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Ee Ding Wong · Min Zhang · Qian Wang
Guangping Han · Shuichi Kawai

Formation of the density profile and its effects on the properties of fiberboard

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Abstract Two main types of fiberboards were produced using lauan (*Shorea* spp.) fibers with an isocyanate resin as the binder; fiberboard with a flat, homogeneous (homo-profile), and typical U-shaped (conventional) density profile along the board thickness. The processing parameters included manipulation of mat moisture content distribution, press closing speed, and hot pressing method. The results are summarized as follows: (1) A larger variation was observed in the peak density (PD) and core density (CD) of fiberboards at 0.5 g/cm^3 mean density (MD) level than in those at 0.7 g/cm^3. Generally, PD showed a greater variation than CD, irrespective of MD level. (2) Boards produced using two-step hot pressing recorded substantially higher PD with reduced CD. (3) Multiple regression analysis showed that CD and PD could be calculated based on the other profile defining factors, and a rough estimation for peak distance and gradient factor was possible. (4) Based on static bending, conventional fiberboard had a higher modulus of rupture (MOR) than the homo-profile board but a similar modulus of elasticity (MOE). (5) At 0.5 g/cm^3 the MOR and dynamic MOE of fiberboard increased by up to 67% and 62%, respectively, when the PD increased from 0.5 to 1.07 g/cm^3. Similarly, an increase of PD from 0.7 to 1.1 g/cm^3 resulted in corresponding increases of 55% and 34% in the MOR and dynamic MOE of 0.7 g/cm^3 boards. (6) The internal bond strength and screw withdrawal resistance were almost entirely dependent on the CD and MD, respectively. (7) Homo-profile fiberboards registered higher thickness swelling and water absorption than conventional fiberboards throughout the dry/wet conditioning cycle.

Key words Fiberboard · Density profile · Hot pressing method · Mat moisture content

E.D. Wong[1] (✉) · M. Zhang · G. Han · S. Kawai
Wood Research Institute, Kyoto University, Uji, Kyoto 611-0011, Japan
Tel. +81-774-38-3677; Fax +81-774-38-3678
e-mail: edingw@hotmail.com

Q. Wang
Hokushin Co. Ltd., Kishiwada 596-0011, Japan

Present address
[1] Faculty of Forestry, University Putra Malaysia, 43400 UPM Serdang, Salangor, Malaysia
Tel. +603-9486101 (ext. 2450); Fax +603-9432514

Introduction

Our previous studies investigated the formation of the density profile along the thickness of particleboard, with statistical analysis on the effects of selected processing variables.[1,2] A subsequent report analyzed the net quantitative effect of density profile on the bending properties of particleboard using the finite element method.[3] In particleboard, the formation of density profile during the manufacturing process is dependent on interaction among the movements of heat, moisture, and pressure in the mat during hot pressing.[4,5] The same conditions pertain to the fiberboard manufactured by the dry process. During platen hot pressing of particle- or fiber-based composites, the main mechanism of heat transfer from the mat surface to the core is by convection via the movement of water vapor. The speed of heat transfer is therefore greatly affected by the permeability of the mat and the resultant vapor pressure gradient created across the mat thickness, which are in turn highly dependent on the geometry of the mat elements.[6,7] Consequently, compared to particleboard, similar processing variables affect the formation of the density profile and the board properties of fiberboard to a different extent owing to a difference in mat permeability and compressibility. Although still lacking, the literature on this subject for particleboard is more extensive than that for fiberboard, which is a relatively new product. Deviating from our previous studies, which focused on particleboard, this study investigates the effects of the hot pressing method and mat moisture content (MC) on formation of the density profile and its effects on the properties of fiberboard.

Materials and methods

Two main types of fiberboard were produced: (1) fiberboard with a flat, homogeneous (homo-profile), and (2) typical U-shaped (conventional) density profile along the board thickness. The fiberboards were produced using lauan (*Shorea* spp.) fibers. The lauan fibers were produced by cooking the chips in a digester set at 160°–200°C (0.8–1.0 MPa) for 7–10 min, then passed through a pressurized double disk refiner. The resin adhesive used was isocyanate resin (UL 4811) formulated by Gun-ei Chemical Corporation.

Homo-profile fiberboard

The lauan fibers were first conditioned to about 10% MC. The fiber lumps were segregated into individual fibers by brushing and blowing-up by air in an air-cyclic pipeline blender of about 20 m length.[8] Resin adhesive was then added to the fibers in the pipeline by means of an air-gun. Isocyanate (8%) was added based on the oven-dried weight of fibers. To obtain suitable viscosity for resin spraying and to ensure uniform distribution of adhesive, the isocyanate resin was diluted by adding 30% acetone, based on the weight of adhesive. After blending with adhesive, the fibers were extracted from the silo and measured into batches for producing boards with targeted densities of 0.3, 0.5, 0.6, 0.8, 1.0, and 1.1 g/cm^3. Mats were formed by passing the fibers blended with adhesive through the same pipeline, this time ending in a forming box via a forming roller. The dimensions of boards were 12 × 365 × 385 mm. The six mats were compressed simultaneously to a targeted thickness of 12 mm using distance bars in a 900 × 2000 mm single-opening press of 500 ton capacity at ambient temperature. The platens were then heated from room temperature to 160°C. It took about 50 min for the platens to reach 160°C, upon which the boards were removed from the press immediately.

Conventional fiberboard

For the fabrication of conventional fiberboard, mat MC distribution, press closing speed, and pressing method were varied to produce boards with different density profiles at 0.5 and 0.7 g/cm^3 density levels. Fibers of about 10% MC were used for fabricating boards from mats with uniform MC. For distributed mat MC, the mat MC was adjusted according to face/core/face MC (%) of 15:3:15, at oven-dried fiber weight proportions of 1:8:1. Supplied fibers of about 8% MC were oven-dried at 40°C to 3% MC. For 15% MC, fibers sprayed with the necessary amount of water were kept in plastic bags for about a week prior to board making. The segregation of fibers and addition of resin were done using the same equipment as for the fabrication of homo-profile fiberboards. For normal hot pressing at 160°C (3 min), the closing speed was adjusted to slow (5.3–5.8 mm/s) and fast (7.5–9.4 mm/s) by adjusting the flow controller. The fiber mat was compressed to the targeted board thickness of 12 mm in a newly developed press that adjusts the board thickness by displacement control (i.e., raising or lowering of spacers). For slow and fast press closing speeds, the maximum pressing pressures for 0.5 g/cm^3 density boards were 0.7 and 2.5 MPa, respectively. For 0.7 g/cm^3 boards, these pressures were correspondingly 2.5 and 5.9 MPa. For two-step hot pressing, the fiber mat was compressed to an initial thickness of 8 or 10 mm to obtain highly densified surfaces during the first step. The pressure was then released immediately by raising the spacers to a final thickness of 12 mm. The maximum pressing pressure recorded in the two-step pressing was 6.9–7.4 MPa during the first step pressing. The dimensions of the boards were the same as those of the homo-profile (i.e., 12 × 365 × 385 mm). The selected processing variables are summarized in Table 1.

Table 1. Fabrication conditions for conventional fiberboard

Code	MC (%)	Particle proportions	Hot pressing method
Uniform mat MC			
10MC-S	10	–	*A*
10MC-F	10	–	*B*
10MC-10/12	10	–	*C*
10MC-8/12	10	–	*D*
Distributed mat MC (face/core/face)			
MC15/3-F	15:3:15	1:8:1	*B*
MC15/3-8/12	15:3:15	1:8:1	*D*

A, *B*, normal hot pressing at 160°C for 3 min, press closing speeds of 5.3–5.8 and 7.5–9.4 mm/s, respectively; *C*, *D*, two-step hot pressing at 160°C, with first step closing to 10 and 8 mm, respectively, then opening immediately to a final thickness of 12 mm; total pressing time was 3 min

Evaluation of fiberboards

Prior to evaluation of the mechanical properties and dimensional stability, the fiberboards were conditioned at 20° ± 1°C and 65% ± 5% relative humidity (RH) until they reached equilibrium. The properties of the fiberboards were then evaluated with reference to the Japanese Industrial Standard for Fiberboards (JIS A 5905, 1994).

Three specimens of 12 × 40 × 200 mm were prepared from each board for static bending tests. The static bending test was conducted using three-point bending over an effective span of 180 mm at a loading speed of 10 mm/min. The dynamic modulus of elasticity (MOE) of the boards was measured by the nondestructive dynamic flexural method (i.e., free-free beam method), where the MOE was calculated based on the resonance frequency of the first mode vibration.[9] The dimensions of the specimens for free-free beam method were the same as those used for the static bending test.

Four specimens of 12 × 50 × 50 mm from each board were used for internal bond (IB) testing. Prior to the IB test, the density profile of the specimens were determined using a density profile meter (Institute of Geological and

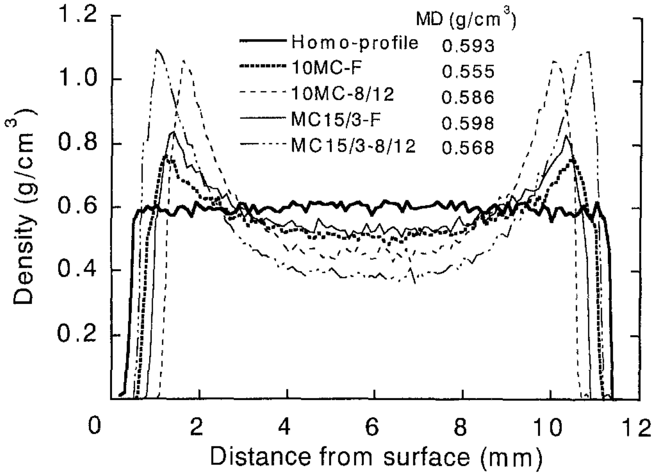

Fig. 1. Examples of the density profiles of homo-profile and conventional fiberboards. Refer to Table 1 for explanation of the codes

Nuclear Sciences, 1994), where a gamma ray was transmitted through the specimen along the thickness at 0.1-mm intervals.

For evaluation of dimensional stability, four specimens of $12 \times 50 \times 50$ mm were prepared from each sample board and subjected to thickness swelling (TS) and water absorption (WA) tests. In addition to the standard test, the specimens were further evaluated under a dry/wet conditioning cycle: soaking in ambient temperature water (20°C) for 24 h, oven-drying at 60°C for 72 h, soaking in 70°C water for 24 h, oven-drying at 60°C for 72 h, boiling for 4 h, oven-drying at 60°C for 72 h, and finally conditioning at 20° ± 1°C and 65% ± 5% RH until equilibrium was reached.

Results and discussion

Two major types of fiberboard were produced successfully. Figure 1 shows some examples of the density profiles of homo-profile and conventional fiberboards with similar mean density (MD). The MD was calculated as the weight of the sample divided by its volume after standard conditioning at 20° ± 1°C and 65% ± 5% RH. Irrespective of the MD level, the homo-profile board has a flat, homogeneous density profile, whereas those of the conventional fiberboards' resemble a typical U-shape.

Figure 2A depicts the variations of peak density (PD) and core density (CD) of fiberboards produced using various parameters, as related to their MD. As shown in Fig. 2A, the PD and CD of the fiberboards were affected by variations in the hot pressing method and mat MC distribution to a greater extent at 0.5 g/cm³ MD than at 0.7 g/cm³. This is attributed to the reduced compressibility of the mat at higher board density and hence a lower impact of the initial press closing pressure. Compared to PD, the CD did not differ much despite variation in the processing parameters. A similar phenomenon was observed in particleboard.[2]

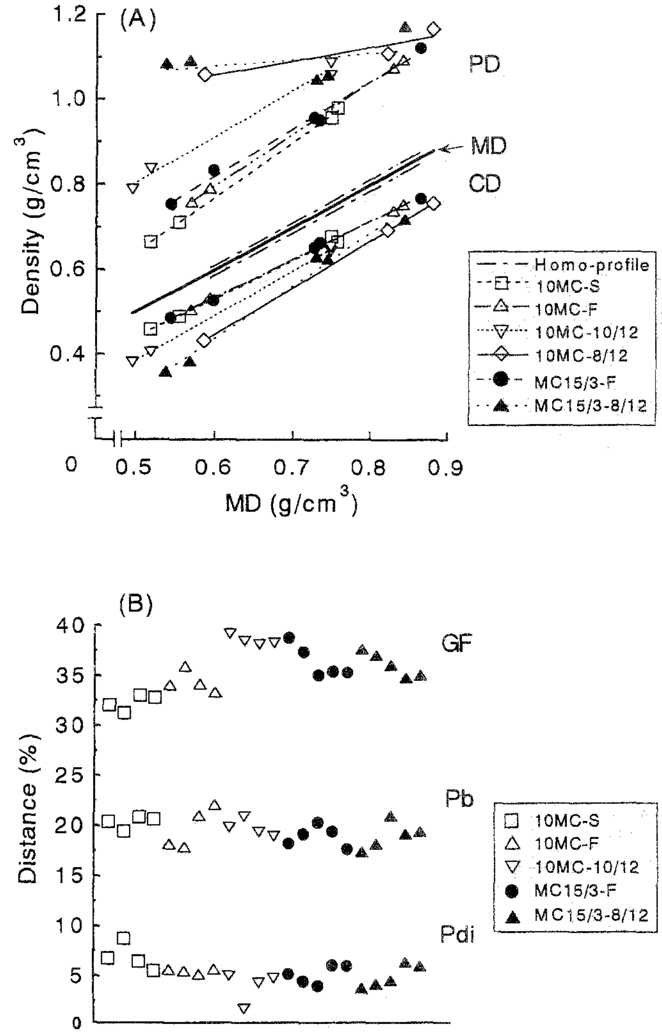

Fig. 2. **A** Peak density (*PD*) and density (*CD*) as related to mean density (*MD*). **B** Gradient factor (*GF*), peak base (*Pb*), and peak distance (*Pdi*) based on the total board thickness of various fiberboards. Refer to Table 1 for explanation of the codes

Two-step hot pressing was found to be the most effective method for raising the PD of the board, irrespective of the mat MC distribution. The final board density profile is highly dependent on the target thickness in the first step. Lower thickness during the first step resulted in a sharper, higher PD and a slightly lower CD. Earlier study reported the face density of 20 and 40 mm thick lauan particleboards to increase with increasing pressure (0.49–2.00 MPa) and pressing time (10–30 s and 40–60 s for 20- and 40-mm boards, respectively) during the first pressing step, irrespective of board thickness.[10] In this study, the platen was increased to the final thickness as soon as the mat was compressed to the targeted "negative" thickness in the first step. This is because the final target thickness of fiberboards is only 12 mm, so a shorter time is required for heat to transmit from the face to the core, compared to that in 20- and 40-mm thick particleboards. A prolonged first-step pressing is expected to result in a higher degree of resin cure, thus a reduction in the spring-back capacity of the

Table 2. Correlations among the various density profile defining factors in fiberboard

Factor	MD	CD	PD	Pdi	GF	Pb	PA
MD	1.0000						
CD	0.9638**	1.0000					
PD	0.7549**	0.5619**	1.0000				
Pdi	0.1459	0.2316	−0.1913	1.0000			
GF	−0.3799*	−0.4505	0.0255	−0.7458**	1.0000		
Pb	0.4754*	0.5042*	0.1811	−0.0435	−0.3520	1.0000	
PA	−0.0214	−0.2744	0.6319**	0.4884*	0.4676*	−0.1611	1.0000

MD, mean density; CD, core density; PD, peak density; GF, gradient factor; Pdi, peak distance; Pb, peak base; PA, peak area [estimated as 1/2*Pb*(PD-MD)]
*Significance level ≤ 95%; **significance level ≤ 99%

board, giving rise to a final thickness lower than the targeted value. Even though the final thickness of MC15/3–8/12 was similar to that produced with normal hot pressing, the 10MC-8/12 boards were about 1 mm thinner than the others. This is probably due to its higher overall mat MC, which resulted in an increased rate of consolidation, faster heat transmission into the core, and higher overall plasticization of the fibers, thus more rapid curing of resin and setting of the board.[11] Because the gradient factor, peak base, and peak distance are expressed as percents of the total board thickness, 10MC-8/12 boards are omitted from the following analyses.

Based on the definition of density profile in our earlier report,[2] the peak base of all types of conventional fiberboard were found to be almost the same, accounting for about 20% of the total board thickness (Fig. 2B). The 10MC boards produced at slow closing speed had a slightly lower gradient factor and higher peak distance, reflecting its relatively wider peak located further from the board surface. In contrast, the 10MC-10/12 boards recorded a high gradient factor with low peak distance, indicating a comparatively slimmer peak located closer to the board surface. In general, the gradient factor and peak distance of all the boards ranged from 30% to 40% and from 2% to 9% of the total board thickness, respectively.

Analyses of the correlations among the various density profile defining factors based on the density profile of all 0.5 and 0.7 g/cm^3 MD boards revealed that the MC, CD, and PD are highly correlated to each other, and the peak distance and gradient factor are interdependent, as shown in Table 2. Although some correlations exist among the peak base, gradient factor, MD, and CD at the 95% significance level, these correlations are not strong, as reflected in the higher deviations of their correlation coefficients from 1. Unlike in particleboard, where the peak area (PA) is almost directly dependent on the board MD,[2] the PA in fiberboard is highly correlated to PD and to a lesser extent the peak distance and gradient factor. This is because the PD formed in 0.5 g/cm^3 boards were almost the same as that in 0.7 g/cm^3 boards due to the higher compressibility of fibers compared to particles.

Furthermore, multiple regression analysis was conducted to define the individual density profile-defining factors in terms of the other profile factors. Because of the nonconventionally high PD of 0.5 g/cm^3 boards produced using 8/12 two-step pressing (Fig. 2A), these boards were excluded in the following analysis. The results of the analysis are as shown below.

$$CD = -0.01 + 1.3MD - 0.3PD, R^2 = 0.994$$
$$PD = -0.37 + 2.7MD + 0.01GF - 1.6CD, R^2 = 0.994$$
$$GF = 60 - 0.89Pb - 1.35\,Pdi, R^2 = 0.688$$
$$Pdi = 31 - 0.29GF, R^2 = 0.656$$

where GF is the gradient factor, Pb is the peak base, and Pdi is the peak distance. Based on the analysis, Pb could not be expressed using other defining factor(s). In the above derivations, the selection of the factors was based on a minimum improvement of 1% in R^2 value as each additional factor was included in the equation. The high R^2 values show that CD and PD could be derived reliably from other factors, whereas a rough estimation of GF and Pdi based on other factors is possible.

Bending properties

Three-point static bending test of 200 × 40 × 12 mm fiberboard specimens showed that boards with conventional U-shaped density profile had higher bending strength but a similar MOE compared to homo-profile boards (Fig. 3). From a structural engineering point of view, a load-bearing member with highly densified surfaces (i.e., fortified load-bearing zones) should be better than that with homogeneous structure as far as bending performance is concerned. Because the modulus of rupture (MOR) is dependent on the maximum load bearable by the member, conventional fiberboards that had a higher surface density were able to bear a higher load before failing during static bending, recording higher MOR values than the homo-profile boards (Fig. 3A).

Based on the results of the static bending tests, the MOE of the conventional fiberboard were found to be similar to those of the homo-profile board at equal MD (Fig. 3B). Although conventional fiberboard is expected to have a higher MOE owing to its highly densified surface layers, the low density core might have contributed to exaggerated deformation in conventional fiberboard during static bending. Furthermore, some shear stresses could have been induced by the big contrast between the PD and CD in conventional fiberboard, as reflected in the T- or Y-shaped line of failure formed from the core to the bottom

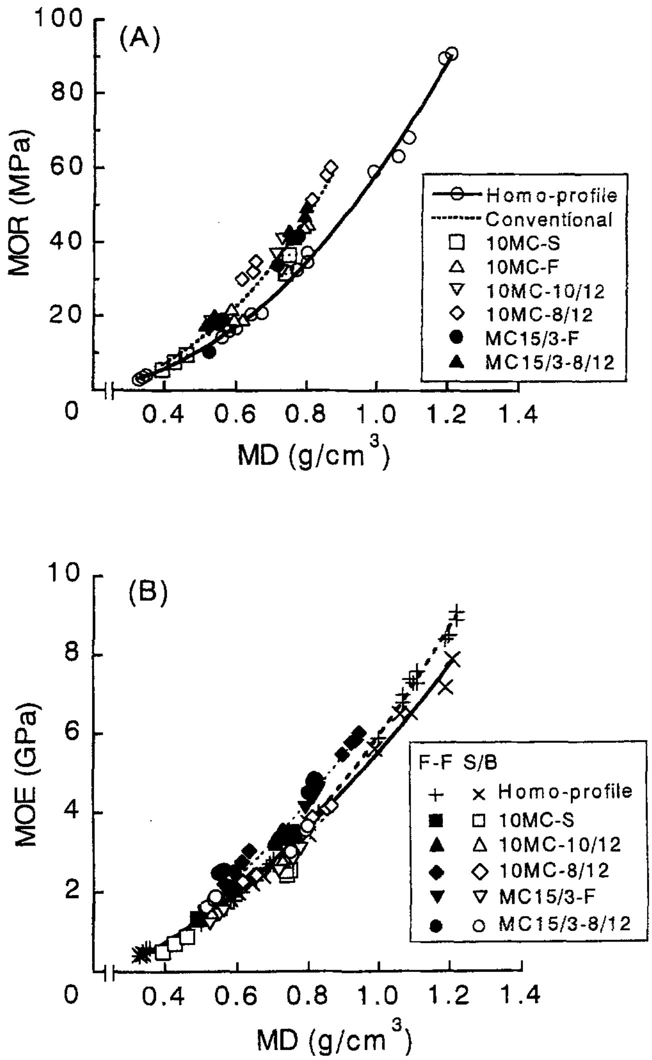

Fig. 3. **A** Correlations between the modulus of rupture (MOR) and mean density (MD) of various fiberboards. **B** Comparison of their modulus of elasticity (MOE) measured using free-free (*F-F*) beam and static bending (*S/B*) methods. Refer to Table 1 for explanation of the codes

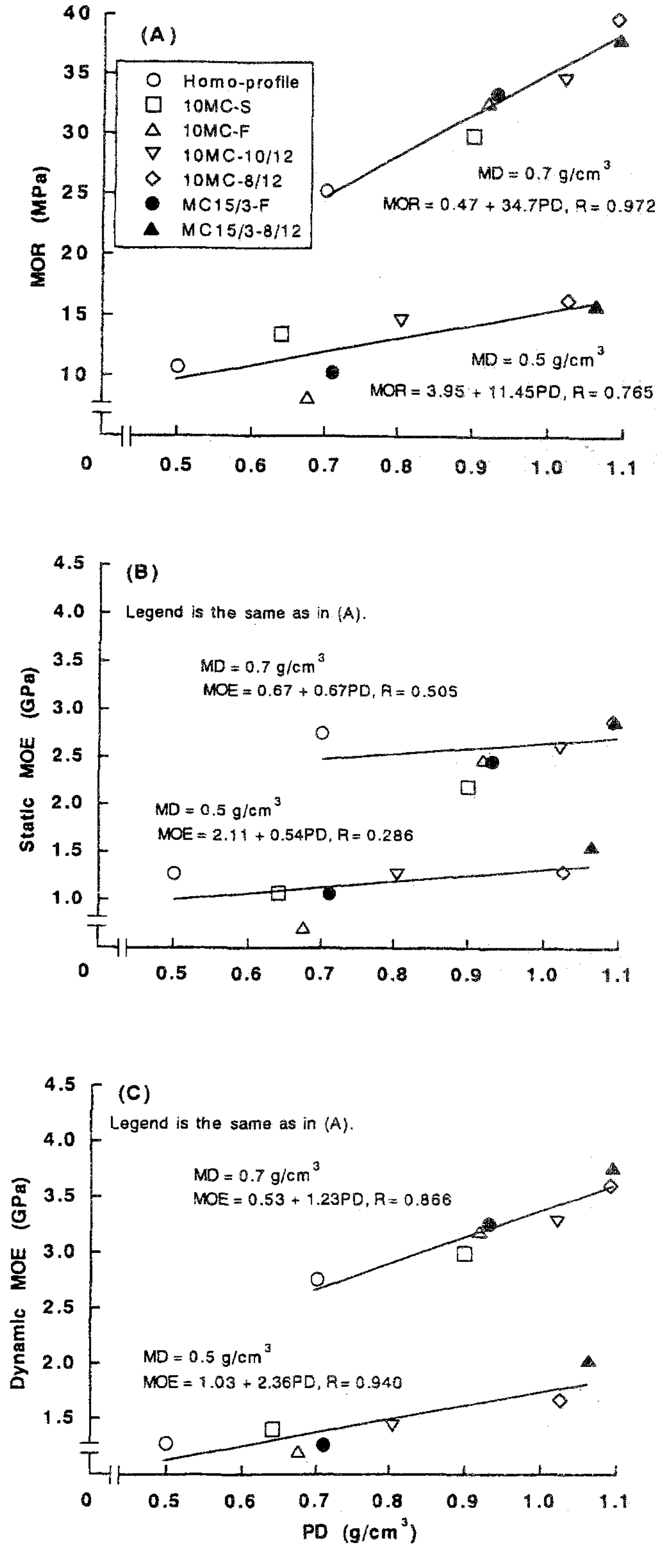

Fig. 4. Correlations between the modulus of rupture (**A**), static modulus of elasticity (MOE) (**B**), and dynamic MOE (**C**) and peak density (PD) in various fiberboards at 0.5 and 0.7 g/cm^3 mean density (MD) levels. Refer to Table 1 for explanation of the codes

surface. From an additional evaluation of dynamic MOE using a free-free beam method, the dynamic MOEs determined were generally higher than the values obtained from the static bending test, as shown in Fig. 3B. The dynamic MOE of conventional fiberboard determined by free-free beam and static bending methods were almost the same at 0.5 g/cm^3 MD, but the former exceeded the latter by about 13% at 0.9 g/cm^3 MD.

Figure 4 illustrates the net effects of PD on the MOR, static MOE, and dynamic MOE of various fiberboards, at 0.5 and 0.7 g/cm^3 MD. Because of the limitation of the density profile meter used, it was not possible to determine the density profile of the bending specimen owing to its large dimensions. From the data obtained for IB specimens, except for 10MC-8/12 and MC15/3–8/12 boards, a high correlation was found to exist between the PD and MD for other categories of boards, with the R^2 exceeding 0.99. Consequently, the values of PD for bending specimens depicted in Fig. 4 were calculated based on their MD using the correlations between PD and MD determined for corresponding categories of IB specimens. Furthermore, the values of dynamic and static MOR and MOE plotted in

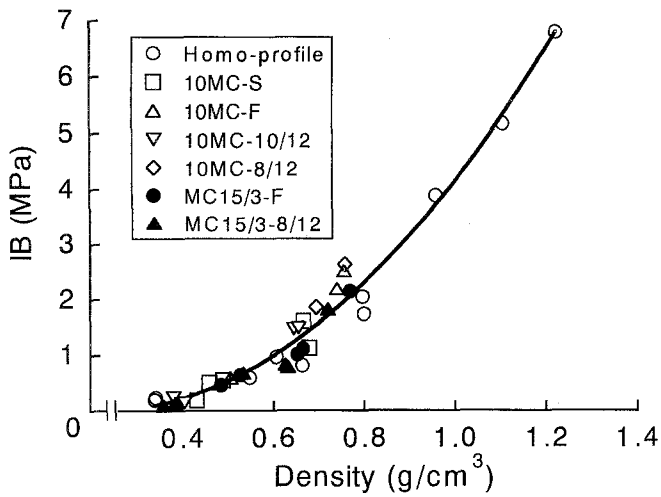

Fig. 5. Correlation between internal bond (IB) strength and mean/core density of homo-profile and conventional fiberboards, respectively. Refer to Table 1 for explanation of the codes

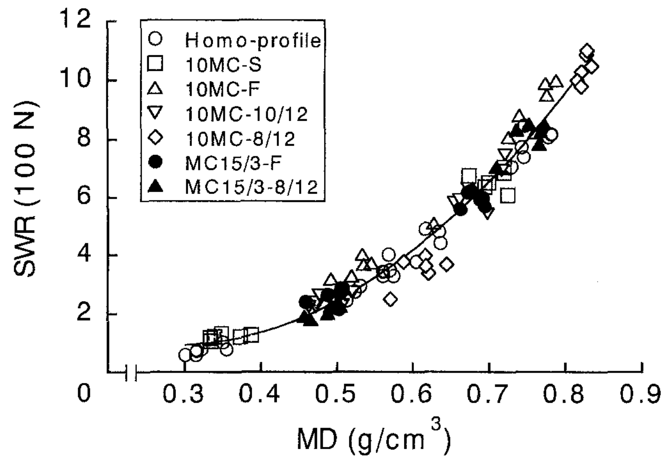

Fig. 6. Correlation between the screw withdrawal resistance (SWR) and mean density (MD) in various fiberboards. Refer to Table 1 for explanation of the codes

Fig. 4 are corrected to 0.5 and 0.7 g/cm^3 MD based on the corresponding correlation of MOR or MOE with MD for each board category.

As shown in Fig. 4B, unlike the dynamic MOE the static MOE indicates no direct correlation with PD at both 0.5 and 0.7 g/cm^3 MD levels. The following discussion therefore focuses only on the specific effect of PD on the dynamic MOE of fiberboard. Despite having almost equally high PD, the MOR and MOE of 0.7 g/cm^3 boards were, correspondingly, 2.4–2.5 and 1.9–2.2 times the values for 0.5 g/cm^3 boards. Hence MD is still the dominant factor affecting the overall bending performance of fiberboard. At both 0.5 and 0.7 g/cm^3 MD, the MOR and MOE generally increased with increasing PD, but the specific effect of PD on the bending performance is greater at 0.7 g/cm^3 MD, with a better correlation of R exceeding 0.9. This could be because at lower MD the low CD is more susceptible to the effect of shear owing to the inferior bonding among the loosely packed fibers. Thus the boards may experience flexural and shear failures simultaneously, resulting in unpredictable bending performance. Based on the experimental data, at 0.5 g/cm^3 MD the MOR and MOE of fiberboard improved by up to 67% and 62%, respectively, when PD increased from 0.5 to 1.07 g/cm^3. Similarly, in 0.7 g/cm^3 boards, an increase of PD from 0.7 to 1.1 g/cm^3 resulted in corresponding increases of 55% and 34% in MOR and MOE.

Internal bond

In the homo-profile fiberboards of 0.3–1.1 g/cm^3 MD, about 90% of the IB specimens failed near the surface, whereas almost all of the conventional fiberboards failed in the core region. The correlations of IB with MD and CD for homo-profile and conventional fiberboards, respectively, could be represented by a curve as shown in Fig. 5. The IB of fiberboard was, on the whole, determined by the board CD; it was not dependent on the board processing conditions used.

Screw withdrawal resistance

Figure 6 shows the correlation between the screw withdrawal resistance (SWR) and MD for fiberboards with homo- and U-shaped density profiles, which can be represented by a curvilinear regression line. As seen in Fig. 6, almost all of the SWR values are well scattered around a common curve, showing that the SWR of the board is more highly dependent on the MD than on the variation in board density profiles.

Thickness swelling and water absorption

In addition to standard cold water soaking, all of the fiberboard specimens were subjected to a dry/wet conditioning cycle for additional dimensional stability evaluation. For homo-profile fiberboard, as the severity of the wet conditioning increased (from TS1 to TS2 to TS3), the mean density at which the maximum TS was recorded shifted to higher levels (Fig. 7). The initial 24 h soaking at 20°C (TS1) might not be severe enough to allow thorough penetration of water into the high density specimen; hence a reduced TS was recorded at above 0.8 g/cm^3 MD. Generally, the TS after wet conditioning tends to level out gradually at higher MD, probably due to the low porosity and good IB contributed by the greater interfelting and contact among the fibers. A reduction in TS was registered at about 1.2 g/cm^3 MD (i.e., a compaction ratio of 3). One of the possible reasons for this reduction in TS is that the fibers might have experienced a higher degree of flow and plasticization under excessive pressure at high temperature; hence the consolidated board became less hygroscopic and more dimensionally stable against moisture. Except after the first oven drying (OD) process where homo-profile boards of all MD registered low spring-back, ranging from 0 to 1.4%, the degree of spring-back after each subsequent OD increased proportionally with MD. This irreversible TS could be due to stress release, which together with the interventions of

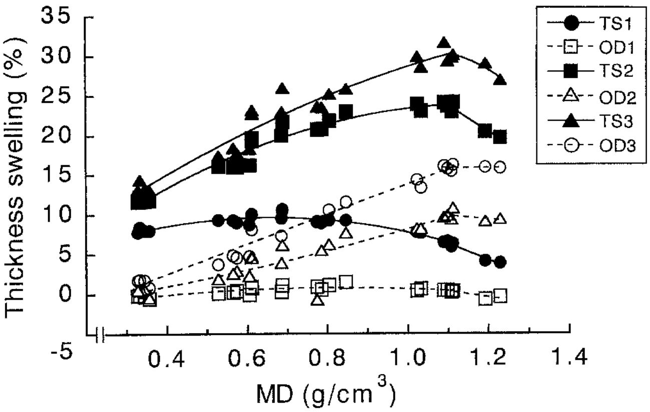

Fig. 7. Variation of thickness swelling as related to mean density (MD) in homo-profile fiberboards after each stage of accelerated aging exposures during the dry/wet cycle. *AD*, air drying; *TS1*, water-soaking at 20°C for 24h; *OD1*, *OD2*, *OD3*, over-drying at 60°C for 72h; *TS2*, water soaking at 70°C for 24h; *TS3*, boiling for 4h. Refer to Table 1 for explanation of the codes

moisture and temperature propagated the deterioration of internal bond as the conditioning cycle proceeds.

Figure 8 shows a comparison of the TS and WA, respectively, among the various fiberboards at a MD of 0.80–0.88 g/cm^3. If we consider conventional fiberboard to be composed of thin layers of homo-profile boards, then the overall TS of conventional fiberboard may be calculated as the sum of the TS of each of these layers. This calculation was done based on the MD-TS correlations of homo-profile boards depicted in Fig. 7. The results of the above calculation, based on thin layers (0.1 mm thickness), showed that boards with similar MDs had similar TSs, irrespective of the board density profile. However, the experimental values showed a different trend, where the homo-profile boards had a higher TS than conventional boards throughout the dry/wet cycle, as shown in Fig. 8A. Moreover, the former also recorded a higher WA than the latter, as shown in Fig. 8B.

These findings indicate that despite having similar MDs each layer in the homo-profile board behaved differently from conventional board in terms of dimensional stability. The low-density core region in conventional board could have allowed a higher degree of internal swelling, thereby giving rise to a lower apparent TS than the homo-profile board. In addition, homo-profile fiberboards might have experienced greater spring-back owing to higher internal stress built up during the cold pressing, which was not relaxed during the heating process. Upon exposure to moisture during the first soaking, this residual stress was released, creating force on the interfiber bonding and initiating bond failure, which in turn resulted in slightly higher spring-back than that seen with conventional fiberboard. During the subsequent accelerated aging conditioning, the additional deteriorating actions of moisture and temperature coupled with the stresses of spring-back caused further breakage of interfiber bonding, resulting in high water penetration and aggravation of board integrity.

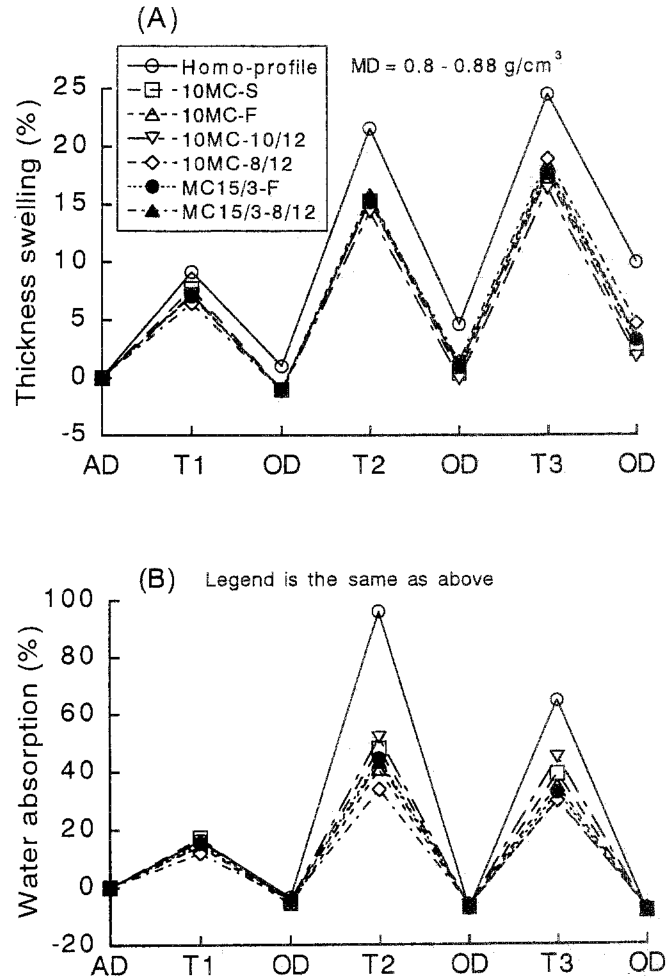

Fig. 8. Thickness swelling (**A**) and water absorption (**B**) of various fiberboards under the dry/wet cycle. Refer to Table 1 and Fig. 7 for explanations of the codes and the dry/wet cycle, respectively

Conclusions

The effects of the hot pressing method and mat MC distribution on the formation of the density profile and its effects on fiberboard were investigated. The correlations among the various density profile defining factors were analyzed statistically. A quantitative analysis was also conducted on the effects of MD and PD on the bending performance of fiberboard in addition to the conventional board evaluation in terms of IB, SWR, and dimensional stability.

It is possible to adjust the PD and CD of fiberboards over a wide range at 0.5 g/cm^3 MD via manipulations of the hot pressing method and mat MC distribution, but only limited effects were observed in 0.7 g/cm^3 boards. Irrespective of the board MD, the PD showed a greater variation than the CD. Boards produced using two-step hot pressing had substantially higher PD with reduced CD. The Pdi, GF, and Pb of all types of conventional fiberboards were 30%–40%, 2%–9%, and about 20%, respectively, based on the total board thickness. Multiple regression analysis showed that CD and PD could be well defined by other profile-defining factors, and a rough estimation for Pdi and GF was possible. Pb however, could not be expressed using other factor(s).

Results of the static bending showed that conventional fiberboard had a higher MOR but similar MOE compared to homo-profile fiberboard, probably owing to the interference of shear effect during bending. Based on the MOE measured using the free-free beam method, the MOR and MOE of 0.7 g/cm^3 boards were, correspondingly, 2.4–2.5 and 1.9–2.2 times the values for the 0.5 g/cm^3 boards, despite having similar PD. At 0.5 g/cm^3, when the PD increased from 0.5 to 1.07 g/cm^3, the MOR and MOE of fiberboard increased by up to 67% and 62%, respectively. Similarly, corresponding increases of 55% and 34% in the MOR and MOE were recorded for 0.7 g/cm^3 boards when the PD was increased from 0.7 to 1.1 g/cm^3.

The IB and SWR of the fiberboard were almost entirely dependent on the board CD and MD, respectively. The homo-profile fiberboards recorded higher TS and WA than the conventional fiberboards during the dry/wet conditioning cycle.

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