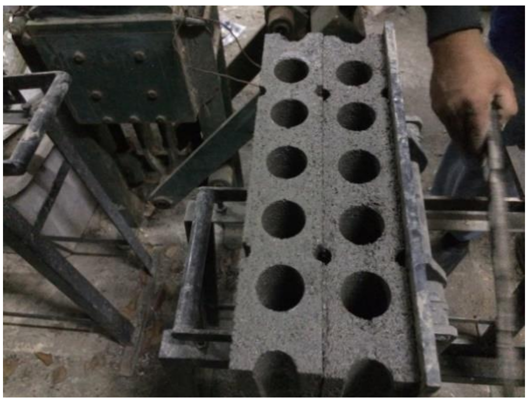

Figure 5. Hollow concrete blocks ready to be cured.

2.3 Test Method

1. The density of hollow concrete blocks is tested according to ASTM C140 standards [17] after a curing period of 28 days.

2. The moisture content and water absorption of hollow concrete blocks are tested according to ASTM C426 standards [18] after a curing period of 28 days.

3. The compressive strength of hollow concrete blocks is tested according to ASTM C140 standards [17] at the curing ages of 7, 14, 21, and 28 days, as shown in Figure 6.

Figure 6. Compressive Strength Test of Hollow concrete blocks.

4. The practical use of hollow concrete blocks is tested by constructing walls and plastering them with mortar. This process is used to evaluate the durability and characteristics of the plastered wall surface.

3. Results and Discussion

3.1 Test results of weight per lump and density of hollow concrete blocks

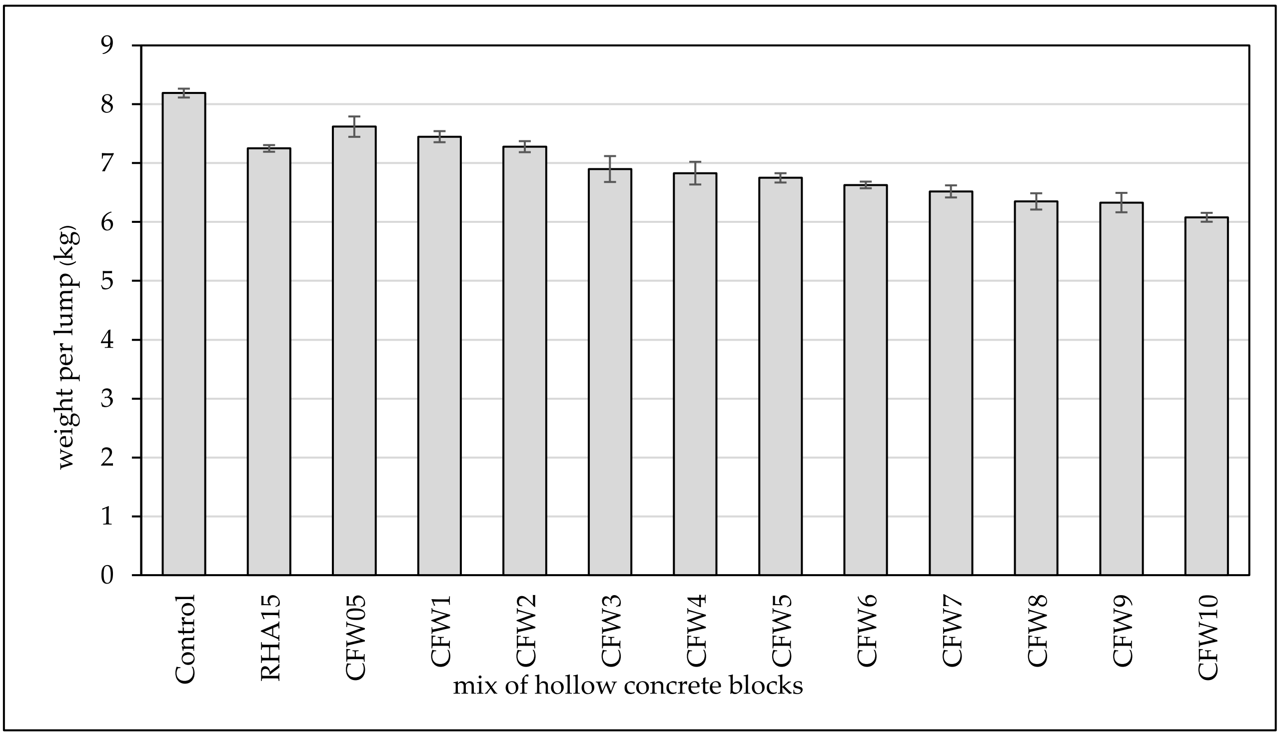

Figure 7. Weight per lump of hollow concrete blocks at the age of 28 days.

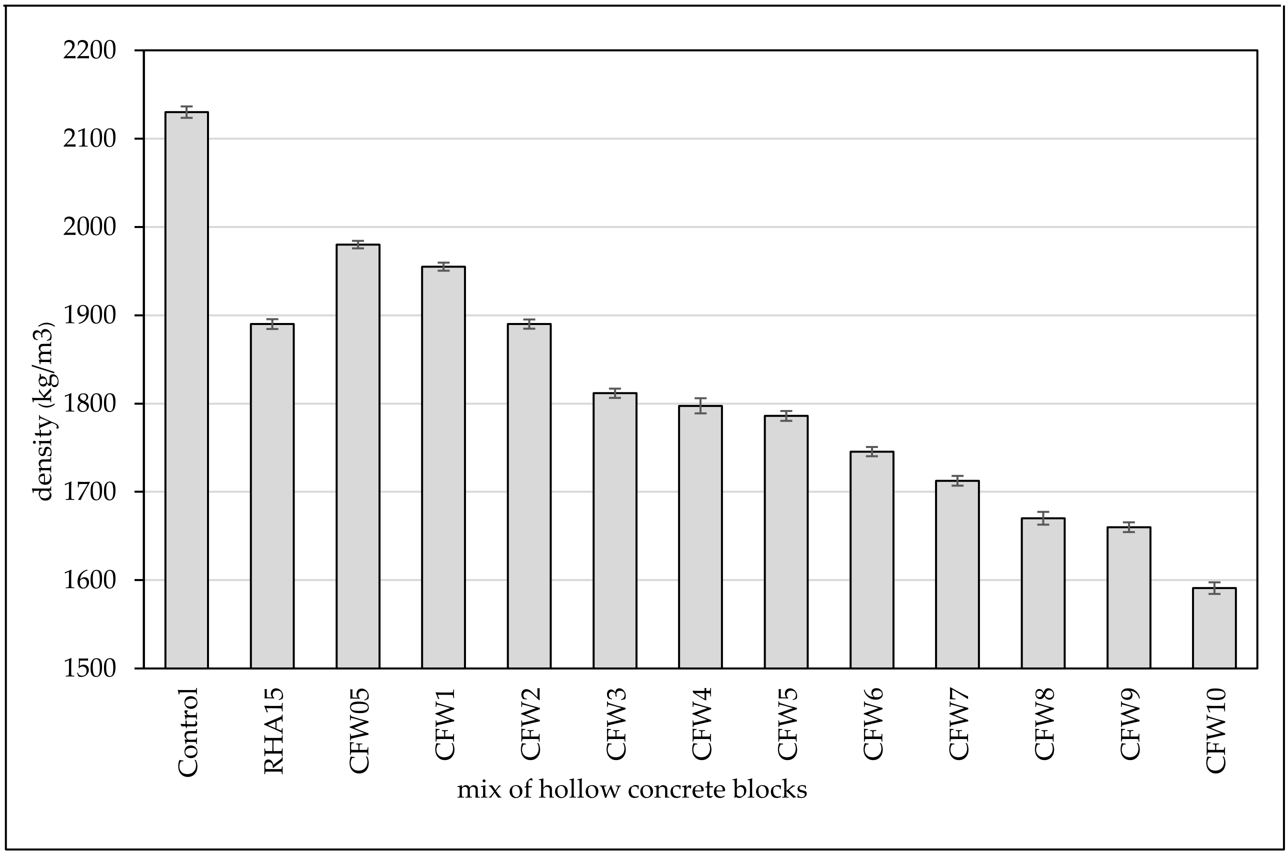

Figure 8. The density of hollow concrete blocks at the age of 28 days.

Figures 7 and 8 show that incorporating cassava fermentation waste into hollow concrete blocks mixed with fine-sized rice husk ash (from the Bag Filter source) affects both the weight and density of the blocks. The weight and density per unit increase when a small amount of cassava fermentation waste is added to the rice husk ash concrete blocks. However, when larger quantities of cassava fermentation waste are used, the weight and density decrease significantly, resulting in lower values than concrete blocks mixed only with rice husk ash.

Comparing these blocks to conventional hollow concrete blocks, rice husk ash and rice husk ash with cassava fermentation waste mixtures exhibit lower weight and density per unit. This is because conventional hollow concrete blocks typically use stone dust or limestone chips with a density of 2,611 kg/m^3 [19]. In contrast, rice husk ash has a bulk density ranging from 540–860 kg/m^3 and a compact density ranging from 1,120–1,500 kg/m^3 [5, 20]. As a result, hollow concrete blocks made with rice husk ash have lower weight and density than conventional blocks. Most conventional hollow concrete blocks and those made with rice husk ash have larger aggregate particles (larger than a No. 4 sieve), resulting in a porous texture. When cassava fermentation waste smaller than a No. 4 sieve is added in the right amount, it contributes to a denser texture, increasing the concrete block's density [21]. However, excessive cassava fermentation waste can negatively impact the blocks' binder content, alignment, and adhesion, leading to reduced weight and density. The effects of mixing new versus old tapioca starch into rice husk ash concrete blocks are similar in weight and density. According to ASTM C129 [22], the density classification of concrete blocks shows that the control concrete blocks are categorized as normal weight. Concrete blocks mixed with rice husk ash (RHA15) and those mixed with rice husk ash and cassava fermentation waste (CFW05-CFW9) are classified as medium weight. Meanwhile, concrete blocks that include 10% cassava fermentation waste (CFW10) are classified as lightweight.

3.2 Test results of moisture content and water absorption of hollow concrete blocks

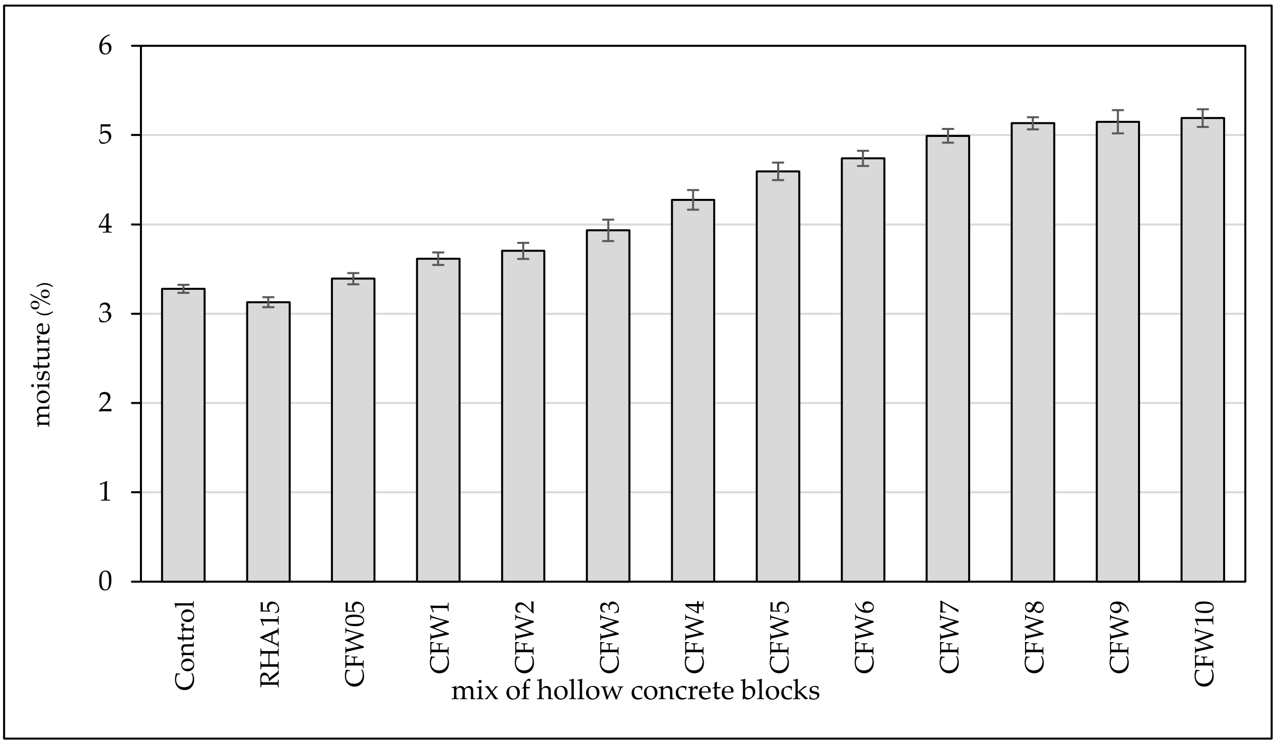

Figure 9. The moisture content of hollow concrete blocks at the age of 28 days.

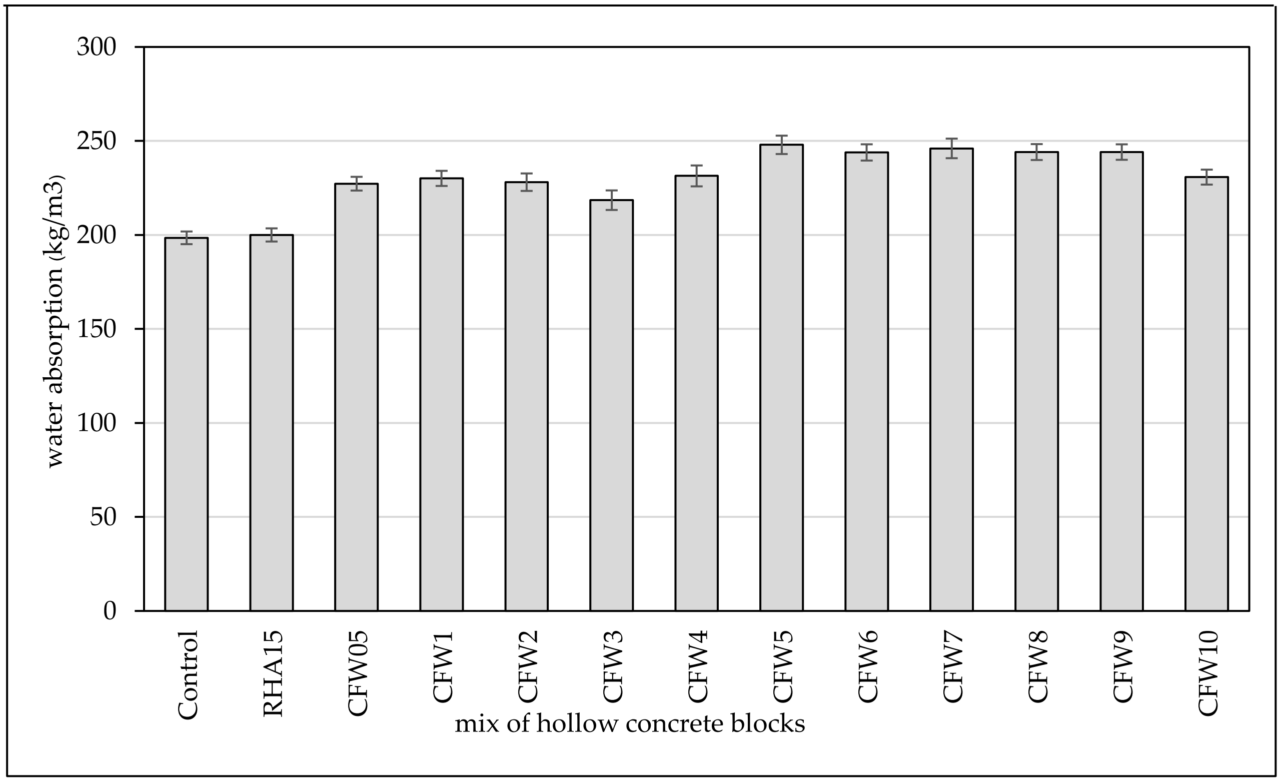

Figure 10. Water absorption of hollow concrete blocks at the age of 28 days.

Figures 9 and 10 reveal that hollow concrete blocks mixed with rice husk ash have lower moisture content but higher water absorption values than conventional hollow concrete blocks. When a small amount of cassava fermentation waste is added to these rice husk ash blocks, the moisture content increases, and water absorption decreases. However, increasing the amount of cassava fermentation waste in the hollow concrete blocks results in higher moisture content and water absorption values. This is because the texture of rice husk ash hollow concrete blocks varies with different amounts of cassava fermentation waste; dense concrete has lower water absorption, while porous concrete has higher water absorption [20]. The water absorption value is a property of hollow concrete blocks that indicates their plastering capacity. Hollow concrete blocks suitable for construction should have low water absorption to minimize cracking in plastered walls. Blocks with high water absorption can cause the mortar (cement, sand, and water) to lose moisture, leading to an incomplete hydration reaction between cement and water. This can result in small, invisible cracks that may develop into larger ones. When comparing the dry shrinkage value to the ASTM C129 [22] standard for non-load-bearing concrete blocks, it was found to meet the specification that the total linear drying shrinkage should not exceed 0.065%. According to the TIS 57-2017 [23] standard for water seepage, which varies based on the type and density of concrete blocks, it was found that the control concrete block, as well as those mixed with rice husk ash and 0.5-4% cassava fermentation waste, met the standard criteria. However, concrete blocks mixed with rice husk ash and 5-10% cassava fermentation waste did not meet the criteria.

3.3 Hollow Concrete Blocks Compressive Strength Test Results

Figure 11 shows that hollow concrete blocks mixed with rice husk ash have significantly higher compressive strength than conventional hollow concrete blocks. This increase in strength is due to the pozzolanic reaction, where the silica in the rice husk ash reacts with calcium hydroxide ($Ca(OH)_2$) produced during the hydration of cement and water [5, 24].

$$2SiO_2 + 3Ca(OH)_2 \xrightarrow{H_2O} 3CaO.2SiO_2.3H_2O \quad (1)$$

Calcium silicate hydrate ($3CaO\cdot 2SiO_2\cdot 3H_2O$ or C-S-H) is crucial for strengthening concrete [5, 24-25]. Consequently, hollow concrete blocks mixed with rice husk ash exhibit higher compressive strength than conventional blocks. The comparison results indicate that rice husk ash hollow concrete blocks (RHA15) achieve the highest compressive strength, followed by those mixed with small amounts of cassava fermentation waste (CFW05). The compressive strength gradually decreases as the amount of cassava fermentation waste increases. Previous research has shown that sugar content can slow down the setting process of concrete and reduce its compressive strength [26-29]. The equation is as follows:

$$\underset{\text{(tapioca)}}{(C_6H_{12}O_5)n} + nH_2O \xrightarrow{\text{enzyme}} \underset{\text{(sugar)}}{nC_6H_{12}O_6} \xrightarrow{\text{yeast}} \underset{\text{(ethanol)}}{2nC_2H_5OH} + 2nCO_2 \quad (2)$$

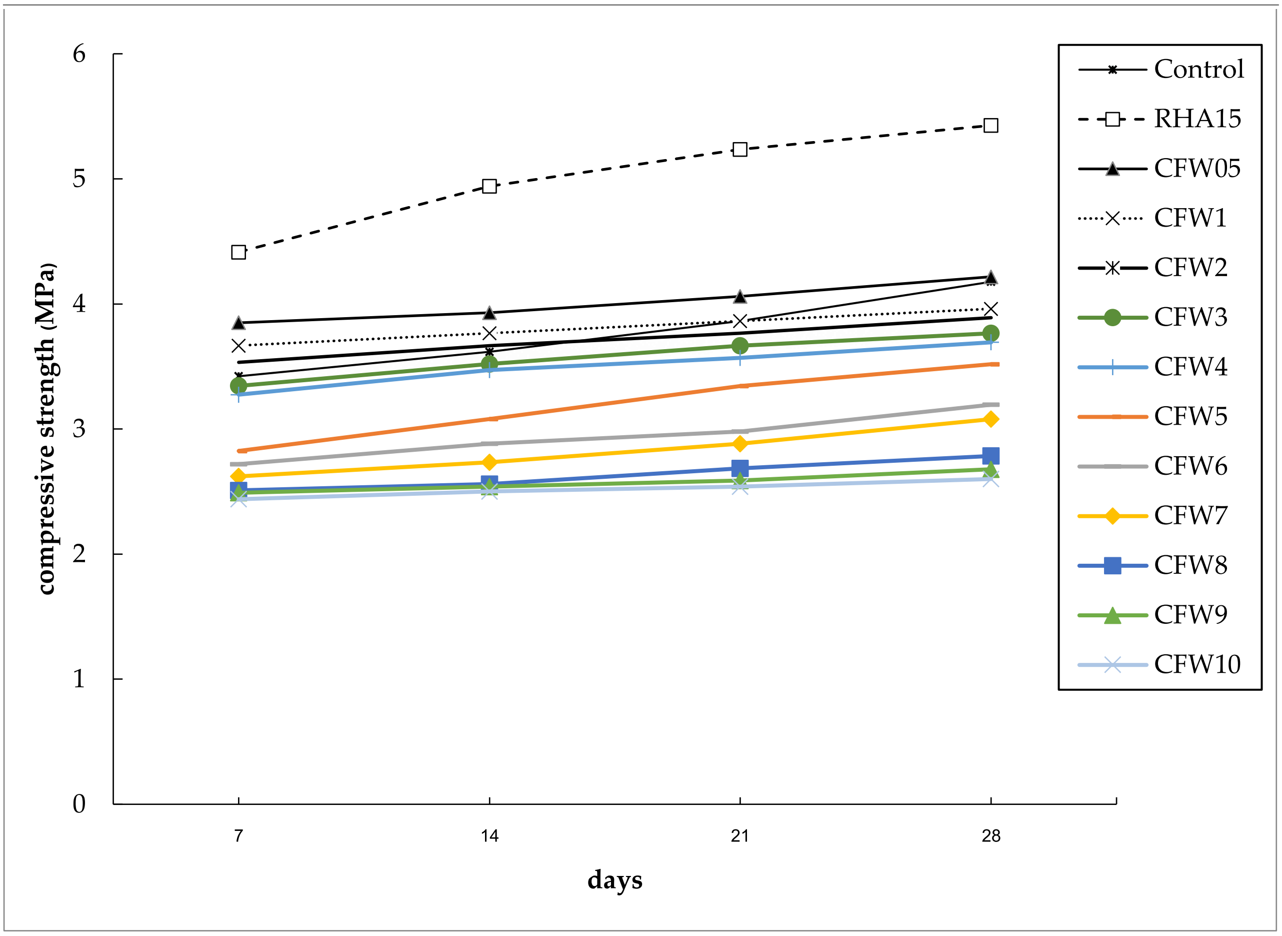

Figure 11. Compressive strength of mixed hollow concrete blocks.

A comparison of the compressive strength of hollow concrete blocks mixed with cassava fermentation waste against the ASTM C129 [22] standard for non-load-bearing concrete masonry units—which requires an average compressive strength of at least 4.14 megapascals for five blocks—revealed that only the rice husk ash hollow concrete blocks without cassava fermentation waste met this criterion. However, adding small amounts of cassava fermentation waste to hollow concrete blocks resulted in compressive strength similar to conventional blocks. Although the compressive strength of all tested hollow concrete blocks was lower than the ASTM C129 [22] requirement, these blocks can still be used in general applications. The ASTM C129 [22] standard does not mandate that all hollow concrete block products meet the criteria. Furthermore, the typical use of hollow concrete blocks in wall construction does not require them to withstand compressive loads greater than those of the walls built with them. Therefore, if rice husk ash hollow concrete blocks mixed with cassava fermentation waste are to be used, it is recommended to select blocks with a compressive strength of at least 4.14 megapascals, such as those with small amounts of cassava fermentation waste in the CFW05 ratio. ASTM C129 [22] stipulates an average compressive strength value for five blocks, with no individual block having a compressive strength lower than 3.45 megapascals [30]. This indicates the minimum compressive strength required for practical use as a building wall, ensuring that the compressive strength of all blocks is above the standard, even if the average exceeds it.

3.4 Practical Test Results of Hollow Concrete Blocks

When rice husk ash hollow concrete blocks mixed with cassava fermentation waste in the CFW05 ratio were tested for wall construction and plastered with mortar, as shown in Figures 12 and 13, it was concluded that these blocks perform similarly to ordinary hollow concrete blocks in wall construction.

Figure 12. Testing the use of hollow concrete blocks by wall formation.

Figure 13. Hollow concrete blocks walls that have already been plastered.

3.5 Cost calculation results of hollow concrete blocks

The cost of hollow concrete blocks mixed with rice husk ash and cassava fermentation waste can be determined by accounting for the costs of raw materials, labor, electricity, management, and depreciation of machinery and equipment. However, the preliminary cost calculation considers only the cost of raw materials. This calculation is based on the weight per block at 28 days of curing, with rice husk ash and cassava fermentation waste considered costless raw materials. The results of this calculation are summarized in Table 2.

From the raw material costs detailed in Table 2, it is evident that hollow concrete blocks mixed with rice husk ash and cassava fermentation waste are less expensive than conventional hollow concrete blocks, with savings ranging from $0.013 to $0.030 per block (compared to $0.085 per conventional block). Given that these blocks meet the ASTM C129 [22] standards, the CFW05 ratio, which includes the highest amount of cassava fermentation waste, offers substantial cost reductions. The raw material cost for these blocks is $0.072 per block, representing a reduction of $0.013, or 15.29%, compared to the cost of raw materials for standard hollow concrete blocks. This preliminary cost estimate is based on the weight per block and mixture ratios and may differ from actual production costs. Therefore, checking the standard prices of raw materials in different regions for more precise cost assessments is advisable.

Table 2. Cost of raw material cost of rice husk ash hollow concrete blocks mixed with cassava fermentation waste.

Mix	cost (Dollar)	Different cost (Dollar)	Different cost (%)
Control	0.085	0.00	0
RHA15	0.069	-0.016	-18.82
CFW05	0.072	-0.013	-15.29
CFW1	0.070	-0.015	-17.65
CFW2	0.068	-0.017	-20.00
CFW3	0.064	-0.021	-24.71
CFW4	0.063	-0.022	-25.88
CFW5	0.063	-0.022	-25.88
CFW6	0.061	-0.024	-28.24
CFW7	0.060	-0.025	-29.41
CFW8	0.058	-0.027	-31.76
CFW9	0.057	-0.028	-32.94
CFW10	0.055	-0.03	-35.29

Remark Cement price from building materials store, Pathum Thani
Price of stone dust from stone mill Sila Theptawan, Saraburi
Water supply price from Provincial Waterworks Authority, Pathum Thani

4. Conclusions

Developing hollow concrete blocks mixed with rice husk ash and cassava fermentation waste revealed that cassava fermentation waste is unsuitable for inclusion in hollow concrete blocks or other cement-based products. This is due to the presence of sugary residues from the enzymatic reaction of tapioca starch, which prevents the concrete from hardening and reduces its compressive strength. Among the various tested ratios, the CFW05 ratio, which includes the highest amount of cassava fermentation waste, showed potential for practical application. In this ratio, the hollow concrete blocks weighed 7.62 kilograms, with a density of 1,980 kilograms per cubic meter, a moisture content of 3.39 percent, water absorption of 227 kilograms per cubic meter, and a compressive strength of 4.20 megapascals. Although this ratio meets the ASTM C129 [22] standard for non-load-bearing concrete masonry units, it only meets individual blocks' compressive strength requirements. It does not meet the average compressive strength requirement of 4.14 megapascals for five blocks. Nonetheless, this ratio is still suitable for use in building wall construction.

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