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A SYSTEMATIC ANALYSIS ON THE USE OF WOOD WITH LONG SERVICE LIFE IN ARCHITECTURE

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Abstract

Responsible architectural practices are becoming increasingly important in the face of global environmental problems. Depending on the understanding of sustainable architecture, the importance of wooden building materials and the need for the material are increasing daily. This situation brings with it the necessity to ensure that the existing material's service life is long. Impregnation applications constitute an essential part of the commonly used methods to extend the service life of wooden materials against various damaging factors. However, the diversity in impregnation applications makes it difficult for the architect to choose impregnated wood. In this context, this research aims to analyze impregnation research and present a framework that will rationalize the architect's choice of impregnated wood materials with long service lives.

Keywords: Architecture, Building Material, Impregnation, Service Life, Wood.

MIMARIDE HIZMET ÖMRÜ UZUN AHŞAP MALZEME KULLANIMINA YÖNELIK SISTEMATIK BIR ANALIZ

Özet

Küresel çevresel sorunlar karşısında, sorumlu mimarlık uygulamaları, giderek önem kazanmaktadır. Sürdürülebilir mimarlık anlayışına bağlı olarak, ahşap yapı malzemesinin önemi ve malzemeye olan gereksinim de günden güne artmaktadır. Bu durum ise mevcut malzemenin hizmet ömrünün uzun olmasını sağlama zorunluluğunu beraberinde getirmektedir. Çeşitli olumsuz etkenler karşısında, ahşap malzemenin hizmet ömrünün uzatılması için, yaygın olarak kullanılan yöntemlerin önemli bir bölümünü emprenye uygulamaları oluşturmaktadır. Ancak, emprenye uygulamalarındaki çeşitlilik, mimarın emprenyeli ahşap seçimini zorlaştırmaktadır. Bu bağlamda bu araştırmanın amacı; emprenye araştırmalarını analiz ederek, mimarın hizmet ömrü uzun emprenyeli ahşap malzeme seçimini rasyonel hale getirecek bir matris sunmaktır.

Anahtar Kelimeler: Mimarlık, Yapı Malzemesi, Emprenye, Hizmet Ömrü, Ahşap.

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1. INTRODUCTION

The importance of wooden building materials is increasing daily in the architectural environment, where the search for solutions to environmental problems is gaining importance, and the concept of sustainable architecture is becoming increasingly widespread. In addition to being a natural building material, its high carbon storage capacity, offering species alternatives, and superior mechanical and physical properties enable wood to be accepted as the future building material. The need for wooden materials is increasing daily in such an architectural environment. The increasing need for wooden materials brings with it the necessity of ensuring that the existing material is used efficiently and has a long life.

The task undertaken by each building element in an architectural structure changes, and accordingly, different performances are expected from the materials used in that building element. Despite its superior properties as a building material, wood is in architectural structures; may encounter physical, chemical, mechanical, biological, and human-induced negative factors (Perker, 2004; Perker & Akıncıtürk, 2006). Failure to take any precautions to protect the wooden material against the negative factors it may encounter causes it to fail to show the expected performance for a long time. When the safe use of a building element is at risk, it may need to be replaced early, or the material loses its economy due to maintenance and repair costs (Yalınkılınç et al., 1996).

Against the effects that damage the wooden material itself, it is known that it is possible to protect it by impregnation, drying, and various surface treatments, and the effects of undesirable conditions on wooden materials can be reduced with the mentioned methods (Altay & Özdemir, 2023; Şen & Hafızoğlu, 2008; Kılınç et al., 2022). Impregnation processes based on extending the service life of wooden materials against various factors stand out as the most common approaches to material protection (Bozkurt et al., 1993).

Wooden material can be impregnated with various substances with protective properties against negative factors. However, the diversity in the tree species used in the production of wooden building materials, the diversity in the expected performances due to the role of the wooden element used in the structure, and the diversity in the materials and methods used in the impregnation process make it difficult for the architect to choose impregnated wood. It is of great importance for the architect to rationalize the selection process.

There are various experimental studies on impregnating wooden materials in Türkiye-based literature. However, in the relevant literature, holistic research has yet to focus on extending the service life of impregnated wooden materials for building element design. It provides a guide that can help the architect in material selection. In this context, this research aims to analyze of experimental research focusing on the effect of impregnation on the service life of wooden materials in articles of in DergiPark. The aim is to present a guiding matrix that will help the architect rationally choose the impregnated wooden material to be used in the design, maintenance, repair or renewal of building elements.

2. EFFECT OF IMPREGNATION ON THE SERVICE LIFE OF WOOD

Against the damaging effects it may encounter, wooden material can be protected by impregnation, drying, and various surface treatments. However, the most common protection process is impregnation. The impregnation of wood material varies significantly in terms of materials and methods used. Generally, oil-borne, water-borne, or organic solvent preservatives are used in impregnation. It penetrates the wooden material through pressure or non-pressure methods.

It is generally accepted that the impregnation process of wooden materials is carried out to extend the service life of the wooden material. However, since the success of the impregnation process and the degree of preservation are essential, the evaluation of the effect of impregnation on the service life of the wooden material is made depending on some factors. The most important of these factors are wood type and properties, impregnation material, impregnation method, the amount of net dry impregnation material adhered to the wood material after the impregnation process (retention), and the penetration depth of the impregnation material into the wood material (Yalınkılınç et al., 1996; Baysal et al., 2005). In studies examining the effect of impregnation on the service life of wooden materials, analyses were made regarding the wood type and properties before the impregnation process. After the impregnation process, in order to evaluate the effectiveness of the process, properties such as the net dry impregnation amount (retention), the penetration depth of the impregnation into the wood material, the specific gravity values of the wood material, and the swelling - contraction values of the wood material are compared. In some studies, in addition to the properties listed, it is also evaluated whether there is any change in the various properties of the wood material after the impregnation process.

The impregnability of wood material is related to the permeability of the wood species from which the wood material is obtained. Permeability is an important factor determining the degree of impregnability of wood. It is a term that generally describes the rate at which liquids pass under pressure through a porous surface (Naval Facilities Engineering Command, 1990). If a material allows liquid flow easily under pressure, it is understood to have high permeability. Since increasing the permeability of wood positively affects its impregnability, the permeability values of the wood material are examined before the impregnation process. In addition, before the impregnation process, studies can be carried out to increase the material's permeability to increase the process's effect. (Jang et al., 2020). The type of tree from which the wooden building material is obtained and whether the part of the tree from which the wooden material is obtained is sapwood or heartwood causes significant differences in permeability values. The permeability of wooden materials can be divided into four groups according to the penetration ability of the heartwood: easily impregnable, moderately impregnable, difficult, and very difficult impregnable wooden materials (Bozkurt et al., 1993). Accordingly, woods that are easily impregnated under pressure and fully penetrated are in the "easy impregnation" class in terms of permeability class. The permeability class for wood impregnated under pressure for 2-3 hours and with a penetration of 6-18 mm in the transverse direction is accepted as "medium strength impregnation." The permeability class for wood power impregnated under pressure for 4-10 hours, and 1-6 mm penetration achieved in the transverse direction is expressed as "difficult to impregnated" wood that provides a penetration depth not exceeding 1 mm when impregnated under pressure for more than 10 hours is considered as "very difficult to impregnated" wood (Güler, 2011; Ayar, 2008).

After the impregnation process, some values need to be examined to evaluate the effectiveness of the process. These values generally include retention (the amount of impregnation material retained in the wood material after the impregnation process), penetration depth, washing rate of the impregnation material, moisture-related deformation of the wood material, and specific gravity. High retention levels encountered after the impregnation process, high penetration depth, low washing rate of the impregnation material, decreased moisture-related deformation of the wood material, and increased specific gravity indicate that the impregnation process is effective. The changes in the type mentioned after the impregnation process are interpreted as extending the service life of the wooden material.

3. METHOD

The academic studies to be discussed within the scope of the research were obtained from the Dergipark database. First, the relevant database was searched with the keyword "impregnation." The article list obtained as a result of the search was examined in detail. Studies published focusing on the effect of impregnation on the service life of wooden materials and having experimental content were selected from the list. Thus, the 17 studies obtained constituted the data set of this research (Table 1).

Table 1. Information about the articles in the dataset

Title of Journal	Authors, Year
Artvin Çoruh University Faculty of Forestry Journal	Bardak et al., 2011 Yalçın et al., 2018
ECJSE El-Cezeri	Var & Yaldız, 2017
Erciyes University Journal of The Institute of Science and Technology	Baysal et al., 2005
European Journal of Science and Technology	Ulusoy & Peker, 2020
Fırat University Journal of Engineering	Tan & Peker, 2015
Journal of Bartın Faculty of Forestry	Var & Soygüder, 2017
Journal of Polytechnic	Tan & Peker, 2015
Kastamonu University Journal of Forestry Faculty	Atılgan et al., 2013
Pamukkale University Journal of Engineering Sciences	Yalınkılıç et al., 1996
Turkish Journal of Forestry	Var et al., 2005 Var et al., 2013 Var et al., 2014 Var et al., 2015 Var & Özkan, 2018 Can & Sivrikaya, 2019
Turkish Journal of Forest Science	Demir & Aydın, 2021

The research method is the systematic analysis of the data set obtained due to the scanning in terms of content. In this context, first of all, the contents of the articles that make up the data set, the tree/wood type, impregnation material, and impregnation method, were analyzed and evaluated regarding the effect of impregnation on the service life of the wooden material.

4. RESULTS

Among the tree species used in the studies covered within the scope of the research, softwood such as Scotch pine, black pine, Anatolian black pine, red pine, Picea orientalis, and hybrids were used. It has been determined that hardwood species such as oriental beech, ash, poplar, black poplar, eucalyptus, beech, alder, and iroko are used (Table 2).

Table 2. Wood species used in the articles (Table 2 was prepared by the authors using the sources in Table 1).

WOOD SPECIES			ARTICLES																
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
NATURAL WOOD	SOFTWOOD	Scotch Pine	■	■				■			■	■					■		
		Black Pine						■	■	■				■					
		Anatolian Black Pine			■														
		Red Pine					■		■	■			■						
		Picea Orientalis	■																
		Hybrid						■											
	HARDWOOD	Oriental Beech	■								■	■							
		Ash													■				
		Poplar						■											
		Black Poplar														■			
		Eucalyptus				■													
		Beech																■	
		Alder	■																
		Iroko						■											
ENGINEERED WOOD	SOFTWOOD	Scotch Pine																	■
	HARDWOOD	Alder																	■
		Poplar																	■

Impregnation materials used in the studies can be classified in four ways: natural, oil-borne, water-borne, and organic solvent preservatives. Natural preservatives used in the studies included in the research include Asphodeline taurica, flaxseed oil, pomegranate and walnut fruit shells, quince leaves, tall oil, and tea plant extract (Table 3). Methyl hydrogen silicone and Paraffin were used as oil-borne preservatives (Table 4). Among the water-borne preservatives, alkali/copper/quat (ACQ), ammonium sulfate (AS), borax (Bx), boric acid (BA), copper azole (Tanalith-E), Copper-chrome-borate (Tanalith-CBC), diammonium phosphate (DAP), geothermal water, Immersol aqua, Immersol-WR, micronized copper quat (MCQ), mono ammonium phosphate (MAP). Nano boron (NB), polyethylene glycol (PEG-400), sodium silicate, Vacsol, Vacsol-WR, and zinc borate (Table 5). Organic solvent preservatives include Isocyanate (ISO), Methylmethacrylate (MMA), Styrene (St), and Barite (Baso4) (Table 6).

Table 3. Natural preservatives used in articles (Table 3 was prepared by the authors using the sources in Table 1).

NATURAL PRESERVATIVES	ARTICLES																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Asphodeline Taurica																■	
Flaxseed Oil															■		
Pomegranate and Walnut Fruit Shells														■			
Quince Leaf														■			
Tall Oil															■		
Tea Plant Extract						■											

Table 4. Oil-borne preservatives used in articles (Table 4 was prepared by the authors using the sources in Table 1).

OIL-BORNE PRESERVATIVES	ARTICLES																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Methyl Hydrogen Silicone															■		
Paraffin		■															

Table 5. Water-borne preservatives used in articles (Table 5 was prepared by the authors using the sources in Table 1).

WATER-BORNE PRESERVATIVES	ARTICLES																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Alkaline Copper Quaternary															■		
Ammonium Sulfate	■	■		■													■
Borax	■	■		■													
Boric Acid	■	■		■											■		
Copper Azole													■				
Copper-Chrome-Borate	■	■		■													
Diammonium Phosphate	■	■															
Geothermal Water					■		■	■			■	■		■			
Immersol Aqua			■														
Immersol-WR 2000				■													
Micronized Copper Quaternary															■		
Monoammonium Phosphate																	■
Nano Boron															■		
Polyethylene Glycol	■	■		■													
Sodium Silicate															■		
Vacsol	■	■															
Vacsol-WR				■													
Zinc Borate																	■

Table 6. Organic solvent preservatives used in articles (Table 6 was prepared by the authors using the sources in Table 1).

ORGANIC SOLVENT PRESERVATIVES	ARTICLES																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Isocyanate	■	■															
Methyl Methacrylate	■	■		■													
Styrene	■	■		■													
Barite									■	■							

In the studies covered within the scope of the research, two groups of impregnation methods were used: non-pressure and pressure methods. It has been observed that dipping and hot-cold bath methods are among the non-pressure impregnation methods used in the studies. It has been determined that full-cell and vacuum methods are preferred among the methods where pressure is applied (Table 7).

Table 7. Impregnation methods used in articles (Table 7 was prepared by the authors using the sources in Table 1).

	IMPREGNATION METHODS	ARTICLES																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
NON-PRESSURE	Brushing or Spraying																	
	Dipping			■				■	■				■		■			■
	Hot-Cold Bath					■						■						
	Soaking																	
PRESSURE	Full Cell Process															■		
	Vacuum process	■	■		■		■			■	■			■			■	

In the studies covered within the scope of the research, it was determined that polyethylene glycol-400 (PEG-400) substance has a reducing effect on water resistance and affects the swelling and contraction values of wood (Baysal et al., 2005; Bardak et al., 2011; Var et al., 2013). In addition, it was determined that the retention amount of the impregnation material named PEG-400 was high. Increasing the amount of retention increases the permeability of the wooden material, such as its impregnation effectiveness. It can be said that geothermal waters with high retention and absorption amounts (İzmir-Doğanbey, Afyonkarahisar-Gecek, Kütahya-Eynal, Sakarya-Kuzuluk/Geyve, Aydın-Alangüllü/Çamköy/Germencik, Antalya-Demreburguç) positively affect the service life of wooden materials (Yes). et al., 2013; Var et al., 2014; Var et al., 2015; Var and Soygüder, 2017; Var and Yaldız, 2017; Var and Özkan, 2018). It was determined that vacsol on spruce and 3% asphodel on beech had a high retention amount (Yalınkılıç et al., 1996; Ulusoy & Peker, 2020). It was also found that the retention amounts of tea plant extract and 50% barite solution were high in beech (Atılgan et al., 2013; Tan & Peker, 2015a). Again, it is stated in the document that 1% barite solution causes the specific gravity to increase (Tan & Peker, 2015b). It has been observed that nano boron impregnation increases the washing resistance of wooden materials, thus positively affecting the material's service life (Can and Sivrikaya, 2019; Öztürk, 2024).

As a result of analyzing the experimental studies included in the research, a matrix was created that holistically reveals the positive contribution of impregnation to the service life of wooden materials (Table 8). Only impregnation materials and methods that positively contribute to the service life of wooden materials are included in the matrix.

Table 8. Matrix for impregnation materials and methods that positively affect the service life of wood. (Table 8 was prepared by the authors using the sources in Table 1)

	PRESERVATIVES	IMPREGNATION METHODS			
		Dipping	**Hot-Cold Bath**	**Full Cell**	**Vacuum**
NATURAL	Asphodeline Taurica				Beech
	Pomegranate Shells	Black Poplar			
	Tea Plant Extract				Oriental Beech
WATER-BORNE	Borax				Scotch Pine Picea Orientalis Oriental Beech Alder
	Boric Acid				Scotch Pine Picea Orientalis Oriental Beech Alder
	Copper Azole				Ash
	Geothermal Water (İzmir-Doğanbey)		Red Pine		
	Geothermal Water (Afyonkarahisar, Gecek)	Red Pine Black Pine			
	Geothermal Water (Kütahya, Eynal)	Red Pine			
	Geothermal Water (Sakarya, Kuzuluk)		Red Pine		
	Geothermal Water (Aydın)	Black Pine			
	Nano Boron			Scotch Pine	
	Polyethylene Glycol				Eucalyptus
	Vacsol				Picea Orientalis
ORGANIC SOLVENT	Isocyanate				Scotch Pine
	Methyl Methacrylate				Scotch Pine
	Styrene				Scotch Pine
	Barite				Scotch Pine Oriental Beech

5. CONCLUSION

In the scope of the research, 17 articles obtained from the Dergipark database containing academic articles in Türkiye and focusing on the effect of impregnation on the service life of wooden materials were examined. Articles covered within the scope of the research: The tree/wood type, impregnation material, and impregnation method were analyzed in the context of the effect of the impregnation process on the wooden material's service life.

In studies focusing on the effect of impregnation on the service life of wooden materials, Except for a limited number of studies, it has been observed that natural wood types are mostly preferred. It has been determined that different types of impregnation materials, such as natural, oil-borne, water-borne, and organic solvent preservatives, are used as impregnation materials in the studies. As an impregnation method, from pressure-applied methods to full cell methods and vacuum methods, it has been observed that dipping and hot-cold bath methods are included among the methods that do not apply pressure.

As a result of the research, a matrix was created that holistically reveals the positive contribution of impregnation to the service life of wooden materials. It is believed that the matrix created is a guide to help the architect rationally choose the impregnated wooden material to be used in the design, maintenance, repair, or renewal of building elements, focusing directly on the material's service life.

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