CHAPTER 31

PERFORMANCE OF HARDBOARDS MADE FROM KENAF

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ABSTRACT

This paper reports on the performance of dry-process hardboards made from pressurized refined whole kenaf stalks. Twenty hardboard panels were made from kenaf using 3% and 7% phenolic resin and 0 and 1.0% wax. Test results showed that nearly all mechanical and physical properties improved with increased resin content, but wax had a negative effect. Some property values met American National Standards Institute/American Hardboard Association (ANSI/AHA) A135.4 standards for Basic Hardboard while others did not. The results indicate that kenaf panels can be made to perform at acceptable levels for certain hardboard applications.

INTRODUCTION

As the cultivation of kenaf increases, new markets are needed for its use. Paper has been the main outlet for kenaf, and studies have focused on using kenaf for animal feed and bedding (Chow and Youngquist 1993). Another potential use for kenaf is hardboard or medium-density fiberboard. Very little research has looked into this possibility, particularly in using the whole stalk. This paper investigates the feasibility of using the whole kenaf stalk as a fiber source for hardboards and the physical and mechanical properties of such boards.

MATERIALS AND METHODS

Experimental Design

The experiment involved making dry-process hardboards from the entire kenaf stalk. The experimental design was two levels of resin content (3% or 7%) two levels of wax content (0 or 1.0%), and one species of fiber (Table 31.1). Each treatment combination was considered a replicated set consisting of five individual panels, In total, 20 panels were made for this experiment.

Table 31.1. Experimental design for production of 3.2-mm-thick dry-process hardboard from whole-stalk kenaf[a].

Number of panels	Resin content (%)	Wax content (%)
5	3	0
5	3	1.0
5	7	0
5	7	1.0

[a] Specific gravity of panels = 1.0.

Resin levels were chosen for comparison of kenaf panel properties to properties of standard commercial products. The 3% phenolic resin level compares with resin levels used in commercial hardboard products. The 7% phenolic resin level was used to compensate for the shorter kenaf core fiber (average 0.6 mm) compared to wood fiber (average 2.7 - 4.6 mm). Typically, 0.5% to 1.5% wax is added to commercial hardboard to reduce water absorption. Therefore, for the purpose of comparing panel properties, the addition of 1% wax to one-half of the panels and none to the remaining panels was chosen.

Materials

Cut, green kenaf has a moisture content between 200% and 400%. The ratio of bast to core fiber is 30:70 to 40:60 (w/w). The kenaf stalks used in this project were obtained from the University of Illinois and had been dried to approximately 8% moisture content and cut into 7.5-mm lengths.

Phenol-formaldehyde resin, a commercial hardboard resin, was obtained from Georgia Pacific Company (Atlanta, GA). It had a solids content of 40%, viscosity of 75 to 125 mPa•s at 25°C, and pH of 9.5 to 10.4. All resin applications were based on resin solids content as a percentage of total board weight.

The paraffin emulsion wax, obtained from Borden Chemical, Inc. (Columbus, OH), had a solids content of 58%, viscosity of 30 to 50 mPa•s at 25°C, and pH of 8.3.

Production of Hardboard

Dry-formed hardboard is prepared by placing a formed mat under pressure in a hot press until the fibers are bonded together by a thermosetting resin. When a hardboard mat with high moisture content is pressed, a screen on one surface allows the moisture to escape, which results in a final product that is smooth on one side (S-l-S). For a hardboard mat with lower moisture content, the use of caul plates on both surfaces results in a final product that is smooth on two sides (S-2-S). Hardboard is also separated into medium- and high-density categories. Medium-density hardboard has a specific gravity between 0.5 and 0.8, whereas high-density hardboard has a specific gravity above 0.8 (USDA Forest Service 1987).

Kenaf Refining

Kenaf fiber, as removed from the stalk, is too long to be used for conventional hardboards. By using a steam-pressurized refiner, a very good quality fiber suitable for making hardboards was produced. Before refining, the stalks were pre-steamed in a digester for 3 min under 310 kPa steam pressure. Open plates with subsurface dams were used for the refining process; the plate gap was 380 μm. Some of the kenaf was initially refined by putting the cut stalk into the digester for the steaming process. However, it was found that as the bast fiber separated from the pith (core), it became wound around the rotating mixing bar in the digester as the kenaf was being fed into the refiner. Also, it was discovered that many stalks were too large in diameter to be fed into the auger that transferred the kenaf to the refiner. To resolve theses problems, the kenaf stalks were hammermilled. Since the objective was to break the stalks apart rather than to shorten the fiber, no screen was used in the hammermill. Consequently, the kenaf was fed much more evenly into the refiner and winding around the shaft was greatly reduced.

The stalks were fiberized in a 305-mm Sprout-Bauer single rotating disk pressurized refiner (a batch process with a digester at the front end and a receiving tank at the outlet into which fiber is discharged). The refiner was limited to batches of 2000 g dry kenaf stalks; when refined, this amount filled the receiving tank.

When the refined kenaf was removed from the receiving tank, it had from 40% to 60% moisture content. The kenaf was immediately air-dried, which reduced moisture content to around 8%. Drying took from 36 to 48 h.

Resin and Wax Application

Resin and wax were applied in a rotating-drum blender fitted with a pneumatic spray gun. The resin and wax were applied separately; the wax was applied first. Enough fiber was blended in one batch so that all the panels at a particular resin and wax level could be formed. During resin application, some balling of the kenaf fibers occurred as a result of the tackiness of the resin and the tumbling action of the rotating drum. After the wax and resin were applied, the drum blender was stopped to prevent further balling of the fiber.

Two levels of phenolic resin (3% and 7%) and two levels of wax (0% and 1.0%) were used. Both resin and wax contents were based on solids content of total board weight.

Formation of Mat

Five hardboards with a specific gravity of 1.0 and a target thickness of 3.2 mm were produced for each condition (Table 31.1). Mats were hand-formed by brushing the fiber through a 6-mm screen on a 380- by 380-mm vacuum forming box. The forming box was located on top of a wire screen fine enough to prevent fiber from passing through. Under the screen, a vacuum pipe was attached to a vacuum system. The vacuum helped to draw the fibers down onto the mat and to reduce mat loft. After the forming box was removed, the mat was transferred to a caul plate for pressing.

Pressing of Panels

The caul plates between the kenaf mat and the press platens were made of 610 mm square, 6 mm thick aluminum. These plates protected the press platens and allowed easy insertion of the mat into the press and removal of the panel after the pressing cycle. The manually controlled hydraulic press was steam heated to 187°C.

When the mat entered the press, it was 380 by 380 mm in size and 50 mm high. Moisture content ranged from 7% to 12%, depending on resin content. Press closure took an average of 1 min at 6.0 MPa maximum board pressure. Panel thickness was controlled by 3.2-mm stops. When the stops contacted the top caul plate, panel pressure was reduced to 2.8 MPa, enough to keep tight contact. From the time of mat consolidation, press time was 4 min until opening. During the pressing cycle, one to three de-gassing cycles were made, depending on mat moisture content and amount of steam released during each de-gassing cycle.

During pressing, the panel expanded to approximately 400 by 400 mm, which caused a low-density area along the edges. This part of the panel was trimmed off, and the final panel size was 355 by 355 mm, which allowed a more accurate determination of specific gravity.

Testing

The panels were cut into specimens for tests on mechanical and physical properties. From each panel, two specimens each were used for tests on static bending, tensile strength, internal bond strength, and water absorption. Five panels were used for each resin/wax (R/W) combination, for a total of 20 test panels. Thus, 10 specimens were used for each test. Properties were determined according to appropriate sections of ASTM D 1037 (ASTM 1994). Prior to mechanical and physical property tests at room temperature (about 23°C), the specimens were conditioned to equilibrium at 50% relative humidity and 20°C. Specimens had minimal exposure to ambient humidity during the tests.

RESULTS AND DISCUSSION

Mechanical and physical property data are presented in Tables 31.2 and 31.3 and Figures 31.1 to 31.7. The data are reported as mean values and were statistically analyzed using analysis of variance at a 0.05 level of significance. The letters S and N indicate whether the values are statistically significant (S) or not significant (N).

Mechanical Properties

Specimens were tested for static bending modulus of rupture (MOR) and modulus of elasticity (MOE), tensile strength and modulus of elasticity (MOE), and internal bond strength.

Bending Modulus of Rupture

Modulus of rupture indicates the ability of a specimen to withstand a traverse (bending) force perpendicular to its longitudinal axis. This force produces combined shear, compressive, and tensile stresses in the specimen (Jacobs and Kliduff 1994). The flexural three-point loading test utilizes a center-point pivot through which the load is applied to a specimen, which is spanned between two rods held by support blocks, until rupture occurs.

For MOR, values were below the hardboard standard value of 31.0 MPa, except for panels made with 7% resin (7R) and no wax (0W) (Table 31.2, Figure 31.1). Addition of wax apparently caused some reduction in MOR. The MOR values of panels made with 3% resin (3R) and 1% wax (1W) and the 7R/1W panels were lower than those of the 3R/0W and 7R/0W panels. Furthermore, the 3R/0W and 7R/0W panels had a greater increase in MOR than did the 3R/IW and 7R/1W panels.

Table 31.2. Static bending and internal bond properties of kenaf dry-process hardboard[a].

Board characteristic	Static bending		Internal bond
	MOR (MPa)	MOE (GPa)	(MPa)
ANSI/AHA A135.4[b]	31.0	MA	0.62
Effect of Resin			
at 0% wax			
3% resin	25.9	2.93	0.33
7% resin	35.1 S	3.29 S	0.45 S
at 1% wax			
3% resin	24.3	2.60	0.27
7% resin	26.4 N	3.29 N	0.31 S
Effect of wax			
at 3% resin			
0% wax	25.9	2.93	0.33
1% wax	24.3 N	2.60 S	0.27 N
at 7% resin			
0% wax	35.1	3.29	0.45
1% wax	26.4 A	2.39 A	0.31 S

[a] Each value is average for 10 tests. Statistical analysis was performed using an analysis of variance (ANOVA) general linear model at a 95% confidence level. S: statistically significant, N: not statistically significant within a given wax or resin percentage group in columns.
[b] ANSI/AHA 1995.

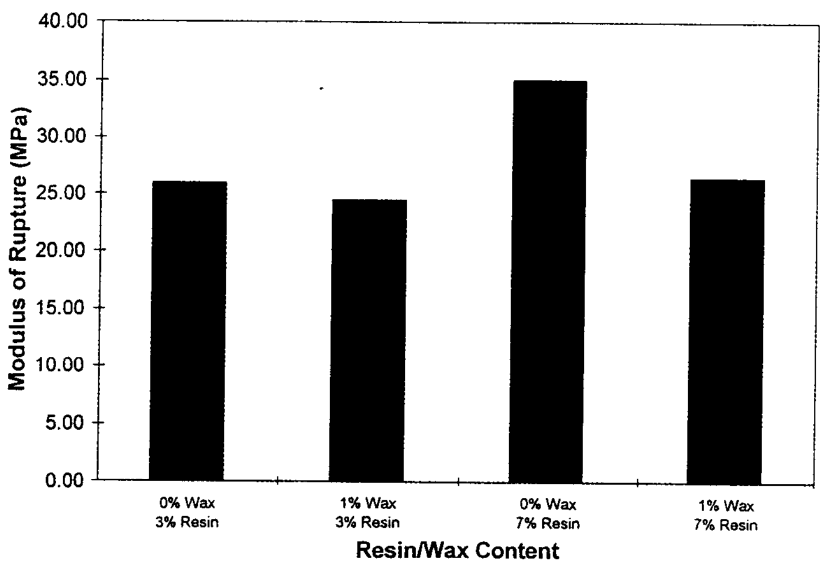

Figure 31.1. Bending modulus of rupture of kenaf hardboard panels.

Bending Modulus of Elasticity

Like MOR, MOE increased with increase in resin content in panels made without wax (Table 31.2, Figure 31.2). Also like MOR, MOE was affected by the addition of wax; however, MOE was slightly lower at the 7R level compared to the 3R level. Furthermore, the higher resin level had a greater influence on MOE than did the lower resin level. This indicates that the addition of wax exerted a greater effect at the higher resin level. There is no ANSI/AHA A135.4 standard for comparing these values.

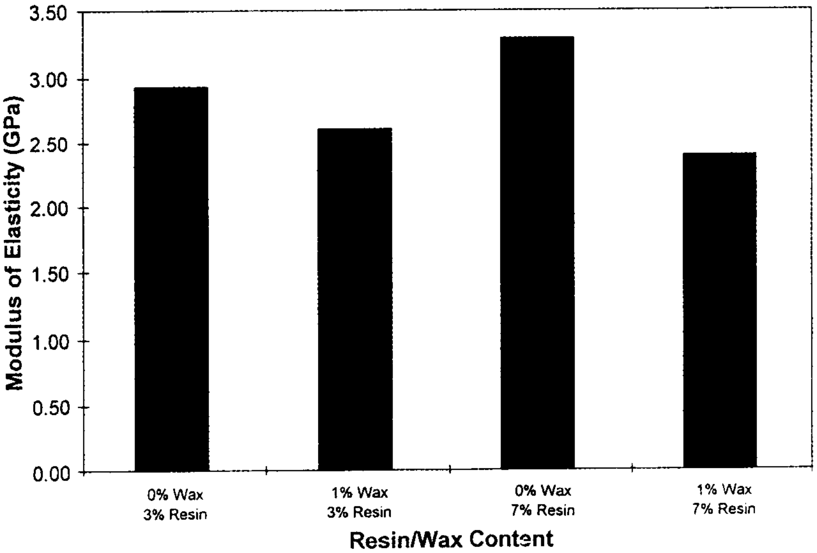

Figure 31.2. Bending modulus of elasticity of kenaf hardboard panels

Tensile Properties

Strength properties followed the pattern found for bending MOR properties. As resin content increased from 3% to 7%, strength values increased (Table 31.3, Figure 31.3). Strength also increased with the addition of wax from 3R/1W to 7R/1W. When the values within a resin level are compared, strength properties decreased at both resin levels when wax was present, but the decrease was greater at the 7R than the 3R level. Nevertheless, all values for tensile strength were above the ANSI/AHA (1995) A 135.4 minimum value of 15.2 MPa for hardboard.

Table 31.3 Mechanical and physical properties of kenaf dry-process hardboard[a].

Board characteristic	Tensile strength (MPa)	Tension MOE (GPa)	Thickness swell (%)	Water absorption (%)
ANSI/AHA A135.4[b]	15.2	NA	25.0	35.0
Effect of Resin				
at 0% wax				
3% resin	16.9	4.09	69.3	90.1
7% resin	24.4	4.39 N	35.9 S	57.0 S
at 1% wax				
3% resin	16.1	3.56	64.2	94.9
7% resin	19.4 S	3.37 N	39.9 S	64.5 S
Effect of wax				
at 3% resin				
0% wax	16.9	4.09	69.3	90.1
1% wax	16.1 N	3.56 N	64.2 N	94.9 N
at 7% resin				
0% wax	24.4	4.39	35.9	57.0
1% wax	19.4 S	3.37 S	39.9 S	64.5 S

[a] Each value is average for 10 tests. Statistical analysis was performed using an analysis of variance (ANOVA) general linear model at a 95% confidence level. S: statistically significant, N: not statistically significant within a given wax or resin percentage group in columns.
[b] ANSI/AHA 1995.

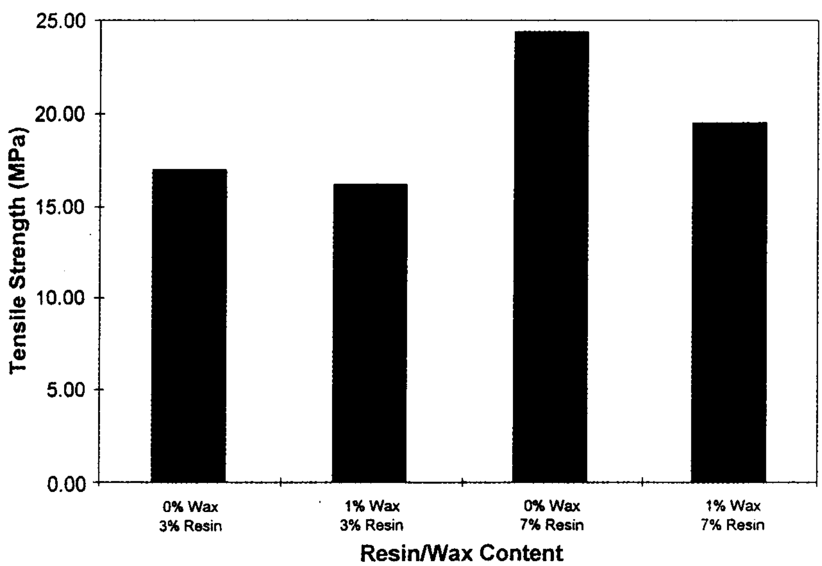

Figure 31.3. Tensile modulus of rupture of kenaf hardboard panels.

As with bending MOE, the lowest tensile MOE values were found in the 7R/1W panels (Table 31.3, Figure 31.4). Again, MOE increased with an increase in resin content without wax, but was lower at each resin content for panels with wax. Also, as with other properties, tensile properties showed a greater decrease at the higher resin level. This result may be a further indication of the interference of wax on the mechanical properties of kenaf. These data were not compared to the standard values for basic hardboard because ANSI/AHA does not set a standard for tensile MOE.

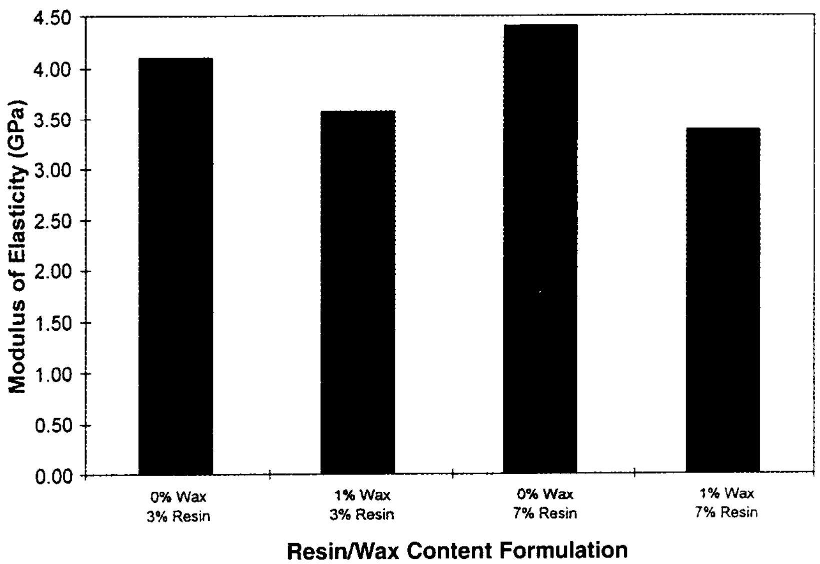

Figure 31.4. Tensile modulus of elasticity of kenaf hardboard panels.

Internal Bond Strength

Although internal bond (IB) values were well below the minimum ANSI/AHA value of 0.62 MPa set for hardboard, the data followed the same pattern as that for bending MOR and tensile strength (Table 31.2, Figure 31.5). Increasing the resin level, with and without wax, increased IB values; IB values were lower at both resin levels with the addition of wax. However, there was a greater reduction in IB when wax was added at the 7% level than at the 3% level.

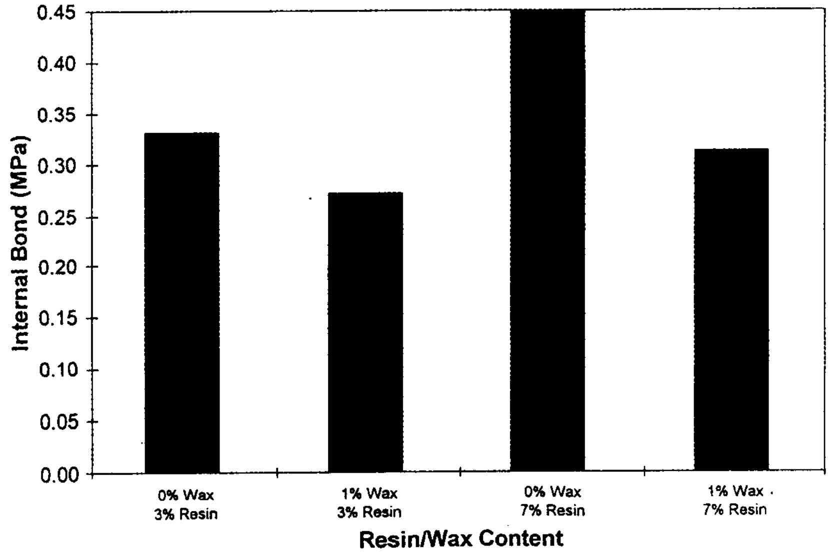

Figure 31.5. Internal bond strength of kenaf hardboard panels.

Physical Properties

Physical properties for water absorption and thickness swell are shown in Table 31.3 and Figures 31.6 and 31.7.

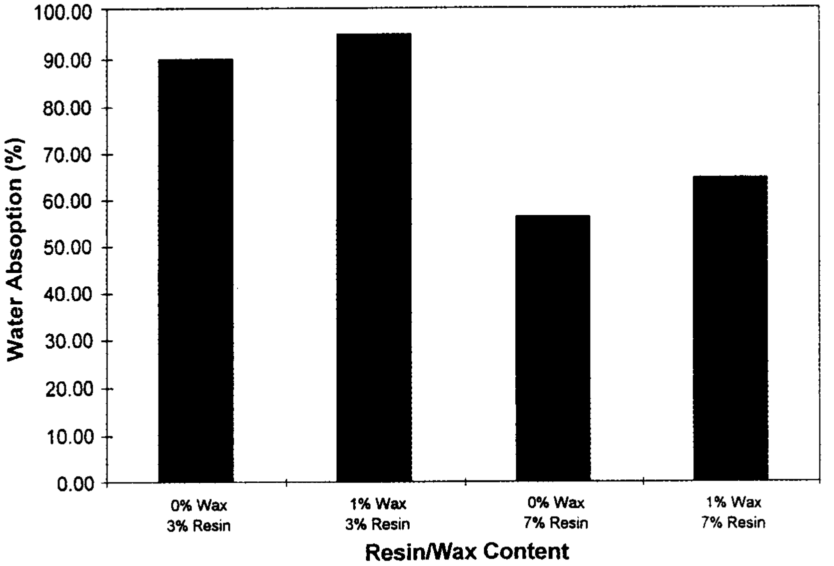

Figure 31.6. Water absorption of kenaf hardboard panels.

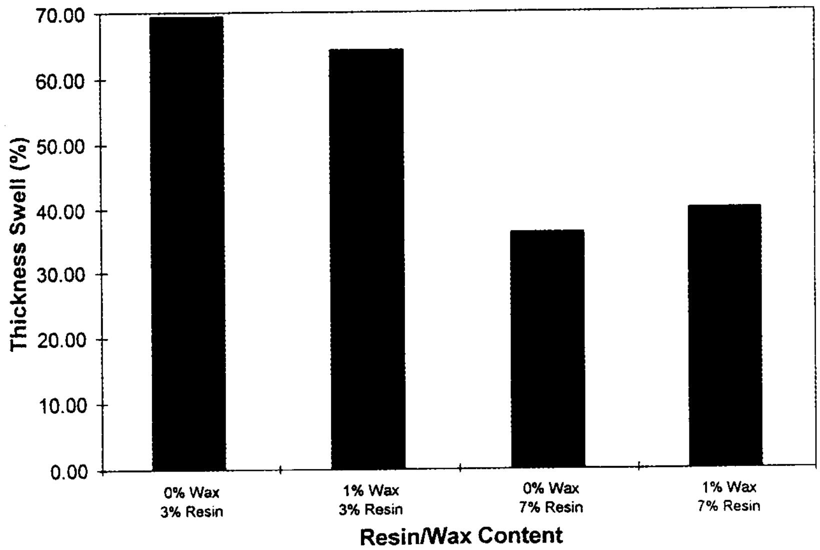

Figure 31.7. Thickness swell of kenaf hardboard panels.

Water Absorption

Increasing the resin content decreased water absorption at both resin levels (Table 31.3, Figure 31.6). However, contrary to our expectations, the addition of wax increased water absorption. Furthermore, as in the mechanical tests. the addition of wax had a negative effect on water absorption at both resin levels. All water absorption values were well above the maximum level of 35% established by ANSI/AHA (1995) A135.4.

Thickness Swell

The higher resin content decreased thickness swell (Table 31.3, Figure 31.7). However, the addition of wax reduced thickness swell at the 3% resin level and slightly increased thickness swell at the 7% level. The decrease in thickness swell for 3% resin was not significant. Thickness swell values were above the maximum level of 25% set by ANSI/ABA (1995) A135.4.

CONCLUSIONS

Making hardboard panels from alternative materials such as kenaf has many advantages and applications. In these tests, although some of the mechanical and physical properties exceeded the standards listed in ANSI/AHA (1995) A135.4 for hardboards, others did not. The kenaf panels were not made with the intention to use them as a direct substitute for basic hardboard. The kenaf panels were made simply to determine what properties could be obtained when kenaf fiber is substituted for a traditional wood fiber. The references to ANSI/AHA values are given to lend a perspective to the values obtained from the kenaf panels since there are no standard property values for panels made from alternative fibers.

The primary trends in mechanical and physical properties of hardboards made from kenaf are interesting and fairly consistent. Generally, increasing the resin content from 3% to 7% improved both mechanical and physical properties regardless of whether wax was present. In nearly all cases, however, the addition of 1% wax lowered properties. Also, for panels made with wax and 7% resin, there was a greater reduction in property values compared to panels made with wax and 3% resin. Thus, wax had a negative effect on properties, and increasing resin content had a positive affect.

Undoubtedly, the high values obtained from the water absorption and thickness swell tests were a result of the high percentage of highly absorbent core fiber in the panels. Because the core fibers of kenaf are very short and constitute a high percentage of total fiber content, they present a very large and highly absorbent surface area. This research indicates that higher resin content, higher density, and other improvements will be required to achieve acceptable properties.

DISCLAIMER

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