# CEMENT-BONDED BOARD FROM

# AGROWASTES

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# CEMENT-BONDED BOARD FROM AGROWASTES

A Research Paper Presented to the

Faculty of Philippine Science High School Western Visayas

Iloilo City

In Partial Fulfillment

of the Requirements in

Science Research II

by

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February 2000

**PHILIPPINE SCIENCE HIGH SCHOOL WESTERN VISAYAS**
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APPROVAL SHEET

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Abstract

This study determined the feasibility of cement-bonded board (CBB) from agricultural wastes, such as rice stalks, coconut husks, and bagasse. These agrowastes were prepared in three different mixtures, i.e., 50%-25%-25%, 25%-50%-25%, and 25%-25%-50% rice stalks, coconut husks, and bagasse. These CBB mixtures were further mixed with cement-sand mixture in a 50:50 ratio. The products were tested on physical appearance, water absorption, fire resistance, and compression strength.

Results showed that cement-bonded board (CBB) from agrowastes in different mixtures was feasible. The different tests conducted showed that the products were of high quality. In terms of physical appearance, the products were highly to moderately smooth and also of highly to moderately superior finish. The products absorbed water of mean amounts ranging from 20.08% to 30.62% of their actual weights, and resisted water infiltration of mean amounts ranging from 69.38% to 79.92% of their actual weights. The products did not show signs of burning, charring or discoloration due to fire exposure. Lastly,

the products sustained mean compression loads in one instance from 31.567 kN to 35.200 kN, and in another instance, from 18.000 kN to 22.000 kN.

There were no significant differences in the finish and fire resistance among the CBB products. There were, however, significant differences in the smoothness, water absorption, and compression strength among the CBB products.

CBB products from mixture B, which was 25% rice stalks-50% coconut husks-25% bagasse, proved to be the most superior among the products, while CBB products from mixture A, which was 50% rice stalks-25% coconut husks-25% bagasse, proved to be the most inferior. CBB products from mixture C, which was 25% rice stalks-25% coconut husks-50% bagasse, was intermediate in quality between CBB products from mixtures A and B.

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# Chapter 1

## Introduction to the Study

### Background of the Study

The plywood industry has become a heavy burden to people of low income. This is because plywood products seem to have lower quality than before, despite being expensive. These products are justifiably expensive because the raw materials are expensive also. One way of lowering the prices of manufactured products is to find alternative raw materials that are cheap and readily available, much more waste products that do not have economic value any more.

This study considered using agrowastes, which are relatively useless, and to some extent, pollutants to the environment, in producing cement-bonded boards as construction materials. These agrowastes--bagasse, rice stalks, and coconut husks--were chosen based on their economic significance, source location, and price value. Since all these materials are easy to find, and does not entail cost at all, the possibility of producing cheaper CBB is great.

The production of building materials such as CBB, from solid wood evidently caused rapid destruction to our forests and eventually, our natural resources thus, CBB from agrowastes becomes the conservationists' alternative to CBB from wood lumber.

Just like plywood, CBB is considered stronger than wood because it is less likely to split during nailing and shows little shrinkage and changes in moisture (Popular Science, 1993).

In this study, the independent variable is the different mixtures of bagasse, rice stalk, and coconut husks, while the dependent variables are the physical appearance, water resistance, fire resistance, and compression strength of the CBB products.

The relationship between the independent and the dependent variables of the study is presented in Figure 1.

## Statement of the Problem and the Hypothesis

This study aimed to determine the feasibility of producing cement-bonded board (CBB) using agro-wastes, such as bagasse, rice stalks, and coconut husks mixed accordingly.

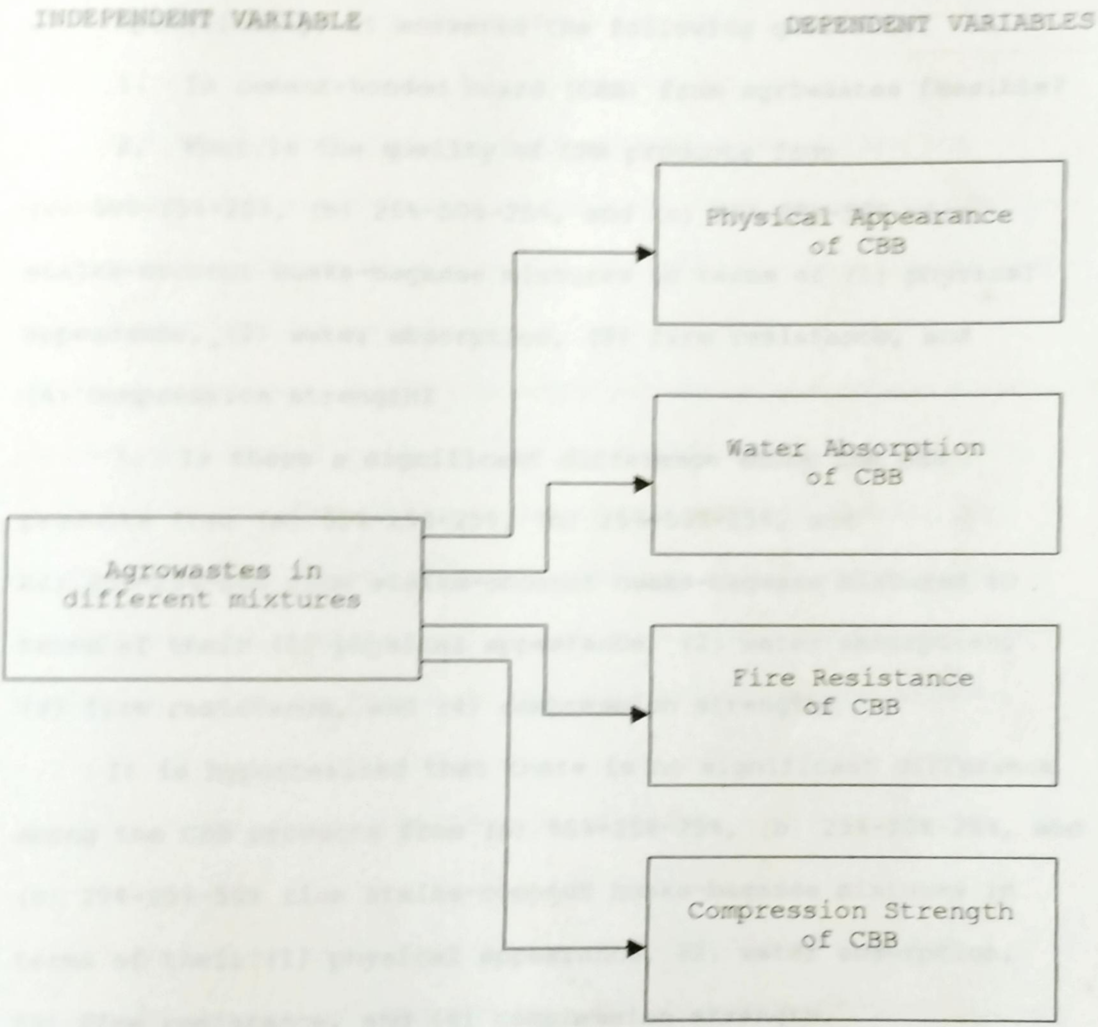


Figure 1. Qualities of cement-bonded board (CBB) from agrowastes mixtures in terms of physical appearance, water absorption, fire resistance, and compression strength.

Specifically, it answered the following questions:

1. Is cement-bonded board (CBB) from agrowastes feasible?

2. What is the quality of CBB products from (a) 50%-25%-25%, (b) 25%-50%-25%, and (c) 25%-25%-50% rice stalks-coconut husks-bagasse mixtures in terms of (1) physical appearance, (2) water absorption, (3) fire resistance, and (4) compression strength?

3. Is there a significant difference among the CBB products from (a) 50%-25%-25%, (b) 25%-50%-25%, and (c) 25%-25%-50% rice stalks-coconut husks-bagasse mixtures in terms of their (1) physical appearance, (2) water absorption, (3) fire resistance, and (4) compression strength?

It is hypothesized that there is no significant difference among the CBB products from (a) 50%-25%-25%, (b) 25%-50%-25%, and (c) 25%-25%-50% rice stalks-coconut husks-bagasse mixtures in terms of their (1) physical appearance, (2) water absorption, (3) fire resistance, and (4) compression strength.

## Significance of the Study

The CBB product becomes an excellent product when its production cost gives in to its quality. The agrowastes that served as the raw materials to the CBB products have proven that. With lesser cost of raw materials, and tangible, superior physical qualities, the CBB product can be as useful and durable as the other lumber products for construction purposes.

The use of CBB from agrowastes will not only lessen the financial burden of the majority, it will also lower the demand for logging, thus saving our forest resources. Ultimately, the environment will be free from the piling agricultural wastes.

## Definition of Terms

Some key terms in this study need definition for the purpose of achieving understanding and single-mindedness.

[Cement]-Bonded Board (CBB)- is any of the various construction adhesive, consisting essentiality of powdered calcified rock and clay materials that form a paste with water and can be poured to set as a solid mass (Grolier International Dictionary, 1979).

In this study, the term meant the produced material from the different mixtures of agrowastes and cement.

Agrowastes- are those liquid or solid wastes that result from agricultural practices, such as cattle manure, crop residue, pesticides, and fertilizers (McGraw-Hill Dictionary of Scientific and Technical Terms, 1994).

In this study, the term referred to rice stalks, coconut husks, and bagasse, which were used as the raw materials.

Mixture- is something consisting of diverse elements (McGraw-Hill Dictionary of Scientific and Technical Terms,, 1994).

In this study, the term meant the proportion of rice stalks, coconut husks, and bagasse, i.e., 50%-25%-25%, 25%-50%-25%, and 25%-25%-50%, respectively.

[Physical] Appearance- relates to nature or laws of nature; relating to material things, not mental or spiritual (The Merriam Webster Dictionary, 1994).

In this study, the term referred to the quality of the CBB product in terms of surface smoothness and finish.

Resistance- is the act or the capacity to resist or any force that tends to oppose or retard motion (Grolier International Dictionary, 1994).

In this study, the term referred to the ability of the product to resist being easily infiltrated by water and consumed by fire. The product should have minimal water absorption of less than 10% in order to be of superior water resistance. It should also have a minimal charring and discoloration due to heat of 10% in order to be of superior heat resistance.

[Compression] Strength- is a maximum stress a material, subjected to a stretching load, can withstand without tiring (McGraw-Hill Dictionary of Scientific and Technical Terms, 1994).

In this study, the term referred to the maximum compression load in kiloNewtons that the product can withstand.

## Scope and Delimitation of the Study

This study aimed to determine the feasibility of producing CBB from agrowastes was conceptualized by the researcher and his friends in the early part of August 1999. The raw materials were gathered from Dueñas, Passi City and Cebu City. The production stage was initiated at the Philippine Science High School Western Visayas last October and November 1999, and completed at the researcher's home in Cebu City last December 1999. The products were ready for the testing stage by the first week of January 2000.

Agrowastes, such as bagasse, rice stalks, and coconut husks were considered as raw materials in the production of CBB. The quality of the products were tested in terms of smoothness and finish, water resistance, fire resistance, and compression strength. Testing for smoothness and finish were done through a survey of ten jurors, composed of six students and four teachers. Testings for water absorption and fire resistance were done by the researcher with the help of some friends, while the test for compression strength was done at the construction laboratory of the Prestress International Corporation in Pavia, Iloilo. The products were treated with commercial anti-termite solution for its termite-proofing capability. This study did not aim to compare the CBB products with commercial ones.

# Chapter 2

## Review of Related Literature

Wood has been widely used as building and engineering material because of its advantages over other materials. It is more economical, requires lower processing energy, and is stronger. However, recent studies showed that the supply of wood especially from the tropical rain forest has been on decline at an average of 2% a year (Valmayor, 1986). This results in several problems such as ecological imbalance, soil erosions, and floods, among others. Another major problem is the dwindling supply of traditionally wood species for housing and building constructions (Philippine Technology Journal, 1995).

Wood is the world's great utilitarian building material. There are probably more structures made of wood than of any other material. It takes many respects in ideal building material for light construction. It is relatively inexpensive and still plentiful in many parts of the world. Unlike masonry, wood resists both compression and tension and other natural forces. It is light yet strong, making it efficient structural material-beams made of wood can span wide spaces. Also, wood is easily worked and is a good insulator. But it does have certain disadvantages. Wood burns rapidly in fire and is susceptible to rotting and insect infestations. It also shrinks and swells in changes with moisture.

There are two kinds of wood: soft wood, which comes from cone-bearing trees such as spines, spruce, and firs; and hardwood, which comes from broad-leaf trees such as maple, oak, and poplar. These kinds of wood are frequently used in construction. A truly hardwood, oak is used for floors, stair tread s, doorsills, and other places that are subject to heavy wear. Wood is also used in construction as sawed into standard sizes of lumber. Next, the lumber is planed smooth and its size reduced. A standard "two by four" is 2 inches (5 cm) thick and 4 inches (10 cm) wide when it comes from the saw but measures only 15 inches (8.9 cm) wide after it has been planed. Other products such as logs, which are used to make construction lumbers, are simply sawn down the length of the log. Other methods of sawing that improves the beauty of the grain pattern are used for wood that will be seen, as in paneling and furniture. But before wood can be used in constructions, It would gradually pull out nails or distort shapes. The traditional method of drying wood was to stack the wood so that air could reach all the sides of the boards. Depending on the type of wood and the size of the boards, air-drying can take a month or several years. Today most of the woods are dried in kilns. In this process, the time of drying is reduced from months to days (Popular Science, 1994).

There is storage of lumber and plywood supplies in the industrial construction all over the country. Based on the Medium-Term Philippine Development Plan, (in Philippine Technology Journal, 1995), the housing is estimated at around 3.4 mil. units for the country on an increasing yearly increment of nearly 15%.

The ever-increasing demand for construction materials and the dwindling supply of wood is one of the factors for the housing backlog experienced by the country today. From 1993 to 1998, the National Housing Authority (NHA) estimates from 1993 to 1998 a total housing need of about 3.85 million units, with an annual housing requirements of 642,224 units (NHA, 1993 in Philippine Technology Journal, 1995).

To help alleviate the problems being encountered by the construction industry, particularly the low and middle-income group planning to put up a decent house, the Forest Products Research and Development Institute (FPRDI) developed a new construction material, the cement-bonded board (CBB). CBB is made of wood excelsior flakes and press to form a board of desired thickness and density. It is an economical material that appears to be suitable for the Philippine climate. It has the essential properties to withstand earthquakes, typhoons, and high humidity temperatures. The panel product is technically proven to be water-, weather-, fire-, termite-, fungi-, and rot-resistant. It also possesses excellent insulating properties. It can be a good substitute for concrete hollow blocks and is cheaper than the conventional construction materials. It is also said that several agricultural residues such a bagasse, tobacco stalks, and coconut coir are potential raw materials for the production of cheap but durable composite panels thereby decreasing our demand for wood-based construction materials. Tapping these wastes would not only solve the housing problems but would also help in the environmental efforts at the government and the private sectors. Among recent studies by the FPRDI showed that the agricultural wastes such as coconut husks, tobacco stalks and others, could be a potential raw material for the production of cement-bonded boards. An agricultural residue such as sugarcane bagasse is also ligno-cellulosic in nature and can be used for the production of cement-bonded boards or panels (Philippine Technology Journal, 1995).

Sugarcane is a total tropical grass with a solid pointed stalk rich in sugar. In CY 1990 to 1991, about 1,729,042,000 metric tons of sugarcane was produced in the Philippines. This resulted into about 5,801,407 metric tons of sugarcane bagasse, a large portion of which is used a fuel and the surplus is normally incinerated or brought back to the field to decay. When used as fuel, the value of this material is very low. A considerable amount of bagasse (25-30%) is discharged as surplus (Philippine Technology Journal, 1995).

Cement-bonded technology makes possible the utilization of the wood wastes and some agricultural residues for board manufactures. Sugarcane bagasse as a promising material for cement-bonded board manufactured was considered as possible substitute for other biomaterials that have already been studied because of their abundance. By processing this waste as building boards, its value could probably increase to approximately twice its value as fuel. The utilization of sugar cane bagasse in the production of cement-bonded board will surely reduce the housing problem besetting the country. The availability of the durable panel product for low-cost housing will help solve the housing backlog especially for the urban poor and in the rural areas. Utilization of these untapped biomaterials will be beneficial to the industry in particular and to the country in general (Philippine Technology Journal, 1995).

# Chapter 3

## Research Design and Methodology

This study aimed to determine the feasibility of producing cement-bonded board (CBB) using agro-wastes, such as bagasse, rice stalks, and coconut husks mixed accordingly.

Specifically, it determined if cement-bonded board (CBB) from agrowastes is feasible or not. It also determined the quality of CBB products from 50%-25%-25%, 25%-50%-25%, and 25%-25%-50% rice stalks-coconut husks-bagasse mixtures in terms of physical appearance, water absorption, fire resistance, and compression strength. It further determined the difference among the CBB products from the different mixtures in terms of their physical appearance, water absorption, fire resistance, and compression strength.

It was hypothesized that there is no significant difference among the CBB products from the different rice stalks-coconut husks-bagasse mixtures in terms of their physical appearance, water absorption, fire resistance, and compression strength.

# Methodology

The whole process of producing cement-bonded board (CBB) involved the following methods: material preparation and initial termite-treatment , weighing and mixing of agrowastes, weighing and mixing of CBB components, preparation of the CBB casting mold, forming, curing and final termite-treating, and finally, testing.

## Materials and Equipment

In this study, the following materials were used: rice stalks, bagasse, coconut husks, cement and sand, abaca rope, and anti-termite solution. The angle bars, flat bars, mild steel plates, screws and bolts were used to form the casting mould.

## Methods

Standard methods of CBB production were followed. The different processes involved were as discussed.

Material Preparation. The commercial anti-termite solution was prepared based on its label instruction. The rice stalks, coconut husks, bagasse, and abaca ropes were then soaked separately in the solution for 48 hours for the initial termite-treatment. The agrowastes were then cut into 1-inch length and dried at ambient conditions to reduce moisture.

The cement and sand mixture was prepared in an 80:20 ratio.

Preparation of the CBB casting mold. The CBB casting mold was prepared by a competent person. Four pieces of 1-inch angle bars 12″ in length were cut to serve as the perimeter frames of the mould. A mild steel plate measuring 1/4″ x 14″ x 14″ was also cut to serve as the base. Another mild steel plate measuring 1/4″ x 12″ x 12″ was also cut to serve as the cover. The angle bars were then drilled with holes with a diameter of 1/8 inch and were 1/2 inch away from the base of each angle bar. The center of one hole was 1 inch away from the center of the next. These holes will serve as guide holes for the abacca rope. Using a screw with a diameter of 1/4″, the angle bars were assembled. The assembled angle bars were then drilled with 1/4" hole and fixed to the base using 1/4″ screw. Four pieces of 2-inch flat bars were formed into 2 brackets with a 1/4 " hole on top. The two brackets were welded to the base of the mold. A 1/4″ bolt was fitted each into the holes of the brackets.

Appendix A shows the mold specifications.

Weighing and Mixing of Agrowastes. The three mixtures were prepared by weighing the agrowastes according to the following proportions: mixture A consisted of 50% rice stalks, 25% coconut husks, and 25% bagasse; mixture B consisted of 25% rice stalks, 50% coconut husks, and 25% bagasse; mixture C consisted of 25% rice stalks, 25% coconut husks, and 50% bagasse.

Weighing and Mixing of CBB Components. The different CBB mixtures namely, A (50%-25%-25% rice stalks-coconut husks-bagasse), B (25%-50%-25% rice stalks-coconut husks-bagasse), and C (25%-25%-50% rice stalks-coconut husks-bagasse) and cement-sand mixture were weighed according to their exact proportions, i.e., 50% agrowastes mixture and 50% cement-sand mixture. These were mixed thoroughly for five minutes.

Forming the CBB. The base of the mold was covered with plastic. Using the guide holes in the angle bars, the abacca rope was woven horizontally, and then, vertically, into a net. The net served as the inner framework of the product to ensure its strength. The frame was placed over the base and the CBB mixture was spread evenly unto the casting mold. The steel cover was placed over the frame and clamped using the bracket bolts.

After 24 hours, the clamp was released, and the product was taken from the mold.

Curing of the CBB. The products were cured for seven days in an improvised pond (glass aquarium) with commercial anti-termite solution. This process was done for the curing and the final anti-termite treating of the products.

Testing

Before the 1-square foot CBB product in each mixture was subjected to the different testings, it was divided into eight equal parts, each measuring 3″ x 6″. Three pieces were used for the physical appearance (smoothness and finish) test. After this, the three pieces were subjected to water absorption test and three other pieces were subjected to fire resistance test. The pieces that were subjected to both water absorption and fire resistance tests were further subjected to compression test.

Physical Appearance. The researcher devised the jury rating and grade scales for the smoothness and finish tests, which were validated by three persons: two engineers and one fabrication shop supervisor. The products were then rated by ten jurors, composed of six students and four teachers, in terms of surface smoothness and finish. The product was rated 1, when the surface of the product is highly rough and product is of highly inferior finish; 2, when moderately rough and moderately inferior finish; 3, when fairly smooth and fairly superior finish; 4, when moderately smooth and moderately superior finish; and 5, when highly smooth and highly superior finish. The mean scores were then taken and the products were graded accordingly.

For the Smoothness test, the following grade scale was used:

| Mean | Description |
|---|---|
| 4.00 - 5.00 | Highly smooth |
| 3.00 - 3.99 | Moderately smooth |
| 2.00 - 2.99 | Fairly smooth |
| 1.00 - 1.99 | Moderately rough |
| 0 - 0.99 | Highly rough |

For the Finish test, the following grade scale was used:

| Mean | Description |
|---|---|
| 4.00 - 5.00 | Highly superior finish |
| 3.00 - 3.99 | Moderately superior finish |
| 2.00 - 2.99 | Fairly superior |
| 1.00 - 1.99 | Moderately inferior finish |
| 0 - 0.99 | Highly inferior finish |

Water Absorption. The products were initially weighed and then soaked in water for 12 hours. After 12 hours, they were wiped dry and weighed for the second time in order to determine the weight of the water absorbed by each product. The weight of the water absorbed was taken as the difference between the final weight and the initial weight of each product. The percentage of water absorbed by each product was calculated as:

$$\% \text{ of water absorbed} = \frac{\text{final weight} - \text{initial weight}}{\text{initial weight}} \times 100$$

The water resistance of the product was determined by the amount of water (in %) that was not absorbed.

The most resistant and the least resistant to water infiltration among the products was determined.

Fire Resistance. The products were placed in an oven and heated to $100^{0}$ C for 12 hours, after which they were examined and rated for signs and/or degree of burning, charring, or discoloration. They were then placed in an open fire in a gas stove for 30 minutes. The products were rated as 1, when 10% or less of the product was burned, charred, or discolored; 2, when 11%-25%; 3, when 26%-50%; 4 when 51%-75%, and 5, when 76%-100%.

The most resistant and the least resistant to fire destruction among the products were determined.

Vertical Compression Strength. Pieces of CBB products measuring 3″ x 6″ were subjected to compression testing using a compression machine at the construction laboratory of the Prestress International Corporation in Pavia, Iloilo. The amount of pressure in kiloNewtons that each product can vertically sustain before breaking was considered its compression strength.

The most resilient and the least resilient to compression pressure among the products were determined.

## Statistical Data Analysis

In treating the data gathered from this study, the mean and the standard deviation were used as descriptive statistical tools. The mean was used to determine the average scores of the CBB products in the different tests. The Multiple Analysis of Variance (MANOVA), set at 0.05 alpha level of significance, was used as inferential statistical tool. It was used to determine the significant difference in the smoothness and finish, water absorption, fire resistance, and compression strength among the CBB products of the three agrowaste mixtures. The Scheffe test, also set at 0.05 alpha level, was used as post hoc multiple comparison test.

Superiority Analysis

In order to determine which among the three mixtures of agrowastes (A- 50% rice stalks-25% coconut husks-25% bagasse; B- 25% rice stalks-50% coconut husks-25% bagasse; and C- 25% rice stalks-25% coconut husks-50% bagasse) produced the most superior CBB product, each mixture was given ranking points for all the testing, i.e., 1 if the mixture ranked first, 2 if the mixture ranked second, and 3 if the mixture ranked third.

Cost Analysis

In determining cost of the CBB product, the cost of each component materials was considered. The cost of the product per square foot was then determined.

Chapter 4

Results

This study aimed to determine the feasibility of producing cement-bonded board (CBB) using agro-wastes, such as bagasse, rice stalks, and coconut husks mixed accordingly.

Specifically, it determined if cement-bonded board (CBB) from agrowastes is feasible or not. It also determined the quality of CBB products from 50%-25%-25%, 25%-50%-25%, and 25%-25%-50% rice stalks-coconut husks-bagasse mixtures in terms of physical appearance, water absorption, fire resistance, and compression strength. It further determined the difference among the CBB products from the different mixtures in terms of their physical appearance, water absorption, fire resistance, and compression strength.

It was hypothesized that there is no significant difference among the CBB products from the different rice stalks-coconut husks-bagasse mixtures in terms of their physical appearance, water absorption, fire resistance, and compression strength.

Feasibility of producing cement-bonded board using agrowastes

This study was able to successfully produce CBB from agrowastes in three different mixtures (50% rice stalks-25% coconut husks-25% bagasse; 25% rice stalks-50% coconut husks-25% bagasse; 25% rice stalks-25% coconut husks-50% bagasse;).

These products were likewise subjected to the different tests of their quality, namely the physical appearance that included smoothness and finish test, water absorption, fire resistance, and compression strength.

Physical appearance of the CBB products. In determining the smoothness and finish of the CBB products, the following rating scale was used: 1, when the surface of the product is highly rough and product is of highly inferior finish; 2, when moderately rough and moderately inferior finish; 3, when fairly smooth and fairly superior finish; 4, when moderately smooth and moderately superior finish; and 5, when highly smooth and highly superior finish.

In the survey made with 10 jurors composed of six students and four teachers, the CBB products from Mixture A (50% rice stalks-25% coconut husks-25% bagasse) and B (25% rice stalks-50% coconut husks-25% bagasse) were rated highly smooth, while the

CBB products from Mixture C (25% rice stalks-25% coconut husks-50% bagasse) were rated only moderately smooth. Among the CBB products, the products from Mixture A had the highest mean (4.50) while the products from Mixture C had the lowest mean (3.30).

Table 1 shows the data.

In the same survey, the CBB products from Mixture B (25% rice stalks-50% coconut husks-25% bagasse) and C (25% rice stalks-25% coconut husks-50% bagasse) were rated highly superior finish, while the products from Mixture A (50% rice stalks-25% coconut husks-25% bagasse) were rated only moderately superior. Among the CBB products, the products from Mixture B had the highest mean (4.80) and the products from Mixture A had the lowest (3.70).

Table 1 shows the data.

Based on the data presented in the findings, CBB products from mixtures A and B, and from mixture C, were highly smooth and moderately smooth, respectively. Among the products, the ones from mixture A were the most superior (mean score of 4.50) as far as the smoothness test is concerned, and the ones from mixture C were the least superior (mean score of 3.30).

Table 1

Means of scores and values of the different CBB product mixtures for the physical appearance, water absorption, fire resistance, and compression strength

| Test | CBB Product | N | Mean | S. D. | Description |
|---|---|---|---|---|---|
| Smoothness | Product A | 10 | 4.50 | .71 | Highly smooth |
| | Product B | 10 | 4.30 | .67 | Highly smooth |
| | Product C | 10 | 3.30 | .82 | Moderately smooth |
| Finish | Product A | 10 | 3.70 | .95 | Moderately superior |
| | Product B | 10 | 4.80 | .42 | Highly superior |
| | Product C | 10 | 4.00 | .82 | Highly superior |
| Water absorption (%) | Product A | 3 | 187.67 | 15.70 | Intermediate resistance |
| | Product B | 3 | 150.67 | 6.03 | Highest resistance |
| | Product C | 3 | 229.67 | 24.13 | Lowest resistance |
| Fire resistance | Product A | 3 | 1.00 | .00 | High resistance |
| | Product B | 3 | 1.00 | .00 | High resistance |
| | Product C | 3 | 1.00 | .00 | High resistance |
| Compression, after water absorption test (kN) | Product A | 3 | 31.567 | .802 | Lowest strength |
| | Product B | 3 | 35.200 | .819 | Highest strength |
| | Product C | 3 | 32.000 | .954 | Intermediate strength |
| Compression, after Fire resistance test (kN) | Product A | 3 | 18.000 | 1.00 | Lower strength |
| | Product B | 3 | 18.000 | 1.00 | Lower strength |
| | Product C | 3 | 22.000 | 1.00 | Higher strength |

In the finish test, products from mixtures B and C were considered highly superior while the one from mixture A was moderately superior. As far as this test is concerned, the products from mixture B were the most superior in finish (mean score of 4.80) and the ones from mixture A were the least superior (mean score of only 3.70).

Water Absorption of the CBB products. The CBB products from Mixture A (50% rice stalk-25% coconut husks-25% bagasse) absorbed a mean amount of water which was equivalent to 25.02% of their total weights; B (25% rice stalk-50% coconut husks-25%bagasse), absorbed water which was equivalent to 20.08% of their weights; and C (25% rice stalk-25% coconut husks-50% bagasse) absorbed 30.62% of their weights.

The CBB products from Mixture C showed the highest water absorption (30.62%) and lowest water resistance (69.38%), while those from Mixture B had the lowest water absorption (20.08%) and highest water resistance (79.92%).

Table 2 shows the data.

Water absorption and resistance of the CBB products. In the water absorption test, the products from mixture B absorbed a mean amount of water which was only 20.08% of their own weights,

Table 2

Water absorption (and resistance tests) of the CBB products

| Product | Proportion (rice stalks, coconut husks, bagasse) | Initial Weight (grams) | Mean Final Weight (grams) | Mean Weight of Water (grams) | % water absorbed | % water resisted | Description Of Relative Water Resistance |
|---|---|---|---|---|---|---|---|
| A | 50%-25%-25% | 750 | 937.67 | 187.67 | 25.02 | 74.98 | Intermediate resistance |
| B | 25%-50%-25% | 750 | 900.67 | 150.67 | 20.08 | 79.92 | Highest resistance |
| C | 25%-25%-50% | 750 | 979.67 | 229.67 | 30.62 | 69.38 | Lowest resistance |

thus, they showed the greatest resistance (79.92%) to water infiltration. The products from mixture C absorbed a mean amount of water that was 30.62% of their own weights, thus they showed the least resistance (69.38%) to water infiltration.

Fire resistance of the CBB products. In rating the products for fire resistance, the following scale was used: 1, when 10% or less of the product was burned, charred, or discolored; 2, when 11%-25%; 3, when 26%-50%; 4 when 51%-75%, and

5, when 76%-100%.

All products showed no signs of burning, charring, or discoloration. By inspection, all the products were rated 1, descriptive of 10% or less burning, charring, or discoloration.

Due to oven heating, the products even became whiter and smoother after this test was conducted.

All products showed the same results for the fire resistance test.

Table 1 shows the data.

Compression strength of the CBB products. Two sets of CBB products were subjected to strength testing. The first set consisted of three products from each mixture that underwent absorption testing, and the second set, of three products from each mixture that underwent fire testing.

Among the products that underwent absorption testing, the result was: The CBB products from mixture A yielded to a mean maximum load of 31.567 kiloNewtons while the products from mixture B yielded to 35.200 kiloNewstons. Products from mixture C yielded to 32.000 kiloNewtons.

Table 1 shows the data.

The compression tests showed that the products from mixture B yielded to a greater mean compression force (35.200 kN), thus, they were the ones with the greatest compression strength. The products from mixture A yielded to a smaller mean compression force (31.567 kN), thus, they were the ones with the least compression strength.

Among the products that underwent fire testing, the following was the result: CBB products from mixture A and B yielded to a mean maximum load of 18.000 kiloNewtons. Products from mixture C yielded to 22 kiloNewtons.

Table 1 shows the data.

The compression test showed that the products from mixture C yielded to a greater mean compression force (22.000 kN), thus, they were the ones with the greater compression strength. The products from mixtures A and B yielded to a lower mean compression force (18.000 kN), thus, they were the ones with the lesser compression strength.

<u>Differences in the physical appearance of the CBB products</u>

The Multiple ANOVA showed that there was no significant difference in the scores of the finish test among the CBB products from the different mixtures, as reflected by $F(2) = .171$, $p$, > .05.

Table 3 shows the data.

There was, however, a significant difference in the scores of the smoothness test among the CBB products from different mixtures, as reflected by $F(2) = .011$, $p < .05$.

Table 3 shows the data.

The Scheffe test showed that the mean differences in smoothness were significant between the products from mixtures A and C, and products from mixtures B and C.

Table 4 shows the data.

Differences in the water absorption of the CBB products

The Multiple ANOVA showed that there was a significant difference in the water absorption capacity among the CBB products from different mixtures, as reflected by $F(2) = .004$, $p < .05$.

Table 3 shows the data.

The Scheffe test showed that the mean difference in water absorption was significant between the products from mixtures B and C.

Table 4 shows the data.

Table 3 

Multiple Analysis of Variance of the significant differences in the physical appearance, water absorption, fire resistance, and compression strength of the CBB products

| Source | Dependent Variables | Sums of Squares | df | Mean Square | F | Significance |
|---|---|---|---|---|---|---|
| CBB Products | Smoothness | 4.667 | 2 | 2.333 | 10.5000 | .011 |
| | Finish | 2.667 | 2 | 1.333 | 2.4000 | .171 |
| | Water Absorption | 9374.000 | 2 | 4687.000 | 4687.0000 | .004 |
| | Compression (after water absorption) | 21.029 | 2 | 10.514 | 14.187 | .005 |
| | Compression (after fire resistance) | 32.000 | 2 | 16.000 | 16.000 | .004 |

Table 4

Schefie test as post hoc multiple comparison test for Multiple ANOVA in Table 3

| Category | | | Mean Difference | Significance |
|---|---|---|---|---|
| Smoothness | Product A | Product B | .330 | .702 |
| | | Product C | .167* | .014 |
| | Product B | Product C | 1.333* | .037 |
| Water absorption | Product A | Product B | 37.000 | .096 |
| | | Product C | -42.000 | .062 |
| | Product B | Product C | -79.000* | .004 |
| Compression (after water absorption) | Product A | Product B | -3.330* | .006 |
| | | Product C | -1.033 | .398 |
| | Product B | Product C | 2.600* | .028 |
| Compression (after fire resistance) | Product A | Product B | .000 | 1.000 |
| | | Product C | -4.000* | .008 |
| | Product B | Product C | -4.000* | .008 |

*The mean difference is significant at the 0.05 level.

Differences in the fire resistance of the CBB products

There was no need to determine the significant difference in the fire resistance among the CBB products, since the products from the different mixtures had the same score values.

Table 1 shows the data.

Differences in the compression strength (after the water absorption test) of the CBB products

The Multiple ANOVA showed that there was a significant difference in the compression strength among the CBB products from different mixtures that have undergone the water absorption test, as reflected by $F(2) = .005$, $p$, $< .05$.

Table 2 shows the data.

The Scheffe test showed that the mean differences in this compression testing were significant between the products from mixtures A and B, and products from mixtures B and C.

Table 4 shows the data.

Differences in the compression strength (after the fire resistance test) of the CBB products

The Multiple ANOVA showed that there was a significant difference in the compression strength among the CBB products, as reflected by $F(2) = .004$, $p$, $< .05$.

Table 3 shows the data.

The Scheffe test showed that the mean differences in this compression testing were significant between the products from mixtures A and C, and products from mixtures B and C.

Table 4 shows the data.

Summary of testing results. In order to determine which among the three mixtures of agrowastes (A- 50% rice stalks-25% coconut husks-25% bagasse; B- 25% rice stalks-50% coconut husks-25% bagasse; and C- 25% rice stalks-25% coconut husks-50% bagasse) produced the most superior CBB product, each mixture was given ranking points for all the testing, i.e., 1 if the mixture ranked first, 2 if the mixture ranked second, and 3 if the mixture ranked third.

In the smoothness test, the product from mixture A ranked 1, the one from mixture B ranked 2, and the one from mixture C ranked 3. In the finish test, the product from mixture B ranked 1, the one from mixture C ranked 2, and the one from mixture A ranked 3. In the water absorption test, the product from mixture B ranked 1, the one from mixture A ranked 2, and the one from mixture C ranked 3. In the fire resistance test, all the products got the same rating, thus a rank of 2. In the compression strength test after the water absorption test, the product from mixture B ranked 1, the one from mixture C ranked 2, and the one from mixture A ranked 3. In the compression strength test after the fire resistance test, the product from mixture C ranked 1, the ones from mixtures A and B got the same value, thus the rank of 2.5.

The most superior CBB product mixture was mixture B (25%-50%-25% rice stalks-coconut husks-bagasse), and the least superior was mixture A (50%-25%-25% rice stalks-coconut husks-bagasse).

Table 5 shows the data.

Cost Analysis

In determining cost of the CBB product, the cost of each component material was considered. The cost of the product per square foot was then determined. The total production cost was P 123.80. This was divided by 3, which was the number of 1-square foot CBB products, and the cost of a square foot CBB product was determined to be P 41.30.

Table 6 shows the data.

Table 5 

Summary of rank scores of the CBB products from different mixtures

| Product | Mixture (rice stalks-coconut husks-bagasse) | Tests | | | | | | Total | Rank | Description of Relative Quality |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | | | |
| A | 50%-25%-25% | 1 | 3 | 2 | 2 | 3 | 2.5 | 13.5 | 3 | LEAST SUPERIOR |
| B | 25%-50%-25% | 2 | 1 | 1 | 2 | 1 | 2.5 | 9.5 | 1 | MOST SUPERIOR |
| C | 25%-25%-50% | 3 | 2 | 3 | 2 | 2 | 1 | 13 | 2 | INTERMEDIATE |

Test 1: Smoothness test
Test 2: Finish test
Test 3: Water absorption test
Test 4: Fire resistance test
Test 5: Compression strength test after Test 3
Test 6: Compression strength test after Test 4

Table 6

Production cost of the CBB products

| Quantity | Unit | Materials | Unit Cost (in pesos) | Total Cost (in pesos) | Actual Production Cost (in pesos) |
|---|---|---|---|---|---|
| 3 | Kilograms | Cement | 5.00 | 15.00 | 15.00 |
| 240 | Milliliters | Lentrex® | 160.00 | 160.00 | 80.00 |
| 18 | Meters | Abaca rope | 1.60 | 28.80 | 28.80 |
| TOTAL | | | | | 123.80 |
| Number of 1 square foot CBB Products | | | | | 3 |
| COST PER SQUARE FOOT CBB PRODUCT | | | | | *P 41.30* |

# Chapter 5

## Summary, Conclusions, and Recommendations

This study aimed to determine the feasibility of producing cement-bonded board (CBB) using agrowastes, such as bagasse, rice stalks, and coconut husks mixed accordingly.

Specifically, it answered the following questions:

1. Is cement-bonded board (CBB) from agrowastes feasible?

2. What is the quality of CBB products from (a) 50%-25%-25%, (b) 25%-50%-25%, and (c) 25%-25%-50% rice stalks-coconut husks-bagasse mixtures in terms of (1) physical appearance, (2) water absorption, (3) fire resistance, and (4) compression strength?

3. Is there a significant difference among the CBB products from (a) 50%-25%-25%, (b) 25%-50%-25%, and (c) 25%-25%-50% rice stalks-coconut husks-bagasse mixtures in terms of their (1) physical appearance, (2) water absorption, (3) fire resistance, and (4) compression strength?

It was hypothesized that there is no significant difference among the CBB products from (a) 50%-25%-25%, (b) 25%-50%-25%, and (c) 25%-25%-50% rice stalks-coconut husks-bagasse mixtures in terms of their (1) physical appearance, (2) water absorption, (3) fire resistance, and (4) compression strength.

Findings

1. The study was able to successfully produce CBB from agrowastes in three different mixtures (50% rice stalks-25% coconut husks-25% bagasse; 25% rice stalks-50% coconut husks-25% bagasse; 25% rice stalks-25% coconut husks-50% bagasse;).

These products were likewise subjected to the different tests of their quality, namely the physical appearance that included smoothness and finish test, water absorption, fire resistance, and compression strength. Based on these tests, the most superior CBB product mixture was mixture B (25%-50%-25% rice stalks-coconut husks-bagasse), and the least superior was mixture A (50%-25%-25% rice stalks-coconut husks-bagasse).

The cost of a square foot CBB product was determined to be P 41.30.

2.1. In terms of physical appearance, CBB products from mixtures A and B, and from mixture C, were highly smooth and moderately smooth, respectively. Among the products, the ones from mixture A were the most superior as far as the smoothness test is concerned, and the ones from mixture C were the least superior.

CBB products from mixtures B and C were considered highly superior in finish while the ones from mixture A were moderately superior. The products from mixture B were the most superior in finish and the ones from mixture A were the least superior.

2.2. In terms of water absorption, CBB products from Mixture A (50% rice stalk-25% coconut husks-25% bagasse) absorbed a mean amount of water equivalent to 25.02% of their total weights; B (25% rice stalk-50% coconut husks-25%bagasse), absorbed water which was equivalent to 20.08% of their weights; and C (25% rice stalk-25% coconut husks-50% bagasse) absorbed 30.62% of their weights.

The CBB products from Mixture C showed the highest water absorption and lowest water resistance, while those from Mixture B had the lowest water absorption and highest water resistance.

2.3. In terms of fire resistance, all products showed no signs of burning, charring, or discoloration. By inspection, all the products were rated 1, descriptive of 10% or less burning, charring, or discoloration. Due to oven heating, the products even became whiter and smoother after this test was conducted.

All products showed the same results for the fire resistance test.

2.4. In terms of compression strength of CBB products that had undergone water absorption testing, CBB from mixture A yielded to a mean maximum load of 31.567 kiloNewtons while the products from mixture B yielded to 35.200 kiloNewstons. Products from mixture C yielded to 32.000 kiloNewtons.

The compression tests showed that the products from mixture B yielded to a greater mean compression force, thus, they were the ones with the greatest compression strength. The products from mixture A yielded to a smaller mean compression force, thus, they were the ones with the least compression strength.

In terms of compression strength of CBB products that underwent fire resistance testing, CBB products from mixture A and B yielded to a mean maximum load of 18.000 kiloNewtons. Products from mixture C yielded to 22 kiloNewtons.

The compression test showed that the products from mixture C yielded to a greater mean compression force, thus, they were the ones with the greater compression strength. The products from mixtures A and B yielded to a lower mean compression force, thus, they were the ones with the lesser compression strength.

3.1. There was no significant difference in the characteristic finish among the CBB products from the different mixtures. There were, however, significant differences in the characteristic smoothness among the CBB products from different mixtures, between the products from mixtures A and C in favor of Mixture A, and products from mixtures B and C in favor of Mixture B.

3.2. There was a significant difference in the water absorption capacity between the products from mixtures B and C in favor of Mixture B.

3.3 There was no significant difference in the fire resistance of the CBB products from the different mixtures.

3.4. There were significant differences in the compression strength among the CBB products from different mixtures that have undergone the water absorption test between the products from mixtures A and B in favor of Mixture B, and products from mixtures B and C in favor of Mixture B.

There was also a significant difference in the compression strength among the CBB products that have undergone water resistance test between the products from mixtures A and C in favor of Mixture C, and products from mixtures B and C in favor of Mixture C.

## Conclusions

The following conclusions were established after the data were thoroughly presented and analyzed:

1. Cement-bonded board (CBB) from agrowastes such as rice stalks, coconut husks, and bagasse in different mixtures, was feasible. The different tests conducted upon the products showed that they were of high quality.

Based on these tests, the most superior CBB product mixture was mixture B (25%-50%-25% rice stalks-coconut husks-bagasse), and the least superior was mixture A (50%-25%-25% rice stalks-coconut husks-bagasse). CBB products from mixture C, which was 25% rice stalks-25% coconut husks-50% bagasse, was intermediate in quality between CBB products from mixtures A and B.

The cost of a square foot CBB product was determined to be P 41.30.

2. In terms of physical appearance, the products were highly to moderately smooth, and also of highly to moderately superior finish. The products absorbed water of amounts ranging from 20.08% to 30.62% of their actual weights, and resisted water infiltration of amounts ranging from 69.38% to 79.92% of their actual weights. The products did not show signs of burning,

charring or discoloration due to fire destruction. Lastly, the products carried compression loads in one instance from 31.567 kN to 35.200 kN, and in another instance, from 18.000 kN to 22.000 kN.

3. There were no significant difference in the scores of the finish and fire resistance tests among the CBB products. There were, however, significant differences in the scores and values of the smoothness test, water absorption capacity, and compression strength among the CBB products.

## Recommendations

The researchers recommend the use of CBB from agrowastes due to its good qualities.

The researchers, given another chance, also wish to improve the testings done to the CBB products, as:

First, the products be compared with a commercial CBB in terms of physical appearance, water and fire resistance test, and the test for tensile strength;

Along with the comparison with commercial CBB, jury ratings for smoothness and finish be further validated and properly standardized;

The water absorption test be shortened from 12 hours to 0 hour in a regressive manner.

The products be subjected to temperature higher than $100^0$ C for the fire resistance test.

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