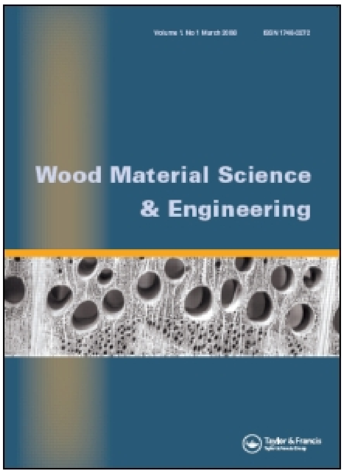

Wood Material Science and Engineering
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t741771155

Green gluing of oak wood (Quercus conferta L.) with a one-component polyurethane adhesive

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Online Publication Date: 01 September 2008

To cite this Article Karastergiou, Sotirios, Mantanis, George I. and Skoularakos, Konstantinos(2008)'Green gluing of oak wood (Quercus conferta L.) with a one-component polyurethane adhesive',Wood Material Science and Engineering,3:3,79 — 82

To link to this Article: DOI: 10.1080/17480270802605537

URL: http://dx.doi.org/10.1080/17480270802605537

Wood Material Science and Engineering, 2008; 3–4: 79–82

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SHORT NOTE

Green gluing of oak wood (*Quercus conferta* L.) with a one-component polyurethane adhesive

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Abstract
This research work presents a study on the properties of finger jointing green oak wood (*Quercus conferta* L.) using a one-component polyurethane 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 the green gluing of a high-density species such as oak wood is feasible.

Keywords: *Adhesives, finger-jointing, green wood gluing, oak wood, polyurethanes.*

Introduction

Green gluing, or wet gluing, of wood refers to gluing of unseasoned or green wood as opposed to conventional gluing of dried wood. There is a growing interest today in green gluing of wood and its applications, especially for re-engineering and enhancing the quality of lower grade softwoods (Maun & Cooper, 1999).

Several technologies using a number of different adhesive systems for green gluing have been developed over the years (e.g. see the review in Sterley, 2005). In the very beginning, melamine urea formaldehyde (MUF) and phenol resorcinol formaldehyde (PRF) resin systems were used (Källander, 2005).

Parker and co-workers enabled the development of a resin system, known as Greenweld, for finger-jointing green softwood species (Parker *et al.*, 1991; Parker, 1994). This technology is today widespread in countries such as the USA, Australia and New Zealand. Lipke (2005) provided practical experience using the Greenweld technology for green-glued finger-jointed wall studs. Properzi *et al.* (2001*a*, b, 2003) carried out tests using a new structural cold-setting MUF resin system which was successfully implemented for gluing green wood. A two-component adhesive, named SoyBond, based on hydrolysed soy protein and conventional PRF adhesive, has also been introduced for jointing of green timber (e.g. Kreibich *et al.*, 1998).

An important area of research is the wood–adhesive bond performance, which deals with the properties of the cured adhesive in the bond line and its behaviour when stresses and climatic degradation might occur. In particular, the bond performance between wood and polyurethane (PUR) adhesives has been investigated (Vick & Okkonen, 1998, 2000; Maun & Cooper, 1999; Verreault, 1999, 2000; George *et al.*, 2003; Sterley, 2004). Sterley (2004) found that the tensile strength in a dried state of green-glued finger joints is higher using a one-component PUR adhesive compared with using modified and conventional PRF adhesives. The general observation was that the PUR adhesive was more ductile and created stronger joints because of a higher fracture energy. Other investigations have concentrated on studying the final properties of green-glued wood such as creep, resistance to high temperature and resistance to moisture (Lange *et al.*,

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(Received 24 August 2007; accepted 25 August 2008)

ISSN 1748-0272 print/ISSN 1748-0280 online
DOI: 10.1080/17480270802605537

Table I. Modulus of rupture (MOR) of green-glued finger-jointed oak wood.

MOR (MPa)				
Solid wood	Horizontal fingers		Vertical fingers	
	Finger length (mm)			
	4	10	4	10
99.2 ± 5.9	62.2 ± 5.9	71.6 ± 7.1	68.3 ± 7.1	74.9 ± 8.1

Note: data are shown as mean ± SD.

2000; Rajakaruna, 2001; Richter & Schirle, 2002; Serrano, 2004; Na *et al.*, 2005).

Several studies have also demonstrated equal or superior strength for green-glued finger joints compared with dry-bonded reference joints, showing that acceptable joint strength can be achieved (Sterley, 2004, 2005; Pommier *et al.*, 2005; Lipke, 2005; Källander, 2005; Pommier & Elbez, 2006). In addition, a pilot plant for scaling up the technology of finger-jointing green maritime pine is underway in France with the participation of many industrial companies and sawmills (Elbez, 2006).

The objective of this work was to investigate the potential of finger-jointing green oak wood (*Quercus conferta* L.), using a one-component PUR adhesive. The work presented here includes the results from measurements of modulus of rupture (MOR) and modulus of elasticity (MOE) of green-glued finger-jointed specimens.

Materials and methods

Green oak wood (*Q. conferta* L.), a common Greek hardwood species characterized by short dimensions, originating from Pindos mountain area, was used in this work. Oak wood with an average density of 0.76 g cm^{-3} (0.74–0.79 g cm^{-3}) was cut into small specimens with dimensions 50 × 30 × 400 mm^3, physical defects having first been removed according to EN 385/2001. The average moisture content was approximately 57%, ranging between 45% and 75%. 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 a one-component PUR adhesive donated by the resin manufacturer Dynea ASA (Prefere 6000), and was applied by a small brush on one side of the joints. The applied end pressure (~6–8 N mm^{-2}) was accomplished with manually operated press and lasted for 60 s. The green-glued finger-jointed specimens as well as the solid oak wood controls were conditioned (20°C temperature, 65% relative humidity) to a moisture content of ~ 12% and then cut to the dimensions 20 × 20 × 360 mm^3. The bending strength, i.e. MOR, as well as the bending MOE, of the tested specimens were evaluated according to standards ISO 10983/1999 and DIN 52186/1978 (three-point bending). In addition, the effect of finger-joint orientation (vertical or horizontal fingers) was examined. For each finger length, 30 specimens were tested according to EN 385/2001. In all tests, the loading of the glued specimens was carried out in the tangential direction.

Results and discussion

The results are shown in Tables I and II. The solid oak wood controls had an average MOR strength of 99.2 MPa (Table I). The MOR of the 4 mm long finger-jointed specimens was 62.2 and 68.3 MPa in the horizontal and vertical orientation, respectively. For the 10 mm long specimens, the MOR varied from 71.6 MPa (horizontal orientation) to 74.9 MPa (vertical orientation). A wood failure mode was

Table II. Modulus of elasticity (MOE) of green-glued finger-jointed oak wood.

MOE (GPa)				
Solid wood	Horizontal fingers		Vertical fingers	
	Finger length (mm)			
	4	10	4	10
10.7 ± 1.3	10.0 ± 0.8	10.7 ± 0.9	11.6 ± 1.4	12.2 ± 1.3

Note: data are shown as mean ± SD.

observed in almost all of the specimens. The bending strength was clearly dependent on the finger orientation, since in all instances higher MOR values were obtained with the vertical finger-jointed wood.

The MOE of the solid oak wood controls was 10.7 GPa (Table II). The MOE of the 4 mm long finger-jointed specimens was estimated to be 10.0 and 11.6 GPa in the horizontal and vertical orientation, respectively. For the 10 mm long specimens, the MOE varied from 10.7 GPa (horizontal orientation) to 12.2 GPa (vertical orientation). In other words, these results indicate that the MOE values for green-glued oak wood were on the same level as those for the solid wood controls. As for the MOR, a higher MOE was found in all cases for the specimens with 10 mm length and for specimens with vertical fingers.

This work indicates that green-glued finger-jointing of a high-density species such as oak wood is feasible, with regard to the resulting MOR and MOE properties. However, more trials using the same wood species, which is available in large quantities in southern Europe, and other adhesive systems, should be carried out.

Acknowledgements

The financial aid from the National Ministry of Education (EPEAEK Office) for this research work through "Archimedes Programme II" is highly acknowledged. The authors thank also Mr Egil Ormstad and Mr Ronny Bredesen, as well as the resin manufacturer Dynea ASA, for the kind supply of polyurethane glue.

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