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The effect of natural fibers and para rubber latex on adobe bricks

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Abstract

The aim of this study was to enhance the strength and water resistance of adobe bricks through the combination of natural fibers and para rubber latex. The initial mixing ratio of the ingredients consisted of clay: rice husk: sand in proportions of 6: 0.72: 2 by weight. Para rubber latex is mixed with 10% of the weight of the soil in mixtures containing latex. Natural fibers such as rice husk or coconut fibers replace rice husk at a rate of 4.5% of the soil weight. The materials were compressed into wooden molds measuring 10 cm in width, 35 cm in length, and 17.5 cm in height. This study aimed to simulate real conditions in curing bricks under the sun for 21 and 28 days without using plastic wrapping. The bricks were subjected to tests for compressive strength, flexural strength, and erosion at 21 and 28 days of curing. The results of the tests showed that the addition of para rubber latex or various types of natural fibers to the adobe bricks enhanced their properties.

Keywords: Adobe bricks, Para rubber latex, Natural fibers

1. Introduction

Various agricultural waste materials that can be effectively utilized. Several studies have demonstrated success in utilizing agricultural waste to produce building materials [1-4]. Adobe, a traditional building material widely used in arid regions consists of a mixture of various ingredients. The main components of adobe include clay, sand, water, and organic materials such as straw or other natural fibers. Clay provides cohesion and plasticity to the mixture, while sand acts as an aggregate, enhancing its strength and preventing excessive shrinkage during drying. Water is added to achieve the right consistency for molding and binding the materials together. Organic materials, such as straw, are incorporated as additives to improve the tensile strength and prevent cracking in the adobe structure. The combination of these ingredients creates a durable and environmentally friendly construction material [5]. In saturated conditions, their poor water resistance could lead to a progressive reduction

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in strength, potentially culminating in total disintegration [5]. The compressive strength of adobe bricks displays a wide variation, extending from a minimum of 0.6 MPa up to a maximum of 7 MPa. However, their tensile strength is considerably lower, estimated to be roughly 10% of their compressive strength [6]. Several techniques, including mechanical compaction, chemical stabilization, and the addition of natural fibers [7] have been utilized to enhance the engineering properties and erosion resistance. Increasing the proportion of para rubber latex in the brick enhances both its flexural and compressive strength [1]. Nevertheless, cement stabilization is generally discouraged due to its negative environmental implications [8].

Adobe bricks have been the subject of various research studies in Thailand aimed at improving their properties and performance. Promluangsri and Wongpa (2015) [9] conducted to investigate the use of natural rubber latex as an additive to enhance the strength and water barrier properties of adobe bricks. The researchers explored different ratios of clay, rice husk, sand, and water mixed with natural latex and examined the effects on compressive strength, flexural strength, and leaching resistance of the bricks. Promluangsri et al., (2017) [10] study focused on developing adobe bricks reinforced with natural fibers to improve their mechanical properties. The study explored the use of various natural fibers, such as bamboo fibers and coconut coir, in the clay mixture to enhance the strength and durability of the bricks.

Thailand experiences tropical weather with extended periods of heavy rainfall. A theoretical gap appears when natural fibers are added to raw clay bricks, which are then tested for erosion as adobe bricks. The purpose of this study was to investigate the best ratio for using para rubber and natural fibers in the production of adobe brick products. This was accomplished through considering factors such as resistance to erosion testing, bending strength and compressive strength characteristics. The discoveries of this study will serve as a reference for future development of safer adobe bricks, potentially suitable for ecotourism purposes.

2. Materials

2.1 Clay and sand

The clay used in this research is clay soil and sand from the Salaya sub-district, Phutthamonthon district, Nakhon Pathom province, Thailand. The clay soil, sand possesses the following in Table 1.

Table 1 Properties of experimental clay soil and sand

Properties	Clay soil	Sand
Natural water content (%)	30.5	-
Liquid limit (%)	41.8	NP
Plastic limit (%)	32.25	NP
Plastic index (%)	9.45	NP
Unified Soil Classification System (USCS)	MH	SP
Specific gravity	2.65	2.63
Fineness Modulus (FM)	-	2.44
Absorption (%)	-	1.51

The soils in the MH groups are sandy silts, clayey silts, or inorganic silts with relatively low plasticity. Also included are loss-type soils and rock flours. Micaceous and diatomaceous soils generally fall within the MH group. The river sand utilized in this research is the commonly available sand found at local construction materials stores in Nakhon Pathom Province, Thailand.

2.2 Rice husk

In Thailand, rice husk typically refers to the outer covering of rice grains, known as rice husk. Thailand is one of the world's major rice-producing countries, and rice husk is abundantly available as a byproduct of rice milling processes. Figure 1 illustrates rice husk used as an ingredient of this study.

Figure 1 Rice husk used as an ingredient

2.3 Para rubber latex

Para rubber latex is a significant agricultural product in Thailand, with the country being one of the largest producers and exporters in the world. The latex is extracted from rubber trees cultivated in vast plantations across Thailand, benefiting from the country's favorable climate and expertise in rubber cultivation. Thailand's para rubber latex is known for its high quality and plays a crucial role in various industries, including the production of rubber products, adhesives, and latex-based materials. Para rubber latex with a 2.5% ammonia content is employed as an additive in this study. Figure 2 demonstration para rubber latex.

Figure 2 Para rubber latex

2.4 Straw

Straw, a byproduct of grain crops such as rice, wheat, and corn are widely used in Thailand for various purposes. Straw is commonly used as animal feed and bedding for livestock, providing a sustainable and cost-effective solution. The abundance of straw in Thailand allows for its versatile and practical use in different industries and cultural practices. Figure 3 illustrates the utilization of rice straw.

Figure 3 Rice straw on a farm

2.5 Coconut fiber

Coconut fiber also known as coir is a valuable natural resource abundantly available in Thailand due to the country's extensive coconut plantations. The fibers derived from the coconut rice husks are known for their strength, durability, and eco-friendly properties. In Thailand, coconut fiber is widely utilized in various industries such as agriculture, horticulture, and handicrafts, contributing to the country's economy and sustainable development. In this study, the coconut fibers were trimmed to a maximum length of 5 cm. Figure 4 presentations the incorporation of coconut fibers in this study.

Figure 4 The coconut fibers in this study

3. Methodology

3.1 Ingredients ratio

The adobe bricks are made by combining seven materials in the mix: clay, rice husk, sand, water, para rubber, rice straw, and coconut fiber. The ideal water ratio is one that reduces the clay texture liquid, sticky, and not excessively dry, facilitating easy mixing. The appropriate amount of water in the soil in this research is based on expertise. This is because there is no standard method for assessing the liquidity of raw clay bricks, and the ingredients can vary. Prior to this study, a preliminary molding was conducted, and the potential ratios of the materials used in this study are summarized in Table 2.

Table 2 Ingredients ratio of a specimen

Symbol	Clay (kg)	Sand (kg)	Rice husk (kg)	Para rubber (kg)	Straw (kg)	Coconut fiber (kg)	Approximate water (kg)
OR	6	2	0.72	-	-	-	2.5
OR +P	6	2	0.72	0.8	-	-	2.5
OR+P+S	6	2	0.36	0.8	0.36	-	2.5
OR+P+C	6	2	0.36	0.8	-	0.36	2.5

*OR=Clay+Rice husk+Sand, P = Para rubber, S = Straw, C = Coconut fiber

All ingredients are approximate by weight based on the natural moisture content of the material.

3.2 The samples

The adobe brick samples for testing were prepared using traditional wooden molds in dimensions of 10×17.5×35 cm as shown in Figure 5. The methods as follows:

1. Pour the clay and sand into the yard mix in the ratio of 6 parts clay to 2 parts sands.
2. Add water to the soil and trample the soil together with the feet.
3. Pour the para rubber latex mixed with the nonionic compound onto the soil and stomp it together again.
4. Pour the rice husks and the natural fibers into the soil and tread them together again.
5. Compress about 10 kilograms of soil into the mold per block.
6. Leave the raw clay bricks to dry in the sun for about 48 hours, then turn the bricks upright to expose to the sun and leave them for 21 and 28 days, then test their properties. Figure 5 presents the sample of adobe bricks after the extrusion process.

The curing samples following NZS 4297:1998, Engineering Design of Earth Buildings, Standards New Zealand [11] which takes only 28 days to cure. This study aimed to determine whether using the bricks after 21 days would pass the test. Tests were conducted at both 28 and 21 days to assess this.

Figure 5 Adobe bricks formed by pouring clay into a mold and compacting it with foot pressure

4. Testing

4.1 Compression test

Measure the dimensions of the brick to determine the cross-section area. Pour the plaster onto the brick, ensuring a smooth surface that can uniformly withstand the initial pressure. Place the brick in the testing machine and apply pressure until the brick breaks. The compressive strength is the ratio of the maximum load in the cross-section area. The testing process followed TIS 77-2545 standard [12].

$$P = \frac{F}{A} \tag{1}$$

P is compressive strength, kg/cm^2
F is the maximum load, kg
A is the cross sectional area, cm^2

4.2 Flexural strength

In this study, the flexural strength of the materials was tested in both the flat wise and edge wise orientations as shown in Figure 6. Measure the size of the sample in centimeters and place the bricks on the sample supports with a length of 12 cm. The loading applies at the middle of the length. The loading rate should be limited to a maximum of 1,000 kg/min or a speed of 1 mm/min. Flexural strength is calculated as follows. The testing process followed ASTM C67 standard [13].

$$\sigma = \frac{3FL}{2bd^2} \tag{2}$$

F is the load (force) at the fracture point, kg
L is the length of the support span, cm
b is width, cm
d is thickness, cm

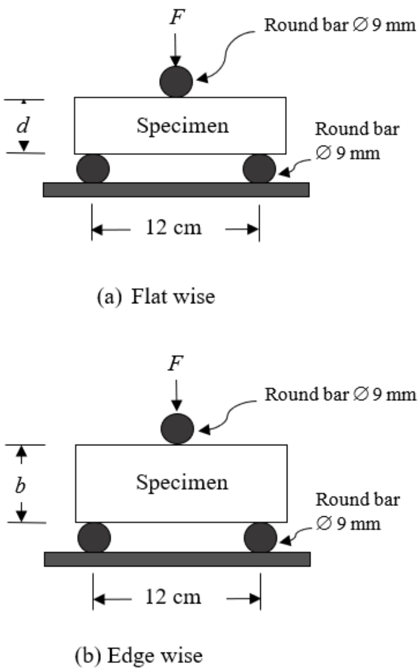

Figure 6 The flexural strength examined (a) flat wise, (b) edge wise

4.3 Erosion test

Erosion test adapted from Heathcote [14]. This spray test is referenced in the Building Code of Australia and a modified version was included in the New Zealand Code of Practice on earth wall buildings (NZS 4297, 1998) [11]. Distance between nozzle and the test sample is 50 cm, water pressure in the pipe 50 kPa, spray water with a nozzle into the sample for 60 minutes. The adobe samples for remolding were packed into cylinders with a diameter of 10 cm and a height of 10 cm. Figure 7 shows the erosion tested equipment of this study.

The criteria for classifying show in Table 3. This standard, NZS 4299:1998 "Earth Buildings Not Requiring Specific Design" was the result of a joint collaboration between Australia and New Zealand [15].

Figure 7. Erosion testing equipment

Table 3 Criteria for classifying the erosion test of adobe bricks [15]

Waterproofing level	Corrosion depth (mm)
Excellent	≤10
Good	10-20
Fair	20-30
Poor	> 30

5. Result and discussion

5.1 Compression test result

Figure 8 shows the flat-wise and edge-wise strength tests of samples with 21 and 28 days curing time. It was discovered that para rubber can enhance the compressive strength of adobe bricks by displacing the air in the voids in the soil. The sample curing was carried out in the sun leading to a decrease in soil moisture over time. As a result, the compressive strength was measured at 28 days of curing instead of 21 days [16]. The combination of rice straw fibers and coconut fibers in the mixture significantly enhances the compressive strength of the bricks. The inclusion of fibers effectively enhances the binding of the soil, providing additional reinforcement and surpassing the strength achieved by using rice husk alone. The natural fibers contribution in bearing the lateral tensile force on the sample material during unconfined compression strength testing [17]. Coconut fibers exhibit a slightly higher compressive strength compared to rice straw fibers. Furthermore, the duration of air drying of the sample also influenced their compressive strength, with the 28 day curing period resulting in higher strength than the 21day samples. The 28 day old sample had lower moisture content than the 21 day old sample, resulting in higher compressive strength. This higher compressive strength in the upper part of the bending sample also contributes to the higher flexural strength. The test results indicated that all composites demonstrated a significant improvement in flat wise strength compared to edge wise strength.

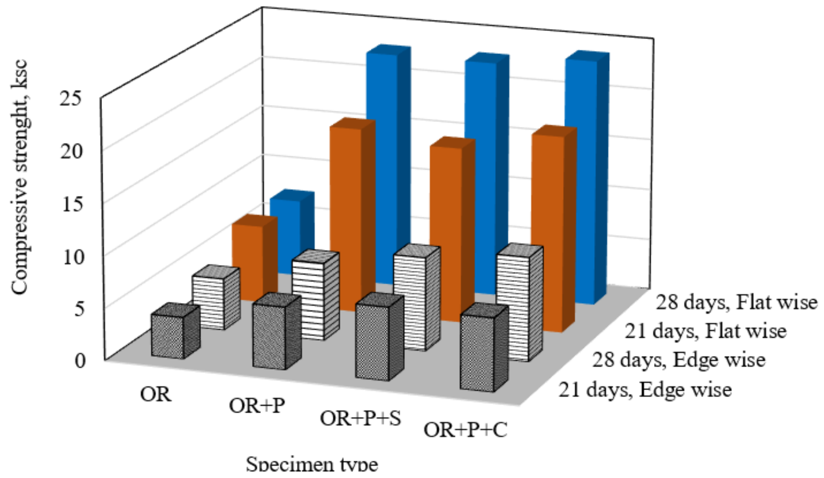

Figure 8 Compressive strength of adobe brick of 21 and 28 days curing

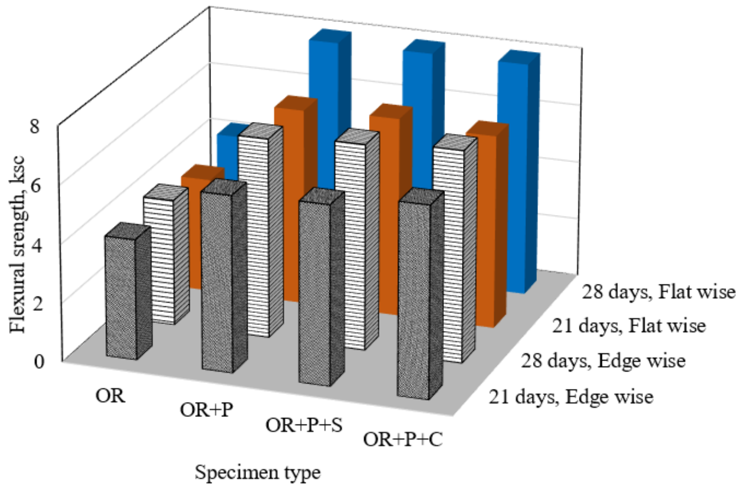

Figure 9 Flexural strength of adobe brick of 21 and 28 days curing

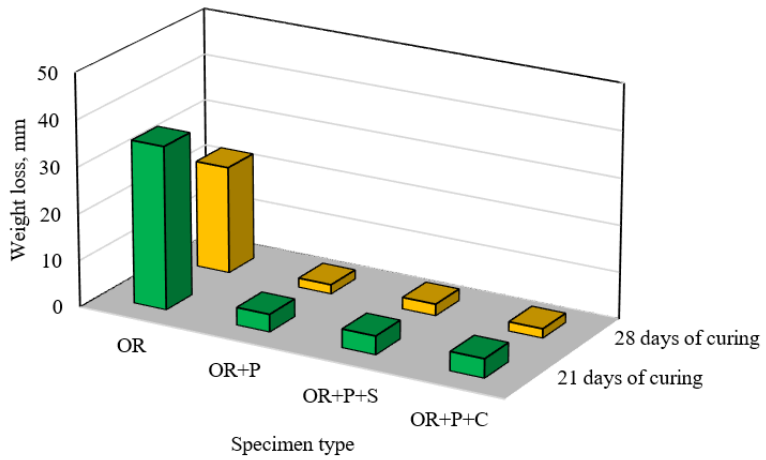

Figure 10 Weight loss of adobe brick of 21 and 28 days curing

5.2 Flexural strength result

Figure 9 presents the results of the flexural strength test conducted on samples with curing periods of 21 and 28 days. The addition of para rubber or various fibers to adobe clay bricks can improve their flexural strength properties. This occurs because natural fibers enhance the tensile strength of the lower portion of the test sample, thereby leading to the higher flexural strength properties in samples mixed with natural fibers compared to normal samples [1]. The inclusion of natural fibers in the adobe clay brick contributes to a slightly higher flexural strength compared to the compressive strength. Furthermore, a longer period of air-drying curing for adobe bricks led to increased flexural strength as well as compressive strength. The flexural strength in the flat-wise tends to be higher compared to the edge wise due to the deeper width of the samples used in the edge wise testing case.

5.3 Erosion test result

Figure 10 illustration weight loss of varies sample types of 21 and 28 days curing. Classifying test results with Table 2, it is evident that adobe bricks mixed with para latex or nature fibers demonstrate excellent level, but regular adobe bricks exhibit a water resistance level that fair to poor. Adobe bricks mixed with latex or various fibers can prevent water or water leaching much better than normal clay bricks. Natural fibers act as additional reinforcement within the soil, so reducing the dispersion of soil particles caused in the erosion test [14].

6. Summary

1. In the compression test, the samples mixed with latex exhibited higher compressive strength compared to the original samples. This is attributed to the latex filling the air voids within the soil, thereby enhancing the overall strength of the mixture [16]. It was observed that adding para rubber and a combination of rice straw fibers and coconut fibers significantly increased the compressive strength of adobe bricks. Coconut fibers exhibited slightly higher compressive strength than rice straw fibers. Longer air-drying curing periods also resulted in higher compressive strength of the samples.

2. The compressive strength of flat-wise clay brick samples is higher than those tested edge-wise. This because the horizontal sample press is a smaller height, which allows for better compression of the samples [18]. The compressive strength of the samples mixed with latex and natural fibers, both flat-wise and edge-wise, was greater than that of the original sample. This is because latex replaces air voids and natural fibers receive lateral tensile force [19].

3. In the flexural strength test, the addition of para rubber or various fibers improved the flexural strength properties of adobe clay bricks. The inclusion of natural fibers contributed to a slightly higher flexural strength compared to compressive strength [19].

4. For the erosion test, adobe bricks mixed with para latex or natural fibers exhibited excellent water repellency, while regular adobe bricks showed fair to poor water resistance. Adobe bricks mixed with latex or various fibers demonstrated better resistance to water and leaching compared to normal clay bricks [20].

Overall, the test results indicated the positive impact of additives such as para rubber, rice straw fibers, coconut fibers, and latex on the compressive strength, flexural strength, and water resistance properties of adobe bricks.

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