African Journal of Biotechnology Vol. 8 (8), pp. 1680-1688, 20 April, 2009
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2009 Academic Journals

Full Length Research Paper

The effect of open air conditions on the properties of wooden material

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Accepted 20 February, 2009

In this study, the impregnation materials of Tanalith-C (CCA) and Protim 230 WR were used as preservative and water repellant. Wooden materials were taken from beech and black pine. The samples were made subject to weathering conditions for one year. At the end of this period, changes occurred in the samples' bending strength, compression strength and physical properties were examined. As a result of this study, it was observed that no significant variations occurred in mechanical values of the impregnated samples; however, severe losses occurred in case of the non-impregnated samples. It was seen that impregnation type provides different protection according to the type of the wooden material. It was observed that discoloration is more significant in the non-impregnated samples compared with those impregnated. Both of the impregnation materials provide sufficient protection.

Key words: Wood, bending resistance, pressure resistance.

INTRODUCTION

Forests have decreased significantly in Turkey and also around the world as a result of developments in wooden works industry and they are also continuing to decrease day by day. The demand for wooden materials has been increasing day after day because it is easily handled and treated and provides insulation against noise and heat, as well as due to its natural texture, colorful patterned nature, its high resistance against fatigue compared with steel and concrete and aesthetic appearance. Wooden materials should be used carefully for satisfying this demand (Ozalp, 2003). Wooden material is the first building material, which has been used by human being in construction. Despite technological innovations of today and completion with many new materials, it keeps its important position in many areas due to its superior characteristics (Bozkurt and Goker, 1981). Wooden materials are preferred in manufacturing of many products as a raw material due to its aesthetic appearance and natural properties. Wooden materials should be protected against indoor and outdoor conditions due to its aesthetic appearance and natural properties (Yalinkilic, 1997).

Wooden materials are employed in many areas according to their natural properties. One of the most important processes employed for making wooden materials' lifecycle longer is impregnation process. Although naturally resistant wood materials keep their existence for long years in places in where they have been used, this period changes depending on the said places' conditions and tree species (Bal, 2006). Wooden materials treated with preservatives have been used in national parks, recreational area and other public places as a natural building material due to their durability, reasonable cost and aesthetic appearance. Therefore, it has to be made sure that, the preservatives to be used do certainly not threaten human health and the environment (Lebow, 1996). Wooden materials have been used for long years in building bridges, telephone piles, columns in mines and bonding piles as well as in relative small works such as park and garden furniture, piers, banks, pergolas, wooden houses, wooden works of

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main door and windows, wooden stairs and molds under outdoor conditions. Wooden materials are generally preferred for outdoor use especially, due to its reasonable cost compared with other building materials and because it is a renewable resource (Avlar and Limoncu, 2001).

In the previous studies, it was evidenced that, wooden materials treated with various chemicals becomes more resistant against weather conditions. Temperature and humidity are among the most important factors, which decay and diminish wooden materials. Decaying is an undesired fact in building because it reduces durability properties rapidly. Decays and decomposition may be prevented in wooden materials by using various chemical preservatives (Winandy, 1994). Hedley and Drysdale observed that, the impregnated wooden piles, which are made of trees with needle-leaf, existing under garden conditions, are under higher degradation risk compared with those existing in countryside in their study performed in New Zealand. Wright and Ladrach obtained well results in 10 years in their study in which wooden fences from *Pinus, Cupressus* and *Eucalyptus grandis* species were impregnated with CCA. Those, which were not impregnated, were destroyed completely within 10 years (Sivrikaya, 2003). Keskin (2001) reported that, no change occurred in bending and compression strengths of the pine wood impregnated with CCA salts. Clausen et al. (2003) reported as a result of their visual examinations that, decays caused by fungi occur on the surfaces of wooden materials, which are not treated with preservatives after 3 years especially used in wetlands and places with high humidity. Cole and Clausen (1996) reported that, wooden materials treated with CCA are protected against bacteria inside it and weather conditions, keep their functions for long time and keep their liveliness for a long time, based on their study, which took 20 years. Decays caused by bacteria existing in the wooden materials were observed before treatment with CCA. They were treated with CCA and left for 3 weeks and they were re-examined. It was observed that, harmful effects of bacteria existing in them were reduced from 46 to 22%.

Feist (1983) observed the changes occurred in the treated with preservatives and non-treated wooden materials have being left under outdoor conditions in his study. He observed expansions caused by water, discoloration, decays caused by fungi and micro-organisms and fluctuations on the surfaces in case of non-treated samples. However, no change occurred in nature of the treated samples for long years and they resisted against micro-organisms and environmental effects. Winandy (1989) treated *Pinus taeda* timbers with CCA wood preservative, made them dry by air and then at 116°C in an oven in his study. Drying process under atmospheric conditions done after impregnation process affected bending strength at a rate of 20 - 40% depending on impregnation degree. Drying in furnace affected all bending strength distribution. Lebow (1996) researched harmful effects of preservatives for human health and the environment on treated samples with various preservatives for ensuring that, treatments were done with harmless preservatives for people and also for the environment. CCA, ACZA, ACQ, CDDC and CC, which are among water-soluble impregnation materials, were used as preservative. As a result of this study, it was concluded that, restriction should be applied in using them due to complex chemical reactions. However, it was reported also that, CCA was used prevalently.

Satish and Pant (1991) researched the effects of retention and penetration depth on performance against decays caused by termites and fungi on the samples treated with BCCA. It was understood that, the performance against decays caused by termites and fungi and penetration depth is higher compared with CCA (Ozalp, 2003). Feist and Williams (1991) left their samples made of southern pine and treated with chromium and CCA on their test area under aging by weathering conditions to search their resistance against weathering conditions and other conditions and discoloration. It was observed that, damages caused by ultraviolet (UV) beams and corrosion on the surfaces decreased in case of the samples treated with chromium. It was also observed that, pine samples treated with CCA resisted against corrosion for a long time. It was concluded that, the wooden materials treated with CCA yielded better results and increased wood's lifecycle and durability compared with those treated with chromium tri oxide.

Feist and Ross (1995) left their samples from south pines and coastal firs treated with CCA and non-treated in Wisconsin and Mississippi toward south with an angle of 45° for 2 years under atmospheric conditions. At the end of this period, variations were observed between treated with CCA and non-treated samples and reported that, performance of the samples treated with CCA is higher than that of non-treated. It was also concluded that, notwithstanding CCA amount, wooden materials from firs treated with CCA yield better results compared with those from pine. Morrell and Smith (1988) impregnated eight block samples cut from alder in size of 8.75 x 8.75 x 10 cm with CCA. As a result of this study, they concluded that, damages caused by fungi are at minimum rate on the alder samples treated with CCA (Ozalp, 2003). Also, it was observed that, breaking modulus of the samples impregnated with CCA decreased due to drying at high temperatures (Winandy, 1994). Gillwald searched compression, bending and tension strengths pine and beech woods after impregnated them with UA salts and tar oil form coal. He reported that, tar oil increased compression strength by only 10% and UA salts in insignificant amounts. He also observed that, tar oil increases bending strength and water-soluble salts de-

decrease it (Keskin, 2001).

In this study, the impregnation materials of Tanalith-C (CCA) and Protim 230 WR were used as preservative and water repellant.

MATERIALS AND METHODS

In this study, black pine (*Pinus nigra*) and beech (*Fagus orientalîs Lipsky*) wood species were employed. Samples in suitable sizes were prepared from these live parts of these woods according to the standards for the study. Tanalith-C (CCA) and Protim 230 WR, water-soluble salts, were used for impregnation for all tests.

Wood species used in this study

In this study, black pine from trees with needle-leaf and beech from trees with leaf were used. Samples from black pine were supplied from Golcuk Mount with an altitude of 1200 m in Simav County of Kutahya City. Trunk diameter is 65.2 cm. Samples from beech were supplied from Akdağ with an altitude of 1700 m in Simav County of Kutahya City. Trunk diameter is 40.2 cm.

Attention was paid to preferring black pine (*P. nigra)* and beech (*F. orientalîs Lipsky*) wooden materials, which were almost perfect, with smooth fibers, free from knots, free from diseases caused by fungi, normally grown, free from reactive woods and also free from diseases caused by fungi and insects, in choosing test materials. Test samples were prepared from live parts of the wood material.

Impregnation materials and their properties

In this study, two types of impregnation material were used as preservative and water repellent. Tanalith-C (CCA: copper-chromium-arsenic) was used as preservative and Protim 230 WR organic solvent impregnation material as water repellant. The samples used in the study were impregnated in Semitas Company. Impregnation was made under pressure for 1.5 h in case of Protim 230 WR and under vacuum-pressure for 3.5 h in case of Tanalith-C (CCA). General characteristics of the impregnation materials used in this study are seen below:

Protim 230 WR

Because this impregnation material is not water-soluble naturally, it provides long-term protection. Solvent vaporizes completely after impregnation process from the wooden material and active material keep staying in the material and functions as preservative. This type of impregnation materials consists of active chemical matters having fungicide and insecticide characteristics being solved in organic solvents manufactured as oil distillation products.

This impregnation material, which provides extremely effective protection against insects and fungi, should not be used in places in contact with soil. Its color is pale yellow. Its density is 0.8 g/cm^3 and inflammable at temperatures higher than 36°C. It contains Tri butyl tin-Naphtenate (14.4 g/l) and Permethrin (0.8 g/1) (Anon., 2007).

Tanalith-C (CCA)

CCA combination used in impregnation as preservative is obtained by mixing some compounds in certain ratios (chromium, copper, arsenic). Copper functions as preservative against fungi and arsenic against termites. In case that, three of them are used in combination, they can protect wooden materials completely. It has been seen that, timbers treated with CCA are more resistant against damages caused by environmental conditions, human being and animals. Accordingly, this combination was specified according to Australian standards (Anon., 2004).

Pre-protection materials existing in CCA group are bonded to the wood chemically and cannot be removed by washing (Anon., 2006). CCA impregnation materials are generally applied on air-dried materials and by full cell method. The impregnated material is clean and free from odor and allows process on the surface such as coating and varnishing. They become resistant against fire and abrasion (Sivrikaya, 2003).

Preparation of samples

Samples were cut from black pine and beech according to the requirements about sample sizes specified in TS 2474 and TS 2595 (Anon, 1976a,b). Thus, they were prepared in size of 20 x 20 x 300 mm for bending tests and in size of 20 x 20 x 30 mm for compression tests.

Impregnation of test materials

These samples were impregnated with Protim 230 WR and also Tanalith-C as preservative when they were air-dried. Compression method was used in impregnation with Protim 230 WR and compression under vacuum method in impregnation with Tanalith-C. Impregnation time was 3.5 h in impregnation with Tanalith-C and 1.5 h in impregnation with Protim 230 WR. This variation in times was raised from the difference between the methods.

Placing samples on the test area

Impregnated and non-impregnated wooden samples were made subject to weathering conditions in a penthouse existing in Simav, Kutahya being within Central-Aegean Region, 50 cm above from the floor with an angle of 45 degree toward south for one year (between 09 January 2005 and 09 January 2006 dates). Suitable conditions were provided for avoiding confusion and making them subject to atmospheric conditions (rain, snow, sunshine).

Test Methods

Visual observation

After the samples were left to the test area, their positions under atmospheric conditions were checked regularly once a week. Also, these samples were carefully examined visually in certain periods.

Mechanic tests

In this study, static bending tests and compression tests parallel to the fibers were done on the samples. The samples were left in a climate-controlled cabin at 20ºC and 65% of relative humidity until humidity balance was received. Then, humidity was brought down to 12%. Thus, humidity variations between test samples were eliminated before these tests. How these tests were performed and their experimental characteristics are seen below.

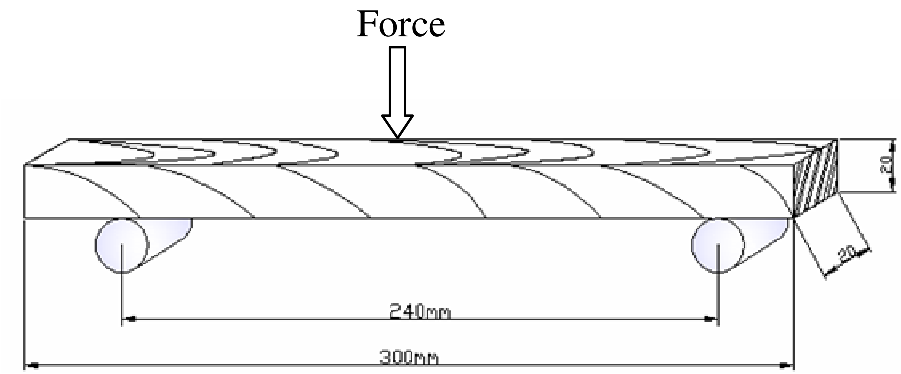

Figure 1. The dimensions of bending strength test specimens.

Static bending test

Ten samples were prepared in size of 20 x 20 x 300 mm for each test according to the requirements specified in TS 2474 [20], static bending strength tests. The distance between the bases of the test apparatus was adjusted to 240 mm and the force was applied to the surface of the samples perpendicular to annual rings exactly at the center. 12-fold of thickness of the samples (h*12:240 mm) was considered in specifying the distance between the bases of the test apparatus. Loading rate was so set that breaking would occur after 1.5 - 2 min and maximum force at breaking moment was determined with a precision of 1 kp and calculated by the equation below:

Static bending strength: $$\sigma_e = \frac{3.P.L}{2.b.h^2} \quad (1)$$

Where σ_e = bending strength (N/ mm^2), P = max. force at the moment of breaking (N), L = distance between points of support (mm), b = width of sample piece (mm), and h = thickness of sample piece (mm).
Bending strength test mechanism is given in Figure 1.

Compression test parallel to fibers

Ten samples were prepared in size of 20 x 20 x 30 mm for each test according to the requirements specified in TS 2595 for compression tests parallel to grain. A constant loading was applied at precisely center of the horizontal cross-section of the samples. Loading was so set that it can smash the samples within 1.5 - 2 min. Appearances of samples after the compression test are seen in Figure 2.

Loading was continued to be applied until the samples broke down and maximum force (F_{max}) at the moment of the breaking was written down and compression resistance parallel to the fibers ($\sigma_{B//}$) was calculated by using the following equation:

$$\sigma_{B//} = \frac{F_{\max}}{a.b} \text{ (N/mm}^2\text{)} \quad (2)$$

Where; σ_b: Pressure strength (N/mm^2), F_{max} = max. force at the moment of breaking (N), a = width of sample breadth cross-section (mm), and b = length of sample breadth cross-section (mm).

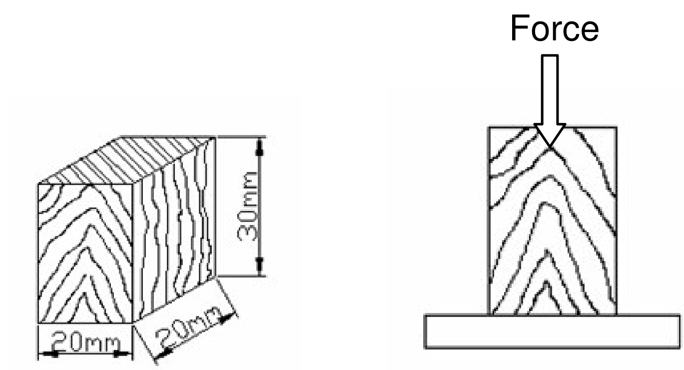

Figure 2. The dimensions of pressure strength test specimens.

Climatic conditions

The samples were made subject to atmospheric conditions for one year in Simav County of Kütahya. Climatic conditions occurred in this period are seen in Table 1 (Anon., 2005). Simav is close to Central Anatolia; however, there are many forests due to the characteristics of transition climate. The watercourse, which will be called as Susurluk River later, is born here under the name of Simav Creek. Golcuk is one of the most important natural beauties with its Crater Lake and pine forest.

RESULTS AND DISCUSSION

Findings obtained from mechanical tests

Compression tests parallel to fibers and static bending tests were done on lively parts of the black pine and beech samples treated with preservative (Tanalith-C) and water repellent (Protim 230 WR) and also control group. The findings obtained and analyses relating to them are seen below.

Table 1. Climate conditions exposed of specimens according to months.

Month	Mean temperature (˚C)	Max. temperature (˚C)	Min. temperature (˚C)	Average relative humidity (%)	Average total rain (mm)	Rainy day	Covered snow day
January	4.1	16.0	-6.4	67	138.7	20	3
February	2.6	14.3	-10.0	64	157.7	23	5
March	6.4	19.9	-8.0	59	141.9	19	2
April	10.8	27.6	-3.1	53	61.4	14	-
May	15.8	30.0	2.7	52	59.9	15	-
June	19.0	30.2	7.7	48	39.3	5	-
July	23.2	34.8	9.6	48	30.6	7	-
August	23.4	37.8	12.6	47	18.7	2	-
September	18.0	32.9	4.8	52	7.1	4	-
October	11.0	24.2	-1.9	58	40.7	8	-
November	6.8	19.2	-5.4	60	149.3	18	1
December	5.3	21.7	-13.0	62	154.6	16	8
Annual	12.2	37.8	-13.0	55	999.6	152	19

Findings obtained from compression test parallel to fibers

Compression tests parallel to fibers were done on live parts of the black pine and beech samples treated with preservative (Tanalith-C) and water repellent (Protim 230 WR) and also control group after they were made subject to atmospheric conditions. The values obtained are seen in Table 2.

Variance analysis results relating to compression strength parallel to fibers are seen in Table 3. Application variation affected compression values with an error of 1%. The variation found in the comparisons done for examining the effects of tree species and impregnation material on compression strength was considered statistically significant at reliability levels of 99 and 95% as seen in Table 3. It is seen here that, the best results among compression strength values were yielded by beech wood impregnated with tanalith-C and black pine wood impregnated with 230 WR for tree species.

Findings relating to bending strength

Bending strength tests were done on live parts of black pine and beech woods in only one direction, as tangential. The results relating to bending strength tests done on lively parts of black pine and beech woods in only one direction, as tangential are seen in Table 4.

Variance analysis results relating to tangential bending strength values are seen in Table 5. Application variation affected bending strength values with an error of 1%.

The variation found in the comparisons done for examining the effects of tree species and impregnation material on bending strength was considered statistically significant at reliability levels of 99 and 95% as seen in Table 5. It is seen here that, the best results among compression strength values were yielded by beech wood impregnated with tanalith-C and black pine wood impregnated with 230 WR for tree species.

Findings relating to physical properties

Visual examinations were done regularly on the samples impregnated with preservative and water repellent materials, on control group just after the impregnation process, and on the impregnated and non-impregnated and also on the control group after they were made subject to atmospheric conditions number 1 to detect the defects such as discoloration, fungus-like appearance and decays. As a result of these examinations, it was seen that, the samples treated with preservative were more decayed compared with those of non-impregnated after this period. Colors periodically became lighter. Darkening was seen on non-impregnated samples. Photos of the samples are seen in the chapter of attachments.

Results relating to mechanical tests

Tangential bending strength tests and compression test parallel to the fibers were done on the black pine and beech samples to detect changes in their mechanical characteristics. The results obtained from the impregnated and non-impregnated samples are presented.

Table 2. Compression test results relating to black pine and beech samples.

Used impregnating compounds		Values of average pressure strength (N/mm^2)				
		Black pine			Beech	
Non impregnated		Starting	One year		Starting	One year
	Min	19.211	17.518		25.997	22.531
	Max	23.944	20.904		30.716	26.157
	Average	22.499	19.528		27.988	23.997
	δ_x	1.442	1.144		1.395	1.134
	n	10	10		10	10
Protim 230 WR		Starting	One year		Starting	One year
	Min	19.211	18.878		25.997	24.170
	Max	23.944	22.784		30.716	29.810
	Average	22.499	21.672		27.988	26.307
	δ_x	1.442	1.215		1.395	1.577
	n	10	10		10	10
Tanalith-C		Starting	One year		Starting	One year
	Min	19.211	19.944		25.997	25.730
	Max	23.944	23.091		30.716	30.263
	Average	22.499	21.539		27.988	27.388
	δ_x	1.442	1.082		1.395	1.437
	N	10	10		10	10

Table 3. Variance analysis table relating to compression strength parallel to fibers.

Variance source	SD	Sum of squares	Average squares	Calculated F	P (probability) (%)
Repetition	9	16.457	1.829	0.946	0.494
Factor (Leaving Time)	7	662.794	94.685	48.962**	0.000
Error	63	121.931	1.934	-	
General	79	801.820	-		

Results relating to the compression strength tests parallel to the fibers

Losses occurred in compression strength of black pine and beech woods, which were impregnated and non-impregnated, after they were made subject to atmospheric conditions for 12 months are seen in Table 6.

Table 6 shows losses in compression strength parallel to the fibers of black pine and beech wooden samples. These are -13.20% in control group, -3.67% in the samples impregnated with Protim 230 WR and -4.26% in the samples impregnated with Tanalith- C for black pine wood. These are -14,314% in control group, -6.00% in the samples impregnated with Protim 230 WR and -2.14% in the samples impregnated with Tanalith- C for beech wood.

According to the compression strength results, variation was higher in the control group compared with the impregnated samples. Different impregnation materials caused different loss rates in the same wood species. According to the test results, it was understood that, losses occurred in black pine woods impregnated with Protim 230 WR after made subject to atmospheric conditions for one year are less compared with those occurred in the samples impregnated with Tanalith-C. In case of beech woods, variations occurred in the control group are higher than those occurred in the impregnated samples. It was seen that, different impregnation materials caused different loss rates in the same wood species. Also, it was understood that, losses occurred in black pine woods impregnated with Tanalith-C after made subject to atmospheric conditions for one year are less compared with those occurred in those impregnated with 230 WR.

Table 4. The results relating to bending strength tests done on lively parts of black pine and beech woods in only one direction, as tangential.

Used impregnating compounds		Values of average bending strength (N/mm^2)				
		Black pine			Beech	
Nonimpregnated		Starting	One year		Starting	One year
	Min	41.121	28.793		54.930	44.564
	Max	46.954	36.822		60.135	50.575
	Average	43.970	32.913		57.392	46.779
	δ_x	1.625	2.141		1.750	1.941
	n	10	10		10	10
Protim 230 WR		Starting	One year		Starting	One year
	Min	41.121	37.505		54.930	51.267
	Max	46.954	44.863		60.135	56.309
	Average	43.970	40.666		57.392	53.099
	δ_x	1.625	2.336		1.750	1.685
	n	10	10		10	10
Tanalith-C		Starting	One year		Starting	One year
	Min	41.121	35.169		54.930	54.456
	Max	46.954	41.636		60.135	60.912
	Average	43.970	39.182		57.392	56.386
	δ_x	1.625	1.863		1.750	1.926
	N	10	10		10	10

Table 5. Variance analysis table relating to tangential bending strength values.

Variance source	SD	Sum of squares	Average squares	Calculated F	P (probability) (%)
Repetition	9	48.766	54.8	1.282	0.264
Factor (Leaving Time)	7	5457.159	779.594	184.415**	0.000
Error	63	266.325	4.277	-	
General	79	5772.250	-		

Table 6. Losses occurred in compression strength of black pine and beech samples.

Used impregnating compounds	The rate of losses occurred in compression strength (%)	
	Black pine	Beech
Nonimpregnated	-13.20	-14.314
Protim 230 WR	-3.67	-6.00
Tanalith-C	-4.26	-2.14

Results relating to the bending test

Bending strength tests were conducted in tangential direction. Losses occurred in bending strength of black pine and beech woods, which were impregnated and non-impregnated, after they were made subject to atmospheric conditions for 12 months are seen in Table 7.

Table 7 shows losses in bending strength parallel to the fibers of black pine and beech wooden samples. These are -25.00% in control group, -7.51% in the samples impregnated with Protim 230 WR and -10.88% in the samples impregnated with Tanalith- C for black pine wood. These are -18.49% in control group, -7.48% in the samples impregnated with Protim 230 WR and -1.75% in

Table 7. Losses occurred in bending strength of black pine and beech samples.

Used impregnating compounds	The rate of losses occurred in bending strength (%)	
	Black pine	Beech
Nonimpregnated	-25.00	-18.49
Protim 230 WR	-7.51	-7.48
Tanalith-C	-10.88	-1.75

the samples impregnated with Tanalith- C for beech wood.

According to the bending strength test results, variation was higher in the control group compared with the impregnated samples. Different impregnation materials caused different loss rates in the same wood species. According to the test results, it was understood that, losses occurred in black pine woods impregnated with Protim 230 WR after made subject to atmospheric conditions for one year are less compared with those occurred in the samples impregnated with Tanalith-C. In case of beech woods, variations occurred in the control group are higher than those occurred in the impregnated samples. It was seen that, different impregnation materials caused different loss rates in the same wood species. Also, it was understood that, losses occurred in black pine woods impregnated with Tanalith-C after made subject to atmospheric conditions for one year are less compared with those occurred in those impregnated with 230 WR. According to the results mentioned above, it was evidenced that, different impregnation materials caused different loss rates in the same wood species. Thus, it is believed that, black pine woods should be impregnated with Protim 230 WR and beech woods should be impregnated with Tanalith-C.

According to the results relating to compression and bending strength tests, losses occurred in control group are more significant than those occurred in the impregnated samples. Wooden materials are very important for our lives and occupy a large area in our daily lives. Thus, more efficient ways should be researched in using it.

As a result of this study, it is recommended that, wooden materials to be used in places with high humidity such as garden furniture, outdoor joinery works etc in Central-Aegean Region should be impregnated with Protim 230 WR in case of black pine woods and with Tanalith-C in case of beech woods.

In this study, it was evidenced that, protim 230 WR provides protection as well as Tanalith–C does. Therefore, protim 230 WR impregnation material may be preferred under outdoor conditions rather than Tanalith-C because it is known that, it keeps natural color of the wood and it is not harmful for human health. Due to this study, it was evidenced that, protim 230 WR provides protection against fungi and insects as well as tanalith-C.

Conclusion

Physical examinations were conducted on the black pine and beech samples impregnated with Tanalit - C and Protim 230 WR after made subject to weathering conditions. According to the visual examinations conducted on non-impregnated black pine and beech samples, more decays caused by fungi and more severe discoloration were seen compared with those impregnated. In case of impregnated samples, changes in odor and color are insignificant and also, any significant decay was not seen. Therefore, it may be said that, these two impregnation materials provide sufficient protection under outdoor conditions for a short time.

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