

DETERMINING THE BENDING AND TENSILE STRENGTH OF IMPREGNATED WITH RAPESEED OIL EUROPEAN BEECH (FAGUS SYLVATICA) WOOD JOINTS GLUED WITH PVAc AND PU

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Abstract

The objective of this study was to examine bending and tensile strength of beech wood (Fagus sylvatica) joints (basic mortise and tenon) along with the effect of wood impregnation with rapeseed oil and type of glue (PVA or PU). The wood specimens were impregnated with the empty-cell treatment (Lowry process). Retention of rape oil was about 273 kg/m³. Beech wood impregnation led to some reduction of the bending and tensile strength. Bending strength of the specimens reduced from 9,9% up to 25,9% while tensile strength reduced from 19,7 up to 35,2% for joints glued with PVA and from 2,1 up to 16,7% for joints glued with PU. Joints glued with PU had higher bending and tensile strength in most cases. Joints constructed from wood impregnated before mortise and tenon construction had generally higher mechanical strength. Joints constructed from impregnated wood that primarily treated with turpentine, had lower mechanical strength, than the non treated with turpentine joints.

Key words: beech wood, impregnation, rapeseed oil, bending, tensile strength

1. INTRODUCTION

Wood joints consist parts of furniture that will be loaded with great mechanical stresses. The appropriate construction of wood joints is very important for the stability and duration of the furniture. Wood joints, according to their position in the furniture, are mainly form corner or middle joints. Mortise and tenon joint is the most usual and effective way for joint constructions in many common wood products such as chair.

Beech wood is a raw material used for various technical uses especially furniture. When it is treated to improve some properties as dimensional stability and duration, the mechanical strength may be affected. Some effects of joints construction parameters and impregnation with natural oils have been investigated in the past.

Flexibility and bending strength of rectangular mortise tenon joints was investigated by Hill and Eckelman (1973). They concluded that bending strength of mortise and tenon joints is the function of wood species, mortise and tenon dimensions.

Ishii and Miyajima (1981) investigated the effect of tenon length and tenon depth on bending moment capacity and found that near linear relationships existed between these factors and moment capacity.

Wilczyński and Warmbier (2003) demonstrated that the strength of examined joints depended, primarily, on the length of the tenon, whereas the stiffness of the joint depended on the tenon width.

Tankut and Tankut (2005) showed that rectangular end mortise and tenons are about 15% stronger than both round end mortise and tenons and rectangular end tenons fitting into round end mortise joints. Meanwhile, joint geometry has a significant effect on the strength of those particular joints. As tenon width and length were increased, the strength of the joints was correspondingly improved. The type of mortise and tenon end has an appreciable effect on the breaking strength of the joints as rectangular end mortise and tenons are stronger than round end mortise and tenon joints, however, this does not limit the use of round end mortise and tenon joints in chair construction. It may actually be advantageous to use round end tenon and mortise joints for the front leg/side rail joint in a chair frame, as the internal stresses may be more uniformly distributed over the rounded ends of the mortise, thus

reducing the risk of splitting the leg member. The third type of construction, with a square end tenon fitting into a round end mortise, was, however, less satisfactory.

Tankut (2007) showed that the highest strength is achieved when a close tolerance between mortise and tenon is maintained.

Octavia et al. (2011) investigated the dimensional stability of spruce and beech samples treated with linseed oil. Samples were treated by immersion in simple and double bath at low temperature. The simple bath treatment proved moderate efficiency compared to double bath. The oil treated samples have showed higher dimensional stability in terms of anti-shrink efficiency and weight percent gain compared to untreated wood.

Kureli et al. (2013) determined that bending and bonding strength have increased on oak wood joints and decreased on pine wood joints (mortise and tenon), impregnated with solution of 5 % natural oak tannin.

In this study, the bending and tensile strength of beech wood joints (basic mortise and tenon) were examined along with the effect of wood impregnation with rapeseed oil and type of glue (polyvinyl acetate or polyurethane).

2. MATERIALS AND METHODS

Wood specimens of various dimensions were prepared from Greek originated European beech (*Fagus sylvatica*) wood. The specimens were separated in three categories: 1) non-treated (control), 2) impregnated with hot rapeseed oil before mortise and tenon construction, and 3) impregnated with hot rapeseed oil after mortise and tenon construction. Two types of mortise-tenon construction were used to prepare joint parts for bending test and tensile strength, corner joints and middle joints approximately.

The specimens were impregnated with hot (60°C) rapeseed oil by pressure in a closed cylinder with the empty-cell treatment (*Lowry process*). The impregnation process included an initial pressure of 3 bars for 25 minutes, followed by a release of pressure and exit of oil and a final vacuum of 0,6 bar for 40 minutes.

Oil retention was determined from the relation $OR = (M_2 - M_1) / V$: OR=Oil Retention, M_2 = air dried (T=20°C, RH=65%) weight after impregnation, M_1 = air dried weight before impregnation.

After impregnation, mortise and tenons were constructed on specimens of category 3, too. Half of the impregnated wood specimens were additionally surface treated with turpentine, before joint construction.

Two types of glue were used to prepare wood joints: polyvinyl acetate (PVA) and polyurethane (PU). Also, two types of wood joints were prepared: joints for bending strength measurements (corner joints) and joints for tensile strength measurements (middle joints). Bending test was performed on corner joints as shown in fig.1 and tensile test was performed on middle joints as shown in fig. 2.



Fig. 1. Bending test of impregnated beech wood corner joints.



Fig. 2. Tensile test of impregnated beech wood middle joints.

3. RESULTS AND DISCUSSION

Bending and tensile strength results are shown in table 1.

Table 1. Bending and tensile strength of impregnated beech wood joints.

Treatment of beech wood joints	Adhesion type			
	PVA (polyvinyl acetate)		PU (polyurethane)	
	Bending strength (N·m)	Tensile strength (N/mm ²)	Bending strength (N·m)	Tensile strength (N/mm ²)
Impregnated* before mortise and tenon construction	201.07	6.47	245.87	6.92
Impregnated before mortise and tenon construction and surface treated with turpentine	197.60	6.46	202.27	6.87
Impregnated after mortise and tenon construction	199.87	5.22	208.80	7.37
Impregnated after mortise and tenon construction and surface treated with turpentine	213.73	6.32	202.80	6.27
Untreated (control)	244.67	8.06	272.93	7.53

* Oil retention was measured about 273 kg/m³.

3.1 Adhesive effect

Joints glued with PU had higher bending and tensile strength in all cases, except for the case of wood impregnated after mortise and tenon construction and surface treated with turpentine. In this case, joints glued with PVA had 5,4% higher bending strength and 0,8% higher tensile strength. In the other cases joints glued with PU had:

- 22,3% higher bending strength and 7% higher tensile strength for wood impregnated before mortise and tenon construction,
- 2,4% higher bending strength and 6,3% higher tensile strength for wood impregnated before mortise and tenon construction and surface treated with turpentine, and
- 4,5% higher bending strength and 41,2% higher tensile strength for wood impregnated after mortise and tenon construction.

3.2 Impregnation effect

Joints constructed from impregnated wood had lower mechanical strength than joints constructed from totally untreated wood. Particularly:

- joints from wood impregnated before mortise and tenon construction had 17,8% lower bending strength and 19,7% lower tensile strength than joints from untreated wood,

- joints from wood impregnated before mortise and tenon construction and surface treated with turpentine had 19,2% lower bending strength and 19,9% lower tensile strength than joints from untreated wood,
- joints from wood impregnated after mortise and tenon construction had 18,3% lower bending strength and 35,2% lower tensile strength than joints from untreated wood, and
- joints from wood impregnated after mortise and tenon construction and surface treated with turpentine had 12,6% lower bending strength and 21,6% lower tensile strength than joints from untreated wood.

3.3 Impregnation stage effect

Joints constructed from wood impregnated before mortise and tenon construction had generally higher mechanical strength. When impregnated wood was surface treated with turpentine, joints constructed from wood impregnated before mortise and tenon construction had lower bending strength but higher tensile strength than joints from wood impregnated after mortise and tenon construction. Particularly:

- joints from wood impregnated before mortise and tenon construction had 0,6% higher bending strength and 23,9% higher tensile strength when glued with PVA and 17,8% higher bending strength and 6,1% lower tensile strength when glued with PU, compared to joints from wood impregnated after mortise and tenon construction, and
- joints from wood impregnated before mortise and tenon construction and surface treated with turpentine had 7,5% lower bending strength and 2,2% higher tensile strength when glued with PVA and 0,3% lower bending strength and 9,6% higher tensile strength when glued with PU, compared to joints from wood impregnated after mortise and tenon construction and surface treated with turpentine.

3.4 Surface treatment with turpentine effect

Joints constructed from impregnated wood surface treated with turpentine had generally a little lower mechanical strength than joints from impregnated wood without surface treatment except for the case of wood impregnated after mortise and tenon construction glued with PVA. In this case, joints constructed from impregnated wood surface treated with turpentine had higher mechanical strength. Particularly:

- joints from wood impregnated before mortise and tenon construction and surface treated with turpentine had 1,7% lower bending strength and 0,2% lower tensile strength when glued with PVA and 17,7% lower bending strength and 0,7% lower tensile strength when glued with PU, compared to joints from impregnated wood without surface treatment, and
- joints from wood impregnated after mortise and tenon construction and surface treated with turpentine had 6,9% higher bending strength and 21,1% higher tensile strength when glued with PVA and 2,9% lower bending strength and 14,9% lower tensile strength when glued with PU, compared to joints from impregnated wood without surface treatment.

4. CONCLUSIONS

Beech wood impregnation led to some reduction of joints bending strength ranged from 9,9% to 25,9%. Regarding the stage of impregnation, in the case of joints glued with PU without turpentine surface treatment, specimens impregnated before mortise and tenon construction had 17,7% higher bending strength compared to specimens impregnated after mortise and tenon construction. In other cases no significant difference occurred.

Beech wood impregnation led to some reduction of joints tensile strength, especially in the cases of joints glued with PVA and particularly in the case of specimens impregnated after mortise and tenon construction. The reduction ranged from 19,7% to 35,2% for joints glued with PVA. For joints glued with PU, the reduction ranged from 2,1% to 16,7%.

Joints glued with PU had higher bending and tensile strength in all cases, except for the case of wood impregnated after mortise and tenon construction and surface treated with turpentine. Only in this case, joints glued with PVA (polyvinyl acetate) had higher bending and tensile strength.

Joints constructed from wood impregnated before mortise and tenon construction had generally higher mechanical strength. When impregnated wood was surface treated with turpentine, joints constructed from wood impregnated before mortise and tenon construction had lower bending strength but higher tensile strength than joints from wood impregnated after mortise and tenon construction.

Joints constructed from impregnated wood surface treated with turpentine had generally a little lower mechanical strength than joints from impregnated wood without surface treatment except for the case of wood impregnated after mortise and tenon construction glued with PVA. In this case, joints constructed from impregnated wood surface treated with turpentine had higher mechanical strength.

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