International Journal of Chemical, Materials and Biomolecular Sciences
ISSN: 2415-6620
Vol:9, No:1, 2015

The Experimental and Statistical Analysis of the Wood Strength against Pressure According to Different Wood Types, Sizes, and Coatings

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***Abstract*—** In this study, an experiment was executed related to the strength of wooden materials which have been commonly used both in the past and present against pressure and whether fire retardant materials used against fire have any effects or not. Totally 81 samples which included 3 different wood species, 3 different sizes, 2 different fire retardants and 2 unprocessed samples were prepared. Compressive pressure tests were applied to the prepared samples, their variance analyses were executed in accordance with the obtained results and it was aimed to determine the most convenient wooden materials and fire-retardant coating material. It was also determined that the species of wood and the species of coating caused the decrease and/or increase in the resistance against pressure.

***Keywords*—**Resistance of wood against pressure, species of wood, variance analysis, wood coating, wood fire safety.

I. Introduction

THE wood has been used as a building construction material for many years from the past up to present due to its strength and its multifunctional ease of use [1]. Wooden material is a natural material which has been used in the construction sector; it is currently being used and will be used in the future. In addition, wood may be considered as a renewable and boundless resource since it may be replaced with a new one [2]. Although the accelerations seen in the technological developments of the construction sector in recent years; the naturalness and warmth of wood, its lightness, its environment-friendly aspects, earthquake proofing, construction flexibility, compatibility with materials such as steel, concrete and adobe, its aesthetical and acoustic characteristics have all been effective in choosing it [3].

The historical buildings which are the beautiful examples of wood applications and numerous other fields which wood is applied can be seen both in our country and most of the countries in the world. Numerous buildings which wooden materials were applied were completely burned down or suffered extensive damage due to the lacking of necessary precautions in those places against fire. Most recently, the historical wooden Hüseyin Avni Paşa mansion in Üsküdar, İstanbul was burned to ground with a fire which began in the roof on June 28, 2014 [4]. Numerous examples of it may be given from different countries of the world.

In order to protect the wooden materials against fire, fire retardant polishers [6], boron-based impregnated materials and fire retardant paints etc. are used. An experimental study was carried out in order to determine whether those coating materials which delay the fire to some extent decrease the strength of wooden materials used in the construction. Three different sizes used in the building construction for various purposes, 3 different wood types which are easily accessible in our country and commonly used 2 different coating materials and raw materials as arbitration specimen which weren't coated were employed in the experimental study.

The objective of this study is to determine a change exists in the pressure strengths of wood through applying polishers and impregnated materials among the fire-retardant materials which are frequently available in the markets. At the end of testing procedures it was aimed to reveal the differences between the pressure strengths of unprocessed samples and the samples which were applied polishers and impregnation.

II. Materials and Methods

For the experimental studies, primarily, the types of fire retardant materials which are most frequently available in the markets were analyzed. For wood, an imported fire retardants which are in conformity with UNI EN ISO 14001: 2004 (ISO 14001: 2004) [5] standards and boron impregnated material in conformity with (ISO 14001, 2004) standards were preferred.

Three types of wood were chosen to use in the experimental studies. One of them is Scotch Pine (*Pinus silvestris* L.) with the density of 620-780 kg/m³ frequently preferred in the buildings, the other is fir tree (*Abies* sp.) which has the density of 430-520 kg/m³ and poplar tree (*Populus* sp.) with the density of 310-400 kg/m³ were preferred. Those wooden materials were chosen among the materials which are knot-free smooth trunk and free of molds, mushrooms and insects. The chosen wooden samples were prepared in three different sizes such as 100x100x300 mm, 140x140x300 mm and 160x160x300 mm which are most frequently preferred. The wooden samples were kept in the air conditioning room with 30 ± 3% relative humidity and 27 ± 2°C temperatures until its rate of humidity reaches to 7% (1year). All the samples coming from the Wood Cutting Workshop were coded and recorded.

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All the wooden samples were sandpapered and their surfaces were made smooth. In the samples of the first group, 3 pieces of samples from each size and each group with a total of 27 were left unprocessed and no coating was applied on them. In the samples of the second group, 3 pieces of samples from each size and each group with a total of 27 were applied polishers. In the samples of the third group, 3 pieces of samples from each size and each group with a total of 27 were applied boron impregnated materials and totally 81 samples were prepared and those prepared samples were left to dry. When all the samples reached to constant weight and dimensional stability, they were weighed through an analytical scale with precision of 0.001 g and measured through a caliper with precision of 0.01 mm and their preliminary cross-section measurement and their volume were determined. The picture related to the preparation of wooden samples in the laboratory environment was given in Fig. 1.

Fig. 1 Preparation of wooden samples in the laboratory environment

For pressure tests, a computerized full automatic testing device with the capacity of 200 tons (2000 kN) which was produced by Ankara originated Yüksel Kaya Machinery in accordance with the standards of ISO9001(2000) Quality Management System and Press 5.4 version prepared by the company and the experiments were conducted. The pressing machine and computer program which the experiments were conducted are seen in Fig. 2.

Fig. 2 The image of the pressing machine and the computer program used in the experiments

The experiments were conducted in the laboratory of Construction Technology at Vocational High School of Technical Sciences, Selcuk University. The prepared wooden samples were located centering the pressing machine a gradually increasing pressure stress (0.3 - N/s) was applied from bottom and top surfaces until the samples were broken. The pressure values applied to the wooden samples were automatically given by the computer program. In the experiment, the averages of each 3 samples were taken and the results of the obtained values were given in Table I. In Fig. 3, the samples which were broken at the end of the experiment were shown.

TABLE I
THE VALUES OF COATING TYPES, MATERIAL WEIGHTS, BREAKING LOADS AND TENSILE VALUES OF THE WOODEN SAMPLES USED IN THE EXPERIMENT

Material	Coating Type	Test Material Code	Test Material Weight (gr)	Material Cross-Section (mm^2)	Material Volume (mm^3)	Breaking Load kgf	Tension kgf/cm^2
Pine	Raw	PR1	1724.10	9312	2793600	54861	589.27
		PR11	4000.10	18900	5670000	68823	369.43
		PR111	4308.60	24025	7207500	104861	436.38
	Impregnated	PI1	1928.60	9312	2793600	46654	501.12
		PI11	3946.50	19180	5754000	53472	278.79
		PI111	4345.50	24000	7200000	69412	289.22
	Polished	PP1	1755.60	9500	2850000	54292	571.49
		PP11	3668.00	19180	5754000	91761	478.42
		PP111	4756.00	24335	7300500	87784	360.06
Fir	Raw	FR1	1009.90	7917	2375100	22916	289.34
		FR11	2755.40	18221	5484521	78030	428.27
		FR111	3485.20	24025	7207500	85732	356.77
	Impregnated	FI1	1182.40	8280	2484000	33554	405.24
		FI11	2763.20	18354	5506200	75157	409.57
		FI111	3749.50	23870	7161000	92108	385.87
	Polished	FP1	1003.50	8100	2446200	26483	326.95
		FP11	2688.00	18224	5467200	89015	488.56
		FP111	3922.70	24025	7207500	106092	441.50
Poplar	Raw	POR1	1141.60	9025	2707500	32922	364.58
		POR11	2282.50	18225	5467500	73074	400.84
		POR111	2781.00	23103	7023312	89772	388.62
	Impregnated	POI1	1102.80	9021	2706300	32828	363.95
		POI11	2298.10	17956	5386800	71022	395.45
		POI111	2793.50	23104	6931200	98737	427.43
	Polished	POP1	1136.10	9409	2822700	34059	361.94
		POP11	2303.70	17688	5306400	67834	383.46
		POP111	2647.30	22800	6840000	82133	360.23

Fig. 3 The examples of wooden samples after the experiment

III. Results and Discussion

All the prepared samples were applied pressure tests and each group was evaluated within itself. The graphic for material-pressure tension for Scotch pine was given in Fig. 4. The graphic for material-pressure tension for fir tree was given in Fig. 5 and that of poplar trees was given in Fig. 6.

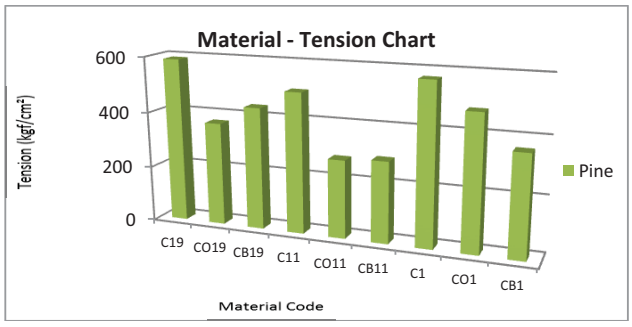

Fig. 4 Material-pressure tension of Scotch pine (Pine)

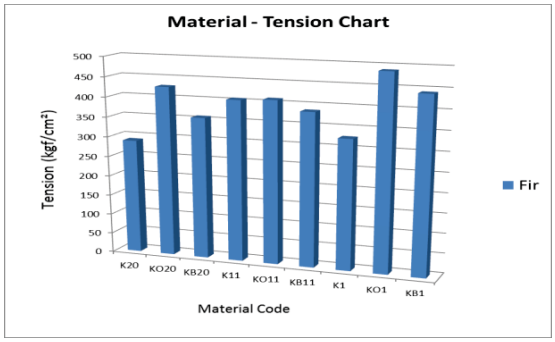

Fig. 5 Material-pressure tension of fir trees (Fir)

For the executed experimental study, the variance analyses were carried out in all the sampling groups and Breaking Load, Material Weight and Material Volume were accepted as the input units. The tension was taken as output unit. The values of R: 0.991 and R^2: 0.982 were found significant for Scotch pine (pine). The results of variance analysis for Scotch pine were given in Table II while the results of ANOVA were given in Table III. The Weight – Tension graphic for Scotch pine were given in Fig. 7.

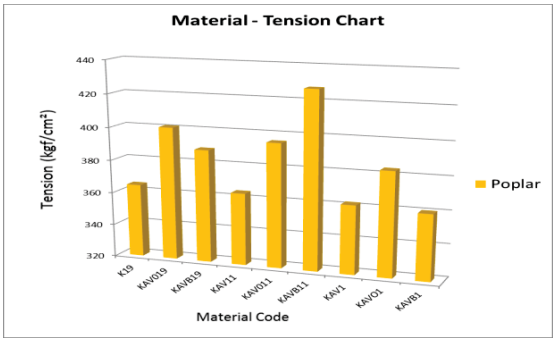

Fig. 6 Material-pressure tension of poplar trees (Poplar)

TABLE II
The Results of Variance Analysis for Scotch Pine

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0,991[a]	0,982	0,971	19,40234

a. Predictors: (Constant), BREAKINGLOAD, WEIGHT, VOLUME

TABLE III
The Results of ANOVA[A] Statistical Analysis for Scotch Pine

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	102189,213	3	34063,071	90,485	0,000[b]
	Residual	1882,255	5	376,451		
	Total	104071,468	8			

a. Dependent Variable: TENSION
b. Predictors: (Constant), BREAKINGLOAD, WEIGHT, VOLUME

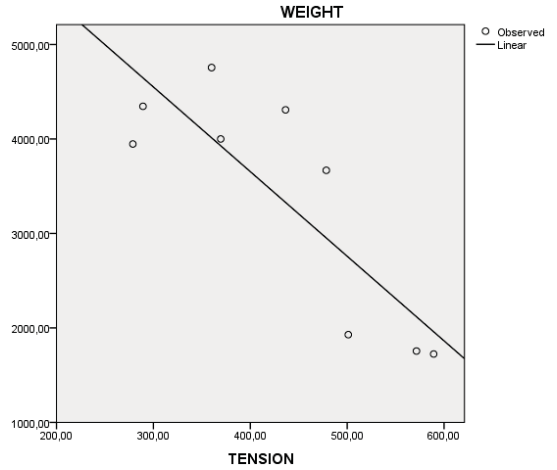

Fig. 7 Weight – Tension graphics for Scotch pine

R: 0.956 and R^2: 0.915 were found significant for fir trees (Fir). The variance analyses for Fir were given in Table IV and the ANOVA results of Fir were given in Table V. The Weight – Tension graphic for Fir were given in Fig. 8.

TABLE IV
THE RESULTS OF VARIANCE ANALYSIS FOR FIR TREES

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0,956[a]	0,915	0,864	22,45875

a. Predictors: (Constant), BREAKINGLOAD, VOLUME, WEIGHT

TABLE V
THE RESULTS OF ANOVA[A] STATISTICAL ANALYSIS FOR FIR TREES

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	27099,089	3	9033,030	17,909	0,004[b]
	Residual	2521,977	5	504,395		
	Total	29621,066	8			

a. Dependent Variable: TENSION
b. Predictors: (Constant), BREAKINGLOAD, VOLUME, WEIGHT

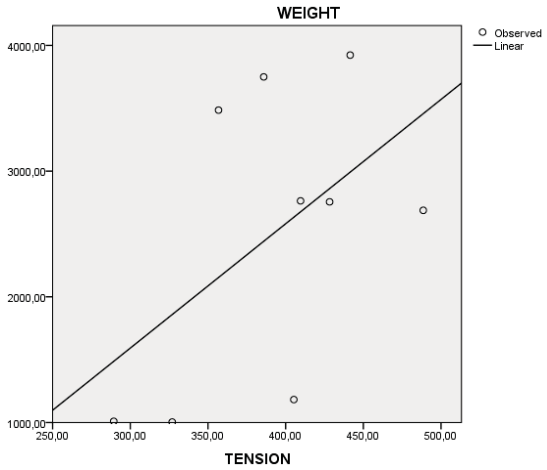

Fig. 8 Weight – Tension graphics for Fir trees

R: 0.996 and R²: 0.992 were found significant for poplar trees (Poplar). The variance analyses for Poplar were given in Table VI and the ANOVA results of Poplar were given in Table VII the Weight – Tension graphic for Poplar were given in Fig. 9.

TABLE VI
THE RESULTS OF VARIANCE ANALYSIS FOR POPLAR TREES

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0,996[a]	0,992	0,987	2,61202

a. Predictors: (Constant), BREAKINGLOAD, VOLUME, WEIGHT

TABLE VII
THE RESULTS OF ANOVA[A] STATISTICAL ANALYSIS FOR POPLAR TREES

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4109,143	3	1369,714	200,760	0,000[b]
	Residual	34,113	5	6,823		
	Total	4143,257	8			

a. Dependent Variable: TENSION
b. Predictors: (Constant), BREAKINGLOAD, VOLUME, WEIGHT

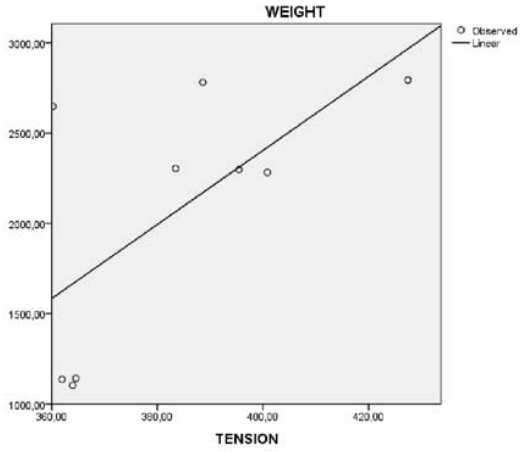

Fig. 9 Weight – Tension graphics for Poplar trees

IV. CONCLUSION

When the Scotch pine (Pine) was analyzed in the executed study, the pressure strength for the unprocessed materials was the highest and the second was the polished samples while the weakest was the samples which were +87 applied boron impregnated materials. This shows us polishers could be more convenient fire retardant materials for Scotch pine if a fire retardant application is required. When the evaluation is carried out for Fir; it gave the weakest pressure strength when the samples were unprocessed and the second was boron impregnated materials while the strongest pressure strength was achieved when the polishers were applied. As seen in Scotch pine, the most convenient coating material for Fir is polisher. When the poplar was analyzed, finally, it was found that both unprocessed samples and polished samples had almost same pressure strength while the samples processed with boron impregnated materials had increased pressure strength at least in small amounts. It is thought that the materials which give the best pressure strength should be used in the future studies through using various wood types and various fire retardant materials.

ACKNOWLEDGMENT

This study has been supported by Selcuk University's Scientific Research Unit.

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