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SAKARYA ÜNİVERSİTESİ

Suggestions for Designing Test Specimens and Testing Procedures to Impregnate Wood Material by Pre-vacuumed Immersion Method Realized Using a Special Device

İlker USTA*[1]

Abstract

This study, which promised remarkable contributions for designing of experimental samples and trial device to treat wood by pre-vacuumed immersion method, was conducted to test the impregnability of wood material according to the pre-vacuumed immersion process and to reveal the usability of plug (cylindrical) samples in impregnation experiments in addition to the cuboid (rectangular prism) samples. In this perspective, samples to be subjected to immersion test were initially dried to an average moisture content of 12% and than prepared for the flow pathways to determine the possible preservative uptake as the percentage of void volume filled and net dry salt retention in radial and longitudinal flow pathways, and in triplex [i.e. three flow pathways including tangential flow] and than impregnated using with 3% concentration of boron compound by normal and pre-vacuumed immersion method based on the immersion of 120 minutes, and pre-vacuum process of 30 minutes at –0.84 bar (640 mmHg). According to the experimental evidences that have been provided, it was observed that the preparation techniques for cuboids and plugs were suitable with each other in terms of the preservative uptake in either flow pathway, while the preparation process and the period of the data collection were shorter in plugs than that for cuboids. And samples impregnated by pre-vacuumed immersion method were determined to have a slightly higher preservative uptake than those impregnated with normal immersion method. At this point, it was also observed that in both experimental arrangements, the level of preservative uptake was minimal in radial samples compared to longitudinal samples. Therefore, based on the outcomes of this study, some remarks and recommendations for future work can be deduced on the use of plugs and cuboids, and also pre-vacuumed immersion process in the context of permeability examinations of any wood material.

Keywords: Wood, impregnation, immersion method, test device, cuboid and plug samples

1. INTRODUCTION

This study has been carried out with an innovative perspective in terms of its depth, and it contains original constructions aiming to test the impregnability of wood material with a new methodological arrangement within the scope of the immersion method. Although impregnation of wood material is based on experience gained through trial and error learning, it is in fact a very

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special subject developed based on the numerous findings obtained through long-term scientific research involving extensive tests. Therefore, this experimental study, which includes a methodological innovation, is expected to make a significant contribution to the field of wood science and technology, primarily in the wood protection area.

As mentioned by Usta [1], wood, the most valuable and functional material on earth derived from trees grown with the practices of sustainable forestry, has been widely used for various purposes in everyday life since the beginning of human history. Wood, however, is a natural material that needs to be protected against biotic and abiotic pests exposed by the conditions beyond its natural endurance limit. In this respect, the protection of wood, which is a naive material with its fibrous and porous structure, against these pests is at the focus of the impregnation applications realized by the many different methods with the presence of various preservatives. However, amenability to preservative treatment of wood is a very real problem with some of the refractory tree species in terms of the flow rate of liquid which can be synonymously described with permeability. Therefore, the subject of impregnation of wood with the theme of permeability has been extensively investigated in many studies in wood science and technology literature.

As we all know that submerging wood samples in a liquid until a set of time and then comparing with either the weight gained due to fluid uptake or in relation to an absolute quantity of liquid within volume, is the most simple and reliable technique to determine permeability. At this point, the most convenient way of measurement for permeability which can be synonymously described with flow rate of liquid [2], the most effective method of sample preparation for the impregnation test as either cubic or cuboid (i.e. longer in the axial direction) [3, 4], the most suitable practice for sealing all but one of the surfaces of the experimental sample to restrict penetration to one direction either parallel to grain (i.e. longitudinally) or perpendicular to grain (i.e. either tangentially or radially) [5], and the most usable manner to prepare test sample from bark to pith using a borer to give a cylindrical core [6] have been explained and exemplified in detail. In addition, various wood protection methods and many preservatives have been developed in order to protect wood material and to extend its service life against any damages and pests that destroy wood. Accordingly, the immersion method, one of the oldest known methods of wood preservation, is one of the methods developed for the impregnation of wood throughout human history, and it is widely used today with several different operational arrangements to effectively protect wood [7]. In this context, as we can easily see the protective fluids manufactured in a wide range of products for use in the operational arrangements of the immersion method designed in different constructions and point of views, this study was carried out as a new methodological approach to impregnation of wood by pre-vacuumed immersion method using cuboid and plug samples.

This study was therefore conducted following the pioneering comparative works of Usta on the impregnation of wood material by pre-vacuumed method [7] and special preparation of the experimental samples as cuboid and plug samples [8]. Thus, in this study, the impregnation of wood material based on the trial species Bornmullerian fir (*Abies bornmulleriana* Mattf.) by pre-vacuumed immersion method and the special preparation of the experimental samples as the plugs and cuboids were demonstrated in terms of both the preparative period of time and the amenability to fluid uptake. In this context, this experimental study was carried out on the basis of the studies conducted by Usta [7, 8]. Also, the data assembly regarding the experimental processing was made according to the exemplification by Usta and Hale [9] and Usta [10] for the determination of the physical properties of wood material including kiln drying and preservative treatment.

2. MATERIALS AND METHODS

Within the scope of the study, the issues that form the basis of the realization of the research were explained under the following headings: wood species, impregnation solution, preparation of experimental samples, wood preservation, data assembly and experimental processing.

2.1. Wood Species

The wooden test samples used in this study were selected from Bornmullerian fir (*Abies bornmulleriana* Mattf.), i.e. also known as Uludağ Göknarı in Turkish [11], which is a major softwood species indigenous to Turkey [12]. This tree species was particularly selected for this study, because it is being representative of the most important commercial plantation fir species within the country.

At this point, according to data related to Turkey's forest assets described in 2015, in the forests in Turkey where a spreading area up to 2.62% of fir taxa [13], Bornmullerian fir has the most extensive distribution, and spreads almost as much as the sum of the spreading areas of all other fir taxa in the forests [14].

Bornmullerian fir is a different type of tree species with its unique nature and this situation is reflected in wood material derived from it. For instance, wood material that is obtained from Bornmullerian fir is used in many fields, especially in joinery, and has the potential to provide long-term service when used after impregnation. However, because of its difficult impregnability due to its anatomical structure, Bormullerian fir is tried to be protected by impregnation with various techniques and preservatives, at least with a required amount of preservative [7].

2.2. Impregnation Solution

In our study, although there are many different types of preservatives for wood impregnation in terms of immersion method, Wolmanit-CB was used particularly. In this regard, Wolmanit-CB, which is a CCB based preservative prepared from copper-chromium-boron mixture from the water-soluble salts in the form of mixture of potassium dichromate ($K_2Cr_2O_7$) and copper sulfate ($CuSO_4$ $5H_2O$) and boric acid (H_3BO_3) as a dry mixture in certain proportions [15], is one of the most effective preservatives for protecting wood from deterioration caused by fungi and insects, and also from degradation by fire [16].

Therefore, since it is a widely used preservative in the framework of wood protection applications in the priority of immersion method, Wolmanit-CB (containing approximately 48% $K_2Cr_2O_7$, 28% $CuSO_4$ $5H_2O$, and 24% H_3BO_3) was preferred as an experimental impregnation solution and used at a concentration of 3%.

2.3. Preparation of Experimental Samples

As it can be seen in Figure 1, for preparation of the specimens, a disk of 35 cm in diameter and 40 cm in length was cut into halves from the pith and flattened to form an internal edge as a large part. Then the experimental samples were produced as the plugs and the cuboids from the sapwood zone of Bornmullerian fir (*Abies bornmulleriana* Mattf.) according to the descriptions of Usta [8]. In this respect, based on the operational workflow as shown in Figure 2, after the workbench-based preparation of the disc, which was the source of the experimental samples, the cuboid (rectangular prism) samples were produced as 30 mm in length, 20 mm in width, and 20 mm in thickness using band saw, plane, thickener, and circular saw machines respectively, whereas the plug (cylindrical) samples were prepared with a diameter of 15 mm and a length of 30 mm by core forming drill using band saw, top drill, and circular saw machines.

A schematic overview of the sample preparation for the experimental wood preservation by both cuboid and plug samples can be seen in Figure 1, where the anatomical sections of wood and the flow pathways were also illustrated. The test pieces, which were prepared in this way, were dried up to 12% of the air dry moisture content and were subjected to the surface preparation process according to the fluid permeability directions determined in the experimental design and prepared for impregnation by normal or pre-vacuumed immersion method. In this case, the diagrammatic representation for the process of coating and leaving open of the sample surfaces for the examination of fluid uptake was demonstrated in Figure 3.

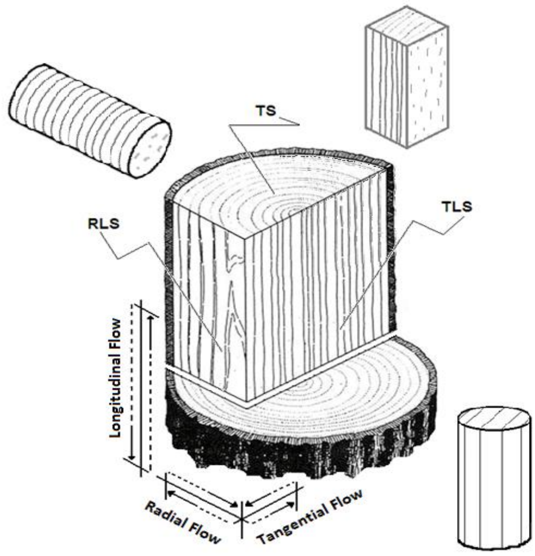

Figure 1 Schematic overview of the sample preparation for the experimental wood preservation by the cuboid and plug samples (i.e. the anatomical sections and flow pathways were also illustrated)

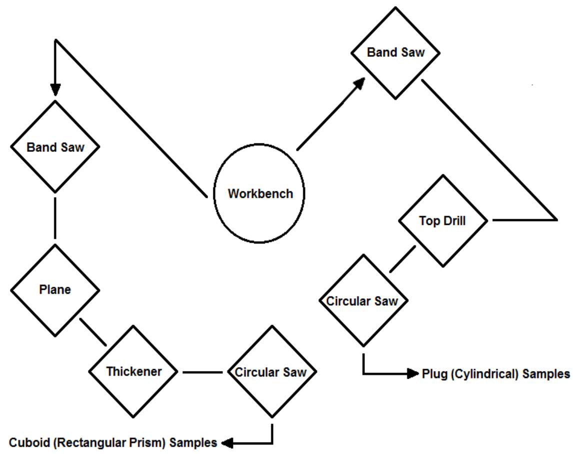

Figure 2 Operational workflow for collecting samples

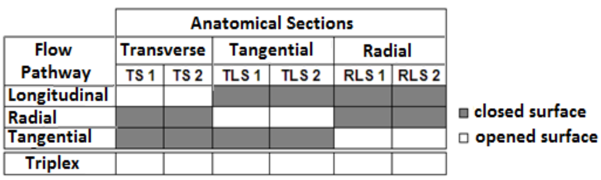

Figure 3 The diagrammatic representation for the process of coating and leaving open of the sample surfaces for the examination of fluid uptake [10]

In this study, as shown in Figure 3, longitudinal and radial flow pathways and also triplex were prepared to determine preservative uptake, apart from the tangential flow pathway. In this setup, which was based on the primary preparation of significant flow differences, the radial and longitudinal flow directions were specially prepared for the purpose of conducting a comparative fluid uptake both radially and longitudinally, while the triplex (three flow pathways including tangential flow) was prepared for control purposes. In this context, although tangential flow was not included in a review in this study, triplex flow was considered as a composite of flow in all three directions.

The experimental design, in terms of the criteria to provide information regarding exemplary subjects about the differences between the preparation and application methods, was shown in Table 1, in which the number of trial combinations was represented for either impregnation method to determine the possible fluid uptake in both radial and longitudinal flow pathways (i.e. while in this process, one surface of the related pathway can be closed or left opened if necessary, one surface was left opened for radial and longitudinal directions and no surfaces of the triplex samples were covered in our study). At this point, the sealant, which was adhering well to wood material and be strong and elastic enough coating to withstand wetting and lateral swelling, was used for sealing the surfaces of the experimental samples. Also, as the number of replicates in a comparison the experimental findings should be at least three to allow a minimal statistical analysis, the number of the test samples for determination the fluid uptake was made five in each examination.

Table 1 The experimental design based on the period of time (v: vacuum, i: immersion)

Method		**Flow Pathway**	**Period of Time (minutes)**	
Sample	**Immersion**		**v**	**i**
Cuboid	Normal	Radial	---	120
		Longitudinal	---	120
		Triplex	---	120
	Pre-Vacuumed	Radial	30	120
		Longitudinal	30	120
		Triplex	30	120
Plug	Normal	Radial	---	120
		Longitudinal	---	120
		Triplex	---	120
	Pre-Vacuumed	Radial	30	120
		Longitudinal	30	120
		Triplex	30	120

2.4. Wood Preservation

In this study, which was carried out in order to make a theoretical contribution by looking at wood preservation applications with a new perspective, it has been investigated how pre-vacuum application affects the absorption of the protective liquid in the longitudinal and radial directions (and also the combinations of all flow pathways including the tangential with the triplex samples) in wood protection performed by the immersion method using cuboid and plug samples with boron compound for the Bornmullerian fir (*Abies bornmulleriana* Mattf.) which is one of the refractory tree species. In this context, after the samples were dried to an air dry state of 12% moisture content, they were prepared by the surface preparation process according to the experimental design shown in Table 1 and were equally distributed according to the fluid flow direction group and were impregnated using boron compound with 3% concentration by normal and pre-vacuumed immersion method. Meanwhile, the immersion time was applied 120 minutes for all samples, and pre-vacuum process was performed for the test pieces subjected to pre-vacuumed immersion for 30 minutes at –0.84 bar (640 mmHg) as described by Usta [7].

The impregnation of the test samples was carried out in the test device shown in Figure 4. In terms of its importance in the realization of this study, this device, which has been designed by Usta [7] for the purpose of improving the protective liquid absorption by applying pre-vacuum in the immersion method and is an innovative idea in the field of wood protection, is an experimental design named as wood impregnation media combined with the holding container, is equipped with a mechanism that allows vacuuming to be carried out, as well as equipment that allows the intake of the protective liquid and to be discharged at the end of the process, and hence it provides pre-vacuum treatment in the immersion method. Accordingly, the control samples were placed in the holding container shown in Figure 4, and covered with lid, and then they were impregnated in normal immersion process for 120 minutes in the preservative liquid filled into the impregnation media, whereas in the pre-vacuumed immersion process, all of the trial samples were impregnated for a period of 120 minutes in the preservative liquid filled into the impregnation media after pre-vacuum application of –0.84 bar (640 mmHg) for 30 minutes.

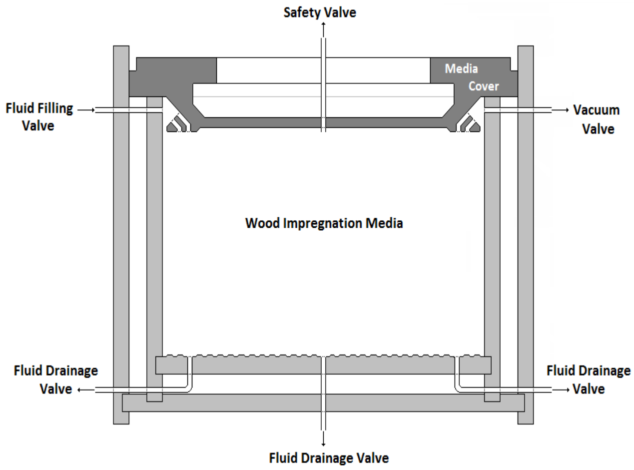

Figure 4 Illustration of experimental device designed for pre-vacuum process in wood preservation by immersion method [7]

2.5. Data Assembly and Experimental Processing

Since studies of the physical properties of wood are normally made on representative samples, in addition to the preparation of the samples to be impregnated, twelve cuboid samples with a length of 20 mm were also prepared and used to determine the following physical properties of wood material subjected to impregnation testing according to the instructions in Figure 5, which was designed by Usta and Hale [9], i.e. Do (g cm^{-3}) oven-dry wood density; Volumetric Shrinkage (%) based on the directions T tangential (the way to the growth ring cycle), R radial (the way to the radial tissue), L longitudinal (the way to the axial tissue); Volumetric Swelling depending on the volumetric shrinkage; FSP (%) fibre saturation point; MC (max) (%) maximum amount of moisture that wood material can reach. Each of these physical properties has different details in themselves [17, 18], it is important to emphasized, however, that numerous research data in relation with determination of properties under the scope of wood physics revealed that these properties were interrelated with one another directly or indirectly [19-23]. Possible effects of these factors reflect as quantitative to accomplishment potential aimed at wood material impregnation and make causality remarkable [24]. In this respect, the determination of these properties before impregnation is an important issue since they all have reflections on the evaluation of wood preservation process. According to this, because the interaction between moisture content and wood density and porosity directly affects the level of preservative liquid [25], the physical properties that must be known prior to the impregnation process for the experimental wood samples are the amount of moisture available in wood material and the density value and porosity ratio at this moisture level [26-27]. On the other hand, as described by Usta [7], fibre saturation point (FSP) ranging from 25% to 35% at all tree species, which is a function of the oven-dry density and the percentage of volumetric swelling values of wood material, stands out as an important factor for the possible absorption of protective liquid. Accordingly, the high FSP value of the experimental wood material subjected to impregnation can be considered to contribute to the relative increase in the amount of preservative bonding to the cell wall as it will affect the inclusion of the protective fluid in the intercellular spaces in the cell wall in addition to the lumen. In addition or alternatively, some modifications to the present impregnation process, re-arrangement of the permeability of the protective liquid, and some special preparation of wood material may be required for this to be carried out effectively.

Inasmuch as the fact that the physical properties studied within wood physics have direct or indirect effects on wood protection, when it is described and interpreted consistently as to how they inter-direct each other, level of absorption of protective liquid by wood material becomes meaningful and may convert to an effective qualification in terms of all implementations [9, 28]. Because of this, after completion of the impregnation process according to normal or pre-vacuumed immersion method, DMC (wood density at respective moisture content as gram per cubic centimetre) and P (porosity, i.e. percentage of void volume of wood material in terms of the amount of moisture available) were determined primarily for the examination of the values of VVF (percentage of void volume filled by preservative solution depending on the percentage of available moisture content of wood material which was being questioning) and NDS (net dry salt absorbed after impregnation as kilogram per cubic metre) according to the directive in Figure 5, which was prepared in detail by Usta and Hale [9]. It is, in fact, that this experimental process, which appears to be complex in content, involves successive data compilations. In this perspective, in accordance with the data collection guide shown in Figure 5, the basic physical properties of the experimental material were determined by the oven drying process, while the test samples were impregnated with the immersion treatment process after they had reached a moisture content of 12 percent by the kiln drying process and after preparing the surfaces of the test samples in accordance with the flow directions.

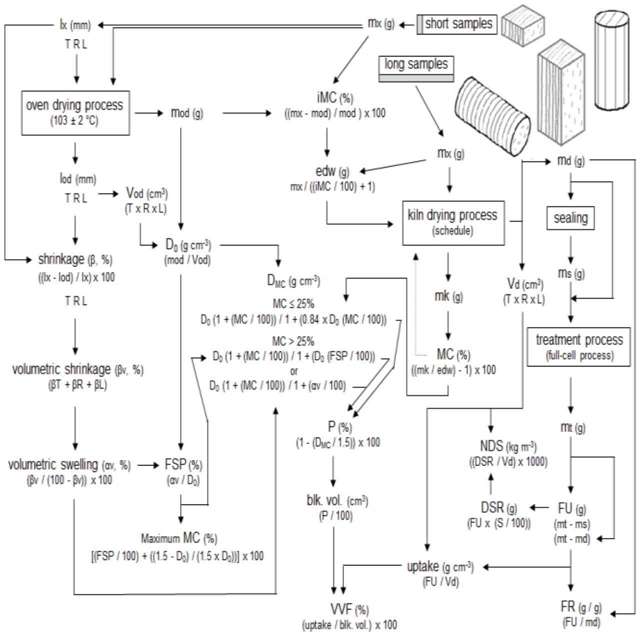

Figure 5 A schematic representation of data assembly and the experimental processing [9]

Citations of abbreviations and definitions used in this guide that were shown in Figure 5 sequentially on the base of the process can be defined as follows: mx (g), the green mass; lx (mm), length at green condition in either of the 3 directions (T, tangential; R, radial; L, longitudinal); lod (mm), length after oven drying; Vod (cm^3), block volume after oven drying; mod (g), oven-dried mass; D_0 (g cm^{-3}), oven-dry wood density; D_{MC} (g cm^{-3}), wood density at respective moisture contents (MC ≤ 25%, equal to-and/or-below 25 percent moisture content; MC > 25%, above 25 percent moisture content); P (%), porosity; blk. vol. (cm^3), the amount of space available in a given block volume; FSP (%), fibre saturation point; iMC (%), initial moisture content; edw (g), estimated dry weight after kiln drying; mk (g), mass of the sample for control the current MC at regular intervals; MC (%), current moisture content at regular intervals during drying; Vd (cm^3), block volume after kiln drying; md (g), mass after kiln drying (before treatment); ms (g), sealed mass; mt (g), mass after treatment process; FU (g), fluid uptake (the gross preservative solution absorption), FR (g/g), fluid retention (preservative retention on a whole-block basis); NDS (kg m^{-3}), net dry salt absorbed after impregnation; DSR (g), dry salt retention on the base of its strength; S (%), strength of solution; uptake (g cm^{-3}), dry salt loadings based on weight per volume; VVF (%), void volume filled by preservative solution.

3. RESULTS AND DISCUSSIONS

The results were explained and evaluated under the following headings, according to the purpose of the study: collection of samples, physical properties of wood material, preservative uptake.

3.1. Collection of Samples

When we look at the comparison of the preparation processes of the different sample types in terms of cuboid (rectangular prism) samples and plug (cylindrical) samples, which is one of the main objectives of this study, it was seen that the sample preparation process was different due to the production of the existing sample types by using the necessary machines within different works and processes. In this perspective, regarding the preparation of samples required for the study, the cuboids (20 mm in width and 20 mm in thickness and 30 mm in length) were produced using band saw, planer, thickness and circular saw machines, while the plugs (15 mm in diameter and 30 mm in length) were produced using band saw, top drill and circular saw machines. Accordingly, while the band saw centered work was in the preparation of cuboid samples, the top drill machine came to the fore in the production of plug samples. In this context, it was seen that according to the period of time for collection of the experimental samples both the cuboid (rectangular prism) samples and the plug (cylindrical) samples, the preparation of the plugs were completed in almost half the time of the preparation of the cuboids.

3.2. Physical Properties of Wood Material

The physical properties of wood material experimented in this study were given in Table 2 as a basic indicator of the oven-dry wood density and fibre saturation point. Because the effects of these properties of wood on fluid uptake in the impregnation process cannot be ignored, the shrinkage and swelling, which closely concerns both of these properties, were also shown in this table, i.e. the shrinkage was shown for all three directions and volumetrically, while the swelling was only shown volumetrically.

Table 2 Physical properties of wood material (Bornmullerian fir) tested in this study

D_o	Shrinkage (%)				α_v (%)	FSP (%)
	T	R	L	β_v		
0.425	8.4	3.7	0.6	12.7	14.5	34.1

Abbreviations shown in Table 2 regarding the physical properties of experimental wood material can be defined as follows: D_o: oven-dry density (g cm^{-3}), T: tangential direction (the way to the growth ring cycle), R: radial direction (the way to the radial tissue), L: longitudinal direction (the way to the axial tissue), β_v: volometric shrinkage, α_v: volumetric swelling, FSP: fibre saturation point (%).

In addition to the data shown in Table 2, the other physical properties of Bornmullerian fir regarding the permeability were found to be as follows: the maximum amount of moisture that wood material can reach (MC max) was 202.6%; percentage of available moisture content of test samples (MC) was 12.0%; wood density (D_{MC}) of test samples at respective moisture content was 0.457 g cm^{-3}; porosity (void volume of wood material in terms of the amount of moisture available) (P) was 69.5%.

When Table 2 was evaluated, it was alson seen that the moisture of Bornmullerian fir at the fibre saturation point was high when compared to other coniferous species described by Tsoumis [29], and Bozkurt and Göker [30] as a reflection of the volumetric swelling value. In this context, as explained by Forest Products Laboratory [31], high fibre saturation point is considered to be an important indicator that contributes to the realization of high level of liquid absorption since it is a factor to increase the maximum moisture content. This findings were compatible with the results obtained by Usta [7] and it was seen that the experimental samples typically exemplified the trial tree species in terms of their physical characteristics.

3.3. Preservative Uptake

The preservative fluid absorption performance due to absolute void volume and flow directions of impregnated wood material according to normal and pre-vacuumed immersion method was shown in Table 3 as a fundamental indicator of wood density at respective moisture content and the porosity (void volume) of wood material in terms of the amount of moisture available in this moisture level. Table 3 herein illustrates the findings of the percentage of void volume filled by preservative or in other words, it shows preservative fluid absorption performance of experimental wood material due to void volume and flow directions of impregnated samples according to normal and pre-vacuumed immersion method. The results given in Table 3 for the impregnation of the test samples of the Bornmullerian fir with normal and pre-vacuumed immersion applications showed that the preparation of the experimental samples as either cuboid or plug has no effect on the fluid uptake in either flow direction (radially and longitudinally, and also in triplex that was standing for the combinations of all flow pathways including the tangential direction). Furthermore, it was found that the amount of preservative liquid absorption in the samples treated with the pre-vacuumed immersion process was a slightly higher in comparison with normal immersion process when all the test samples subjected to impregnation were compared in terms of the amount of preservative solution contained by the existing cell cavities of wood. These results coincide with the results obtained by Usta [7] for the experimental samples impregnated in accordance with the normal and pre-vacuumed immersion method based on the same amount of moisture. This was also the case in the amount of dry salt, which means that the impregnation solution loaded into the impregnated specimens to be settled in wood in the form of a residue after the solvent water has evaporated completely. In this respect, it was found that the net dry salt retention (the quantity of preservative solution absorbed by the experimental wood specimens) showed a similar distribution with void volume filled by preservative solution as a result of all samples impregnated with normal and pre-vacuumed immersion method. Of course, although the impregnability of the experimental wood material was evaluated based on the percentage of void volume filled by preservative solution and net dry salt absorbed after the impregnation process without indication of depth penetration, this was supported by the outcomes of this study.

On the other hand, as an important determination, the amount of void volume filled by preservative fluid were found to be greater than 10% but less than 30% when all experimental samples were evaluated, since the immersion process was performed with samples having air dry moisture of 12%. To take a closer look at this result, the percentage of void volume filled with preservative solution for all types of test specimens varies between 10.2% and 25.9% in normal immersion, and 12.5% and 28.0% in pre-vacuum immersion. At this point, when a comparison was made according to the trial pattern, it was seen that the least uniform alignment of the preservative fluid uptake according to the flow pathways was revealed in the form of Radial < Longitudinal < Triplex, regardless of the type of the sample preparation and the way of impregnation either normal or pre-vacuumed immersion.

Table 3 The absorption performance of wood material in terms of flow directions according to normal and pre-vacuumed immersion method

Method		Flow Pathway	Absorption	
Sample	Immersion		VVF	NDS
Cuboid	Normal	Radial	10.2	2.1
		Longitudinal	18.1	3.7
		Triplex	25.9	5.3
	Pre-Vacuumed	Radial	12.5	2.6
		Longitudinal	22.0	4.5
		Triplex	27.6	5.7
Plug	Normal	Radial	10.4	2.1
		Longitudinal	18.2	3.8
		Triplex	25.8	5.3
	Pre-Vacuumed	Radial	12.7	2.6
		Longitudinal	22.3	4.6
		Triplex	28.0	5.8

Abbreviations in Table 3 for the preservative fluid absorption were as follows: VVF: percentage of void volume filled by preservative solution, NDS: net dry salt absorbed after the impregnation process (kg m^{-3}).

4. CONCLUSIONS

This study, which aims to determine the effect of pre-vacuum process according to the flow directions in the protection of wood material by the immersion method in 12% moisture content, which is a common use condition, is a clear example in terms of impregnation of the dried wood material by immersion method. Considering that this study was carried out with the samples having air dry moisture content at 12% level, the preservative fluid uptake of the test samples was found to be relatively low compared to impregnation by the immersion method using samples with high moisture content. However, the feasibility of the immersion method with a pre-vacuumed process has been proven experimentally once again and it may be useful to examine this subject in detail through extensive research in the field of wood preservation. In addition, if a general evaluation is made in the context of the impregnation results obtained by this study, it has been observed that the plug samples (15 mm in diameter and 30 mm in length) can be used for the same purposes as well as the cuboids (20 mm in width and 20 mm in thickness and 30 mm in length) in the experimental wood impregnation applications. It is obvious that this would also provide significant savings in terms of sample preparation and detection cycle, because in this study, the period of the data collection were shorter in plugs than that for cuboids.

In light of these findings, it can be stated that this study is meant to be a reference for interested implementers to examine wood material to expand its capability in impregnation by immersion method. It is therefore obvious that this study will shed light on future studies involved in the same topic by comparing the experimental samples to be prepared in different moisture contents and the tests to be carried out with different immersion times.

When we compare the usage areas of wood, which is widely used as a versatile and functional material, it is obvious that the impregnation of wood material is a great necessity when viewed in terms of its use in wet interiors (due to direct splash) and outdoors (because of direct rain or sprinkler). In this study, which was carried out with a special test device, it was determined that performing the immersion method in the pre-vacuum priority increased protective fluid uptake and contained relatively more impregnation material (as the amount of net dry salt) in the fibrous and porous structure of wood material. Therefore, it can be said that moving the results of this study to an industrial dimension "within the framework of wood preservation by pre-vacuumed immersion method" will have an important place in the preservation of wood material by immersion method using boron compounds. Because of the fact that wood is in the life with appropriate protection processes and makes a great contribution to the protection of nature and environment, the design and development of wood preservation applications with different propositions is necessary for the existence of wood. Thus, the diversification the immersion method, as exemplified in this study with reference to the pre-vacuumed process, can be considered as an effort involving originality and innovation in terms of impregnating wood material with a woodlover approach.

Overall, the outcomes of this study showed a comprehensive understanding and methodological view of wood science and technology, and thereby enlarging our experience for looking for the new challenges and opportunities for wood preservation.

Acknowledgments

This study, which is carried out to devise ways to examine wood protection in terms of the collection and preparation of the experimental samples, and also the application of vacuum process in immersion method, is an improved version of the preliminary study entitled “Suggestive remarks for designing of experimental samples and trial devices to treat wood by pre-vacuumed immersion method” that was presented in summary on the IRG (International Wood Protection Research Group) website in 2019, (available via https://www.irg-wp.com/search-irg-docs.html) (access date; 21 December 2019), and hence, the author would like to express his sincere thanks and gratitude to the IRG.

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