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RADIATA PINE COREWOOD AND SLABWOOD, AND THEIR INTERRELATIONS WITH PULP AND HANDSHEET PROPERTIES

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The basic densities and tracheid lengths of the wood of nine 52-year-old radiata pine trees from the same site in Kaingaroa Forest were measured and related to kraft pulp and handsheet properties. From each tree corewood (wood billet containing 15 growth layers) and slabwood (outer 20 growth layers of a wood billet containing 40 growth layers) samples were chipped and pulped to kappa numbers of 27 ± 2. An additional 7 samples were taken at 5 internode intervals (5 growth layers) from the 10th to the 40th internodes of 3 trees with average basic densities. Each internode sample from each of the 3 trees was combined on equal oven-dry basis, and kraft pulps were prepared.

Wood basic densities, chip basic densities, and wood tracheid lengths for each of the 25 samples were compared with weighted average pulp fibre lengths, pulp fibre cross-sectional dimensions, fibre wall thickness : fibre diameter ratios, and pulp fibre coarseness. For all 25 pulps, chip basic density was found to be the wood property most closely related to pulp and handsheet qualities. About 80% of the variation in handsheet tear, burst, and density properties were accounted for by variations in chip basic density. Inclusion of pulp fibre length in the regression analyses increased this variation accountability by 5-10%. Of the pulp properties measured, the wall thickness : fibre diameter ratio was most closely correlated with chip basic density and therefore with the selected handsheet characteristics. Fibre coarseness was slightly less highly correlated but probably of more practical importance because of the relative ease of measuring this pulp parameter.

INTRODUCTION

The within-tree variation of the intrinsic wood properties of radiata pine grown in New Zealand (e.g., basic density and tracheid length) is extremely high and dependent on wood-age and geographic location (Cown & Kibblewhite 1980). Compounded with this within-tree variation are very high degrees of between-tree variation (Cown & McConchie 1980). The properties of pulp and paper products produced from radiata pine are in turn strongly affected by differences in intrinsic wood properties (Kibblewhite 1973; Uprichard 1980).

The purpose of the present study was to characterise radiata pine wood through the measurement of selected properties and to relate these to the kraft pulps and handsheets produced from them. In this preliminary examination nine 52-year-old trees,

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selected for their wide range in basic wood densities, were studied. An additional study is underway which involves a similar number of 25-year-old radiata pine trees which were grown in accordance with current silvicultural practices. It is confidently anticipated that the general conclusions of this second study will prove to be similar to those described here.

MATERIALS AND METHODS

Wood selection and preparation

Nine 52-year-old radiata pine trees from the same site in Kaingaroa Forest were selected on the basis of their wood basic densities (Cown & McConchie 1980). Of the 9 trees, 3 had low densities, 3 had medium densities, and 3 had high densities. For each tree, billets of wood were taken from the 15th internode (wood containing 15 growth layers) and from the 40th internode from which the outer 20 of the 40 growth layers (slabwood) were included in the sample. The nine 15th internode samples (corewood) and the nine slabwood samples were chipped in a conventional laboratory chipper. Chips used in the study passed through a 32 mm screen and were retained on a 19 mm screen.

Additional material was prepared from the 3 medium density trees. Discs about 2.5 cm thick were cut from every 5th internode from the 10th to the 40th and chipped in the disc chipper located in the N.Z. Forest Products Ltd, Penrose, laboratories. The chips were screened as for the slabwood and corewood material and those from each internode (from each tree) were combined into composite samples on equal oven-dry (o.d.) weight bases. Thus, 25 chip samples consisting of 7 composite, 9 slabwood, and 9 corewood samples were prepared.

Pulping conditions

Kraft pulps with kappa numbers of 27 ± 2 were prepared by conventional procedures. The following conditions were used: active alkali charge on wood 18 or 20% Na_2O depending on wood sample requirements; liquor-to-wood ratio 4 : 1; sulphidity 23%; time from room temperature to maximum temperature (170°C) 90 min. Time at temperature was varied from pulp to pulp in order to attain the required kappa number.

Pulp processing and evaluation

Pulps were refined in a PFI mill at 10% stock concentration with an applied load of 1.77 N/mm. Each pulp was refined for 2000, 4000, 8000, and 16 000 rev. in the PFI mill.

Tear index, burst, bulk, and air resistance were obtained on $60 \pm 2\ g/cm^2$ handsheets using Appita standard methods. Tensile index, stretch, tensile energy per unit area, and Young's modulus were determined with a table model Instron instrument. Determinations were made on 15-mm wide strips of gauge length 100 mm and an extension rate of 10 mm/min. Scattering coefficient was determined on $60 \pm 2\ g/m^2$ handsheets by the SCAN procedure using an Elrepho reflectance meter.

Wood properties

Wood and chip basic densities were measured by water immersion and oven drying of individual samples. Chip samples were immersed within a wire basket of a pre-determined immersed volume (Cown 1980).

Wood tracheid lengths were estimated by weighting (by volume) the values obtained for macerated material taken from the 2nd, 5th, 10th, and 15th growth layers from the pith for the corewood samples. Slabwood tracheid lengths were determined for the outer 20 growth layers of each 40th internode sample. For the composite medium wood density samples, the tracheid lengths of the 2nd, 5th, and every subsequent 5th growth layer were weighted by volume for each of the 7 samples which respectively contained 10 to 40 growth layers from the pith. Wood material used for the tracheid length measurements were macerated in a 1 : 1 mixture of hydrogen peroxide and glacial acetic acid and measured by the method of Harris (1966) except that the two observers each measured 50 rather than 25 whole tracheids.

Pulp properties

Fibre length: Fibre length was estimated by tracing projected fibre images and recording their length with a measuring wheel. Trials showed that about 300 fibres had to be measured to obtain mean length confidence limits of about ± 0.1 mm at the 95% level. For each pulp, 50 fibres on each of 6 microscope slides were measured.

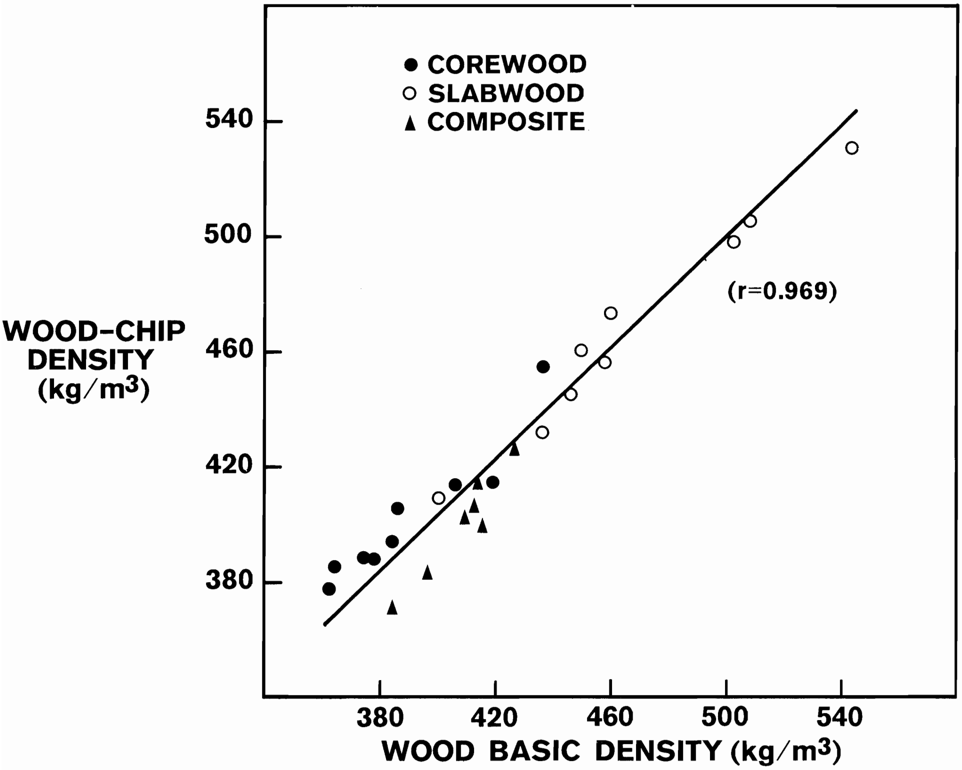

FIG. 1—Wood-chip density for corewood, slabwood, and composite samples.

Samples were coded and examined in a randomised order to eliminate observer bias. The shortest "intact" fibre included in the length measurements was 0.2 mm. "Intact" fibre fragments were defined as shortened fibres with definite or collapsed lumens. Thus, split fibre fragments or fibrillar debris were not included in the fibre length analyses.

The weighted average fibre length was defined as: $\dfrac{\sum l^2_i n_i}{\sum l_i n_i}$

where l_i was the length of any one fibre in the sample, and n_i the number of fibres of length l_i.

Fibre cross-sectional dimensions: The measurement of fibre wall thickness, fibre diameter, and lumen diameter were measured using the procedure outlined previously (Kibblewhite & Brookes 1977) for embedded fibre cross-sections.

Fibre coarseness: The measurement of fibre coarseness was in general accordance with the method detailed by Britt (1966).

RESULTS

Wood and chip basic densities

Chip basic density was highly correlated with wood basic density and values were essentially identical for the two methods (Fig. 1). Chip densities varied substantially for the 9 corewood and the 9 slabwood samples (Table 1), as expected (Cown & McConchie 1980). The range for the corewood chips was 378 to 450 kg/m^3 whereas that for the corresponding slabwood material was 409 to 531 kg/m^3. For the composite medium density samples taken at 5 internode intervals along the length of a tree, chip density increased with increasing numbers of growth layers (increasing wood age) included in the sample (371–426 kg/m^3).

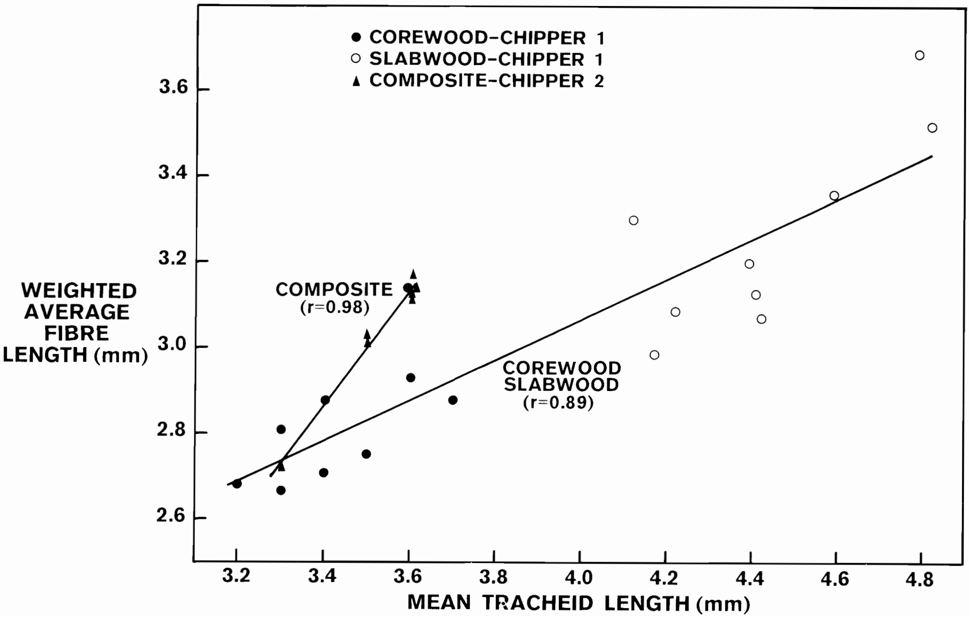

FIG. 2—Tracheid length/pulp fibre length regressions for corewood, slabwood, and composite samples.

TABLE 1 — Wood and fibre properties

Tree number		Wood basic density (kg/m³)	Chip density (kg/m³)	Wood tracheid length (mm)	Weighted av. pulp fibre length (mm)	Fibre wall thickness (μm)	Fibre diameter (μm)	Fibre lumen diameter (μm)	Fibre coarseness	(Wall thickness × 2) / (Fibre diameter)	(Fibre lumen diameter) / (Fibre diameter)
Corewood	1	378	388	3.4	2.71	7.39	40.74	25.97	19.72	0.381	0.619
	2	365	386	3.2	2.68	7.24	41.24	26.76	21.23	0.365	0.635
	3	419	415	3.7	2.88	7.75	42.30	26.80	23.15	0.385	0.615
	4	396	414	3.4	2.88	6.99	40.57	26.59	22.16	0.356	0.644
	5	437	450	3.5	2.75	7.54	38.60	23.52	20.97	0.404	0.596
	6	363	378	3.3	2.67	6.20	38.42	26.02	18.55	0.338	0.662
	7	375	387	3.6	3.15	7.12	41.08	26.84	19.32	0.364	0.636
	8	384	392	3.6	2.93	7.10	40.40	26.21	19.30	0.363	0.637
	9	386	406	3.3	2.81	7.45	42.95	27.97	22.20	0.360	0.640
Slabwood	1	502	498	4.1	3.30	8.61	40.32	23.10	24.76	0.447	0.553
	2	401	409	4.4	3.20	7.76	43.03	27.51	23.69	0.377	0.623
	3	543	531	4.8	3.69	9.87	42.01	22.26	30.19	0.487	0.513
	4	446	445	4.8	3.52	8.23	42.10	25.64	26.95	0.405	0.595
	5	508	505	4.4	3.13	8.12	37.15	20.90	24.20	0.450	0.550
	6	436	432	4.2	3.09	7.05	39.49	25.40	23.86	0.376	0.624
	7	458	457	4.6	3.36	7.80	41.16	25.56	23.47	0.393	0.607
	8	448	461	4.4	3.07	7.45	38.14	23.20	22.25	0.405	0.595
	9	460	473	4.2	2.99	6.82	36.89	23.25	22.16	0.393	0.607
Composite sample "rings"	10	385	371	3.3	2.72	6.57	38.90	25.76	17.44	0.348	0.652
	15	397	382	3.5	3.03	6.35	39.49	26.79	19.96	0.338	0.662
	20	409	401	3.6	3.17	7.26	40.98	26.46	21.55	0.368	0.632
	25	415	399	3.6	3.15	7.07	41.07	26.93	22.52	0.356	0.644
	30	412	405	3.5	3.02	7.93	40.71	24.84	22.99	0.399	0.601
	35	415	414	3.6	3.08	7.62	41.37	26.13	22.00	0.384	0.616
	40	426	426	3.6	3.12	7.93	41.07	25.21	21.73	0.397	0.603

Statistical significance: Mean pulp fibre length different at the 95% level if differ by more than 0.21 mm; Mean fibre wall thickness different at the 95% level if differ by more than 0.77 μm; Mean fibre diameter different at 95% level if differ by more than 3.05 μm; Mean lumen diameter different at the 95% level if differ by more than 2.97 μm; Wall thickness : fibre diameter ratio different at 95% level if differ by more than 0.04; Lumen diameter : fibre diameter ratio different at 95% level if differ by more than 0.04.

Wood tracheid length and pulp fibre length

Tracheid lengths for the various wood samples showed considerable between-tree variation (Table 1). For the 9 corewood samples tracheid length values ranged from 3.2 to 3.7 mm, and for the corresponding 9 slabwood samples the range was 4.1 to 4.8 mm. The range for the 7 composite samples taken at 5 internode intervals was narrow and for the 15 to 40 growth layer samples was between 3.5 and 3.6 mm. The 10-growth-layer sample contained the shortest tracheids (3.3 mm) in accordance with the findings of Cown & McConchie (1980). Similar trends (but different magnitudes) were obtained for the weighted average pulp fibre lengths of the 25 kraft pulps (Table 1).

Separate tracheid length/pulp fibre length regressions were obtained for the 7 composite pulps, and for the 18 corewood and slabwood pulps (Fig. 2). The different regression slopes for the two sets of data have been related to different methods of wood chipping. The composite chips were prepared from 2.5-cm thick wood-discs whereas the slabwood and corewood chips were processed in a conventional laboratory chipper. Chips prepared from the discs were cut in the grain direction whereas the conventional chips were cut across the grain at an oblique angle.

The correlations between wood tracheid length and pulp fibre length were significant in that they showed that tracheid length data can be related to kraft pulp fibre properties. Furthermore, it allows the regional variations in tracheid length determined by Cown & Kibblewhite (1980) to be correlated directly with the lengths of fibres in chemical pulps.

Chip density and pulp fibre length

There was low correlation ($r = 0.633$) between chip basic density and weighted average pulp fibre length for the 25 slabwood, corewood, and composite pulps. Thus, only about 40% of the variation in chip density is associated with variation in pulp fibre length, and this was largely fortuitous due to the inclusion of corewood and slabwood pulps in the same regression.

Chip density and pulp properties

Chip density and fibre wall thickness were not strongly correlated although separate correlations existed for the 9 slabwood ($r = 0.659$), and for the 9 corewood ($r = 0.565$) and 7 composite ($r = 0.892$) pulps. As expected, chip density was found to be highly correlated with the fibre wall thickness : fibre diameter ratio which reflects fibre density on a cross-sectional basis (Fig. 3).

Whereas chip density can be readily estimated in a mill situation on a routine basis, the measurement of pulp fibre wall thickness is time-consuming and requires somewhat sophisticated microscopic techniques and equipment. Fibre coarseness on the other hand can be readily determined (Britt 1966). For the 25 kraft pulps, fibre coarseness was found to be reasonably well correlated with chip density (Fig. 4) although not to the same high degree as was the wall thickness : fibre diameter ratio (Fig. 3).

Handsheet properties

In accordance with the variability in wood and pulp properties noted in Table 1, the handsheet strengths of kraft pulps prepared from the 9 corewood and from the 9 slabwood samples were extremely variable (Figs 5, 6, 7). The handsheet strengths of the 7 composite pulps increased with increasing numbers of growth layers included in

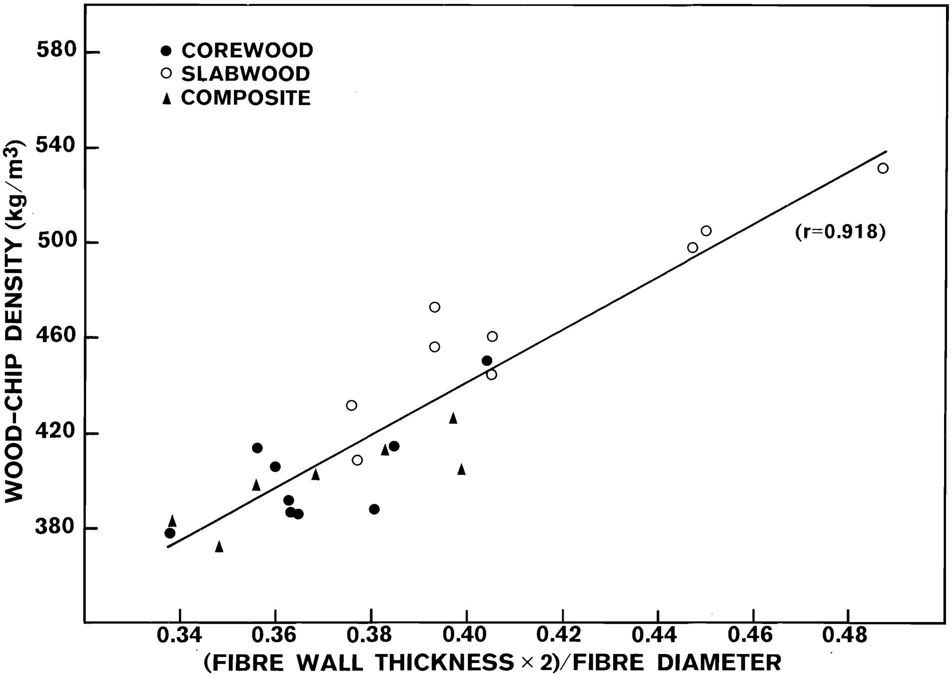

FIG. 3—Fibre wall thickness : fibre diameter for corewood, slabwood, and composite samples.

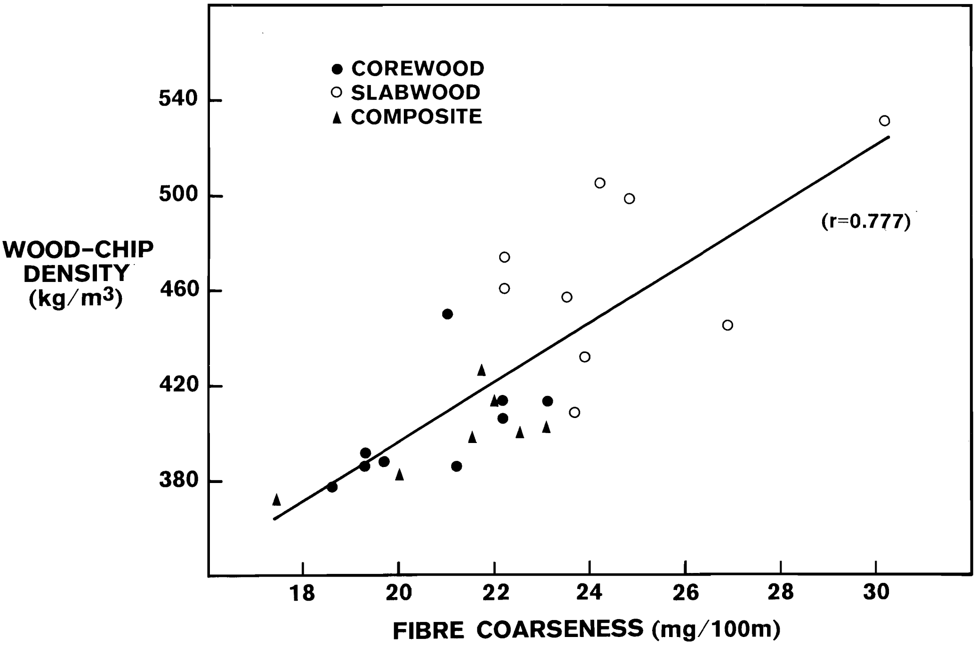

FIG. 4—Fibre coarseness for corewood, slabwood, and composite samples.

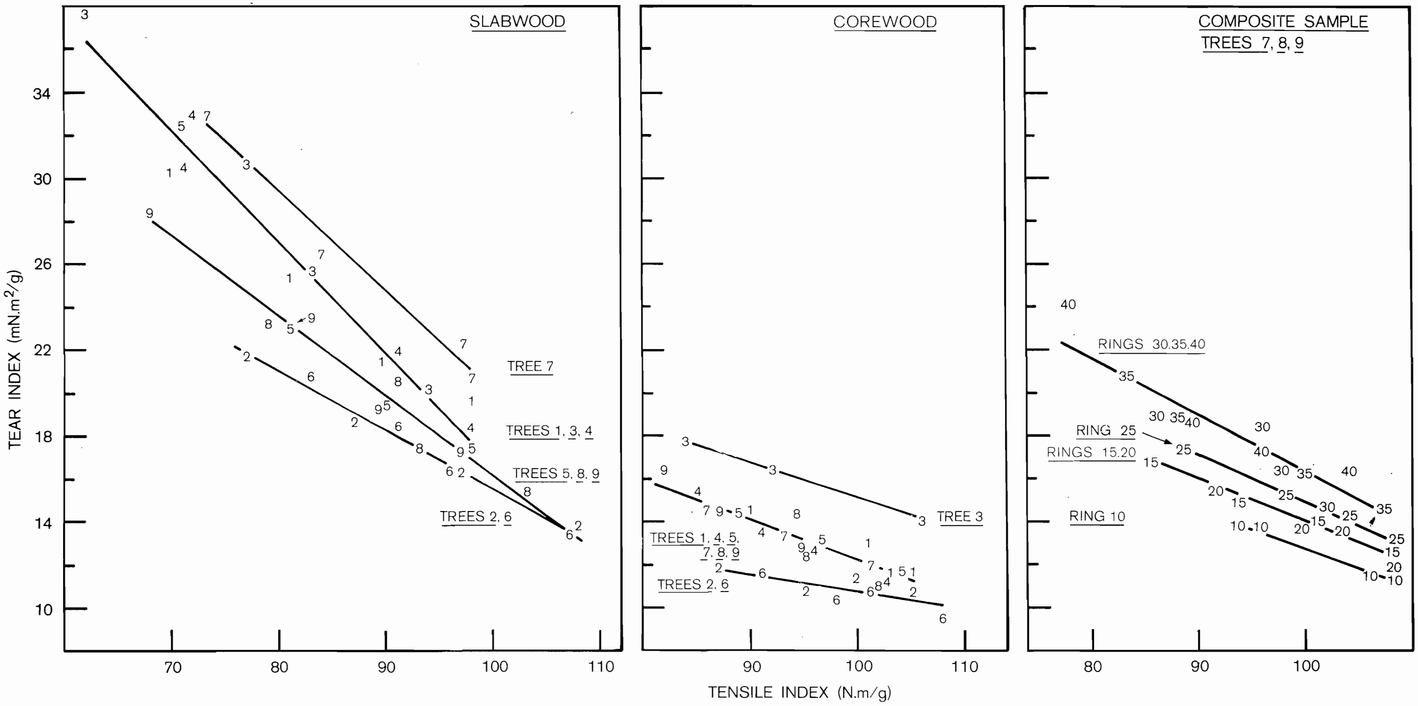

FIG. 5—Tensile Index for slabwood, corewood, and composite samples.

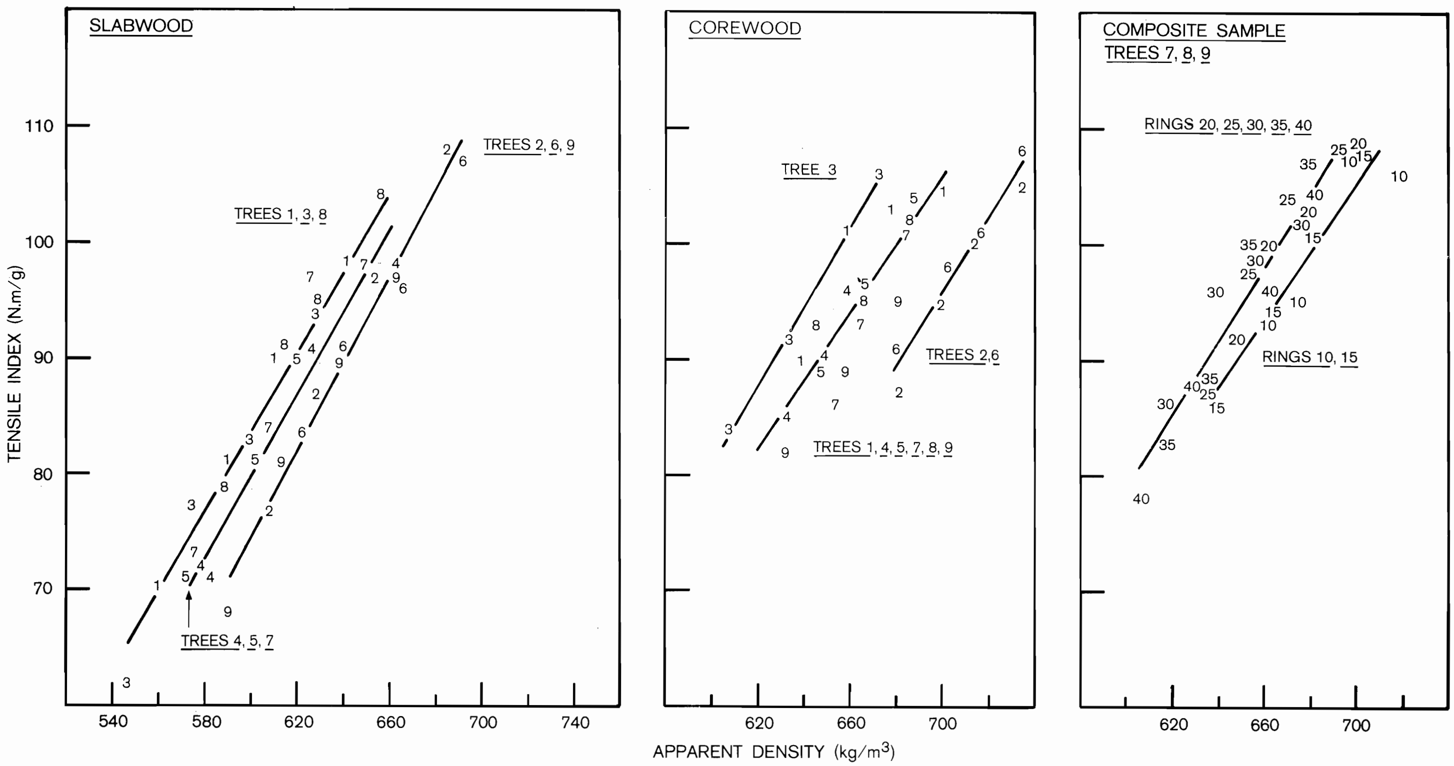

FIG. 6—Apparent density for slabwood, corewood, and composite samples.

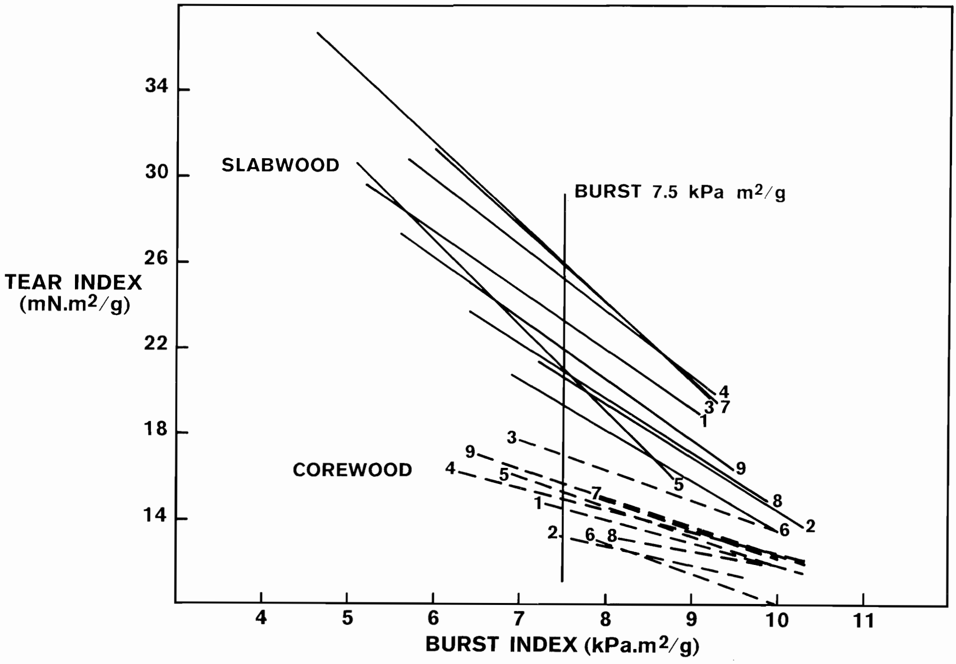

FIG. 7—Burst Index for slabwood and corewood.

the sample and were also in accordance with the measured wood and pulp properties listed in Table 1. Overall, the corewood pulps gave handsheets with high densities, high tensile strengths, and low tearing strengths, when compared with those of the slabwood pulps. The composite pulps gave handsheets with properties roughly intermediate between those of the corewood and slabwood pulps.

For given tensile indexes wide variations in handsheet tearing strengths were obtained (Fig. 5). The regressions for the composite pulps occurred at positions intermediate to those of the corewood and slabwood pulps. Rankings for specific trees were generally similar for the corewood and slabwood pulps. A specific instance where this did not occur was that tree 7 had the highest tear strength of the slabwood pulps whereas tree 3 held this position for the corewood pulps.

Tensile strength/apparent handsheet density relationships also showed wide between-tree variation (Fig. 6). Tree 3 had consistently high tensile strengths and trees 2 and 6 consistently low tensile strengths for the slabwood and corewood pulps. Tree 2 contained both long and relatively dense fibres (Table 1); trees 2 and 6, on the other hand, contained shorter fibres of relatively low density or low wall thickness : diameter ratios.

Handsheet, and wood and fibre characteristics

Identification of the effects of wood and pulp properties (Table 1) on specific handsheet strengths depended on the bases of comparison. For the present study handsheet tear and burst strength, and handsheet apparent density were examined for pulps which had been refined for 2000 rev. in the PFI mill. Tear index and burst index were also examined at a sheet density of 600 kg/m^3, and tear index only at a burst of 7.5 kPa.m^2/g. The 2000 rev. PFI treatment appeared to be the most meaningful basis for comparison since it allowed all pulps to be treated to similar extents before sheetmaking. Extents of refining were different for each pulp when the bases for comparison were given burst indexes or sheet densities.

Techniques of multiple regression analysis were used to determine the effects of the various wood and pulp properties (Table 1) on handsheet tear and burst strength, and apparent density.

Tear index at 2000 PFI rev.: Chip density was strongly correlated with handsheet tearing strength for pulps which had been refined 2000 rev. in the PFI mill (Fig. 8). In accordance with the chip density/fibre coarseness relationship of Fig. 4, fibre coarseness was also found to be correlated with handsheet tear index (Fig. 9) but to a lesser extent than chip density. Weighted average pulp fibre length also showed a reasonable correlation with handsheet tear index (Fig. 10).

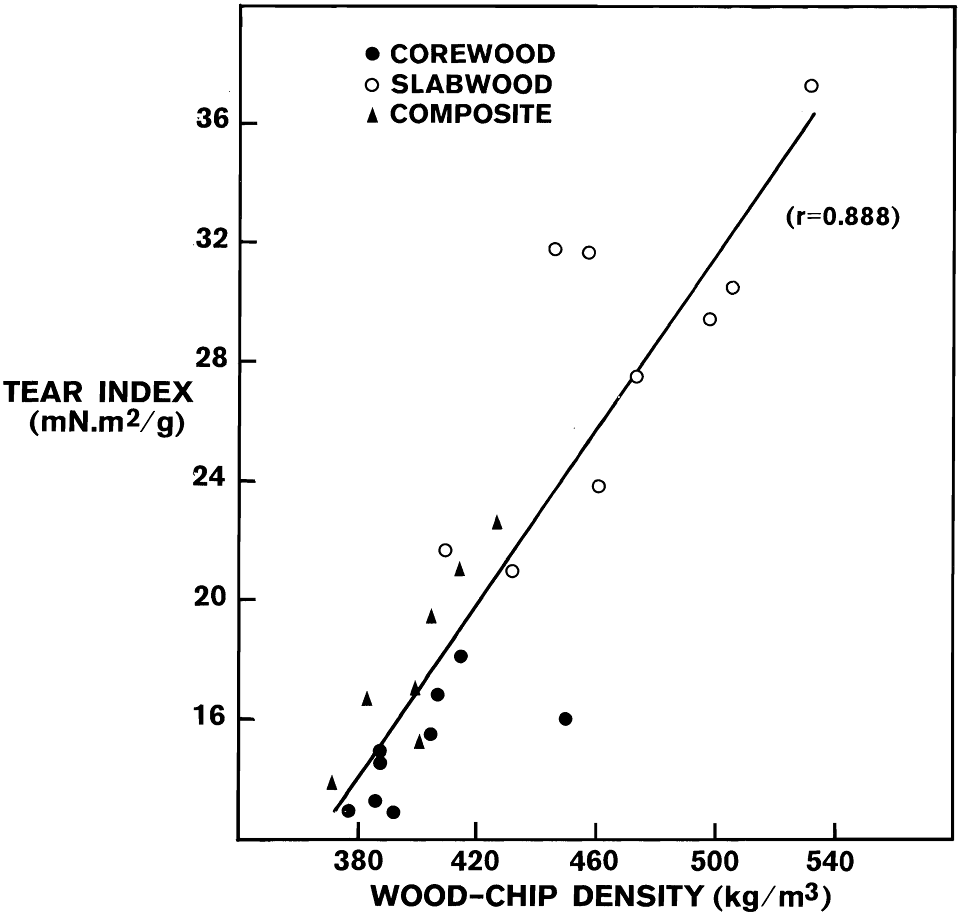

FIG. 8—Wood-chip density for corewood, slabwood, and composite samples.

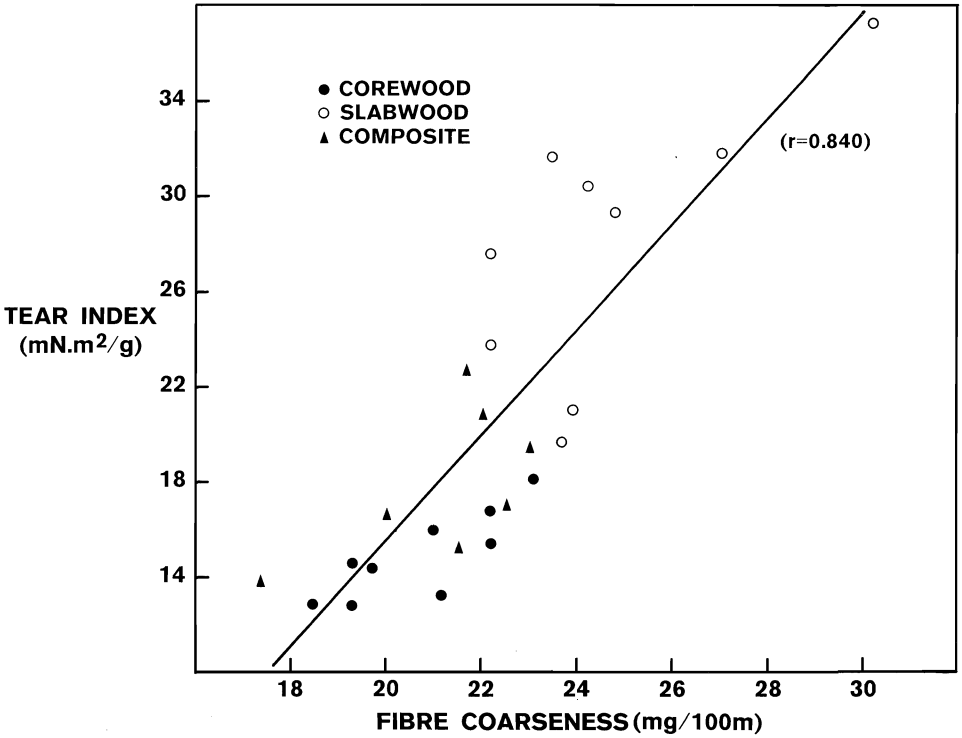

FIG. 9—Fibre coarseness for corewood, slabwood, and composite samples.

Multiple regression analysis showed that chip density alone accounted for 78.9% of the variation in tear index. The inclusion of fibre length in the equation increased the accountability of the tear index variation to 89.5%. When fibre coarseness (a pulp rather than a wood characteristic) replaced chip density in the regression equation, 70.6% of the variation in tear index was explained. The inclusion of fibre length into this equation increased the tear index variation accountability to 76.2%.

$$\text{Tear} = 0.146\ (\text{Chip density}) - 41.6 \qquad (1)$$
$$r^2 = 0.789$$

$$\text{Tear} = 0.103\ (\text{Chip density}) + 11.46\ (\text{Fibre length}) - 57.9 \qquad (2)$$
$$r^2 = 0.895$$

$$\text{Tear} = 2.206\ (\text{Fibre coarseness}) - 28.5 \qquad (3)$$
$$r^2 = 0.706$$

$$\text{Tear} = 1.38\ (\text{Fibre coarseness}) + 10.76\ (\text{Fibre length}) - 42.9 \qquad (4)$$
$$r^2 = 0.762$$

Tear index at burst of 7.5 kPa.m²/g: A wide range of tear strengths at a burst of 7.5 kPa.m^2/g occurred for the 9 corewood and 9 slabwood pulps (Fig. 7). With a burst index of 7.5 kPm.^{2}/g as the basis for comparison, pulp fibre length replaced chip

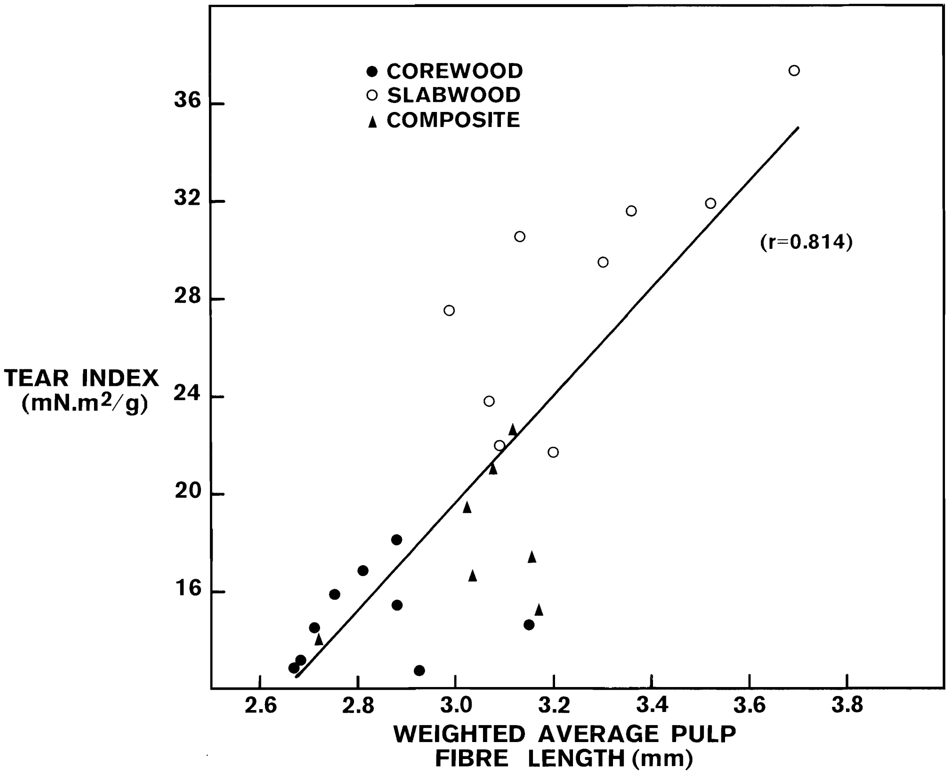

FIG. 10—Pulp fibre length for corewood, slabwood, and composite samples.

density as the variable which accounted for the major proportion of the variation in tearing strength. Multiple regression analyses showed that fibre length accounted for 74% of the variation whereas fibre length and chip density together explained 82.8%.

$$\text{Tear} = 13.25\ (\text{Fibre length}) - 21.8 \qquad (5)$$
$$r^2 = 0.740$$

$$\text{Tear} = 9.53\ (\text{Fibre length}) + 0.035\ (\text{Chip density}) - 25.5 \qquad (6)$$
$$r^2 = 0.828$$

When chip density was considered separately from pulp fibre length it accounted for 60% of the variation in tear index.

$$\text{Tear} = 0.072\ (\text{Chip density}) - 11.97 \qquad (7)$$
$$r^2 = 0.598$$

Tear at sheet density of 600 kg/m³: Comparison of tear index and wood or pulp properties at sheet densities of 600 kg/m³ again showed that by far the greatest proportion of the variation in tearing strength can be explained by chip density.

$$\text{Tear} = 0.072\ (\text{Chip density}) - 9.7 \qquad (8)$$
$$r^2 = 0.577$$

$$\text{Tear} = 0.044\ (\text{Chip density}) + 7.3\ (\text{Fibre length}) - 2.01 \quad (9)$$
$$r^2 = 0.708$$

Together, chip density and pulp fibre length accounted for 70.8% of the variation in tear index at sheet densities of 600 kg/m³.

Burst index at 2000 PFI rev.: Burst index was highly correlated with chip density and to a lesser extent with the "corresponding" pulp property fibre coarseness (Figs 11, 12). The correlation between fibre length and burst index ($r = 0.583$) was substantially lower than those of chip density and fibre coarseness. Multiple regression analysis showed that chip density or fibre coarseness respectively accounted for 87.8% and 64.9% of the variation in burst index. Fibre length was found to have no significant effect on burst index.

$$\text{Burst} = -0.024\ (\text{Chip density}) + 17.1 \quad (10)$$
$$r^2 = 0.878$$

$$\text{Burst} = -0.326\ (\text{Fibre coarseness}) + 14.2 \quad (11)$$
$$r^2 = 0.649$$

Burst index at sheet density of 600 kg/m³: Pulp fibre length was the only wood or pulp property listed in Table 1 which gave a reasonable correlation with burst index. This correlation accounted for 61.4% of the variation in burst index. By itself chip density accounted for only 29.5% of the variation.

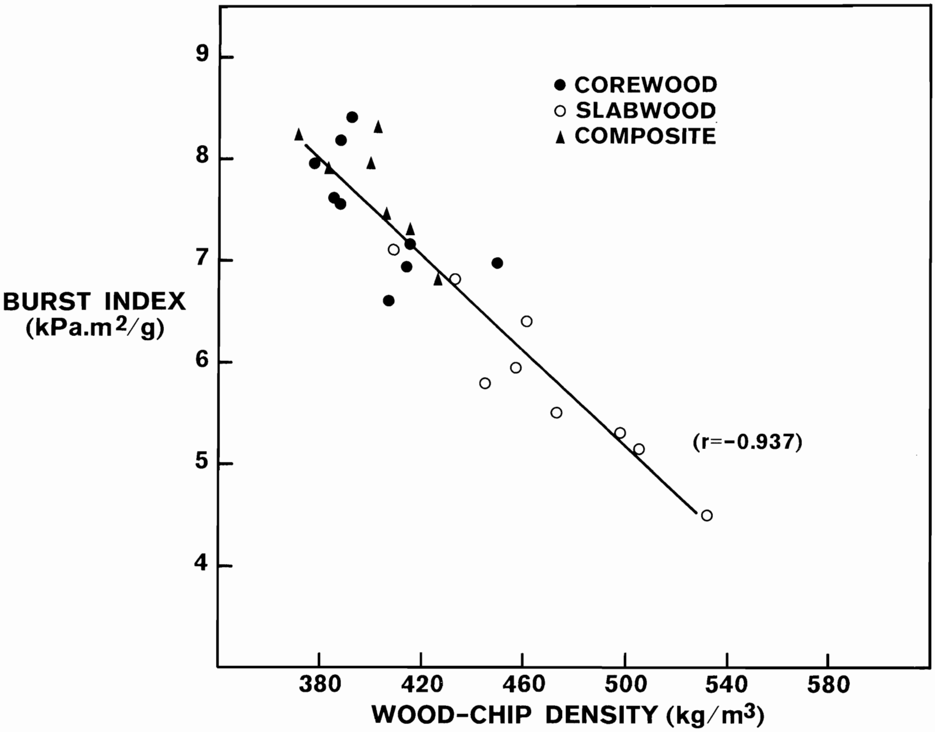

FIG. 11—Wood-chip density for corewood, slabwood, and composite sample.

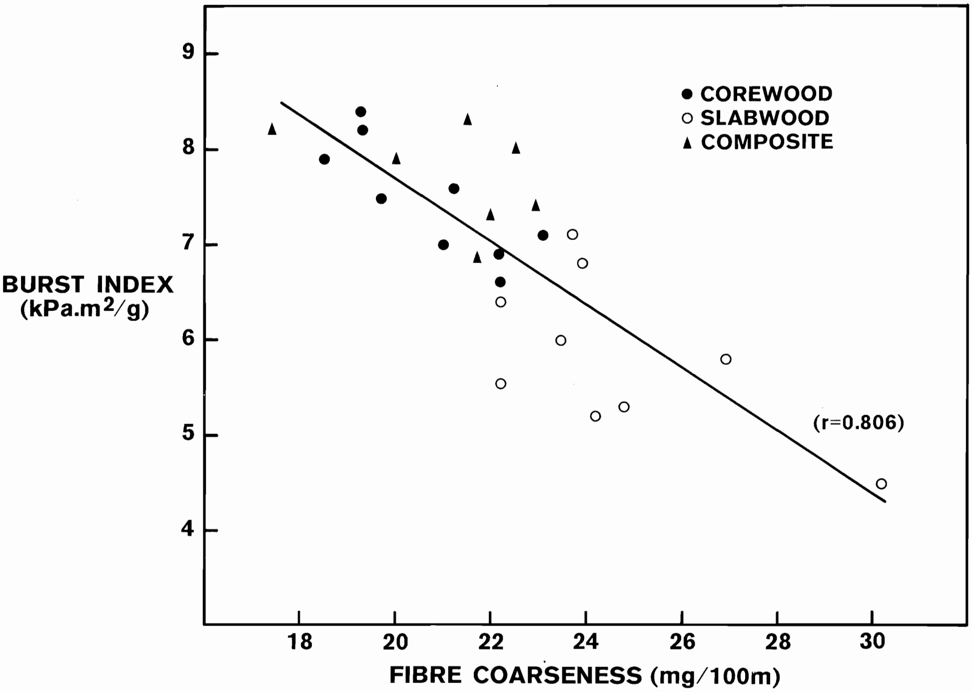

FIG. 12—Fibre coarseness for corewood, slabwood, and composite samples.

Handsheet apparent density at 2000 PFI rev.: Handsheet density was strongly correlated with both chip density (wood property) and fibre coarseness (pulp property) and in this respect was very similar to tear index (Figs 13, 14). Fibre length also influenced handsheet density although to a lesser degree than either chip density or fibre coarseness. Chip density and fibre coarseness respectively accounted for 81.4 and 68.8% of the variation in handsheet density. In combination with fibre length the proportion of the variability accounted for in the sheet density/chip density relationship increased to 86.8%. Fibre length made a negligible contribution to the sheet density/fibre coarseness equation.

$$\text{Sheet density} = -0.732\ (\text{Chip density}) + 928.4 \qquad (12)$$
$$r^2 = 0.814$$

$$\text{Sheet density} = -0.579\ (\text{Chip density}) - 40.16\ (\text{Fibre length}) + 985.5 \qquad (13)$$
$$r^2 = 0.868$$

$$\text{Sheet density} = -10.72\ (\text{Fibre coarseness}) + 855.9 \qquad (14)$$
$$r^2 = 0.688$$

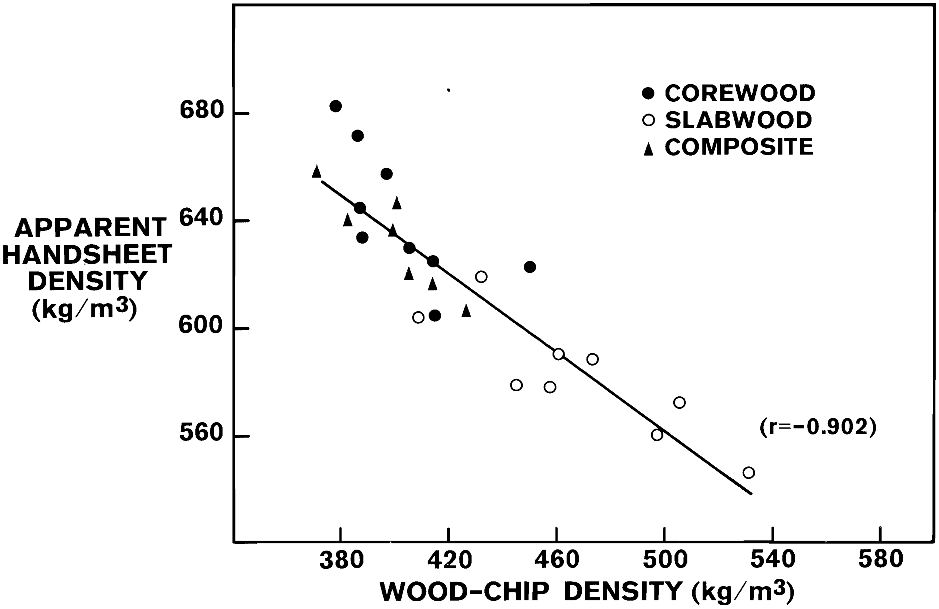

FIG. 13—Wood-chip density for corewood, slabwood, and composite samples.

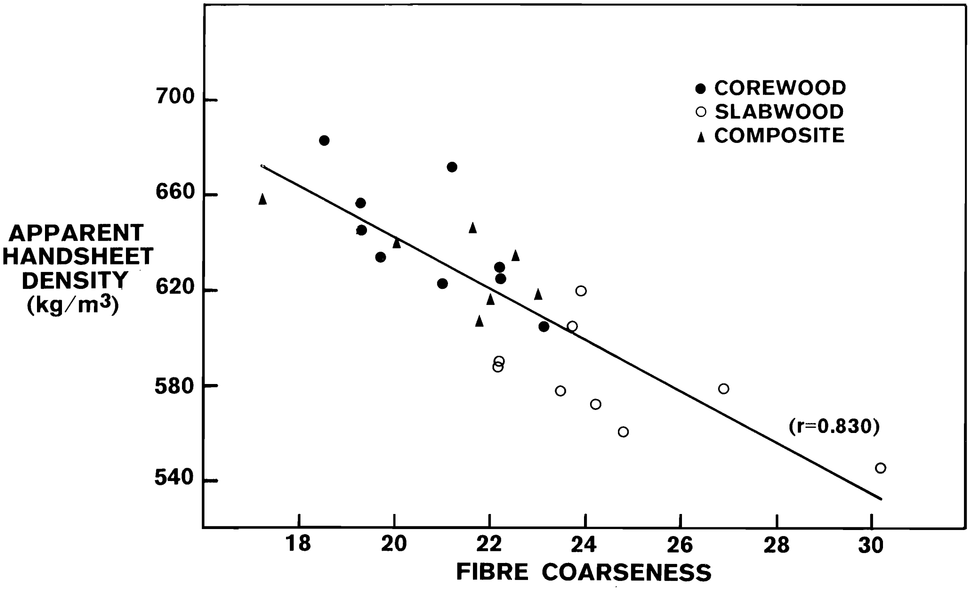

FIG. 14—Fibre coarseness for corewood, slabwood, and composite samples.

DISCUSSION AND CONCLUSIONS

Wood and pulp properties

Chip basic density was shown to be the most important wood property as far as the prediction of pulp and paper qualities were concerned. Chip density was readily measured, and consistent and reliable results were obtained which were highly correlated with ($r = 0.969$), and equivalent to, corresponding wood basic densities (Fig. 1). For pulp properties the wall thickness : fibre diameter, or the lumen diameter : fibre diameter ratios were found to be the most closely correlated with chip basic density ($r = 0.918$) (Fig. 3). Unfortunately the measurement techniques of these pulp parameters would be unsuitable as routine quality control procedures at production plants. For this reason the potential of the more readily measured and related property of fibre coarseness was examined (Fig. 4). The correlation between chip density and fibre coarseness ($r = 0.777$), although somewhat less than that of the wall thickness : fibre diameter ratio ($r = 0.918$), was considered satisfactory in view of the very comparable correlations obtained with these wood and pulp variables and handsheet tear strength and apparent density (Figs 8, 9, 13).

The lengths of intact and undamaged wood tracheids were measured by the maceration method (Harris 1966). Tracheid lengths were found to be correlated with weighted average pulp fibre lengths (Fig. 2) which took into account all fibres and "intact" fibre fragments longer than 0.2 mm. Correlations between wood tracheid and pulp fibre lengths were, however, dependent on the type of chipper used (Fig. 2). Thus, the regional tracheid length data for New Zealand radiata pine of Cown & Kibblewhite (1980) can be related directly to pulp fibre lengths provided wood preparation and chipping conditions are taken into account.

Wood, pulp, and handsheet relationships

For pulps which had been refined for 2000 rev. in the PFI mill, handsheet tearing strength and apparent density were both strongly correlated with chip basic density which accounted for 78.9 and 81.4% of the variation in these handsheet properties respectively. Fibre length also influenced these handsheet properties and together with chip basic density accounted for 89.5 and 86.8% of the respective variation in tear index and apparent density. The respective values for fibre coarseness were 70.6 and 68.8%. Based on these multiple regression data and the trends shown in Figs 8 and 13 it was concluded that the quality of radiata pine kraft pulps can be predicted from a knowledge of their chip basic densities alone. If pulps only were available for analysis then estimates of fibre coarseness (Fig. 9) can be used to predict paper quality, although such a prediction would not be as accurate as either chip basic density or the pulp fibre wall thickness : fibre diameter ratio (Fig. 3).

For kraft pulps prepared from radiata pine wood grown in the Kaingaroa area, the importance of fibre length in the prediction of product quality has been shown to be small when compared with chip basic density. It is confidently expected that chip basic density will also be found to be the major determinant of pulp quality for radiata pine wood grown in other regions of New Zealand with the possible exception of Northland. Regional wood basic density and tracheid length data of Cown & Kibblewhite (1980) have shown that radiata pine wood from Northland contained tracheids which were consistently about 0.5 mm longer than those from trees grown in other regions of New Zealand. There is therefore a possibility, although unlikely, that for Northland radiata pine wood, pulp fibre length may be found to influence product quality to a greater extent than shown for the present study.

When the basis of comparison was 2000 rev. of PFI mill pulp refining the 3 handsheet properties of tear index, burst index, and apparent density were most strongly correlated with chip basic density. Such a relatively light refining treatment allowed direct comparison of wood or pulp properties and selected handsheet characteristics. Correlations were somewhat more variable when specific handsheet burst and apparent density values were the bases of comparison. Chip basic density and pulp fibre length were, however, again found to be the most important properties to influence handsheet tear, burst, and density. The lower correlations obtained were to be expected because each pulp would have had to be refined to very different extents before sheetmaking. Thus, for each pulp many of the intrinsic wood and pulp properties would have been substantially different from those listed in Table 1.

Corewood and slabwood

Corewood pulps from radiata pine wood containing 15 growth layers produced handsheets with low tear indexes, and high tensile and burst indexes, and high apparent densities when compared with corresponding slabwood pulps from radiata pine wood containing the outer 20 of 40 growth layers.

Pulps prepared from radiata pine wood containing 10, 15, 20, 25, 30, 35, and 40 growth layers from the pith gave handsheets with increasing tear indexes and decreasing burst and tensile indexes, and apparent densities as the number of growth layers in the wood sample increased. Handsheet properties of these composite pulps were either similar to those of the corewood pulps or intermediate between those of the corewood and slabwood pulps.

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