AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
Batch 41

1. SUBJECT CLASSIFICATION

A. PRIMARY
Food production and nutrition — AK50-0000-G732

B. SECONDARY
Wood technology and industries--Philippines

2. TITLE AND SUBTITLE
Properties of particleboards from mixtures of Philippine hardwoods

3. AUTHOR(S)
Gertjejansen,R.O.; Haavik,D.W.; Carino,H.F.; Okoro,S.P.A.; Hall,H.J.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1976	53p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
USDA/FS

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

9. ABSTRACT

Particleboards were manufactured in a laboratory of the Department of Forest Products, University of Minnesota, from three different mixtures of hardwood chips imported from the Philippines, using 5% and 8% levels of urea formaldehyde resin. The three chip mixtures, A, B, and C, contained different proportions of 50 Philippine species. The average specific gravities of the mixtures were 0.50, 0.70, and 0.52, respectively. Boards were also manufactured from a planer shavings mixture with a species composition identical to chip mixture C, and from steamed and unsteamed ring-flaked chips of mixture A. All strength properties increased with an increase in either resin content or board density. Linear expansion and thickness swelling were reduced by an increase in resin content but were not significantly affected by density. There were no differences between boards from ring-flaked steamed and unsteamed chips. Of the three furnishes from hammermilled chips, mixture B had properties inferior to the other two mixes. The strength properties of all the urea-bonded boards compared favorably with Commercial Standard CS 236-66 type 1B2 board. However, the maximum allowable linear expansion was, with one exception, met only by the boards from ring-flaked furnishes. Exterior type boards made with phenol formaldehyde resin from a furnish of mixture A hammermilled chips met the minimum property requirements of commercial standard type 2B2 boards at the 8% resin level but not at the 5% resin level.

10. CONTROL NUMBER
PN-AAC-708

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Chips
Hardwoods
Shavings
Particle boards
Philippines
Product development

13. PROJECT NUMBER

14. CONTRACT NUMBER
PASA TA(AG) 03-75 Res.

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

Properties of Particleboards from Mixtures of Philippine Hardwoods

by

R. O. Gertjejansen, D. W. Haavik,
H. F. Carino, S. P. A. Okoro, H. J. Hall

Department of Forest Products
College of Forestry
University of Minnesota
St. Paul, Minnesota 55108

The authors are, respectively, Professor, Undergraduate Research Assistant, Graduate Research Assistants, and Assistant Scientist, Department of Forest Products, College of Forestry, University of Minnesota

ERRATA

Page 4, Line 1 -- steaming resulted in a somewhat higher percentage of large material (that retained on the 1/2" screen) but less in the middle and lower range.

Figure 1 --

o———— Ring-flaked (Unsteamed) Mix A

⊙———— Ring-flaked (Steamed) Mix A

Table 8 -- Add a vertical solid line between AR-8 and CH-8 (between 2.0 and 2.7).
Add a vertical dashed line between AR-5 and CH-5 (between 0.6 and 1.8).

Table 10 --

KEY

■ □ planer shavings, species mixture C
▲ Δ ring-flaked, species mix A, unsteamed
▼ ∇ ring-flaked, species mix A, steamed
● o hammermilled, species mixture A, B, C

Abstract

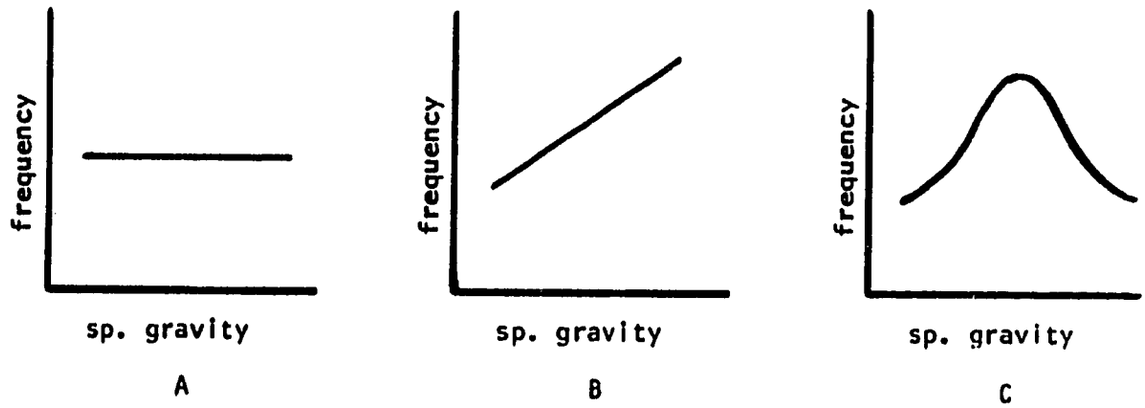
Laboratory particleboards were manufactured from furnishes of three hammermilled Philippine hardwood chip mixtures at urea formaldehyde resin levels of 5% and 8%. The three mixtures, A, B, and C, contained different proportions of 50 Philippine species, and the average specific gravities of the mixtures were 0.50, 0.70, and 0.52 respectively. Boards also were manufactured from a planer shavings mixture with a species composition identical to chip mixture C and from furnishes from steamed and unsteamed ring flaked chips of mixture A.

All strength properties increased with an increase in either resin content or board density. Linear expansion (LE) and thickness swelling were reduced by an increase in resin content but were not significantly affected by density. There were no differences between boards from ring flaked steamed and unsteamed chips, and these two boards were superior in MOR, MOE, and LE but not in IB and thickness swelling to the boards from furnishes of hammermilled chips and planer shavings. Of the three furnishes from hammermilled chips, mixture B (0.70 sp. gr.) generally had inferior properties when compared to the other two. The properties of the planer shavings boards were always intermediate to those from furnishes of hammermilled chips and ring flaked chips except for thickness swelling where the planer shavings boards were superior.

The strength properties of all the urea bonded boards compared favorably with Commercial Standard CS 236-66 type 1B2 board, but the maximum allowable LE was, with one exception, met only by the boards from ring flaked furnishes. Exterior type boards made with phenol formaldehyde resin from a furnish of mixture A hammermilled chips met the minimum property requirements of commercial standard type 2B2 boards at 8% resin level but did not meet MOR and MOE minimums at the 5% resin. Loss of MOR after accelerated aging was 50% or less for both resin contents.

Introduction

Three bark free chip mixtures -- A, B and C -- each comprised of different proportions of 50 Philippine hardwood species and representing three potential naturally occurring density distributions were hammermilled to produce furnishes for the manufacture of laboratory particleboards. The chips were nominal 5/8" in length and were produced in a commercial size chipper. Particleboards also were manufactured from a furnish of planer shavings with a species composition of chip mixture C and from furnishes of steamed and unsteamed ring flaked chips of mixture A. The common and botanical names, specific gravities, and ash and silica contents of the 50 species are in Table 14, and the compositions of the three chip mixtures are in Table 15. The average specific gravities (oven dry weight and green volume basis) were 0.50, 0.70, and 0.52 for chip mixtures A, B, and C respectively. Their frequency distributions are shown below.



Hammermilling was chosen as the primary method of chip breakdown because of its relative simplicity and economic attractiveness. Ring flaking was included to determine to what extent it improved board properties over hammermilling. Mixture A was chosen for ring flaking because of its low average specific gravity (0.50), but mixture C (0.52) also could have

been used. Planer shavings were included in the study to compare that particle type to a furnish from hammermilled chips. Mixture C was chosen for the planer shavings - hammermilled furnish comparison because it contained the highest proportion of species in the density range of commercial sawlog species, the commercial source of planer shavings.

Preparation of Particle Furnishes

The furnishes from hammermilled chips were prepared by milling green chips in a 10" hammermill fitted with a 7/16" screen. After milling the particles were screened and all material retained on a 1/4" screen[1/] was remilled using a 5/16" screen. The particles were then air dried and rescreened and all material passing the 1/32" screen was rejected as fines[2/] and that retained on the 1/4" screen was rejected as being too coarse. The percent coarse and fine particles rejected and the percent retained as useable furnish were as follows.

Chip Mixture	% rejected (air dry basis)		% useable furnish (air dry basis)
	fine	coarse	
A	9.8	1.4	88.8
B	10.0	2.5	87.5
C	11.0	1.9	87.1

It is obvious from the above data that there was very little difference in the amount of useable material obtained from the three chip mixtures.

Planer shavings were produced on an 8" jointer-planer from green blocks of the 50 Philippine species. After air drying, the shavings were mixed together in proper proportions to obtain a species mixture identical to chip

---

1/ The diameter of the circular holes in the vibratory screen.

2/ In this report, fines are defined as all material passing a screen with 1/32" diameter circular holes.

mixture C. The mixture was then hammermilled (no screen) to break up the large curled shavings and screened to remove fines. Fines accounted for 6% of the weight of the furnish. The average thickness of the planer shavings was 0.020" and ranged from 0.005" to 0.047".

Green flakes from both steamed and unsteamed chips of chip mixture A were produced in a Pallmann PZ6 ring flaker that was fitted with a new set of knives before each run. Steaming was done in a fiber drum with steam injected at the bottom of the drum. Internal drum temperatures were measured at three heights, and after 15 minutes of steaming, the entire drum had stabilized at 101°C. Steaming was continued for another 50 minutes, and the hot chips were then fed immediately into the PZ6 flaker.

After flaking, both furnishes were air dried and then screened to remove fines. Fines accounted for 9.8% and 11.0% of the total air dried weights of the furnishes from the steamed and unsteamed chips respectively. If this difference was in fact significant, it would indicate that steaming reduced the loss of fines by approximately 10%. The average thickness of flakes from steamed chips was 0.018" and ranged from 0.004" to 0.037". Flakes from unsteamed chips averaged 0.015" in thickness and ranged from 0.004" to 0.034". Chips which escaped between the knives and knife holders were screened out and rejected. They accounted for approximately 4% of the total weight of both furnishes.

Sieve analyses of the six furnishes after they had been screened to remove fines are shown in Figure 1 and Table 1. Of the three hammermilled furnishes, chip mixture B, which had the highest average specific gravity, produced the least amount of large material (that retained on the 1/4" screen) and the greatest amount in the middle range (retained on the 1/8" screen). All three had approximately the same amount of fine material. For the ring flaked chips,

steaming resulted in a somewhat lower percentage of large material (that retained on the 1/2" screen) but more in the middle and lower range. The furnish of planer shavings did not contain the large particles characteristic of the ring flaked furnishes, but its average size was greater than that of the hammermilled chips.

Figures 13 through 17 are photographs of the five furnishes as they appear on a 1" grid.

Experimental Design and Procedure

The following experimental design and manufacturing conditions were employed.

I. Seven particle furnishes:

1. Chip mixture A - hammermilled chips - urea resin
2. Chip mixture B - hammermilled chips - urea resin
3. Chip mixture C - hammermilled chips - urea resin
4. Chip mixture A - hammermilled chips - phenolic resin
5. Chip mixture A - ring flaked chips - urea resin
6. Chip mixture A - presteamed ring flaked chips - urea resin
7. Planer shavings with composition of chip mixture C - urea resin

II. Two board densities (nominal): 42 and 48 pcf based on oven dry weight and volume at 50% RH.

III. Two resin contents: 5% and 8% solids based on the oven dry weight of wood in the panels.

IV. Replications: 2 (56 boards manufactured)

V. Board size: 18" x 18" x 1/2" thick

VI. Board construction: homogeneous

VII. Resin types: Borden Chemical's WW-17 GN liquid urea formaldehyde resin @ 65% solids and PB-65 liquid phenol formaldehyde resin @ 45% solids

VIII. Wax size: 0.5% solids (Hercules' Paracol 404N wax emulsion)

IX. Press temperature: 320°F and 375°F for urea and phenolic bonded boards respectively.

X. Press time: 7.5 and 9.0 minutes for urea and phenolic bonded boards respectively.

XI. Time to 1/2" stops: 1.2 to 2.2 minutes depending on board density and type of furnish.

The liquid resins were applied to the particles by spraying into a rotating drum-type laboratory blender containing the particle furnish. The wax size was mixed directly with the urea formaldehyde resin, but because of its incompatibility with the phenol formaldehyde resin, it was sprayed on the particles prior to the application of that resin. After blending the particles were post blended for 5 minutes and then hand felted into 18" x 18" mats. The mats were prepressed and then hot pressed according to the conditions described above. After pressing the urea bonded boards were cooled immediately whereas the phenolic boards were hot stacked for 24 hours to insure complete cure of the resin. The boards were then edge trimmed to 14" x 14", and four 2.5" x 14" static bending samples and two 1.75" x 14" linear expansion (LE) samples were cut from each panel. The samples were equilibrated at 72°F and 50% relative humidity (RH) prior to testing. Board densities were determined by oven drying the LE samples after testing.

For the urea bonded boards, all four static bending samples were used to determine modulus of elasticity (MOE) and modulus of rupture (MOR) at the 50% RH control test condition. Internal bond strengths (IB) were determined from two 2" x 2" specimens cut from one half of the static bending samples after they had been tested. The remaining half of each static bending sample was

cut into one 2 1/2" x 5" water soak sample from which percent water absorption and thickness swelling were determined after water soaking for 24 hours at 72°F.

For the phenolic bonded boards, two of the four static bending samples from each board were tested at the 50% RH control test condition, and the remaining two were subjected to the ASTM accelerated aging test. After aging, the samples were re-equilibrated at 50% RH and tested in static bending. MOR and MOE were calculated based on the original thickness at 50% RH. Internal bond strengths of both the control and aged samples were obtained in the same manner as for the urea boards.

Percent linear and thickness swelling from equilibrium at 50% RH to equilibrium at 90% RH and back to equilibrium at 50% were obtained from the LE samples.

For statistical analyses boards were divided into treatments according to species mixture, furnish type, and resin level. Regression lines were fitted to each treatment with density as the independent variable, and then each property was adjusted to 45 pcf (721 kg/m^3). An independent, normal distribution was assumed. The estimated standard error of the adjusted property was computed and 95% confidence intervals of the predicted mean values were established according to Draper and Smith.[3/]

At the $\alpha = .05$ probability level significant differences between treatments or their interactions were determined by Scheffé's S-method.[4/] The S-method also was used to locate significant differences due to species mixture or furnish type when the effect of resin level was omitted. Another

---

3/ N. R. Draper and H. Smith (1967), Applied Regression Analysis, John Wiley and Sons, Inc., New York (21, 24).

4/ H. Scheffé (1967), The Analysis of Variance, John Wiley and Sons, Inc., New York (68-72).

approach, the Q method,[5/] was used as a somewhat less conservative test to determine the effect of treatments and their interactions.

Results

The static bending properties of the 12 urea bonded board types (treatments) adjusted to 45 pcf density are shown in Figures 2 and 3 and Tables 2, 3, and 4. Significant differences between board types at the 95% confidence level, as determined by Scheffé's test and the Q method are bracketed to the right in Tables 3 and 4 with solid lines for Scheffé's test and with dashed lines for the Q method.[6/] Throughout this paper, statements concerning significant differences are based on Scheffé's S-method unless otherwise indicated. It is evident from the data that the ring flaked furnishes produced boards with superior MOR's and MOE's, and that steaming the chips prior to flaking had no significant effects on these properties. For the boards from hammermilled chips, there were no significant differences in either MOR or MOE between boards from chip mixtures A, B, or C at either resin level. However the MOR's of the boards from chip mixture B were lower than those from mixtures A and C but were significantly different only by the Q method. The high average specific gravity of chip mixture B (0.70) and corresponding low densification ratio during board manufacture would account for the reduced MOR of boards from mixture B. The boards from planer shavings of chip mixture C had static bending properties intermediate to the boards from the ring flaked and hammermilled furnishes. For all six furnish types, both MOR and MOE were improved by increasing the urea resin content from 5% to 8%.

5/ G. W. Snedecor and W. G. Cochran (1967). Statistical Methods, The Iowa State University Press, Ames, Iowa (272-274).

6/ The same applies for Tables 5, 7, 8, and 9.

Figures 4 and 5 are common slope regression lines of MOE and MOR as a function of board density for the 12 board types. Individual slopes were determined by analysis of covariance and an F test showed that the slopes for both MOE and MOR could be expressed as a common slope at the 95% confidence level. As would be expected, both MOR and MOE increased with an increase in board density.

Internal bond strengths (IB) of the urea bonded boards at 45 pcf are illustrated in Figure 6 and Tables 2 and 5. Generally speaking, the IB's were all quite high but not unusual for homogeneous laboratory particleboards. The boards from hammermilled chips showed a greater overall strength than those from ring flaked chips and planer shavings. This presumably was due to a more uniform density in the boards from hammermilled chips which is a typical effect of small particles. The IB of the board from hammermilled chips of mixture B at 5% resin was significantly lower than the IB of the mixture C board but not different from mixture A. However there were no significant differences at the 8% resin level. There was no significant difference between the boards from steamed and unsteamed ring flaked chips at either resin level. The planer shavings boards had somewhat higher IB values than those from ring flaked chips, which probably was due to the former's smaller average particle size. An increase in resin content resulted in a significant increase in the IB of the boards from the three hammermilled furnishes and planer shavings but not in the boards from the ring flaked chips.

Common slope regression lines, determined by analysis of covariance with density as the covariate are shown in Figure 7.[7/] As was the case with MOR and MOE, IB increased with an increase in board density.

The linear expansion (LE) of the urea bonded boards at 45 pcf from equilibrium at 50% RH, 72°F to equilibrium at 90% RH, 72°F are shown in Figure 8 and Tables 6 and 7. The superiority of the ring flaked furnishes in producing panels with excellent linear dimensional stability is quite evident. The relatively short, chunky particles of the hammermilled furnishes accounted for their greater LE. The boards from planer shavings exhibited LE's intermediate to the boards from ring flaked and hammermilled chips. In all cases LE decreased with an increase in urea resin content, but the effect of resin was statistically significant only for one of the boards from the hammermilled furnishes. For all 12 board types board density had a negligible effect on LE.

Total and irreversible thickness swellings from equilibrium at 50% RH to equilibrium at 90% RH and then back to 50% RH are in Figure 9 and Tables 6, 8, and 9. For all 6 furnish types, irreversible thickness swelling was reduced significantly by an increase in resin content, and this in turn was reflected in the total thickness swellings of the boards. The boards from planer shavings exhibited the least total and irreversible thickness swelling and the boards from hammermilled chips the greatest at either resin level. However it is evident from Figure 9 and the Tables that the differences among board types at a given resin level were not large. As was the case with linear expansion, there was not a consistent relationship between board density and total and irreversible thickness swellings. However this is not unusual for either laboratory or commercial particleboards.

7/ Unlike MOR and MOE there was considerable variation in the slopes of the regression lines for the IB's of the 12 board types. For this reason, the 12 slopes cannot be statistically represented as one common slope at the 95% confidence level. Therefore the information in Figure 7 as it regards the use of a common slope is at a lower confidence level than the conventional 95% level.

The percent water uptake and total thickness swelling of the urea boards at 45 pcf after a 24 hour water soak are in Figure 10 and Table 10. The following relationships are apparent from Figure 10.

a) Thickness swelling was a linear function water uptake.

b) Water uptake and swelling were greatest at the 5% resin level.

c) The general trend at both resin levels was that the boards from ring flaked chips had the greatest water uptake and/or swelling and the planer shavings boards the least.

d) For the boards from hammermilled chips, chip mixture C resulted in the least amount of swelling.

It is interesting to note that the planer shavings boards, which exhibited the best overall behavior, had the same species composition as chip mixture C, and this mixture performed the best among the three hammermilled furnishes.

The greater absorption and swelling at 5% resin content would be expected since less bonding existed to hold the matrix together. The greater water absorption by boards from ring flaked chips would be due to the larger internal voids in those boards because of their larger particle size and corresponding less uniform density. This resulted in more water uptake, and hence greater swelling within the 24 hour period. Whether or not the above relationships would hold if the boards were soaked for longer periods of time is not known.

The strength properties of the phenolic bonded boards from hammermilled chips of mixture A at 45 pcf density before and after ASTM accelerated aging are in Table 11 and Figure 11. As was the case with the urea bonded boards from the same furnish (Figures 2, 3, and 6), MOR, MOE, and IB all increased with an increase in resin content, but for some unapparent reason the three strength properties at 5% phenolic resin content were considerably less than those of the urea boards at 5% resin. MOR and MOE were reduced no more than

50% by accelerated aging at both resin levels, but IB was reduced an average of 75% for the two resin contents. An increase in resin content somewhat decreased the percent reduction in MOR and IB by aging but had no effect on MOE.

Linear and thickness swellings from equilibrium at 50% to equilibrium at 90% RH and irreversible thickness swelling after accelerated aging of the phenolic bonded boards are in Figure 12 and Table 12. Both LE and thickness swelling from 50% to 90% RH were reduced by increasing resin content from 5% to 8%. The reduction in thickness swelling was due to a reduction in the irreversible component. When compared to the urea bonded boards from the same hammermilled furnish (Figure 9), the thickness swellings were approximately the same but the LE of the phenolic bonded boards was considerably less at both resin levels (Figure 8). Also the effect of the 8% resin level in reducing LE was greater for the phenolic resin. Why these differences occurred between the two resin types is not known.

The minimum property requirements of medium density 1B2 interior type (urea) particleboards and 2B2 exterior type (phenolic) boards in Commercial Standard CS 236-66 are as follows.

Type	MOR (psi)	MOE (1000 psi)	IB (psi)	LE (%)
1B2	2400	400	60	0.30
2B2	2500	450	60	0.25

When the 12 urea boards in this study with properties adjusted to 45 pcf are compared to the 1B2 board, all boards except the board at 5% resin content from hammermilled chips of mixture B (the high specific gravity mixture) met or exceeded the 2400 psi MOR requirement and the 400,000 psi MOE requirement. All boards greatly exceeded the 60 psi minimum IB requirement. With respect

to LE, only the boards from the ring flaked furnishes had LE's less than 0.30% at both resin levels. The other boards all exceeded 0.30% except for the 8% resin board from hammermilled chips of mixture C. The relatively high LE of the planer shavings boards was not expected but probably was related to its low thickness swelling (Figure 9).

A comparison of the properties of the phenolic bonded board from hammermilled chips of mixture A to those of the 2B2 board shows that the boards in this study exceeded all of the minimum requirements at the 8% resin level. They did not meet the MOR and MOE minimums at 5% resin content, and, as stated earlier, the reason for these low values is not known. However they did meet the minimum LE and IB requirements. A reduction in MOR of not more than 50% after accelerated aging as specified in the Standard was met at both phenolic resin levels.

Comparisons between furnish types and chip mixtures with the effects of resin eliminated are in Table 13. The comparisons show for the three hammermilled furnishes that with the exception of one IB comparison, there were no significant differences in the properties of the three furnishes. In other words by Scheffé's method of comparison, species mixture did not have a contributing influence on board properties. The Table also shows the advantages of ring flaking over hammermilling for chip mixture A. With the exception IB, ring flaking resulted in a superior board regardless of resin content. Manufacturing boards from planer shavings did not offer any significant advantages over hammermilling for chip mixture C. In fact the IB of the board from the hammermilled furnish was superior to that of the planer shavings board. The Table also substantiates the previous conclusions that steaming chips prior to ring flaking did not improve board properties.

Although hammermilled furnishes have the advantages of being economical to prepare, easy to control, and require a minimum equipment investment, they have the distinct disadvantage of generally producing a lower quality board

when compared to those from ring flaked chips. If the phenolic bonded boards in this study had been made from mixture A ring flaked chips their MOE and MOR would have readily met the minimum requirements of CS 236-66 at 5% resin content and perhaps even lower.

General Conclusions

1. Satisfactory urea bonded particleboards could be manufactured from chip mixtures of Philippine hardwoods representing three distinct wood density distributions.
2. Board properties were influenced by the chip mixture and the type of furnish (hammermilled chips, ring flaked chips, and planer shavings).
3. An increase in resin content improved all board properties. Generally speaking, the minimum property requirements of Commercial Standard CS 236 type 1B2 boards were met or exceeded at the 5% resin level except for the LE of the boards from hammermilled furnishes and planer shavings.
4. An increase in board density improved all strength properties.
5. When all properties were considered, boards from ring flaked chips were superior to those from hammermilled chips of the same chip mixture (mixture A).
6. Boards from hammermilled chips of the high density mixture (mixture B) generally were of poorer quality than boards from the other two mixtures.
7. Boards from planer shavings (mixture C) generally had properties intermediate to the boards from hammermilled chips and ring flaked chips.

Table 1. Values representing the frequency of occurrence (in percent) of the different particle sizes for the six particleboard furnishes as determined by sieve analysis.

Particle Size Classes 1/	Planer Shavings spp. mix C	Ring-Flaked spp. mix A		Hammermilled		
		steamed	unsteamed	spp. mix A	spp. mix B	spp. mix C
greater than 1/2	2.20	32.10	26.85	-0-	-0-	-0-
1/2-1/4	36.95	32.85	33.80	28.14	13.96	19.39
1/4-1/8	41.64	23.47	26.49	52.19	63.35	59.08
1/8-1/16	14.96	9.03	10.29	15.95	17.62	17.35
1/16-1/32	2.98	2.10	2.21	3.16	4.16	3.67
less than 1/32	1.27	0.45	0.36	0.56	0.91	0.51
Total	100.00	100.00	100.00	100.00	100.00	100.00

1/ Diameter (in inches) of circular holes in the screens of a Williams Chip Classifier.

Figure 1. Distribution of particle sizes for the various types of furnish determined by sieve analysis.

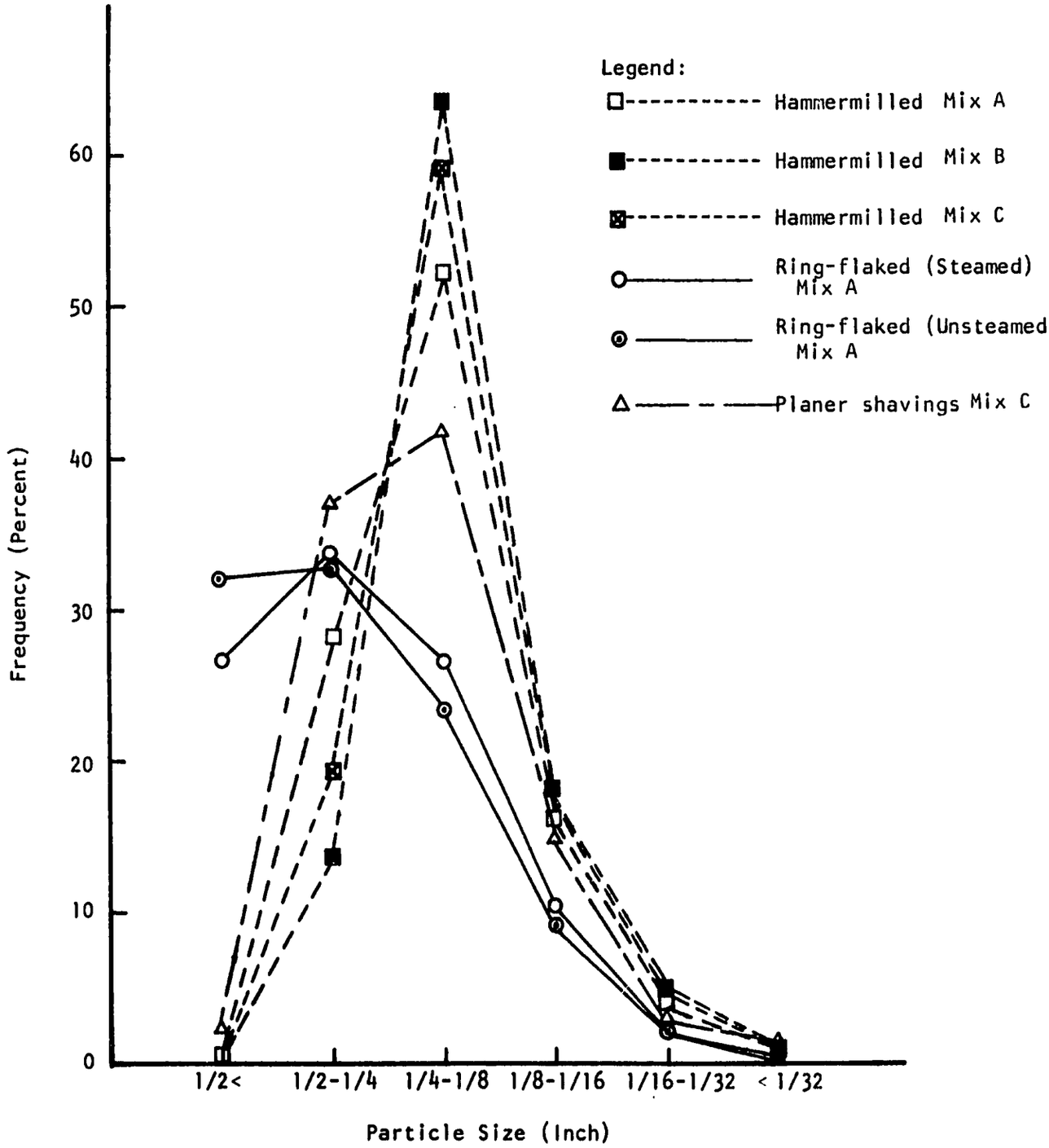


Table 2. Predicted Mean Values of Strength Properties of Urea Bonded Particleboards from Philippine Species at 45 pcf (721 kg/m^3).

Treatment No.	Code[1/]	Modulus of Elasticity: value @ 45 pcf (1000 psi)	Modulus of Elasticity: ±95% c.i. (1000 psi)	Modulus of Elasticity: Regression Coefficient (slope) (1000 psi/pcf)	Modulus of Rupture: value @ 45 pcf (psi)	Modulus of Rupture: ±95% c.i. (psi)	Modulus of Rupture: Regression Coefficient (slope) (psi/pcf)	Internal Bond: value @ 45 pcf (psi)	Internal Bond: ±95% c.i. (psi)	Internal Bond: Regression Coefficient (slope) (psi/pcf)
1	AH-5	398	±23	20.7	2700	±150	155	192	±14	5.79
2	AH-8	440	±23	26.8	3090	±180	210	270	± 9	10.2
3	BH-5	371	±33	14.5	2210	±220	118	161	±13	-0.673
4	BH-8	402	±34	24.8	2440	±180	181	267	±11	11.8
5	CH-5	430	±30	28.7	2640	±210	162	221	±13	10.1
6	CH-8	456	±18	25.2	3110	±140	199	290	±16	11.2
7	AR-5	634	±24	29.2	4080	±220	175	145	±15	6.06
8	AR-8	670	±33	28.4	4590	±310	234	180	±11	5.34
9	ARS-5	614	±34	26.9	4100	±250	194	146	± 5	3.37
10	ARS-8	656	±33	19.9	4700	±230	176	186	±14	6.12
11	CP-5	470	±17	17.8	3090	±130	120	164	± 7	3.49
12	CP-8	533	±24	13.5	3780	±240	67.3	235	± 6	7.44
common				23.1			170			6.99

1/ AH-5 species mixture A, hammermilled chips, 5% resin
AH-8 species mixture A, hammermilled chips, 8% resin
BH-5 species mixture B, hammermilled chips, 5% resin
BH-8 species mixture B, hammermilled chips, 8% resin
CH-5 species mixture C, hammermilled chips, 5% resin
CH-8 species mixture C, hammermilled chips, 8% resin
AR-5 species mixture A, ring-flaked chips, unsteamed, 5% resin
AR-8 species mixture A, ring-flaked chips, unsteamed, 8% resin
ARS-5 species mixture A, ring-flaked chips, steamed, 5% resin
ARS-8 species mixture A, ring-flaked chips, steamed, 8% resin
CP-5 species mixture C, planer shavings, unsteamed, 5% resin
CP-8 species mixture C, planer shavings, unsteamed, 8% resin

Table 3. Differences between treatments for modulus of elasticity of 45 pcf (721 kg/m^3) urea bonded particleboards from Philippine species. Significant differences determined by Scheffé's method are with a solid line and by the Q method with a dashed line. All values are 1000 psi.

Treatment No.			3	1	4	5	2	6	11	12	9	7	10	8
	Code[1/]		BH-5	AH-5	BH-8	CH-5	AH-8	CH-8	CP-5	CP-8	ARS-5	AR-5	ARS-8	AR-8
		MOE	371	398	402	430	440	456	470	533	614	634	656	670
3	BH-5	371	-	27	31	59	69	85	99	162	243	263	285	299
1	AH-5	398		-	4	32	42	58	72	135	216	236	258	272
4	BH-8	402			-	28	38	54	68	131	212	232	254	268
5	CH-5	430				-	10	26	40	103	184	204	226	240
2	AH-8	440					-	16	30	93	174	194	216	230
6	CH-8	456						-	14	77	158	178	200	214
11	CP-5	470							-	63	144	164	186	200
12	CP-8	533								-	81	101	123	137
9	ARS-5	614									-	20	42	56
7	AR-5	634										-	22	36
10	ARS-8	656											-	14
8	AR-8	670												-

[1/] AH-5 species mixture A, hammermilled chips, 5% resin
AH-8 species mixture A, hammermilled chips, 8% resin
BH-5 species mixture B, hammermilled chips, 5% resin
BH-8 species mixture B, hammermilled chips, 8% resin
CH-5 species mixture C, hammermilled chips, 5% resin
CH-8 species mixture C, hammermilled chips, 8% resin
AR-5 species mixture A, ring-flaked chips, unsteamed, 5% resin
AR-8 species mixture A, ring-flaked chips, unsteamed, 8% resin
ARS-5 species mixture A, ring-flaked chips, steamed, 5% resin
ARS-8 species mixture A, ring-flaked chips, steamed, 8% resin
CP-5 species mixture C, planer shavings, unsteamed, 5% resin
CP-8 species mixture C, planer shavings, unsteamed, 8% resin

Figure 2. (see tables 2, 3) Predicted mean values for modulus of elasticity of 45 pcf (721 kg/m^3) urea bonded particleboards from Philippine species.

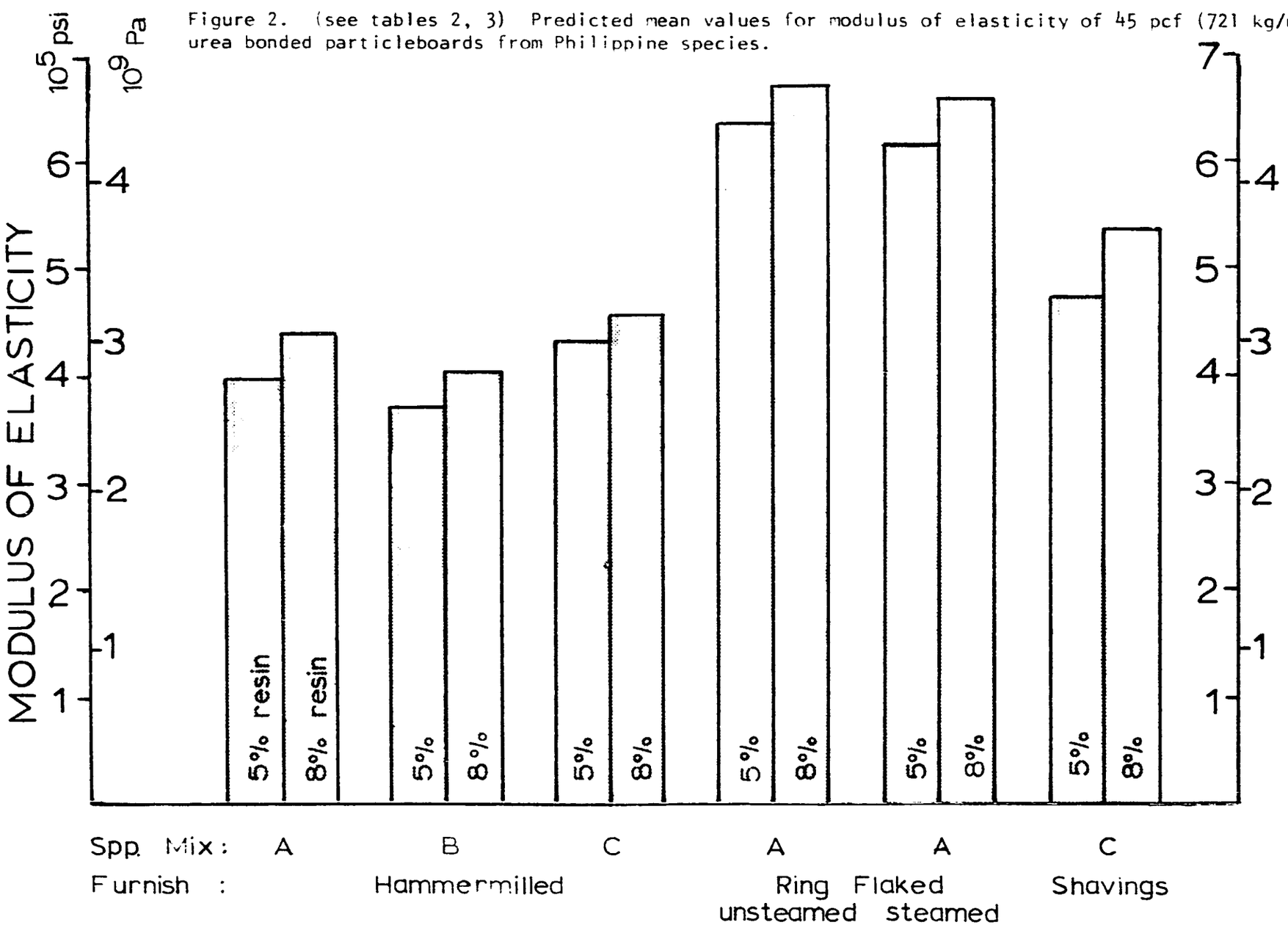


Table 4. Differences between the treatments for modulus of rupture of 45 pcf (721 kg/m^3) urea bonded particleboards from Philippine species. Significant differences determined by Scheffé's method are with a solid line and by the Q method with a dashed line. All values are psi.

Treatment No.			3	4	5	1	2	11	6	12	7	9	8	10
	Code 1/		BH-5	BH-8	CH-5	AH-5	AH-8	CP-5	CH-8	CP-8	AR-5	ARS-5	AR-8	ARS-8
		MOR	2210	2240	2640	2700	3090	3090	3110	3780	4080	4100	4590	4700
3	BH-5	2210	-	230	430	490	880	880	900	1570	1870	1890	2380	2490
4	BH-8	2440		-	200	260	650	650	670	1340	1640	1660	2150	2260
5	CH-5	2640			-	60	450	450	470	1140	1440	1460	1950	2060
1	AH-5	2700				-	390	390	410	1080	1380	1400	1890	2000
2	AH-8	3090					-	0	20	690	990	1010	1500	1610
11	CP-5	3090						-	20	690	990	1010	1500	1610
6	CH-8	3110							-	670	970	990	1480	1590
12	CP-8	3780								-	300	320	810	920
7	AR-5	4080									-	20	510	620
9	ARS-5	4100										-	490	600
8	AR-8	4590											-	110
10	ARS-8	4700												-

1/ AH-5 species mixture A, hammermilled chips, 5% resin
AH-8 species mixture A, hammermilled chips, 8% resin
BH-5 species mixture B, hammermilled chips, 5% resin
BH-8 species mixture B, hammermilled chips, 8% resin
CH-5 species mixture C, hammermilled chips, 5% resin
CH-8 species mixture C, hammermilled chips, 8% resin
AR-5 species mixture A, ring-flaked chips, unsteamed, 5% resin
AR-8 species mixture A. ring-flaked chips, unsteamed, 8% resin
ARS-5 species mixture A, ring-flaked chips, steamed, 5% resin
ARS-8 species mixture A, ring-flaked chips, steamed, 8% resin
CP-5 species mixture C, planer shavings, unsteamed, 5% resin
CP-8 species mixture C, planer shavings, unsteamed, 8% resin

Figure 3. (see tables 2, 4) Predicted mean values for modulus of rupture of 45 pcf (721 kg/m^3) urea bonded particleboards from Philippine species.

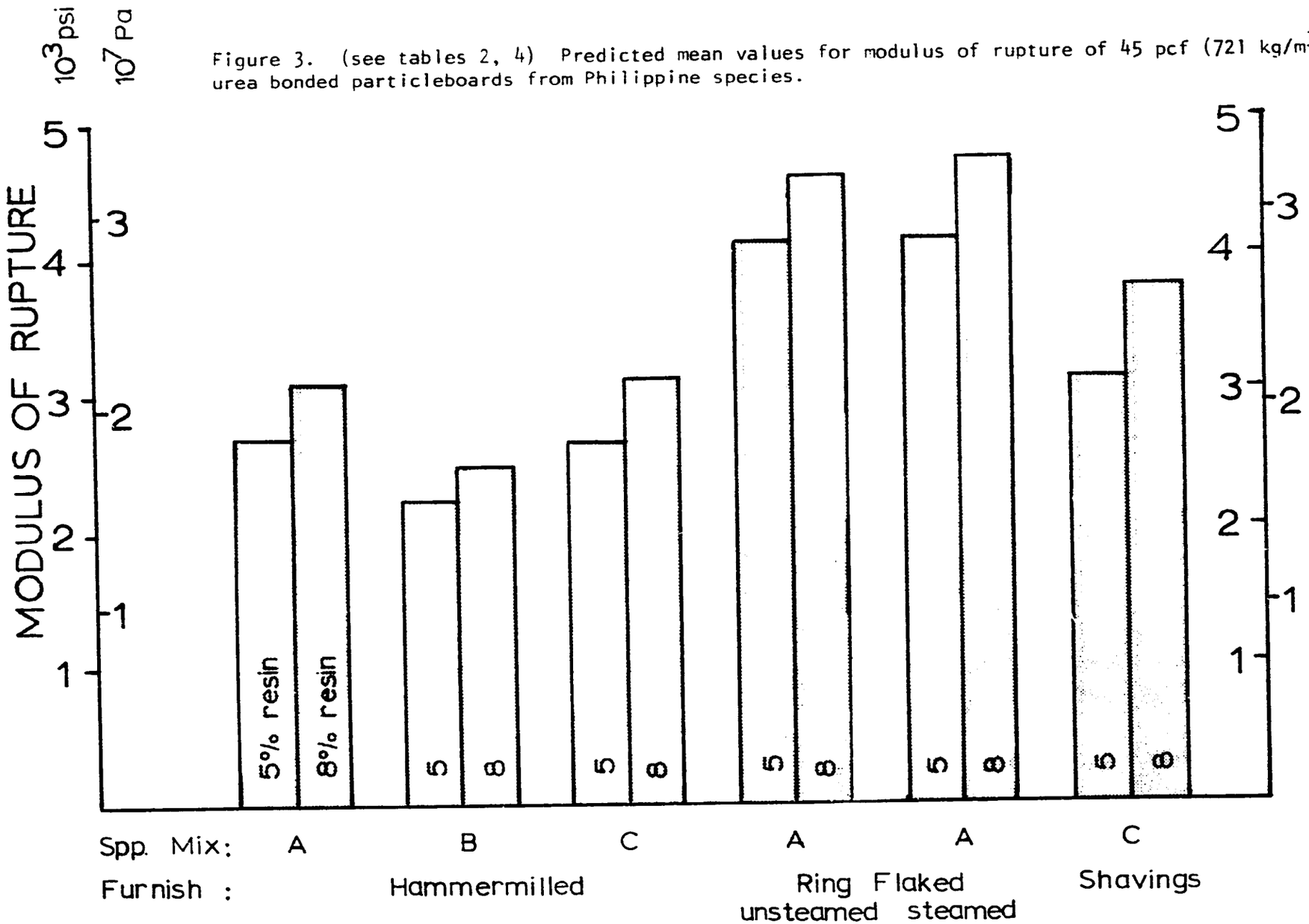


Figure 4. (See Table 2) Modulus of Elasticity of urea bonded particleboards from Philippine species as a function of board density. Common slope (regression coefficient) is 23,100 psi/pcf.

Treatment No.	Species Mixture	Particle Type	% Resin Content	
8	A	ring-flaked	8	
10	A	ring-flaked	8	steamed
7	A	ring-flaked	5	
9	A	ring-flaked	5	steamed
12	C	planer shavings	8	
11	C	planer shavings	5	
6	C	hammermilled	8	
2	A	hammermilled	8	
5	C	hammermilled	5	
4	B	hammermilled	8	
1	A	hammermilled	5	
3	B	hammermilled	5	

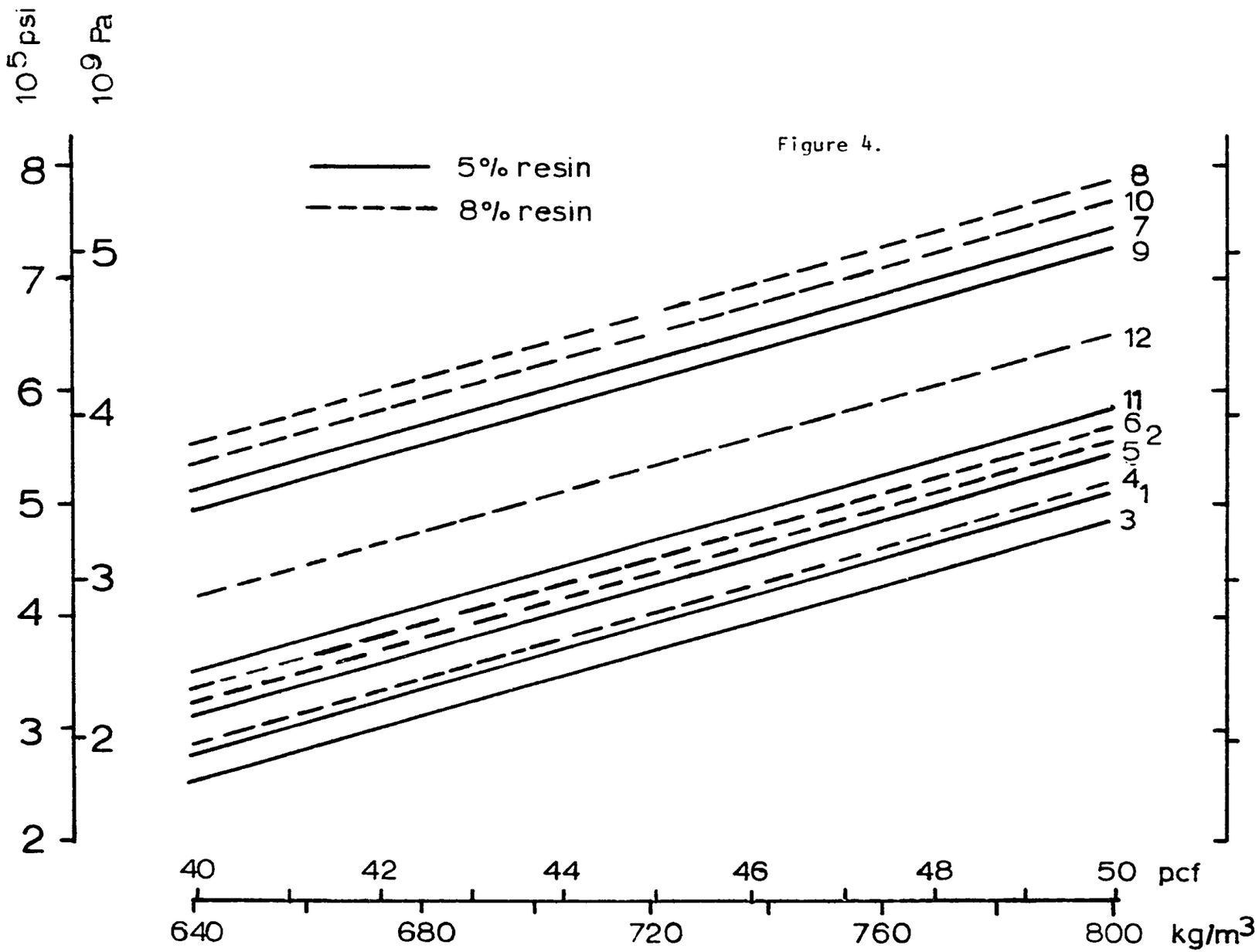

10^5 psi
10^9 Pa
5% resin
8% resin
8
10
7
9
12
11
6
2
5
4
1
3
8
7
6
5
4
3
2
5
4
3
2
40
42
44
46
48
50 pcf
640
680
720
760
800 kg/m^3

Figure 4.

Figure 5. (See Table 2) Modulus of Rupture of urea bonded particleboards from Philippine species as a function of board density. Common slope (regression coefficient) is 170 psi/pcf.

Treatment No.	Species Mixture	Particle Type	% Resin Content	
10	A	ring-flaked	8	steamed
8	A	ring-flaked	8	
9	A	ring-flaked	5	steamed
7	A	ring-flaked	5	
12	C	planer shavings	8	
6	C	hammermilled	8	
11	A	planer shavings	5	
2	A	hammermilled	8	
1	A	hammermilled	5	
5	C	hammermilled	5	
4	B	hammermilled	8	
3	B	hammermilled	5	

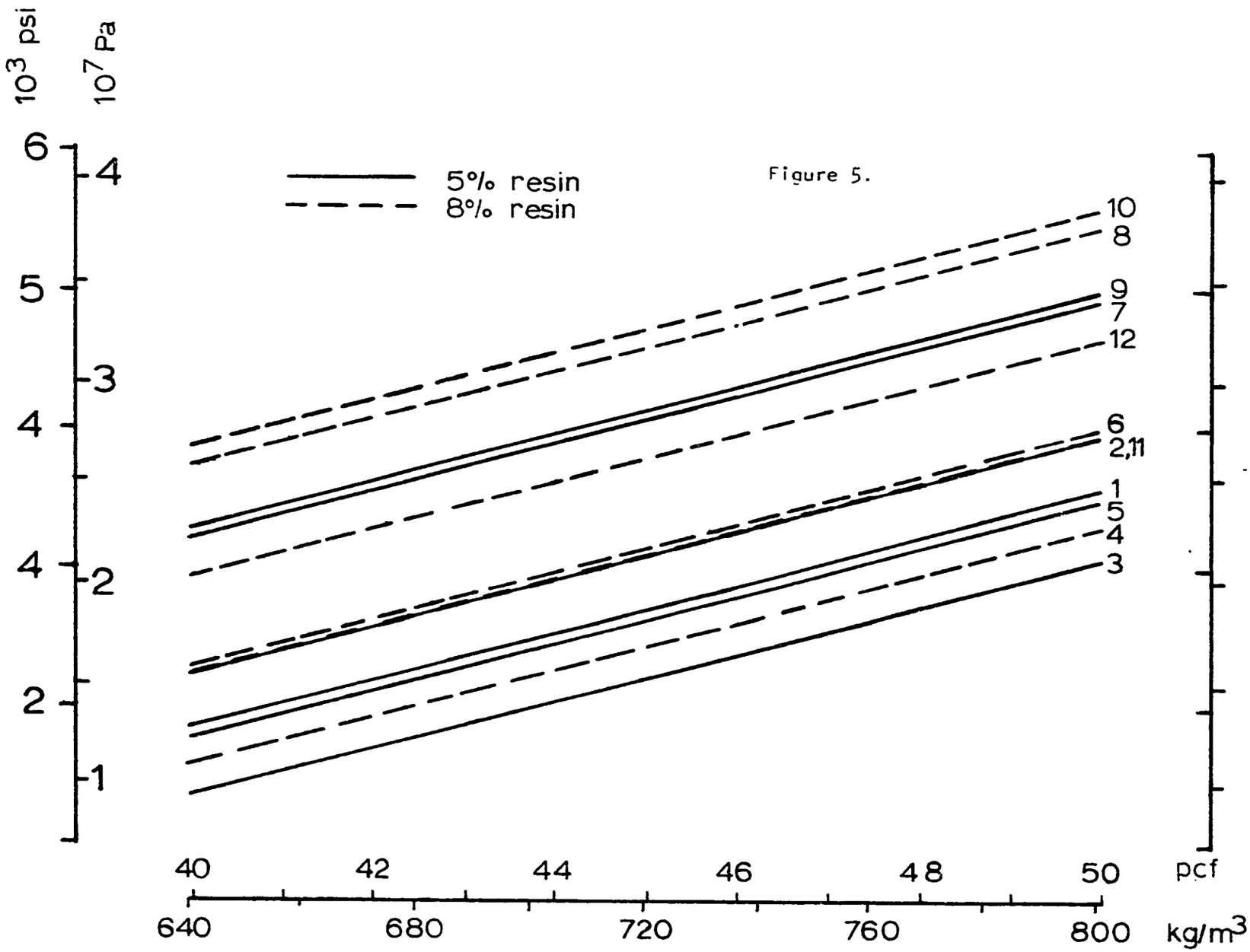

10^3 psi
10^7 Pa
6
5
4
4
2
4
3
2
1
5% resin
8% resin
10
8
9
7
12
6
2,11
1
5
4
3
40
42
44
46
48
50
pcf
640
680
720
760
800
kg/m^3

Figure 5.

Table 5. Differences between treatments for internal bond of 45 pcf (721 kg/m^3) urea bonded particleboards from Philippine species. Significant differences determined by Scheffé's method are with a solid line and by the Q method with a dashed line. All values are psi.

Treatment No.			7	9	3	11	8	10	1	5	12	4	2	6
	Code[1/]		AR-5	ARS-5	BH-5	CP-5	AR-8	ARS-8	AH-5	CH-5	CP-8	BH-8	AH-8	CH-8
		IB	145	146	161	164	180	186	192	221	235	267	270	290
7	AR-5	145	-	1	16	19	35	41	47	76	90	122	125	145
9	ARS-5	146		-	15	18	34	40	46	75	89	121	124	144
3	BH-5	161			-	3	19	25	31	60	74	106	109	129
11	CP-5	164				-	16	22	28	57	71	103	106	126
8	AR-8	180					-	6	12	41	55	87	90	110
10	ARS-8	186						-	6	35	49	81	84	104
1	AH-5	192							-	29	43	75	78	98
5	CH-5	221								-	14	46	49	69
12	CP-8	235									-	32	35	55
4	BH-8	267										-	3	23
2	AH-8	270											-	20
6	CH-8	290												-

1/ AH-5 species mixture A, hammermilled chips, 5% resin
AH-8 species mixture A, hammermilled chips, 8% resin
BH-5 species mixture B, hammermilled chips, 5% resin
BH-8 species mixture B, hammermilled chips, 8% resin
CH-5 species mixture C, hammermilled chips, 5% resin
CH-8 species mixture C, hammermilled chips, 8% resin
AR-5 species mixture A, ring-flaked chips, unsteamed, 5% resin
AR-8 species mixture A, ring-flaked chips, unsteamed, 8% resin
ARS-5 species mixture A, ring-flaked chips, steamed, 5% resin
ARS-8 species mixture A, ring-flaked chips, steamed, 8% resin
CP-5 species mixture C, planer shavings, unsteamed, 5% resin
CP-8 species mixture C, planer shavings, unsteamed, 8% resin

Figure 6. (see tables 2, 5) Predicted mean values for internal bond strengths of 45 pcf (721 kg/m^3) urea bonded particleboards from Philippine species.

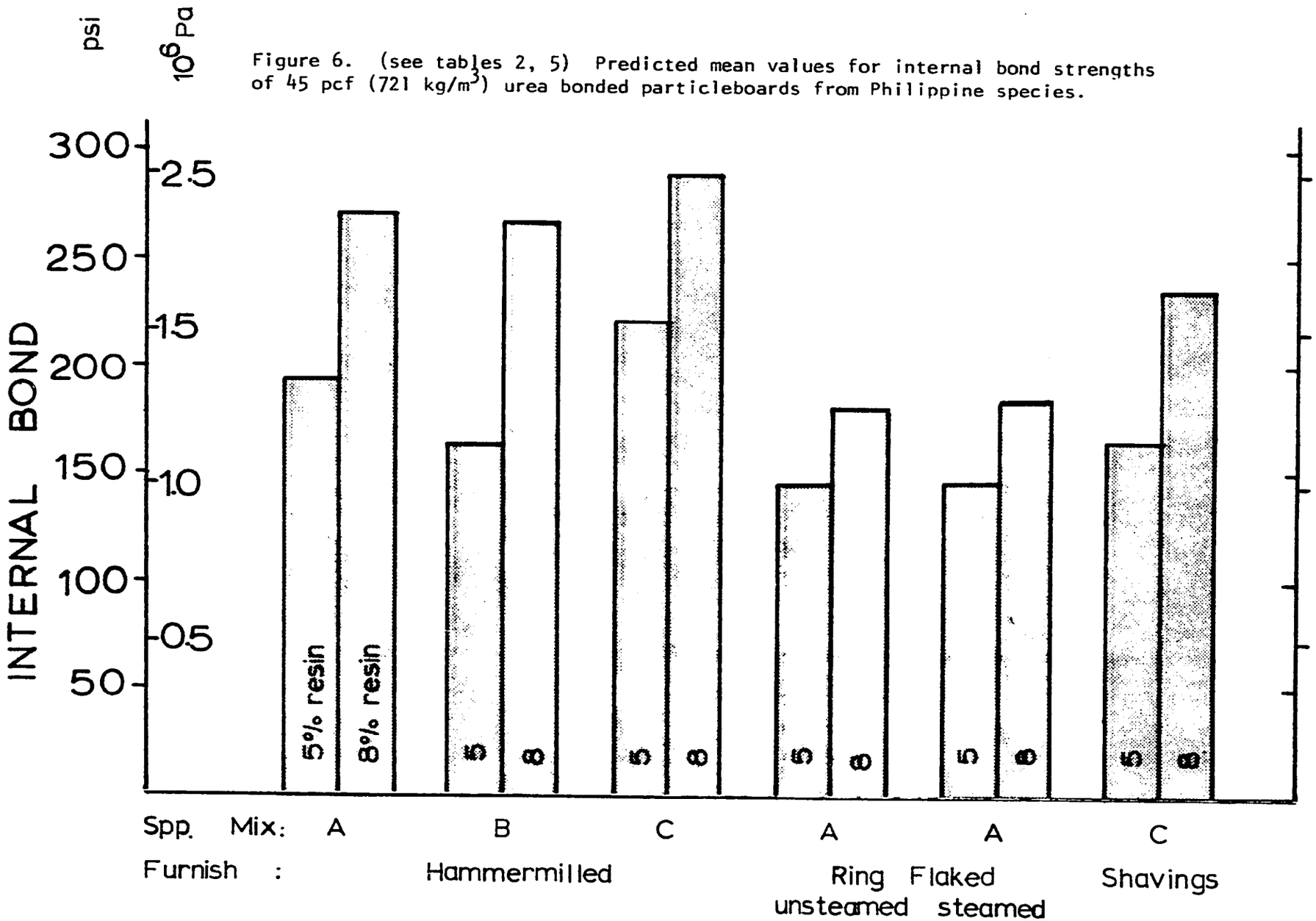


Figure 7. (See Table 2) Internal bond of urea bonded particleboards from Philippine species as a function of board density. Common slope (regression coefficient) is 6.99 psi/pcf.

Treatment No.	Species Mixture	Particle Type	% Resin Content	
6	C	hammermilled	8	
2	A	hammermilled	8	
4	B	hammermilled	8	
12	C	planer shavings	8	
5	C	hammermilled	5	
1	A	hammermilled	5	
10	A	ring-flaked	8	steamed
8	A	ring-flaked	8	
11	C	planer shavings	5	
3	B	hammermilled	5	
9	A	ring-flaked	5	steamed
7	A	ring-flaked	5	

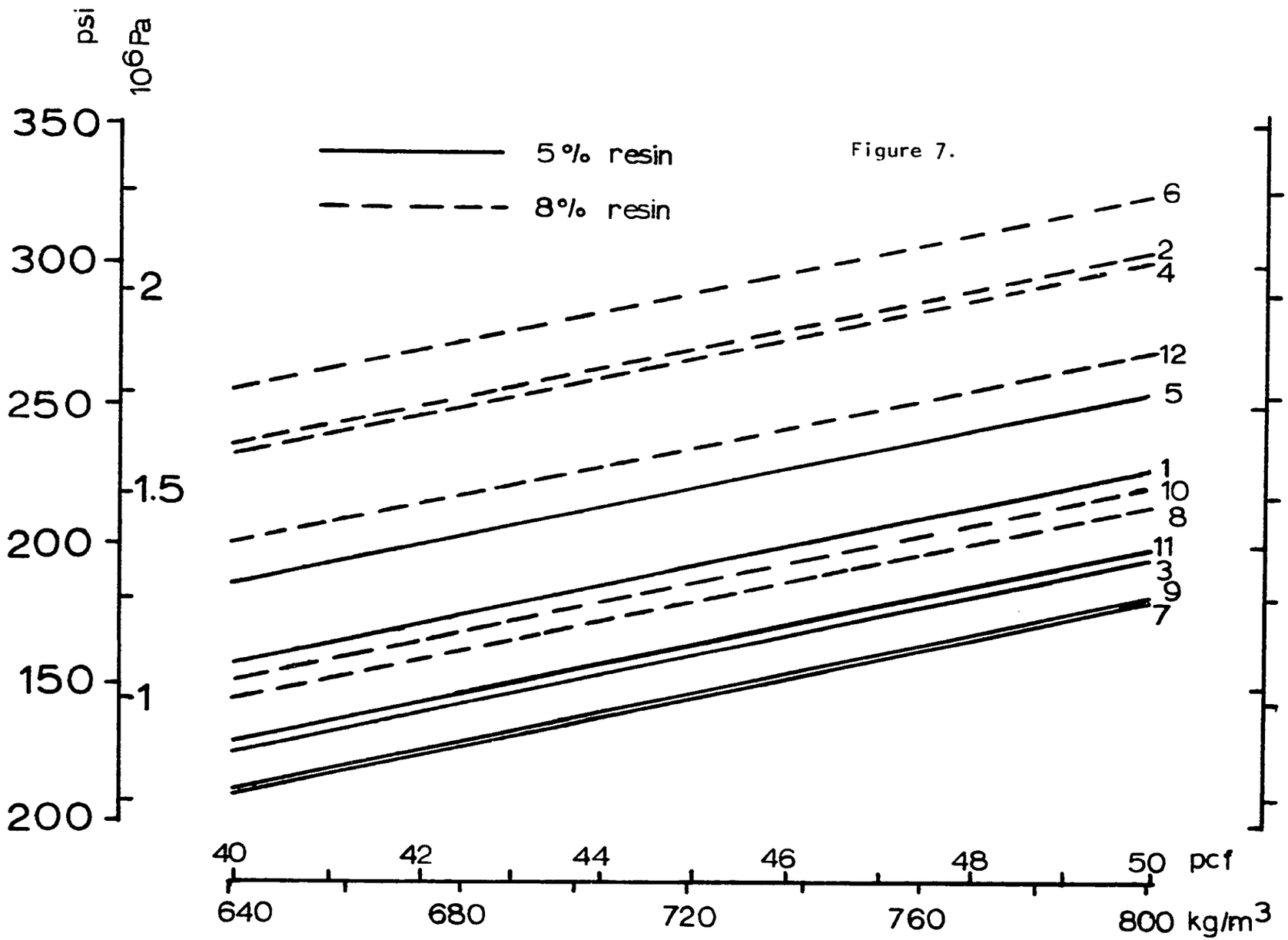

psi
10^6Pa
350
300
250
200
150
200
2
1.5
1
5 % resin
8 % resin
6
2
4
12
5
1
10
8
11
3
9
7
40
42
44
46
48
50 pcf
640
680
720
760
800 kg/m3

Figure 7.

Table 6. Predicted Mean Values for Linear Expansion and Total and Irreversible Thickness Swelling of Urea Bonded Particleboards from Philippine Species at 45 pcf (721 kg/m^3).

Treatment No.	Code[3/]	Linear Expansion[1/] value @ 45 pcf (%)	Linear Expansion[1/] ±95% c.i. (%)	Linear Expansion[1/] Regression Coefficient (slope) (%/pcf)	Total Thickness Swelling[1/] value @ 45 pcf (%)	Total Thickness Swelling[1/] ±95% c.i. (%)	Total Thickness Swelling[1/] Regression Coefficient (slope) (%/pcf)	Irreversible Thickness Swelling[2/] value @ 45 pcf (%)	Irreversible Thickness Swelling[2/] ±95% c.i. (%)	Irreversible Thickness Swelling[2/] Regression Coefficient (slope) (%/pcf)
1	AH-5	0.37	±0.03	2.03×10^{-3}	17.9	±0.5	0.212	12.9	±0.5	0.173
2	AH-8	0.31	±0.02	6.41×10^{-3}	13.1	±0.3	0.012	8.7	±0.2	0.075
3	BH-5	0.37	±0.02	8.06×10^{-3}	16.1	±0.3	0.373	10.9	±0.4	0.219
4	BH-8	0.30	±0.01	1.33×10^{-3}	11.1	±0.3	0.253	7.8	±0.2	0.215
5	CH-5	0.38	±0.02	4.13×10^{-3}	16.0	±0.3	0.229	11.6	±0.3	0.208
6	CH-8	0.27	±0.03	2.49×10^{-3}	11.8	±0.4	0.112	8.5	±0.4	0.079
7	AR-5	0.18	±0.01	1.57×10^{-3}	14.8	±0.5	-0.057	10.7	±0.4	-0.098
8	AR-8	0.15	±0.01	0.89×10^{-3}	11.1	±0.5	-0.065	7.9	±0.4	-0.066
9	ARS-5	0.19	±0.01	6.94×10^{-3}	14.2	±0.5	0.181	10.1	±0.3	0.057
10	ARS-8	0.16	±0.01	0.33×10^{-3}	11.1	+0.5	-0.029	7.1	±0.5	-0.011
11	CP-5	0.35	±0.02	-4.09×10^{-3}	12.6	±0.5	0.171	8.3	±0.4	0.146
12	CP-8	0.33	±0.01	-4.58×10^{-3}	9.1	±0.3	0.122	5.5	±0.3	0.062
common				1.41×10^{-3}			0.109			0.081

1/ From equilibrium at 50% RH to equilibrium at 90% RH

2/ From equilibrium at 50% RH to equilibrium at 90% RH to equilibrium at 50% RH

3/ AH-5 species mixture A, hammermilled chips, 5% resin
AH-8 species mixture A, hammermilled chips, 8% resin
BH-5 species mixture B, hammermilled chips, 5% resin
BH-8 species mixture B, hammermilled chips, 8% resin
CH-5 species mixture C, hammermilled chips, 5% resin
CH-8 species mixture C, hammermilled chips 8% resin
AR-5 species mixture A, ring-flaked chips, unsteamed, 5% resin
AR-8 species mixture A, ring-flaked chips, unsteamed, 8% resin
ARS-5 species mixture A, ring-flaked chips, steamed, 5% resin
ARS-8 species mixture A, ring-flaked chips, steamed, 8% resin
CP-5 species mixture C, planer shavings, unsteamed, 5% resin
CP-8 species mixture C, planer shavings, unsteamed, 8% resin

Table 7. Differences between treatments for linear expansion[1/] of 45 pcf (721 kg/m^3) urea bonded particleboards from Philippine species. Significant differences determined by Scheffé's method are with a solid line and by the Q method with a dashed line. All values are percent.

Treatment No.	Code[2/]	LE[1/]	8 AR-8 0.15	10 ARS-8 0.16	7 AR-5 0.18	9 ARS-5 0.19	6 CH-8 0.27	4 BH-8 0.30	2 AH-8 0.31	12 CP-8 0.33	11 CP-5 0.35	3 BH-5 0.37	1 AH-5 0.37	5 CH-5 0.38
8	AR-8	0.15	-	0.01	0.03	0.04	0.12	0.15	0.16	0.18	0.20	0.22	0.22	0.23
10	ARS-8	0.16		-	0.02	0.03	0.11	0.14	0.15	0.17	0.19	0.21	0.21	0.22
7	AR-5	0.18			-	0.01	0.09	0.12	0.13	0.15	0.17	0.19	0.19	0.20
9	ARS-5	0.19				-	0.08	0.11	0.12	0.14	0.16	0.18	0.18	0.19
6	CH-8	0.27					-	0.03	0.04	0.06	0.08	0.10	0.10	0.11
4	BH-8	0.30						-	0.01	0.03	0.05	0.07	0.07	0.08
2	AH-8	0.31							-	0.02	0.04	0.06	0.06	0.07
12	CP-8	0.33								-	0.02	0.04	0.04	0.05
11	CP-5	0.35									-	0.02	0.02	0.03
3	BH-5	0.37										-	0	0.01
1	AH-5	0.37											-	0.01
5	CH-5	0.38												-

1/ From equilibrium at 50% RH to equilibrium at 90% RH.

2/ AH-5 species mixture A, hammermilled chips, 5% resin
AH-8 species mixture A, hammermilled chips, 8% resin
BH-5 species mixture B, hammermilled chips, 5% resin
BH-8 species mixture B, hammermilled chips, 8% resin
CH-5 species mixture C, hammermilled chips, 5% resin
CH-8 species mixture C, hammermilled chips, 8% resin
AR-5 species mixture A, ring-flaked chips, unsteamed, 5% resin
AR-8 species mixture A, ring-flaked chips, unsteamed, 8% resin
ARS-5 species mixture A, ring-flaked chips, steamed, 5% resin
ARS-8 species mixture A, ring-flaked chips, steamed, 8% resin
CP-5 species mixture C, planer shavings, unsteamed, 5% resin
CP-8 species mixture C, planer shavings, unsteamed, 8% resin

Figure 8. (see tables 6, 7) Predicted mean values for linear expansion from equilibrium at 50% RH to equilibrium at 90% RH of 45 pcf (721 kg/m^3) urea bonded particleboards from Philippine species.

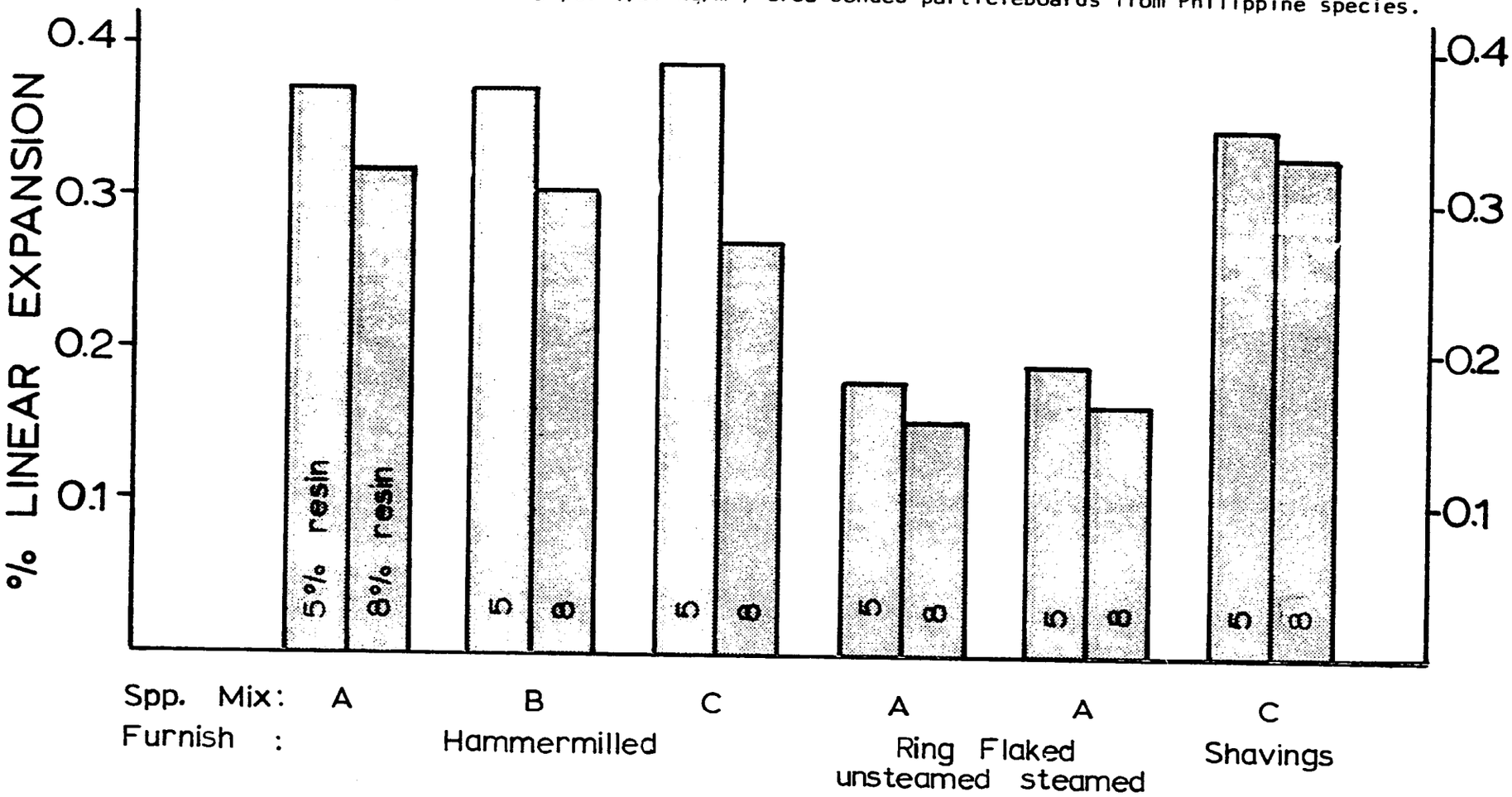


Table 8. Differences between treatments for total thickness swelling[1/] of 45 pcf (721 kg/m^3) urea bonded particleboards from Philippine species. Significant differences determined by Scheffé's method are with a solid line and by the Q method with a dashed line. All values are percent.

Treatment No.			12	10	4	8	6	11	2	9	7	5	3	1
	Code[2/]		CP-8	ARS-8	BH-8	AR-8	CH-8	CP-5	AH-8	ARS-5	AR-5	CH-5	BH-5	AH-5
		Total[1/] th. swell	9.1	11.1	11.1	11.1	11.8	12.6	13.1	14.2	14.8	16.0	16.1	17.9
12	CP-8	9.1	-	2.0	2.0	2.0	2.7	3.5	4.0	5.1	5.7	6.9	7.0	8.8
10	ARS-8	11.1		-	0	0	0.7	1.5	2.0	3.1	3.7	4.9	5.0	6.8
4	BH-8	11.1			-	0	0.7	1.5	2.0	3.1	3.7	4.9	5.0	6.8
8	AR-8	11.1				-	0.7	1.5	2.0	3.1	3.7	4.9	5.0	6.8
6	CH-8	11.8					-	0.8	1.3	2.4	3.0	4.2	4.3	6.1
11	CP-5	12.6						-	0.5	1.6	2.2	3.4	3.5	5.3
2	AH-8	13.1							-	1.1	1.7	2.9	3.0	4.8
9	ARS-5	14.2								-	0.6	1.8	1.9	3.7
7	AR-5	14.8									-	1.2	1.3	3.1
5	CH-5	16.0										-	0.1	1.9
3	BH-5	16.1											-	1.8
1	AH-5	17.9												-

1/ From equilibrium at 50% RH to equilibrium at 90% RH

2/ AH-5 species mixture A, hammermilled chips, 5% resin
AH-8 species mixture A, hammermilled chips, 8% resin
BH-5 species mixture B, hammermilled chips, 5% resin
BH-8 species mixture B, hammermilled chips, 8% resin
CH-5 species mixture C, hammermilled chips, 5% resin
CH-8 species mixture C, hammermilled chips, 8% resin
AR-5 species mixture A, ring-flaked chips, unsteamed, 5% resin
AR-8 species mixture A, ring-flaked chips, unsteamed, 8% resin
ARS-5 species mixture A, ring-flaked chips, steamed, 5% resin
ARS-8 species mixture A, ring-flaked chips, steamed, 8% resin
CP-5 species mixture C, planer shavings, unsteamed, 5% resin
CP-8 species mixture C, planer shavings, unsteamed, 8% resin

Table 9. Differences between treatments for irreversible thickness swelling[1/] of 45 pcf (721 kg/m^3) urea bonded particleboards from Philippine species. Significant differences determined by Scheffé's method are with a solid line and by the Q method with a dashed line. All values are percent.

Treatment No.			12	10	4	8	11	6	2	9	7	3	5	1
	Code[2/]		CP-8	ARS-8	BH-8	AR-8	CP-5	CH-8	AH-8	ARS-5	AR-5	BH-5	CH-5	AH-5
		irrev.[1/] th. swell.	5.5	7.1	7.8	7.9	8.3	8.5	8.7	10.1	10.7	10.9	11.6	12.9
12	CP-8	5.5	-	1.6	2.3	2.4	2.8	3.0	3.2	4.6	5.2	5.4	6.1	7.4
10	ARS-8	7.1		-	0.7	0.8	1.2	1.4	1.6	3.0	3.6	3.8	4.5	5.8
4	BH-8	7.8			-	0.1	0.5	0.7	0.9	2.3	2.9	3.1	3.8	5.1
8	AR-8	7.9				-	0.4	0.6	0.8	2.2	2.8	3.0	3.7	5.0
11	CP-5	8.3					-	0.2	0.4	1.8	2.4	2.6	3.3	4.6
6	CH-8	8.5						-	0.2	1.6	2.2	2.4	3.1	4.4
2	AH-8	8.7							-	1.4	2.0	2.2	2.9	4.2
9	ARS-5	10.1								-	0.6	0.8	1.5	2.8
7	AR-5	10.7									-	0.2	0.9	2.2
3	BH-5	10.9										-	0.7	2.0
5	CH-5	11.6											-	1.3
1	AH-5	12.9												-

1/ From equilibrium at 50% RH to equilibrium at 90% to equilibrium at 50% RH.

2/ AH-5 species mixture A, hammermilled chips, 5% resin
AH-8 species mixture A, hammermilled chips, 8% resin
BH-5 species mixture B, hammermilled chips, 5% resin
BH-8 species mixture B, hammermilled chips, 8% resin
CH-5 species mixture C, hammermilled chips, 5% resin
CH-8 species mixture C, hammermilled chips, 8% resin
AR-5 species mixture A, ring-flaked chips, unsteamed, 5% resin
AR-8 species mixture A, ring-flaked chips, unsteamed, 8% resin
ARS-5 species mixture A, ring-flaked chips, steamed, 5% resin
ARS-8 species mixture A, ring-flaked chips, steamed, 8% resin
CP-5 species mixture C, planer shavings, unsteamed, 5% resin
CP-8 species mixture C, planer shavings, unsteamed, 8% resin

Figure 9. (see tables 6, 8, 9) Predicted mean values for total and irreversible thickness swelling from equilibrium at 50% RH to equilibrium at 90% RH of 45 pcf (721 kg/m^3) urea bonded particleboards from Philippine species.

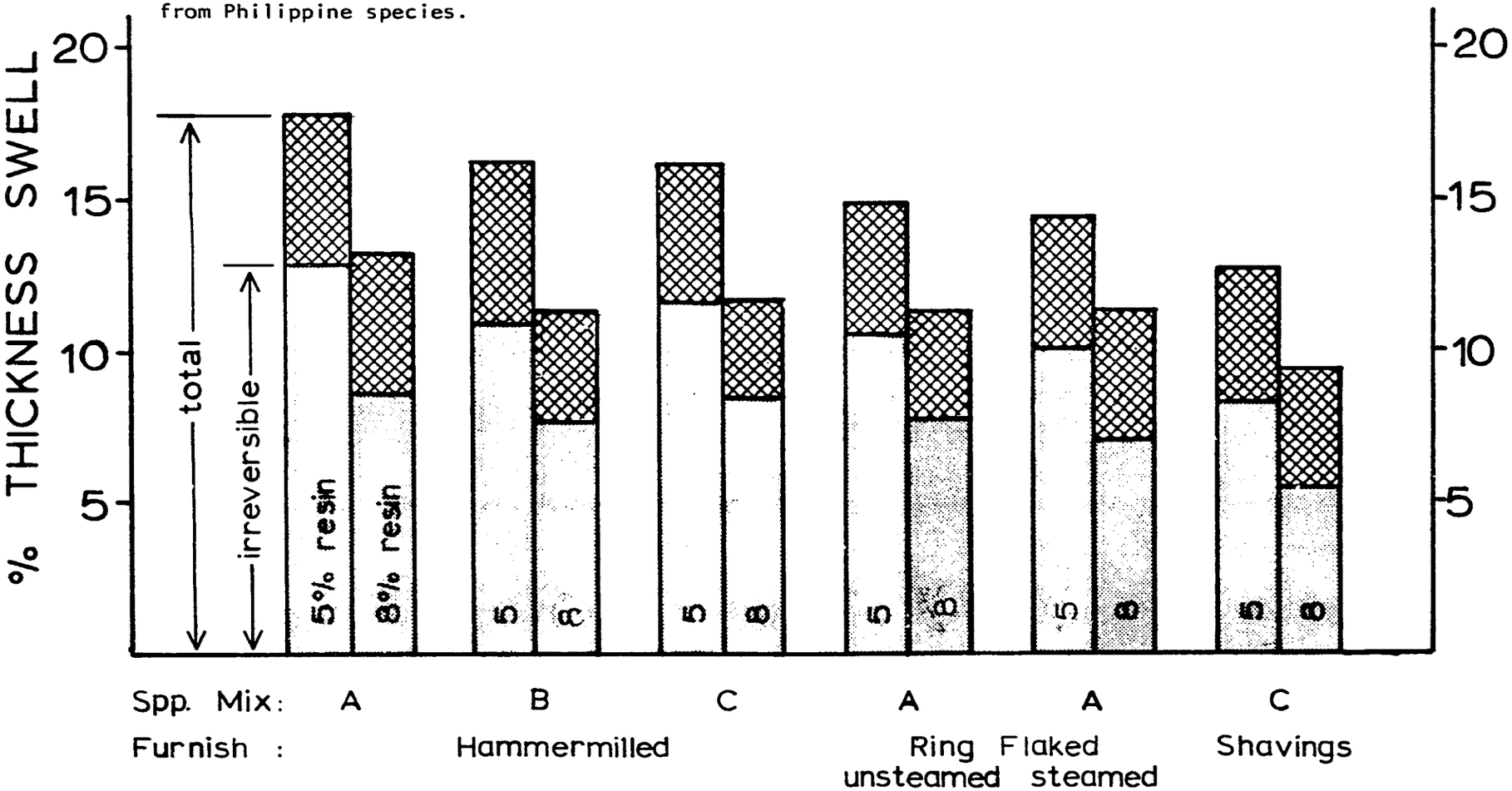


Table 10. Percent Water Uptake and Percent Total Thickness Swelling for 24 Hour Soak Samples of Urea Bonded Particleboards from Philippine Species. All Values Adjusted to 45 pcf (721 kg/m^3).

Treatment No.	Code[1/]	% water uptake	% total thickness swelling
1	AH-5	66.2	28.1
2	AH-8	54.6	17.5
3	BH-5	65.7	24.8
4	BH-8	51.2	14.8
5	CH-5	62.8	24.5
6	CH-8	42.9	13.5
7	AR-5	75.1	29.5
8	AR-8	56.7	17.1
9	ARS-5	77.3	29.1
10	ARS-8	56.7	15.1
11	CP-5	66.3	21.4
12	CP-8	43.6	10.1

Figure 10. (See Table 10) Percent Total Thickness Swelling as a Function of Percent Water Uptake for 24 Hour Soak Samples of Urea Bonded Particleboards from Philippine Species. All Values Adjusted to 45 pcf (721 kg/m^3). Common Slope (Regression Coefficient) is 0.568%/%.

planer shavings, species mixture C
ring-flaked, species mix A, unsteamed
ring-flaked, species mix A, steamed
hammermilled, species mixture A, B, C

open symbols - 5% resin
solid symbols - 8% resin

AH-5 species mixture A, hammermilled chips, 5% resin
AH-8 species mixture A, hammermilled chips, 8% resin
BH-5 species mixture B, hammermilled chips, 5% resin
BH-8 species mixture B, hammermilled chips, 8% resin
CH-5 species mixture C, hammermilled chips, 5% resin
CH-8 species mixture C, hammermilled chips, 8% resin

AR-5 species mixture A, ring-flaked chips, unsteamed, 5% resin
AR-8 species mixture A, ring-flaked chips, unsteamed, 8% resin
ARS-5 species mixture A, ring-flaked chips, steamed, 5% resin
ARS-8 species mixture A, ring-flaked chips, steamed, 8% resin
CP-5 species mixture C, planer shavings, unsteamed, 5% resin
CP-8 species mixture C, planer shavings, unsteamed, 8% resin

Figure 10.

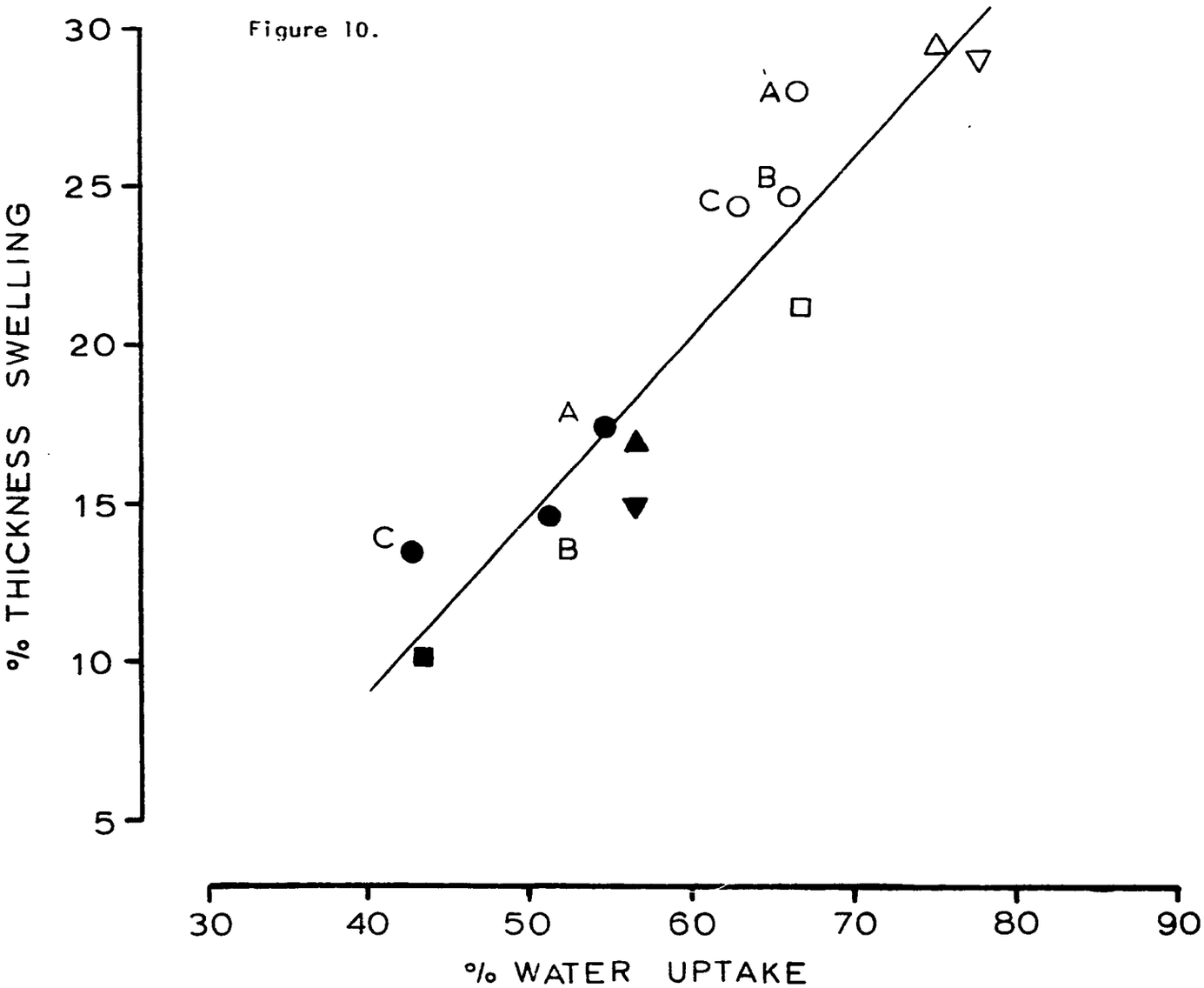

30
25
20
15
10
5
% THICKNESS SWELLING
A
B
C
AO
BO
CO
30
40
50
60
70
80
90
% WATER UPTAKE

Table 11. Predicted mean values of strength properties and percent strength reduction after ASTM accelerated aging of 45 pcf (721 kg/m^3) phenolic bonded particleboards from hammermilled chip mixture A Philippine species.

Treatment No.	Code[1/]	Modulus of Elasticity			Modulus of Rupture			Internal Bond		
		value @ 45 pcf (1000 psi)	±95% c.i. (1000 psi)	Regression Coefficient (slope) (1000 psi/pcf)	value @ 45 pcf (psi)	±95% c.i. (psi)	Regression Coefficient (slope) (psi/pcf)	value @ 45 pcf (psi)	±95% c.i. (psi)	Regression Coefficient (slope) (psi/pcf)
1	AHP-5	332	±37	1.52	2230	±260	43.3	138	±25	-1.02
2	AHP-8	449	±43	15.1	3280	±400	137	251	±11	8.00
3	AHP-5A	194	±22	4.44	1110	±90	5.40	30.6	±12	-1.84
4	AHP-8A	266	±15	13.8	1850	±120	150	83.2	±11	4.92
common				10.2			100			3.81

Percent Strength Loss Between Control and Accelerated Aging Samples						
Property	Modulus of Elasticity		Modulus of Rupture		Internal Bond	
% resin	5	8	5	8	5	8
strength loss	42%	41%	50%	44%	78%	67%

1/ AHP-5 species mixture A, hammermilled chips, 5% phenolic resin, control
AHP-8 species mixture A, hammermilled chips, 8% phenolic resin, control
AHP-5A species mixture A, hammermilled chips, 5% phenolic resin, accelerated aged
AHP-8A species mixture A, hammermilled chips, 8% phenolic resin, accelerated aged

Figure 11. (see table 11) Predicted mean values for modulus of elasticity, modulus of rupture and internal bond of control and ASTM accelerated aged samples of 45 pcf (721 kg/m^3) phenolic bonded particleboards from hammermilled chip mixture A Philippine species.

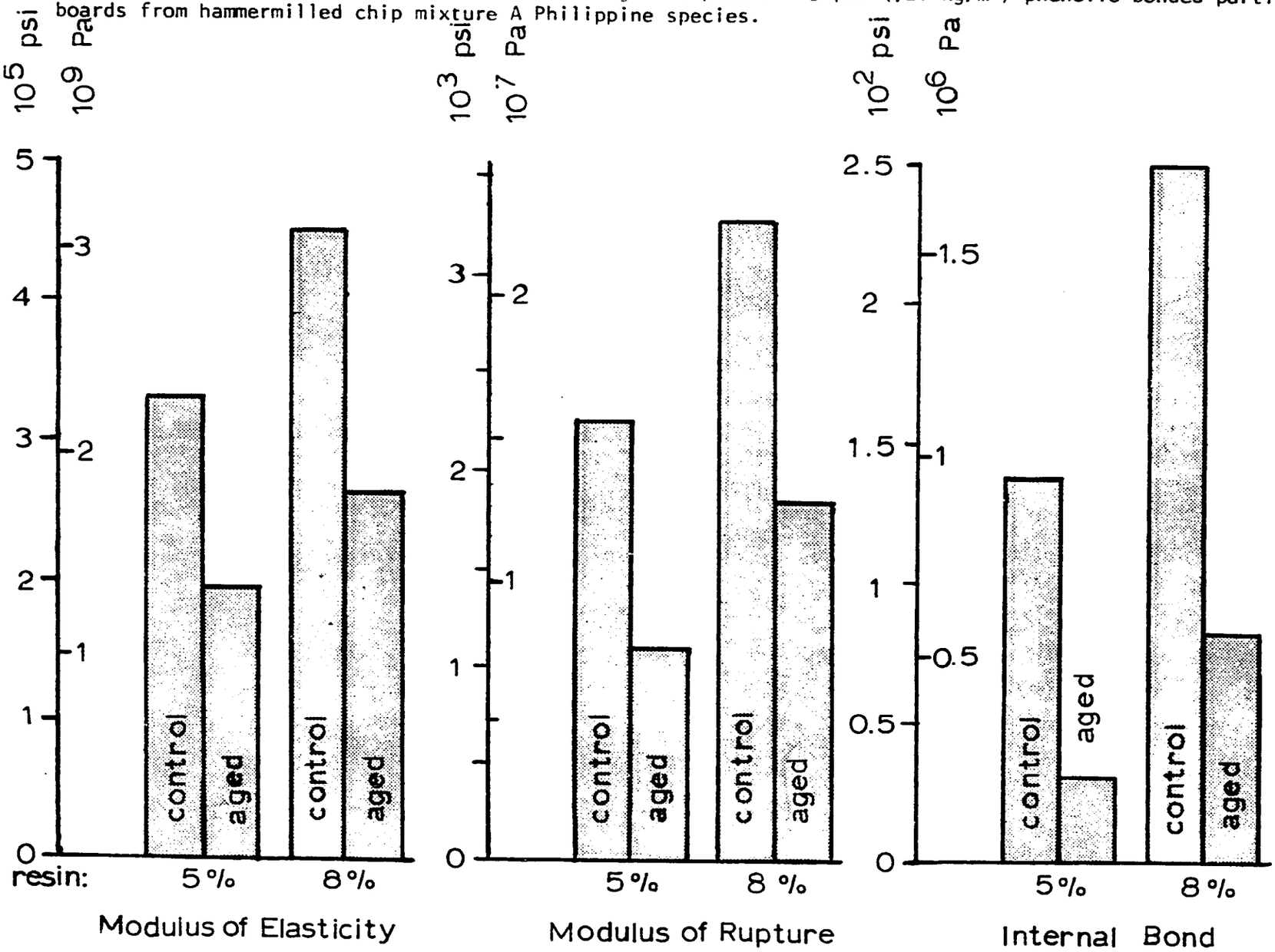


Table 12. Predicted mean values for linear expansion, total and irreversible thickness swelling, and total thickness swelling after ASTM accelerated aging of 45 pcf (721 kg/m^3) phenolic bonded particleboards from hammermilled chip mixture A Philippine species.

Property	Code 4/	Value @ 45 pcf (%)	±95% c.i. (%)	Regression Coefficient (slope) (%/pcf)
Linear Expansion 1/	AHP-5	0.25	±0.03	5.82×10^{-3}
	AHP-8	0.19	±0.01	-4.46×10^{-3}
	common			-1.17×10^{-3}
Total Thickness Swelling 1/	AHP-5	16.6	±0.8	0.481
	AHP-8	12.1	±0.5	0.167
	common			0.268
Irreversible Thickness Swelling 2/	AHP-5	10.8	±1.0	0.393
	AHP-8	7.0	±0.3	0.0899
	common			0.187
Irreversible Thickness Swelling After ASTM Accelerated Aging 3/	AHP-5A	52.5	±1.5	2.83
	AHP-8A	26.2	±1.2	0.139
	common			1.12

1/ From equilibrium at 50% RH to equilibrium at 90% RH
2/ From equilibrium at 50% RH to equilibrium at 90% RH to equilibrium at 50% RH
3/ Thickness compared before and after accelerated aging
4/ AHP-5 species mixture A, hammermilled chips, 5% phenolic resin, control
AHP-8 species mixture A. hammermilled chips, 8% phenolic resin, control
AHP-5A species mixture A, hammermilled chips, 5% phenolic resin, accelerated aged
AHP-8A species mixture A, hammermilled chips, 8% phenolic resin, accelerated aged

Figure 12. (see table 12) Predicted mean values for linear expansion and total and irreversible thickness swelling from equilibrium at 50% RH to equilibrium at 90% RH and irreversible thickness swelling after ASTM accelerated aging of 45 pcf (721 kg/m^3) phenolic bonded particleboards from hammermilled chip mixture A Philippine species.

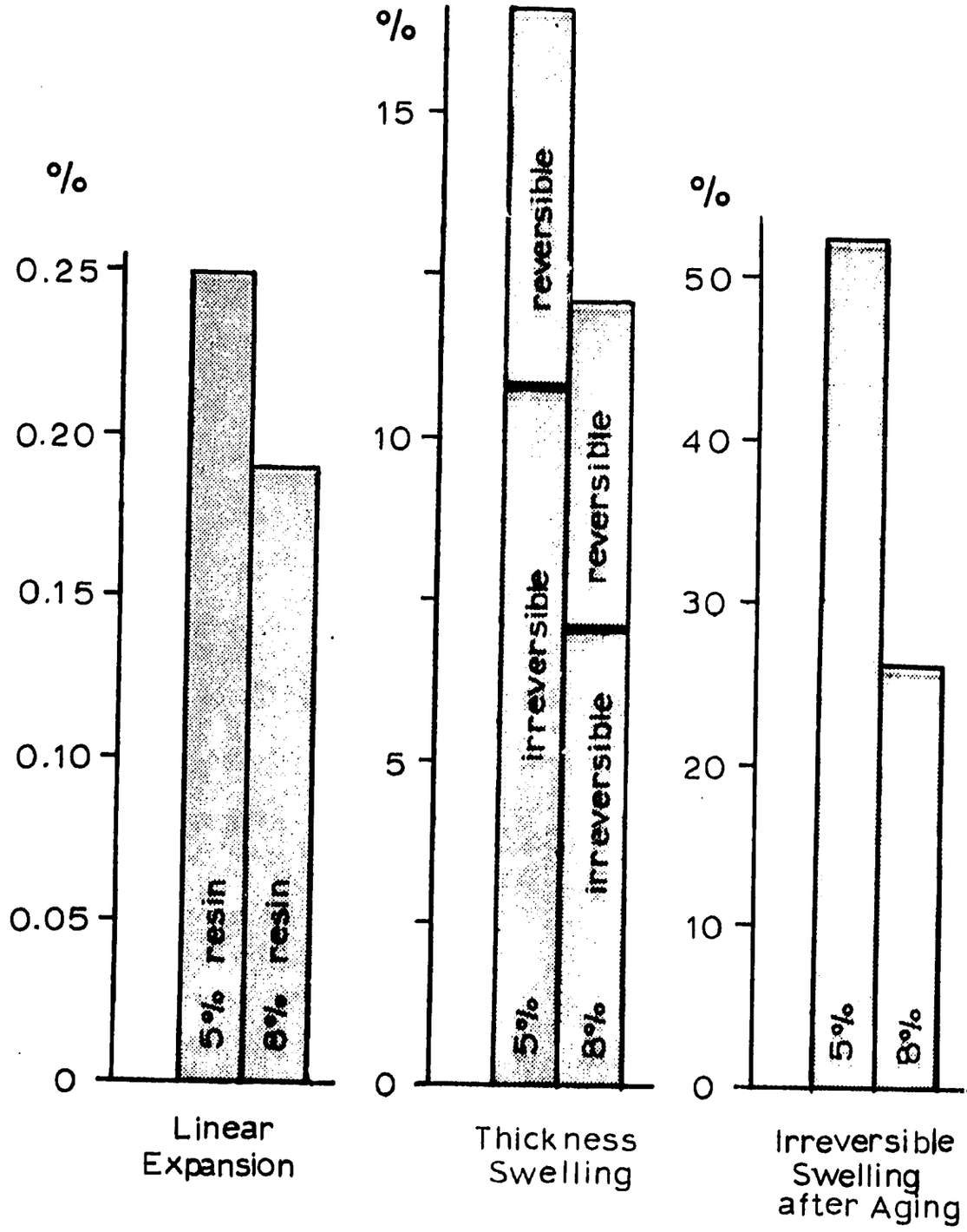


Table 13. Differences in MOE, MOR, IB and LE of urea bonded particleboards from Philippine species due to species mixture or furnish type when the effect of resin level is omitted. Significant differences as determined by Scheffé's method occur when the difference between means exceeds the test statistic. An asteric denotes significant difference. All values are psi.

Comparison	MOE		MOR		IB		LE	
$\bar{X}_{trt\ i_{5\%}} + \bar{X}_{trt\ i_{8\%}}) - (\bar{X}_{trt_{5\%}} + \bar{X}_{trt\ j_{8\%}})$	Difference Between Means	Test Statistic	Difference Between Means	Test Statistic	Difference Between Means	Test Statistic	Difference Between Means	Test Statistic
Mixture A - Hammermilled vs. Mixture B - Hammermilled	64,800 <	170,200	1147 <	1306	34.7 <	71.4	.0117 <	.1345
Mixture A - Hammermilled vs. Mixture C - Hammermilled	47,900 <	172,500	37 <	1323	48.2 <	72.4	.0360 <	.1343
Mixture B - Hammermilled vs. Mixture C - Hammermilled	112,700 <	171,600	1110 <	1315	*82.9 >	72.0	.0243 <	.1352
Mixture A - Hammermilled vs. Mixture A - Ring flake	*465,400 >	159,700	*2877 >	1224	*137.4 >	67.0	*.3557 >	.1283
Mixture A - Hammermilled vs. Mixture A - Ring flake steamed	*432,300 >	163,500	*3011 >	1254	*130.3 >	68.6	*.3371 >	.1286
Mixture A - Ring flake vs. Mixture A - Ring flake steamed	33,100 <	151,500	134 <	1162	7.1 <	63.55	.0206 <	.1231
Mixture C - Hammermilled vs. Mixture C - Planer Shavings	116,900 <	163,500	1113 <	1254	*111.9 >	68.6	.0257 <	.1309

Table 14. Specific Gravity, Ash, and Silica Content of 50 Philippine Woods

	Species		Specific gravity		Ash	Silica
	Common name	Latin name	Previously published	Forest Products Laboratory		
					Pct.	Pct.
1	Tangisang-bayauak	Fiscus variegata	0.28	0.236	3.64	0.02
2	Binuang	Octomeles sumatrana	.37	.242	1.32	0
3	Kapok	Ceiba pentandra	.23	.244	4.45	0
4	Balilang-uak	Meliosma macrophylla	.27	.260	1.34	.04
5	Rarang	Erythrina subumbrans	.24	.264	1.61	0
6	Kaitana	Zanthoxylum rhetsa	.33	.296	.75	<.01
7	Ilang-ilang	Cananga odorata	.29	.308	1.46	.02
8	Gubas	Endospermum pletatum	.31	.316	.62	<.01
9	Dita	Alstonia scholaris	.36	.316	1.08	.01
10	Anabiong	Trema orientalis	.31	.319	1.00	0
11	Hamindang	Macaranga bicolor	.29	.324	1.46	.02
12	Balanti	Homalanthus populneus	.38	.356	1.17	<.01
13	Mayapis	Shorea squamata	.39	.366	.36	.04
14	Matang-arau	Melicope triphylla	.37	.381	1.05	.43
15	Malasantol	Sandoricum vidalii	.43	.394	.61	.01
16	White lauan	Pentacme contorta	.44	.401	.72	.06
17	Tulo	Alphitonia philippinensis	.40	.422	.47	<.01
18	Tangile	Shorea polysperma	.46	.429	.20	.08
19	Pahutan	Mangifera altissima	.55	.435	2.91	.02
20	Apanit	Mastixia philippinensis	.47	.447	1.72	.10
21	Lago	Pygeum vulgare	.57	.451	.50	<.01
22	Antipolo	Antocarpus blancoi	.41	.469	5.21	4.55

Continued--

	Species		Specific gravity		Ash	Silica
	Common name	Latin name	Previously published	Forest Products Laboratory		
					Pct.	Pct.
23	Bagtikan	Parashorea plicata	0.51	0.478	1.42	<.01
24	Sakat	Terminalia nitens	.56	.485	.68	.10
25	Red lauan	Shorea negrosensis	.44	.510	.09	.03
26	Itangan	Weinmannia luzoniensis	.49	.526	1.52	<.01
27	Piling-liitan	Canarium luzonicum	.49	.549	.73	.21
28	Palosapis	Anisoptera thurifera	.51	.554	1.17	.72
29	Lomarau	Swintonia foxworthyi	.63	.559	1.00	.10
30	Malabetis	Madhuca oblongifolia	.53	.560	3.01	2.19
31	Dangkalan	Calophyllum obliquinervium	.58	.568	.65	<.01
32	Panau	Dipterocarpus gracilis	.61	.576	.93	.43
33	Katmon	Dillenia philippinensis	.68	.592	1.06	.02
34	Batitinan	Lagerstroemia piriformis	.49	.597	3.56	.01
35	Katong-lakihan	Amoora macrophylla	.54	.608	.84	.03
36	Narig	Vatica mangachapoi	.68	.618	.74	.22
37	Miau	Dysoxylum euphlebium	.63	.623	1.16	.04
38	Apitong	Dipterocarpus grandiflorus	.62	.623	.69	.23
39	Bok-bok	Xanthophyllum excelsum	.63	.639	1.11	0
40	Kamatog	Erythrophloeum densiflorum	.67	.650	1.62	.01

Continued--

	Species		Specific gravity		Ash	Silica
	Common name	Latin name	Previously published	Forest Products Laboratory		
					Pct.	Pct.
41	Dalingdingan	Hopea foxworthi	0.62	0.667	0.70	0.04
42	Katilma	Diospyros nitida	.71	.679	2.51	.02
43	Yakal	Shorea astylosa	---	.718	.92	.03
44	Kamagong	Diospyros philippinensis	.78	.720	2.98	<.01
45	Katong-matsin	Chisocheton pentandrus	.52	.725	.78	.02
46	Manaring	Lithocarpus soleriana	.63	.736	.79	.02
47	Ipil-ipil	Leucaena leucocephala	.73	.737	.91	.01
48	Bolong-eta	Diospyros pilosanthera	.81	.743	1.96	.02
49	Makaasim	Syzygium nitidum	.75	.778	.78	.03
50	Alupag-amo	Litchi philippinensis	.89	.793	1.10	<.01

Forest Products Laboratory
Forest Service
U.S. Department of Agriculture
Madison, Wisconsin 53705

Table 15.--Composition of three chip mixtures of 50 Philippine hardwoods

Species[1]	Specific gravity range	Mixture composition[2]		
		A	B	C
		Pct	Pct	Pct
1 - 6	0.236 - 0.296	16.67	2	4
7 - 15	.308 - .394	16.67	4	8
16 - 24	.401 - .485	16.67	9	20
25 - 34	.510 - .597	16.67	15	40
35 - 42	.608 - .679	16.67	20	20
43 - 50	.718 - .793	16.67	50	8

[1]See Table 14 for names of the individual species.

[2]Moisture-free wood basis.

Forest Products Laboratory
Forest Service
U.S. Department of Agriculture
Madison, Wisconsin 53705

Figure 13. Furnish from hammermilled chips of chip mixture A (actual size).

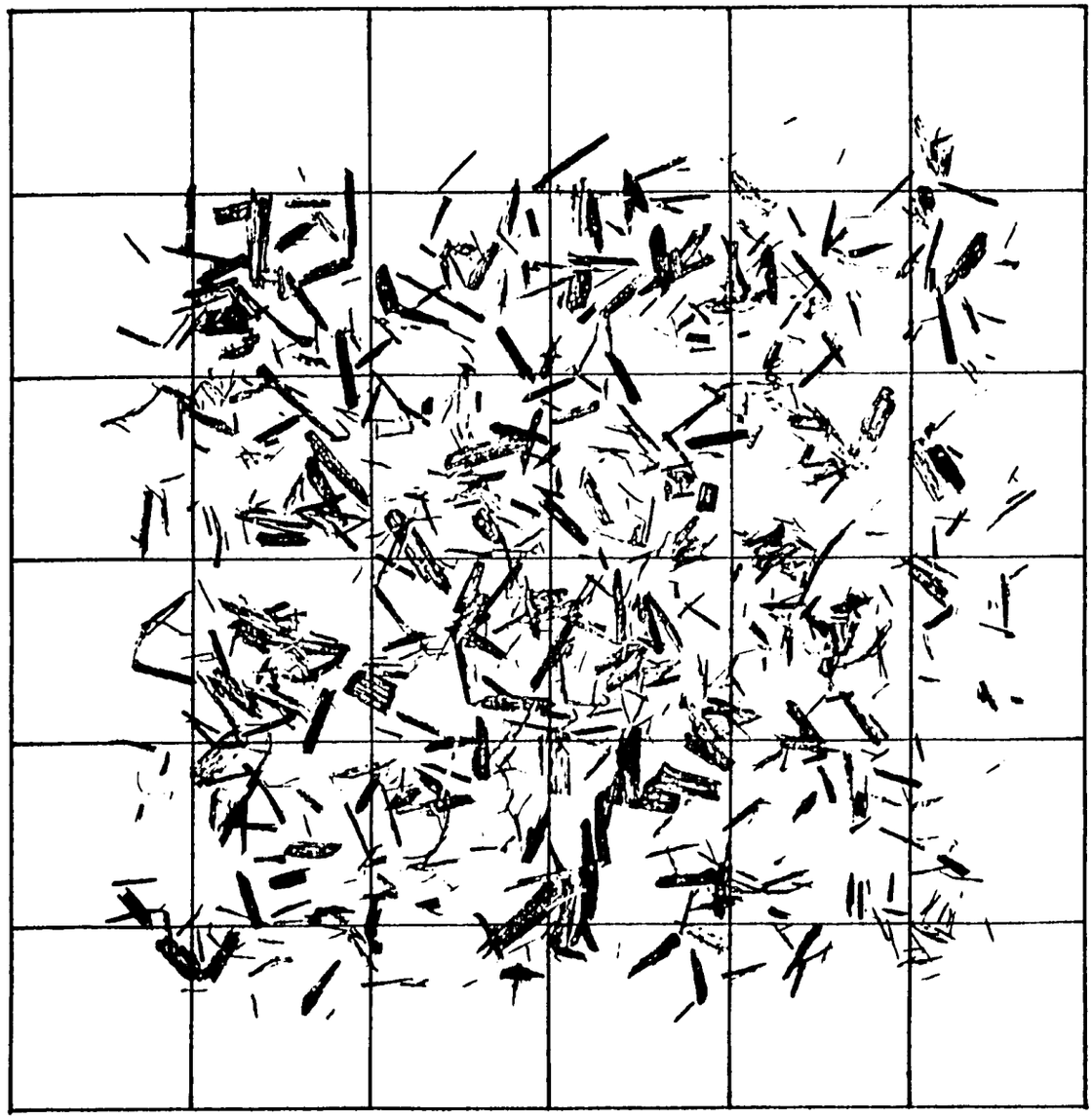


Figure 14. Furnish from hammermilled chips of chip mixture B (actual size).

Figure 15. Furnish from hammermilled chips of chip mixture C (actual size).

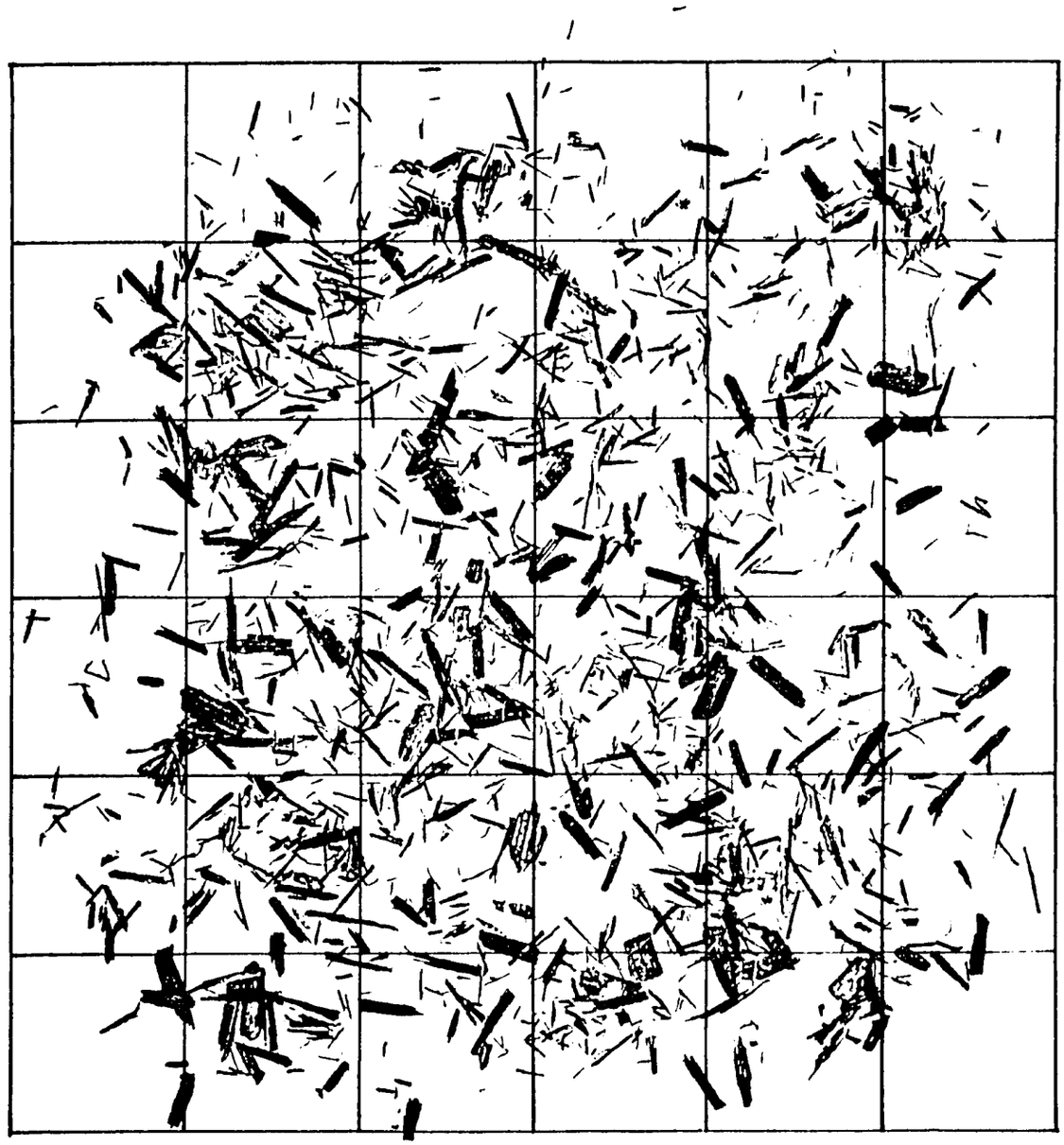


Figure 16. Furnish from ring flaked chips of chip mixture A (actual size).

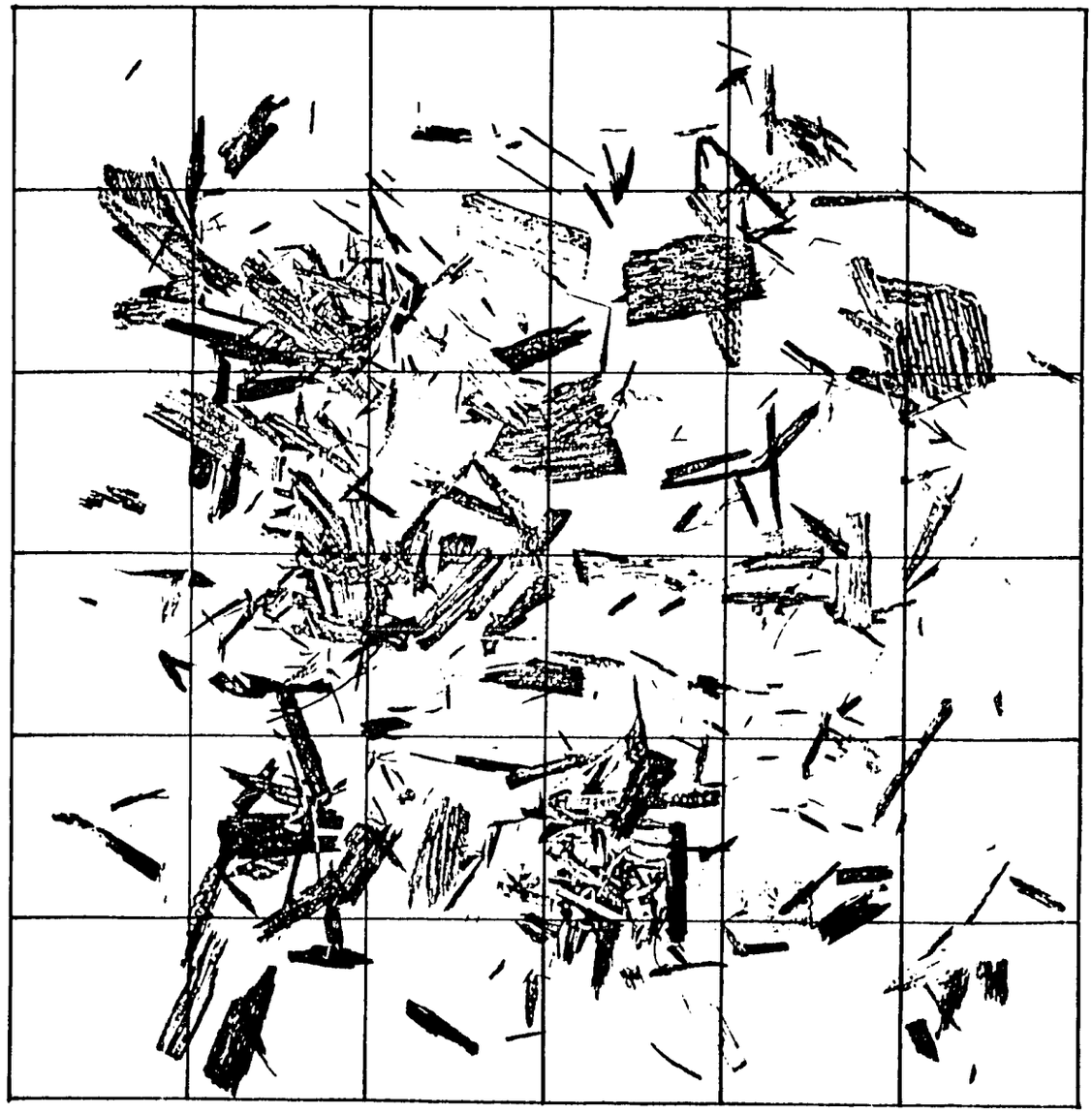
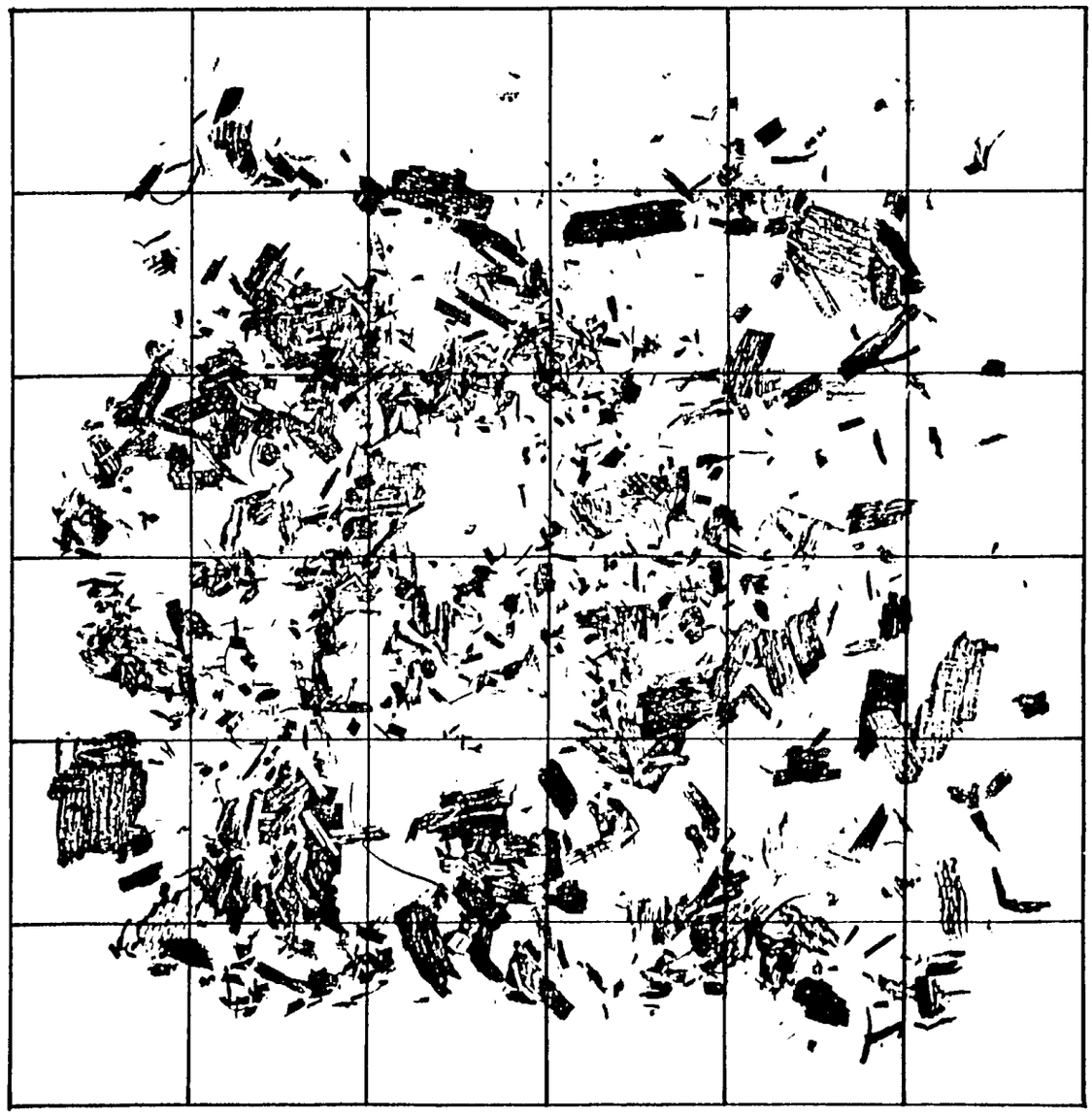



Figure 17. Furnish of planer shavings with a species composition identical to chip mixture C (actual size).