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Research Article

House Built with Interlocking Blocks Containing Para-Wood Ash

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ABSTRACT

This research aimed to determine the optimal mixing ratio of rubberwood ash in the aggregate of masonry blocks. The most suitable ratio was selected to construct a prototype house wall using masonry blocks mixed with rubber wood ash. The cement-to-aggregate ratios tested were 1:4, 1:5, 1:6, 1:7, and 1:8 by weight. The aggregate was a mixture of laterite and heavy rubber wood ash in ratios of 100:0, 90:10, 80:20, 70:30, 60:40, and 50:50 by weight of the aggregate. The blocks were molded using a small-scale industrial press. The results were compared to the Community Product Standard 602/2547, which specifies that the compressive strength of non-load-bearing masonry blocks must be at least 25 kg/cm², while load-bearing blocks must have a compressive strength of at least 70 kg/cm² and a water absorption rate not exceeding 288 kg/m³. All ratios met the criteria for non-load-bearing blocks, while only 11 ratios met the standard for load-bearing blocks. These included a cement-to-aggregate ratio of 1:4 with aggregate mixed with 0, 10, 20, 30, 40, and 50 percent of rubberwood ash; a cement-to-aggregate ratio of 1:5 with aggregate mixed with 0, 10, 20, and 30 percent of rubberwood ash; and a cement-to-aggregate ratio of 1:6 with aggregate mixed with 0 percent of rubberwood ash. Therefore, the cement-to-aggregate ratio of 1:8 with 50% heavy rubberwood ash was the most suitable ratio for constructing a prototype house wall. The resulting blocks exhibited a maximum heat resistance of 2.0 degrees Celsius, were 60% cheaper than commercial products, did not develop mold or mildew, and had no odor of rubberwood ash. The masonry blocks mixed with rubberwood ash could be successfully used to construct residential walls and were deemed a practical building material. This innovative building material offers a cost-effective solution and effectively converts industrial waste into a valuable product.

1. Introduction

Thailand currently ranks second globally in rubber plantation area, following Indonesia. In 2022, the country had approximately 24.23 million rai of rubber plantations, producing around 4.78 million metric tons of rubber. The northeastern and southern regions exhibited the highest rubber yield per tapped area. Once rubber trees become unproductive, farmers often resort to felling them for furniture manufacturing or as biomass fuel for electricity generation. The production of 22 megawatts of electricity requires approximately 750 metric tons of rubber wood chips, which are burned at a temperature of around 1,000 degrees Celsius. This combustion process results in approximately 15 metric tons of rubber wood ash (Dasaesamoh *et al.*, 2011). This results in a significant amount of rubber wood ash as a byproduct of the production process, posing a significant disposal challenge and requiring considerable storage space. A particleboard manufacturer in Hat Yai district, Songkhla province, is one such company facing this issue. The company generates over 10 metric tons of rubber wood ash per month. While the chemical contaminants in the ash fall within the permissible limits set by the Pollution Control Department, the predominant chemical composition is calcium oxide (CaO), accounting for 41.19%. This directly influences the compressive strength of the ash. Other components include silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), and iron oxide (Fe_2O_3), at 2.57%, 0.53%, and 0.56%, respectively (Hawa and

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Tonnayopas, 2008). When rubber wood ash is mixed with cement and water, a pozzolanic reaction occurs, enhancing the bonding properties and resulting in increased strength of the concrete block.

The utilization of recycled materials in interlocking concrete block production has been extensively studied by researchers from multiple countries. Researchers from Anna University, India, and Covenant University, Nigeria, developed an optimal mix design for interlocking blocks using fly ash and GGBS by applying an ANN model with the Levenberg-Marquardt algorithm in MATLAB to analyze data from 2,600 samples. Their study achieved 98% prediction accuracy, and the optimal mix composition resulted in 50% cost reduction with 10-fold faster construction speed (Krishna Prakash *et al*., 2021). Taking a different approach, researchers from Universitas Sumatera Utara investigated wood sawdust ash (WSA) as an eco-friendly additive in interlocking brick production by manufacturing 25×12.5×10 cm bricks with WSA replacement ratios of 0-10% and conducting comprehensive testing across multiple properties. Their results showed 20% weight reduction and enhanced sound insulation of 34.6 dB, though compressive strength decreased significantly from 13.54 to 0.81 MPa (Karolina *et al*., 2024). Meanwhile, Vietnamese researchers studied the use of municipal solid waste incineration fly ash (IFA) to replace 0-60% of cement in interlocking concrete bricks using the Densified Mixture Design Algorithm and 56-day testing protocols. Their findings demonstrated that all formulations met Vietnamese construction standards and were environmentally safe, despite compressive strength reduction from 45.04 to 28.01 MPa (Nguyen and Huynh, 2022). Finally, Ghanaian researchers tested burnt sawdust ash (BSDA) from seven timber species as partial cement replacement in laterite interlocking blocks by producing 396 blocks with 0-30% BSDA replacement and conducting 28-day testing according to British Standards. They found that 10% replacement level was optimal, with Wawa, Odum, and Mansonia species performing best (Assiamah *et al*., 2025). These research studies demonstrate the high potential of using recycled materials in interlocking concrete blocks for sustainable construction, though careful consideration must be given to the trade-offs between special properties and material strength.

Nonetheless, rubber wood ash can be incorporated as an aggregate in the production of non-loadbearing concrete blocks. Previous studies have shown that rubber wood ash can be mixed into concrete blocks at a cement-to-aggregate ratio of 1:6 and 1:8. Moreover, the optimal ratio of laterite to rubber wood ash in the aggregate mixture, based on previous research, is 50:50 or 75:25, which meets the Community Product Standards for Interlocking Blocks for non-loadbearing concrete blocks (Kuasakul *et al*., 2017). However, this research focused on load-bearing concrete blocks, using cement-to-aggregate ratios of 1:4, 1:5, 1:6, 1:7, and 1:8 by weight. The aggregate mixture consisted of various proportions of laterite to rubber wood ash, ranging from 100:0, 90:10, 80:20, 70:30, 60:40, and 50:50 by weight, with the aim of maximizing the amount of rubber wood ash in the aggregate while still meeting the Community Product Standards for Interlocking Blocks (Association of Block Manufacturers of Thailand, 2004), which stipulate a minimum compressive strength of 70 kg/cm^2 for load-bearing concrete blocks and 25 kg/cm^2 for non-loadbearing blocks, as well as a maximum water absorption of 288 kg/m^3 for load-bearing blocks. The optimal ratio will be determined through experimentation by constructing a 3x4 meter prototype wall using the rubber wood ash-concrete blocks. This research may lead to the development of a new type of concrete block with a distinctive and aesthetically pleasing appearance compared to conventional concrete blocks available on the market.

2. Materials and Methods

2.1 Materials for interlocking block production

The primary constituents of the concrete blocks used in this study were a cement binder, and an aggregate mixture comprising of laterite and rubber wood fly ash. These three materials share similar chemical compositions, particularly the cement and rubber wood fly ash. The incorporation of rubber wood fly ash into the aggregate mixture served to introduce a pozzolanic material, which potentially enhanced the strength and durability of the concrete blocks. The materials used in this study are illustrated in Figure 1.

Figure 1 Materials used in research.

The objective of this study is to examine the fundamental properties of lateritic soil and rubber wood ash. To achieve this goal, several tests will be carried out, including particle size distribution analysis of Soil as per ASTM D 422-63 (ASTM, 2002a), specific gravity determination of Soil as per ASTM D 143-94 (ASTM, 1994), modified Proctor compaction as per ASTM D 1557-02 (ASTM, 2002b), and liquid limit determination as per ASTM D 2216-98 (ASTM, 1998). These tests will provide valuable insights into the engineering characteristics of the materials, which are essential for subsequent analysis and design.

The results of the sieve analysis showed that 90.76% of laterite and 93.23% of rubber wood fly ash passed through a No. 4 sieve, while 28.37% of laterite and 4.25% of rubber wood fly ash passed through a No. 200 sieve. The specific gravity of laterite and rubber wood fly ash was determined to be 2.62 and 2.25, respectively. The maximum dry density of laterite and rubber wood fly ash obtained from the standard Proctor test was 1.80 g/cm³ and 1.62 g/cm³, respectively, at optimum moisture contents of 10.60% and 7.60%, respectively. The liquid limit, plastic limit, and plasticity index of laterite were found to be 28.15%, 22.91%, and 5.24%, respectively. However, the liquid limit test could not be performed on rubber wood fly ash due to its non-plastic nature. The results of this study are generally consistent with previous research on the properties of laterite and rubber wood fly ash. The high percentage of fines in rubber wood fly ash may contribute to its pozzolanic properties and improve the long-term performance of concrete (Kuasakul *et al*., 2017). The results of the tests revealed significant variations in the properties of the materials. The particle size distribution showed a maximum difference of 37.65% between samples. The specific gravity of the laterite and rubber wood fly ash varied by a maximum of 4.44%. The standard Proctor test results indicated a maximum difference of 14.89% in dry density and 83.55% in optimum moisture content. The liquid limit test results for laterite showed a maximum variation of 155.61%. This significant variation is likely due to the different sources of laterite, indicating that the engineering properties of laterite can vary considerably depending on its origin.

2.2 Mix design for interlocking blocks

To investigate the optimal mix design, various cement-to-aggregate ratios 1:4, 1:5, 1:6, 1:7, and 1:8 by weight were tested. The aggregate consisted of varying proportions of laterite to rubber wood ash 100:0, 90:10, 80:20, 70:30, 60:40, and 50:50 by weight. Five specimens were prepared for each mix ratio, and compressive strength and water absorption tests were conducted at 7, 14, and 28 days of curing, following standard engineering practices. A total of 600 specimens were required for this study. To ensure accurate identification and prevent sample mix-ups, a labeling system was developed as follows

$$A - B – C \tag{1}$$

A : Cement-to-aggregate ratio

B : Laterite-to-rubber wood ash ratio

C : Curing age

Examples of interpreting the symbols and specifications of interlocking blocks

1:4 - 80:20 - 14 The interlocking blocks were composed of a 1:4 cement-to-aggregate ratio, where the aggregate consisted of 80:20 percent of rubberwood ash, and were cured for 14 days.

1:8 - 50:50 - 28 The interlocking blocks were composed of a 1:8 cement-to-aggregate ratio, where the aggregate consisted of 50:50 percent of rubberwood ash, and were cured for 28 days.

2.3 Molding of interlocking blocks with rubber wood ash

To accommodate the large-scale testing and construction of a sample house using interlocking blocks with rubber wood ash, a small-scale industrial molding process at a local block manufacturing plant in Hat Yai was deemed most suitable. The process began with (1) the preparation of raw materials, including laterite, rubber wood ash, cement, and water. Both the laterite and rubber wood ash were sieved through a 10-mesh sieve. (2) The mixture of laterite, rubber wood ash, and cement was thoroughly mixed using a large-scale plant mixer, followed by the addition of clean water via a spray nozzle. (3) The mixed soil was then conveyed by a conveyor belt to the molding machine. (4) After molding, the interlocking blocks were air-dried in the shade for approximately one day before curing. Curing involved sprinkling or spraying the blocks with water to keep them moist and covering them with plastic sheets to prevent moisture loss. This process was repeated for 7, 14, and 28 days, after which the blocks were subjected to standard testing procedures.

Figure 2 The molding of interlocking blocks with rubberwood ash mixture.

Figure 3 The compressive strength test of interlocking blocks.

Figure 4 Evaluation of water absorption capacity of interlocking blocks.

2.4 Testing of interlocking blocks

Prior to compressive strength and water absorption tests, interlocking blocks were subjected to a visual inspection to assess overall condition, including dimensions, cracks, and chipping, following the procedures outlined in Community Product Standard 602/2547. Only specimens that passed this initial visual inspection were then subjected to the compressive strength and water absorption tests.

3. Results and Discussion

3.1 The compressive strength of interlocking blocks

Compressive strength testing of interlocking blocks is a crucial step in evaluating the strength and quality of the binding material and aggregates. This ensures that interlocking blocks produced with rubber wood ash have sufficient and safe compressive strength, in accordance with Community Product Standard 602/2547, which specifies a minimum compressive strength of 70 kg/cm² for load-bearing blocks and 25 kg/cm² for non-load-bearing blocks. By varying the cement-to-aggregate ratio (1:4, 1:5, 1:6, 1:7, and 1:8 by weight) and the laterite-to-rubber wood ash ratio in the aggregate (100:0, 90:10, 80:20, 70:30, 60:40, and 50:50 by weight), and curing the specimens for 7, 14, and 28 days, it was found that all mixtures achieved their highest compressive strength at 28 days. The development of compressive strength for cement-to-aggregate ratios of 1:4, 1:5, 1:6, 1:7, and 1:8 was 59.63-79.76%, 64.78-83.45%, 49.67-56.13%, 26.16-32.28%, and 38.66-59.74% of the 7-day strength, respectively.

Since interlocking blocks rely on cement as a binding material, the observed increase in compressive strength with curing time is consistent with the well-established understanding of concrete hydration. Cement hydration reactions typically reach completion by 28 days, and while concrete strength continues to increase after this period, the rate of increase is significantly reduced (Thai Industrial Cement, 2014). Given the significant increase in compressive strength with curing time, this study focuses on reporting the average compressive strength of five interlocking blocks containing rubber wood ash at 28 days of curing, as presented in Table 1.

Table 1 The effect of cement-aggregate ratio on 28-day compressive strength.

Laterite to rubber wood ash ratio (%)	compressive strength (kg/cm^2)				
	cement-to-aggregate ratios 1:4	cement-to-aggregate ratios 1:5	cement-to-aggregate ratios 1:6	cement-to-aggregate ratios 1:7	cement-to-aggregate ratios 1:8
100 : 0	144.46	90.67	75.29	56.47	41.92
90 : 10	130.14	86.12	72.27	51.57	39.06
80 : 20	120.15	82.65	64.97	48.61	35.36
70 : 30	107.67	79.14	61.32	46.27	33.77
60 : 40	97.66	72.58	55.34	44.47	30.62
50 : 50	90.13	68.22	53.24	40.16	26.94

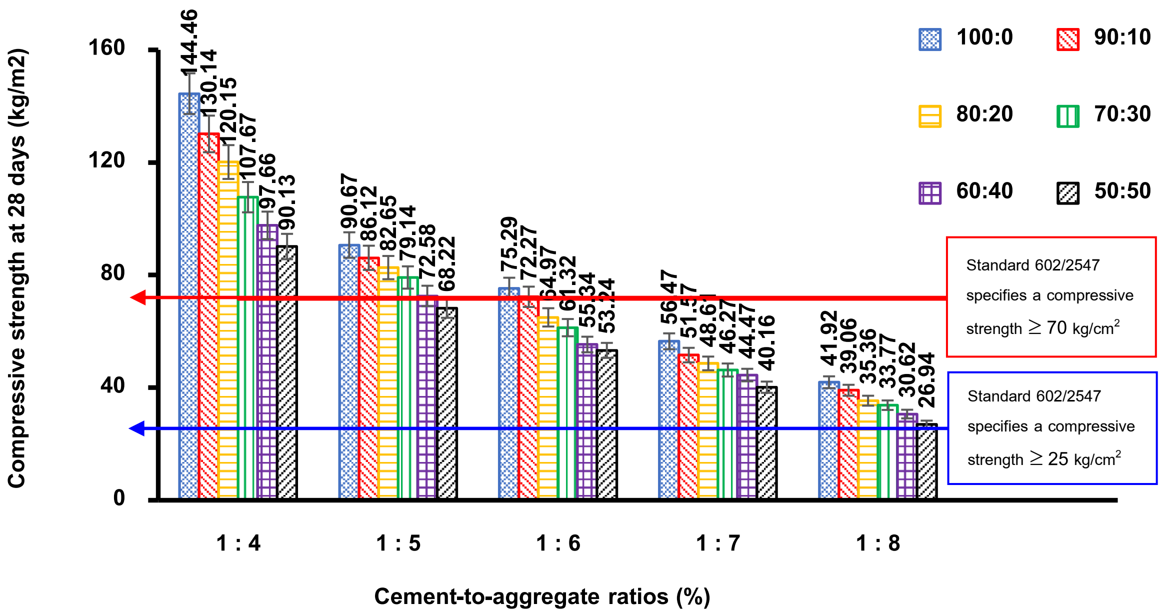

Figure 5 The effect of cement-aggregate ratio on 28-day compressive strength.

The compressive strength test results of interlocking blocks containing rubber wood ash after 28 days of curing showed that the mixture with a ratio of 1:4-100:0-28 exhibited the highest compressive strength at 144.46 kg/cm^2. The mixture with a ratio of 1:4-90:10-28 had the second-highest compressive strength at 130.14 kg/cm^2, while the mixture with a ratio of 1:8–50:50-28 had the lowest compressive strength at 26.94 kg/cm^2. These findings are consistent with previous research on the engineering properties of interlocking blocks containing rubber wood ash from a fishmeal factory (Kuasakul *et al.*, 2017). At a cement-to-aggregate ratio of 1:8 with a laterite-to-rubber wood ash ratio of 50:50, the compressive strength was approximately 47.50 ksc, representing a 76.32% difference, which may be attributed to the molding process. The study used a manual interlocking block machine, and when comparing the results to the Community Product Standard 602/2547, all mixtures passed the non-load-bearing criteria, while 12 mixtures passed the load-bearing criteria. These included 6 mixtures with a cement-to-aggregate ratio of 1:4, 5 mixtures with a ratio of 1:5, and 1 mixture with a ratio of 1:6. Considering compressive strength alone, a correlation equation between compressive strength and cement-to-aggregate ratio was developed, as shown in Figure 6.

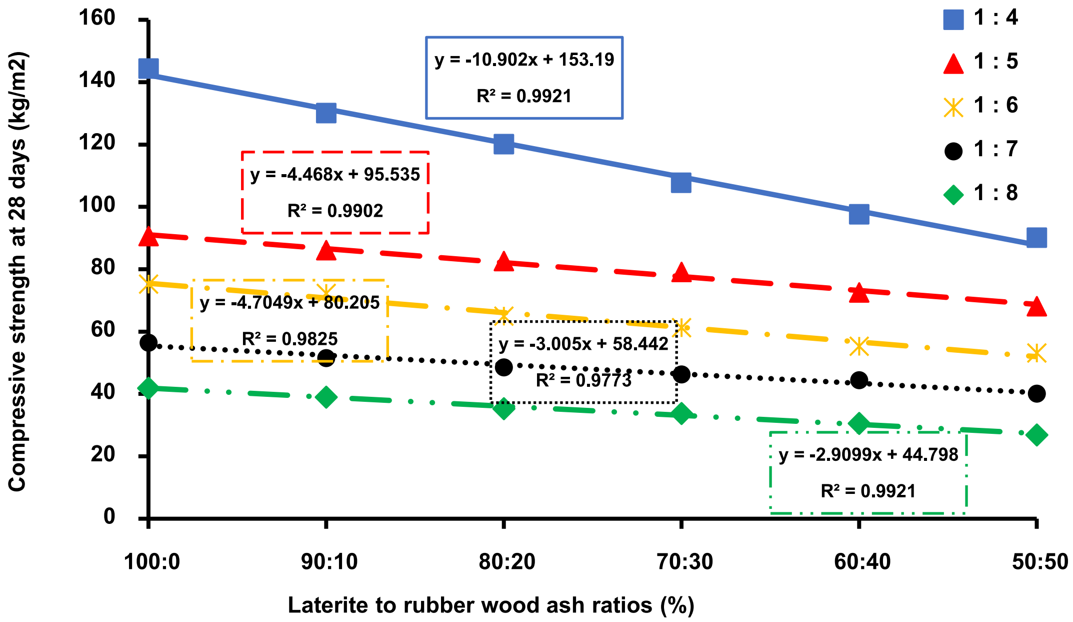

Figure 6 The relationship between cement-aggregate ratio and 28-day compressive strength.

Table 2 The equation of the relationship between compressive strength and cement-to-aggregate ratio.

Cement-to-aggregate ratios	Equation of relationship	R^2	Equation
1:4	$COMP_{1:4-28} = -10.902B_{S:A} + 153.19$	0.9921	1
1:5	$COMP_{1:5-28} = -4.468B_{S:A} + 95.535$	0.9902	2
1:6	$COMP_{1:6-28} = -4.7049B_{S:A} + 80.205$	0.9825	3
1:7	$COMP_{1:7-28} = -3.005B_{S:A} + 58.442$	0.9773	4
1:8	$COMP_{1:8-28} = -2.9099B_{S:A} + 44.798$	0.9921	5

When considering the correlation between the compressive strength equation and the cement-to-aggregate ratio, it was found that the equations of different ratios can be used to predict the compressive strength of interlocking blocks mixed with rubber wood ash. This can serve as a guideline for future research in selecting the cement-to-aggregate ratio and the mixture ratio between laterite and rubber wood ash in the aggregate.

3.2 Water absorption of interlocking blocks

Water absorption testing of interlocking blocks containing rubber wood ash is an essential component of quality control procedures for the production and utilization of interlocking blocks. This testing ensures that the blocks possess suitable properties for various applications and have a long service life. Excessive water absorption can lead to moisture accumulation, promoting the growth of mold and potentially causing deterioration or dissolution, especially in environments with extreme temperature fluctuations. To assess the water absorption properties of rubber wood ash-based interlocking blocks, an average of five samples is tested after 28 days of air curing. This curing period is selected because cement-based interlocking blocks typically reach their maximum strength within this timeframe (Thai Industrial Cement, 2014). The results are presented in Table 3.

Table 3 The average water absorption of interlocking blocks containing para-wood ash, measured over 5 samples, after a curing period of 28 days.

Laterite to rubber wood ash ratio (%)	Average water absorption of interlocking blocks after 28 days of curing (kg/m3)				
	cement-to-aggregate ratios 1:4	cement-to-aggregate ratios 1:5	cement-to-aggregate ratios 1:6	cement-to-aggregate ratios 1:7	cement-to-aggregate ratios 1:8
100 : 0	162.15	186.40	195.54	205.72	218.10
90 : 10	180.57	214.79	240.25	244.50	251.47
80 : 20	200.41	245.20	266.30	272.44	286.75
70 : 30	214.01	280.31	300.17	310.14	315.46
60 : 40	223.76	296.41	320.18	330.45	340.18
50 : 50	245.68	310.70	338.97	355.62	361.20

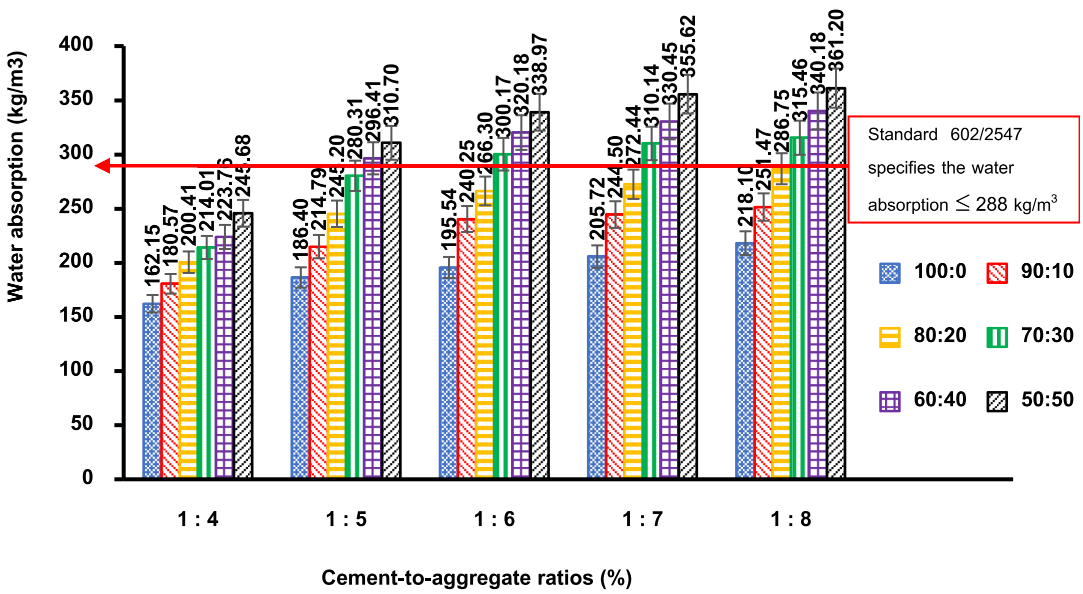

Figure 7 Average water absorption of rubber wood ash-blended interlocking blocks at 28 days.

The water absorption test results of interlocking blocks containing rubber wood ash revealed that mixtures with 50 percent of rubberwood ash exhibited the highest water absorption, ranging from 245.68 to 361.20 kg/m³. Mixtures with 40% rubber wood ash had the second-highest water absorption, ranging from 223.76 to 340.18 kg/m³, while mixtures without rubber wood ash had the lowest water absorption, ranging from 162.15 to 218.10 kg/m³. This indicates that increasing the proportion of rubber wood ash leads to higher water absorption. This phenomenon is likely due to the finer particle size of rubber wood ash compared to laterite, resulting in higher water absorption for blocks with higher proportions of rubber wood ash in the aggregate mixture. When compared to the standard for water absorption of load-bearing interlocking blocks, which is a maximum of 288 kg/m³, 19 mixtures met the standard. These included 6 mixtures with a cement-to-aggregate ratio of 1:4, 4 mixtures with a ratio of 1:5 (1:5-100:0-28 1:5-90:10-28 1:5-80:20-28 and 1:5-70:30-28), 3 mixtures with a ratio of 1:6 (1:6-100:0-28 1:6-90:10-28 and 1:6–80:20-28), 3 mixtures with a ratio of 1:7 (1:7-100:0-28 1:7-90:10-28 and 1:7-80:20-28), and 3 mixtures with a ratio of 1:8(1:8-100:0-28 1:8-90:10-28 and 1:8-80:20-28). The specific mixture proportions for these compliant blocks are listed in detail. The relationship between the proportion of laterite to rubber wood ash and water absorption was analyzed, and the resulting equation is shown in Figure 8.

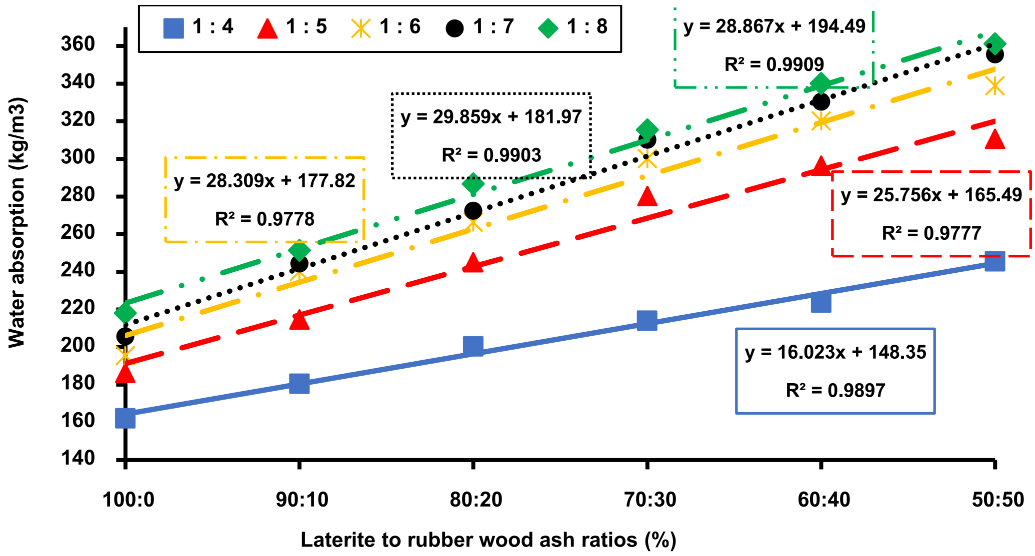

Figure 8 The relationship between average water absorption of rubber wood ash-blended interlocking blocks at 28 days.

Table 4 The equation of the relationship between average water absorption and the cement-to-aggregate ratio.

Cement-to-aggregate ratios	Equation of relationship	R^2	Equation
1 : 4	$ASB_{1:4-28} = 16.023B_{S:A} + 148.35$	0.9401	6
1 : 5	$ASB_{1:5-28} = 25.756B_{S:A} + 165.49$	0.9777	7
1 : 6	$ASB_{1:6-28} = 28.309B_{S:A} + 177.82$	0.9778	8
1 : 7	$ASB_{1:7-28} = 29.859B_{S:A} + 181.97$	0.9903	9
1 : 8	$ASB_{1:8-28} = 28.867B_{S:A} + 194.49$	0.9909	10

Table 5 Density test results for interlocking blocks containing rubber wood ash at 28 days.

Laterite to rubber wood ash ratio (%)	Density test results for interlocking blocks containing rubber wood ash at 28 days (kg/m^3)				
	cement-to-aggregate ratios 1:4	cement-to-aggregate ratios 1:5	cement-to-aggregate ratios 1:6	cement-to-aggregate ratios 1:7	cement-to-aggregate ratios 1:8
100 : 0	1712.28	1701.95	1686.73	1673.63	1672.35
90 : 10	1692.44	1675.89	1660.10	1653.88	1650.67
80 : 20	1663.73	1654.98	1639.66	1632.68	1626.05
70 : 30	1643.66	1634.57	1614.95	1606.58	1602.00
60 : 40	1627.51	1607.68	1594.08	1586.23	1585.50
50 : 50	1598.78	1573.55	1568.08	1562.57	1562.08

When considering the correlation between the average water absorption equation and the cement-to-aggregate ratio, it was found that the equations of different ratios can be used to predict the water absorption of interlocking blocks mixed with rubber wood ash. This can serve as a guideline for future research in selecting the cement-to-aggregate ratio and the mixture ratio between laterite and rubber wood ash in the aggregate.

Results of density tests conducted on interlocking blocks. The density test of interlocking blocks with rubber wood ash was conducted to determine a key property of the samples. Given that rubber wood ash has a specific gravity of 2.05, which is lower than that of laterite at 2.29, incorporating rubber wood ash into the aggregate mixture can reduce the density of the interlocking blocks. The density of the rubber wood ash interlocking blocks was determined by averaging the values of five samples after 28 days of air curing. This curing period was chosen because interlocking blocks typically require at least 28 days to reach full strength. The results of the density tests are presented in Table 5.

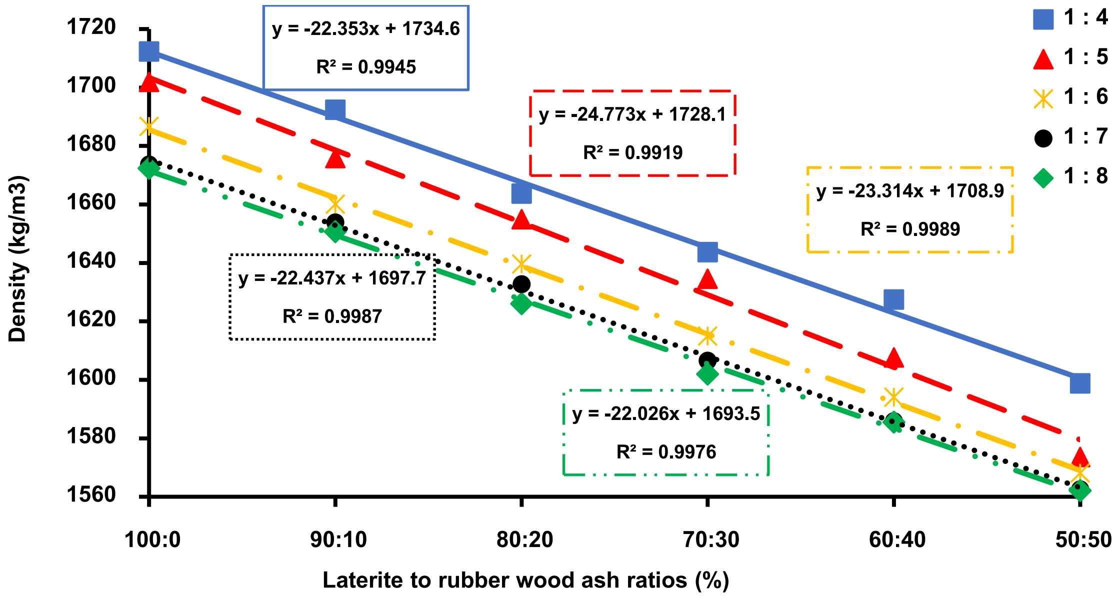

Figure 9 Density test results for interlocking blocks containing rubber wood ash at 28 days.

Density tests on interlocking blocks with rubber wood ash revealed that mixtures without rubber wood ash exhibited the highest density, ranging from 1672.35 to 1712.28 kg/m³. Mixtures with 10 percent of rubberwood ash had the second-lowest density, ranging from 1650.67 to 1692.44 kg/m³, while mixtures with 50% percent of rubberwood ash had the lowest density, ranging from 1562.08 to 1598.78 kg/m³. It is evident that increasing the proportion of rubber wood ash reduces the density of the interlocking blocks. This suggests that incorporating rubber wood ash into the aggregate mix can reduce the structural load on buildings, allowing for smaller structural elements such as beams, columns, and foundations. These findings are consistent with previous studies on interlocking blocks made with rubber wood ash and Narathiwat kaolin (Dasaesamoh *et al.*, 2014). The density values obtained from the 28-day curing test of interlocking blocks with varying mixture ratios ranged from 1532 to 1932 kg/m³. The correlation between density and mixture ratio was analyzed, and the resulting equation is presented in Figure 9.

3.3 Construction of a prototype House built with interlocking blocks containing para-wood ash

After 28 days of curing, compressive strength, water absorption, and density tests were conducted on all interlocking block mixtures. Results indicated that all mixtures met the non-load-bearing standards specified in the Community Product Standards for Interlocking Blocks (Association of Block Manufacturers of Thailand, 2004), which requires a minimum compressive strength of 25 kg/cm². Based on these findings, a cement-to-aggregate ratio of 1:8 with a 50:50 mixture of laterite and rubber wood ash (1:8-50:50-28) was selected for the prototype wall construction due to its lowest cement content and highest rubber wood ash content among all tested mixtures, making it the most cost-effective option. For load-bearing applications, a cement-to-aggregate ratio of 1:4 with a 50:50 mixture of laterite and rubber wood ash (1:4-50:50-28) was selected, as it met the minimum compressive strength requirement of 70 kg/cm² for load-bearing interlocking blocks and utilized the highest percentage of rubber wood ash among all suitable mixtures. A cost analysis of producing interlocking blocks with rubber wood ash revealed that non-load-bearing blocks have a production cost of 6.41 baht per block, which is 13.59 baht cheaper than the market price, representing a 67.95% reduction. Load-bearing blocks have a production cost of 8.00 baht per block, which is 12.00 baht cheaper than the market price, representing a 60.00% reduction. These cost comparisons do not include profit margins or marketing costs. However, it is evident that incorporating rubber wood ash into interlocking blocks can reduce production costs by at least 0.20-0.23 baht per block. Additionally, considering the environmental benefits of reducing industrial waste and mitigating air pollution, soil contamination, and water pollution, the production of interlocking blocks with rubber wood ash is both feasible and economically viable.

Therefore, based on the comprehensive analysis of data and components, it can be concluded that a cement-to-aggregate ratio of 1:8 with an aggregate mixture of 50:50 rubber wood ash (1:8-50:50-28) is the most suitable and cost-effective option for constructing a prototype wall using interlocking blocks made from rubber wood ash.

Figure 10 House built with interlocking blocks containing para-wood ash.

3.4 Initial data collection of the prototype house regarding thermal resistance and physical properties

This study presents the initial findings of a month-long monitoring of a prototype house constructed using interlocking blocks made from a mixture of cement, laterite, and rubber wood ash at a ratio of 50:50 (1:8-50:50-28), respectively. The primary focus was on assessing the thermal performance and physical properties of the blocks, including mold growth, color changes, and odors. Results showed that the interlocking blocks made from rubber wood ash were successfully used to construct the prototype house and provided a maximum heat resistance of 2.0 degrees Celsius. Since the prototype house was constructed behind a school building, where the ambient temperature is relatively low, the temperature difference between the interior and exterior of the house was not significant.

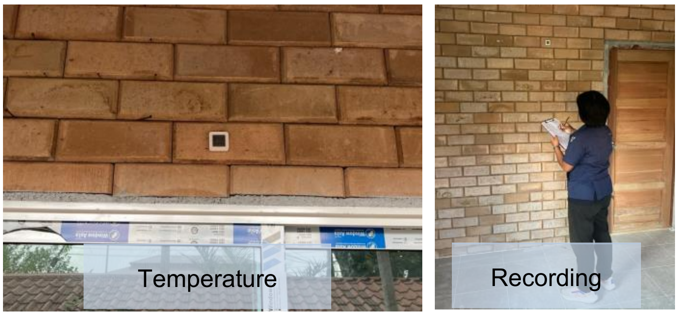

Figure 11 Temperature recording of a house built with interlocking blocks containing para-wood ash.

Visual observations of the interlocking blocks were conducted daily from July 17 to August 17, 2024, to monitor the occurrence of mold, color changes, and odors. No mold growth or rubber wood ash odor was observed on the interlocking blocks. The only detectable odor was that of cement, which is commonly associated with the construction process. While the interior interlocking blocks maintained their original grayish-brown color, the exterior blocks exhibited a color change from grayish-brown to reddish-brown after 31 days. This color change is likely attributed to the constant exposure to salt-laden aerosols carried by sea breezes, as the prototype house is located near the coast. Consequently, the exterior wall surface experienced color alteration before the interior surface.

Figure 12 Color of interlocking blocks with rubber wood ash admixture inside a house.

Figure 13 Changes in the surface color of interlocking blocks with rubber wood ash admixture on the exterior of a house.

4. Conclusion

The production of interlocking blocks using rubber wood ash by a particleboard manufacturer in Hat Yai district, Songkhla province, has proven to be a feasible endeavor. This initiative not only promotes the development and utilization of industrial waste but also contributes to the creation of environmentally friendly construction materials. By substituting traditional raw materials with rubber wood ash, production costs can be reduced, enhancing the product's competitiveness in the market. Based on tests conducted according to the Community Product Standards for Interlocking Blocks (Association of Block Manufacturers of Thailand, 2004), it was found that increasing the aggregate content while maintaining a constant cement ratio resulted in a decrease in compressive strength and an increase in water absorption. Similarly, increasing the proportion of rubber wood ash and decreasing the amount of laterite led to a reduction in compressive strength and an increase in water absorption. The optimal cement-to-aggregate ratios of 1:4, 1:5, and 1:6 by weight allowed for the incorporation of up to 50, 30, and 0 percent of rubberwood ash by weight, respectively, while still meeting the standards for load-bearing interlocking blocks. A cement-to-aggregate ratio of 1:4 by weight, with 50 percent of the aggregate replaced by rubber wood ash, was found to be the optimal mix for producing load-bearing interlocking blocks. All block mixtures within the scope of this research met the standards for non-load-bearing interlocking blocks. Consequently, a cement-to-aggregate ratio of 1:8 by weight, with 50% of the aggregate replaced by rubber wood ash, was selected as the most suitable mixture for constructing a prototype wall using interlocking blocks made from rubber wood ash. This mixture resulted in a production cost of 6.41 baht per block, which is 13.59 baht cheaper than the market price, representing a 67.95 percent cost reduction. The resulting blocks exhibited a maximum heat resistance of 2.0°C, no mold growth, and no rubber wood ash odor. These findings demonstrate the feasibility and practicality of using interlocking blocks made from rubber wood ash for residential construction. The production of interlocking blocks from rubber wood ash offers a cost-effective and sustainable solution for converting industrial waste into a valuable product.

5. Recommendations

In this research, interlocking blocks made from rubber wood ash were produced using a manual interlocking block press in the Civil Engineering Department's laboratory. The optimal mixture ratio has been determined based on the previous study titled 'The Feasibility of Using Rubberwood Bottom Ash in The Mixture of Interlocking Block' (Chumprom *et al*., 2024). However, when the aforementioned mixture ratio was applied to a small-scale industrial interlocking block press at a local factory in Hat Yai, it was found that the blocks could not be successfully molded. Consequently, all mixture ratios were retested using the factory's equipment. Based on these findings, it is recommended that future research involving large-scale production of interlocking blocks should utilize industrial-scale molding equipment.

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