How Species and Board Densities Affect Properties Of Exotic Hardwood Particleboards

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Abstract

Four exotic hardwood species, kiri *(Paulownia tomentom)*, Virola *(Virola* spp.), limba *(Terminalia superba)*, and afrormosia *(Pericopsis eluta)*, were used to make three-layer particleboards with one species and in combinations of equal parts of two, three, and four species. Mechanical properties were determined by static bending and IB tests. Dimensional stability properties *were* measured after exposure to 30 to 90 percent and 50 to 90 percent RH and by a 24-hour water-soak test. MOR and MOE increased linearly with increase in wood density and particleboard density. IB increased as board and species density increased, but also was affected to some extent by inherent characteristics of each species. MOR and MOE of mixed species were equal to the weighted mean of the properties of boards made of single species at the same board density. No linear relation was found between dimensional stability and board density, but water absorption was inversely proportional to board density. Thickness swelling was inversely proportional to board density and directly proportional to solid wood volumetric change and in multiple regression was directly proportional to water absorption and solid wood volumetric change. Within the species, an increase in board density generally resulted in a decrease in thickness swelling and an increase in linear expansion.

PARTICLEBOARD was introduced in the United States about 25 years ago to utilize wood residues from secondary milling operations, but has succeeded so well that some producers are using wood from trees and primary milling operations in addition to other sources. Thus they are competing for raw materials with other wood industries, such as pulp, paper, fiberboard, and hardboard manufacturers.

Technically it is possible to make particleboards from many species of wood in almost any form, regardless of board qualities and economic considerations. However, at present, only a limited number of species are used, and information on many hardwood species. is lacking. Although processing heavy hardwoods is actually a fundamental problem internationally, only limited information is available.

A major problem in utilizing hardwoods, and particularly tropical hardwoods, is the great number of species found on a given area of forest. The use of mixtures of many species for making particleboards as well as other wood products could be a partial answer for utilizing the tropical forests that cover more than 3 million square miles.

The objectives of this study were to investigate the effects of hardwood density, both by single species and by mixtures of species, and to investigate relationships of board density to species density on the strength and dimensional stability properties of particleboards.

Background

Wood Density

No single property is known that alone will indicate conclusively the suitability of wood species as a raw material for particleboard manufacture. However, wood density is considered the most important species variable that affects particleboard properties (5,6,16,-18). Wood density influences binder consumption, the bulk of particles to be consolidated; therefore, it influences the strength and the surface smoothness of the board (l8,26). As a general conclusion, at a given board density, an increase in raw material density causes a decrease of particleboard strength properties (6,14,16,20) and an increase in linear expansion and thickness swelling (16,20).

Particleboard Density

Density is a measure of the compactness of the individual particles in a board, and is dependent mainly on the density of the wood and the pressure applied during pressing. An increase in board density is accomplished essentially by increasing the weight of the wood in the mat or the compression of the mat or by both. This results in an increase in resin efficiency by additional and improved glue bonds (7). Most researchers have found a positive relationship between particleboard properties and board density. An increase in board density increases values for modulus of rupture (MOR), modulus of elasticity (MOE), and internal bond (IB) (7,18,19,24,25).

Increases in swelling should be expected with increase in board density (7,12,21,22-24,27). However, increases in mechanical strength with increases in density can be sufficient to offset increased swelling tendency (15), and high density can increase efficiency of resin usage, therefore reducing thickness swelling (4).

Mixture of Species

Use of mixed wood species, particularly in those operations in which the raw material is residue from other manufacturing processes, is a common practice. Mixtures of softwoods and hardwoods and in some cases a small percentage of bark (up to 15 percent) may be used (5). The characteristics of wood particleboard from mixed species are comparable with those of particleboard from a single species (13), and are dependent primarily on the average density of the mixture used (2,3,8-11,17). In an approximate calculation of the production costs, addition of heavy hardwoods to softwood chips was economically advantageous (11).

Material and Methods

Experimental Variables

Four hardwood species that represent a wide range in density were chosen for this study. The four species encompass a wide range of physical and mechanical properties of hardwoods. Kiri *(Paulownia tomentosa)*, Virola *(Virola* spp.), limba *(Termindia superba)*, and afrormosia *(Pericopsis elata)* were selected, and the densities and physical properties of the test materials were determined (Table 1).

Three-layer boards were manufactured using each species alone as well as mixtures of species. In the species mix-ratio variables, all possibilities for one and for mixtures of two, three, or four species were considered.

The study variables were as follows:

1) Species density (g/cm^3)-ovendry (OD) weight and volume: Kiri (A), 0.28; virola (B), 0.43; limba (C), 0.57; and afrormosia (D), 0.65.

2) Board density: species density (compression ratio)-1.2:1.0 (low) and 1.6:1.0 (high).

3) Species mixtures: A, B, C, D (four combinations, all one species); AB, AC, AD, BC, BD, CD (six combinations, equal parts two species); ABC, ABD, ACD,

Table 1. - PHYSICAL PROPERTIES OF FOUR EXOTIC HARDWOOD SPECIES.

Physical properties[1]	Kiri (A)	Virola (B)	Limba (C)	Afror-mosia (D)
Density (g/cm^3)				
OD weight/OD volume	0.28	0.43	0.57	0.65
Weight at about 30 percent RH/volume soaked	.35	.49	.67	.77
pH	4.3	5.6	5.1	4.9
Buffering capacity	.050	.160	.275	.075
Water absorption (%)				
50 to 90 percent RH	9.5	12.1	10.3	0.8
30 to 90 percent RH	12.9	14.6	13.1	10.7
OD to water soak	224.3	175.7	81.6	92.6
Radial swelling (%)				
50 to 90 percent RH	1.0	2.1	2.0	1.9
30 to 90 percent RH	1.3	2.5	2.5	2.3
OD to water soak	1.7	4.4	4.1	3.5
Tangential swelling (%)				
50 to 90 percent RH	2.2	3.0	2.6	3.0
30 to 90 percent RH	2.9	4.6	3.4	3.6
OD to water soak	4.0	9.9	6.7	6.0
Longitudinal swelling (%)				
50 to 90 percent RH	.06	.05	.08	.05
30 to 90 percent RH	.10	.08	.12	.10
OD to water soak	.18	.22	.29	.21
Volumetric swelling (%)				
OD to water soak	6.1	14.6	10.6	10.1

[1]OD, ovendry; RH, relative humidity.

BCD (four combinations, equal parts three species); and ABCD (one combination, equal parts four species).

Duplicate particleboards, a total of 60, were made at each level under the following constant conditions:

1) Board size: 1/2 inch by 24 inches by 28 inches.

2) Face-core-back weight ratio: 25-50-25 percent.

3) Binder: Borden's WW-17 urea-formaldehyde, 67 percent resin solids.

4) Resin solids content: Face flakes–9 percent (based on OD weight of flakes). Core flakes–7 percent (based on OD weight of flakes).

5) Wax: 0.75 percent of Paracol 404N wax emulsion, 50 percent solids (based on OD weight of flakes).

6) Catalyst: 1.5 percent (liquid-to-liquid weight basis) of the following solution: 16.8 percent ammonium chloride, 14.8 percent hexamethylenetetramine, and 68.4 percent water.

7) Flakes: Flakes from 3/4-inch pulp chips processed through a ring flaker, 0.020 inch thick.

8) Mat moisture content (MC) 9±1 percent.

9) Pressing: Press temperature was 325°F and presstime, 5 minutes (1 min. to thickness) for all boards except for four boards involving three-species mixtures at the 1.6:1.0 compression ratio. These were pressed at 300°F for 6 minutes to avoid blowing. Afrormosia boards at the high-compression ratio required more than 1 minute to reach the desired thickness.

Board Manufacture

The raw material was chipped in a pulpwood chipper with knives set for 3/4-inch chip length, then flaked with a ring flaker. The particles were dried to about 4 percent MC and stored in plastic bags. Each species was screen-analyzed with screens in the following size fractions: 1/2, 1/4, 1/8, and 1/16 inch. Samples of face and core flakes (primarily separated at the 1/8-inch screen fraction) of each species are shown in Figure 1.

pH and buffering capacity were measured as described by Stewart and Lehmann (24) to determine the amount of catalyst needed in the 15 wood resin systems (Table 1). The 1.5 percent catalyst was used in all boards as determined from an average of the buffering capacity of all mixtures.

The particleboards were prepared in a random order according to the following procedure: The particles were loaded in a drum-type blending device that provided a uniform distribution of the resin on the flakes. Resin, wax, and catalyst were mixed together and applied by air-spray to the tumbling particles.

After removing particles from the blender, the MC and correct weight for face or core were determined. Then the mat was formed in a 24- by 28-inch forming box using a mat-laying device.

The formed mat was loaded into a 36- by 36-inch single-opening hot press and pressed to 0.5-inch thickness. The pressure required for any particular board was dependent on the combination of wood density or the mixture of wood density and on the compression ratio. After pressing, the finished board was weighed and allowed to cool. The boards were not sanded.

Preparation of Specimens and Testing

Four specimens were cut from each board for determining average MOE,[1] MOR, IB, specific gravity (SD), and MC. Six specimens were used for dimensional stability and water absorption tests. All tests used specimens representing both major board dimensions.

The mechanical property test specimens were conditioned at 80°F and 65 percent RH before testing according to procedures outlined in ASTM D 1037 (1).

The dimensional stability tests consisted of measuring the change in weight, thickness, and length of two strips per board from equilibrium conditions at 80°F and 30 percent RH or 80°F and 50 percent RH to equilibrium at 80°F and 90 percent RH or of two specimens from each board soaked horizontally under 1 inch of water at 70°F for 24 hours after conditioning at 80°F, 30 percent RH.

Specimens were weighed to the nearest 0.01 g. Thickness was determined to the nearest 0.001 inch. Length changes were determined to the nearest 0.001 inch from eyelets in two holes drilled on 10-inch centers in each specimen.

[1]MOE of the board as used here refers to the bending stiffness of the board divided by the geometric moment of inertia.

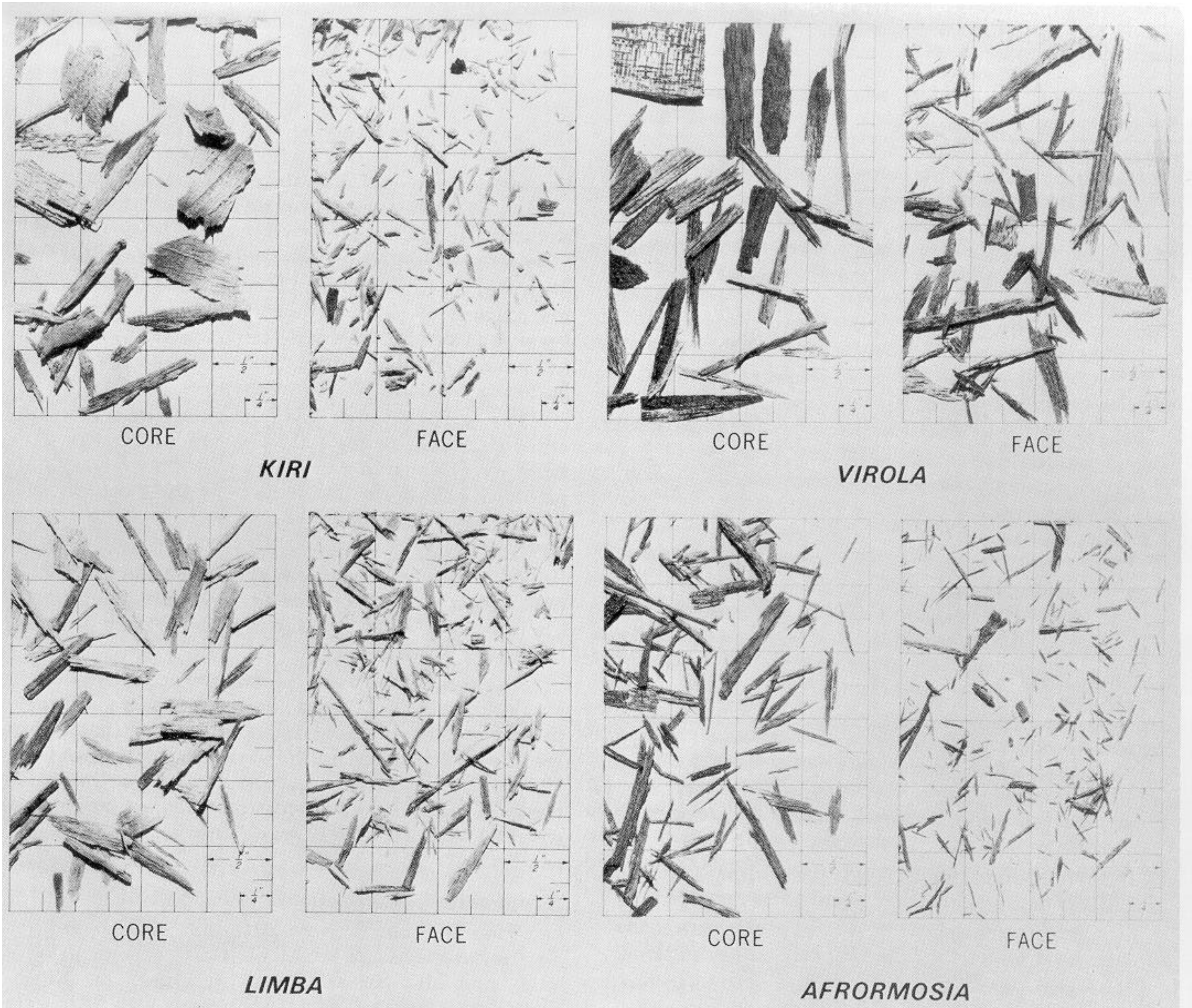

Figure 1. - Size of particles used in faces and core of particleboards.

Results and Discussion

Physical and Mechanical Properties

Density. – Actual board density, based on ovendry weights and volumes at 65 percent RH, showed an average of 0.56 g/cm^3 and a range from 0.34 to 0.76 g/cm^3 with the low-compression ratio and an average of 0.71 g/cm^3 and a range from 0.43 to 0.93 g/cm^3 with the high-compression ratio.

Strength and Stiffness. – The strength properties from determining MOR and MOE are tabulated in Table 2, and MOE data are shown as functions of board density in Figure 2.

Both MOR and MOE increased linearly with increase in board SG. Properties were directly related to species density whether of a single species or of a mixture of species, with small variations in the mixtures. Boards with the same density showed higher MOR and MOE at the high-compression ratio than did boards with the low-compression ratio. This is related to the volume of wood substance compacted to form a board. Although of the same density, a greater amount of wood was pressed to form the board at the high-compression ratio. This resulted in an increased volume of wood available to distribute stresses and increased contact between the flakes that resulted in improved bonding.

A comparison between properties of single-species and mixed-species boards showed that, at each compression ratio for each mixture of species, boards are approximately equal in MOR and MOE to the weighted mean of the results observed with the single species.

Regression equations (Table 3 and Fig. 2) are included to predict MOR and MOE from any board density within the range studied at the two compression

Table 2. - EFFECT OF SPECIES AND BOARD DENSITY ON STRENGTH AND STABILITY PROPERTIES OF HARDWOOD PARTICLEBOARD.

Compression ratio and species[1]	Actual panel density[2] (ovendry basis) (g/cm^3)	Modulus of elasticity[2] (1.000 lb./in.^{2})	Modulus of rupture[2] (lb./in.^{2})	Internal bonds (lb./in.^{2})	Water sorption[3]: 50 to 90 percent RH (%)	Water sorption[3]: water absorption in 24-hour water soak (%)	Thickness swelling[3]: 50 to 90 percent RH (%)	Thickness swelling[3]: Thickness swelling in 24-hour water soak (%)	Linear expansion[3]: 50 to 90 percent RH (%)	Linear expansion[3]: Linear expansion in 24-hour water soak (%)
L -A	0.34	143	1,110	75	7.8	148.0	6.6	14.0	0.11	0.21
H - A	.43	269	2,130	91	7.4	104.2	6.7	25.4	.13	.21
L - B	.51	324	2,130	70	8.7	129.5	12.3	37.8	.12	.28
H - B	.65	522	3,680	94	8.2	84.7	11.9	37.6	.12	.16
L - C	.68	444	3,670	237	8.1	62.2	10.2	21.8	.15	.21
H - C	.81	684	5,590	247	7.0	24.7	6.9	8.3	.17	.12
L - D	.76	530	4,130	295	5.6	16.0	6.0	7.8	.16	.17
H - D	.93	773	6,380	296	4.4	7.0	4.0	4.1	.18	.09
L - AB	.42	223	1,610	70	8.7	130.0	9.6	21.2	.11	.19
H - AB	.56	446	3,430	85	7.8	84.1	8.2	23.4	.12	.16
L - AC	.50	317	2,340	98	0.2	101.0	9.0	20.0	.14	.22
H-AC	.64	523	4,020	97	7.2	62.2	7.0	16.3	.16	.23
L - AD	.53	281	2,140	107	7.3	85.0	8.3	18.0	.15	.22
H-AD	.70	512	4,040	158	6.6	57.4	7.6	19.8	.17	.26
L - BC	.58	397	2,860	109	8.0	96.3	10.1	30.7	.13	.26
H - BC	.74	618	4,790	139	7.4	46.5	8.4	17.3	.15	.16
L - BD	.62	407	2,970	115	7.2	73.6	9.2	23.7	.14	.25
H - BD	.80	689	5,270	143	6.0	27.0	6.5	9.4	.17	.10
L - CD	.69	430	3,210	215	7.5	62.6	9.5	20.5	.18	.26
H - CD	.87	708	5,660	327	6.1	18.7	6.6	8.0	.23	.10
L - ABC	.51	324	2,200	87	8.7	103.7	9.5	22.7	.10	.19
H-ABC	.65	532	4,010	115	7.8	67.2	8.4	22.1	.12	.20
L - ABD	.53	307	2,180	95	7.3	93.8	7.9	22.0	.13	.21
H - ABD	.67	515	4,140	137	6.3	63.1	6.7	20.4	.13	.21
L - ACD	.67	335	2,700	120	7.0	78.2	7.4	19.1	.16	.21
H - ACD	.74	576	4,760	161	5.8	49.2	6.0	15.2	.18	.21
L - BCD	.64	423	3,060	133	7.3	69.6	8.3	24.5	.11	.27
H - BCD	.81	672	5,510	199	6.0	28.0	6.8	9.3	.15	.10
L - ABCD	.53	293	2,040	87	7.7	99.4	9.5	22.3	.14	.28
H - ABCD	.69	507	4,070	134	7.0	62.4	8.8	23.4	.14	.31

[1]Board density:species density: L, low (1.2:1.0); H, high (1.6:1.0); A, kiri; B, virola; C, limba; and D, afrormosia.

[2]Each figure is an average of 8 specimens.

[3]Each figure is cm average of 4 specimens; RH, relative humidity.

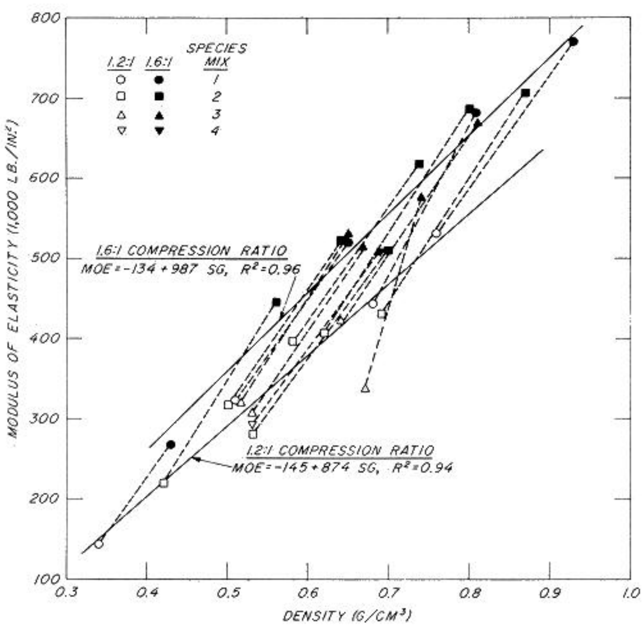

Figure 2. - Relationship of MOE to particleboard density as affected by species mixture and compression ratio of raw material.

ratios. A comparison between the equations confirmed increased MOR and MOE values for boards with the same density but made with the high-compression ratio. At a density of 0.60 g/cm3 and a compression ratio of 1.2:1.0, the equations gave 2,840 lb./in.^{2} for MOR and 380,000 lb./in.^{2} for MOE, whereas at a compression ratio of 1.6:1.0, these values are 3,550 lb./in.^{2} for MOR and 459,000 lb./in.^{2} for MOE. Using these bases, a change of 0.10 g/cm^3 in board density produced a change of 710 lb./in.^{2} in MOR and 87,000 lb./in.' in MOE and a change of 842 lb./in.^{2} in MOR and 99,000 lb./in.^{2} in MOE at the low- and high-compression ratios, respectively.

There was a linear relation between MOE and MOR (Table 3). This relation was almost independent of compression ratio.

Internal Bond Tests. – IB strengths (Table 2 and Fig. 3) generally increased with increase in board density, but the correlation was lower than with bending properties. The regression lines for MOR and MOE for each species were approximately linear with equal slopes. These characteristics did not hold for IB properties. Most lines were not parallel (Fig. 3), and a linear regression did not show good correlation between IB and density of boards with the following species: limba, afrormosia, kiri-virola, kiri-limba, and kiri-virola-limba.

Increasing board specific gravity had different effects from species to species. Boards made from afrormosia increased in IB only 1 lb./in.^{2} with a change of the compression ratio from 1.2:1.0 to 1.6:1.0, and boards made with mixture kiri-limba decreased 1 lb./in.^{2} with the same variation in compression ratio. Virola boards increased in IB with increase in board density, but showed low values when compared with other boards of the same density. Examination of the particles from the four species, and mainly the partitles used in the core, provided a logical explanation

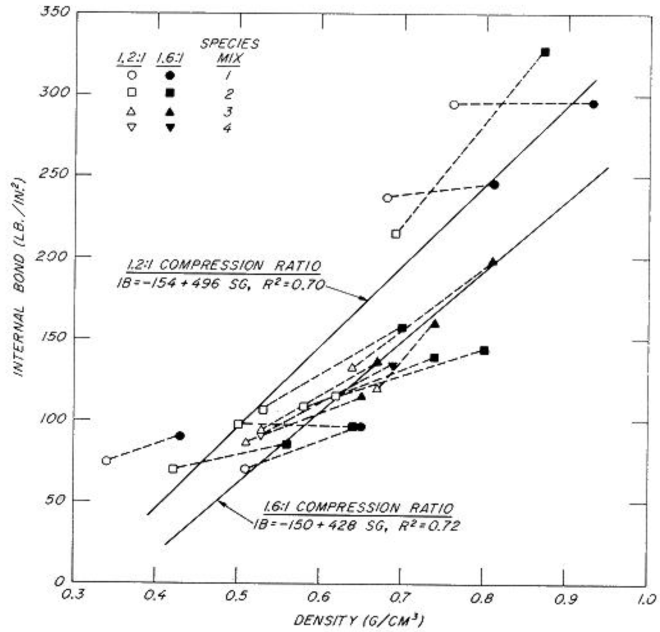

Figure 3. - Relationship of IB to particleboard density as affected by species mixture and compression ratio of raw material.

Table 3. - REGRESSION EQUATIONS RELATING PARTICLEBOARD PROPERTIES TO PARTICLEBOARD STRENGTH AND DIMENSIONAL STABILITY.

Compression ratio[a]	$y = a + b X_1 + c X$ [b]				R^2
L	MOR	= −1,438.9	+ 7,126.5 SG		0.96
H	MOR	= −1,504.3	+ 8,427.9 SG		.98
L	MOE	= −144.7	+ 873.7 SG		.94
H	MOE	= −133.7	+ 987.0 SG		.96
L	IB	= −154.2	+ 496.0 SG		.70
H	IB	= −150.2	+ 427.6 SG		.72
L	MOE	= 38.0	+ .120 MOR		.96
H	MOE	= 47.0	+ .116 MOR		.98
	24-HOUR WATER SOAK				
L	WA	= 250.746	− 286.605 SG		.89
H	WA	= 203.971	− 212.461 SG		.94
L	TS	= 6.360	− 30.833 SG	+ 3.157 SVC	.81
H	TS	= 43.537	− 66.600 SG	+ 2.055 SVC	.79
L	TS	= −15.731	+ .103 WA	+ 2.728 SVC	.85
H	TS	= −14.647	+ .313 WA	+ 1.503 SVC	.92
	30 TO 90 PERCENT RELATIVE HUMIDITY EXPOSURE				
L	TS	= −5.927	+ 1.096 WA	+ .534 SVC	.84
H	TS	= −7.653	+ 1.356 WA	+ .498 SVC	.88
L	LE	= .165	+ .219 SG	− .008 SVC	.68
H	LE	= .154	+ .233 SG	− .010 SVC	.68
	50 TO 90 PERCENT RELATIVE HUMIDITY EXPOSURE				
L	TS	= −4.823	+ 1.195 WA	+ .440 SVC	.87
H	TS	= −5.458	+ 1.367 WA	+ .351 SVC	.85
L	LE	= .074	+ .181 SG	− .004 SVC	.59
H	LE	= .079	+ .215 SG	− .008 SVC	.67

[a]Board density:species density: L, low (1.2:1.0); and H, high (1.6:1.0).

[b]MOR, modulus of rupture; MOE, modulus of elasticity; IB, internal bond; SG, panel density; TS, thickness swelling; LE, linear expansion; WA, water absorption; and SVC, wood volumetric change from ovendry to soak.

for this result. Virola produced the largest flakes, followed by kiri, limba, and afrormosia (Fig. 1). IB is known to be influenced by the geometry of the flakes. Stewart and Lehmann (24) found high IB strengths closely related to flake or particle types with a high percentage of small particles.

Regression equations are included (Table 3 and Fig. 3) to predict IB for any board density at the high- and the low-compression ratios. According to these equations, boards with the same density but made with the low-compression ratio generally attained higher IB strength than did boards made with the high-compression ratio. At a density of 0.60 g/cm^3 and a compression ratio of 1.2:1.0, the equations give 143 lb./in.‘, whereas at a compression ratio of 1.6:1.0, the value decreases to 106 lb./in.^{3}. This may be due to the increasing amount of crushing and flake damage occurring at the high-compression level. Although with most species, IB strength increased with increased board density, the two species of low density (kiri and virola) in the mixtures exerted the controlling influence on IB. Thus, IB properties with mixtures cannot be predicted from the weighted means of the results with the single species.

Dimensional Stability

The particleboard dimensional stability tests are summarized by species and board density in Table 2 and in Figures 4 to 7.

Water Absorption. – In the 24-hour water-soak test, board density had a substantial effect on the amount of water absorbed (Fig. 4). Boards of kiri in the low-compression ratios absorbed as much as 148 percent water, whereas those of afrormosia absorbed only 7 percent in the high-compression ratio. The specimens

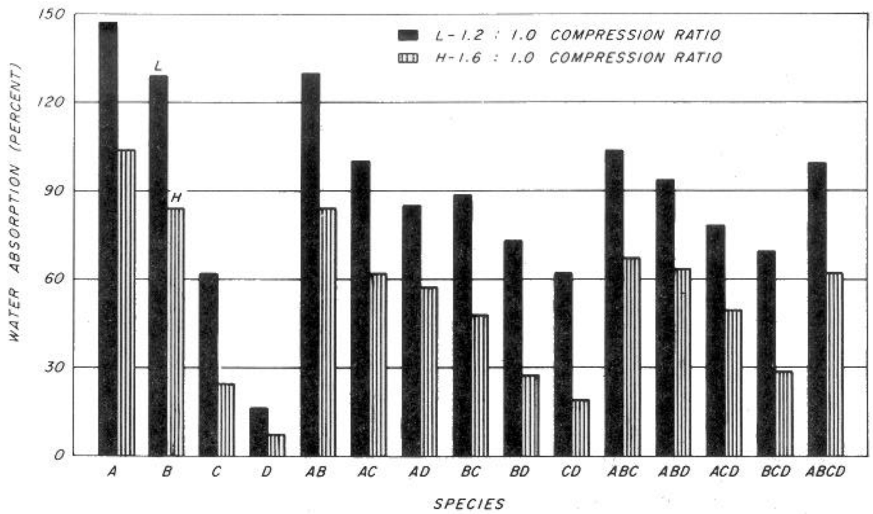

Figure 4. - Relationship of water absorption to species mix and compression ratio of particleboards exposed to 30 percent RH to 24-hour water soak.

exposed to high RH conditions were affected by density also, as shown in Figure 5, but the effect was not so marked as in the water-soak test. For the same species, increasing board density always decreased the amount of water absorbed in the water-soak or RH tests.

Regression equations (Table 3) are included to predict water absorption from any board density for both compression ratios. In the water-soak test the linear regression showed a high correlation between water absorption and density. In the RH tests the correlation between water absorption and board density was lower than in the water-soak test.

Thickness Swelling. –No linear relation was found between thickness swelling and board density in a preliminary examination of the data when all boards were considered. When each type of board was considered separately, density had some effect on the amount of thickness swelling, but that relation seemed to be closely related to species and was not constant from test to test.

In the exposure to 30 to 90 percent RH (Fig. 6), the boards with kiri, virola, virola-limba, and the four species were more stable at low density (Table 2). All other boards swelled less at high density. In the 50 to 90 percent RH exposure, all boards but kiri were more stable at high density. In the water-soak test, boards from kiri, kiri-virola, kiri-afrormosia, and all four species were more stable at low density. All others were more stable at high density. In all tests, boards from virola showed the greatest amount of thickness swelling, and in all tests boards from afrormosia were the most stable of the species. At this point, it should be noted that virola (solid wood) also showed the largest volumetric change (Table 1). Multiple regression equations relating board density, water absorption, and total wood volumetric change to thickness swelling are presented in Table 3.

Low swelling values for high-density boards have not been common, as Klauditz (10), for example, found an increase in swelling with increase in density. For a particular wood species, the compression needed in mat consolidation increases as the desired density increases. In this study, however, the increase in density generally resulted in increase in thickness stability; this may have been due to several factors. One factor is undoubtedly related to the low moisture absorption values always associated with high density. Also, high SG may have resulted in a closer approach to maximum glue-bond strength. Another possibility is suggested by Lehmann (15). The lower porosity of the high-density boards restricts the moisture flow so that a high MC prevails during most of the press cycle. This in turn should result in increased compressive set.

Linear Expansion.-As with thickness swelling, no linear relation was found between linear expansion and density, but when each board was considered separately the linear expansion was affected by board density (Fig. 7) with some variation between tests. In the 30 to 90 percent RH exposure, all boards but those from virola and from the mixture of kiri-limba-afrormosia were more stable at low density. In the 50 to 90 percent RH exposure, virola boards were not affected by increase in the panel density. All of the other boards except those of the four-species mixture were more stable at low density.

The water-soak test showed greater variation in the effect of density on linear expansion (Table 2). The boards from the mixtures of kiri-limba, kiri-afrormosia, kiri-virola-limba, and of the four species were most stable at low density although differences were small. Other boards were equally or more stable at high density. In the water-soak test, the boards from the four species showed the largest amount of linear expansion, and boards from afrormosia were the most stable. In the 30 to 90 percent RH exposure, the mixture of kiri-afrormosia produced the most unstable boards. Kiri and virola resulted in the most stable boards. In the 50 to 90 percent test, boards made with the mixture limba-afrormosia were the most unstable.

Multiple regression equations relating linear expansion to board density and wood volumetric change are presented in Table 3. According to these equations,

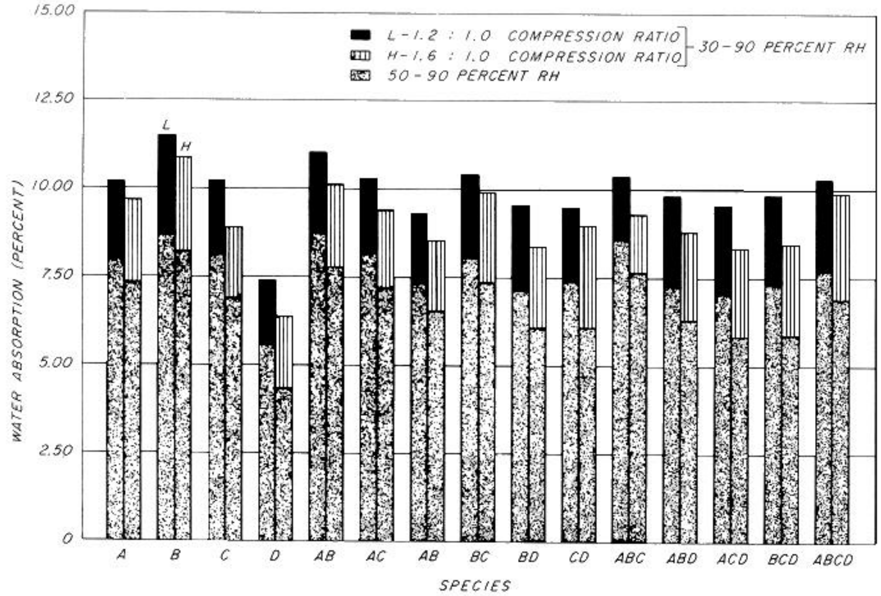

Figure 5. - Relationship of water absorption to species mix and compression ratio of particleboards exposed to 30 to 90 and 50 to 90 percent RH.

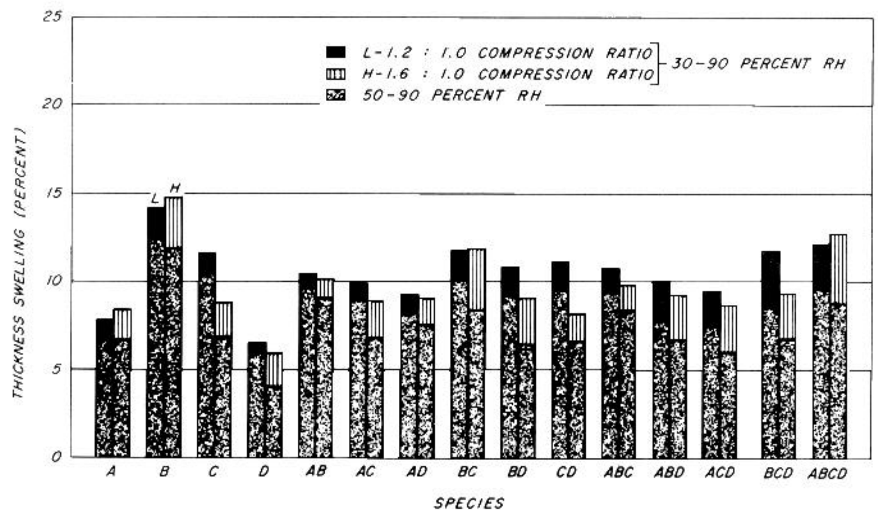

Figure 6. - Relationship of thickness swelling to species mix and compression ratio of particleboards exposed to 50 to 90 and 30 to 90 percent RH.

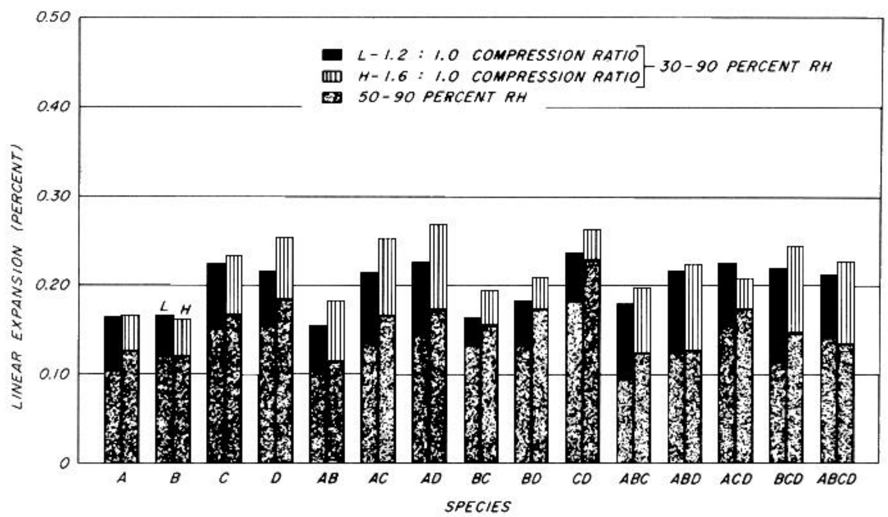

Figure 7. - Relationship of linear expansion to species mix and compression ratio of particleboards exposed to 30 to 90 and 50 to 90 percent RH.

linear expansion was directly proportional to board density and inversely proportional to wood volumetric change. However, the effect of wood volumetric change was small when compared to the effect of density. The negative sign probably was an effect of virola, a low-density species with the highest volumetric change. The regression was not significant in the water-soak test.

An attempt to find a relation between particleboard linear expansion and wood linear expansion was without significant results. Multiple regressions between linear expansion, water absorption, and wood volumetric change also showed low correlation.

Conclusions

The most important results of this study of the effects of density of four exotic hardwood species used to produce particleboards can be summarized as follows:

MOR and MOE (bending stiffness of the board divided by the geometric moment of inertia) increased linearly with increased wood density and particleboard density with small variations between species.

Boards pressed under a high-compression ratio (board density: species density, 1.6:1.0) showed higher moduli of rupture and elasticity than did panels made with a low-compression ratio (1.2:1.0) at the same board density.

Bending strengths of mixed-species boards could be predicted from the weighted means of the board properties if the boards were made with a single species under similar conditions. IB and dimensional stability could not be predicted by this technique.

IB values generally increased linearly with increased board density but were not as well related to wood density as were MOR and MOE.

Boards of the same density but made with the low-compression ratio generally showed better IB than did panels made at the high-compression ratio.

Water absorption was found closely related inversely to board density in a water-soak test. In an RH exposure the relation between water absorption and board density, although existing, was not as marked as in the water-soak test.

No linear relation was found between thickness swelling and board density or between linear expansion and board density. However, as a general conclusion, when the same species was considered, an increase in board density caused a decrease in thickness swelling and an increase in linear expansion. Thickness swelling was found inversely proportional to board density and wood volumetric change, and directly proportional to water absorption and wood volumetric change.

Based on the results here, it is possible to mix species of a wide range of density and produce acceptable particleboards in several density grades. Mixtures of species for particleboard and other products can be a partial answer for increased utilization of the timber of tropical forests.

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