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Session III. – Wood processing and modification

Poster session

Bending strength of the finger jointed Chestnut wood

I. Barboutis[1]

Abstract

In this research, the utilization of small dimensions Chestnut wood (Castanea sativa Mill.) by finger jointing in the production of high-added-value products, was evaluated. Particularly, the effects of four finger lengths (4mm, 10mm, 15mm and 20mm) and of the orientation of the fingers on static bending strength properties (modulus of rupture and modulus of elasticity), were investigated. The finger jointed Chestnut wood was connected across the grain with a polyvinyl-acetate based adhesive, varying in durability class from D1, D2 to D3, according to EN 204:2001 standard.

Modulus of rupture (MOR) of Chestnut wood joints ranged from 55.3 N/mm^2 to 83.5 N/mm^2, which corresponds to a percentage of 57.7% to 87.2% respectively, in relation to that of the control solid wood (95.8 N/mm^2). It was found that the 4mm finger length led to the lower MOR values and the 20mm finger length to the higher MOR values, whereas, the samples with a horizontal finger orientation showed slightly higher MOR values, in relation to that of a vertical finger orientation. Also, it was found that the durability class of the PVAc adhesive affected significantly the MOR values. The use of the D1 adhesive led to the lower MOR values and the use of the D3 adhesive led to the higher MOR values, whereas, the D2 adhesive resulted in intermediate MOR values.

Modulus of elasticity (MOE) of all the investigated joints was found to be slightly greater in mean values than that of the solid wood.

Key words: chestnut wood, finger joint, PVAc, bending strength

Introduction

Although, finger jointing has been in use in wood industry for many years, yet it is only with the decline in resource quality that interest in it for furniture has increased. Nonstructural finger joints are used if strength is not a primary concern. The benefits of finger joints in furniture and cabinet manufacturing are: 1) clear lumber from low grade stock, 2) less short length of waste material, and 3) increased yield of usable long parts (Jokerst 1981, Nestic and Milner 1993). Chestnut wood, thanks to its good technological characteristics and the very much appreciated aesthetic properties is suitable for a variegate range of products, especially for furniture production and joinery (Fonti 2002). For Greece, the interest of improving chestnut wood utilizations is exceptionally strong, because of the small dimensions of chestnut wood produced from coppice managed stands of chestnut trees. Polyvinyl acetate (PVAc) is one of the most common adhesives used in nonstructural applications. Polyvinyl resin emulsions are thermoplastic, softening if temperature is raised to a particular level and hardening again when cooled. They are prepared by emulsion polymerization of vinyl acetate and other monomers in water under controlled conditions. In emulsified form, the PVAc is dispersed in water and has a consistency and nonvolatile content generally comparable to thermosetting resin adhesives. PVAc is capable of producing strong and durable bonds on hardwood and hardwood - derived products. Although PVAc adhesives are not generally recommended for joints under continuous load or subjected to high temperatures and/or high humidity, these adhesives can be formulated for improved performance under such conditions. Thermosetting polyvinyl emulsions are modified PVAc emulsions and are more resistant to heat and moisture than are ordinary PVAc glues, and perform well in most nonstructural interior and protected exterior uses (Jokerst 1981, Sellers et al 1988, River 1994).

Limited information is available on end gluing hardwoods, in contrast to softwoods, which have been extensively investigated and industrially utilized. Pena (1999) studied the suitability of producing nonstructural finger joints made from beech wood (*Fagus sylvatica*) and European oak (*Quercus*

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petraea). Barboutis et al (2005) and Vassiliou et al (2006) studied the effect of finger length and the effect of PVAc bonding on the strength of finger-jointed steamed and unsteamed beech wood (*Fagus sylvatica*), correspondingly. The strength properties of some finger jointed oakwoods have been studied by Barboutis et al (2005) in holm oakwood (*Quercus ilex* L.), by Vassiliou et al (2005), and by Karastergiou et al (2006) in turkey oak (*Quercus cerris* L.).

The objective of the study presented here was to examine the effects of four finger lengths (4mm, 10mm, 15mm, and 20mm) with respect to the PVAc gluing (D1, D2 and D3 durability classes according to EN 204), and finger orientation on bending properties of finger jointed chestnut wood (*Castanea sativa* Mill.).

Materials and methods

Experiments were carried out with chestnut wood with dimensions 50 x 30 x 400 mm. Natural defects were removed by trimming according to EN 385:2001. The material was placed in a conditioning room at 20^o C and 65% relative humidity and allowed to reach a nominal equilibrium moisture content (EMC) of 12%. Four finger joints were performed by profiling cutterheads with the characteristics given in **Table 1**.

Following finger jointing, the blocks were bonded in keeping with the technical recommendations provided by the adhesive manufacturers. Three classes of Polyvinyl-acetate (PVAc) based adhesives (D1, D2, and D3 durability classes) for interior use, were studied.

A one-face glue application by brush was used. The assembled joints were pressed manually with a constant end pressure for 60 sec. The jointed pieces were then cut to final dimensions 20 x 20 x 360 mm to produce bending strength samples. Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) tests were performed in accordance with ISO 10983:1999 and DIN 52186:1978 standards with a Shimatzu machine. For each finger length the influence of the finger orientation (horizontal and vertical) with regard to the direction of the load was also examined (**Figure 1**). For every parameter 15 specimens were tested according to EN 385:2001. After each bending test two samples were cut from each side of the failed joint and moisture content (MC) and density were determined.

Results and discussion

Modulus of Rupture (MOR)

Mean values of the bending strength properties (MOR) measured on the chestnut wood are given totally in **Table 2**. The average density of the specimens was 0.57 g/cm^3 (std 0.06) and the average moisture content 10.55 % (std 0.61).

We can see in this table, that the bending strength (MOR) of the tested specimens fluctuated from 55.3 up to 83.5 N/mm^2 and affected by the finger length (4mm, 10mm, 15mm, and 10mm), the durability class of adhesive (D1, D2, D3), and the orientation of the finger joints (horizontal and vertical). The higher percentage values compared to the solid wood values, appeared in the specimens with 20mm lengths with D3 adhesive class (85.4% in vertical and 87.2% in horizontal fingers).

Table 1. *Fingers configuration used in research*

Fingers configuration	Values			
Length (l) (mm)	4	10	15	20
Pitch (p) (mm)	1.6	3.8	3.8	6.2
Tip (t) (mm)	0.4	0.16	0.11	0.08
Angle (α^o)	12.0	11.0	7.5	9.0

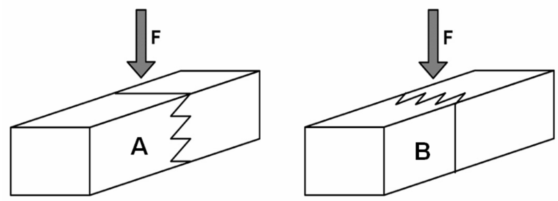

Figure 1. *Orientation of finger joints and loading direction in samples (A: horizontal and B: vertical fingers).*

Table 2. *Modulus of Rupture (MOR) of the finger jointed chestnut wood*

Adhesive Durability class	Modulus of Rupture (MOR)* (N/mm^2)									
	Finger length (mm)								Solid wood	
	4mm		10mm		15mm		20mm			
	N/mm^2	sd	N/mm^2	sd	N/mm^2	sd	N/mm^2	sd	N/mm^2	sd
Vertical fingers										
D1	55.3	7.8	65.4	7.3	69.4	9.0	73.2	11.8	95.8	15.1
D2	63.5	10.5	70.5	10.2	74.6	8.2	76.7	8.1		
D3	69.6	7.7	75.5	7.0	79.3	9.5	81.8	7.6		
Horizontal fingers										
D1	59.7	8.1	67.4	7.9	70.0	8.5	73.1	8.2		
D2	64.2	12.1	69.2	12.2	75.0	8.4	77.8	5.9		
D3	70.8	8.0	76.7	8.6	80.6	8.9	83.5	7.0		

* Mean values of 15 samples.

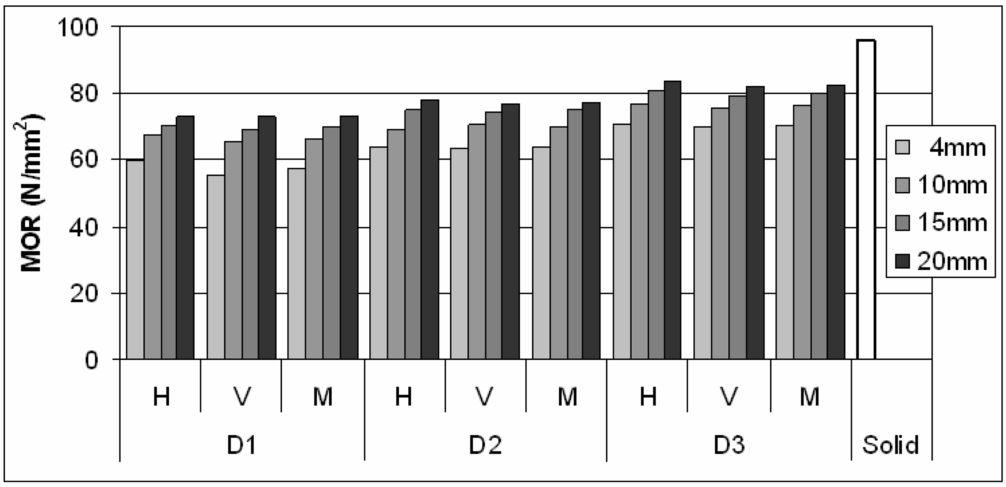

Figure 2. *Effect of finger length on MOR of the chestnut wood (Where: H is horizontal, V is vertical and M is without orientation of fingers)*

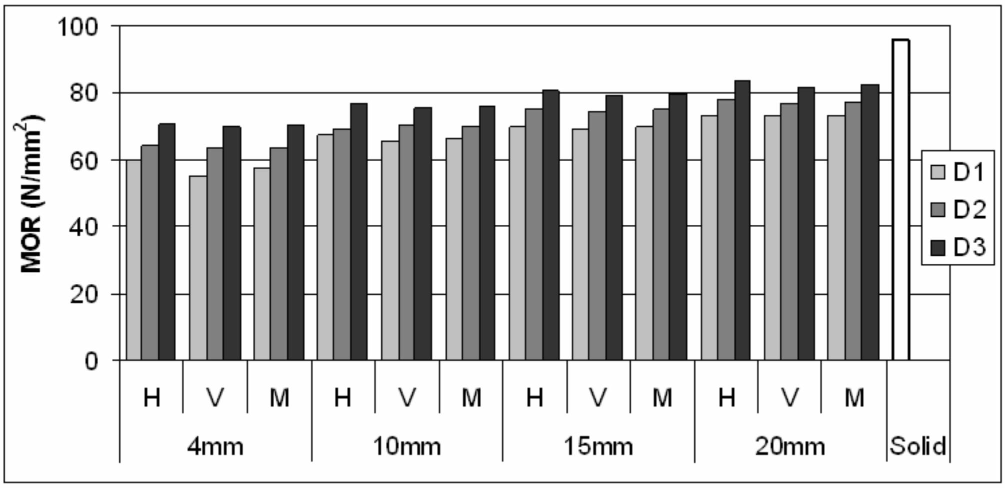

Figure 3. *Effect of adhesive class on MOR of the chestnut wood*
(Where: H is horizontal, V is vertical and M is without orientation of fingers)

We see that MOR is affected by the orientation of the fingers. It was found that, in most cases the horizontal fingers appeared higher MOR values (about 2%) than the vertical ones (with the exception of the specimens with 10mm finger length, bonded with D2 adhesive class, and of the specimens with 20mm finger length, bonded with D1 adhesive class).

Effect of finger length

The results in **Table 2** show that MOR is affected by the finger length (**Figure 2**). In all cases, specimens with 20mm finger length showed higher values of MOR than the specimens with smaller finger lengths. The increase ranged in samples with vertical fingers from 2.8% in comparison with specimens of 15mm finger length bonded with D2 adhesive class up to 32.4% in comparison with specimens of 4mm finger length bonded with D1 adhesive class.

The corresponding increase, in samples with horizontal fingers ranged from 3.7% in comparison with specimens of 15mm finger length bonded with D2 adhesive class up to 22.4% in comparison with specimens of 4mm finger length bonded with D1 adhesive class.

Effect of adhesive class

Table 2 and **Figure 3** show, that MOR of all the finger lengths of chestnut wood affected by the PVAc adhesive class, in the same way.

In samples with vertical orientation of fingers, specimens bonded with D3 adhesive class showed the higher values of MOR (from 69.6 up to 81.8 N/mm^2), specimens bonded with D1 adhesive class the lower values (from 55.3 up to 73.2 N/mm^2), and specimens bonded with D2 adhesive class intermediate values (from 63.5 up to 76.7 N/mm^2). In the case of specimens with 20mm finger length the increase in MOR by replacing the class of adhesive from D1 to D2 was 4.8%. Correspondingly, the increase in MOR by replacing the class of adhesive from D2 to D3 was 6.7%. In the case of specimens with 15mm finger length the increase in MOR by replacing the class of adhesive from D1 to D2 was 7.5%. Correspondingly, the increase in MOR by replacing the class of adhesive from D2 to D3 was 6.3%. In the case of specimens with 10mm finger length the increase in MOR by replacing the class of adhesive from D1 to D2 was 7.8%. Correspondingly, the increase in MOR by replacing the class of adhesive from

D2 to D3 was 7.1%. In the case of specimens with 4mm finger length the increase in MOR by replacing the class of adhesive from D1 to D2 was 14.8%. Correspondingly, the increase in MOR by replacing the class of adhesive from D2 to D3 was 9.6%.

In samples with horizontal orientation of fingers, specimens bonded with D3 adhesive class showed the higher values of MOR (from 70.8 up to 83.5 N/mm^2), specimens bonded with D1 adhesive class the lower values (from 59.7 up to 73.1 N/mm^2), and specimens bonded with D2 adhesive class intermediate values (from 64.2 up to 77.8 N/mm^2).

Table 3. *Modulus of Elasticity (MOE) of the finger jointed chestnut wood*

Adhesive Durability class	Modulus of Elasticity (MOE)* (kN/mm^2)									
	Finger length (mm)								Solid wood	
	4mm		10mm		15mm		20mm			
	kN/mm^2	sd	kN/mm^2	sd	kN/mm^2	sd	kN/mm^2	sd	kN/mm^2	sd
Vertical fingers									**10.70**	**1.64**
D1	12.03	1.32	12.06	1.69	9.82	1.48	10.48	1.36		
D2	10.64	1.07	11.15	1.14	11.27	1.09	10.79	1.23		
D3	11.37	1.16	11.79	1.27	11.54	1.24	11.70	1.31		
Horizontal fingers										
D1	12.21	1.67	12.10	1.43	10.08	1.42	10.91	1.52		
D2	10.07	1.45	11.19	1.59	11.20	1.30	11.41	1.08		
D3	11.26	1.15	12.01	1.44	12.18	1.21	11.66	1.45		

* Mean values of 15 samples.

Modulus of Elasticity (MOE)

As we can see in **Table 3**, the MOE of the tested specimens ranged from 9.82 kN/mm^2 (in specimens with 15mm finger length horizontally oriented, bonded with D1 adhesive class) up to 12.21 kN/mm^2 (in specimens with 4mm finger length vertically oriented, bonded with D3 adhesive class). From these results it is concluded that finger jointing of the chestnut wood didn't affect the MOE of the tested specimens in a distinct manner, which ranged in the same levels of the control solid wood (10.7 kN/mm^2). The same conclusion is confirmed by the results given by Pena (1999) for finger jointed beech wood and oak wood.

Conclusions

Chestnut wood has a very good potential in finger jointed nonstructural uses. It is used in many furniture and joinery applications. Within the range of parameters studied the bending strength (MOR) of the finger jointed chestnut wood was affected by the type of the PVAc adhesive (D1, D2, D3 durability classes), the finger length (4mm, 10mm, 15mm, and 20mm), and the orientation of the finger joints (horizontal, vertical).

- Specimens with 20mm finger length showed higher values of MOR than the specimens with smaller finger lengths.
- Specimens bonded with D3 adhesive class showed the higher values of MOR, specimens bonded with D1 adhesive class the lower values, and specimens bonded with D2 adhesive class intermediate values.

- MOR affected by the orientation of the fingers. Specimens with horizontal fingers appeared slightly higher MOR values than the specimens with vertical ones (about 2%).

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