



A MECHANICAL PROPERTY-FOCUSED ANALYSIS FOR THE USE OF IMPREGNATED WOOD IN ARCHITECTURE

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Abstract

Wood has played a crucial role as one of the fundamental materials in architecture throughout civilization's history. It holds significance in maintaining architectural heritage while paving the way for a sustainable architectural future. Despite its excellent properties, wood deteriorates due to various physical, chemical, mechanical, biological, and human-induced factors. Impregnation is the most commonly applied technique among the methods used to enhance its durability. However, the materials and processes used in impregnation differ widely. Since wood is utilized in various building components, and the required performances of these components vary, impregnation techniques also diversify. This diversity can make it challenging for architects to select the most suitable impregnated wood. In this regard, this study aims to serve as a practical guide on impregnation procedures, explicitly focusing on the mechanical properties of wood. For this research, 17 experimental articles from the Dergipark database were examined and analyzed based on relevant properties. As a result, guide diagrams were developed to help architects streamline their decision-making process when selecting impregnated wood, emphasizing mechanical characteristics.

Keywords: Architecture, Wood, Material, Impregnation, Mechanical Property.

EMPRENİYE EDİLMİŞ AHŞABIN MİMARİDE KULLANIMINA YÖNELİK MEKANİK ÖZELLİK ODAKLI BİR ANALİZ

Özet

Uygarlık tarihinin en önemli yapı malzemelerinden biri olan ahşap, hem mimari geleneğin korunması hem de sürdürülebilir bir mimari geleceğin kurulması açısından büyük önem taşımaktadır. Üstün özelliklerine karşın, ahşap malzemenin fiziksel, kimyasal, mekanik, biyolojik ve insan kaynaklı nedenlerle bozulmaya uğradığı da bilinmektedir. Ahşap malzemenin çeşitli etkenlere karşı performansını arttırmak için uygulanan en yaygın koruma yöntemi emprenyedir. Ancak ahşap malzemenin emprenye edilmesinde kullanılan malzeme ve yöntemler farklılık göstermektedir. Ahşap malzemenin kullanıldığı yapı elemanlarının çeşitliliği ve söz konusu elemanlardan beklenen performanslar emprenye işlemlerini çeşitlendirmektedir. Bu çeşitlilik içerisinde, mimarın amaca yönelik emprenyeli ahşap malzeme seçmesi zorlaşmaktadır. Bu bağlamda bu araştırma, ahşap malzemenin mekanik özelliklerini hedef alan emprenye işlemleri üzerinden yol gösterici bir rehber sunmayı

amaçlamaktadır. Araştırma kapsamında Dergipark veri tabanında konuyla ilgili, deneysel içerikli 17 adet makale ele alınmış ve amaca yönelik özellikler açısından analiz edilmiştir. Araştırma sonucunda, mimarlar için emprenyeli ahşap seçim süreçlerini rasyonelleştirecek ve ahşap malzemenin mekanik özelliklerine odaklanan, rehber niteliğinde diyagramlara ulaşılmıştır.

Anahtar Kelimeler: Mimarlık, Ahşap, Malzeme, Emprenye, Mekanik Özellik.

1. INTRODUCTION

Wood is a building material that is important for preserving universal architectural culture on the one hand and the sustainability of the architectural structures of the future on the other. Due to its superior properties, wood has been preferred as a building material in history and various regions, providing significant examples of the universal architectural heritage. Wood, one of the oldest known building materials, has become an important material reflecting the traditional architectural characteristics of that region in every region where it is used. It has ensured the continuation of architectural culture to the extent it can be preserved. Transferring the universal cultural heritage created using wood to future generations will only be possible by protecting the materials used in the mentioned buildings.

On the other hand, wood is an important building material for environmentally responsible architecture in an environment where all countries are looking for solutions to environmental problems. The fact that its source is renewable has carbon storage capacity and is a recyclable and environmentally friendly material makes wood stand out among building material alternatives.

Despite its superior properties, wood deteriorates due to physical, chemical, mechanical, biological, and anthropogenic reasons (Perker, 2004; Perker & Akıncı, 2006). Impregnation, an in-depth protection application that ensures that the wood has a long life against adverse factors, is the most common application in wood protection (Bozkurt, Göker & Erdin, 1993).

Natural and engineered wood can be used in structural elements of architectural structures such as pillars and beams or in window and door joinery, as well as as a covering material on the surfaces of building elements such as floors, walls, and roofs. The performance expected from the wood also varies depending on the function of the building element in which the wood is used. The wood used in architectural structures can be produced from different tree species, and the diversity in tree species also changes the behavior of the wood in the structure. On the other hand, the materials and impregnation methods used in impregnating wood, which can be impregnated for different purposes, also vary. In this diversity, it becomes difficult for architects to choose impregnated wood options rationally. When choosing impregnated wood, it is necessary to focus on the different performances of the wood, depending on the function of the building element in which the material will be used.

In this context, this study aims to conduct an analysis that will help the architect to rationally select the impregnated wood to be used in building elements in terms of mechanical properties and to create guiding diagrams for the architect as a result of the analysis.

2. CONCEPTUAL FRAMEWORK

The conceptual framework of the research is based on the mechanical properties and impregnation of the wood. In this context, within the scope of the conceptual framework, information about the mechanical properties of the wood and the impregnation of the wood is included.

2.1. Mechanical properties of wood

The mechanical properties of wood define its resistance to mechanical external forces that cause size and shape changes, stress, and fractures in the wood. Since wood has a heterogeneous and anisotropic structure, its resistance properties vary depending on various factors. These factors include tree type, specific gravity, anatomical and chemical structure, climate and humidity conditions of the location, and the angle between the direction in which the force is applied and the fiber direction (Bozkurt & Erdin, 2011; Örs & Keskin, 2001; Perker, 2004).

Mechanical properties are the most important features, especially when using wood as a building material. When selecting materials for any application, these properties must be determined. Wood's Mechanical properties are examined under the headings of modulus of elasticity, compressive strength, tensile strength, bending strength, cleavage strength, shear strength, hardness, dynamic bending strength, and wear resistance.

The ability of a material to change its shape due to a force acting on it and to return to its previous shape when the force is removed is defined as "elasticity." The modulus of elasticity is a property that determines the ability of materials to resist forces that create deformation. As the module grows, the materials show more resistance and are more resistant to deformation. As it gets smaller, it undergoes deformation more easily. Due to the anisotropic structure of the wood, the elasticity modulus varies according to the fibers' parallel, radial, and tangential directions. While the modulus of elasticity is highest in the direction parallel to the fibers, it is lower in the radial direction and lowest in the tangential direction (Anonim, 1980; Bozkurt & Erdin, 2011; Örs & Keskin, 2001).

The compressive strength of wood is defined as its resistance to forces applied parallel and perpendicular to the fibers. While the wood shows low resistance to the pressure force applied perpendicular to the fibers, it shows high resistance to buckling and crushing by working like a column against the forces applied parallel to the fibers. Among the factors affecting the pressure resistance of wood are the moisture content of the material, specific gravity, fiber direction, hardness, temperature, knotiness, and extractive substances. In this context, specific gravity and pressure resistance are directly proportional; that is, as specific gravity increases, pressure resistance also increases. However, there is an inverse relationship between temperature and pressure resistance; as temperature increases, pressure resistance decreases (Bozkurt & Erdin, 2011; Çalışkan et al., 2019; Öztürk, 2024).

Tensile strength is the resistance of the wood against two opposing forces that try to separate and tear the fibers. Two types of tensile strength are parallel and perpendicular to the fibers. In a wood, the tensile strength parallel to the fibers can generally be more significant than all other types of resistance. This is because the microfibrils in the cell wall are parallel to the axis. Density, humidity, fiber direction, knots, and temperature are among the factors affecting tensile strength. According to this, As density increases, tensile strength also increases. Considering its relationship with humidity, generally at humidity levels below LDN (Fiber saturation point), tensile strength increases as humidity decreases. An inverse

relationship is observed in its relationship with temperature, as in its relationship with humidity. In other words, as the temperature increases, the tensile strength decreases. Knots are a factor that can significantly reduce tensile strength and have a significant impact on this resistance (Bozkurt & Erdin, 2011; Örs & Keskin, 2001).

The resistance of a wood placed on support at both ends against a force acting perpendicular to the fibers from one or both sides trying to bend is called bending strength. Factors such as density, moisture, knots, fiber orientation, and temperature in the wood affect the bending resistance. As wood's density increases, its bending strength increases in this context. Flexural strength is highest at 35% humidity. Knots, especially those falling between support points, reduce bending strength. The angle between the direction in which the bending force is applied and the direction of the fibers is highest when it is 0° and lowest when it is 90°. As the temperature increases, the density decreases, which causes the bending strength to decrease (Bozkurt & Erdin, 2011; Kretschmann, 2010; Örs & Keskin, 2001).

Cleavage strength is the resistance of a wood against an object entering between the fibers and trying to split it. The density of the wood, moisture content, fiber direction, and defects in the material are factors that affect cleavage strength. In this situation, As density increases, cleavage strength also increases. When the moisture content of a wood is between 12-17%, the cleavage strength does not change significantly. However, below or above these values, the cleavage strength decreases. In addition, the cleavage strength in the tangential direction is higher than in the radial direction.

Shear strength is the resistance of wood against forces that tend to shift two adjacent planes in opposite directions. This resistance is an important factor at the junctions of building materials and in notched areas. Density, moisture, fiber direction, and wood defects are effective on shear strength. In this situation, it has a direct proportional relationship with density. This strength is highest when the humidity is 10%, and this strength decreases at other values. This strength is lowest when the angle between the applied force and the fibers is 90° and highest when it is 0°. Wood defects, especially cracks and rotten knots, reduce shear strength (Bozkurt & Erdin, 2011; Örs & Keskin, 2001; Öztürk, 2024).

Hardness is defined as the resistance of a wood to a harder object trying to penetrate it. Hardness can be affected by factors such as the density of the material, moisture level, anatomical structure, and section direction. In this context, as density increases, hardness also increases. As moisture increases up to the fiber saturation point, hardness decreases. When completely dry, the material reaches maximum hardness. When evaluated according to the section direction, The hardness value is highest in the cross-section, lower in the radial section, and lowest in the tangential section.

Dynamic bending (shock) strength is the resistance of the wood against sudden forces. Material that cannot withstand shock forces is called brittle wood. The density of the wood, humidity rate, temperature, anatomical and chemical structure of the cell wall, and fiber direction are effective in shock strength. In this context, humidity rate and temperature show highly variable characteristics of dynamic bending strength. The shock resistance is higher in the material where the microfibrils in the cell wall are parallel to the cell axis. Additionally, increasing the lignin ratio in the cell wall reduces shock strength (Bozkurt & Erdin, 2011; Örs & Keskin, 2001).

Wear resistance is the resistance of wood to corrosive effects in various areas of use. Factors that trigger wear include loads due to movement (walking, carrying, and friction), sudden impacts (shock), impact, sand, dirt, and other foreign materials, the effect of chemical substances, humidity, and temperature changes. Wear resistance is closely related to

hardness, pressure, and shear resistance, and the density, moisture content, anatomical structure, fiber direction, and surface treatments of the wood affect the wear resistance. In this context, as the density increases, the resistance of the wood to abrasion also increases. As moisture increases up to the fiber saturation point, wear resistance decreases. Generally, the greater the angle between the fibers' direction and the forces' direction of action, the greater the wear resistance. Some surface treatments can provide Good protection against wear (Bozkurt & Erdin, 2011; Örs & Keskin, 2001; Öztürk, 2024).

2.2. Impregnation of wood

Wood, an organic building material, needs to be protected by various methods to increase its service life and protect it from external influences. Impregnation, one of the methods of wood protection, is injecting various preservatives into the wood. This process prevents wood size and shape changes, fungal and insect attacks, rotting, and mold formation. Thus, the useful life of wood is increased (Berkin, 2022; Bozkurt et al., 1993; Kartal, 2009; Milton, 1995).

The preservation of wood has been an important issue since prehistoric times, and this protection has been achieved using various substances and techniques. Carbonization, found in archaeological excavations, is one of the first preservation methods. The Temple of Diana at Ephesus in Turkey was built on charred wooden pillars. Ancient Chinese, Egyptian, Roman, and Greek civilizations used vegetable, animal, and mineral oils to protect trees. Starting from the 16th century, in addition to carbonization and wood tar immersion methods, materials such as oils, glues, resins, rubber, and salts began to be used with industrial developments to protect merchant ships (Bozkurt et al., 1993). Various substances have been tried for 2000 years to protect wood.

The impregnability of wood depends on the anatomical structure of the wood and the previous drying and slit opening processes. The effectiveness of the impregnation process depends on the toxicity of the applied substance, which depends on the penetration depth and the retention amount (Örs & Keskin, 2001).

The selection of impregnation materials and methods varies depending on the type of wood, environmental conditions, and place of use. Today, impregnation processes are used not only for natural wood but also for producing boards of wood origin. Blending and shaping wood chips with impregnation materials makes it possible to produce boards resistant to various properties (Bozkurt, 2008; Öztürk, 2024). Chemical impregnation substances are divided into three groups: oily impregnation materials, water-soluble impregnations, and organic solvent-soluble impregnations (Erten, 1988). It is also known that today research is being carried out on natural impregnation materials as an alternative to chemicals.

The methods used to impregnate wood are divided into five groups based on application methods. These are methods non-pressure, pressure, water extraction, diffusion, and on-site maintenance (Bozkurt & Erdin, 2011; Örs & Keskin, 2001). It is known that the methods commonly used in wood impregnation today are methods without pressure (brushing or spraying, dipping, hot-cold bath, soaking) and methods with pressure (full cell process, vacuum process) (Öztürk, 2024).

Recent studies have shown that impregnation techniques can significantly increase the mechanical properties of wood. For example, with modern compression and impregnation processes, longitudinal (X) direction compressive strength can be increased to 103 MPa, tensile strength to 165 MPa, and flexural strength to 264 MPa. These mechanical

improvements are especially evident in engineered woods, as these materials offer higher stability and homogeneity compared to natural wood (Wang et al., 2024).

Thanks to these improved properties, impregnated and engineered wood materials are widely used in floor and roof systems requiring high bending and compressive strength, in columns, beams, purlins, and header elements used as carriers in residential and commercial buildings, in wall panels of medium and high-rise buildings where dimensional stability and shear performance are critical, and in outdoor applications such as facade cladding, deck systems, pergolas and exterior cladding where resistance to moisture and biological effects is important. Therefore, impregnation is not only a protection method but also an application that increases the performance of wood and expands its use in sustainable and long-lasting architectural designs.

3. MATERIAL AND METHOD

The "Dergipark" database, an extensive database comprehensively containing Turkey-based articles, was used to obtain the research dataset. First, a search was made with the keyword "impregnation" to obtain the study material. Experimental studies focusing on the effect of impregnation on the mechanical properties of wood were filtered from the articles encountered as a result of the search. Thus, the 17 studies obtained constituted the dataset of this research. Imprint the information regarding the research dataset is shown in Table 1.

Table 1. Articles included in the data set

Title of Journal	Authors, Year
Artvin Çoruh University Faculty of Forestry Journal	Keskin & Dağlıoğlu, 2016 Temiz, Yıldız, Gezer, Yıldız & Dizman, 2004
Düzce Universty Journal of Science and Technology	Alkan, Şen, Fidan & Yaşar, 2018
El-Cezeri	Var & Kaplan, 2019
European Journal of Science and Technology	Ulusoy & Peker, 2020a Ulusoy & Peker, 2020b
Journal of Advanced Technology Sciences	Yaşar, Yaşar, Fidan, Ertaş & Altınok, 2017
Journal of Bartın Faculty of Forestry	Doruk, Perçin & Yörür, 2019 Var, 2012 Var & Kardaş, 2017
Journal of Polytechnic	Altınok & Doruk, 2010 Özçiftçi & Batan, 2009 Tan & Peker, 2015
Journal of Science and Technology of Dumlupınar University	Özalp & Hafizoğlu, 2008
Turkish Journal of Forestry	Var, Yıldız & Kalaycıoğlu, 2002
Turkish Journal of Forestry Research	Kılıç & Yıldız, 2020 Köse Demirel & Temiz, 2022

Within the scope of the research, systematic analysis of the data set obtained in terms of content was adopted as the method. In this context, a list including the titles of the articles constituting the data set, journal names, authors, and years was created and coded in no particular order. Then, to systematically analyze the contents of the articles, classifications, including wood types, impregnation preservatives, impregnation methods, and the effect of impregnation on the mechanical properties of wood, were created. A two-stage study was conducted to create the classifications. Accordingly, in the first stage, primary titles, including wood types, impregnation preservatives, impregnation methods, and the effect of impregnation on the mechanical properties of wood, were determined. In this context, wood/wood types were primarily classified as natural wood (hardwood and softwood) and treated wood (hardwood and softwood); The substances used in the impregnation of wood were natural, oil-based, water-based, and organic solvent preservatives; The methods used in impregnation of wood are non-pressure (brushing or spraying, dipping, hot-cold bath, soaking) and pressure (full cell process, vacuum process) impregnation methods; The mechanical properties of wood are classified as elasticity modulus, compressive strength, tensile strength, bending strength, separation strength, shear strength, hardness, dynamic bending strength, abrasion resistance. In the second stage, all articles included in the research were read, and the wood species and impregnation materials in the articles were divided into detailed subcategories.

4. RESULTS

This section includes findings of studies focusing on the effects of the impregnation process on the mechanical properties of wood. Within the scope of the findings, The type of wood and tree species to be impregnated, the impregnation material used, impregnation methods, and the effects of impregnation on the mechanical properties of wood are included. It was determined that natural and engineered wood were used in the studies in the data set. Additionally, it was determined that the materials used were obtained from different tree species. Table 2 shows that softwood species include Scots pine, red pine, black pine, Anatolian black pine, cedar, cedar of Lebanon, Uludağ fir, Larch wood, and *Picea Orientalis*. hardwood species were determined as poplar, black poplar, alder, beech, oriental beech, *Quercus Petraea*, walnut, and ash.

Table 2. Wood species

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		✓						✓								
		Red Pine								✓			✓					
		Cedar									✓							
		Uludağ Fir			✓													
		Picea Orientalis													✓			
		Larch Wood														✓		
	HARDWOOD	Oriental Beech			✓	✓		✓	✓						✓			
		Quercus Petraea				✓			✓									
		Ash							✓									
		Walnut							✓									
		Black Poplar							✓									
		Beech															✓	
		Alder		✓														
ENGINEERED WOOD	SOFTWOOD	Red Pine	✓				✓											
		Black Pine	✓											✓				
		Cedar	✓															
		Anatolian Black Pine					✓											
		Cedar of Lebanon					✓											
	HARDWOOD	Poplar	✓				✓											
		Oriental Beech												✓				

When looking at the impregnation materials used in the studies, it was observed that there were examples of natural, oil-borne, water-borne, and organic solvent preservatives.

As seen in Table 3, colophon (pine resin), boron oil, linseed oil, pine tannin, acorn, tara solution, and Asphodeline Taurica were used as natural preservatives in the studies. Among the oil-borne preservatives, alkyd resin and paraffin were preferred (Table 4). Among the water-borne preservatives, boric acid (BA), borax (Bx), ammonium sulfate (AS), copper sulfate, potassium dichromate, copper-chrome-borate (Tanalith-CBC) / (Wolmanit-CB), Immersol-WR 2000, copper-chrome-arsenic (CCA), copper azole (Tanalith-E), geothermal water (Kütahya, Eynal-Çitgöl-Naşa) / (Konya, Ilgın), immersol aqua, timber care aqua, diammonium phosphate (DAP), modern stone water and alkyl ketene dimer (AKD) are included (Table 5). ProtimWR230, white spirit, barite (Baso4), and organosilicon compounds (Dow Corning 1-6184; Z-6341, 2-9034, IE 6683, Z70) were used as organic solvent preservatives in the studies (Table 6).

Table 3. Natural preservatives

NATURAL PRESERVATIVES	ARTICLES																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Acorns										✓							
Asphodeline Taurica																✓	
Boron Oil				✓													
Colophon (Pine Resin)	✓																
Linseed Oil					✓												
Pine Tannin										✓							
Tara Solution											✓						

Table 4. Oil-borne preservatives

OIL-BORNE PRESERVATIVES	ARTICLES																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Alkyd Resin	✓																
Paraffin					✓												

Table 5. Water-borne preservatives

WATER-BORNE PRESERVATIVES	ARTICLES																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Alkyl Ketene Dimer																	✓
Ammonium Sulfate	✓														✓		
Borax	✓					✓					✓						
Boric Acid	✓					✓					✓		✓		✓		✓
Copper Azole								✓									
Copper Sulfate													✓				
Copper-Chrome-Arsenic		✓															
Copper-Chrome-Borate	✓		✓			✓							✓		✓		
Diammonium Phosphate																✓	
Geothermal Water									✓			✓					
Immersol Aqua										✓							
Immersol-WR 2000	✓																
Modern Stone Water																✓	
Potassium Dichromate													✓				
Timber Care Aqua										✓							

Table 6. Organic solvent preservatives

ORGANIC SOLVENT PRESERVATIVES	ARTICLES																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Organosilicon Compounds														✓			
ProtimWR230			✓														
White Spirit					✓												
Barite							✓										

In the studies discussed, it is seen that pressure (full cell and vacuum) and non-pressure (spraying, dipping, soaking, and hot-cold) methods are used for impregnation (Table 7).

Table 7. Impregnation methods

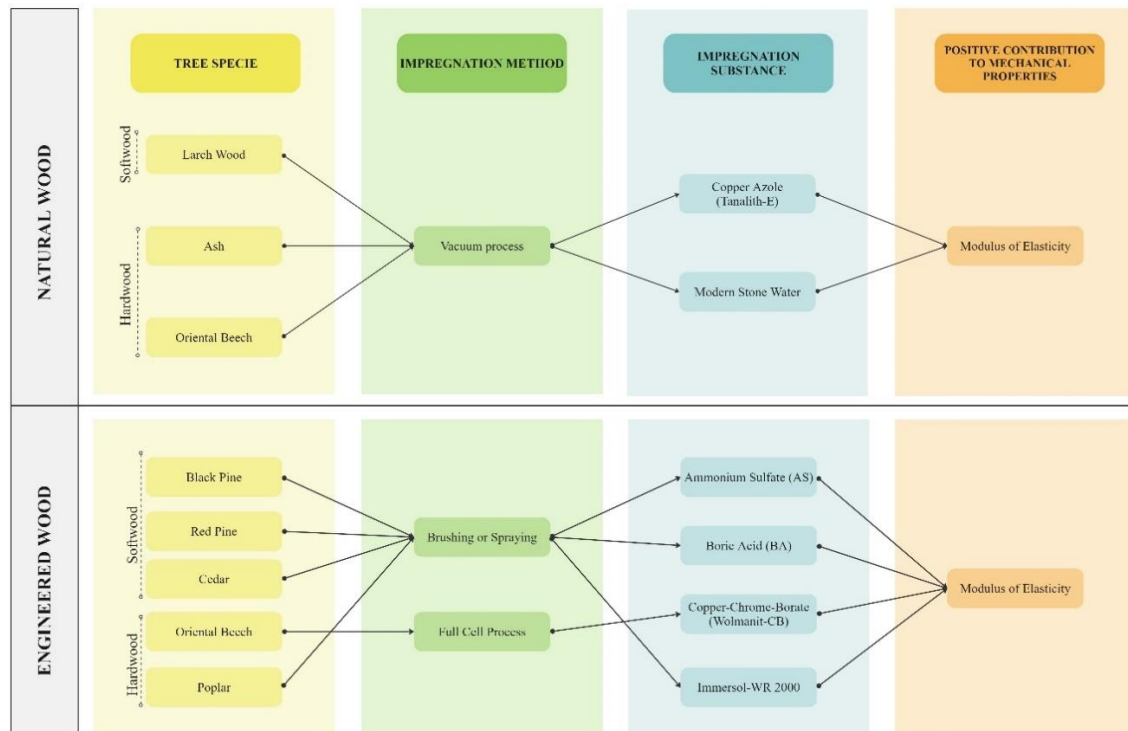
	IMPREGNATION METHODS	ARTICLES																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
NON-PRESSURE	Brushing or Spraying	✓																
	Dipping			✓	✓		✓				✓							
	Hot-Cold Bath												✓					
	Soaking									✓								
PRESSURE	Full Cell Process				✓									✓	✓			✓
	Vacuum process		✓		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

The studies included in the research determined that the impregnation process affected the wood's modulus of elasticity, compressive, tensile, bending, and dynamic bending strength. It has been observed that in the studies discussed, there is no evaluation of the mechanical properties of wood, such as cleavage strength, shear strength, hardness, and wear resistance. Table 8 shows which mechanical properties of the wood the impregnation process used in the studies affects.

Table 8. Matrix showing the effect of impregnation on the mechanical properties of wood

MECHANICAL PROPERTIES	ARTICLES																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Modulus of Elasticity	✓			✓				✓		✓		✓				✓	
Compressive Strength		✓	✓	✓			✓		✓	✓				✓			✓
Tensile Strength	✓				✓	✓					✓						
Bending Strength	✓	✓	✓	✓				✓	✓	✓		✓	✓		✓		
Cleavage Strength																	
Shear Strength																	
Hardness																	
Dynamic Bending Strength				✓										✓		✓	
Wear Resistance																	

According to the results obtained from the analyzed studies, The use of boric acid for engineered wood (Var et al., 2002), Tanalith-E for beech and ash from natural wood (Keskin & Dağlıoğlu, 2016), and stone water for Larch wood (Ulusoy & Peker, 2020a) provide an increasing effect on the elasticity modulus of wood. In addition, it is seen that Tanalith-E and stone water have a positive effect in terms of bending strength. Within the scope of the research, a diagram was created that holistically reveals the positive contribution of impregnation to the elasticity modulus of wood (Figure 1).

**Figure 1.** Positive contribution of impregnation to the elasticity modulus of wood (It was prepared by analyzing Keskin & Dağlıoğlu, 2016; Ulusoy & Peker, 2020a; Var et al., 2002)

It is understood that the use of boron oil and geothermal water taken from Konya-İlgin reduces the modulus of elasticity (Özçiftçi & Batan, 2009; Var & Kaplan, 2019).

Impregnating substances that increase the compressive strength of wood; CCA is a mixture of Wolmanite-CB, 50% barite solution boric acid, and alkyl ketene dimer (AKD) (Köse Demirel & Temiz, 2022; Özalp & Hafızoğlu, 2008; Tan & Peker, 2015; Temiz et al., 2004). Within the scope of the research, a diagram was created that holistically reveals the positive contribution of impregnation to the compressive strength of wood (Figure 2).

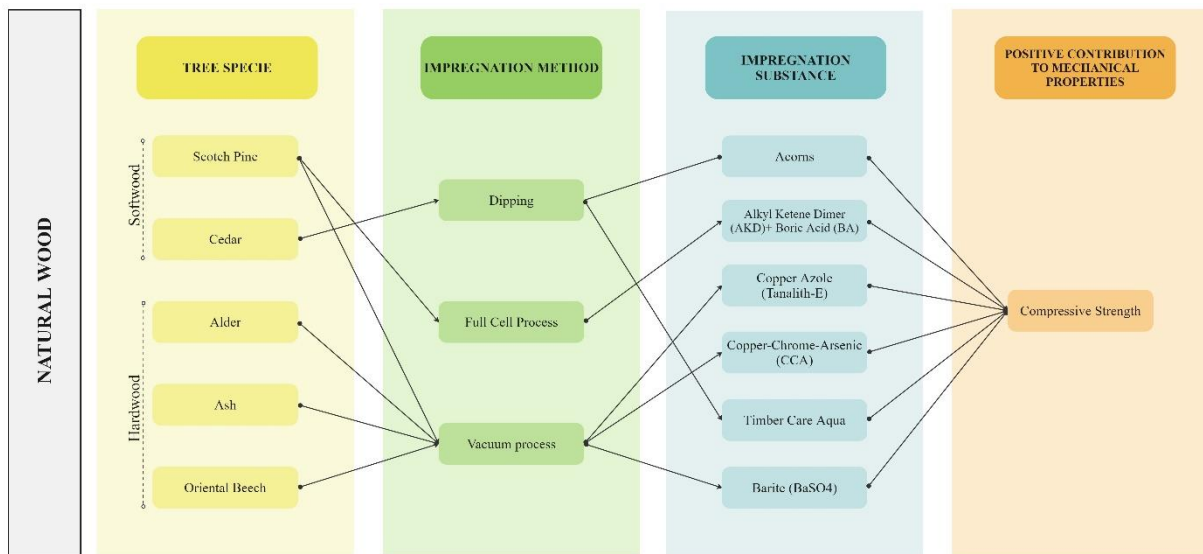


Figure 2. Positive contribution of impregnation to the compressive strength of wood (It was prepared by analyzing Köse Demirel & Temiz, 2022; Özalp & Hafızoğlu, 2008; Tan & Peker, 2015; Temiz et al., 2004)

The impregnation materials that affect reducing the compressive strength are geothermal water taken from Kütahya - Eynal / Çitgöl / Naşa and pine tannin and acorns from natural tanning materials. In addition, geothermal and natural materials have a negative effect on bending strength (Var & Kardaş, 2017; Yaşar et al., 2017).

Impregnation substances that increase the tensile strength of wood are immersol, borax, linseed, paraffin, and tara solution (Alkan et al., 2018; Altınok & Doruk, 2010; Var et al., 2002; Var, 2012). Within the scope of the research, a diagram was created that holistically reveals the positive contribution of impregnation to the tensile strength of wood (Figure 3).

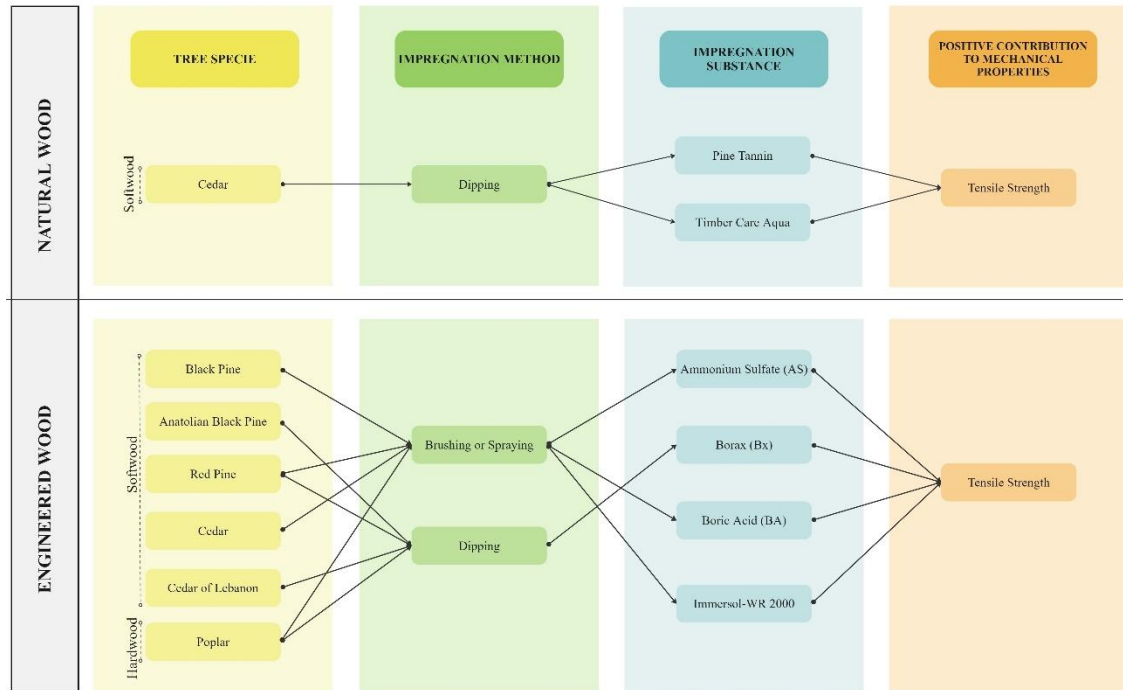


Figure 3. Positive contribution of impregnation to the tensile strength of wood (It was prepared by analyzing Alkan et al., 2018; Altınok & Doruk, 2010; Var et al., 2002; Var, 2012)

Ammonium sulfate, one of the impregnating materials, increases the bending strength of wood (Var et al., 2002). In addition, Wolmanite-CB material appears to positively affect bending strength (Doruk et al., 2019; Özalp & Hafizoğlu, 2008). Within the scope of the research, a diagram was created that holistically reveals the positive contribution of impregnation to the bending strength of wood (Figure 4).

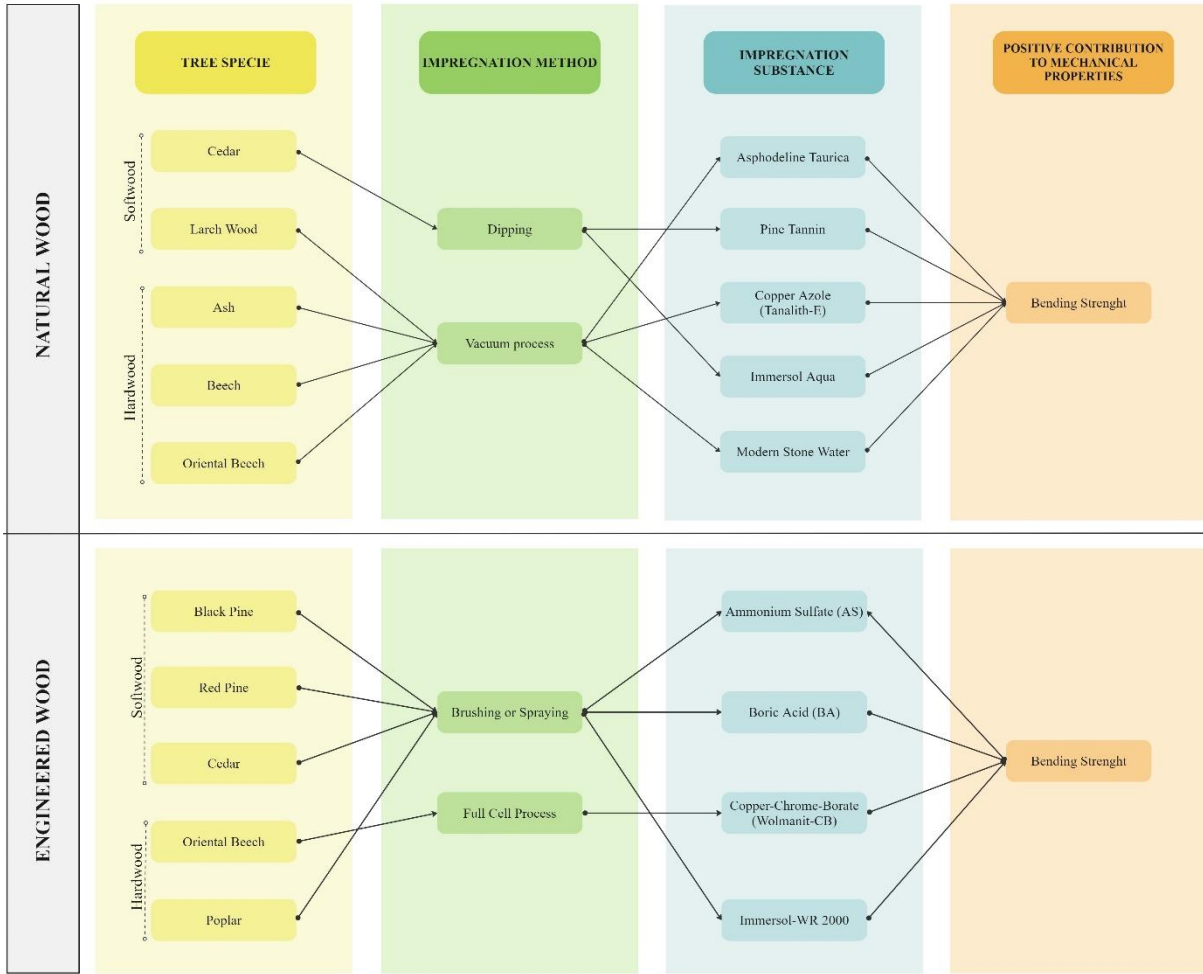


Figure 4. Positive contribution of impregnation to the bending strength of wood (It was prepared by analyzing Doruk et al., 2019; Özalp & Hafizoğlu, 2008; Var et al., 2002)

Organosilicon compounds and 3% asphodel solution negatively affected the dynamic bending (shock) strength of wood (Kılıç & Yıldız, 2020; Ulusoy & Peker, 2020b).

In some of the studies examined, it was determined that the impregnation process caused changes in some physical properties of the wood due to the multiple parameters it involved among the physical features that change: humidity, specific gravity, permeability, and visual properties (Kılıç & Yıldız, 2020; Köse Demirel & Temiz, 2022; Özalp & Hafizoğlu, 2008; Özçiftçi & Batan, 2009; Öztürk, 2024; Tan & Peker, 2015; Ulusoy & Peker, 2020a; Ulusoy & Peker, 2020b; Var & Kaplan, 2019; Yaşar et al., 2017).

5. CONCLUSION

Wood is a natural building material that has been widely used in many disciplines, especially architecture, throughout history. Today, within the framework of sustainable building design and environmental responsibility, making wood more resistant to biological and environmental effects and increasing its lifespan are among the main goals. In this context, impregnation stands out as one of the most widely applied methods, not only because it protects against biotic and abiotic deterioration but also because of its capacity to transform the mechanical properties of wood. In this study, as a result of the analyses conducted based

on 17 scientific articles, the effects of impregnation on the mechanical performance of wood were systematically examined, and a comprehensive classification was made in line with the data obtained.

The findings revealed that chemicals such as Tanalith-E, CCA, Wolmanite-CB, boric acid, borax, and paraffin positively affect mechanical properties such as elasticity modulus, pressure, tensile, and bending strengths. It has been evaluated that woods treated with such impregnation agents can be safely used in architectural areas with high structural requirements, such as load-bearing system elements and exterior facade applications. On the other hand, it has been determined that boron oil, organosilicon, geothermal waters, and some plant-based solvents negatively affect the mechanical properties in question, especially causing a decrease in the elasticity modulus, bending, and shock resistance. It is recommended that such applications be preferred in interior elements that do not carry structural loads and have more aesthetic and superficial functions.

The study presents an original analysis approach that examines the protective effects of impregnation processes and their contributions to material performance; thus, it evaluates the data found scattered in the literature in a holistic and comparative framework. This situation constitutes an important source of information for both practicing professionals and academic researchers.

However, it has been observed that in the current literature review, basic mechanical properties such as elasticity, pressure, tensile, and bending are largely prominent. In contrast, other important parameters, such as splitting resistance, shear strength, hardness, and abrasion resistance, are addressed to a limited extent. This situation presents a considerable gap and potential research area for future experimental and theoretical research.

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