LOCALIZED PROPERTIES IN FLAKEBOARD: A SIMULATION USING STACKED FLAKES[1]

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ABSTRACT

Heat transfer, vertical density distribution, bond strength, and dimensional stability were determined for columns of trembling aspen wood flakes pressed to simulate the density variation found within a flakeboard mat. Variables studied included: 1) the number of wood flakes in each column, 2) face flake moisture content, and 3) press closing time. The face, intermediate, and core layers of the resulting flake assemblies were evaluated in terms of the heat transfer occurring during pressing, their vertical density distribution, shear bond strength, and dimensional stability. More rapid heat transfer to the core of the flake assemblies was generally associated with shorter press closing times, higher moisture content face flakes, and lower initial numbers of flakes. Face densities were greatest for the shorter press closing time and low moisture content face flakes. Relative density differences between face and core layers were greatest for low numbers of flakes. Greatest strengths were found at the face layer and followed the vertical density distributions. Press closing time had no effect on strength. Face flake moisture content affected only the strength of the face and intermediate layers of the flake assembly composed of the greatest number of flakes. Thickness swelling trends closely followed the vertical density distributions.

Keywords: Flakeboard, vertical density distribution, strength, thickness swell, heat transfer.

INTRODUCTION

Flakeboard is manufactured by applying relatively small amounts of adhesive to wood flakes, forming these constituents into a loose mat structure, and then consolidating the mat under heat and pressure to form an integrated board. The mechanical and physical properties of flakeboard have been intensively studied. Although the performance of the material can be assessed by various tests, the underlying phenomena controlling such performance are still unclear. This is due mainly to the complex nature of the flakeboard structure, which makes certain analyses difficult to perform. A number of empirical and theoretical models of the structure of flakeboard have been proposed. These studies have provided valuable predictions and explanations of various aspects of flakeboard formation, such as heat and mass transfer, compression behavior of the flake mat (Harless et al. 1987; Humphrey and Bolton 1989; Wolcott 1990), and horizontal and vertical density distributions (Suchsland 1962; Suchsland and Xu 1991; Dai 1993; Dai and Steiner 1994a,b). However, none of the above studies systematically studied the localized properties in flakeboard.

Four simultaneous major processes are in-

[1] The use of company or product names does not constitute endorsement by the authors.
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volved in conventional hot-pressing of a flakemat (heat and moisture transfer, adhesive flow and cure, mat compression and density gradient development) which determine the final properties of the flakeboard. During pressing, heat is transferred from the face layers to the core layers by means of both conduction and convection. Since wood is a poor conductor of heat, the movement of moisture is important to facilitate the penetration of heat into a compressed mat. Consequently, although the initial face temperature increase results primarily from conductive heat transfer, the temperature increase in the core of a mat depends to a large extent on the flow of steam due to vapor pressure differences.

Since the compression properties of wood are temperature- and moisture-dependent, the transient temperature and moisture gradients in the mat result in a nonuniform compression of wood flakes through the board thickness. Thus a vertical density gradient develops (Strickler 1959; Suchsland 1962). Heat and moisture transfer and subsequent vertical density gradient development in a mat are also influenced by the press closing time (PCT) (Kelly 1977; Smith 1982). The concept of a horizontal density distribution of flakeboard was first introduced by Suchsland (1962). The potential effect of the horizontal density variation on board properties has clearly been demonstrated (Suchsland and Xu 1989, 1991; Steiner and Dai 1993). To date no approach has been described to determine the effect of horizontal density on heat and mass transfer inside a flake mat. In previous studies, temperature and moisture transfer were both assumed to be uniformly distributed in the plane of a mat. In reality, the local horizontal mat densities may influence heat flow in different regions within a compressed mat, and therefore affect the development of the vertical density gradient.

The variation of bonding properties in the thickness directions of a panel has been investigated by a number of researchers (Shen and Carroll 1969; Plath and Schnitzler 1974; Brady 1987). These studies revealed that bonding strengths were higher near the face layer and lower in the core of a board. Studies of bonding properties in the horizontal plane of a board have been less numerous. One approach used a veneer strip model to simulate the structure of flakeboard (Suchsland and Xu 1989). The strength values were generally greater in higher density regions, but decreased when density was above a certain limit.

The dimensional behavior of pressed flakeboard panels involves three major components: natural dimensional changes of wood; release of residual stresses imparted to the board in the pressing operation (Halligan 1970; Anonymous 1987); and nonuniform board structure, in terms of density variation, which results in different localized dimensional properties (Suchsland 1967, 1973). The implications are that a nonuniform local dimensional stability would result in internal stresses between different density regions since higher density regions tend to spring or swell more than do lower density regions (Suchsland 1973).

The objective of this study was to simulate the variation of density found within a flakeboard mat using individual flake columns made from different numbers of flakes. For these columns the heat transfer occurring within the columns during hot-pressing, the subsequent density distributions found, and the strength and dimensional stability of different layers through the thickness of the columns were measured.

MATERIALS AND METHODS

Blocks of wood 55.0 × 17.5 × 44–55 mm in dimension were cut from the sapwood of green trembling aspen (*Populus tremuloides*) logs and were water-soaked for two weeks. Flakes were then cut to 55.0-mm length, 17.5-mm width, and 0.69-mm thickness, using a sledge microtome. The flakes were left in a conditioning chamber to reach an equilibrium moisture content (EMC) of either 4.5% or 15.0%.

A powdered phenol-formaldehyde adhesive was prepared in the laboratory as previously described (Ellis 1993). The adhesive was analyzed using a DuPont DSC 2910 differential scanning calorimeter with an empty DSC pan as the reference cell. Approximately 4.5 mg of resin was placed in a sealed pan. The samples were scanned at a heating rate of 10°C/min in the temperature range of 25°C to 250°C. The adhesive was also analyzed using a DuPont TMA 2940 thermo-mechanical analyzer. Resin pellets were prepared using a TMA pellet cylinder and sample encapsulating press. Approximately 30 mg of resin was used to prepare each pellet. The samples were scanned in the temperature range of 25°C to 200°C using different heating rates and applied pressures. The dimensional changes were measured by the probe of the TMA applied to the pellet.

Resin was mixed with flakes in a plastic bag at a loading level of 1% based on oven-dry weight of wood flakes. Each flake assembly (FA) was manually formed with the flakes uniformly aligned, using a holding device to maintain the vertical stack of flakes while they were held together with paper tape. Flake assemblies were made from 24, 32, and 40 flakes with targeted densities of 0.507, 0.676, and 0.844 g/cm^3, respectively. Unless otherwise stated, FAs were prepared with flakes of 4.5% MC. When 15% MC flakes were used, the outer 4, 5, or 6 flakes on the top and bottom of the 24, 32, and 40 FAs, respectively, were replaced with the higher moisture content flakes. A microcomputer, Material Testing System controlled 300 × 300 mm electrically heated press was used to press the FAs. Three replications of each FA were placed evenly within a mat of wood particles prepared by grinding trembling aspen flakes to a particle size of approximately 1 mm and conditioning to a MC of 4.5%. The particle mat had a target density of 0.5 g/cm^3. The general pressing parameters used were: press temperature—200°C; total press time—7 min; target thickness—12.7 mm; maximum pressure reached at press closure—0.828 MPa. The press was initially under pressure control whereby the time taken from the initial pressure response to the time that the maximum pressure was reached was controlled as the PCT. The maximum pressure was maintained until the target thickness of 12.7 mm was reached. The press then switched to position control whereby only the pressure necessary to maintain the target thickness was applied. Three different pressing conditions were examined: (1) 15 seconds PCT, all flakes at 4.5% MC; (2) 45 seconds PCT, all flakes at 4.5% MC; (3) 15 seconds PCT, flakes in the face layers at 15% MC and flakes in the inner layers at 4.5% MC. During pressing, the internal temperature was monitored at the face (⅛ thickness), intermediate (¼ thickness), and core (½ thickness) layers of selected FAs using thermocouples. After pressing, FAs were removed and conditioned at 50% RH and 23°C.

Vertical density distribution measurements of three replicates of each FA type were performed on a RECOM 8900/DA density analyzer at Alberta Research Council, Edmonton.

Bond strength evaluations were determined on three layers of FAs (face, intermediate, and core) at a distance of approximately 2, 4, and 6 mm, respectively, from the surface. The test specimens were prepared by cutting two narrow grooves (2.5 mm wide) into each side of an FA with a table saw to expose the targeted gluelines. In order to prevent damage at the thin section near the surface rather than at the glueline 2 mm from the surface, a small wood piece was glued to the surface of the FA. A hole (diameter approximately 6 mm) was drilled in both ends of the FA. Two screws were then inserted into the holes. Metal spacers, whose diameter was just a little wider than the width of the FA, were attached on both sides of the FA using matched nuts (Fig. 1). During the test, the spacers on either side of the FA were gripped by the pneumatic jaws. The specimens were pulled in tension at a crosshead rate of 1.27 mm/min and failed in a shear mode. The failed specimens were retained and examined under a stereo-microscope.

The measurement of the thickness swell

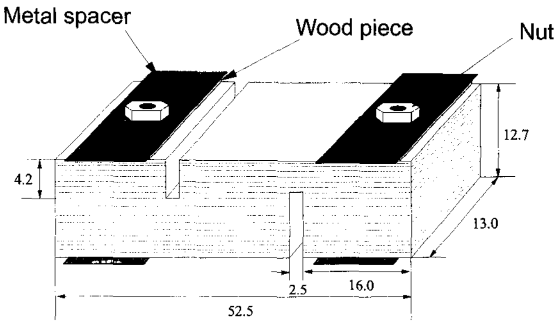

FIG. 1. Flake assembly prepared for strength test of intermediate layer. Dimensions are in mm.

(TS) of the FAs was conducted using an image analysis system. A Javelin® JE 3462HR color video camera transmitted the image to a TARGA+® 16/32 frame grabber. An IBM® 486-compatible microcomputer with Java® image anlaysis software was used to make the appropriate measurements. Three line segments (surface-face; face-intermediate; intermediate-core) were marked on each FA using an indelible pen. The line segments were measured prior to and after 24 hours of water immersion at room temperature. At the magnification level used to capture and analyze the images of the flake assemblies, one pixel on the video monitor used to make the measurements represented 25 μm.

RESULTS AND DISCUSSION

Temperature gradients

The temperature gradients recorded during the hot-pressing of the flake assemblies will influence the cure of the adhesive and the development of the vertical density distribution. The temperatures monitored at the face, intermediate, and core layers of the 24, 32, and 40 flake assemblies are shown in Fig. 2. For a given FA at each layer, a slower initial temperature rise was observed with the longer PCT. A slightly greater initial temperature rise was observed for the flake assemblies prepared with the surface flakes at a higher MC. These differences were most pronounced in the 24 FA. The increased heat transfer observed at shorter PCT and higher MC was believed to be due mainly to an increase in convection. At lower densities (24 FA) the internal structure of the FA would be more permeable, while at higher densities (40 FA) the lower internal void volume might obstruct the migration of moisture and diminish the convective effect, thus decreasing the rate of the initial temperature rise observed. At the 15 seconds PCT and 4.5% MC condition, the core layer initial temperature rise was most rapid in the 24 FA. There was little difference in the initial temperature rise in the face and intermediate layers between the three FAs. At the higher MC condition, the convective effect was accelerated, and the initial temperature

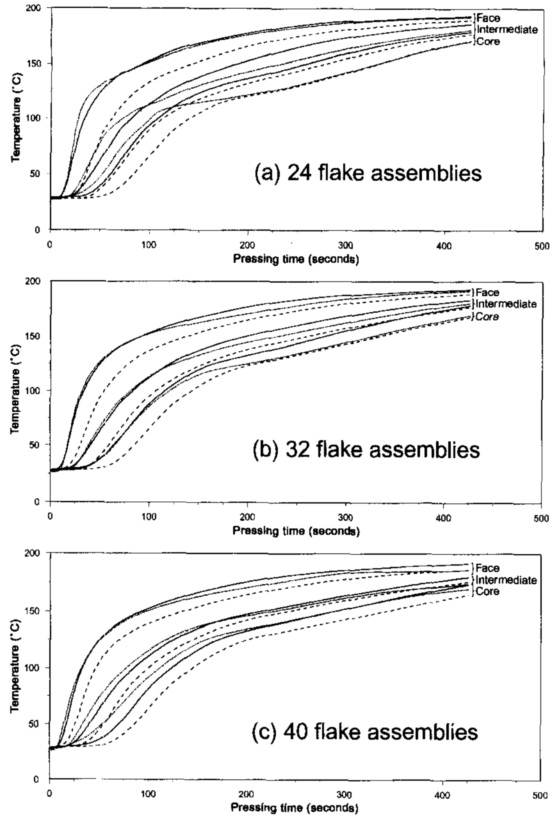

FIG. 2. Temperatures recorded at different layers during hot-pressing of flake assemblies made from different numbers of flakes (——— 15 seconds press closing time, 4.5% moisture content; – – – 45 seconds press closing time, 4.5% moisture content; ······· 15 seconds press closing time, 15.5% moisture content face, 4.5% moisture content core).

rise in the intermediate and core layers of all the FAs was greater than at the lower MC condition, for the same PCT. There was little difference observed for the face layers at the different MC conditions. At the longer PCT, the convective effect was reduced, and the relative importance of the conductive effect was increased. At the face and intermediate layers, initial temperature rise was most rapid for denser FAs, but there was little difference observed between the core layers.

Dai (1993) predicted that between-flake voids occupied less than 5% of total void volume at a mat compaction ratio of 1.5. This suggests that in some portions of a flake mat (high density regions) where no between-flake void existed, moisture flow has to occur through the intra-flake voids. Accordingly, in a flakeboard mat, some high density regions may have a similar rate of heat transfer to that observed in the higher density level FAs. However, low density regions of a flakeboard mat, because of the occurrence of intra-flake water vapor flow, could expect a faster rate of heat penetration into the core compared to the temperature rise in the lower density FAs. Therefore, a larger extent of heat transfer variation in different density regions may exist in flakeboard than in the FAs.

Vertical density distributions

The vertical density distributions determined are presented in Fig. 3. Each distribution shown represents the average of two face-to-core measurements for each of three replications (i.e., six face-to-core measurements). As expected, FAs constructed with a greater number of flakes showed a higher overall density level. Density was greatest at the face layer and least at the core layer. The difference between the face and intermediate layers was generally greater than that between the intermediate and core layers. At the longer PCT, the relative difference between the face and the core was less than that at the shorter PCT. With the shorter PCT, the outer layers experience a higher initial temperature and a greater initial pressure than with the longer PCT, which will lead to a greater densification of the flakes at the surface. For each of the pressing conditions, the relative differences between the face and core diminished as the number of flakes increased. For the 24 FA and 32 FA, there was little difference between the vertical density distributions for the FAs prepared using the 4.5% MC flakes and those prepared using the 15% MC flakes on the surface. The 40 FA, however, showed a much flatter vertical density distribution when the higher MC flakes were used.

Resin cure

The results of the thermal mechanical analyses (TMA) and differential scanning calorimetry (DSC) analyses are presented in Figs. 4 and 5, respectively. As it was heated, the powdered resin experienced both physical and chemical changes. Physically, the resin underwent rheological stages of softening, melting, and hardening. Chemcially, the resin went through a polymerization process, where the resin transformed from low molecular weight prepolymers to a highly branched, cross-linked, three-dimensional network. Softening of the resins started at approximately 50°C, followed by melting of the adhesive (Fig. 4). Above 130°C, the resin became infusible, and little additional flow was observed. Two overlapping exothermic peaks were observed in the temperature range of approximately 90° to 170°C (Fig. 5). The first reaction reached its maximum rate at a temperature of 130°C, the same temperature at which the TMA results displayed a transition from the fusible to the infusible state. Thus the physical properties of a resin are highly dependent on the development of its cure stage. Under different heating rates, the physical transformation and chemical advancement of powdered resin could behave differently. A lower heating rate lets the adhesive gradually undergo its physical changes while allowing an adequate time for polymerization reactions to take place. As a result, the progressive increase in resin molec-

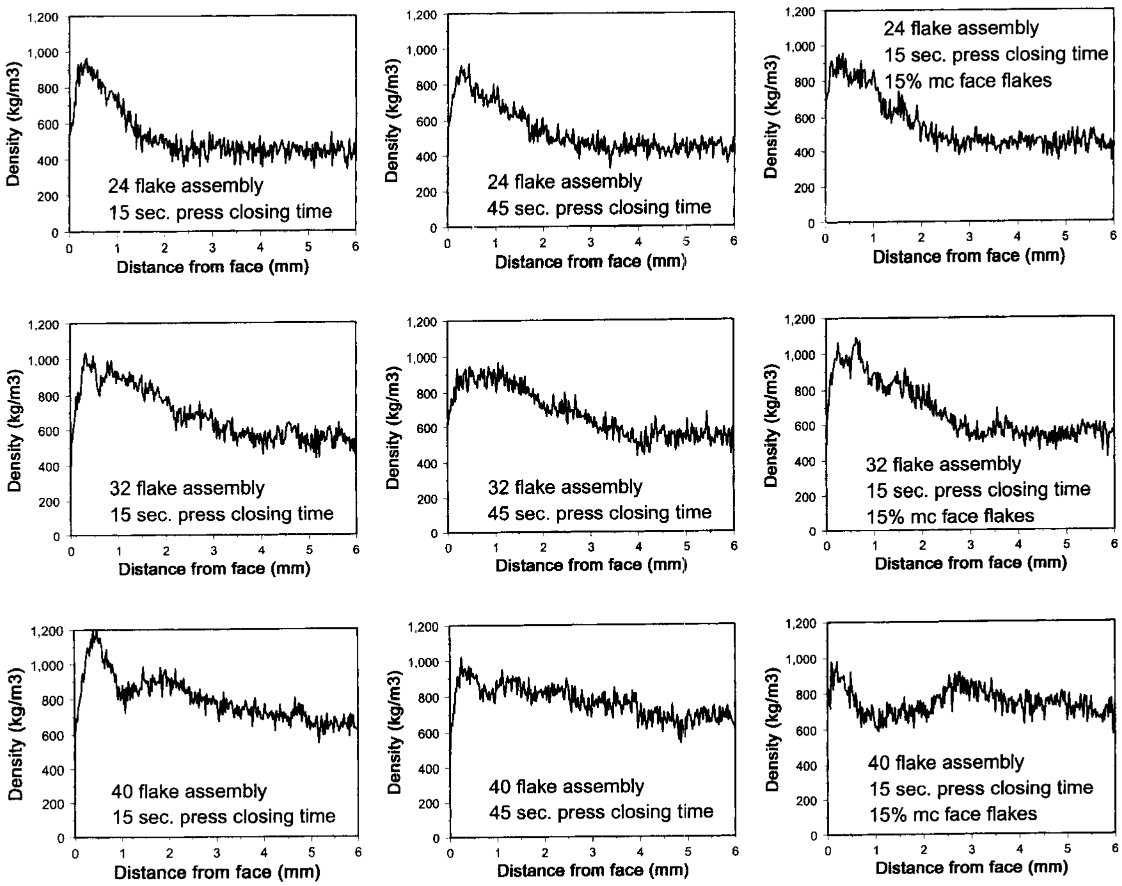

FIG. 3. Vertical density distributions determined for flake assemblies produced using different numbers of flakes and pressed at different press closing times. All flakes at 4.5% moisture content unless otherwise indicated. Each distribution shown represents the average of two face-to-core measurements for each of three replications (i.e., six face-to-core measurements).

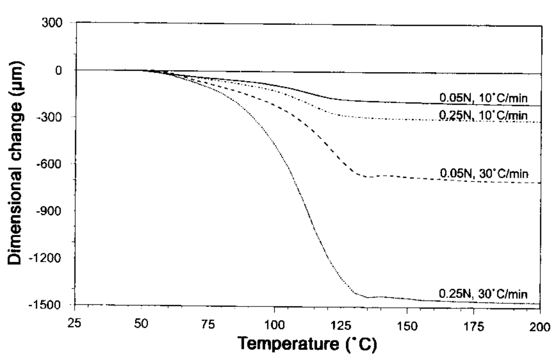

FIG. 4. Thermo-mechanical analysis profiles for powdered resin determined using different heating rates and applied pressures.

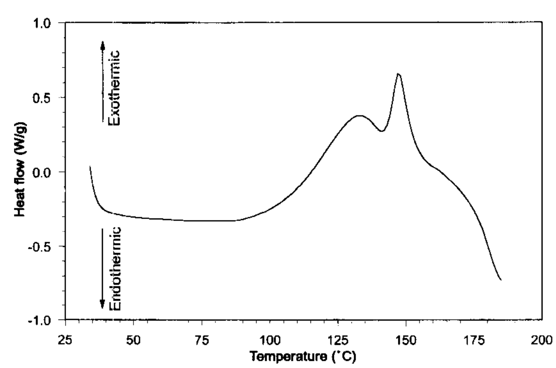

FIG. 5. Differential scanning calorimetry profile of powdered resin.

ular weights simultaneously reduces the resin mobility. On the contrary, at a faster heating rate, melting of resin might occur before cure has taken place. Therefore, resin flow is less affected by the development of resin polymerization, and a larger extent of flow can result. At the higher heating rate, resin flow was significantly promoted by the increase of pressure, while at the lower heating rate the increase of pressure only slightly increased the extent of resin flow.

One function of pressure in bonding is to force the adhesive to wet and flow to the bonding areas. At the higher heating rate, with the rapid increase of resin plasticity, pressure was able to drive the resin to flow to a greater extent. While at the lower heating rate, because of the lower resin mobility, the extent of flow was only slightly improved with the increase of pressure level. Considering the flow of powdered adhesive inside flakeboard, the face layer receives a more rapid heating rate compared to the core. As a result, a greater extent of resin flow would be induced in the face layer. In addition, the face and core regions also experience different pressures. Thus, for the face layer, a higher pressure is applied to the adhesive associated with a higher temperature level; while for the core, the highest pressure is initially applied to the adhesive at a low temperature level. When the temperature in the core reaches high enough for the adhesive to melt, the pressure has already declined. Accordingly, these conditions can further result in an even greater difference in the flow of adhesive between the face and core than that caused by heating rates alone. Horizontally, higher density regions receive greater pressure but low heating rate, while lower density regions receive lower pressure but higher heating rate.

Bond strengths

The average shear strengths determined are summarized in Table 1. Within the same density level and pressing condition, the strength values increased from the core, through the intermediate to the face layer (Table 1a). The higher strength values observed in the face layer were attributed to the greater density levels and heat transfer gradient. There were no significant differences between the strength values of the intermediate and core layers for the 24 and 32 FAs. However, when the density of FAs increased from the 32 FA to the 40 FA, a significant difference in strength was produced between the intermediate and the core layers. With an increase of the density of the FAs from 24, 32, to 40 FAs, at the 4.5% MC condition, it was observed that bonds at different layers responded differently (Table 1b). For the intermediate and core layers, greater FA density always produced stronger bonds than did lower FA density. For the face layer, higher density FAs produced no significant difference in strength values. This result suggests that the flow of resin in the face layer was able to provide adequate wood/adhesive contact to form a stable bond, and further compression of wood elements could not significantly improve bonding strength. Nevertheless, for the intermediate and core layers, since flow of adhesive occurred to a lesser extent due to the delayed temperature rise and its associated declined pressure, a higher compaction ratio could have increased the magnitude of the bonding area and subsequently enhanced bond strength. Press closing time showed no effect on bond strength for the FAs (Table 1c). However, higher face flake MC exhibited a positive effect on bond strength at the face layer. With the higher MC face flakes, an upwared shift of strength values was observed in the face layer for 32 and 40 FAs compared to the 4.5% MC flakes. These results may be attributed in part to a higher degree of adhesive flow at higher MC. However, since this phenomenon was found only in the face layer for higher density FAs, where damage of wood structure could occur (Geimer et al. 1985), the results may also indicate that at higher MC, the strength reduction to wood during the pressing may be lessened by an increase in its thermoplasticity. The bond

TABLE 1. *Average shear strengths (MPa) at the different layers in the flake assemblies. Data analyzed (a) by pressing condition within layer and number of flakes; (b) by layer within number of flakes and pressing condition; (c) by layer within pressing condition and number of flakes. PCT = press closing time (in seconds), MC = moisture content, M = 15% moisture content surface flakes. Within a cell, means designated by the same letter are not significantly different at the 95% confidence level.*

(a)		Pressing condition		
No. of flakes	Layer	15 PCT	45 PCT	M
40	Face	4.65A	4.69A	5.19A
	Intermediate	3.87B	3.90B	4.39B
	Core	3.55C	3.59C	3.58C
32	Face	4.50A	4.37A	4.79A
	Intermediate	3.38B	3.20B	3.26B
	Core	3.05B	2.99B	3.14B
24	Face	4.43A	4.34A	4.55A
	Intermediate	2.63B	2.84B	2.66B
	Core	2.49B	2.67B	2.59B

(b)		Layer		
Pressing condition	No. of flakes	Face	Intermediate	Core
15 PCT	40	4.65A	3.87A	3.55A
4.5% MC	32	4.50A	3.38B	3.05B
	24	4.43A	2.63C	2.49C
45 PCT	40	4.69A	3.90A	3.59A
4.5% MC	32	4.37A	3.20B	2.99B
	24	4.34A	2.84C	2.67B
15 PCT	40	5.19A	4.39A	3.58A
15.0% MC face	32	4.79AB	3.26B	3.14A
4.5% MC core	24	4.55B	2.66C	2.59B

(c)		Layer		
No. of flakes	Pressing conditions	Face	Intermediate	Core
40	M	5.19A	4.39A	3.58A
	15 PCT	4.65B	3.87B	3.55A
	45 PCT	4.69B	3.90B	3.59A
32	M	4.79A	3.26A	3.14A
	15 PCT	4.50A	3.38A	3.05A
	45 PCT	4.37A	3.20A	2.99A
24	M	4.55A	2.66A	2.59A
	15 PCT	4.43A	2.63A	2.49A
	45 PCT	4.34A	2.84A	2.67A

strengths at the different layers in the FAs show similar increasing trends as results presented for flakeboard (Kelly 1977) where bonding strength generally increased from the core to the face regions. Different FAs provided similar strength values in the face layer, but varied strength values in the intermediate and core layers as a result of density differences.

Bond failure

After microscopically examining all the failure surfaces for the FAs, four basic failure types were differentiated: A—cross fiber failure; B—wood/adhesive failure near the interface; C—wood/adhesive failure at the interface; D—adhesive failure. The purpose of distinguishing the failure type for the FAs was to

TABLE 2. *Number of each different failure mode found in different flake assemblies according to glueline location and number of flakes. A–cross fiber failure; B–wood/adhesive failure near the interface; C–wood/adhesive failure at the interface; D–adhesive failure.*

Failure mode	Layer			Number of flakes		
	Face	Inter-mediate	Core	24	32	40
A	13	11	11	3	8	23
B	12	11	11	14	17	4
C	1	4	4	9	0	0
D	1	1	1	1	2	0

identify the failure zones in wood/adhesive bonds that formed under different conditions. Cross fiber failure was characterized by a large percentage of wood failure and fractures usually across wood fiber and gluelines. Adhesive failures were observed where failure surfaces were covered by adhesive exposing little wood. Interface failures were recognized in the FAs' fracture surface as failure occurring both in wood and adhesive at their boundary layer. The failure surfaces with areas of deeper wood failure were designated as failure type B, while the fracture surfaces exhibiting relatively shallow wood failure were designated as failure type C. The number of the different failure types according to layered position and number of flakes is shown in Table 2. The results show little presence of adhesive failure, indicating that good wood/adhesive bonds were produced for the FAs. There was little difference in the type of failure found at the three different layers. However, the face layer did produce a slightly larger proportion of type A failures than did the intermediate and core layers, while the intermediate and core layers produced more type C failures than did the face layer. A trend of failure types occurring in the 24, 32, and 40 FAs clearly existed. Failure type A dominated the failure of 40 FAs, while failure type B with some type A occurred in the 32 FAs, and failure type B with some type C was observed in 24 FAs. These results indicate that higher density FAs had a relatively low cohesion strength in wood, but lower density FAs had a relatively low adhesion strength between wood and adhesive. Geimer et al. (1985) indicated that flakeboard with high density could cause some damage of wood structure and result in strength reduction. The higher proportion of type A failure occurring in the 40 FAs may also be due to the high compaction ratio damaging the wood structure.

Thickness swell

The average thickness swell values for 24 hours of water soaking are summarized in Table 3. Comparing TS values among the face, intermediate, and core layers of the FAs pressed within the same density level and pressing condition, the results show that, except for 40 FAs pressed at 15% MC, TS values were usually higher for the outer layers of the FAs (Table 3a). The higher TS values observed for the face and intermediate layers were probably a result of their greater degree of densification. No significant difference was observed between the core and intermediate layers for 24 FAs, which was in keeping with the relatively flat density gradient determined. There were significant differences between the TS of all the layers in the FAs prepared with different numbers of flakes except between the face layers of the 32 and 40 FA pressed at the longer PCT and with the higher MC face flakes (Table 3b). The PCT showed no significant influence on TS values for the FAs (Table 3c). However, face flake MC illustrated a significant effect on the dimensional stability of the face and intermediate layers of the highest density FA (40 FA).

Both the number of flakes and the layered position in the FAs were seen to influence TS. The face flake MC effect on TS was most significant under high temperature and pressure conditions, such as at the face layer of 40 FAs. Suchsland (1989) indicated that the dimensional stability of flakeboards is controlled by the higher density regions. This study showed that a high moisture condition could improve dimensional properties at outer layers for higher density FAs. It is logical to conclude

TABLE 3. *Average thickness swell values (%) at the different layers in the flake assemblies. Data analyzed (a) by pressing condition within layer and number of flakes; (b) by layer within number of flakes and pressing condition; (c) by layer within pressing condition and number of flakes. PCT = press closing time (in seconds), MC = moisture content, M = 15% moisture content surface flakes. Within a cell, means designated by the same letter are not significantly different at the 95% confidence level.*

(a) No. of flakes	Layer	Pressing condition 15 PCT	45 PCT	M
40	Face	82.0A	80.0A	58.9A
	Intermediate	73.1A	74.4A	55.6AB
	Core	49.9B	83.9B	44.3B
32	Face	67.4A	65.7A	54.7A
	Intermediate	38.9B	36.0B	29.8B
	Core	23.1C	24.5B	20.7B
24	Face	34.3A	36.8A	34.6A
	Intermediate	8.2B	7.3B	7.6B
	Core	6.4B	5.7B	5.5B

(b) Pressing condition	No. of flakes	Layer Face	Intermediate	Core
15 PCT	40	82.0A	73.1A	49.9A
4.5% MC	32	67.4B	38.9B	23.1B
	24	34.3C	8.2C	6.4C
45 PCT	40	80.0A	74.4A	53.9A
4.5% MC	32	65.7A	36.0B	24.5B
	24	36.8B	7.3C	5.7C
15 PCT	40	58.9A	55.6A	44.3A
15.0% MC face	32	54.7A	29.8B	20.7B
4.5% MC core	24	34.6B	7.6C	5.5C

(c) No. of flakes	Pressing conditions	Layer Face	Intermediate	Core
40	15 PCT	82.0A	74.4A	53.9A
	45 PCT	80.0A	73.1A	49.9A
	M	58.9B	55.7B	44.3A
32	15 PCT	67.4A	38.9A	23.1A
	45 PCT	65.7A	36.0A	24.5A
	M	54.7A	29.8A	20.7A
24	15 PCT	34.3A	8.2A	5.5A
	45 PCT	36.8A	7.3A	6.4A
	M	34.6A	7.6A	5.7A

that a higher initial face flake MC may be able to improve the dimensional stability of flakeboard. This improvement might result due to a reduction in the damage experienced by the flakes during pressing.

CONCLUSIONS

Heat transfer to the core of the flake assemblies (FA) was generally accelerated by a short press closing time (PCT), higher moisture content (MC) face flakes, and a lower number of flakes. Face densities were greatest for the short PCT and low MC face flakes. Relative differences in density between face and core layers were greatest for low numbers of flakes. Greatest strengths were found at the face layer and seemed to follow the vertical density distributions.

Press closing time had no effect on strength, and face flake MC only affected the strength of the face and intermediate layers of the 40 FAs. Cross fiber failure dominated the failure mode of the 40 FAs, while wood/adhesive failure was more prevalent in the 24 and 32 FAs. Thickness swelling trends closely followed the vertical density distributions.

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