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ENGINEERING PROPERTIES OF A COIR-BASED PARTICLEBOARD

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ABSTRACT

A 3-layered particle-board was made with coir (coconut fiber) and its engineering properties were compared to the specifications adopted for bagasse board of similar thickness and density by Trinidad Bagasse Products Limited. The density, thickness, bending strength, tensile strength perpendicular to the plane of the board and moisture content were close to the specifications for bagasse board while thickness swelling was excellent. Screwholding properties were fairly lower with edge screwholding, full screwholding and 12 mm screwholding being 32, 13 and 15 percent less respectively than the corresponding specifications. Moreover, water absorption turned out to be unexpectedly higher than the specification for bagasse particle-board by nearly 200 percent.

1.0 INTRODUCTION

As world population grows, there is an increasing need for particle-board for internal building uses in the forms of shelves, furniture, panels and ceilings. The reduction in the availability of natural timber coupled with progressive natural resources conservation laws aimed at preserving rain forests and the fragile ecological balance by preventing the irreversible mining of natural resources make it imperative that alternative environmentally safe sources of raw materials be found for particle-board manufacture.

The purpose of this study was to investigate the possibility of producing a particle-board of suitable quality from coconut fiber. A 3-layered, 18 mm thick, high density particle-board was produced and tests were carried out to determine the following properties:

(a) Density
(b) Moisture content
(c) Water absorption and thickness swelling
(d) Bending strength or modulus of rupture
(e) Tensile strength perpendicular to the plane of the board
(f) Surface screwholding : full and 12 mm
(g) Edge screwholding

The properties of the manufactured particle-board were compared to the specifications adopted by the Trinidad Bagasse Products Limited for a bagasse-based particle-board of similar density and thickness [1]. These specifications are based on German National Standards (DIN).

2.0 MATERIALS AND METHODS

2.1 Procedure

1. Coconut fibers ranging in length from 6 cm to 20 cm were hammer milled using a Cremasco hammer mill into two different sizes. Material for the surface layer was obtained by using a screen size of 1/8 inch (3mm) while the core layer material was obtained using a 1/4 inch (6 mm) screen. It is the larger fiber particles in the core layer which, to a large extent, determine the strength properties of the board. The finer material in the surface layer is used to provide a smooth finish so that little or no sanding is required in the final product.

2. A weighed amount of the shorter fibers was placed in a blender and measured amounts of a resin, urea, insecticide, emulsion solid, ammonium chloride, hexamine and water were injected into the blender through a nozzle by the use of an air compressor. This surface layer material was removed from the blender and stored in a box.

3. The process was repeated using the longer fibers to produce the core layer material.

4. A predetermined amount of the surface layer material was removed and placed into a topless and bottomless box 40 cm by 40 cm by 15 cm thick which was allowed to rest on a 5 mm thick mild steel plate. The surface layer material was spread uniformly within the box. It was then pressed manually using a wooden plate with a handle.

5. A predetermined amount of the core layer material was then introduced into the box on top of the surface layer material. The core layer material was spread evenly over the surface layer and was compressed using the wooden plate.

6. A predetermined amount of surface layer material was then introduced on top of the core layer and was spread evenly over the core layer. The wooden plate was again used to compress the surface layer material thereby compressing all three layers.

7. The box was then removed and a 3-layer cake was left on the mild steel plate.

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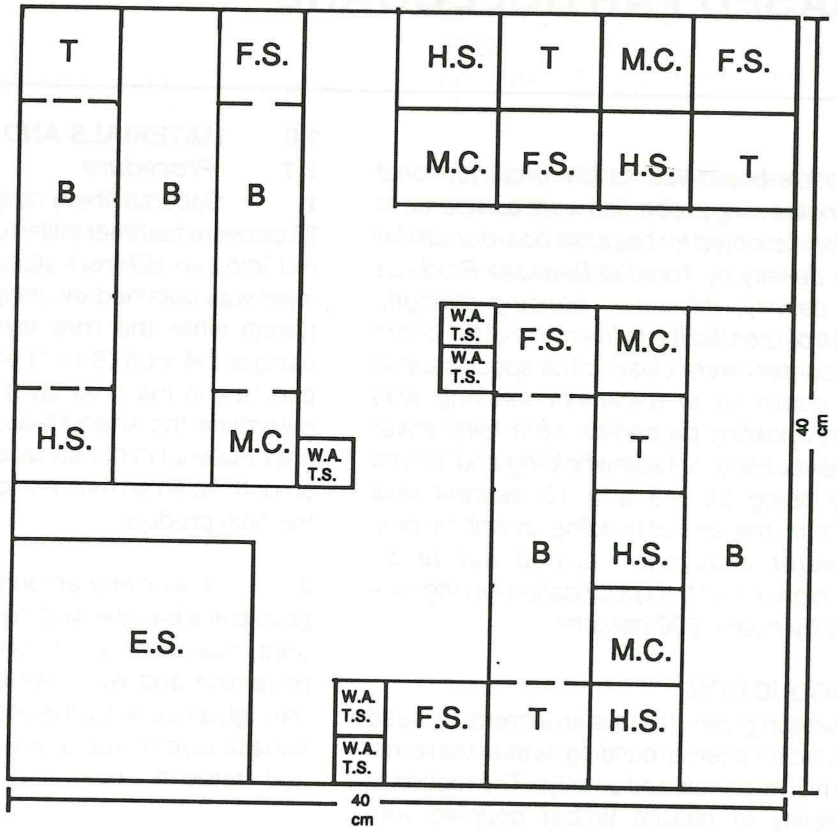

Figure 1. Partitioning of Particle-board to Produce Test Specimens

B = Bending Strength Specimens (5)
T = Tensile Strength Specimens (5)
M.C. = Moisture Content Specimens (5)
W.A. & T.S. = Water Absorption and Thickness Swelling Specimens (5)
E.S. = Edge Screwholding Specimen (1)
F.S. = Full Screwholding (Face) Specimens (5)
H.S. = 12mm Screwholding (Face) Specimens (5)

8. The mild steel plate with the cake was placed on the lower movable press plate of the hydraulic press whose two plates were maintained at 145 degrees Centigrade. The lower press plate was then actuated to move upwards until the distance between the upper surface of the mild steel plate and the lower face of the upper stationary press plate was 18 mm. This condition was maintained for 12 minutes at an operating pressure of 100 kg/cm^2. Adequate pressing temperature and pressing time are necessary for sufficient heat transfer to take place to effect proper hardening and bonding of the fiber particles. There is an inverse relationship between pressing temperature and pressing time.

9. The particle-board produced was then removed and allowed to air cool.

2.2 Preparation of the Test Specimens

The particle-board was marked out as shown in Fig. 1 and the various test specimens were carefully labelled. The test specimens were then carefully cut out using a sharp circular saw.

The bending strength specimens, which were also used to determine the density, had dimensions of 25 cm by 5 cm. The tensile strength, moisture content, full screwholding and 12 mm screwholding were 5 cm by 5 cm while the edge screwholding specimen was 12.5 cm by 12.5 cm. The moisture absorption and thickness swelling specimens were 2.5 cm by 2.5 cm.

2.3 Testing of the Test Specimens

2.3.1 Density

Density is one of the most important physical properties of a particle-board which affects the other engineering properties. The density of each of the five test specimens was determined by weighing the test specimen and measuring its dimensions (length, width and thickness) to calculate its volume. The density of each specimen was found by dividing the mass (kg) of the specimen by the corresponding volume (m^3) to give the density in kg/m^3.

2.3.2 Moisture Content

The test pieces were weighed and then placed in an oven at 130 degrees Centigrade for 24 hours. They were again weighed on removal from the oven. The moisture content of each test piece was then calculated using the following formula:

$$MC = \frac{MW - MO}{MO} \times 100 \qquad (1)$$

where,

MC = relative moisture content (%)

MW = mass of test piece before entry into oven (gms)

MO = mass of test piece on removal from oven (gms)

2.3.3 Water Absorption and Thickness Swelling

The same test procedure was used to evaluate both water absorption and thickness swelling. The samples were weighed and their thicknesses measured before submerging them horizontally in water for two hours. On retrieval from the water the samples were suspended and allowed to drain for 10 minutes to get rid of excess water on the surface. They were then weighed and their thicknesses measured.

The water absorption is expressed as a percentage by weight of water absorbed based on the initial mass of the sample i.e.

$$MA = \frac{M1 - M2}{M1} \times 100 \qquad (2)$$

where,

MA = water absorption (%)

M1 = mass of sample before immersion in water (gms)

M2 = mass of sample after retrieval from water (gms)

The thickness swelling is expressed as a percentage by thickness increase based on the initial thickness of the sample i.e.

$$TS = \frac{T2 - T1}{T1} \times 100 \qquad (3)$$

where,

TS = thickness swelling (%)

T1 = thickness before immersion in water (mm)

T2 = thickness after retrieval from water (mm)

2.3.4 Bending Strength

The bending strength or modulus of rupture is the most important mechanical property of particle-board with respect to their practical application as structural elements or in combination with them.

The bending specimens were simply supported on a span of 20 cm and subjected to a central line load. The maximum load which occured at failure was automatically recorded.

It is well known that, for static bending tests of particle-board, centreloading is standardized. In this case, according to elementary mechanics, the tensile and compressive stresses, σ, developed at any point of the beam may be calculated using the following formula:

$$\sigma = \frac{My}{I} \qquad (4)$$

where,

σ = stress in tension or compression (kg/cm^2)
M = bending moment induced by the applied load (kg.cm)
y = distance from the neutral axis (cm)
I = moment of inertia of the section (cm^4)

For a rectangular, normally loaded section,

$$I = \frac{bt^3}{12} \qquad (5)$$

where,

b = width (cm)
t = thickness (cm)

The bending strength for each test piece was calculated using the following relationship:

$$\sigma_{bB} = \frac{3P_{max}L}{2bt^2} \qquad (6)$$

where,

σ_{bB} = bending strength (kg/cm^2)
P_{max} = ultimate failure load (kg)
L = span between centre of supports (cm)
b = width of test piece (cm)
t = mean thickness of test piece (cm)

Most national standards prescribe a ratio of L : t between 14 and 16. However, a smaller ratio (e.g. 10) may be used to save material in bending tests but L must not be less than 200 mm, DIN 52362 (April 1965) [2].

2.3.5 Tensile Strength Perpendicular to Plane of the Board

The testing of tensile strength perpendicular to the plane of the board (σ_{tB}) has been commonly done since the early days of particle-board manufacture [3]. With this test the layer with the lowest coherence is determined. From this point of view, this test contributes essentially to quality control in plants. There are various methods and devices to carry out this test.

In this study each specimen was strongly bonded between two horizontal mild steel plates. One plate was kept stationary and the other was moved upwards at a constant rate. The maximum load at failure was automatically recorded. Failure should occur in the test piece and not in the glue line. Details of the arrangement can be found in the German standard specification DIN 52365, (April 1965) [3].

The tensile strengths were then calculated using the following formula:

$$\sigma_{tB} = \frac{P_{max}}{A} \qquad (7)$$

where,

σ_{tB} = tensile strength (kg/cm^2)
P_{max} = ultimate load at failure (kg)
A = surface area of specimen (cm^2)

2.3.6 Screwholding

2.3.6.1 Edge Screwholding

In this test a special screw was screwed into the edge of the test specimen until none of the threads were visible. The specimen was then clamped and the screw removed by means of a hydraulic ram moving at a constant rate. The load necessary to remove the screw was automatically recorded. The process was repeated on the four edges of the specimen.

2.3.6.2 Face Screwholding (Full and 12 mm)

In these cases the screw was screwed throughout the entire thickness of the test piece (full) and for only 12 mm of the thickness. The process was repeated as for edge screwholding and the values of the various loads were automatically recorded for each case.

3.0 RESULTS AND DISCUSSION

Tables 1 to 7 summarise the results of the tests carried out on the various test specimens while Table 8 compares the properties of the coir-based particle-board with the specifications for a bagasse-based board of similar thickness and density.

The results summarised in Table 8 indicate that the thickness, density, moisture content and bending strength were close to the specifications for bagasse board. Thickness swelling proved to be extremely good. The screwholding properties were fairly lower than the specifications for bagasse board. Full screwholding, 12 mm screwholding and edge screwholding were respectively 13, 15 and 32 percent less than the corresponding specifications.

Water absorption, however, turned out to be unexpectedly higher than the specification for bagasse board being more than 200 percent greater than the maximum permitted value. High moisture absorbtion is undesirable because it can lead to swelling, cupping and twisting. Moreover, it makes the board more susceptible to attacks by fungi, bacteria and decay.

A possible explanation for the poor properties may lie with the preparation of the core layer. During mixing in the blender, the fibers exhibited a strong tendency to form separate balls that prevented the resin from

Table 1. Thickness, Density and Bending Strength of the Test Specimens

Specimen No.	Mass (gms)	Thickness (mm)	Load (kg)	Density (kg/m³)	Bending Strength (kg/cm²)
1	150	18.6	100	645	173
2	150	18.6	100	645	173
3	149	18.6	98	641	170
4	152	18.7	120	650	205
5	148	18.5	97	640	170
Mean	150	18.6	103	644	178

Table 2. Moisture Content of the Test Specimens

Specimen No.	Moisture Content (%)
1	9.5
2	9.2
3	8.9
4	9.5
5	9.4
Mean	9.3

Table 3. Water Absorption and Thickness Swelling Properties of the Test Specimens

Specimen No.	Water Absorption (%)	Thickness Swelling (%)
1	20	2.15
2	20	2.15
3	30	2.14
4	20	2.15
5	27	2.15
Mean	23.4	2.15

Table 4. Tensile Strength of the Test Specimens

Specimen No.	Tensile Strength (kg/cm²)
1	3.08
2	2.80
3	3.12
4	3.00
5	2.80
Mean	2.96

Table 5. Edge Screwholding Properties of the Test Specimens

Edge No.	Load (kg)
1	70
2	75
3	80
4	75
Mean	75

Table 6. Full Surface Screwholding Properties of the Test Specimens

Specimen No.	Load (kg)
1	105
2	104
3	104
4	106
5	106
Mean	105

Table 7. 12 mm Surface Screwholding Properties of the Test Specimens

Specimen No.	Load (kg)
1	62
2	62
3	65
4	64
5	65
Mean	64

Table 8. Comparison of Coir Particle-board with Specifications for a Bagasse Board of Similar Density and Thickness.

Property	Units	Bagasse Board	Coir Board
Thickness	mm	18	18.6
Density	kg/m³	650	644
Moisture Content	%	6–12	9.30
Water Absorption	%	6–10	23.4
Thickness Swelling	%	10	2.15
Bending Strength	kg/cm²	180	178
Tensile Strength	kg/cm²	3.70	2.96
Surface Screwholding			
Full	kg	120	105
12 mm	kg	75	64
Edge Screwholding	kg	110	75

reaching all the fiber particles. This was due to the curly nature of the longer fibers. Consequently, some fibers were not bonded to each other. Thus, although the individual fiber particles themselves were fairly water resistant, water was able to fill the vacant spaces between the unbonded fiber particles.

The choice of test specimens was made such that they were representative of the entire board. It was seen, however, that the only property that showed fairly constant values throughout the board was thickness swelling which is dependent more on the nature of the individual fibers than on the way they were bonded.

Most properties exhibited significant variations throughout the board. Bending strength varied from 170 to 205 kg/cm², tensile strength perpendicular to the plane of the board from 2.80 to 3.12 kg/cm², edge screwholding from 70 to 80 kgs and water absorption from 20 to 30 percent. An additional probable contributory factor leading to the variation in the properties of the test pieces could have been the method of spreading the resinated fibers. This was hand-done since spiked rollers were unavailable which may have resulted in an uneven spread of fibers.

It should be pointed out that in the manufacture of a particle-board a number of parameters are involved such as size of particles, resin percent, pressing temperature, pressure and pressing time. The choice of values of these parameters determine the properties of the finished board. The values chosen in this study were within the normal range for particle-board manufacture but may not have been the optimum combination for producing the best quality particle-board. Further work is needed to determine the optimal combination of parameters.

The first step would be to determine a suitable particle size for the core layer which would not give rise to the balling effect during blending. The sieve size should vary between 3 mm to 6 mm. Since the particle size used for the surface layer responded well to blending it could again be used. However, the effect of smaller sizes on the quality of the finish should also be investigated.

The second step would be to vary the resin amount from 9 to 12 percent with pressure and temperature held constant at various values for a particular pressing time. Pressure should range from 90 to 140 kg/cm², temperature from 130 to 160°C and pressing time from 9 to 12 minutes.

4.0 CONCLUSION

This study provides some promising results to support the possibility of producing a coir-based particle-board of generally acceptable quality except for water absorption and screwholding properties. However, water absorption can be reduced using a wax-emulsion in the preparation of the board or the finished product can be coated with moisture resistant materials. Further research is needed to determine the optimal combination of parameters which would result in the production of a board with improved engineering properties.

The prospect of economically producing a suitable quality particle-board using an inexpensive agricultural by-product such as coconut fiber could have positive implications for the viability of the presently ailing coconut industry in Trinidad and Tobago.

REFERENCES

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