STRENGTH PROPERTIES OF ENGINEERED WOOD I-JOIST WITH FINGER JOINTED ORIENTED STRAND BOARD (OSB) WEB AND LAMINATED VENEER LUMBER FLANGES (LVL)

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ABSTRACT

Engineered wood I-joist is a system that consists of flanges and web components. Both components have to work together as a system in order to match the strength property of solid wood beam. This study was carried out with the objective of obtaining the strength properties of I-joist made from finger jointed oriented strand board (OSB) web and 2 types of flanges (solid wood and laminated veneer lumber). OSB is recognized as a less costly, structural equivalent alternative to sheathing plywood for use in new home construction. The result showed that the average of modulus of rupture (MOR) of solid timber flanges (37.89 MPa) was higher than I-joist with LVL flanges (31.42 MPa). It was observed that failures in all of the I-joist specimens studied were either in tension or in compression. For specimens of solid timber flanges and LVL flanges, the failure occurred at the web joints. OSB web can be produced from the off-cuts of tertiary processing mills that use OSB for other consumer products. Hence, the full use of off-cuts would consequently increase the recovery rate and the net profit. This study could lead to the utilisation of wood residues from an OSB plant as an alternative raw material for the production of web component in I-joists system.

INTRODUCTION

Various types of structural components can be produced with combination of wood composite materials. These wood composite structural components typically consist of large numbers of separate pieces that must be jointed together for the complex structural components of the whole system. The advantages of I-shapes, compared to solid section, is that higher bending moments and stiffnesses can be achieved with minimum use of the material. Engineered wood I-joists also gain efficiency by using web materials that are strong in shear. Plywood and oriented strand board (OSB) panels can be used also in other high shear applications such as horizontal diaphragms and shearwalls, in addition to being used as web material in fabricated of engineered wood I-beam (Breyer, 1993).

An end joint is a joint formed by joining pieces of timber end to end with adhesives. End jointing is important in providing the required lengths of timbers for particular applications. At the same time it is a method of economically utilizing any short offcuts arising in the manufacturing process and it also makes it possible to upgrade the timber by cutting out and rejecting defects. (Chu, 1987).

According to Judith and Ernest (1997), the most commonly used joint today is the finger joint. The finger joint can carry an appreciable percentage of tensile capacity of the spliced lamination. The value of the joint factor depends on the exact geometry of the joint and on the manufacturing process. The long sloping edges of the finger act like miniature scarf joints, but the end of the finger cannot be perfectly sharp. Finger joints may approach the joint efficiency of well-made scarf joints.

In manufacturing long, glue-laminated timber, end-jointing boards is necessary because the available board length is limited. For end jointing, the finger joint is most commonly used today. Generally, it is said that a finger-jointed board is brittle and the deflection at the time of rupture is comparatively small. In curved glue-laminated timber, which is manufactured by bending each board to a sharp curvature, it is important to find whether the finger-jointed board can be bent safely to the radius of the curvature required (Ikuta, 1997).

This study was carried out with the objective of obtaining the strength properties (MOR and mode of failure during static bending) of engineered wood I-Joist with finger jointed OSB web and laminated veneer lumber flanges.

MATERIALS AND METHODS

In this study, a total of 6 samples of I-joists were tested in bending. The I-joists were prepared with two types of I-joist flanges and OSB webs. The OSB webs were end jointed using finger joints.

OSB Web

For this study, rubberwood (*Hevea brasiliensis*) was used as the raw material for making the OSB panels of density 750 kg/m^3. These panels were used for the web material. Rubberwood was chosen because it is easily sourced from managed forest and tree farms in Malaysia. In addition, OSB production is resource efficient because it maximises the utilisation of the available resource with minimal waste.

This study used rubberwood logs (bolts) which were obtained from an estate at Kg. Chua, Bukit Pelanduk, Port Dickson, Negeri Sembilan. The logs were trunks of TJ1 clones of about 22 years old. The OSB boards of size 340 mm x 340 mm x 12 mm were fabricated at the Wood-based Panel Products Laboratory of Chemistry Division, Forest Research Institute of Malaysia (FRIM).

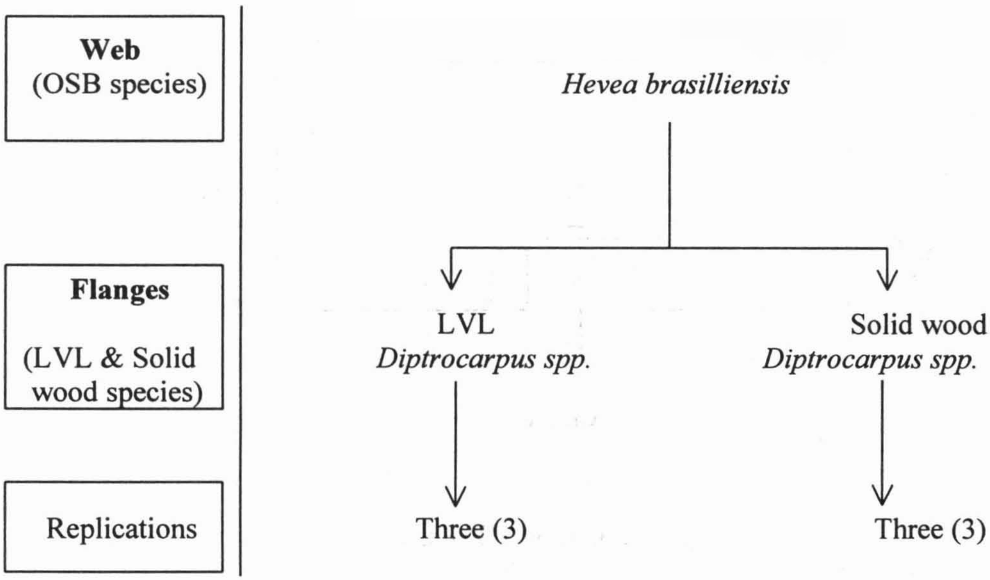

Figure 1: Engineered wood I-joist samples

I-Joist Flanges from LVL

Samples of LVL were supplied by a local plywood mill. In this study, the Keruing species was used to fabricate LVL. The manufacturing process of LVL is similar to plywood except that the orientation of the veneer was parallel to the grain. The LVL panels were bonded using a phenol formaldehyde adhesive which is a water boil resistant adhesive. The size of the LVL used was 1270 mm x 2540 mm x 36 mm of 15 plies. The LVL panels were sanded off 3 mm at the face and back to get a final thickness of 30 mm which was the required thickness.

LVL panels were cut to the size of 60 mm x 30 mm x 2440 mm to form the flanges of I-joists. Each set of the I-joist system used 2 flanges; one each for the top and bottom flanges. The flanges were grooved in the centre as shown geometrically in Figure 2.

I-Joist Flanges from Solid Wood

The solid wood used in this study was purchased from a local supplier. The Keruing solid wood were grooved at 2440 mm (8 ft) lengthwise of 10 mm x 12 mm (Figure 3.8) and assembled onto the OSB web to form an I-joist. The groove was cut in the centre on the wide face of the flange.

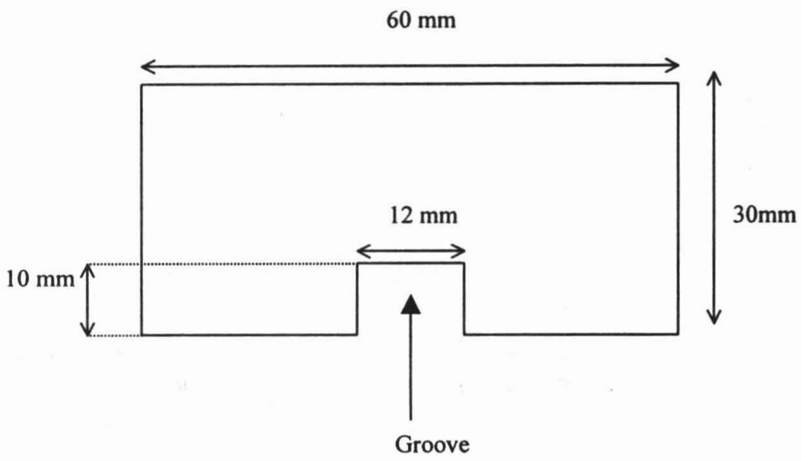

Figure 2 Groove Dimension

Finger Joints

The finger joints were made by passing pieces of OSB through a finger jointing cutter. Each set of finger joint consisted of 36 fingers. The joints were assembled immediately after finger cutting using PRF adhesive, which was applied manually to the finger of both members to be jointed. Sufficient glue was applied to ensure sufficient and even glue spread. Any excess glue was squeezed out along the whole joint profile when end pressure was applied. The joints were assembled using a finger composer. The assembled joints were left in the workshop for 2 days.

I-Joist Fabrication

The I-joists used in this study were constructed using Keruing (*Diptrocarpus spp.)* as flanges and OSB (rubberwood) as a web, glued together with a PRF adhesive. Each set of the I-joist consisted of 7 jointed OSB web. The length was arbitrarily fixed at 8 feet. The PRF adhesive was spread in the groove by using thin veneer and brush. The PRF adhesive was used because of its fast-setting characteristics and exterior exposure durability. Pressure must be applied while the adhesive was still tacky to achieve adequate bonding. I-joist specimens were clamped in beds with the pressure supplied by screwing at 6 MPa to 7 MPa. I-joist specimens were left to cure at room temperature for 2 days.

Cross-section of I-joist

The test specimens had dimensions as in Figure 3 below.

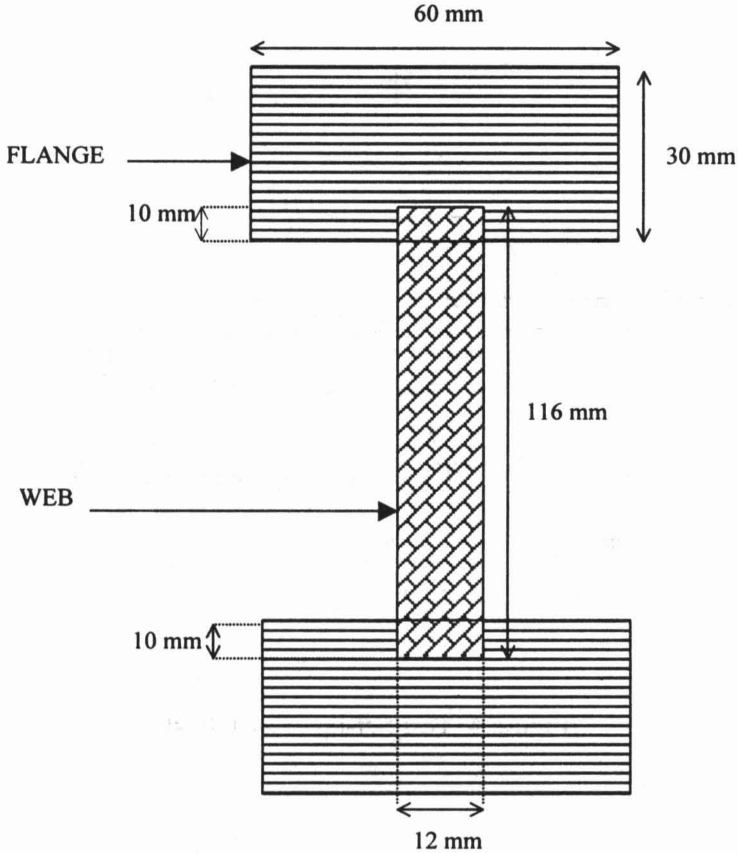

Figure 3: Cross-section of I-Joist

Destructive Testing of I-Joist Samples

Strength performance tests were carried out at the Wood Technology Laboratory of Forest Research Institute of Malaysia (FRIM). I-joists were destructively tested by bending under third-point loading over a 2310 mm span. Each I-joist was tested in bending on a universal testing machine (Figure 4).

The load point was placed symmetrically at the centre of the span. The load should be applied continuously with a uniform rate of cross-head movement throughout the test. The speed of testing was 6.6 mm per minute to achieve failure within 300 ± 120 s as recommended in BS 5820. The specimens were continuously loaded to achieve failure. The MOE was obtained based on deformation and load measurement. Load and displacement readings were taken at suitable intervals to plot a graph of load versus deformation.

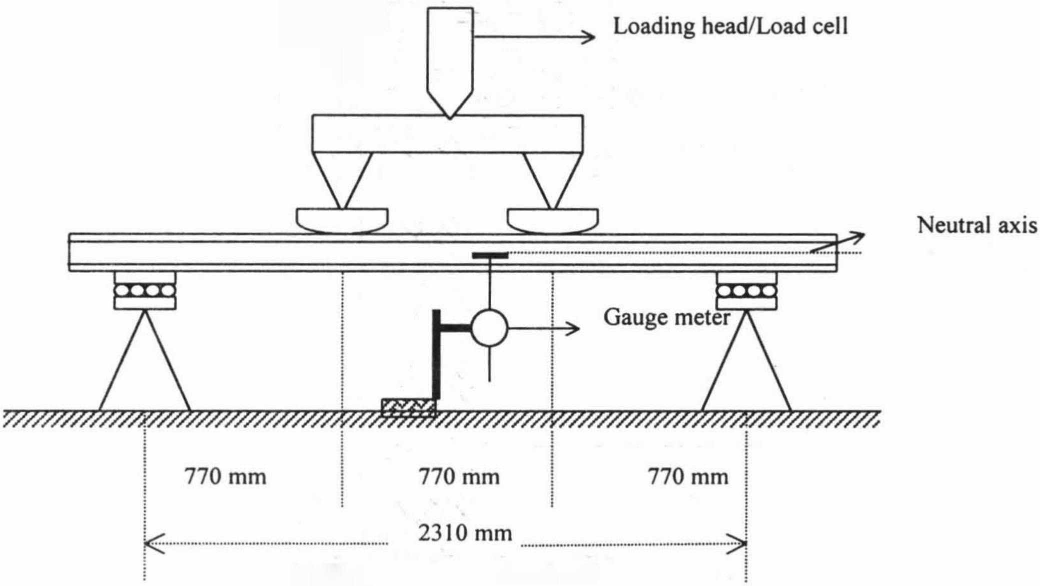

Figure 4 Test Set-up of an I-Joist

RESULTS AND DISCUSSIONS

This study compared the mean effects of two types of I-joist flanges with oriented strand board (OSB) webbing. The result of bending tests for 6 samples are shown in Table 1.

The result showed that the average of MOR of solid timber flange (37.89 MPa) was higher than I-joist with LVL flanges (31.42 MPa). The different of this two results was only 6.47 MPa. This was probably due to the fact that the LVL had similar strength characteristic as that of solid wood. According to Chu et al. (1995), the MOR value of solid Keruing was 96.0 MPa. Low (1999) reported that the MOR value for Keruing LVL was 81.8 MPa. The species of both materials were the same. During the test, the grain alignment was parallel to the bending span.

Table 1: Test result of I-joist.

Number of sample	Max. Load (Kgf)	MOE (MPa)	MOR (MPa)	MOR (MPa) Average
LVL -1	1551.2	10,902.28	29.51	31.42 (2.65)*
LVL -2	1593.2	12,613.51	30.31	
LVL -3	1811.1	14,785.06	34.45	
S -1	1997.5	10,729.98	38.00	37.89 (3.28)*
S -2	1815.9	10,319.48	34.55	
S -3	2160.7	12,345.50	41.11	

Note: * Indicates standard deviations

Standard deviations of MOR of I-joists with LVL flanges were smaller than I-joists with solid wood flanges. This was because LVL comprised many layers of veneer which was free from defects such as knots, rots and sapwood. Layers of ply veneer were glued together while maintaining its wood orientation in the same direction for each layer. According to Kinajil et al. (1994), LVL has a homogeneous nature in weight and strength along the structural member. Thus its properties are generally more uniform than solid wood.

Failure in I-Joists with Finger Joints

Failure in the finger jointed I-joist specimens happened at the joints (Figure 5). This could be attributed to the fact that the phenol resorcinol formaldehyde (PRF) used in finger jointing was a strong glue, hence producing a higher stiffness zone near the joint than in the wood zone away from the joint. The higher stiffness at the finger joint generated discontinuous state of stress, hence it increased the probability of failure at the finger joint location. According to Hayashi et al. (1995), failure of the specimens of Douglas-fir laminae occurred at knots, sloped grain portions, or at finger-joints, both in bending and tension. Page (1958) sugests that to obtain a high strength of the finger joint, the number of fingers should be kept to a minimum, because the tips of the finger are points of serious weakness. In this study, the mode of failure at the finger joint in an I-joist system was found to be consistent with the previous studies.

An I-joist can share induced stresses between its members which act together to support applied loads, so that the failure of one member will result in the redistribution of the stresses to the adjacent members. Web stiffeners may be required to transfer concentrated loads through the flange and into the web.

CONCLUSIONS AND RECOMMENDATIONS

LVL offers greater advantages against solid lumber as flanges as indicated in this study. It was proven that both materials were of about the same level of strength. LVL was constructed from multiple layers of veneer glued together that can provide uniform size and multiple spans. Therefore, the LVL end product has greater flexibility in its dimension. A long continuous flange offers better strength. Solid lumber has become less popular due to its limited availability and high cost. As a conclusion to this study, specimens with LVL flanges performed almost as strong as specimens with solid flanges.

Failures in all the I-joist specimens in this study were either in tension or in compression. The failure that occurred below the neutral axis was tension, while the compression failure occurred above the neutral axis.

More study is required to establish the size effect such as deep and shallow I-joist, finger length and finger angle, and appropriate basic stresses should be derived after considering the variability inherent in the manufacturing process. In the mean time, it is believed that joints can be improved by studying their tensile strength.

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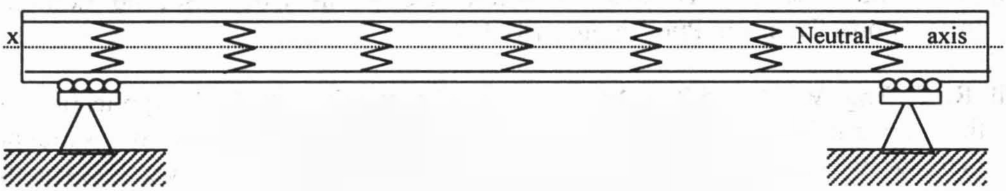


(a) Before Loading

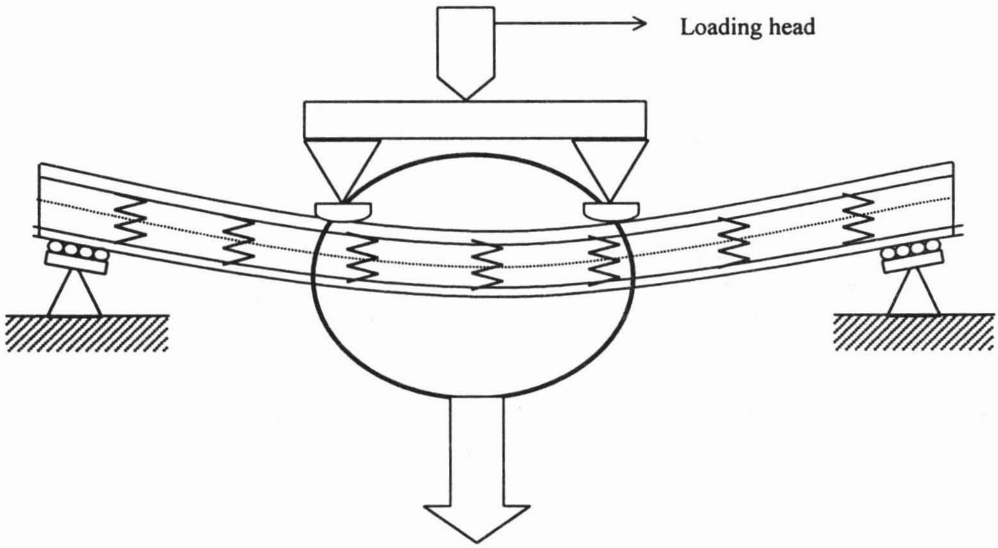
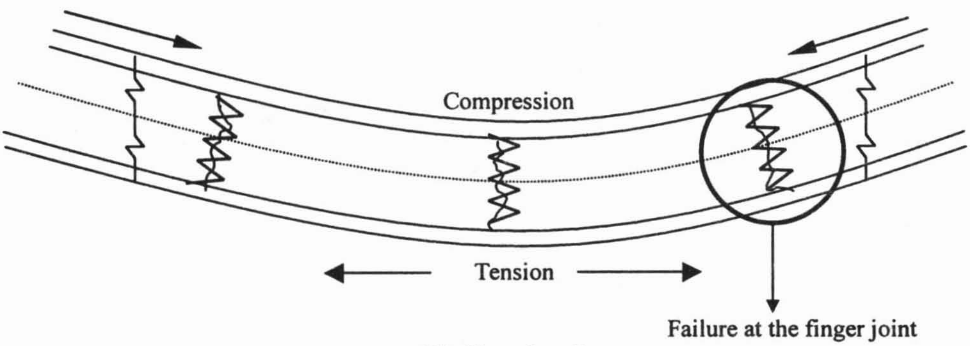


Figure 5 Failure at the Finger Joint



(b) Upon Loading
(c)
Figure 5 Continued