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UTILIZATION OF RICE STRAWS AS FIBER REINFORCEMENT IN RICE HUSK ASH CEMENT BONDED BOARD

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Abstract: **The purpose of this research is to develop an alternative material for composite board that will utilize wastes which are produced by the rice industry. Wood species, agricultural fibrous residues as well as agricultural wastes can be applied inside the fabrication of composite boards, this led the researchers to use the wastes from rice plantations as a raw material for the product. The results showed the significance of the quantity of materials to be used, the Modulus of Rupture Test reveals the strength of 70:30 binder to fiber Ratio to be 6.23 megapascals, in Face Screw Holding Test and Nail Head Pull Test, the board passed having a strength of 105.90-kilogram force and 95.39-kilogram force. The results of Thickness Swell Test showed that the amount of swell of the board after the test is 12.29%, and the amount of moisture of the board is 6.59% which were determined using the Moisture**

Keywords: **Rice Straw, Cement Board, Rice Husk Ash, Cladding.**

I. INTRODUCTION

Building materials cost has increased over the past years. Rapid population growth combined with low income has become a hindrance in the goals of building shelters. This has led to researches in the development of alternative construction materials that is versatile, strong, and relatively low cost. One of such desirable alternative raw construction materials are composite boards which are made from wood-based products. Wood species, agricultural fibrous residues as well as agricultural wastes could be utilized in the fabrication of composite boards.

One of the types of composite boards used in the industry is cement bonded particle board. Cement bonded particle boards has a wide variety of use such as for wall cladding interior surfaces in applications where the surface must be durable, wear-resistant and with good sound insulation properties plus moisture proof and fungus resistant. DOST-FPRDI has also introduced uses for cement bonded particle boards as materials for construction of cabinets, tables, and as accent to wood chairs. Economic potentiality in utilization of rice hull ash and rice straws in production of cement bonded particle board shall be studied in this research.

Being an agricultural country, rice plantations could be found all over the country. During the milling process, only the hulled rice grains are sold and consumed by humans leaving behind the rice straws and rice husks after the milling process. These materials are either burned down contributing to air pollution or left at the fields to decompose and to be utilized as fertilizers. Researches have been conducted and proven that rice husk ash could be utilized as partial cement substitute. It was discovered by researchers in our country and abroad that 25% replacement of rice hull ash in cement exhibited no degradation in strength. Rice straws which are also burned could be used as reinforcing fibers to cement bonded board which could be a sustainable building material.

Philippines produces 15.2 million tons of rice which leaves at about 11.3 million tons of rice straws every year. Rice straws are burned during harvest season causing air pollutants such as carbon dioxide, carbon monoxide, nitrogen oxide, and Sulphur dioxide. According to researches, if such practice was continually done, it will decrease soil's nitrogen. This practice also damages food resources and beneficial insects that are present in the rice fields. These amount of rice straws disposed contribute to the amount of unrecycled wastes. Aside from being used as fertilizers, other alternative uses to the rice straws are encouraged to maximize the use for agricultural products. [8]

Rice hull is a byproduct of rice milling process which are put to waste every harvest season. It was found that in one ton of rice harvested, about 200 kilograms came from rice husk. In addition to this, the huge production of cement industry has a major contribution to pollution. Finding ways in reduction of usage of cement would be beneficial for the environment as it would also mean reduction of the carbon dioxide used in the construction. Researchers discovered that rice husk ash is composed of 205 silica in amorphous form which furthermore proved that rice husk ash from open heap burned rice husk could be used as a partial cement substitute. It was found that by weight ratio, 25% of cement weight could be replaced by rice husk ash without compromise in compressive strength. [13]

The researchers utilized the two components: rice straws and rice husk ash to develop a composite board that would meet the Philippine Standard for Composite Board and Joint Australian/New Zealand Standard in terms of physical and mechanical characteristics. The composite board produced shall not only help reduce the cost of a building but would also be environment friendly for it would introduce a new usage for the material components that were normally considered as wastes. The composite boards will undergo tests that will identify its physical and mechanical properties to determine its sustainability as a building material.

This research aims to investigate the economic utilization of rice straws and rice hull ash by utilizing the aforementioned materials in production of cement bonded particle boards.

Objectives of the Study:

The general purpose of this study was to utilize rice straws and rice husk ash, in the development of a cement bonded particle board that could be used in the industry. Specifically, the study aimed to:

1. Determine the mechanical properties of the cement-bonded particle board produced.

2. Determine the physical properties of the cement-bonded particle board produced.

3. Identify which of the proposed mix design of Portland cement with rice husk ash to rice straw proportion that would meet the Philippine National Standard and Joint Australian/New Zealand Standard for composite board.

Significance of the Study:

This study shall give the following benefit to both the construction industry and the environment particularly:

1. Environment, for it will help lessen the agricultural wastes that are burned down contributing to the air pollution. This would also help reduce the amount of rice hull ash that might be carried by the wind and would further pollute the air and soil.

2. Local Farmers, for it would open opportunity to have an alternative source of income. The procedure for the production of the composite board is simple and could be replicated to sell the produced boards at a price.

3. Future researches in the industry, for it would help provide a baseline of information for better usage of rice straws as reinforcement and rice husk ash as a partial cement replacement in cement bonded particle boards. This will raise awareness that the industry could also depend on the usage of rice husk ash as a partial cement substitute.

Scope and Delimitations

This research only covers the development of cement bonded board using rice husk ash as a partial cement substitute in composite boards and rice straws as reinforcing fiber. This research only focuses on the sustainability of the materials as cement bonded boards based on physical properties including; Water absorption, Thickness Swelling, Relative Density, and Moisture Content and mechanical properties such as Modulus of Rupture, Direct Screw Withdrawal, Nail Head Pull-Through. Three different cement and rice husk ash to rice straw ratio will be used to identify the properties of the composite board that will be compliant to the standards. Such ratio includes 50/50, 60/40, and 70/30 binder to reinforcement ratio. This study is limited only in the analysis of the test conducted to assess the ability of the bonded board to suffice the requirements of Philippine National Standard and Joint Australian/New Zealand Standard for composite board. This research shall also cover the cost analysis of each composite board by comparison to commercially available cement-bonded particle boards.

Definition of Terms

To understand the preparation of the cement bonded boards, the following technical terms must be clarified:

Cellulose: is the main substance found in plant cell walls and helps the plant to remain stiff and strong.

Cement: a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. There are two main forms of cement: Geopolymer cement and Portland Cement

Deforestation: clearance, clearcutting or clearing is the removal of a forest or stand of trees from land which is then converted to a non-forest use.

Modulus of Rupture: is a measure of the maximum load-carrying capacity or strength of the crosstie and is defined as the stress at which the material breaks or ruptures

Particle Board: material made in rigid sheets or panels from compressed wood chips and resin, often coated or veneered, and used in furniture, buildings, etc., where a stronger material is not required.

Plywood: a material manufactured from thin layers or "plies" of wood veneer that are glued together with adjacent layers having their wood grain rotated up to 90 degrees to one another.

Rice: is the seed of the grass species *Oryza sativa* or *Oryza glaberrima*. As a cereal grain, it is the most widely consumed staple food for a large part of the world's human population, especially in Asia.

Rice Husk: The hard-protecting coverings of grains of rice

Rice Husk Ash: byproduct of burning of rice hulls

Rice Straw: is the vegetative part of the rice plant, cut at grain harvest or after.

Sodium Hydroxide: highly caustic base and alkali that decomposes proteins at ordinary ambient temperatures.

Silica: is the name given to a group of minerals composed of silicon and oxygen, the two most abundant elements in the earth's crust.

II. LITERATURE REVIEW

This chapter focuses on the study of the components of the mixture used in the experimentation and the potentiality of the rice straw and rice husk ash to be utilized as a component in the building of a composite board.

Unprocessed Rice Husk Ash as a Partial Replacement of Cement for Low-Cost Concrete

Concrete is a vital component in construction as it was utilized in the development of stable structures. A lot of countries find it costly to produce cement, an important component of concrete because most of the time, it needs to be imported from foreign producers. In rice-delivering nations rice husk ash is a material, normally high in silica, can be utilized as a beneficial cementitious material and can substitute a portion of Portland bond in cement without compromise to the compressive strength. This led to researches regarding the utilization of Cambodian rice husk ash in 10%, 20% and 30% substitutions of Portland bond by mass in mortar, without streamlining of the ash by controlled burning. Rice Husk Ashes gathered from various sources in Cambodia were evaluated for their appropriateness for use in rustic Cambodian development by means of compressive strength testing of 2 inches cylinder mold. A 20% substitution of natural Cambodian rice husk ash was considered proper for use in small scale, rustic auxiliary applications. Low-tech techniques for producing these ashes were additionally explored and were found to build the compressive quality of rice-husk-ash-concrete mortars in contrast with mortars made with unground RHA. [3]

Evaluation Possibilities to Utilize Rice Straw and Plastic Waste for Particle Board

Rice straw is an inexhaustible waste from nearby rice field in Asia. Plastic is likewise an inexhaustible waste in numerous nations which harms nature truly, while the requirement for wood keeps on expanding. To overcome these natural issues, we have built up a particleboard from rice straw by utilizing plastic waste polypropylene as a grid with the rice straw creations of 30, 40, 50, 60, and 70 percent by weight. Some physical properties (thickness and thickness swelling) and mechanical properties (modulus of break, modulus of flexibility, and compressive quality) of the particleboard have been estimated. Our outcomes demonstrated that the thickness of rice straw polypropylene particleboard is observed to be 0.56 grams per cubic centimeter to 0.8 grams per cubic centimeter. Its thickness swelling after inundation in the water for 24 hours is under 5%. Its modulus of crack is observed to be 83 to 134-kilogram force per cubic centimeter. The modulus of flexibility is $3.3x10^4$ to $4.5x10^4$ kilogram force per square centimeter and the compressive quality is about 6.7 Megapascals. Our investigation uncovered that the rice straw polypropylene particleboard with the rice straw pieces of 30, 40, 50, and 60 percent by weight fulfills the Indonesian National Guideline and Japanese Industrial Standard necessities for particleboard.

[5]

Synthesis

In rice-producing countries, rice husk ash is abundant. It is a material normally high in silica and can be utilized as a sustainable cementitious material and can substitute a segment of Portland bond in cement without giving up the compressive strength. The rice husk ash (RHA) contains 85 % to 90 % amorphous silica which is also a component of Portland cement. Cellulose fibers that can be found in rice straws proves that this material has a degradation temperature of more than 280 degree Celsius which also means that rice straws is a durable and suitable material for composite boards and concludes that it can be utilized as material for composite board.

According to statistics conducted from 1984, the Philippines produces around 1.57 million tons of palay which generates about 11.8 million tons of rice straw, by utilizing this material as reinforcement for composite board, the deficiency of construction materials can be reduced. A present, there are rice mills in rice producing industry have begun utilizing Rice Husks for the energy production operation just as household lighting in provincial areas. Burning of rice husks produces the rice husk ash (RHA). This could be used as source for rice husk ash that is used for the production of the composite board.

III. RESEARCH METHODOLOGY

This chapter covered the methods prepared upon the experiment, the materials and its properties.

Collection of Materials:

- **Rice Straw-** The primary component that was used in this study. It is the vegetative part of the rice plant. It is commonly left at the fields to decompose or burned after the harvest season. The researchers collected the rice straws from a local farm in Palangue II, Naic, Cavite. The rice straws are washed down with running water cut down to 2-4 cm length. It was then boiled down to 10% sodium hydroxide solution for 2-3 hours to assure that the hemicellulose and lignin has been completely broken down. These substances may lead to incompatibility between rice straw fibers and cement. After boiling, the rice straw fibers are set to sun dry before mixing.

- **Rice Husk Ash**- The byproduct of burning rice hulls. With the presence of amorphous silica, it is a suitable partial cement replacement that will be used as a binder in the project. 20% weight of the cement will be replaced by rice husk ash. The RHA that will be used in this research must pass the #200 sieve. The researchers also collected the RHA from the same farm from which they gathered the rice straws.

- **Cement-** The type of cement that was used in this research is type 1 cement or general use Portland cement.

- **Water-** The water that was used in this research is tap water which is clean, free from oil, alkali, acid, and organic matter.

- **Equipment Apparatus-** The research made use of Trowel, container, wood forms, and wood clamps.

Composition of the Materials with Varying Ratio:

The formwork used in the research has the inner dimension of 30 centimeters by 30 centimeters with a target compressed thickness of 1.2 centimeters. The target board density is 1.2 grams per cubic centimeter. The target mass of materials 1296 grams. 20% of the original computed mass of the binder has been replaced by rice husk ash.

The respective mixture for the different binder to fiber ratio is shown on Table 1.

Table 1: Specimen Chart

Rice Straw to Binder Ratio	50/50	60/40	70/30
Cement (grams)	471.45	565.77	664.50
Rice Straw (grams)	902.20	721.50	547.30
Water (grams)	419.50	536.50	478.00
Rice Husk Ash (grams)	157.15	188.59	221.50

Mixing:

The RHA and cement were firstly mixed together until homogenous form of the cement was achieved. The fibers are placed in the mixing pan first then cement was put on the fiber to make sure the cement would cover the fiber evenly. Then after the cement was equally distributed, water was poured onto the mixture.

Figure 1: Mixing of the dry components prior to addition of water.

Mat Forming:

After the mixing procedures, the mixture was then poured down into the mold and distributed by hand along a wooden plate with volumetric control to maintain uniform sizes into a 30-centimeter x 30-centimeter mold.

Figure 2: Pouring of the mixture to the mold

Cold Pressing:

The mold is closed after pouring and was dry pressed with a hydraulic jack at a constant pressure of 1.23 Megapascals then held down by wood clamps. The molds are kept at a dry place for 24 hours to let the mixture settle and hold its own form.

Figure 3: Pressing of the board with the use of hydraulic press then clamping the board.

Curing and Conditioning:

After 24 hours, the particle boards are demolded and kept at a dry place with constant humidity for the next 28 days to let the mixture cure and achieve its full strength and prepared for testing.

Testing

In order to determine the physical and mechanical properties of the composite boards, the specimen underwent numerous tests. The test followed the guidelines and test procedures set forth the American Society for Testing and Materials D1037 (Standard Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials.) The aforementioned test procedures include: Moisture Content Determination, Water Absorption Test, Thickness Swell Test, Modulus of Rupture Test, Direct Screw Withdrawal, and Nail Head Pull-Through.

Properties Requirement

In order to identify whether the cement bonded board shall be suitable for usage in the country, the specimen must pass the standards set forth by Philippine National Standards for Composite Boards (PNS 230:1989).

Table 2: Philippine National Standards for Composite Boards

Properties	Modulus of Rupture (Megapascals)	Face Screw Holding /Nail Head Pull-Through (kilogram force)	Thickness Swell (%)	Water Absorption (%)
Type 200	17.652	50		
Type 150	13.729	40	20% max	30% max
Type 100	7.845	30		

Joint Japan, Australian and New Zealand set standards for their wood-based panels to identify whether such could comply with the requirements for usage in dry conditions.

Table 3: Joint Japan, Australian and New Zealand Standard Requirement for Composite Board

Property	Test Method	Unit	Requirement				
			Thickness Ranges(millimeters, nominal)				
			>5 - 8	>8 - 12	>12 - 22	>22 - 33	>33
Bending Strength	JANS 6	Newton per square millimeter	15	13	12	10	9
Thickness Swell	JANS 7	%	30	25	20	18	18

Data Validation

Physical and mechanical properties test of the specimen are conducted by the proponents in Technological University of the Philippines. In order to showcase that the results obtained are legally valid, the physical and mechanical properties test results are attached in the appendices to serve as a proof that actual physical and mechanical tests are going conducted. The test certificates were signed and validated by the laboratory technician and two faculties of the Technological University of the Philippines.

IV. RESULTS AND DISCUSSION

Physical Properties

This section discusses the results of the tests conducted to determine the physical properties of the Rice Straw Fiber Reinforced Rice Husk Ash Cement bonded board. Each test conducted took three trials and the average results were tabulated as follows:

Board Density

The produced cement bonded board has been classified to as high-density composite board obtaining the target density of 1.2 grams per cubic centimeter. The amount of pressing force is significant to maintain the target density of the composite board as it would help maintain the volume of the specimen since mass of the samples are held constant.

Moisture Content

Table 4: Percentage of moisture content in the specimen

Binder to Fiber Ratio	Moisture Content (%)
50/50	16.48%
60/40	6.52%
70/30	5.17%

In the above table, it is observed that moisture content of the material ratio of 70/30 is composed of 70% binder and 30% fiber, produced the least value for moisture content, while the material ratio of 50/50 which is composed of 50% binder and 50% fiber has exhibited the highest moisture content among the different ratio with values of 5.17% and 16.48% respectively.

Thickness Swelling

Table 5: Thickness Swell of the boards after 24 hours of soaking

Binder to Fiber Ratio	Thickness Swell (%)	PNS Maximum Value (%)	JANS Maximum Value (%)
50/50	14.33%	20%	30%
60/40	12.29%	20%	30%
70/30	6.30%	20%	30%

Table 5 shows the values of board thickness swelling. The value on the right shows the maximum value allowed by Philippine National Standard and Joint Japan, Australian, and New Zealand Standard for composite boards respectively. It is observed that thickness swelling of the 70:30 binder to fiber ratio having value of 6.30% which swelled the least due to higher cement content bringing dimensional stability, while the highest value for thickness swell was recorded for the binder to fiber ratio of 50:50 having a value of 14.33%. The behavior of the graph has exhibited that the higher the binder content, the lesser the board would swell when subjected to water soaking. Having more binder improves the overall dimensional stability of the composite boards. All the results from the three binder to fiber ratio setup has passed the Philippine National Standard and Joint Japan, Australian, and New Zealand Standard for composite boards which sets the limitation to 20% and 30% respectively for maximum thickness swell.

Water Absorption

Table 6: Percentage of Water Absorption of the boards after 24 hours of soaking

Binder to Fiber Ratio	Water Absorption (%)	PNS Maximum Value (%)
50/50	32.69%	30%
60/40	23.51%	30%
70/30	22.22%	30%

Table 6 shows the values of board water absorption. The value on the right column is the standard set by Philippine National Standard which limited to 30% of the original mass. It is observed that the Water absorbed by the 70/30 binder to fiber ratio has observed for having the least water absorption having a value of 22.22% increase in mass after being soaked for water for 24 hours which passed the Philippine National Standard limitation of 30%. The value of water absorption recorded at 60/40 binder to fiber ratio was recorded to be 23.51% which also passed the Philippine National Standard for composite boards. The highest value of percentage of water absorption has recorded was measured at 50/50 binder to fiber ratio having a value of 32.69% which surpassed the maximum value limited by Philippine National Standard causing it to fail the said standard. Similar to Thickness Swell, it is also observed that having less amount of fiber exposed in the mixture also helped it to absorb water less.

Mechanical Properties

This section discusses the results of the tests conducted to determine the mechanical properties of the Rice Straw Fiber Reinforced Rice Husk Ash Cement bonded board. Each test conducted took three trials and the average results were tabulated as follows:

Modulus of Rupture

Table 7: Effects of material ratio to Modulus of Rupture of the boards

Binder to Fiber Ratio	Modulus of Rupture (Megapascals)	PNS Minimum Requirement (Megapascals)	JANS Minimum Requirement (Megapascals)
50/50	2.113	7.84	15
60/40	3.293	7.84	15
70/30	5.603	7.84	15

The 28-day average Modulus of Rupture of the rice husk ash cement bonded board is listed in the figure. It is observed that the binder to fiber ratio of 70/30 has achieved the highest value of the Modulus of Rupture with 5.603 Megapascals. However, the aforementioned board did not suffice the mechanical standard set forth by Philippine National Standard PNS 230:1989 and Joint Japan, Australian, and New Zealand Standard for composite board.

It is also observed that the 50/50 binder to fiber ratio produced the least value for Modulus of Rupture with a value of 2.113 Megapascals.

The values show that the flexural strength of the boards increases as the amount of binder increases. It is due to the low density of the rice straw fibers which means that the volume of fiber would require more binder. Utilization of Rice Husk Ash in cement bonded particle boards is possible as demonstrated in the results. Not passing the Modulus of Rupture requirement set by Philippine National Standards could still be addressed by increasing the number of studs and reducing the spaces between them when used as cladding.

Nail Head Pull-Through

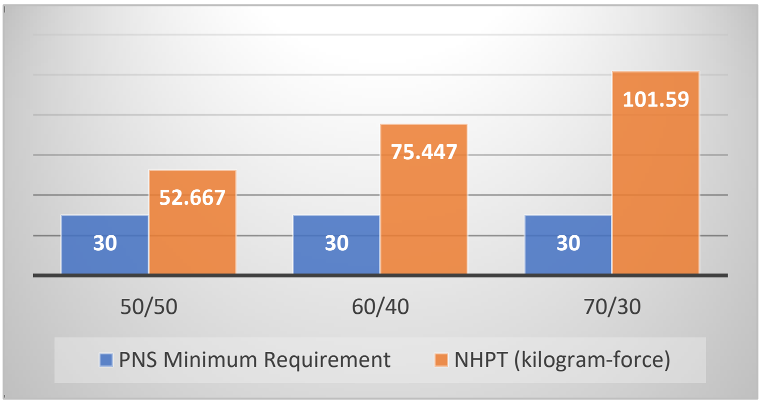

Figure 4: Effect of material ratio to Nail Head Pull-Through Resistance of the boards

The 28-day average nail head pull-through of the rice husk ash cement bonded board is demonstrated in the figure. It is observed in the 50/50 cement to fiber ratio has produced the least values for Nail Head Pull-Through with 52.667 kilogram-force. The highest value for Nail Head Pull-Through recorded was the 70/30 binder to fiber ratio with a value of 101.59 kilogram-force. All of the values passed the 30 kilogram-force requirements set forth by Philippine National Standard PNS 230:1989 for composite boards.

The results indicated that the boards have the sufficient fiber to resist the nail from passing through the board. It can be observed that as the amount of binder in the increases, the force to pull through a nail through the board also increases. The fibers also prevented the board from splitting in half while the nail has been pulled through the board. This is attributed to the effective interlocking of the fibers when a parallel force is applied to the cross section of the board.

Direct Screw Withdrawal

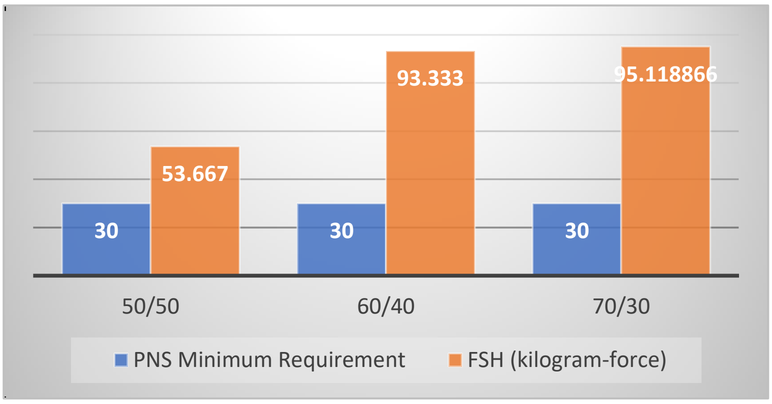

Figure 5: Effect of material ratio to screw withdrawal resistance of the boards

The following figure illustrates the force required to directly withdraw a screw from the board. It has been observed that 70:30 binder to fiber ratio has exhibited the highest value for face screw holding strength with a 95.12 kilogram-force while 50/50 ratio required about 53.667 in order for the screw to be withdrawn from its surface. All of the recorded values have passed the requirement set forth by Philippine National Standard PNS 230:1989 for composite boards. This test measures the capability of the board to hold a load screwed to its surface.

It is observed that increasing the amount of binder helps the fiber to interlock better and have a stronger grip strength. The results also demonstrated that there is an enough amount of fiber in the rice husk ash cement bonded board to resist a screw from being withdrawn directly from its surface, however increasing the amount of binder has its advantages in the mechanical properties of the particle board.

V. SUMMARY, CONCLUSION, AND RECOMMENDATION

Summary:

This study aimed to determine the physical and mechanical properties of rice straw as reinforced fiber materials in cement bonded board. The materials used in achieving the rice straw fiber as reinforced fiber in bonded board are rice straw, Portland cement, water, molder, C-clamp and measuring materials. The researcher used a 50:50, 40:60 and 30:70 ratio of rice straw to binder. The method of research used in achieving rice straw as reinforce fiber in cement bonded board are data gathering and procedure, design mixture and the proportion of mixtures of the specimen, mixing and casting procedure, and the specimen will be air dry for 28 days curing. The researchers found that 30% rice straw: 70% binder considered to be the most effective in terms of physical and mechanical properties which attained 5.603 Megapascals for Modulus of Rupture and passed the Philippine National Standard and Joint Australian/New Zealand Standards requirement for thickness swelling, water absorption, moisture content, nail pull head through and face screw withdrawal having a value of 6.30% for thickness swell, 22.22% for Water Absorption, 5.17% for Moisture Content, 101.58 kilogram-force for Nail Head Pull-Through, 95.11 kilogram-force for Face Screw Holding Strength.

Conclusion:

After the experimentations it has been concluded that Rice Husk Ash could be utilized in the production of cement bonded boards. The 20% partial replacement of Rice Husk Ash to cement still allowed the composite board to decrease the cost without any significant degradation to strength. The result for the testing of modulus of rupture showed the 70:30 binder to fiber ratio of the rice husk ash cement board to be the highest which is 5.603 Megapascals and the lowest is 50:50 which has a strength of 2.113 Megapascals, the test of Nail Head Pull-Through also showed that the 70:30 ratio obtained the highest strength for pulling a nail that has an average of 101.59 kilogram-force, and the ratio which has the least strength is the 50:50 ratio which has 52.667 kilogram-force. The last test for the mechanical properties of the board is the Screw Hold test which the 70:30 appeared the highest strength for pulling the screw which is 95.118866 kilogram-force and the ratio which has the least strength is the 50:50 ratio which has 54.667 kilogram-force. It was then observed from the testing of mechanical properties of rice husk ash cement bonded board that the higher the ratio of binder to fiber ratio, the greater strength that the board will achieve in terms of mechanical properties. The Physical properties of the board were then tested, the result for the Moisture content of the board showed that the 50:50 ratio has the highest content which contains 16.48% and the 70:30 ratio which only contains 5.17% of moisture, the test for the swelling of board also showed the 50:50 ratio to have the highest swelling which is 14.33% , and the 70:30 ratio that only swelled at 6.30% , the final test for physical properties is to determine the percentage of Water that the board absorbed, the results showed that the 50:50 ratio of cement to fiber to have the highest percentage of water absorbed which is 32.69%, and the 70:30 ratio contains the least water absorbed which is 22.22% of water. It was observed that the higher percentage of fiber in the cement board, the higher moisture and water it contains and the higher it will swell because of the quantity of fibers. It was concluded after the test that the rice husk ash cement bonded boards can be utilized as wall cladding, partition, and various applications where there is no direct loading on the surface.

Increasing the amount of binder has its advantages on the mechanical properties of the board. This is due to the observed behavior of the results which demonstrated that the higher the binder, the higher the Modulus of Rupture, Face Screw Holding strength, and Nail Head Pull-Through resistance results would be. The amount of the fiber affects the interlocking action of the fiber. The lowest Modulus of Rupture was recorded at 50:50 ratio obtaining a value of 2.11 Megapascals. The 70:30 has obtained the highest Modulus of Rupture value of 5.603 Megapascals.

Thickness swelling, water absorption, and moisture content values of the board increase as the amount of fiber in the mixture increases. The more the fiber content, the more porous the board becomes. The lowering of the binder proportion in the board leads to a large quantity of exposed particles and free internal spaces which contributes to this behavior.

The researchers observed that the 70:30 binder ratio is the optimum ratio based on the physical and mechanical properties of the board. Achieving satisfactory results in Modulus of Rupture, Direct Screw Withdrawal, Nail Head Pull-Through, Thickness Swell, and Water Absorption. It has also been observed that the said ratio passed the Joint Japan, Australia, and New Zealand Standard requirement for composite boards.

Recommendations:

With the demonstrated results, the researchers recommend the following:

❖ The 70:30 ratio to be utilized in the industry as a wall cladding of interior partition.

❖ Decrease the spaces between the studs in order to compensate with the problem with Modulus of Rupture when used as partitions or cladding in walls of cabinets.

❖ For future researches, due to the behavior of the results where the Modulus of Rupture benefits from increasing the binder amount, the researchers also recommend to further increase the binder ratio, and study which is the enough binder amount that would suffice the PNS 230:1989 standard for Modulus of Rupture of the composite boards.

❖ To be strict in boiling of the rice straws to sodium hydroxide because insufficient time would lead to the cell wall not being completely broken down.

❖ It is also recommended to be strict in washing the fibers after boiling as residues of Sodium hydroxide in the fibers might affect its compatibility and binding with cement.

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