PVAc BONDING OF FINGER-JOINTED BEECH WOOD ORIGINATED FROM ALBANIA AND GREECE

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ABSTRACT: Beech wood is considered as one of the most important species for the furniture production in Europe. In this research, the effects of the finger length (4.5 mm, 6.5 mm and 9.0 mm), and material origination (Albania, Greece) on bending strength of finger-jointed steamed and unsteamed beech wood (Fagus sylvatica), were studied. Modulus of rupture (MOR) and Modulus of elasticity (MOE) of unsteamed and steamed wood joints, were measured. The MOR of unsteamed wood joints ranged from 22.28 to 47.41 N/mm^2, whereas the MOR of the steamed wood joints ranged from 22.73 to 47.52 N/mm^2. In both materials handling (steamed – unsteamed) and both originations (Albania and Greece), the specimens with 9.0 mm finger length showed higher MOR values. The MOE of the tested specimens fluctuated from 8681.4 up to 11674.5 N/mm^2. The research results obtained were discussed in order to evaluate differences in finger jointing of beech wood material originated from the two countries, which could affect its utilization potentials.

Key words: finger joint, PVAc bonding, bending strength**,** beech wood, Albania, Greece

1. INTRODUCTION

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).

In the design of a finger-joint, there are four variables, namely pitch, length, slope, and width (Fig. 1). Research into the effect each variable has on joint strength is complicated because fixing three of them defines the fourth and establishes the joint design. Consequently, one cannot study the effect one variable has on joint strength independently of the other three. Finger length affects joint strength significantly only when it is reduced to approximately the length of a single wood fiber. The main difference between a structural and a nonstructural finger-joint design is the width of the fingertip. In general, fingertips broader than 1.5mm should probably be classified as nonstructural or at least semistructural. At the other end of the scale, fingertips should not exceed 0.8 mm to develop high strength structural joints (Strickler 1980).

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. 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). Ordinary PVAc glues are marketed for use at room temperatures, classified in durability classes (D1, D2, D3 and D4), according to EN-204:2001 Standard.

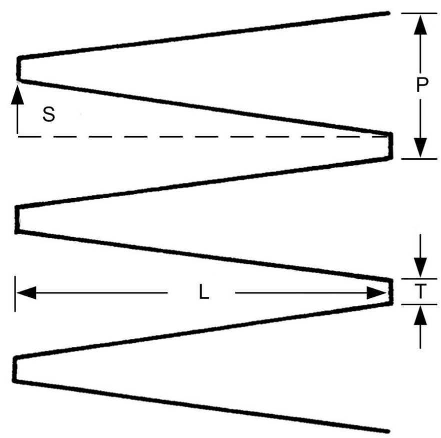

Fig. 1. Design variables of a finger-joint: Pitch (P), Length (L), Slope (S), and Width of fingertip (T).

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). He examined the effect of the geometry of finger joint in bending strength, using 9 mm and 12 mm finger lengths glued with melamine-uria-formaldehyde (MUF) and epoxy resin glues, and concluded that MOE of the jointed specimens did not differ significantly from the unjointed ones. On the contrary, the jointed specimens presented lower values of MOR than the unjointed ones (43%). Aicher et al (2001) studied the tension strength of finger joints in beech wood with 20 mm finger length and glued with melamine glue. They found that the mean tension strength of the finger jointed specimens was 70 ± 11 N/mm^2.

Vassiliou *et al.* (2007) studied the effect of three durability classes of PVAc bonding, and of two finger lengths (4mm and 10mm) on bending strength of steamed and unsteamed beech wood. They found that the higher MOR values derived from D3 adhesive class and 10mm finger length, and the lower MOR values derived from D1 durability class of adhesive, and the 4mm finger length.

The objective of the study presented here was to examine the effects of material origination and finger length on bending strength of finger jointed steamed and unsteamed beech wood (Fagus sylvatica), originated from Albania and Greece, and bonded with PVAc adhesive of D3 durability class.

2. MATERIALS AND METHODS

Experiments were carried out with steamed and unsteamed beech wood originated from Albania and Greece. Both originations material were transferred in the Wood Products Laboratory (Thessaloniki, Greece), and were processed under the same conditions. 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%. Three finger joints (the most commonly used in praxis), were performed by profiling cutterheads with the following characteristics shown in Table 1 and Figure 2. Following finger jointing, the blocks were bonded in keeping with the technical recommendations provided by the adhesive manufacturers. The D3 durability class of a Polyvinyl-acetate (PVAc) based adhesive for interior use, was 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 every parameter 30 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.

Table 1

Configuration of the fingers used in the study

Fingers configuration	**Values**		
Length (l) (mm)	4.5	6.5	9.0
Pitch (p) (mm)	4.95	6.95	6.95
Tip (t) (mm)	1.3	1.3	1.3
Slope (mm/1mm)	0.28	0.37	0.24

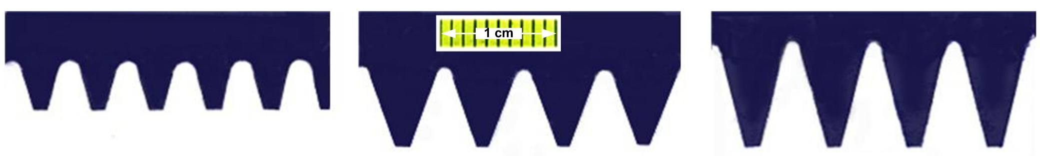

Fig. 2. Finger configuration

Mean values of the density and the moisture content of the material used in the study are given in Table 2.

Table 2

Wood properties of the material used in the study

Properties	Country			
	Albania		Greece	
	Unsteamed	Steamed	Unsteamed	Steamed
	Mean St.D.	Mean St.D.	Mean St.D.	Mean St.D.
Density (g/cm^3)	0.634 (0.022)	0.586 (0.044)	0.605 (0.052)	0.595 (0.022)
Moisture content (%)	10.51 (0.21)	9.54 (0.17)	10. 1 (0.171)	10.4 (0.235)

3. RESULTS AND DISCUSSION

3.1.Modulus of Rupture (MOR)

Mean values of the bending strength measured on both the steamed and the unsteamed beech wood samples, originated from the two countries, are shown in the following Table 3. The bending strength (MOR) of the tested specimens ranged from 23.71 up to 47.52 N/mm^2 and affected by the finger length (4.5mm, 6.5mm, and 9.0 mm), the material treatment (Steamed, unsteamed), and the origination of the material. The higher percentage values compared to the solid wood values, appeared in the specimens with 9.0 mm finger length

(45.0% in steamed material originated from Albania, and 44.5% in steamed wood originated from Greece).

Table 3

Bending strength of the finger jointed beech wood

Material	Country							
	Albania				Greece			
	Finger length (mm)				Finger length (mm)			
	Solid	4.5	6.5	9.0	Solid	4.5	6.5	9.0
Unsteamed wood								
Bending strength (N/mm^2)•	118.14	29.11	23.71	41.91	108.71	35.97	22.28	47.41
Standard Deviation	11.21	3.51	2.86	3.86	5.77	3.68	2.67	4.46
Steamed wood								
Bending strength (N/mm^2)•	98.35	34.26	22.73	44.23	106.81	33.20	25.87	47.52
Standard Deviation	7.33	4.00	5.99	2.47	7.38	3.17	2.39	2.56

- *Mean values of 30 samples.*

The steaming of the beech wood was found to reduce the MOE of the solid wood of both originations, as expected, and resulted in higher values of MOR by finger-jointing in most cases, mainly due to better bonding achieved on (partly extracted) steamed wood.

The material from Albania was found to give lower values of MOR in most cases, which was attributed mainly to the effect of its higher wood density (0.634 g/cm^3) compared to the material originated from Greece (0.605 g/cm^3).

Table 3 and Fig. 3 show that MOR was mainly affected by the finger length. Specimens prepared with 9.0 mm finger length showed the higher values of MOR (from 41.91 up to 47.52 N/mm^2), specimens with 6.5mm finger length the lower values (from 22.73 up to 25.87 N/mm^2), and specimens with 4.5mm finger length intermediate values (from 29.11up to 35.97 N/mm^2).

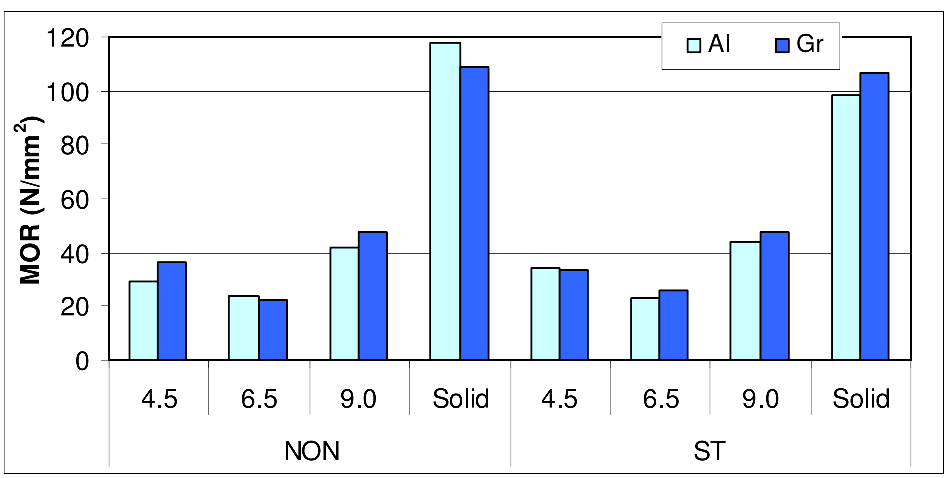

Fig. 3. Effect of finger length and origination on MOR of unsteamed and steamed beech wood

In all cases, specimens with 9.0 mm finger length showed higher values of MOR than the specimens with 4.5mm finger length. The increase ranged from 22.5% in steamed specimens originated from Albania up to 30.5% in unsteamed specimens originated also from Albania. It was found that the finger length of 6.5mm resulted in the worse values of MOR and failed to give intermediate values between the 4.5mm and the 9.0 mm finger lengths, as should be expected. This was attributed to the finger design of this finger which has a significantly greater finger slope (0.37), compared to 0.28 in the 4.5mm finger length and to 0.24 in the 9.0 mm finger length.

Analysis of variance of the mean bending strength (MOR) with the Posthoc = Bonferoni test (Oneway Anova), showed significant differences in MOR in most cases. Finger length, material treatment and origination had a significant effect on the MOR of the finger-jointed beech wood samples at the 0.05 significance level.

3.2. Modulus of Elasticity (MOE)

The corresponding mean values of the MOE measured are given in Table 4 and the following Fig. 4. As we can see, the MOE of the tested specimens ranged from 8,681.4 N/mm^2 (in steamed specimens with 6.5mm finger length originated from Albania) up to 11,674.5 N/mm^2 (in unsteamed specimens with 4.5mm finger length originated from Greece). From these results it is concluded that finger jointing of both material treatment (steamed, unsteamed) resulted in, in most cases lower values of MOE compared to the corresponding solid wood values.

Table 4

Modulus of Elasticity of the finger jointed beech wood

Material	**Country**							
	Albania				**Greece**			
	Finger length (mm)				**Finger length (mm)**			
	Solid	4.5	6.5	9.0	Solid	4.5	6.5	9.0
Unsteamed wood								
MOE (N/mm^2)•	12853.2	9100.2	8890.9	8764.9	11643.0	11674.5	10545.2	10318.2
Standard Deviation	1625.0	1917.3	1087.8	1149.1	1129.7	1583.2	1200.8	893.0
Steamed wood								
MOE (N/mm^2)•	11295.4	9109.9	8681.4	9304.8	11163.8	9696.9	10253.2	11349.3
Standard Deviation	1304.7	1458.9	1194.3	955.8	1246.6	888.4	906.2	950.4

- *MOE = Modulus of Elasticity / Mean values of 30 samples.*

On the other hand, it was found that the beech wood originated from Greece resulted in greater mean values of MOE (10,846.0 N/mm^2 in unsteamed and 10,433.1 N/mm^2 in steamed wood), compared to the material originated from Albania (8,918.7 N/mm^2 in unsteamed and 9,032.0 N/mm^2 in steamed wood).

Regarding the Analysis of variance, it was found that the MOE of the Greek samples was not affected significantly by the finger length and the material treatment, whereas the MOE of the Albanian samples was affected significantly by the finger length.

4. SUMMARY

Beech wood has a very good potential in finger-jointed nonstructural uses. It is used mainly as steamed as well as unsteamed wood in many furniture applications. Within the range of parameters studied the bending strength (MOR) of the finger jointed beech wood was affected by the finger length (4.5mm, 6.5mm, and 9.0 mm), and the handling of beech wood (steamed, unsteamed).

Specimens with 9.0 mm finger length showed higher values of MOR than the specimens with 4.5mm and 6.5mm finger lengths.

In most cases, the steamed wood specimens showed higher MOR values than the unsteamed ones.

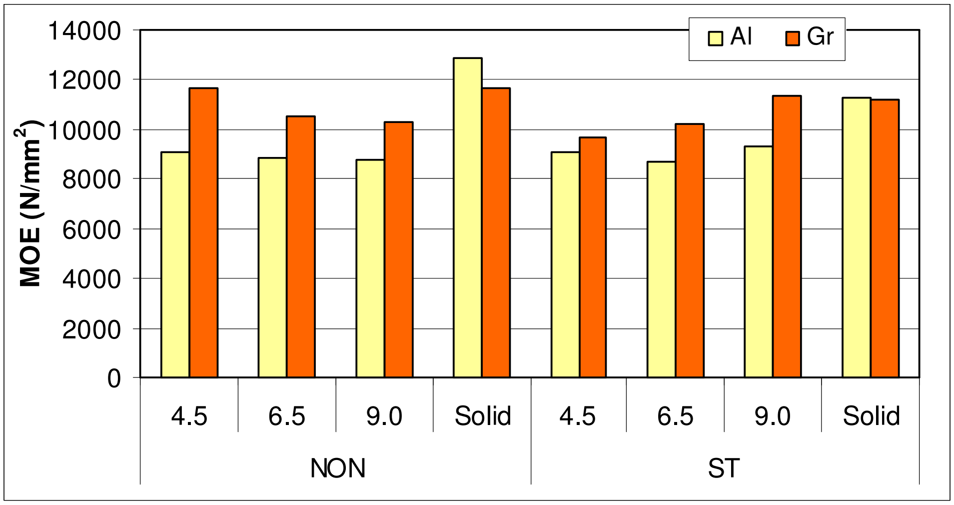

Fig. 4. Effect of origination and finger length on MOE of finger jointed beech wood

Specimens originated from Albania resulted in lower values of MOR compared to the specimens from Greece.

Finger jointing of both steamed and unsteamed material did not affect the MOE of the tested specimens in a distinct manner, although the Greek origination of the material resulted in greater MOE values than the Albanian origination.

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