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INVESTIGATION OF THE EFFECTS OF SOME MODIFICATION PROCESS TO THE MECHANICAL PERFORMANCE AND DEFORMATION OF THE WOODWORK

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ABSTRACT

In this study, wood modification (thermo-processing and impregnation) and outdoor conditions of storage (natural aging) the effects on the mechanical performance of industrial woodwork was investigated. For this purpose, naturally grown in Turkey and the commercial value of high Scots pine (*Pinus sylvestris* L.) and chestnut (*Castanea sativa* Mill) wood was used. Experimental examples are specifically woodwork has been applied in actual size. Considering the previously conducted research literature only diagonal L-type samples used, not on the actual size samples of woodwork. In addition, there is no study that the combination of the heat-treatment and impregnation. This reveals the original values of this study. For preparing of samples is used the double tenon-mortise corner joint from constructions method and as glue polyurethane based Desmodur VTKA and Polyvinyl acetate based two-component D4.

Diagonal woodwork test samples prepared by Thermo S class (185°C temperature with a thermo-vapor process protections) applying. After application of the heat treatment, the test

samples impregnated with a solution of 95 % natural pine cone resin and %5 pine tannin by dip method (2 hours). Then, the untreated samples (control), only heat-treated samples and heat treatment + impregnated samples kept for 1 year with outdoor conditions (aging). At the end of the aging, the samples tested according to the principles stated in TS 2472 and TS 7251 EN 107 standard.

As result, the performance of woodwork decreased after aging in untreated and heat treatment pieces, the other side after aging – heat treatment, impregnation materials increased the values. The deformation value of woodwork increased after aging most untreated materials, Heat treatment and heat treatment-impregnated reduced aging effectiveness.

KEYWORDS: Thermal process, wood modification, impregnation, industrial woodwork, diagonal pressure test.

INTRODUCTION

Due to developments in the woodworking industry wood material has an important place in human life. Easy handling, high resistance of light and wood materials are preferred because of the many positive features and benefits (Özalp 2003).

In the external environment, fungi, insects, effects such as exposure to ultraviolet rays of the sun to protect the remaining wood material, it is important to extend the life and increase the physical strength. The methods used to protect wood against these factors "modification" is defined as the common impregnation thereof (Ayar 2008) and the heat treatment.

Wood and wood products is the traditional material groups are used after being subjected to various modification processes. Wood materials; wooden houses, laying of concrete structures - especially the wall covering work, roofing, widely used in formwork and scaffolding work. In particular, manufacturers of artificial PVC materials cautious prefer wood woodwork again mostly in manufacturing. Joining corner with different techniques are applied in the manufacture of wood joinery. When this corner joints are faced with their own weight and other external loads woodwork, more diagonal tension - compression remains under the influence of pressure (Tokgöz et al. 2005).

In the previously conducted research literature only horizontal, vertical L-type samples used, not on the actual size samples of woodwork (Eckelman 1968, 1987).

Techniques publications related to woodwork sufficiently known. Therefore, the use of woodwork in the process of sagging of the wing, the wing geometry of emerging issues such as corruption and windows broken blade geometry cannot be easily opened-closed (Arslan et al. 2006).

Heat treatment is an important wood modification method is provided for dimensional stabilization of wood. Through this method, without harming the environment and human health, the wood can be used safely outdoors. Also, the volumetric expansion of the heat treated wood (swelling) are reduced by about 50%. But natural preservative for wood heat treatment of materials (tannins, resins, etc.) Transforms completely gas (Altinok et al. 2010).

Altinok et al. (2009) that has been reported, pine and Uludag fir wood with PVA-D3 and PVA-D4 glue in the woodwork corner joints were investigated, diagonal tensile performance of the highest D4 glued Scotch pine and lowest D3 glued Uludag fir was obtained.

Alen et al. (2002) was heat treated spruce (*Picea abies* L.) wood 2 and from 180 to 225°C for 8 hours. The lignin and carbohydrates in samples heat treated was determined that further

degradation. Aydemir and Day (2009), 150˚C and at the top heat treatment change of the color of wood (the darker) was reported to improve the biological resistance and dimensional stability. However, the decrease in the mechanical properties of wood, the chemical structure change occurred and has been reported thus restricting the use of wood where the material. Korkut et al. (2008) it is stated that the temperature and heat treatment time increases the technological properties of the wood even decrease. In Bekhta and Niemz (2003), mechanical properties of the heat-treated beech (Fagus orientalis Lipsky.) wood decrease, bending strength of 5% 40 and elasticity modulus (MOE) the of 4% 9% decrease, the dimensional stability is increased and darkening of wood color they found. Edlund and Germ (2004), 220˚C and 4 hours heat-treated pine and spruce example for 2 years is stated that there is no decay. Folch et al. (2006), because heat treatment, it has been found to increase the bonding strength between the polyethylene and wood surfaces. Ishikawa et al. (2004), steam assisted thermal process, saturated steam is associated with increased degradation of the wood surface and the core.

In this study, has aimed to determine the effects of wood modification and aging to mechanical performance of the woodwork. Also, carbohydrates and resins undergo degradation before the lignin and cellulose they are separated from the wood pulp and the gaseous phase. Therefore, it becomes brittle from the wood and natural preservatives (tannins and resins) deprived. Therefore, impregnated to the both wood tannin and pine resin solution after heat treatment and a new dimension were achieved in the study.

MATERIALS AND METHODS

Materials

In the experiments, Scots pine (*Pinus sylvestris* L.) and chestnut (*Castanea sativa* Mill) wood types were used. Wood materials were obtained by the method of random selection from the site of Ankara Woodworking. Wood material's being natural color, not undergone to insect and fungi damages, clean, free of decay, without growth defects, smooth parallel to grain and part of the sapwood was ensured. To gluing of the experimental samples, two-component polyvinyl acetate (PVAc-D4) and polyurethane based Desmodur VTKA were used. Two-component polyvinyl acetate (PVAc-D4); that was strengthened by adding 5% hardener (Turbo hardener 303.5). According to BS EN 204, PVAc-D4 can be aligned the pasting quality of D4 by increasing the durability to moisture by adding 5% hardener to the Klebit 303 glue solution (Sogutlu 2007).

Methods

Preparation of the test samples

Woodwork samples, including 5 from each variation has prepared 60 pieces in all variations [wood species (pine, chestnut), 2 glue types (PVAc-D4, VTKA), 3 process (control, heat treated, heat treated+impregnated)]. The preparation of test samples with heat treatment was initiated. The heat treatment was applied to draft size wood pieces in TermoWood method (175°C - 36 h). These pieces of heat-treated elements of the samples 0.01 mm woodwork precision mortise and tenon were cut and opened at a certain size specified in the Fig. 1 by automatic control of the machine.

Fig. 1: Inclined platform of test samples stored in the external environment.

Then were realized to assembling and impregnation woodwork test samples. Tenon-mortise surfaces of the test sample to each type of glue 150 $g \cdot m^{-2}$ basis by applying with a brush is mounted corner by the merger. It was compression applied pressure by pressing to corner joints of woodwork samples and one day (24 hours) has been allowed to harden.

Impregnation solution and process

As impregnation material was used concentration (C) 95 % pine resin (liquid) and 5 % tannin (liquid) solution. Liquid pine resin was obtained by dissolving the solid resin in the fresh pine cones waiting in hot water of 80-90 degrees. The tannins are joined up to 5 % of the weight of pine resin solution. After dipping in Pine solution, the Test samples were impregnated by keeping in the solution for 45 minutes. At the end of each period, the surfaces of samples are removed from the solution and dried. The impregnated samples are kept in air-conditioning fridge under 20 ± 2°C temperature and 65 % ± 5 relative moisture content conditions until reaching moisture balance. Impregnated samples, retention rate of which to be determined, were dried in the oven under 55°C until they reach constant weight, cooled in desiccator and weighed. Thus, the amount of net impregnation of each sample, whose exact dry weight was determined after impregnation, was calculated from the below equation.

$$ANI = ((M_s - M_o)/M_o) \times 100$$

where: ANI - amount of net impregnation (%),
M_s - exact dry weight after impregnation (g),
M_o - exact dry weight before impregnation (g).

Determination of the extent of retention

The extent of retention of the impregnating material in the test samples was calculated by making use of the values prior to and post impregnation using the following equation (TS 5724, 1988).

$$R = \left[\frac{G.C}{V}\right] \times 10^3 \quad (kg \cdot m^{-3})$$

where: $G - T_2 - T_1$,
T_1 - sample weight prior to impregnation (g),
T_2 - sample weight post impregnation (g),
V - sample volume (cm^3),
C - concentration of the solution (%).

Natural aging of test samples

Control, heat treatment and heat treatment+impregnated samples were waited between 22.04.2012 - 22.04.2013 dates for 12 mounts periods, according to the principles of ASTM G7 standard. They were placed, in Ankara-Turkey, as to face to the south and 45° from ground in oblique position (Fig. 2).

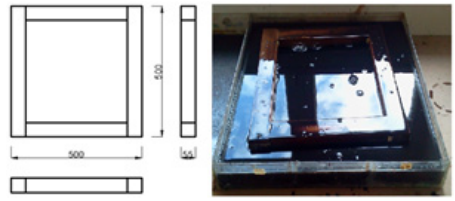
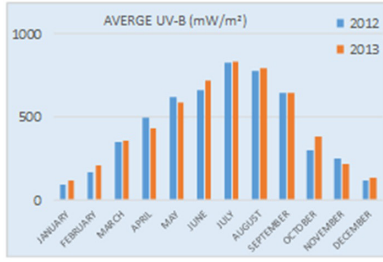


Fig. 2: Woodwork samples (dipp impregnation).

The lowest level of the test sample is 50 cm in height; the attention was paid to the hay etc. around the stand with organic residues in soil, which will increase water content. These mouths' climatic conditions, such as the following have been identified for each month in Graphics by the Center for Meteorology in Fig. 3 (URL-1).



Mounths	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Avr. Temperature (c°)	0,4	1,9	6,1	11,3	16,2	20,2	23,6	23,3	18,7	13,1	7,0	2,6
Avr. Highest Temperature(c°)	4,4	6,5	11,7	17,2	22,3	26,7	30,2	30,2	25,9	19,9	12,9	6,6
Avr. Lowest temperature(c°)	-3,0	-2,2	1,0	5,6	9,7	13,1	16,0	16,0	11,7	7,3	2,5	-0,6
Avr. Sunny Time (h)	2,5	3,5	5,2	6,3	8,4	10,2	11,4	11,0	9,2	6,5	4,4	2,3
Avr. Rainly Day	12,2	11,0	10,9	11,9	12,5	8,6	3,7	2,8	3,9	6,8	8,5	11,8

Fig. 3: UV-B radiation between 2012-2013 years and meteorogical data (20).

Diagonal compression performance and deformation value

The diagonal compression test experiments and deformation value of woodwork examples were held according to the ASTM 1037 standard, in 800 Kp stage of Universal Testing Machine with a capacity of 5 tons in the material laboratory of Technology Faculty - Gazi University. Experimental device was set to increase the compression with a speed of 2 mm·min^{-1}. The maximum force, read from the machine, was recorded in the unit (Fig. 4).

Fig. 4: Universal test machine and test samples.

Evaluation of data

Multiple analysis of variance was made in wood frame corner joints in order to determine the effects of wood type, adhesion type, heat treatment and impregnation. In case of mutual interactions of sources of variance being significant according to $\alpha = 0.05$, for which factors are the differences important was identified by Duncan test.

RESULTS AND DISCUSSION

Specific gravity and retention amount

Specific gravities and retention amount of woodwork are given below (Tab. 1).

Tab. 1: Specific gravity and retention amount of woodwork samples.

Wood types	0 % MC ($g \cdot cm^{-3}$)		12 % MC ($g \cdot cm^{-3}$)		Retention amount ($g \cdot cm^{-3}$)
	Control	Heat treated	Control	Heat treated	Heat treated + impregnated
Scotch pine	0.48	0.44	0.50	0.44	11.26
Chesnut	0.54	0.53	0.59	0.55	10.96

Tab. 1 wherein the heat treatment reduced the specific gravity of both the wood and the process level. In literature there was a loss of density due to heat treatment (Fengel and Weneger 1984, Kollmann and Schneider, 1963, Yıldız 2002, Percin 2012). In case of increase of the balance of moisture, specific gravity rise again despite the control sample, this increase has not been heat treated in the samples. According to chestnut wood due to its low specific gravity occurred more retention pine wood. In other study 5% pine tannin retention amounts showed similar results on pine (11.93 $kg \cdot m^{-3}$) and chestnut: 13.5 $kg \cdot m^{-3}$) wood (Yasar 2014).

Diagonal compression performance on the full-frame samples

Statistical averages of the performance of diagonal compression performance at the level of wood type, glue type and process type of the woodwork samples are summarized before and after the natural aging is given in Tab. 2.

Tab. 2: Statistical averages of the performance of diagonal compression samples.

PROCESS		WOOD TYPES	FULL FRAME SAMPLES	
			PVAc-D4	D-VTKA
Before aging	Control	Pine	2367.85	2895.06
		Chesnut	6236.94	4239.21
After aging	Untreated (like control)	Pine	2059.83	2562.96
		Chesnut	5471.75	3785.11
	Heat treated	Pine	1752.56	2040.18
		Chesnut	3316.38	2808.21
	Heat treated + impregnated	Pine	1878.48	2445.51
		Chesnut	3240.88	3048.15

According to Tab. 2 untreated samples in kept at external environment (all of untreated control samples) is reduced well by the diagonal compression performance according others in both wood and glue level.

At the level of all processes on pine samples of glued with VTKA glue and chestnut samples glued with D4 glue were obtained the highest performance in itself. As in other studies while natural aging (waiting in the external environment) the only heat-treated samples well decreased performance according to the control samples before and after aging, the performance of the heat-treated+impregnated sample was determined to protect himself (Rusche 1973, Kotilainen, 2000, Yıldız 2002, Percin 2012).

By applying multiple variance analysis of the averages of diagonal compression performance of woodwork samples obtained from variation of wood type, glue type and process type on diagonal compression performance results are given in Tab. 3.

Tab. 3: Multiple variance analysis of diagonal compression performance of woodwork samples.

Source of variance	SD.	Sum of squares	Average of	Value of F	P ≤ 0,01
Wood type (A)	1	47704.167	47704.167	0.3774	
Process type (B)	2	8874700.000	4437350.000	35.1068	0.0000
Interaction (AB)	2	1817033.333	908516.667	7.1879	0.0000
Glue type (C)	1	372504.167	372504.167	2.9471	0.1117
Interaction (AC)	1	2325037.500	2325037.500	18.3949	0.0011
Interaction (BC)	2	948133.333	474066.667	3.7507	0.0543
Interaction (ABC)	2	22355200.000	11177600.000	88.4333	0.0000
Error	12	1516750.000	126395.833		
Sum	23	38257062.500			

According to Tab. 3 wood type, glue type and interaction of process and glue type are insignificant (significant α=0.05). Duncan test was performed to determine which groups are important differences. Diagonal compression performance value (Newton) by triple interaction wood type, glue type and process type of woodwork samples are given in Fig. 5.

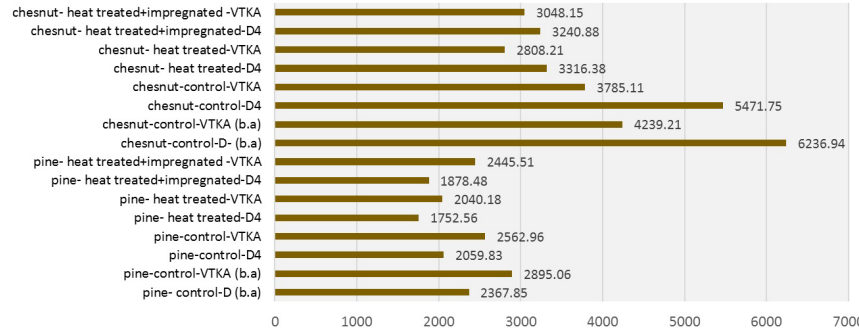


Fig. 5: Diagonal compression performance value by triple interaction of woodwork samples.

Deformation value of full frame examples

Deformation value of woodwork examples (d), was determined at the end of the diagonal compression test by measuring precision of 0.01 mm as a deviation from squareness between the two sides perpendicular to each other (Fig. 6). Measured values are given in Tab. 4.

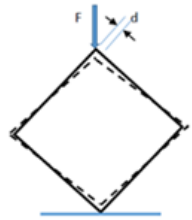


Fig. 6: Deformation measuring.

According to Tab. 4; the biggest deformation on control-with D4 glued chesnut samples, smallest on control-D4 glued pine samples (b.a: before aging) were measured. These are shown in the graph of Fig. 7.

Tab. 4: Deformation value on the woodwork by aging – heat treatment – impregnation.

Wood and glue type	Before aging	After aging					
	Control (mm)	Untreated (mm)	Changing (%)*	Heat-treated (mm)	Changing (%)*	Heat-treated +impregnated (mm)	Changing (%)*
Pine-D4	14.2	18.2	+28.2	16.4	+1.5	16.0	-2.4
Pine-VTKA	17.2	19.9	+15.6	17.8	+3.4	16.8	-5.6
Chesnut-D4	19.4	21.8	+12.3	19.8	+2.1	19.0	-4.1
Chesnut-VTKA	18.2	18.8	+3.2	18.7	+2.7	18.3	-2.1

*Changings are compared with Control Group

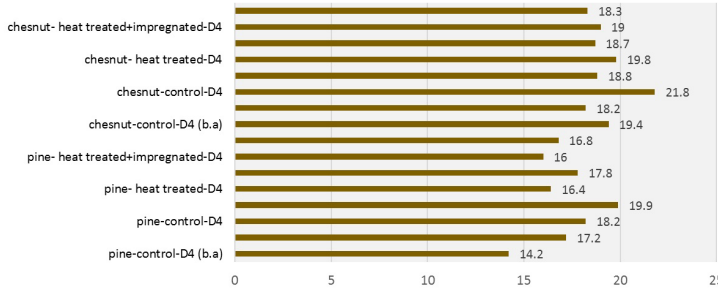


Fig. 7: Deformation value of woodwork samples (d, as mm).

Specific gravity and retention amount

The heat treatment one of wood modification reduced the specific gravity of the both wood types. After heat treatment and impregnation were hold the situation of the both wood types in the natural aging. This decrease of 9% in the pine samples, 7% in the chestnut sample realized. During the aging in natural environment (waiting) and heat treatment especially natural woods heavy loss; degradation to such as lignin, cellulose and extractives of wood components is reportedly due (Edlund1 et al. 2004, Follrich 2006).

A solution of pine cones resin and tannin with impregnated in the wood; the amount of the maximum retention was hold the Scots pine wood. Retention in the chestnuts wood is less than Scots pine. In other experiment showed similar results (Yasar 2014)

Diagonal compression performance on the woodwork

Advanced performance elements that make up the full frame; resist to the diagonal test force (resistance) of the frame is its ability. If this resistance constituent factors; It is sticking to the adequacy of the frame members and corner joining. Specifically, the adhesives resistance to the natural aging it is the most important constituent elements of performance in the woodwork.

In this regard examine the performance of the diagonal compression in woodwork; the diagonal compression performance generally obtained the highest on the control experiments of both types of wood and glue type before aging (Fig. 4). Heat treatment decreased the performance of both types of wood. During the heat treatment of wood materials became brittleness and fragility. Therefore, some heat-treated sample cracked or broken during the test. Because heat-treated samples impregnate the brittleness and fragility reduces and impregnated samples in the external environment of decay to better protect, in heat-treated and impregnated samples were obtained higher performance (Fig 4, heat treated + impregnated of both wood and glue type according to heat treated of both wood and glue type).

According to the untreated (control) and no-aged samples of both wood and glue types; in the aged control samples, heat-treated samples and heat-treated + impregnated samples performance changing (%) is given in Tab. 5.

Tab. 5: Performance changing by aging – heat treatment - impregnation.

Wood and glue type	Before aging	After aging					
	Control	Untreated	Changing (%)	Heat-treated	Changing (%)	Heat-treated + impregnated	Changing (%)
Pine-D4	2367.85	2059.8.	-13	1752.56	-25.9	1878.48	+7.2
Pine-VTKA	2895.06	2562.9	-11	2040.18	-25.5	2445.51	+19.8
Chesnut-D4	6236.94	5471.7	-12	3316.38	-46.8	3240.88	-2.2
Chesnut-VTKA	4239.21	3785.11	-10	2808.21	-33.7	3048.15	+8.5

In this case, the performance decreased by the aging between 10% and 13%, by the heat treatment between 25.5% and 46.8% in untreated samples of both wood and glue types, increased between 7.2% and 19.8% in heat-treated+impregnated samples ("Chesnut-D4+Heat-treated impregnated" excluded).

Deformation value of full frame examples

In contrast to the performance, generally the deformation amount increased with by aging and heat treatment, it decreased by impregnation compared to thermal processing (Fig. 4).

According to the untreated (control) and no-aged samples of both wood and glue types; in the aged control samples, heat-treated samples and heat-treated + impregnated samples deformation changing (%) is given in Tab. 6.

Tab. 6: Deformation changing by aging – heat treatment - impregnation.

Wood and glue type	Before aging	After aging		After aging			
	Control	Untreated	Changing (%)	Heat-treated	Changing (%)	Heat-treated + impregnated	Changing (%)
Pine-D4	14.2	18.2	+28.2	16.4	+15.5	16.0	-2.4
Pine-VTKA	17.2	19.9	+15.6	17.8	+3.4	16.8	-5.6
Chesnut-D4	19.4	21.8	+12.3	19.8	+2.1	19.0	-4.1
Chesnut-VTKA	18.2	18.8	+3.2	18.7	+2.7	18.3	-2.1

In this case, the deformation value increased by the aging between 3.2% and 28.2% and by the heat treatment between 2,1% and 15,5%, decreased by heat-treated+impregnated between 2.1% and 5.6% were found by compared with control samples. The impregnant materials reduces the percentage values when used together with heat-treated.

In this case, in terms of performance and deformation; before chesnut as the wood and VTKA glue as adhesive and then pine wood and D4 glue recommended for the manufacture of joinery.

CONCLUSIONS

This study has been made in order to determine the effect of wood modification (heat treatment and Short-term-45 min- dip impregnation method with natural pine resin and tannin solution) on the specific gravity, diagonal compression performance and deformation by aging. Following conclusions can be drawn from this study.

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