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Moisture Stability of Post-manufacture Thermally Modified Welded Birch (*Betula pendula* L.) Wood

Introduction

Linear friction welding of wood (see Figure 1) provides a strong wood-to-wood bonding without any external adhesives and could therefore be produced with no fossil derivatives, e.g. synthetic resins. However, the bonds suffer from delamination or from poor strength when exposed to moist conditions. Therefore, this work studies whether the delamination tendency of linear-friction welded wood-to-wood bonds could be reduced by post-manufacture thermal modification. The applied species is birch (*Betula pendula* L.). According to the hypotheses, firstly, the friction welded bond line in birch wood has unsatisfactory water resistance and poor bond strength, if any, in moist conditions. Secondly, water resistance, or wet strength, could be maintained above certain level through thermal modification, yet below the level of non-modified welded wood, when immersed in water.

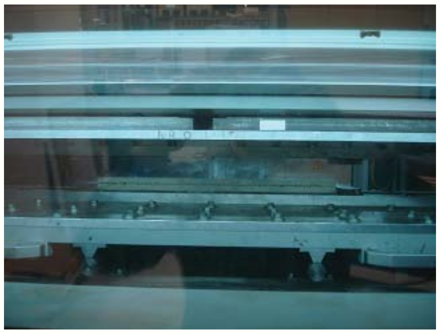

Figure 1: Linear friction welding of wood.

Materials and methods

The wood applied is knotless birch (*Betula pendula* L.), with a mean density of 568 kg/m^3 and conditioned to an MC of 11 %. During welding, two sticks sized 20×20×750 mm^3 were always joined together. The linear friction welding was completed at Bern University of Applied Sciences facilities in Biel, Switzerland, with Branson M-DT24L linear friction welding machine and the welding parameters were as follows:

WT = 3.5 s, WP = 1.9 MPa, HT = 7 s, HP = 1.9 MPa, A = 3 mm, f = 100 Hz.

The post-manufacture thermal modification at 200°C for 3 h and 5 h under superheated steam in atmospheric pressure and all the tests were completed at Aalto University, in Espoo, Finland. The tests included determination of anti-swelling efficiency (ASE), internal bond (IB) strength testing in dry and wet condition, and water immersion to observe delamination behaviour. The ASE was determined for non-welded wood specimens sized 14×14×14 mm^3 whereas the specimens for soaking and IB strength tests were sized 20×40×10 mm^3.

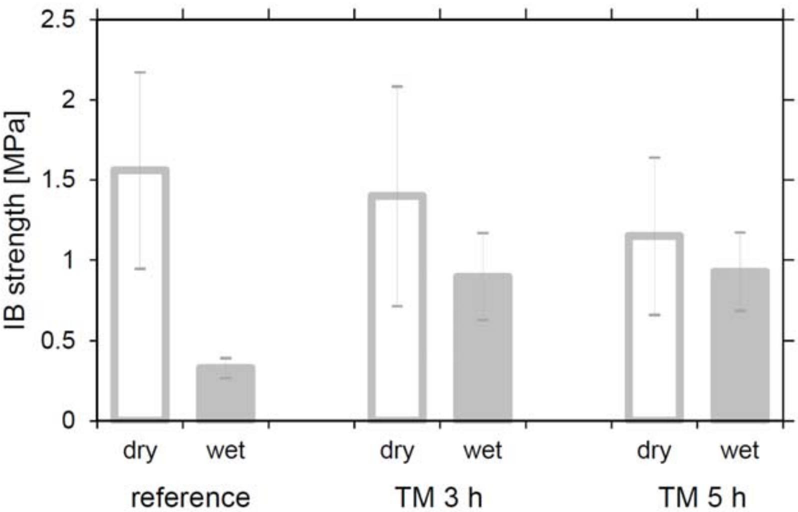

Figure 2: IB strength results in dry and wet condition. Dry condition was reached at RH 65% at 20°C and wet condion in water immersion at 20°C.

Table 1: ASE results [%] in tangential and radial orientation, with standard deviation.

	Tangential	Radial
TM 3 h	*25.9 (3.7)*	*28.0 (1.9)*
TM 5 h	*38.0 (1.4)*	*30.2 (4.4)*

Table 2: Total delaminations [n] over the 7 days soaking test.

	After 7 days	After 1st day
Reference	*4 (from 30)*	2
TM 3 h	*0 (from 14)*	0
TM 5 h	*0 (from 15)*	0

Results and Discussion

The ASE, presented in Table 1 ranged from 25.9 % to 38.0 % indicating that the thermal modification was efficient. The soaking test results showed in Table 2 indicate the same, even though the difference between the three groups is not too great: 4 reference specimens delaminated totally whereas none of the thermally modified specimens delaminated totally over the 7 days soaking time. This supports the hypothesis which stated that ordinary weld line looses most or all of its strength in moist conditions. The same could be seen in Figure 2 showing the IB strength (with standard deviation) of the test sets: the dry strength is clearly greater compared to wet strength in case of the reference set. As regards the thermally modified specimens the difference is lessened and even in a way that a longer thermal modification seems to lessen the difference more. Unfortenately, this includes the loss of dry strength as well but more clearly an enhancement in wet strength is seen. Finally, the dry strength and wet strength are in the same range. In all cases, excluding wet reference, the standard deviation is relatively great.

Conclusions

The research hypotheses were well supported by the study. First, the wet strength of regular linear friction welded birch was poor, and second, after a post-manufacture thermal modification the wet strength was almost on the same level as the dry strength, yet on a level minor to the dry strength of the reference set. The results can be explained the well known phenomena that thermal modification weakens the mechanical properties of wood but increases the dimentional stability of the wood. The results suggest that the method functions for small scale specimens of linear friction welded birch.