Evaluation of Pavement Brick Fabricated using Sta. Cruz Clay, Rice Husk Ash, and Capiz Shell

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Abstract

This study explored the production of pavement bricks using Sta. Cruz clay, rice husk ash, and Capiz shell as additives. Sta. Cruz clay served as the base material, while rice husk ash provided alternative silica, and Capiz shell as a fluxing agent for strength enhancement and waste minimization. Through oxide percentage analysis via EDXRF, a formulation with 80% Sta. Cruz Clay, 15% Rice Husk Ash, and 5% Capiz Shell was identified as optimal, exhibiting no visible cracks post-firing. The optimized product underwent testing for water absorption, volumetric shrinkage, and weight loss, yielding values of 33.1%, 1.02%, and 42.5%, respectively. Consumer surveys indicated high acceptability with an average rating of 2.68, affirming its applicability and design suitability.

Keywords: pavement bricks, clay, rice husk ash, shell, agricultural waste

1. Introduction

Pavement block is one of the most popular flexible surface treatment options for exterior pavement application [1] in substitute to a typical cement cast road. It is known that pavement blocks are in demand in the market as it can lessen the expenses and the time in construction. There are two common types of pavement blocks, the molded concrete block and kiln-fired clay brick. Concrete blocks are mainly made from cement. Concrete pavers coloring fades faster if constantly exposed to sunlight. Though durable, concrete pavers have a shorter lifespan than brick pavers. On the other hand, clay bricks provide sustainable alternative to concrete blocks and are from fired ceramic materials such as clay, silica, and feldspar [2]. In addition, permeable brick pavement can also absorb precipitation and it has a far higher capacity for sustainable development than cement pavement when it comes to operation [3].

Clay, as one of the said components, is usually resulted from weathering process and mainly composed of aluminum oxide, silicon dioxide and trace number of fluxes (potash and soda) [4], clay is an abundant raw material with a variety of usages and properties. It is a compound of group of material that consists of mineral commodities, each having somewhat different mineralogy, geological occurrence, technology, and applications.

In this study, a portion of soil in Sta. Cruz Tangub City, Misamis Occidental, Philippines exhibiting a clay property that can be used as a raw material in pavement block. The Sta. Cruz Clay is a good material for pavement block since its texture is fine, smooth when powdered and forms a paste that feels slippery and has silky texture when mixed with water. Good quality bricks contain 50-60% silica. Silica prevents raw bricks from cracking, shrinking, and warping [4]. It is known that rice husk ash is high in silica, an excellent material for this study. Rice husk ash contains 90-95% silica [5] and is readily available in rice mills [6].

Further, Sta. Cruz clay was added a rice husk ash as a bonding agent as it is abundant of silica. In the study conducted, 5% bentonite was added as binder in the manufacture of bricks made up of 40-95% fly ash and up to 55% rice husk ash [7]. Rice husk/ rice husk ash is an alternative source of silica in ceramics [8]. The usage of rice husk ash in lightweight clay brick improved certain aspects in the brick itself in term of properties and strength [4].

Tangub City, Philippines has a considerable size for fish farming specifically in the sea and considering that there are lots of Capiz Shells waste in the area. Capiz Shells wastes were utilized as additive for the development of pavement bricks. The incorporation of Capiz shell as an additive in the production of clay pavement bricks introduces unique characteristics and potential benefits to the final product [9].

This study was conducted to address solid waste issues and discover an innovative, and economical, for pavement bricks making. By utilizing the existing resources, this innovative approach not only offers replacement for conventional paving materials but also boosts the local economy. This study explored combination of Sta. Cruz clay, rice husk ash, and Capiz shell as additives for the development of pavement bricks. Many resource combinations were already tested and are evident in many studies especially in construction [7, 10-12]. Specifically, the effects of varying the formulation of each material on the properties of the bricks, including economic advantages, and acceptability were investigated.

2. Methods

2.1. Research Design

The study employs experimental and descriptive quantitative methodologies within a developmental framework, focusing on sustainable materials like clay, Capiz shell, and rice husk ash for clay brick production. It adopts a developmental approach as it aims to produce a project output, evolving over time in phases. Descriptive quantitative methods are utilized to evaluate the project's applicability and inform potential implementation areas.

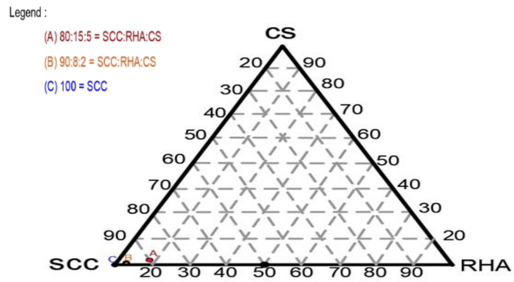

Figure 1: Ternary Phase Diagram of Formulation

The Ternary Diagram illustrates the formulation of SCC, RHA, and CS, highlighting intersecting points representing trials based on oxide analysis results. The study specifically focuses on the intersection part of the diagram, determining suitable material percentages for formulation.

2.2. Research Environment

Materials were sourced from Sta. Cruz, Tangub City (clay), Purok 5 Migpangi, Bonifacio (rice husk ash), and Barangay Migcanaway, Tangub City (Capiz shell). Construction and fabrication took place at NMSCST Labuyo, Tangub City, while firing occurred at Lopez Jeana, Misamis Occidental.

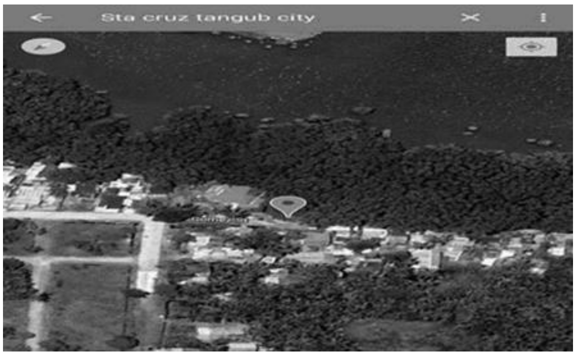

Figure 2: The location map of Sta.Cruz Tangub City where the Clay is collected, and the project was assembled and fabricated.

Figure 3: The location map of Migpange Bonifacio where Rice Husk Ash is collected and burned.

Figure 4: Map Showing the collection of Capiz Shell in Migcanaway, Tangub City.

Figure 5: The location map of NMSCST where the project was tested and evaluated.

Figure 6: Location map of Mamalitas House of Pottery at sibugon, Lopez Jaena, Misamis Occidental where the project was fired.

Maps depict the collection points for clay, rice husk ash, and Capiz shell, as well as fabrication and firing locations.

2.3. Research Respondents

Experts from the institution, including civil engineers, instructors, and skilled workers, were selected as respondents due to their relevant expertise.

Table 1: Distribution of Respondents

Item Group	No.	Respondents	
1		Civil Engineers	2
2		Instructors	3
3		Skilled Workers	5
Total			10

Respondents were distributed among civil engineers, instructors, and skilled workers for a total of ten.

2.4. Research Instrument

A questionnaire served as the main data-gathering tool, focusing on project characteristics. Physical test data, including plasticity index, percent shrinkage, weight loss, and water absorption, were tabulated.

The plasticity index will be computed using the formula:

$$PI = LL - PL$$

where:

PI = Plastic Index

LL = Liquid Limit

PL = Plastic Limit

The formula for percent volumetric shrinkage,

$S = (V_m - V_s)/(V_m) \times 100$

where:

V_m = Volume of Molding

V_s = Volume of Shrinkage

The weight loss is calculated as green pavement bricks weight subtracted by the fired pavement bricks weight.

Where:

Weight loss = Green pavement bricks - Fired pavement bricks

The water absorption is calculated of boiled pavement bricks are deducted from the unboiled pavement bricks after 30mins of boiling.

Where:

Water Absorption= $((W_w - D_w)/D_w) \times 100$

2.5. Scoring Procedure

Quality assessment utilized a 3-point Likert Scale, with scores interpreted as very acceptable, acceptable, or not acceptable.

Where:

Range Value =

(Highest Scale-Lowest Scale)/ (Highest Scale)

2.6. Statistical Tool

Data analysis employed average weighted mean and a 3-point Likert scale to validate the project and assess acceptability.

Table 2: Interpretation and range of verbal scores

SCORE	RANGE VALUE	VERBAL INTERPRETATION
3	2.34-3.00	VERY ACCEPTABLE
2	1.67-2.33	ACCEPTABLE
1	1.00-1.66	NOT ACCEPTABLE

Average Weighted Mean Formula:

$\overline{X} = \Sigma f_w / N$

Where:

$\overline{X}$ is the average weighted mean

Σf_w is the total weighted point

N is the total number of cases

2.7. Design Requirements

This section includes layouts, supplies and materials, tools and equipment, and project output specifications.

2.7.1 Layout

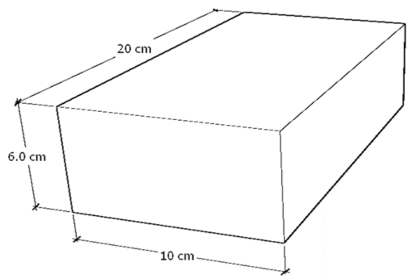

Figure 7: Perspective view

A perspective view of the project with complete dimensions is provided, facilitating understanding of the mold size and volume.

2.7.2 Supplies and Materials

Table 3: List of Supplies and Materials

Materials	Unit	Quantity	Unit Cost
Clay	600	3 Sacks	1800
Capiz Shell	300	1 Sacks	300

ITEM NO.	MATERIALS	%	QTY.	UNIT	UNIT COST	TOTAL COST
1	Clay	80% / 90%	4,000 / 4,500	Grams	₱250 per cu.m	₱1.00
ITEM NO.	MATERIALS	%	QTY.	UNIT	UNIT COST	TOTAL COST
2	Rice Husk Ash	15% / 5%	400 / 750	Grams	₱1 per 1kg	₱0.75 / ₱0.4
3	Capiz Shell	5% / 2%	100 / 250	Grams	₱10 per kg	₱1.00 / ₱2.50
1	Clay	100%	5,000	Grams	₱251 / ₱250 per cu.m	₱1.00
4	Water	40%	2,000	Grams		
Total / 2	Water	40%	5,000 / 2,000	Grams		₱2.25 / ₱4.4
Total			5,000	Grams		₱1.00

Rice Husk	15	3 Sacks	45
1”x6”x4” wood	80	2pcs.	160
1”x6”x4” wood	50	1pc.	50
Hinge	52	1 pack	52
Hok and I	15	2pcs.	30
Sandpaper	20	1pc.	20
Nails	80	¼ kl.	20
Oil	40	¼ liter	10
Plain Sheet	300	1pc.	300
Folder	15	1pc.	15
Total			2,802

Table 4. Trial 1 Cost Computation

Table 5. Trial 2 Cost Computation

Table 6. Trial 3 Cost Computation

2.7.3 Labor and Production Cost

Table 7. Labor and Production Cost

TRIAL	COST OF MATERIAL	30% FOR THE LABOR COST	TOTAL EXPENSES
1	₱ 4.25	₱ 1.28	₱ 5.53
2	₱ 2.4	₱ 0.72	₱ 3.12
3	₱ 1	₱ 0.3	₱1.3

3. Results

3.1. Determining the plasticity index and powder density of Sta. Cruz clay

The data were gathered for the plasticity index by first conducting the liquid limits test using the Casagrande method and a heavy-duty oven. In the Casagrande cup method, soil paste is placed in the cup, and a groove is made at its center. The limit is defined as the moisture content required, in percent, to close a distance of 0.5 inches along the bottom of the groove after 25 blows in a liquid limit device. Adjusting the soil's moisture content to meet the required 12.5 mm (0.5 in.) closure of the groove at 25 blows is challenging. Therefore, at least three tests for the same soil are conducted at varying moisture contents, with the number of blows, N, varying between 15 and 35 (Campbell, 2000). Secondly, the plastic limit test is performed by repeatedly rolling an ellipsoidal-sized soil mass by hand on a non-porous surface. Casagrande defined the plastic limit as the water content at which a thread of soil just crumbles when rolled out to a diameter of 3 mm (1/8”). If the thread crumbles at a diameter smaller than 3 mm, the soil is too wet; if greater, it is drier than the plastic limit. The sample can then be remoulded, and the test repeated. Once the appropriate size rolls are made, their moisture content is assessed using the procedure described previously [13].

Table 8. Presents the findings of the liquid limit and plastic limit test. Three trials were conducted to calculate the total wight average

Trial	Liquid Limit	Plastic Limit	
		Weight of Crumbled soil	Weight of oven dried Crumbled
1	36	4	3
2	35	3	2
3	35	3	3
Weight Average	35.3	3.3	3

Table 9: Calculation for Plastic Index

Plastic Index		
Liquid Limits	Plastic Limit	Plastic Index
35.3	10	25.3

The plastic index is calculated by subtracting the total percentage of plastic limits from the weighted average of the liquid limit. In this case, if the liquid limit average is 35.3 grams and the plastic limit is 10 grams, the plastic index calculated would be 25.3 grams.

3.1.1 Result of Oxide/Elemental Analysis using XRF

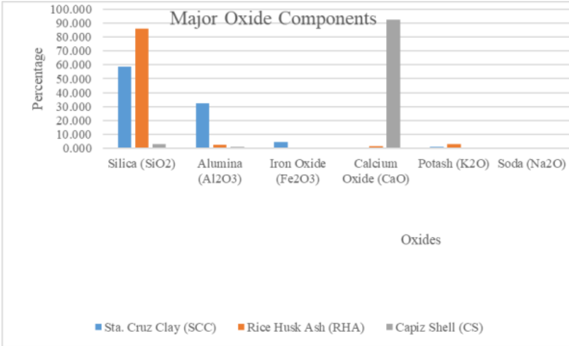

Figure 8: Major Oxide Components.

The main elements from the materials themselves are displayed in the figure. It demonstrates that Sta. Cruz clay contains 58.450% silica, 32.450% alumina, 4.815% iron oxide, 0.858% calcium oxide, and 1.21% potash. Furthermore, rice husk ash has the following composition: 85.850% silica, 2.37% alumina, 0.785% iron oxide, 1.430% calcium oxide, and 3.220% potash. The Capiz shell comes in last, with 2.935% silica, 1.350% alumina, and 92.400% calcium oxide. These ingredients, such as silica, alumina, and fluxes, which are required to make clay bricks, come together in key components.

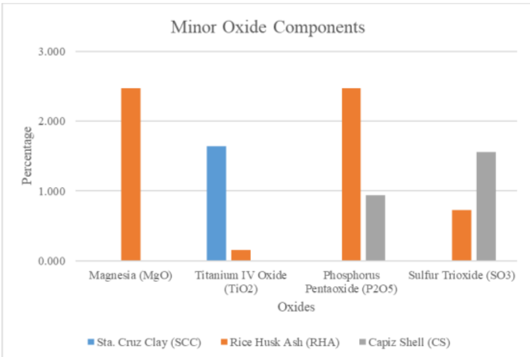

Figure 9: Minor Oxide Component.

The trace elements included in the elemental analysis using XRF are depicted in the graph above and do not need to be combined with the composition to manufacture clay bricks. These elements include magnesia, titanium, phosphorus, pentoxide, and sulfur oxide. Figures 10 and 11 of the graphs display the percentage of the major and minor oxides. It shows that the major components are the most important in the making of clay bricks, as they provide a strong combination to prevent cracking.

3.1.2 Process Flow Chart

The process flow chart in Figure 11 involves obtaining raw materials, including Sta. Cruz clay, capiz shell, and rice husk. These materials undergo sun exposure, crushing, and filtering to obtain powdery materials. After obtaining the powders, they are thoroughly mixed with water; the mixture consists of Sta. Cruz clay, rice husk ash, and capiz shells in different ratios, namely 1:3:16, 1:4:45, and pure clay. The mixture is then transferred to a mold. The mold is aired for 2 weeks, exposed to the sun for 2 weeks, baked for 1 day, and fired for 1 day. This process ensures the production of high-quality, durable materials.

Table 10. Mixture Ratio of Sta.Cruz Clay, Rice Husk Ash, Capiz Shell, and Water.

Mixture #	Ratio	%SCC	%RHA	%CS	Water
Mixture 1	1:3:16	80%	15%	5%	1.5 L
Mixture 2	1:4:45	90%	8%	2%	1.5 L
Mixture 3	1	100%	N/A	N/A	1.5 L

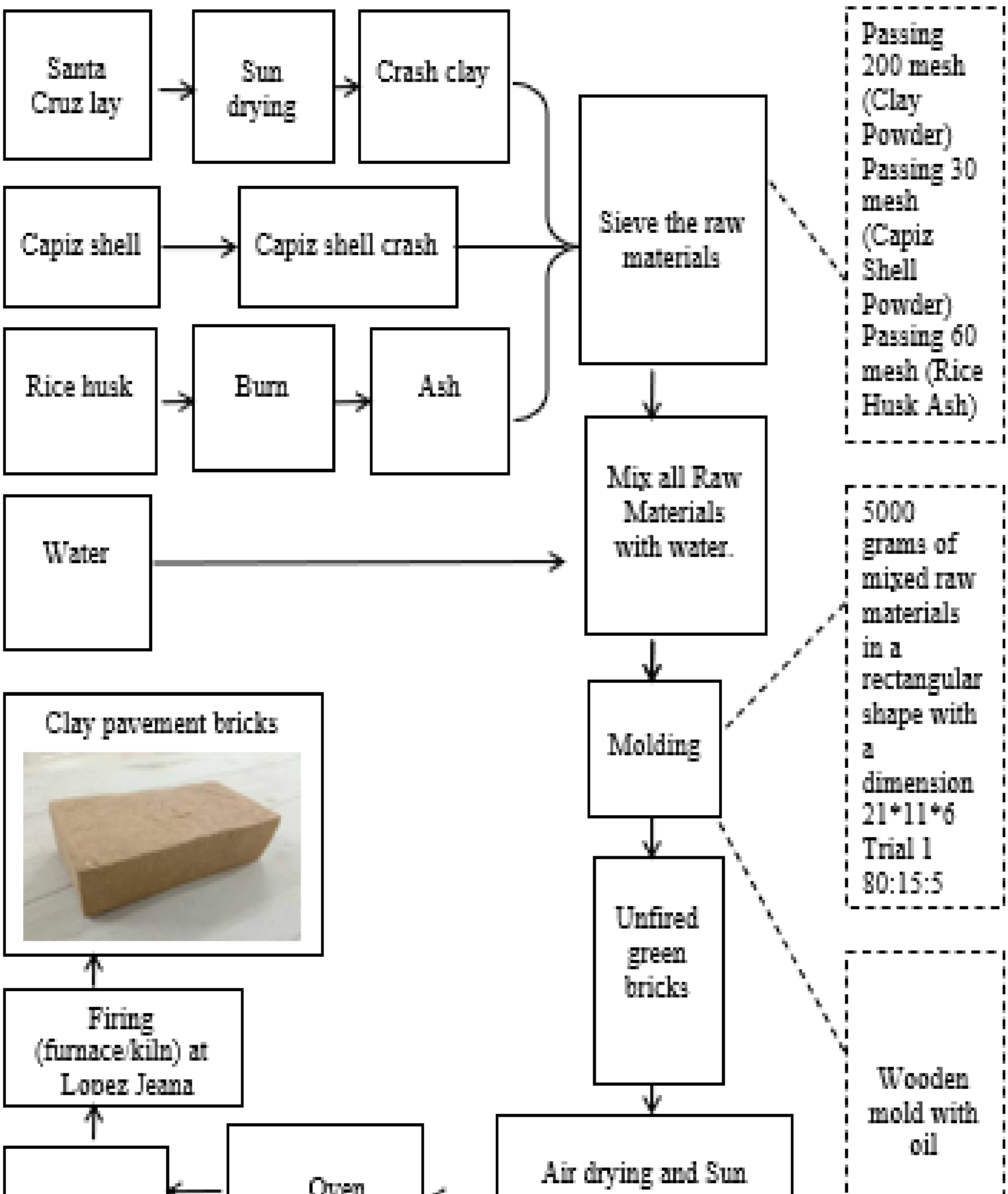

Figure 10: Process Flow Chart

3.1.3 Determining the physical properties (percent shrinkage, weight loss, and water absorption) of fired bricks of the optimized formulation

Table 11: Percent Shrinkage

Sample	Composition (Ratio)	V_s	V_m	Shrinkage (Volume)	Percent Shrinkage
1	80:15:5	1931	2640	26.86	1.02%
2	90:8:2	2272	2640	14	0.35%
3	100	N/A	2640	N/A	N/A

The study computes the percentage shrinkage by cubic meter for each sample brick. This involved subtracting the volume of the sample from the volume of the mold to obtain the volume shrinkage, which was then divided by the volume of the mold and multiplied by 100 to determine the percentage.

As depicted in the table above, the percentage shrinkage was calculated for three trials with different formulations. In the first trial, the achieved volume was 1931 cu.m. After subtracting this from the volume of the mold (2640 cu.m.), the volume shrinkage was found to be 26.86 cu.m. This was then divided by 2640 and multiplied by 100, resulting in a percentage shrinkage of 1.02%. In the second trial, with a achieved volume of 2272 cu.m., the volume shrinkage was calculated similarly, yielding a percentage shrinkage of 0.53%. However, in the case of trial 3, which consisted of 100% pure Sta. Cruz clay, the calculation was not applicable as the sample broke after being fired.

Table 12: Weight Loss

Green Pavement Bricks	Fired Pavement Bricks	Weight Loss
2.1 kg	1.207 kg	42.5%

Based on the three trials, the first sample, which had a formulation of 80% clay, 15% rice husk ash, and 5% capiz shell, survived. The weight of this fired sample, which was 1.207 kg, was subtracted from the weight of the green pavement bricks, which was 2.1 kg. The result was then divided by the weight of the green pavement bricks and multiplied by 100, yielding a weight loss of 42.5%. If the weight change of the green pavement bricks is less than 5% of the visual body weight, the weight change is considered not significant.

Table 13: Water Absorption

Boiled Fired Bricks	Unboiled Fired Bricks	Water Absorption
1.607 kg	1.207 kg.	33.1%

The water absorption is calculated by subtracting the weight of the unboiled fired pavement bricks from the weight of the boiled fired pavement bricks, resulting in a water absorption of 0.4 kilograms or 33.1%.

3.1.4 Result of the economic advantages through costing analysis in comparison to Clay Bricks in market

Table 14: Costing Analysis

Item No.	Parameters	Existing product in the market	Sta. Cruz clay, rice husk ash, and Capiz
1	Thickness	4 cm	5.5 cm
2	Width	10 cm	9.5 cm
3	Lenght	19.5 cm	18.5 cm
4	Place of Origin	Lopez Jaena	Labuyo, Tangub City
5	Color	Red	Light Brown
6	Weight	1.220 kg.	1.207 kg.
7	Price per Piece	₱12.00	₱5.53

The clay pavement bricks available in the market and the newly developed pavement bricks differ in several aspects such as size, origin, color, weight, and price. The existing product sourced from Lopez Jaena is typically red in color and slightly heavier. In contrast, the pavement bricks composed of Sta. Cruz Clay, Rice Husk Ash, and Capiz shell, originating from Labuyo, Tangub City, exhibit a light brown color and are priced lower. Customers have the flexibility to choose based on their preferences and budget, considering factors like size, color, weight, and price.

3.2 Responses of respondents as to the design and operation

Table 15: Evaluation as to design

AS TO DESIGN	3		2		1		Total			Verbal Description
	F	W	F	W	F	W	F	W	$\bar{X}$	
1. The project measures 20cmx10cmx6cm exactly/considerably as planned.	5	15	1	2	-	-	6	17	2.83	Very Acceptable
2. The product is made from 80% of Sta.Cruz Clay, 15% of Rice Husk Ash, and 5% of Capiz Shell.	5	15	1	2	-	-	6	17	2.83	Very Acceptable
3. The Project weight 1.207 kl. per bricks.	3	9	3	6	-		6	15	2.5	Very Acceptable
4. The Project Design for paving.	5	15	1	2			6	17	2.83	Very Acceptable
5. The project considered new materials.	5	15	1	2			6	17	2.83	Very Acceptable
TOTAL							30	83	2.76	Very Acceptable

The table above presents the evaluation results as assessed by the experts. In parameter 1 (The project measures 20 cm. x 10 cm. x 6 cm. as planned), the experts rated it 2.83, signifying it as very acceptable, as the actual size of the project matched the specified measurements. Parameter 2 (The product is made from 80% of Sta.Cruz Clay, 15% of Rice Husk Ash, and 5% of Capiz Shell) also received a rating of 2.83, indicating its very acceptability, as the project indeed consisted of the specified proportions of materials. Parameter 3 (The project weighs 1.207 kg per brick) was rated 2.5, still denoting it as very acceptable, as the project's weight matched the planned weight upon testing. For parameter 4 (The project was designed for paving), the experts rated it 2.83, again deeming it very acceptable, as the project was clearly intended for paving purposes only. Lastly, parameter 5 (The project considered new materials) received a rating of 2.83, also classified as very acceptable, as the project utilized new materials, including Sta. Cruz clay, Capiz shell, and rice husk ash, which had not been previously combined in existing studies. The overall weighted mean from the experts' evaluations was 2.76, indicating a very acceptable rating for the project.

The table 17 illustrates the results of the evaluation as assessed by the experts. In parameter 1 (The project can be installed one by one using mortar cement), the experts rated it 2.66, indicating it as very acceptable, as the project can indeed be installed using mortar cement. For parameter 2 (Half sack (25 kgs.) of processed clay can produce 10 pieces of bricks), the experts also rated it 2.66, signifying it as very acceptable, since 1 piece of brick contains 2.5 kgs. of processed clay. However, in parameter 3 (The product is visually appealing), the experts rated it 2.16, classified as acceptable, due to its lighter color compared to existing commercial bricks. In parameter 4 (The product has been tested to have 0.04% water absorption, limiting external damage from water penetration), the experts rated it 2.66, again denoting it as very acceptable, as the water absorption did not exceed the maximum allowable limit. Finally, in parameter 5 (The project ensures the preparation of bricks with excellent performance), the experts rated it 2.5, indicating it as very acceptable, as the project allows for easy joining of bricks using mortar cement. The overall weighted mean from the experts' evaluations was 2.53, classifying the project as very acceptable.

Table 16: Evaluation as to acceptability

AS TO ACEEPTABILITY	3		2		1		Total			Verbal Description
	F	W	F	W	F	W	F	W	$\bar{X}$	
1. The project can be filled one by one using the mortar cement.	4	12	2	4	-	-	6	16	2.66	Very Acceptable
2. Half sack (25 kls.) of processed clay can produce 10 pcs. of bricks.	4	12	2	4	-	-	6	16	2.66	Very Acceptable
3. The product is visually appealing.	1	3	5	10	-	-	6	13	2.16	Acceptable
4. The project is tested to be 0.04% of water absorption which limits the external damages in water penetration.	4	12	2	4	-	-	6	16	2.66	Very Acceptable
5. The project ensures the preparation of brick with excellent performance.	3	9	3	6	-	-	6	15	2.5	Very Acceptable
TOTAL							30	76	2.53	Very Acceptable

Table 17: Evaluation as to application

AS TO USES	3		2		1		Total			Verbal Description
	F	W	F	W	F	W	F	W	$\bar{X}$	
1. Pavement Bricks	6	18	-	-	-	-	6	18	3.00	Very Acceptable
2. Wall Bricks/Filling	4	12	2	4	-	-	6	16	2.66	Very Acceptable
3. The project can be use as exterior and interior design.	4	12	2	4	-	-	6	16	2.66	Very Acceptable
4. High pottery temperature bricks (kiln bricks)	4	12	2	4	-	-	6	16	2.66	Very Acceptable
TOTAL							24	66	2.75	Very Acceptable

The table provided in Table 18 illustrates the results of the evaluation as conducted by the experts. In parameter 1 (Pavement Bricks), the experts rated it 3.00, indicating it as very acceptable, as the product is designed specifically for use as pavement bricks. Moving on to parameter 2 (Wall Bricks/Filling), the experts assessed it at 2.66, also considered very acceptable, since the product can be utilized in wall bricks/filling for design purposes, although it is not intended for heavy construction. Furthermore, in parameter 3 (The project can be used for exterior and interior design), the evaluators rated it 2.66, once again deeming it very acceptable, given that the product can serve both exterior and interior design purposes. Finally, in parameter 4 (High pottery temperature bricks (kiln bricks)), the experts rated it 2.66, also classifying it as very acceptable, as the clay pavement bricks are fired in high-temperature kiln bricks. The overall weighted mean from the experts' evaluations was 2.75, indicating that the project was deemed very acceptable

4. Conclusion

In conclusion, the development of pavement bricks utilizing Sta. Cruz clay, rice husk ash, and Capiz shell as additives yields the following key points:

1. The Sta. Cruz clay exhibited a high plasticity index of 25.3.

2. Oxide analysis revealed that the Sta. Cruz clay has a higher silica content compared to Lopez Jaena clay.

3. Among the three trials, the formulation with 80% Sta. Cruz clay, 15% rice husk ash, and 5% Capiz shell (1:3:16 ratio) showed no visible cracking.

4. The percent shrinkage of the final product is 22.16%, with dimensions reduced to 19.5×9.5×5.5 from the original 21×11×6.

5. The weight loss during firing is 42.5%, and the water absorption rate is 33.1%.

6. Raw materials must be powdered, and the final product must undergo a drying process of no less than 2 weeks (air drying and sun drying).

7. The pavement bricks produced in this project are more cost-effective, priced at approximately 6 pesos each compared to the market price of 12 pesos each.

8. Overall, the product received high acceptability ratings in terms of design, acceptability, and uses.

It is recommended to vary the formulation of the raw materials for several applications such as pots, souvenirs, and filling bricks. Another approach to production methods, like slip casting, should be tried. Effective mixing tools should be used to precisely control and ensure the mixing process of the materials. Appropriate testing equipment, such as a universal testing machine (UTM), should be used for accurate measurement of the compressive strength of the product. Efficient compaction methods should be employed in the manufacturing process to prevent the misalignment of the product. Additionally, it is essential to determine the mechanical properties of the bricks with respect to ASTM standards for pavement bricks. Furthermore, SEM-EDS characterization of the produced bricks should be conducted to analyze their composition and microstructure. Lastly, for identifying the effectiveness of the clay, future researchers should conduct a study first about the type of clay used in this study.

5. Acknowledgement

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