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ORIGINAL ARTICLE

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Water removal of wet veneer by roller pressing

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Abstract High moisture content, flat sawn Japanese cedar (*Cryptomeria japonica* D. Don) veneer was compressed using a roller press to mechanically remove water. The amount of water removed depended on the amount of compression applied. At 60% compression, 400 kg/m^3 of water was removed. The process was not dependent on the size of the wood, the degree of compression, or the feed speed of the specimen. After compression, the remaining water contents were evenly distributed throughout the veneer regardless of the length of the specimen. The specimens did not completely recover to original thickness. High compression ratio and low temperature intensified the reduction of thickness. The bending strength after compression decreased in an inversely proportional manner with the thickness of the specimen and the compression degree.

Key words Roller press · Compression · Water removal · Moisture content · Free water · Energy savings

Introduction

Wood compression techniques have been applied to wood for various applications: densification of wood,[1–6] liquid impregnation,[7–12] and improvement in drying behavior.[13] Large transverse compression of wood results in very rapid removal of water from the compressed lumens and large amounts of water can be removed very quickly.

Past studies on the removal of water from wood have mainly involved platen pressing of wood chip mats,[14–16] small block,[16,17] stem,[18] and plank.[19] However, the length of examined samples was at most 300 mm due to the constraints imposed by the dimensions of the apparatus.

On the other hand, preliminary research on roller pressing has been performed on stem 140 mm in length[18] and timber over 2000 mm long.[13] The research on stems reported the moisture content distribution around and along roundwood, while that on timber was conducted only with the aim to decrease the incidence of defects that occur in kiln drying. Because the cited studies applied only low degrees of compression, up to 12.5%, no reports are available concerning the effects of compression by roller pressing exceeding 50% on the drying behavior of the material.

The aim of the presents study was to apply roller pressing to water removal of lamina for laminated veneer lumber and glue-laminated lumber. The study reported herein investigated the amount of water removal and the moisture content distribution after roller pressing of high moisture content sawn veneers. Variables in the study included the rate and extent of compression, size of veneers, and amount of water removed as a function of compression. The negative effects of compression on the thickness change and flexural strength were measured.

Materials and methods

Materials

Knot-free sapwood sawn veneer of sugi (*Cryptomeria japonica* D. Don) with the dimensions of 300, 600, and 900 mm (longitudinal, L) by 90 mm (tangential, T) by 4, 6, 8, and 10 mm (radial, R) were prepared. The average and the coefficient of variation (CV) of the density, which was based on oven-dry weight and volume, were 0.32 g/cm^3 and 7.6%,

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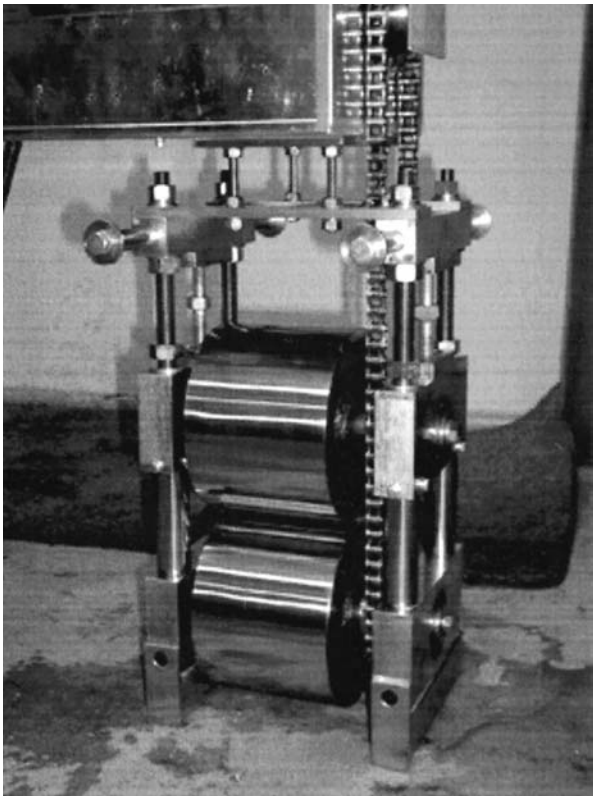

Fig. 1. Roller pressing machine

respectively. After the measurement of the oven-dried size, the specimens were conditioned to a water-saturated condition. Parts of the specimens were conditioned to moisture content (MC) of between 112% and 282% by hot air drying at 40°C. Five to eight specimens were measured for each procedure.

Methods for the removal of water

A roller press was newly designed and manufactured for the compression of wood. The press was equipped with a pair of replaceable metal rollers with a servomotor (4.4kW). The compression degree of specimens was controllable by shifting the position of the upper roller. Figure 1 shows a photograph of the roller press equipped with a pair of 150-mm diameter rollers.

Wet specimens were compressed in the roller press at temperatures ranging from 0° to 80°C. The specimens were compressed from 15% to 75% of their original thickness. The feed speed of specimens into the rollers was 1–10m/min. To avoid resorption of water into the specimens, absorbent paper was placed around the specimens and the roller press was inclined so that the water ran away from the specimens. Some of the specimens were then cut perpendicular to the longitudinal direction into 10-mm sections. Each specimen was then weighed, oven-dried, and remeasured.

Evaluation of bending strength

Specimens were conditioned after compression drying to an air-dry state at 60% relative humidity (RH) and 20°C. The specimens were then cut to 200 (L) × 30mm (T) and were submitted to a bending test to determine the modulus of elasticity (MOE). The span and loading speed were 16 times the thickness of the specimens and 5mm/min, respectively. Air-dried control specimens without compression were also prepared and tested.

Results and discussion

Drying of wood by compression

In general, water is forced out of the specimens compressed by platen pressing from both ends of the specimen. In roller pressing, water is expelled from the cross-grained surface and the tail end of the specimen during rolling.

The relationship between the water content in wood specimens before and after roller-press dewatering with 60% compression is shown in Fig. 2a. This figure shows the plots of the total amount of water retained as a function of the density. It is clear that there is a good correlation between the theoretical total water and the actual experimental value before compression but little correlation between theoretical amount of water removed and the actual experimental value determined after compression. The total amount of water removed by compression was about 400–450kg/m^3 regardless of the density. If a completely saturated piece of wood was compressed to a deformation of 60%, 600kg/m^3 of water should theoretically be eliminated regardless of the density. The low amount of water removed is possibly explained by reabsorption of water and the reduction of potential volume change due to lateral strain (Poisson's ratio) during rolling.

Similar results were found in the relation of the MC before and after compression using roller pressing (Fig. 2b). Once again, good correlation was observed between the theoretical MC and the actual experimental value determined before compression. The higher the specific gravity, the lower the MC after compression. However, it is considered that a change of the density does not affect the MC after compression in this experiment, because the CV of the MC after compression was the same as that of the MC for samples of similar density. Therefore, we applied the MC to assess the effect of water removal.

Some wood species are difficult to dry and green wood, in general, has a very wide range of MC. Figure 3 shows the variation of MC before and after 60% compression of wood with different MC. The white columns represent the decrease in MC and the black columns represent the actual MC after roller pressing. The average initial MC of specimens was 208% with a CV of 24.5%. The average final MC of specimens after 60% compression was 104% with a CV of 18.8%. Because air has a higher permeability than water, the air is discharged first from the lumens by compression

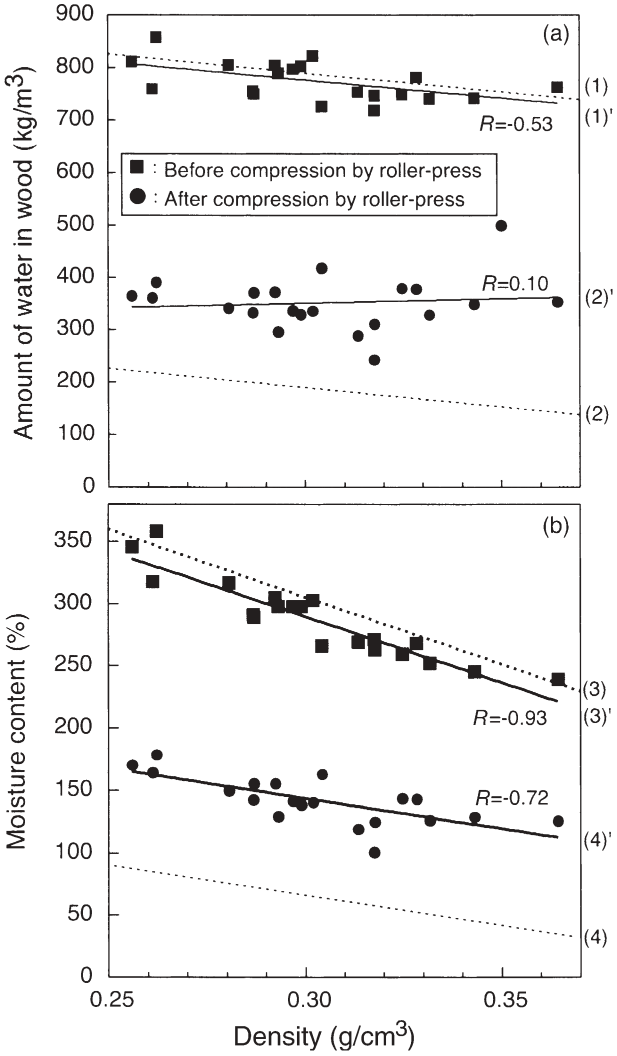

Fig. 2. The influence of the density on the amount of water (**a**) and the moisture content (**b**) after 60% compression. Several lines indicate the value calculated from density: (*1*) is theoretical total water before compression; (*1*)′ is actual total water before compression; (*2*) is theoretical total water after compression; (*2*)′ is actual total water after compression; (*3*) is theoretical moisture content (MC) before compression; (*3*)′ is actual MC before compression; (*4*) is theoretical MC after compression; (*4*)′ is actual MC after compression

and then the water is removed during further compression. Therefore, the MC after compression is a function of compressive degrees regardless of initial MC.

Figure 4 shows the relationship between the MC of specimens and the compression. Line A is the initial MC and line B is the calculated value of MC after compression. Because some resorption of moisture and elongation in the tangential direction of the specimens occurs after compression, the actual MC is higher than the calculated MC. At 15% compression, the MC after compression was not changed. This is due to the extension in radial direction (6%) of specimens, which mainly occurs during the early stages of compression. The MC decreased as the compression increased from 30%, and the slope of the approximate curve was about equal to that of the theoretical curve.

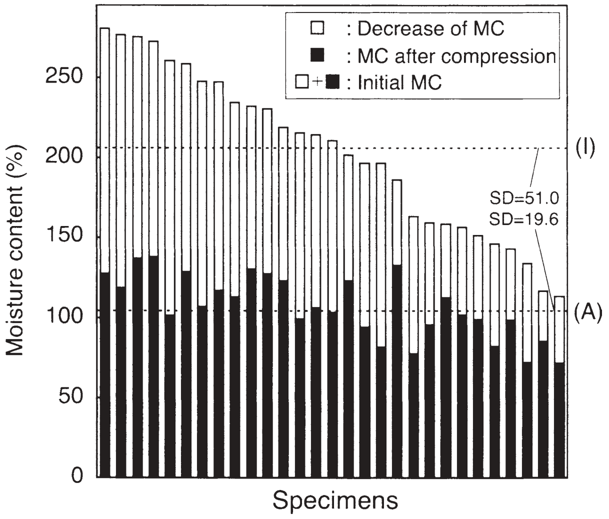

Fig. 3. Leveling off of moisture content (MC) after compression by roller press. Compressive deformation: 60%, feed speed: 6 m/min. *Dotted* lines indicate the average of initial moisture content (*I*) and the average moisture content after compression by the roller press (*A*). *SD*, standard deviation

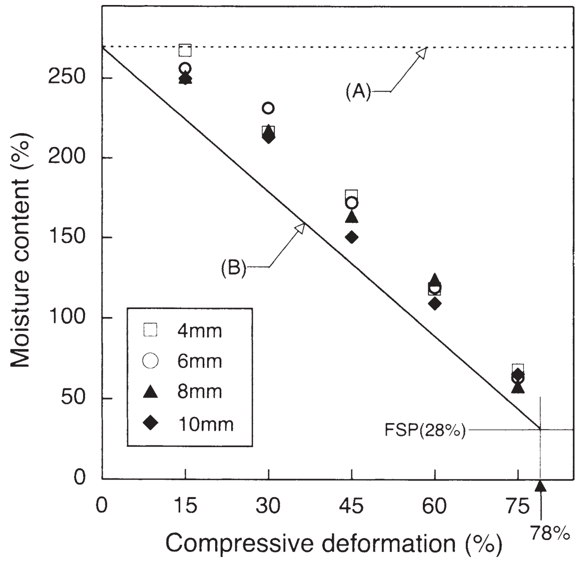

Fig. 4. Relationship between the compressive deformation and the moisture contents after compression by roller press with various thicknesses of specimens. *Line A*, average of initial moisture contents in water-saturated condition; *line B*, moisture contents calculated from the rate of compression

Table 1 shows the MC after roller pressing as functions of other parameters, including specimen initial thickness, length, feed speed, and temperature. The MC after compression was constant regardless of thickness, length, or feed speed of the specimens, because there were no influences on the volume change of compressed lumens at a constant strain applied within the limits of the conditions. Wingate-Hill and Cunningham[17] confirmed that a slow compression rate (e.g., 0.4 mm/min) caused greater water loss than a more rapid rate (e.g., 15 mm/min) when using a

Table 1. Decrease of the moisture content and reduction of thickness after compression by roller pressing

Thickness (mm)	Length (mm)	CD (%)	Speed (m/min)	WT (°C)	MC (%)	T/T_0
4	300	60	6	20	119 (16.2)	0.963
6	300	60	6	20	120 (10.2)	0.947
8	300	60	6	20	125 (9.3)	0.933
10	300	60	6	20	110 (10.5)	0.933
4	**100**	60	6	20	130 (8.0)	0.987
4	**200**	60	6	20	128 (19.2)	0.969
4	**300**	60	6	20	119 (16.2)	0.963
4	**600**	60	6	20	138 (14.2)	0.969
4	**900**	60	6	20	118 (9.7)	0.977
4	300	**15**	6	20	268 (4.4)	0.995
4	300	**30**	6	20	217 (10.3)	0.988
4	300	**45**	6	20	177 (14.1)	0.970
4	300	**60**	6	20	119 (16.2)	0.962
4	300	**75**	6	20	70 (5.6)	0.946
4	300	60	**1**	20	127 (20.5)	0.938
4	300	60	**2**	20	126 (11.0)	0.952
4	300	60	**6**	20	119 (16.2)	0.963
4	300	60	**10**	20	115 (17.3)	0.961
4	300	60	6	**0**	150 (20.8)	1.008
4	300	60	6	**20**	119 (16.2)	0.963
4	300	60	6	**40**	126 (18.8)	0.976
4	300	60	6	**60**	117 (20.5)	0.964
4	300	60	6	**80**	98 (8.8)	0.948

Values in parentheses are standard deviations

CD, Compressive deformation; WT, water temperature; MC, moisture content after compression; T, oven-dried thickness before compression; T_0, oven-dried thickness after compression

platen press. However, no effect of feed speed was observed in this study. The MC after compression decreased with increasing temperature, because the coefficient of viscosity of water reduces on heating.

Figure 5 shows the distribution of the MC along the longitudinal direction after roller pressing as a function of specimen length. The inlet ends of the specimens with lengths of 300, 600, and 900 mm coincide with the left end of the horizontal axis while the outlet ends coincide with the right end of the horizontal axis. In all cases, the MC decreased to 150% and there was little variation of MC along the longitudinal direction. The distribution of MC was not influenced by changes in specimen length. However the middle of the specimen had higher MC than the ends, because negative pressure remained in lumens of the middle section and water, after unloading, was sucked into the middle of the specimens.

Table 1 shows the thickness after roller pressing as a function of initial thickness and length of the specimen, degree of compression deformation, feed speed, and temperature. Compression results in shear flow of constituents in the lignocellulosic cell wall and no visible checking occurs in the wood. The thickness reduction after compression increased with an increase in temperature and with lower feed speed. Creep strain increased with increasing contact time with the roller press and the increase in temperature resulted in plasticity of the cell wall. The thickness reduction increased with the initial thickness and the degree of compression.

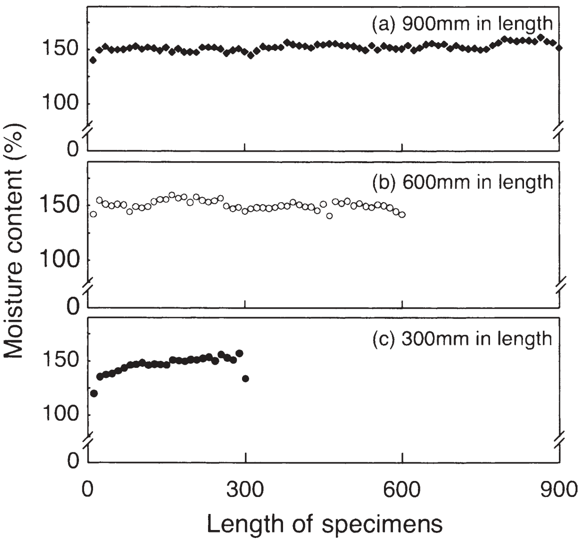

Fig. 5. Moisture distribution along the longitudinal direction at 45% compression for specimens of various length. The origin of the x-axis indicates the leading end of the specimen that is inserted into the roll gap

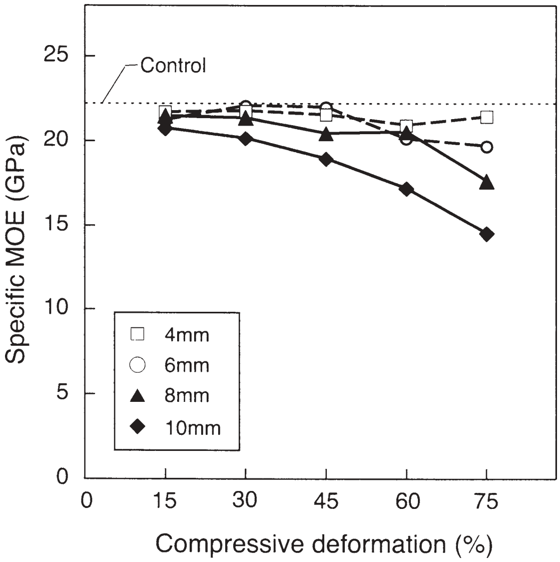

Fig. 6. Effect of compression by the roller press on the specific modulus of elasticity (MOE). Control indicates uncompressed sample

Bending strength of compressed wood

At 75% compressive deformation using a roller press, some of the 6-, 8-, and 10 mm thick specimens had some cupping, end splits, and surface checking. Figure 6 shows the values for specific MOE of roller-pressed wood as compared with wood that was not compressed. For specimens that were 4- or 6-mm thick, Fig. 6 shows that there is very little loss of bending strength with an increase in compressive deformation. This would indicate that there is very little damage to the veneer as a result of compression.

The bending strength of specimens that were 8-mm thick did not change with compression degree up to 60% but decreased at 75%, while that of specimens that were 10-mm thick did not change with compression degree up to 30% but decreased at 45% or more. In the case of specimens that showed strength reduction, the failure interface was observed between earlywood and latewood.

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