Structural Performance Evaluation of Finger-Jointed Rubberwood Manufactured by Factories in Thailand

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In order to utilize finger-jointed rubberwood as raw material for the production of structural wood products, the finger joint efficiencies of rubberwood specimens taken from three factories in Thailand were evaluated. This study investigated the finger profile, modulus of rupture (MOR), and modulus of elasticity (MOE) of finger-jointed rubberwood from all selected factories. The effect of finger orientations (vertical and horizontal) on MOR and MOE values was also examined. The results showed that all selected factories used the same finger profile for manufacturing finger jointing of rubberwood samples. The finger orientations had no noticeable effect on the MOR and MOE values. The MOR values of finger-jointed rubberwood obtained from all selected factories were different. They ranged from 55 to 78 MPa. A primary cause of failure for specimens with lower MOR values was the poor surface bonding of fingers. The MOE values of samples were similar for all selected factories ranging from 9,710 to 12,200 MPa. According to BS EN 338 (2016), finger jointed rubberwood from some factories was inappropriate for production of high strength structural wood products.

Keywords: Finger-joint efficiency; Rubberwood; Bending strength

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INTRODUCTION

Rubber trees are widely planted in the south of Thailand. The major product obtained from rubber trees is latex. At about 25 to 30 years after cultivation, these trees are cut down for replanting to improve the latex yield. The trunks of rubberwood, which are generally cut into 1.0 to 1.2 m long logs, are transported to factories for the production of rubberwood lumber.

The total amount of rubberwood lumber acquired in Thailand is about three million cubic meters per year (Office of Agricultural Economics 2016). About 60% of this lumber is exported for furniture production. There has been a growing interest in utilizing this lumber as raw material for structural wood products used in building construction. For these applications, lumber pieces are joined end grain to end grain using adhesives to obtain the required lumber length (Jokerst 1981). The jointed lumber pieces are used for the production of engineered wood products (Gong *et al.* 2014; Fredriksson *et al.* 2015; Ahmad *et al.* 2017; Lara-Bocanegra *et al.* 2017). Many types of end joints have been used for joining wood such as the scarf joint, butt joint, and finger joint (Jokerst 1981; Roohnia *et al.* 2014). The finger joint is mostly used for joining wood for structural purposes (Jokerst 1981; Frihart and Hunt 2010).

In Thailand, finger-jointed rubberwood is produced in many factories. The manufacturing process used in each factory is based on its own experience because there are no guidelines or standards for manufacturing finger-jointed rubberwood products. Thus, the manufacturing parameters used for finger jointing of rubberwood in each factory could be different, resulting in different finger-joint efficiency of the rubberwood products. To utilize these finger-jointed rubberwood for structural applications where strength is a primary concern (Jokerst 1981; Frihart and Hunt 2010; Rao *et al.* 2014), the joint efficiency is a useful parameter for evaluating the appropriate strength.

This study evaluated the performance of finger-jointed rubberwood manufactured by some factories in Thailand with respect to its suitability for structural use. This information can be used to improve the finger joint efficiency of rubberwood for structural applications.

EXPERIMENTAL

Finger-jointed rubberwood specimens from three factories in Thailand were acquired for the study. A finger profile (Fig. 1a) for the selected specimen was first measured. These finger-jointed rubberwood specimens were cut into test specimens with the dimensions of 20 mm × 20 mm × 300 mm using a circular saw. The position of the finger joint was at the center point of the specimen’s length. A three point bending test was conducted to determine modulus of rupture (MOR) and modulus of elasticity (MOE) of two types of finger-jointed rubberwood with respect to the finger orientations of vertical and horizontal (Figs. 1b and 1c). The span to thickness ratio of 14:1 was used in accordance with ASTM D 143 (2009). The test specimen was loaded at the center point of the span using a 150 kN universal testing machine (Lloyd, UK) until fracture. The MOR and MOE values of defect-free rubberwood specimens (unjointed wood) were also determined. Before testing, all specimens were stored in a conditioned room at 20 °C and 65% humidity to obtain the final wood moisture content of 12%. An average density of rubberwood measured from each test specimen at 12% moisture content was about 688±50 kg/m^3. Thirty specimens were used for each test condition; a total of 210 test specimens were used for this experiment.

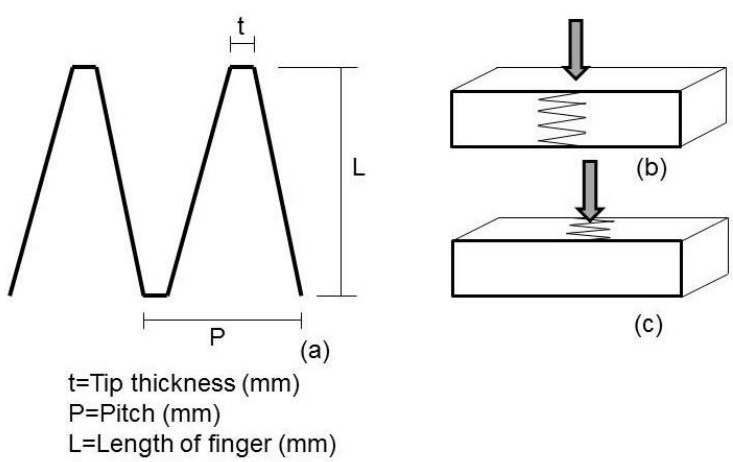

Fig. 1. (a) Finger profile; (b) bending test for horizontal finger joint specimen; and (c) bending test for vertical finger joint specimen

RESULTS AND DISCUSSION

All the selected factories mainly used the same finger profile. The tip, pitch, and length values of the finger profile used were about 1 mm, 4 mm, and 10 mm, respectively. During bending tests, there were three types of failure modes as shown in Fig. 2; all specimens tested failed in some way. Figure 2a shows that the specimen failed entirely along the bondline of finger surface due to poor surface bonding of fingers (failure mode type 1). Figure 2b shows that the specimen failed by two mixed failure modes of wood fracture at finger-joint roots and poor surface bonding of fingers (failure mode type 2). Figure 2c shows that the specimen failed away from the joint by shearing along inclined grain of wood (failure mode type 3). The joint used did not influence the last failure mode, but the specific material characteristics affected it noticeably. Thus, the values for these specimens were not included for further calculation. The fraction of specimens that failed by failure mode type 1 for all factories is shown in Fig. 3. Factory C produced the highest fraction of specimens failing by this mode, followed by Factory B and Factory A.

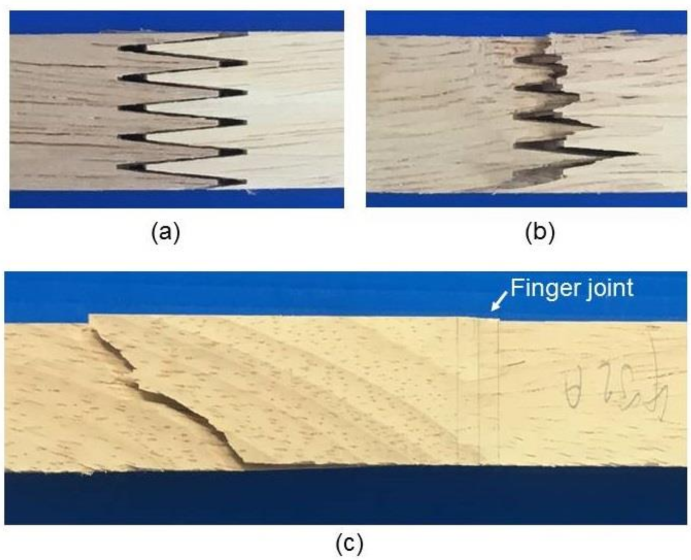

Fig. 2. Failure modes of specimens after bending tests, (a) Failure entirely along the glueline surfaces of the joint profile; (b) two mixed failure modes of wood fracture at finger joint roots and poor surface bonding of fingers; and (c) failure away from the joint

The average MOR values obtained for vertical and horizontal finger orientations for Factory A, Factory B, and Factory C were 78 ± 9 MPa, 73 ± 11 MPa, 55 ± 13 MPa and 68 ± 16 MPa, 63 ± 14 MPa, and 69 ± 20 MPa, respectively (Fig. 4). The MOE values for vertical and horizontal fingers for these factories were 11,664 ± 1,528 MPa, 11,764 ± 2,096 MPa, 10,972 ± 2,580 MPa; and 9,709 ± 2,094 MPa, 12,201 ± 1,464 MPa, 11,644 ± 2,072 MPa, respectively (Fig. 5). Moreover, for both finger orientations the values were similar for all selected factories. However, the MOR values of finger-jointed rubberwood obtained from each factory were different, whereas the MOE values were similar for all selected factories (Fig. 5). Factory A showed the highest MOR value, followed by Factory B and Factory C. It was noticed that the specimens that failed mainly by failure mode type 1 showed lower MOR values than the specimens that failed by mode type 2 for all selected factories. Therefore, Factory A showed the highest average MOR value because this factory possessed the lowest fraction of specimens failing by mode type 1. Generally, the strengths of glued surface of fingers should withstand the shear load and should be similar to the tensile strength of wood (Jokerst 1981). Frihart and Hunt (2010) suggested that to obtain highest performance level of finger joint, the percentage of wood failure around the finger joint area should be more than 85%. The result from this study suggests that the optimization of manufacturing parameters such as types of adhesives, amount of adhesive, pressing condition, curing condition and finger profile etc. is still required to achieve better bonding quality of finger jointing of rubberwood.

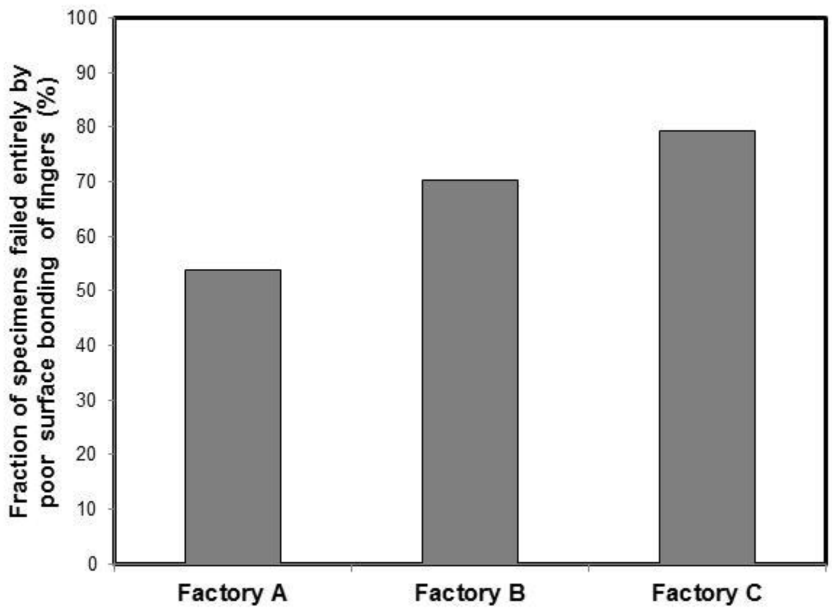

Fig. 3. Fraction of specimens failed entirely by poor surface bonding of fingers for all selected factories

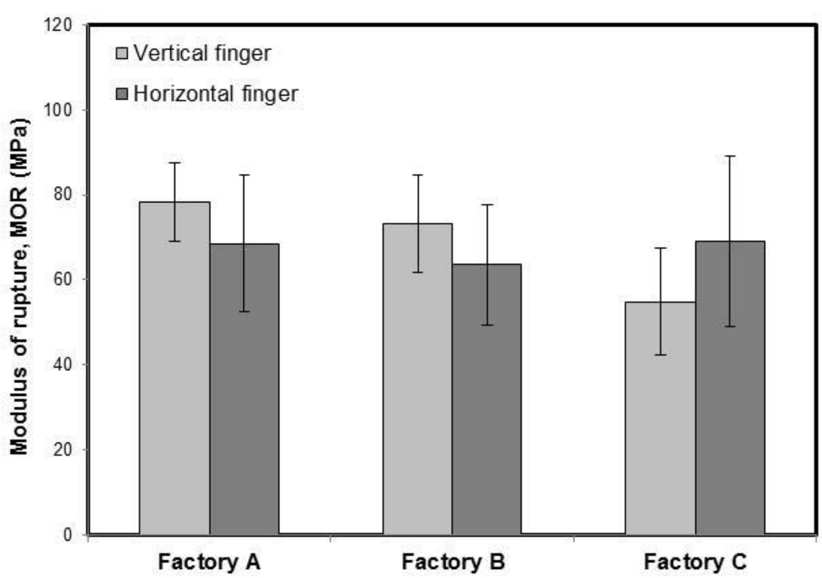

Fig. 4. Modulus of rupture (MOR) of vertical and horizontal fingers for all selected factories

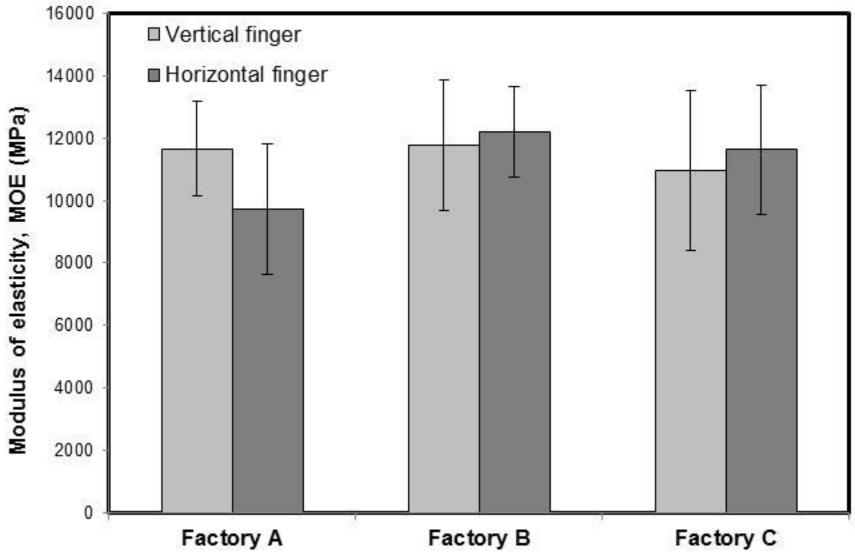

Fig. 5. Modulus of elasticity (MOE) of vertical and horizontal fingers for all selected factories

Finger joint efficiency was expressed in terms of the ratio of jointed and unjointed (defect-free) wood properties, as shown in Fig. 6.

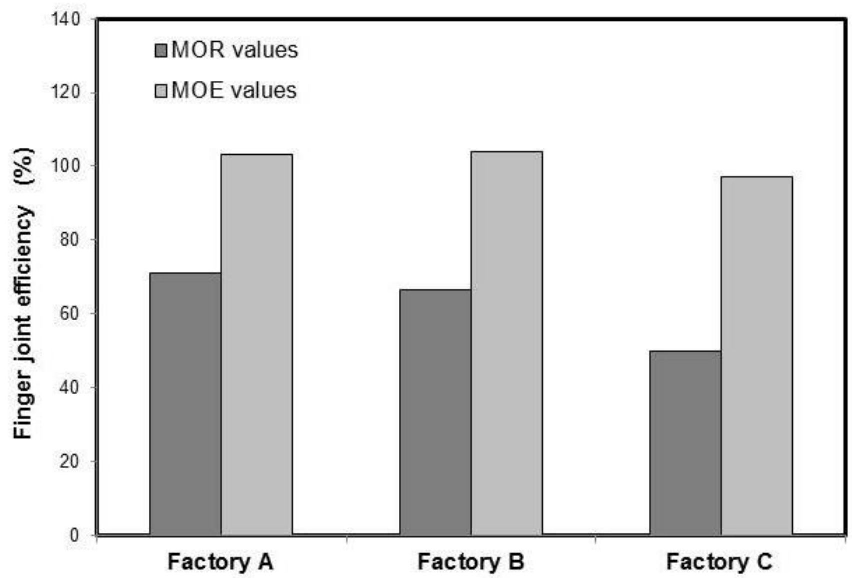

Fig. 6. Comparison of MOR and MOE values between jointed- and unjointed- wood expressed in term of finger-joint efficiency

The MOR values of jointed wood obtained from Factory A, Factory B, and Factory C were 71.2%, 66.6%, and 49.9%, respectively, of the MOR values of defect-free specimens (Fig. 6). Selbo (1975) suggested that the finger joint efficiency should be around 70%. However, Frihart and Hunt (2010) stated that the finger joint efficiency of 90% could be reached if a well-manufactured finger joint is prepared. However, the MOE value of jointed wood was comparable to that of defect-free specimens for all selected factories, as shown in Fig. 6. In comparison to BS EN 338 (2016) standard, it was found that some joints were inappropriate for the production of high strength structural wood products.

CONCLUSIONS

1. The MOR values of finger-jointed rubberwood manufactured from each selected factory were different, while MOE values were similar for all selected factories. The values indicated that some joints were inappropriate for production of high strength structural wood products according to BS EN 338 (2016).
2. The primary cause of failure for specimens with lower MOR values was poor surface bonding of fingers.

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