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Finger jointing of green Black pine wood (*Pinus nigra L.*)

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Abstract This research work presents a study on the finger jointing of green Black pine wood (*Pinus nigra L.*) using a phenol resorcinol formaldehyde adhesive. The effect of finger joint orientation (vertical or horizontal fingers) was also examined. In general, the results from the measurements of modulus of rupture and modulus of elasticity of green glued finger-jointed specimens indicated that green gluing of Black pine wood is feasible.

1 Introduction

Early research on gluing of green wood, often called green gluing, dealt with conventional phenol resorcinol formaldehyde (PRF) and melamine urea formaldehyde (MUF) adhesives, which were used for gluing in a heated press to accelerate adhesive curing (Murphey and Nearn 1956; Currier 1960; Raknes 1967). Strickler (1970) and Troughton and Chow (1980) developed new methods for end gluing of wood and succeeded in joining green wood with moisture contents above fibre saturation point. These methods involved the use of heat, both to pre-dry ends of green wood and to accelerate curing of the adhesive. The method developed by Troughton and Chow was implemented successfully in several factories in Canada. Continued research work (Tiedeman and Sanclemente 1973; Tiedeman et al. 1973; Baxter and Kreibich 1973; Kreibich 1974; Pizzi and Roux 1978; Pizzi and Cameron 1984; Kreibich and Hemingway 1985, 1987; Maun and Cooper 1999; Sterley 2004; Pommier et al. 2005) on the same topic gave encouraging results. In the 90's, an adhesive system known as Greenweld appeared in the market for finger jointing green, unseasoned, never-dried timber. This system consisted of a modified PRF resin, hardener and ammonia as curing accelerator (Parker et al. 1991; Parker 1994). Greenweld has been successfully implemented in the wood industry in New Zealand, Australia, United Kingdom, and the USA. A two-component adhesive, named SoyBond, based on hydrolysed soy protein and conventional PRF adhesive was also introduced for jointing of green timber (Kreibich et al. 1998). Lipke (2005) demonstrated his practical experience in using the Greenweld technology for producing green glued finger jointed wall studs. In addition, a pilot plant for scaling up the finger-jointing of green maritime pine was set up in France with participation of several industrial wood companies (Elbez 2006).

The objective of this work was to investigate the efficiency of green gluing a typical European softwood, namely Black pine (*Pinus nigra L.*) by evaluating the bending strength, i.e. the modulus of rupture (MOR), and the bending modulus of elasticity (MOE) of finger jointed specimens.

2 Experimental

Green *Pinus nigra* wood, a common Greek softwood species originating from the Pindos area, was used in this work. Physical defects of pine wood were first removed according to EN 385 (2001) standard and tests were performed with small clear specimens having cross-sections of 20 mm ×

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20 mm. Average moisture content was approx. 72%, ranging between 55% and 85%. Finger profiling of the specimens was performed by profiling cutter heads with the following characteristics: 4 and 10 mm finger length and 1.6 and 3.8 mm pitch, respectively. The adhesive used was phenol resorcinol formaldehyde (PRF) resin, brand type Aerodux 185 (Dynea ASA). This resin is a cold-setting, weatherproof and gap-filling adhesive for exterior structural components. A hardener HRP 155 (Dynea ASA) was used and mixed with the resin with a mixing ratio of 1:5. The glue mixture was applied by small brush on one side of the joints. The other side of the joints was shortly dipped in ammonia solution (25%) which was used as accelerator. The joints were then closed and applied end pressure (approx. 6 N/mm^2) was accomplished with a manually operated press and lasted 2 h. It should be noted that the duration of finger-joint pressure application of 2 h is rather unusual for finger joints manufactured for structural applications. The green glued finger jointed specimens as well as solid pine wood controls were conditioned (20 °C temperature, 65% relative humidity) to a moisture content of ∼11.5% for eight weeks and cut to dimensions of 20 mm × 20 mm × 360 mm. Black pine wood was found to have an average air dry density of ∼0.53 g/cm^3. The bending strength, MOR, and the bending MOE of the tested specimens were evaluated according to ISO 10983 (1999) and DIN 52186 (1978) standards (3-point bending). In addition, the effect of finger joint orientation, vertical or horizontal fingers, was examined. For each finger length, thirty (30) specimens were tested according to EN 385:2001 standard. In all tests, the loading of the glued specimens was carried out in the tangential direction.

3 Results and discussion

The results of this work are shown in Tables 1 and 2. The solid Black pine wood controls had a MOR strength of 86.6 MPa (Table 1). The MOR of the specimens with 4 mm long fingers was 61.1 MPa and 59.0 MPa in the horizontal and vertical orientation, respectively. For the finger joints with fingers of 10 mm long specimens the mean MOR values varied from 65.9 MPa (horizontal orientation) to 75.6 MPa (vertical orientation). In almost all of the specimens, a wood failure mode was observed. In case of the fingers with 4 mm length, the bending strength was almost equal in both finger orientations; notably higher mean MOR values were obtained with the vertical finger jointed pine wood for fingers with 10 mm length. As expected, the bending strength was dependent on the finger length, since higher strength values were obtained for the longer fingers (i.e., 10 mm length fingers).

The MOE of the solid pine wood controls was 10.5 GPa (Table 2). The MOE of the 4 mm long finger jointed specimens was estimated to be 9.4 GPa and 9.5 GPa in the horizontal and vertical orientation, respectively. For the 10 mm long specimens, the MOE varied from 9.5 GPa (horizontal orientation) to 10.5 GPa (vertical orientation). In other words, these results indicate that the MOE values for green glued Black pine wood were almost in the same levels as those of the solid wood controls.

Hence, this work indicates that green gluing of a softwood species such as *Pinus nigra* wood is viable as from the resulting MOR and MOE properties of green glued joints. However, more thorough studies on the final properties of green-glued pine wood such as resistance to high temperatures, weather conditions and moisture should be carried in the future.

Table 1 Bending strength of green-glued finger jointed Black pine wood
Tab. 1 Biegefestigkeit von im frischen Zustand verklebten Keilzinkenverbindungen aus Schwarzkiefernholz

Solid wood	Modulus of rupture, MOR (MPa)			
	Horizontal fingers		Vertical fingers	
	Finger length (mm)		Finger length (mm)	
	4	10	4	10
86.6	61.1	65.9	59.0	75.6
(6.6)	(6.8)	(6.9)	(6.5)	(6.6)

Mean values and standard deviations in parentheses

Table 2 Bending modulus of elasticity (MOE) of green-glued finger jointed Black pine wood
Tab. 2 Biege-Elastizitätsmodul (MOE) von im frischen Zustand verklebten Keilzinkenverbindungen aus Schwarzkiefernholz

Solid wood	Modulus of elasticity, MOE (GPa)			
	Horizontal fingers		Vertical fingers	
	Finger length (mm)		Finger length (mm)	
	4	10	4	10
10.5	9.4	9.5	9.5	10.5
(1.3)	(0.8)	(0.9)	(1.1)	(0.9)

Mean values and standard deviations in parentheses

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References

Baxter GF, Kreibich RE (1973) A fast-curing phenolic adhesive system. For Prod J 23(1):17–22

Currier RA (1960) Finger jointing at high moisture content. For Prod J 10(6):287–293

DIN 52186 (1978) Testing of wood; bending test. DIN German Institute for Standardization

Elbez G (2006) A new pilot plant for finger-jointing green maritime pine in France. Announcement in COST action E34 meeting, working group II, 27–28 Sept., Brussels, Belgium

EN 385 (2001) Finger jointed structural timber: performance requirements and minimum production requirements. British Standards Institution

ISO 10983 (1999) Timber structures—solid timber finger-jointing—production requirements. ISO International Organization for Standardization

Kreibich RE (1974) High speed adhesives for the wood gluing industry. Adhes Age 17:26–33

Kreibich RE, Hemingway RW (1985) Condensed tannin-resorcinol adducts in laminating adhesives. For Prod J 35(3):23–25

Kreibich RE, Hemingway RW (1987) Condensed tannin-sulfonate derivatives in cold-setting wood laminating adhesives. For Prod J 37(2):43–46

Kreibich RE, Steynberg PJ, Hemingway RW (1998) End jointing green lumber with SoyBond. In: Proceedings of 2nd biennial residual wood conference, Swanson JS, November 4–5, Richmond, BC, USA, pp 28–36

Lipke M (2005) Green glued fingerjoint wall studs: industrial experience of Hampton Lumber Mills. In: Källander, B (ed), Proceedings of COST action E34 international workshop “Green gluing of wood: process, products, market”, 7–8 April 2005, Böras, Sweden, pp 91–98

Maun K, Cooper G (1999) Re-engineering softwood for constructional use by wet (green) gluing. In: Berti, S, Macchioni, N, Negri, M, Rachello, E (eds), Proceedings of eurowood technical workshop “Industrial end-uses of fast-grown species”, Florence, Italy, pp 47–59

Murphey WK, Nearn WT (1956) Effect of moisture content on the appearance of resorcinol glue lines in laminated oak lumber. For Prod J 6:194–197

Parker JR, Taylor JB, Placket DV, Lomax RE (1991) Method of joining wood. US Patent No 5,674,338

Parker JR (1994) Greenweld process for engineered wood products. In: Proceedings of the int panel and engineered wood technology exposition, 5 Oct. 1994, Atlanta, Georgia, USA, pp 10–17

Pizzi A, Roux DG (1978) The chemistry and development of tannin-based weather- and boil- proof cold setting and fast-setting adhesives for wood. J Appl Polym Sci 22:1945–1954

Pizzi A, Cameron FA (1984) Fast-set adhesives for glulam. For Prod J 34(9):61–68

Pommier R, Coureau JL, Legrand G (2005) Finger jointing of green maritime pine timber: evaluation of different adhesives and determination of resulting bending strength. In: Källander B (ed), Proceedings of COST action E34 international workshop “Green gluing of wood: process, products, market”, 7–8 April 2005, Böras, Sweden, pp 48–54

Raknes E (1967) Fingerjointing with resorcinol glues at high wood moisture content. Report No 32, The Norwegian Institute of Wood Working and Wood Technology, Blindern, Norway

Sterley M (2004) Green gluing of wood. Licentiate thesis. Department of Civil and Architectural Engineering, KTH—Royal Institute of Technology, Stockholm, Sweden

Strickler MD (1970) End gluing of green lumber. For Prod J 20(9):47–51

Tiedeman GT, Sanclemente MR (1973) The chemistry of fast-curing phenolic adhesives: part I. J Appl Polym Sci 17:1813–1818

Tiedeman GT, Sanclemente MR, HA Smith (1973) The chemistry of fast-curing phenolic adhesives: part II. J Appl Polym Sci 17:1819-1832

Troughton GE, Chow S (1980) Finger jointing kiln dried and unseasoned white spruce lumber using the WFPL method. For Prod J 30(12):48–49