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ORIGINAL ARTICLE

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Study on sheet material made from zephyr strands V: Properties of zephyr strand board and zephyr strand lumber using the veneer of fast-growing species such as poplar

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Abstract Zephyr strand board (ZSB) and zephyr strand lumber (ZSL) were produced using zephyr made from poplar veneer to investigate the greater utilization of low-density poplar as a structural material. These materials were then compared to ordinary plywood, laminated veneer lumber (LVL) from poplar veneer, lauan plywood, and particleboard. The bending properties (moduli of rupture and elasticity) of ZSB proved superior to those of poplar plywood; and ZSL produced from poplar veneer zephyr had bending properties greater than ordinary LVL from poplar veneer. Apparently, the conversion of the poplar veneer into zephyr material had a positive effect on bending properties. Additionally, poplar ZSB had bending properties superior to those of lauan particleboard and equal to those of lauan plywood. The internal bond strength of poplar veneer ZSB was nearly two times greater than that of lauan particleboard.

Key words Zephyr strand board · Zephyr strand lumber · Poplar veneer zephyr

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Introduction

Background of developing new wood-based materials

It is becoming increasingly necessary to produce a new kind of structural sheet or frame material to substitute for lauan products from sustainable wood resources. It is highly desirable to use a fast-growing species for the production of these materials.

Wood-based materials composed of veneer such as plywood are far superior to other composite materials, such as particleboard or fiberboard, in strength, durability, and workability in general. However, there are many problems when producing plywood or laminated veneer lumber (LVL) from fast-growing species. Strength properties of plywood or LVL made from fast-growing species are lower than those of lauan products owing mainly to the low density of the veneer. It is difficult to obtain good results with the rotary cutting of some species such as sugi (*Cryptomeria japonica* D.Don) due to the large variation in thickness, rough surface, and many deep lathe checks. These factors cause the recovery rate of veneers to be low.

In short, the development of new materials that can substitute for lauan products and can be made from low-density and low-grade veneers efficiently is urgently required. With these considerations in mind, the development of zephyr strand board (ZSB) and zephyr strand lumber (ZSL) was proposed.

Zephyr made from veneer

There were previous reports[1–4] of studies of board production and property improvement using zephyr strand produced from hinoki (*Chamaecyparis obtusa* S. and Z. Endl.) sawn lumber. In this study we attempted to produce zephyr from poplar veneer. Crushing the veneer by rollers works well, with the processing more efficient than sawn lumber. Rough cut, low grade, and small or irregularly sized veneers can be efficiently processed into zephyr.

Materials and methods

Materials

Species of veneer used in this experiment were Italian poplars, mainly I-62, I-69, and I-72. Poplar veneers were produced by Yuasa Industry, with an average thickness of 2.563 mm. The specific gravity of air-dried veneer was 0.330.

Methods

Zephyr strand production

Zephyr sheets were produced by first running poplar veneer through a series of crushing rollers. These sheets were then cut into narrow widths (30 mm) and cut to length (370 mm) for production purposes, called zephyr strand. Zephyr strands, which were used to form ZSB and ZSL, are shown in Fig. 1.

ZSB and ZSL production

The ZSB and ZSL using zephyr strands were made from poplar veneer. ZSB is a structural sheet material similar to structural plywood, and ZSL is a frame material like structural LVL.

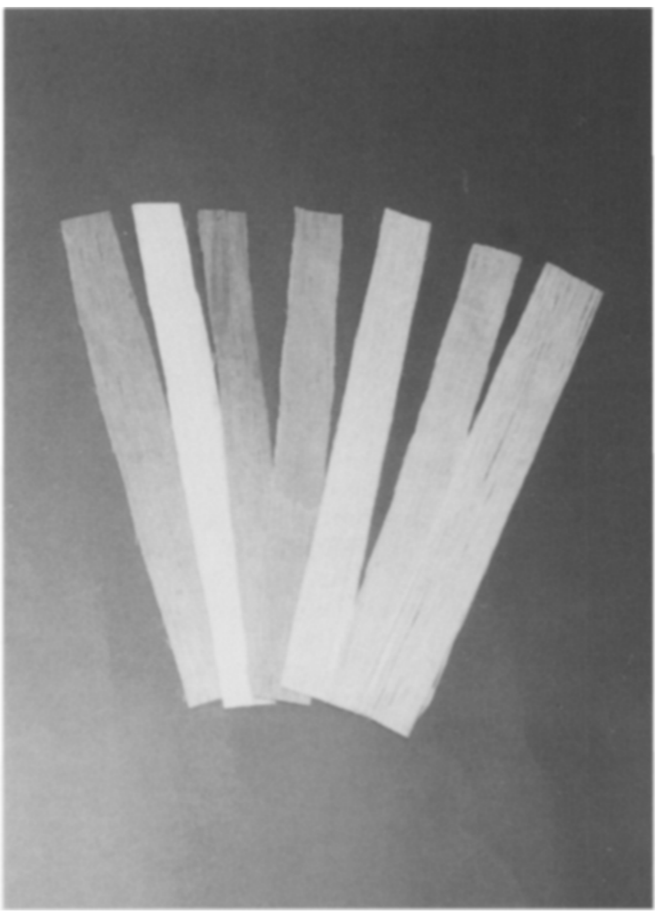

Fig. 1. Zephyr strands from poplar veneer

ZSB. The moisture content of all the zephyr strands was approximately 10% prior to resin addition. Zephyr strands were sprayed with phenol-formaldehyde resin at 10% resin content based on the oven-dried wood weight. These strands were hand-made into mats 370 mm long and 370 mm wide, arranged in layers with the zephyr orientation perpendicular to the adjacent layers, and then pressed into boards of 12 mm nominal thickness. The pressing conditions were as follows: temperature 180°C, maximum pressure 26 kg/cm^2, total pressing time 15 min. The board densities ranged from 0.50 (5-ply) to 0.70 (9-ply) g/cm^3.

ZSL. ZSL was produced in the same manner as ZSB except that the layers were laid parallel, and the maximum pressure was 41 kg/cm^2. The board size was 370 mm long, 150 mm wide, and 23 mm thick. The number of zephyr strand layers varied with the density of the product, which ranged from 0.50 (11-ply) to 0.70 (15-ply) g/cm^3. Samples of ZSB and ZSL are shown in Fig. 2.

Plywood and LVL production

Ordinary plywood and LVL were produced for comparison with ZSB and ZSL.

Plywood. Five-ply plywood was produced with dimensions of 300 mm length, 300 mm width, and 12 mm thickness from 2.5-mm poplar veneer. A density of 0.50 g/cm^3 was targeted with urea-formaldehyde resin at 10% resin content. Though urea-formaldehyde resin was used for production of the plywood, it was thought that the difference between resin adhesive types was negligible in terms of their mechanical properties. The plywoods were cold-pressed for 20 min at a pressure of 2 kg/cm^2 and then hot-pressed at a temperature of 120°C for 5 min at a pressure of 10 kg/cm^2.

LVL. Ordinary LVL was made from 2.5-mm poplar veneers with phenol-formaldehyde resin, and the board size was the same as the ZSL (370 × 150 × 23 mm). The density of nine-ply LVL was 0.50 g/cm^3. Eleven-ply LVL was also produced by applying a higher pressure at the hot-pressing stage, which resulted in the LVL density being increased to 0.60 g/cm^3 at the same board thickness (23 mm). LVL at a density of 0.70 g/cm^3 could not be produced because of the occurrence of blisters in the board.

Testing properties

After conditioning at a controlled temperature of 25°C and 65% relative humidity (RH) for least 2 weeks, the sample materials were tested for bending properties [modulus of rupture (MOR) and modulus of elasticity (MOE)] and internal bond (IB) strength. Tests were conducted in accordance with Japanese Industrial Standard

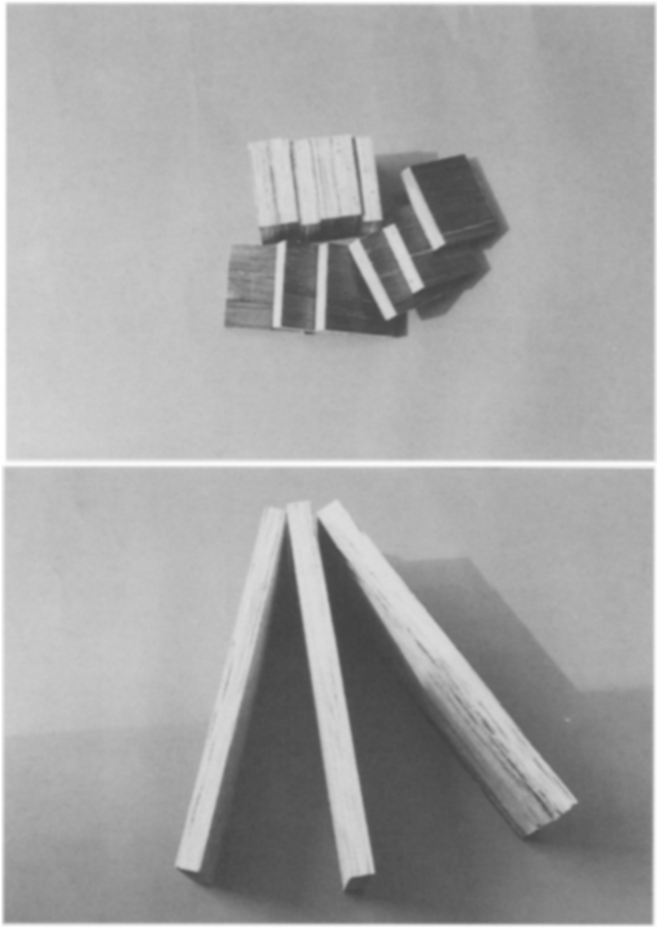

Fig. 2. Samples of zephyr strand board (ZSB) (*top*) and zephyr strand lumber (ZSL) (*bottom*)

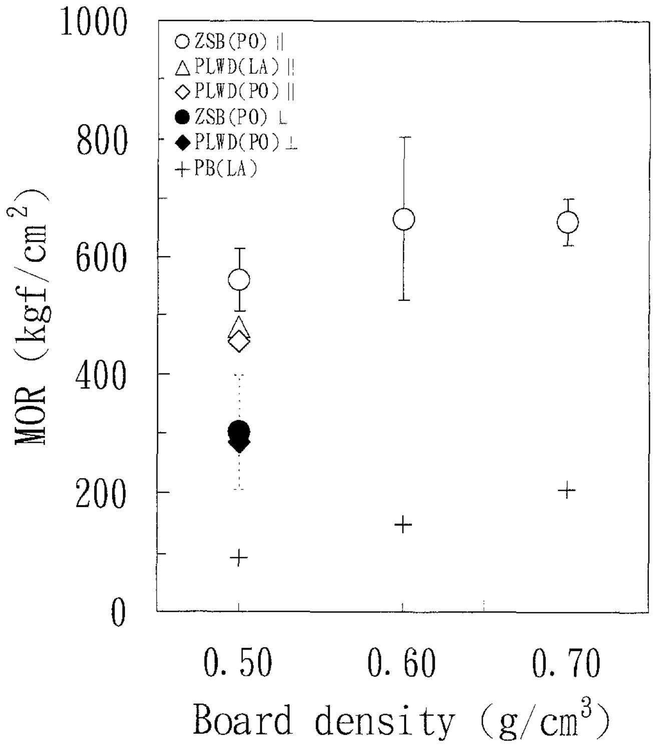

Fig. 3. Comparison of the modulus of rupture (*MOR*) for ZSB made from poplar veneer zephyr, poplar plywood, and others. *ZSB*, zephyr strand board; *PLWD*, plywood[8]; *PB*, particleboard[7]; ∥, ⊥, fiber direction of face layer is parallel or perpendicular to the span direction in the bending test, respectively. Letters inside parentheses show the species use: *PO*, poplar; *LA*, lauan. Dots and vertical bars denote average values and standard deviations, respectively

(JIS) A 5908[5] and Japanese Agricultural Standards (JAS)[6] specifications.

Results and discussion

Bending properties of ZSB and plywood

The MOR and MOE values of the ZSB produced with zephyr strands from poplar veneer are shown in Figs. 3 and 4 as all those of the plywood and the particleboard. Based on these figures, the following observation were made.

1. The average MOR and MOE values for ZSB, in which the grain of the surface layers was parallel to the bending span, increased with board density though with a relatively large deviation. The MOR values tended to level off when the board density exceeded 0.60 g/cm^3, which may be because the ply number increased as board density increased.

2. Comparing to plywood produced with poplar veneer and urea-formaldehyde resin, the MOR and MOE of ZSB are slightly higher than those of the plywood at the similar density.

3. It is important that zephyr from veneer allows higher-density boards to be produced because of the existence of many voids, unlike plywood made from veneer. This has resulted in the possibility of producing a stronger board with low-density materials.

4. As for the bending test the boards were tested parallel and perpendicular to the predominant grain direction (i.e., surface veneer orientation). The samples (both ZSB and ordinary plywood) tested in the cross-grain orientation showed values approximately one-half those for longitudinally oriented samples at a density of 0.50 g/cm^3.

5. For comparison, experimental values from reported data[7,8] for particleboard (thickness 12 mm) and plywood (5 plies, 12 mm in thickness) produced from lauan wood are indicated in Figs. 3 and 4. The MOR and MOE values for ZSB produced with poplar zephyr strands are much greater than those for lauan particleboard. This is due to the nature of the zephyr-strand material, which is composed of long, stiff, longitudinally oriented fiber strands. Also, the MOR values for ZSB are higher than those for lauan plywood at a density of 0.50 g/cm^3.

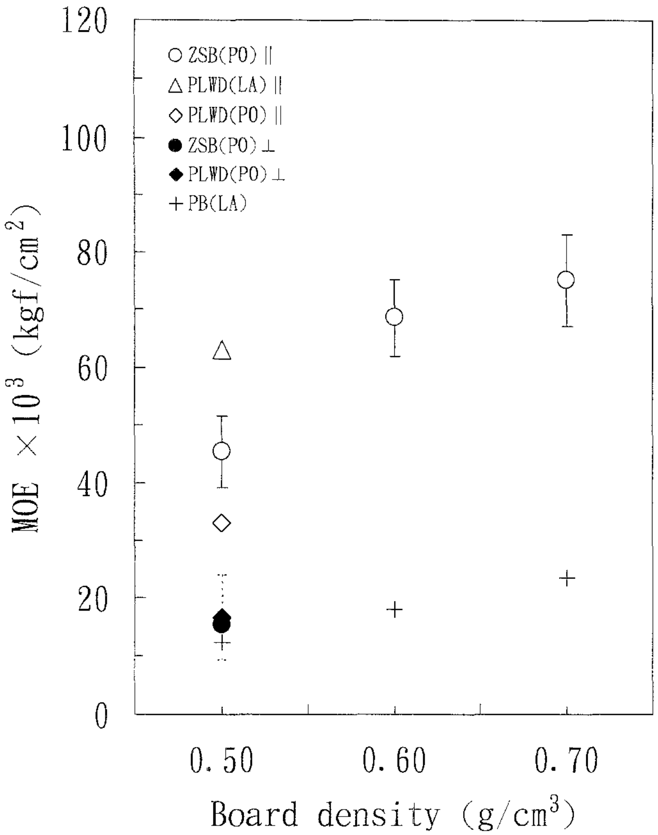

Fig. 4. Comparison of the modulus of elasticity (MOE) for ZSB from poplar veneer zephyr, poplar plywood, and others. All symbols and abbreviations are the same as those shown in Fig. 3

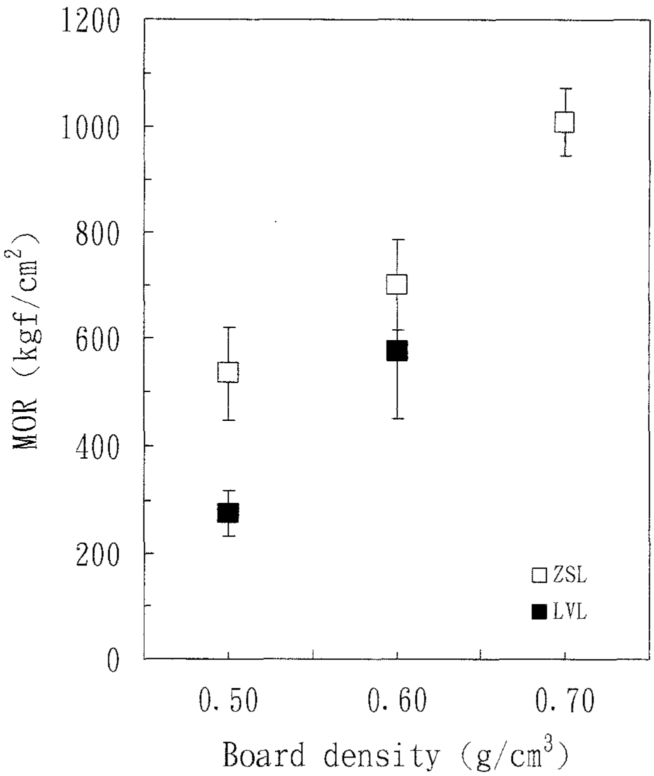

Fig. 5. Comparison of MOR between ZSL from poplar veneer zephyr and laminated veneer lumber (LVL) from poplar veneer. Dots and vertical bars denote average values and standard deviations, respectively

Bending properties of ZSL and LVL

For framing materials, the results of the MOR and MOE for ZSL produced with zephyr strands made from poplar veneer are shown in Figs. 5 and 6, as are those for ordinary LVL made from poplar veneers. The following was observed.

1. The effect of density on the MOR and MOE values for material produced with zephyr is apparent. Increasing the density markedly improved the MOR and MOE strength. The MOR and MOE values reach 1000 kgf/cm^2 and 100 $\times$ 10^3 kgf/cm^2, respectively, at a density of 0.70 g/cm^3, they exceed the 100E standard values for structural LVL established by JAS.[9] This can be explained by the characteristics of the zephyr strands. Zephyr material is highly compressed and crushed by rollers, resulting in zephyr strands that have more densified wood substance per the unit squared than veneer. Moreover, the outer voids between fibers increase because breakable fibers are broken selectively. As a result, they have an irregular network with more strong fibers. The many voids between compressed fibers are easily seen by electron microscopy of the zephyr strand elements. Microphotographs of cross sections of poplar veneer and zephyr made from poplar veneer are shown in Fig. 7. This element makes up a stronger bending material than veneer at the same density because the hot-

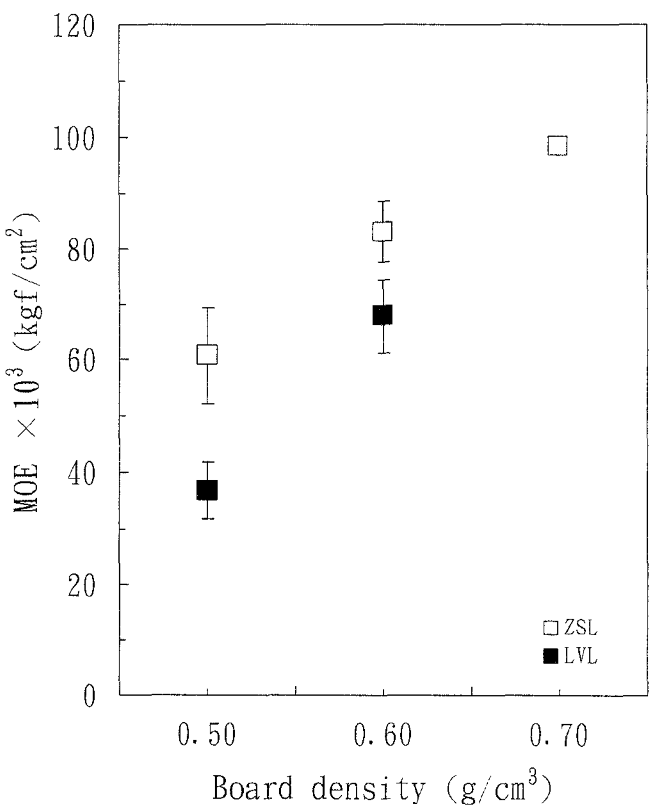

Fig. 6. Comparison of MOE between ZSL from poplar veneer zephyr and LVL from poplar veneer. All symbols and abbreviations are the same as those shown in Fig. 5

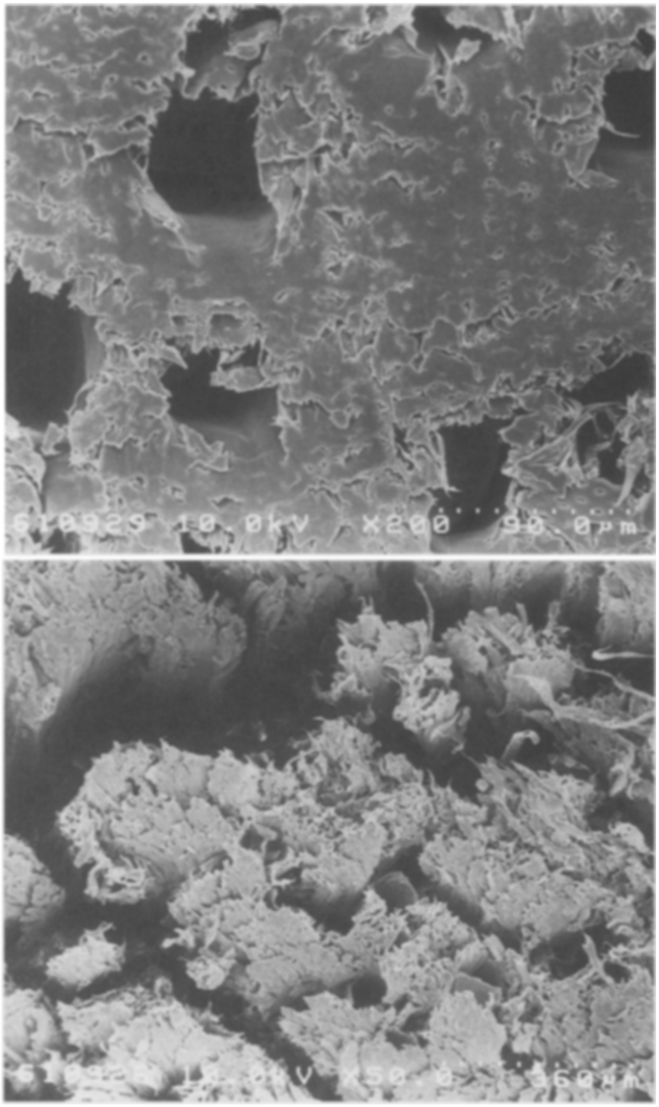

Fig. 7. Poplar veneer (top; ×200) and zephyr made from poplar veneer (bottom; ×50)

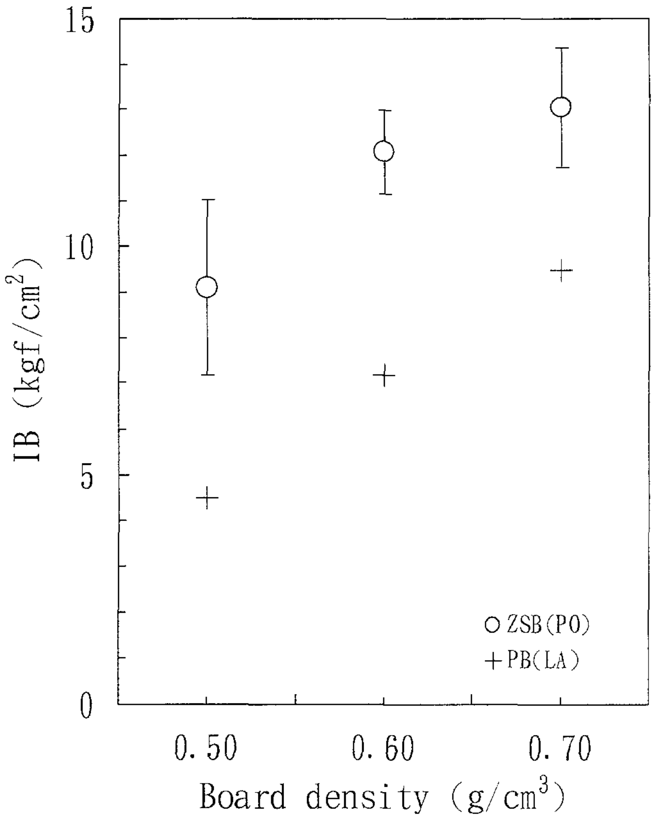

Fig. 8. Comparison of internal bond strength (*IB*) for ZSB from poplar veneer zephyr and particleboard from lauan chip. All symbols and abbreviations are the same as those shown in Fig. 3

pressing pressure during board production is done mainly to obtain better gluing contact between elements and fibers.

2. The MOR and MOE values for LVL made from poplar veneer were low, about half those of the 100E standard values for structural LVL established by JAS. These low values may be due to the low strength of poplar veneer.

Internal bond strength of ZSB

The internal bond (IB) values for ZSB are shown in Fig. 8. As board density increases, the IB correspondingly increases. In published reports[10,11] boards composed of smaller elements generally have larger IB values because of the greater surface area available for bonding, but in this experiment the IB of ZSB from poplar veneer was nearly twice that of lauan particleboard. Compared to lauan species, poplar is of low-density. Additionally, the density of zephyr is lower than that of particle, so the density of zephyr made of poplar veneer is lower than that of lauan particle. When the same board density was targeted, the lower-density elements with many voids were easily compacted and had a wider gluing area. Therefore the IB strength of zephyr board is higher than that of lauan particleboard.

Conclusion

Based on the study, the following conclusions can be reached.

1. The bending properties (MOR, MOE) of ZSB or ZSL produced with zephyr strands made from poplar veneer were higher than those of plywood or LVL produced with ordinary poplar veneer when they were compared at the same density. This may be due to the use of highly compressed zephyr strands as the component elements and the existence of voids in the material.

2. The IB strength of ZSB was nearly twice as great as those of lauan particleboard, which may be due to the greater degree of homogeneity and surface smoothness of the zephyr strands.

3. From these results, it was demonstrated that materials produced with zephyr made from poplar veneer can be used

for structural uses in terms of the MOR, MOE, and IB strength.

It should be recognized that the production of materials with zephyr strands from veneer is one of the most effective uses of low-density wood species such as poplar. Moreover, this production can effectively utilize both the waste veneer from other manufacturing processes and low-grade veneer such as sugi veneer from rough rotary cutting.

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