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Evaluation of urea formaldehyde (UF) as a surface coating material: Black pine wood and oriented strand board (OSB) coating by enhanced UF

Üre formaldehitin (UF) ahşap yüzey kaplama malzemesi olarak değerlendirilmesi: Karaçam ve yönlendirilmiş yonga levhaların (OSB) kaplanması

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Abstract

In this study, the applicability of a urea formaldehyde (UF) resin as a wood surface coater was investigated. Organic fillers were used in the resin solution to prevent crack formation on the surface covered with UF resin. Oriented strand board (OSB) and Black pine (*Pinus nigra* Arnold.) massive wood were used to prepare the samples. To prepare the control group, 4 g of ammonium sulfate (AS) was added to 100 g of UF and blended at 1000 rpm for 5 min. The first group was prepared using 5 g of wheat flour (WF) in 100 g UF as an organic filler. The second group was prepared by adding 5 g of cellulose fiber (CF) to a 100 g of glue solution, and the results were compared with those of the control group. The mechanical characterization of the samples (abrasion and scratch analysis) and staining analyses of the samples were determined according to the relevant standards. In addition, the samples were subjected to accelerated weathering by manually applying periodic moisturizing and drying. According to the results, the abrasion and scratch resistances of the black pine samples were higher than those of the OSB samples. Although the addition of WF reduced the abrasion and scratch resistance of the surfaces, it also eliminated the crack formation on the surface before weathering. The abrasion and scratch analysis results of boards coated with UF were much higher than those of the particleboards and fiberboards covered with decorative paper. The weathering process increased stain visibility in all samples, especially in the WF-added sample. After weathering, an approximately 30-40% decrease in scratch and wear resistance was observed in all the samples. As a result, it was concluded that UF can be used to coat the surfaces of wooden boards together with organic fillers in semi-outdoor environments.

Özet

Bu çalışmada, üre formaldehit (UF) reçinesinin ahşap yüzey kaplayıcısı olarak kullanım olanakları araştırılmıştır. UF reçinesi ile kaplanan yüzeylerde çatlak oluşumunu önlemek için reçine çözeltisine organik dolgu maddeleri eklenmiştir. Ahşap malzeme olarak yönlendirilmiş yonga levha (OSB) ve Karaçam (*Pinus nigra* Arnold.) odunu kullanılmıştır. Kontrol grubu 100 gr UF' ye 4 gr amonyum sülfat (AS) ilâve edilip 1000 rpm'de 5 dakika karıştırılarak elde edilmiştir. Birinci grupta organik dolgu maddesi olarak buğday unu (WF-100 gr UF içine 5 gr WF), ikinci grupta ise selüloz lifi (CF-100 gr UF içine 5 gr CF) kullanılmıştır. Numunelerin üst yüzey mekanik özellikleri (aşınma ve çizilme analizleri) ile leke tutma analizleri ilgili standartlara göre belirlenmiştir. Ayrıca örneklere periyodik olarak nemlendirme ve kurutma işlemi yapılarak hızlı yaşlandırma uygulanmıştır. Elde edilen verilere göre karaçam örneklerinin aşınma ve çizilme direncinin OSB örneklerine göre daha yüksek olduğu bulunmuştur. WF ilâvesi yüzeylerin aşınma ve çizilme direncini düşürmesine rağmen yaşlandırma öncesi yüzeydeki çatlak oluşumlarını engellemiştir. UF kaplı levhaların aşınma ve çizilme analiz sonuçlarının, dekoratif kâğıt kaplı yonga levha ve lif levhalara kıyasla çok daha yüksek olduğu belirlenmiştir. Yaşlandırma işlemi tüm örneklerde, özellikle WF ekli örneklerde leke görünürlük oranını artırmıştır. Yaşlandırma sonrasında, tüm örneklerin çizilme aşınma dirençlerinin %30-40 azaldığı tespit edilmiştir. Yapılan çalışmayla UF'nin organik dolgularla birlikte yarı kapalı ortamlarda ahşap levha yüzeylerinin kaplanmasında kullanılabileceği sonucuna varılmıştır.

INTRODUCTION

Urea-formaldehyde (UF) resins are widely used as adhesive resins in the production of wood-based panels because of their high reactivity and low cost. UF resins, a type of aminoplastic resin, are produced by the reaction of urea and formaldehyde, resulting in a range of possible condensed structures (Dunky 1998).The amino methylene linkage in UF resins is not stable under high relative humidity, especially at elevated temperatures, owing to susceptibility to hydrolysis, which causes degradation of the UF resin. These negative properties of UF resin cause it to be unstable under outdoor conditions. UF-bonded wood boards are classified into different bonding classes based on their behavior at various temperatures and exposure to water and weather, with varying requirements for different applications according to different national and international standards (Yamaguchi et al. 1980, EN 314 1993, EN 622 2003, TS EN 312, 2005, EN 300 2006, EN 204 2016).

Wood is vulnerable to biological damage caused by organisms, such as fungi, termites, and beetles, which feed on wood and use it as their habitat. This can result in severe damage to the wooden products and structures (Dhyani and Tripathi 2006, Oliveira et al. 2018).

The preservation of wood indirectly indicates the protection of forest resources. Therefore, it is important to extend the lifespan of wood. There is much research on the protection of wood materials, especially in outdoor conditions. Some of these are made by thermal modification (Militz 2002, Yan-jun et al. 2002, Esteves 2009), chemical preservation (Barnes 2001, Freeman and McIntyre 2008, Caldeira 2010, Ma et al. 2013, Oliveira et al. 2018). If thermal and chemical protection processes are not performed, the surfaces of the wooden material must be protected.

The chemicals used to coat the wood surface can cause health and environmental problems. Therefore, some chemicals are restricted indoors (Dvorchak 1997, Van den Bulcke et al. 2003, Landry and Blanchet 2012). In this study, we did not aim to preserve indoor wood or absolutely outdoor wood because the use of UF indoors and UF was not resistant to outdoor conditions. For this reason, with this study was aimed to investigate the wooden parts of the construction or furniture, such as camellia, gazebo, porch, terrace, and veranda. These wood parts were neither indoor nor absolutely outdoor (Figure 1).

In addition, harmful volatile effects of UF can be eliminated by supplemental chemicals (Kelleci et al. 2022) and can be turned into a stable material for outdoor usage. Schmalzl and Evans (2003) evaluated the protective efficacy of various titanium, zirconium, and manganese compounds on thin Radiata pine veneers exposed to natural weathering. The results showed that oxidative manganese compounds, such as potassium permanganate and manganic acetate, effectively restricted the weight and tensile strength loss of treated veneers during weathering, while most titanates and zirconates were not as effective in protecting lignin. In our study, we added WF and CF to the UF because cracks on the surface were prevented and artificial weathering was carried out by manually humidifying the wood surface and drying in an oven periodically.

Rosu et al. (2020) investigated the curing and thermal behavior of new castor oil maleic anhydride adduct/epoxy oils/5–Bromosalicylic acid coatings and their composites with wood and tested their resistance against fungal attack. The results showed that the treated wood surfaces had high decay resistance and color changes, and the described materials are recommended for use in wood-protective coatings.

Fluor silanes show great potential as water-repellent materials for preserving cultural heritage monuments and artifacts. A study showed that perfluorooctyl-triethoxysilane can create superhydrophobicity and enhanced hydrophobicity on marble and wood surfaces, while also achieving water repellency on other hydrophobic or superhydrophobic surfaces, with no negative impact on the aesthetic appearance (Adamopoulos et al. 2021).

Song et al. (2022) aimed to develop a sustainable and high-performance flame-retardant wood coating using a bio-based curing agent called ammonium hydrogen phytate (AHP). The researchers controlled the molar ratio of phytic acid and urea to synthesize AHP, which had an appropriate pH for curing melamine-urea-formaldehyde (MUF) resin. By changing the weight ratio of AHP to MUF, the curing rate can be adjusted, making it convenient for wood coating. This is illustrated in Figure 2. The resulting wood coating exhibited Tg, hardness, adhesion, and water resistance comparable to those of the control sample prepared using a commercial curing agent.

Some researchers have reported that cured melamine urea formaldehyde (MUF) resin has several desirable properties, such as excellent water resistance, high interface adhesion, low formaldehyde emission, outstanding hardness, and film-forming properties. It is also cost-effective and has a longer storage period than the MF and UF resins (Ma et al. 2013, Nagamadhu et al. 2020).

No studies have been found in the literature on the use of urea formaldehyde (UF) for the surface protection of wood materials. This may be because surface cracks are created when UF is used on wood surfaces. In this study, wheat flour and cellulose fibers were added to UF to eliminate these cracks. Thus, it is aimed at providing high surface strength and gloss on massive wood and composite boards, such as oriented strand boards (OSB).

Figure 1. Wood material for veranda ceiling and furniture.

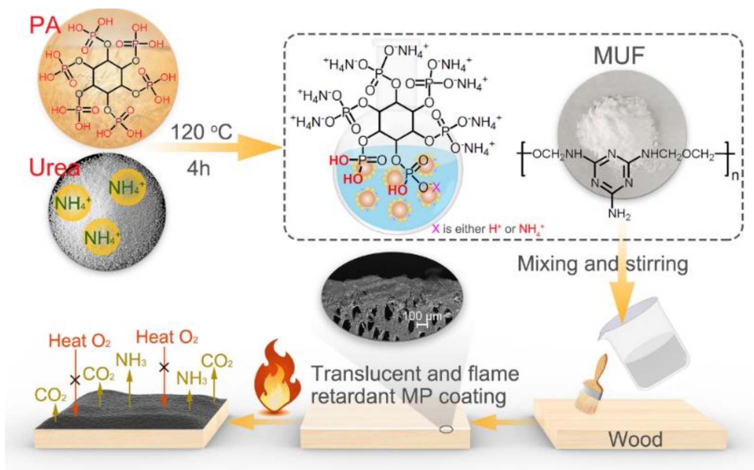


Figure 2. The synthesis of high-performance, bio-based, melamine-urea-formaldehyde wood coatings (Song et al. 2022).

MATERIAL and METHODS

Materials

Black pine (*Pinus nigra* Arnold.) wood and OSB were used to prepare the test samples. Woods were purchased from local markets. Urea formaldehyde (UF) and ammonium sulfate (AS) were obtained from Yıldız Entegre Particleboard Company. UF and AS had solid contents of 65% and 30%, respectively. The properties of the materials used are listed in Table 1. Wheat flour (WF) and cellulose fiber (CF) layers were used as fillers in the UF. All materials were purchased from a local market.

Table 1. Material properties

Materials	Status	Solid Content (%)	Density (gr/cm³)	pH	Viscosity (cp)
UF	solution	65	1.284	7.4	300
AS	solution	30	1.154	5.4	12
Massive	solid	93	0.48	5.9	-
OSB	solid	92	0.600	5.1	-

Preparation of Samples

The OSB and black pine wood were cut to a thickness of 10 mm and dimensions of 10 × 10 cm. The surfaces of the samples were first sanded with 80 and then with 100 and 200 grit sandpaper. The AS hardener was added to the UF resin at a ratio of 4% (w/w) to the control sample. The solution was stirred at 1000 rpm for 5 min. The prepared UF resin solution was applied to the wood surface with a brush at 250 g/m^2. WF and CF were added to the solution in different proportions to prevent cracking of the UF resin after curing. The material ratios used are listed in Table 2. The sample surfaces were coated with a single layer. The samples, whose surfaces were coated with UF solution, were left to harden after curing at room temperature for five days. After five days, the UF coated on the wooden materials had completely hardened and formed a transparent and gloss surface on the wooden samples. The sample surfaces were sanded with 1000 grit sandpaper before analysis. The prepared samples are shown in Figure 3.

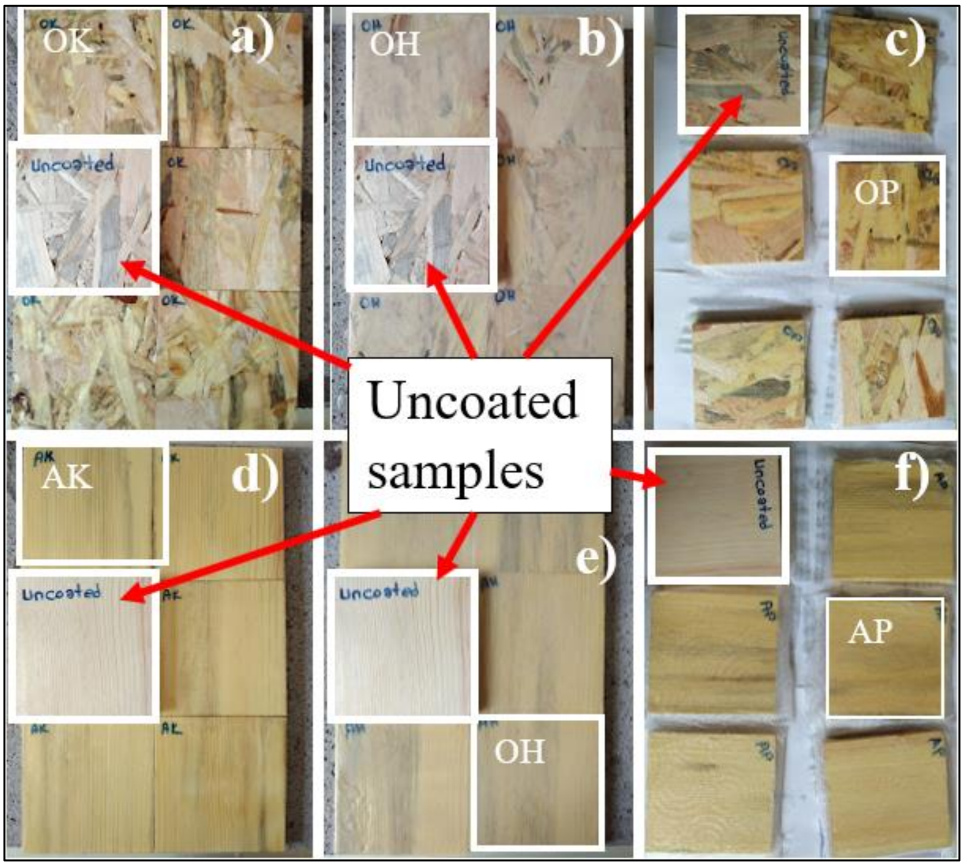


Figure 3. Coated and uncoated samples, a) UF coating on OSB, b) UF+WF coating on OSB, c) UF+CF coating on OSB, d) UF coating on black pine, e) UF+WF coating on black pine, f) UF+CF coating on black pine

Table 2. Materials ratios and samples description

Samples	Description	Applied wooden surface type	UF (g)	AS (g)	Wheat flour (g)	C fiber (g)
OK	UF coating on OSB	OSB	100	4	–	–
OH	UF+WF coating on OSB	OSB	100	4	5	5
OP	UF+CF coating on OSB	OSB	100	4	5	5
AK	UF coating on Black pine	Black pine	100	4	–	–
AH	UF+WF coating on Black pine	Black pine	100	4	5	5
AP	UF+CF coating on Black pine	Black pine	100	4	5	5

The surfaces of the OSB were calibrated by sanding 0.5 mm from the top and bottom. Subsequently, the remaining cavity pores on the OSB surface were filled with the UF and filler materials. After the WF filler material dried, it caused a hazy appearance characterized by whitening on the surfaces of the OSB and larch wood (Figure 3b and 3e).

Wood exposed to weather conditions primarily decays because of the effects of light and water. Water can accelerate surface degradation through the leaching products of photodegradation (Derbyshire and Miller 1981). In addition, water causes the wood to swell and subsequently shrinks with moisture loss. This cyclic change often occurs in wood exposed to outdoor weather conditions and is most prominent on wood surfaces directly exposed to rainwater and sunlight (Zahora 1993). Considering the impact of water on surface deterioration and to gain insight into the degradation occurring on surfaces coated with UP, the following application was tested in our study and yielded successful results.

The UF-covered samples were covered with wet cloth at room temperature and left for 24 h. The samples were then completely dried by placing them in an oven at 105 °C for 2 h. This process was repeated five times. Finally, samples were incubated at room temperature. Subsequently, an analysis was performed. This process was carried out for the accelerated weathering of the samples and was applied for the first time in this study. The results showed a significant difference before and after separation. The application was successful in providing a general idea of weathering. An accelerated weathering apparatus can be used for more detailed analysis.

Methods

The Abrasion Test

Analysis is used to evaluate the durability of material surfaces when subjected to mechanical stress on their surfaces, also known as abrasive stress. This method is applied to finished laminates commonly used in worktops and flooring to protect printed patterns from abrasion or wear over time. The test was conducted according to the DIN EN 13329 standard using a Taber Abraser device. The test specimen was divided into four quadrants and attached to the device, where calibrated sandpaper was attached to the abrading wheels of a specific weight. The wheels were placed on top of the specimen and rotated at a constant speed, and the sandpaper was renewed after 200 revolutions or as required. The initial abrasion point was reached when worn-down spots of at least 0.60 mm^2 in area appeared in two quadrants and an equally large spot appeared in the third quadrant, providing an indication of the abrasion resistance of the material in everyday use.

Evolution

The initial abrasion point (IP) was determined by rounding the number of revolutions at which it occurred to the nearest 100 revolutions, and the average of three measurements was calculated. The IP values provided an indication of the material's resistance to abrasion or wear, which is relevant for laminate flooring. Based on the IP values, the laminate surface could be classified into five different abrasion or wear classes, indicating their respective levels of durability and suitability for various applications (Table 3). The tests were performed in air-conditioned rooms (TABER A 1994).

Table 3. Abrasion wear classes

Abrasion (DIN EN 13329 2021)	ACI	AC2	AC3	AC4	AC5
Average IP value from the specimens	900	1.800	2.500	4.000	6.500

Scratch Analysis

The test principle was consistent across all applicable test methods. The specimen was secured onto a turntable at a standard rotation speed of 5 min^{-1}. An adjustable load arm with a fixed test tool applied pressure onto the specimen, with the pressure level adjustable between 0 and 10 N (in 0.1 N steps) or 0 – 1 N (in 0.01 N steps). A visual evaluation of the specimen's resistance to this pressure was conducted by assessing the score mark, with detailed instructions provided in the Operating Instructions (Table 4).

Evolution

To determine the score mark values of the samples,

1. The samples were visually inspected under 70 watts of fluorescent white light.

2. The sample was held at eye level, 1 m from the eye.

3. The sample was viewed at an angle of 45°.

4. When a full circle scratch was seen under light, the Newton value of the scratch was recorded as the score mark value.

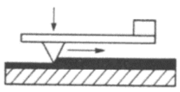
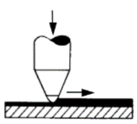
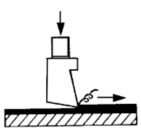
Stain Resistance Analysis

This method can be used to test surface sensitivity or resistance to various foreign substances. This test is critical for determining the resistance of decorative surfaces to various substances, such as acids, alkaline solutions, and solvents, which can come into contact with laminated particleboards during normal use. The duration of surface exposure to the test substances was determined by their category. This test was used to assess the resistance of the surface to staining caused by these substances (DIN 53799 1986).

At room temperature, Faber-Castell lead pencils No. 129902 2 B and 4 B, lipstick or shoe polish, and laminated particleboards were used in the test. After applying a small amount of the test substance to an area measuring at least 5 × 10 cm, the graphite was rubbed off, the shoe polish was wiped off, and the surface was cleaned with ethanol-soaked filter paper. Lipstick has a 16-hour contact time (DIN 53799 1986).

Decorative surfaces should be resistant to the absorption of foreign substances that can manifest as stains or dirt deposits. It is also critical to consider open-pored surfaces where foreign particles can accumulate and make cleaning difficult. Other substances may be used to assess the surface's sensitivity or resistance to staining caused by chemical reactions in addition to the test substances listed here (DIN 53799 1986).

Table 4. Essential test parameters

Sketch	Field of application	Method	Measuring Range/Accuracy	Test Tool	Test Principle
	Decorative laminated sheets (HPL)	Micro scratch hardness acc. to specifications of the plastics industry - ISO 4586-2 DIN EN 438-2	0-10 ± 0.1 N	Diamond test tip, angle 90°, radius on the point 90 µm Ord.-No. 0218.01.32	Advent of a visible score mark
	Paints and similar coating materials	Scratch hardness in acc. with - ISO 1518 - Bosch, Opel, van Laar	0-10 ± 0.1 N	Test tip equivalent to ISO: 1 mm ø Ord.-No. 0539.03.32 Test tip acc. to Bosch: 0.75 mm ø Ord.-No.: 0539.02.32 Test tip acc. to van Laar: 0.5 mm ø Ord.-No.:0539.01.32	Advent of a visible score mark
	Paints and similar coating materials	Scratch hardness acc. to Clemen	0-10 ± 0.1 N	Test tip acc. to Clemen at 2° angle Ord.-No.: 0218.02.32	Advent of a visible score mark

Evaluation

The surface sensitivity test was evaluated by performing a thorough visual examination from various angles to determine whether any stains or marks remained on the surface. To ensure accuracy and consistency in recording the test outcomes, photographs of the surface(s) were taken, as shown in Figure 4 (DIN 53799 1986).

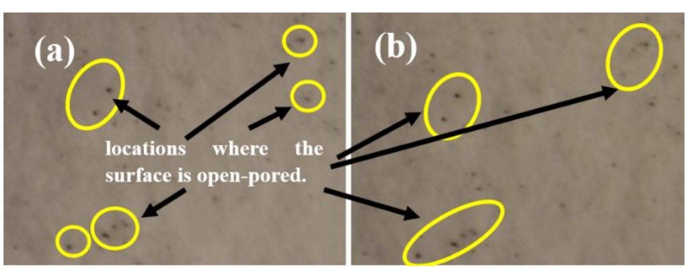


Figure 4. Decorative surfaces treated with graphite **(a)** and lipstick **(b)**. The spots indicate locations where the surface is open-pored and substances were thus able to adhere

RESULTS and DISCUSSION

Surface Mechanical Properties

According to the scratch analysis results, black pine samples (AK, AH, and AP) were more resistant to scratching than the OSB samples (OK, OH, and OP). The cellulose fiber used as a filler was found to increase the scratch resistance in both the wood and OSB samples. Wheat flour, which is used as a filler in UF, has been found to reduce surface hardness, and as a result, scratch resistance. From Table 5, it is clear that the AP and OP samples are the most scratch-resistant before weathering. After weathering, an approximately–30-40% decrease in scratch and wear resistance was observed in the samples. The highest loss of resistance was observed for OP. The addition of CF prevented the decrease in resistance in the wood samples but could not prevent the decrease in surface abrasion and scratch resistance in the OSB samples (Figure 5a, 5b).

Table 5. Surface analysis results

Samples	Before weathering			After weathering		
	Scratch resistance (Newton) Sig*:0,01	Abrasion resistance (rpm) Sig:0,01	Cigarette fire resistance (visibility) Sig:0,01	Scratch resistance (Newton) Sig*:0,01	Abrasion resistance (rpm) Sig:0,01	Cigarette fire resistance (visibility) Sig:0,01
OK	0.4 (±0.1)** a	1923 (±10) b	3	0.3 (±0.1) a	1601 (±28) b	2
OH	0.5 (±0.1) b***	1980 (±5) c	5	0.3 (±0.2) b	1632 (±63) c	4
OP	0.9 (±0.1) d	2234 (±7) e	2	0.35 (±0.4) d	1911 (±7) e	1
AK	0.7 (±0.2) c	2145 (±13) d	3	0.5 (±0.3) c	1854 (±7) d	2
AH	0.7 (±0.2) c	1250 (±5) a	4	0.4 (±0.1) c	957 (±6) a	3
AP	0.9 (±0.3) d	2238 (±9) e	2	0.7 (±0.1) d	1941 (±16) e	1

*Significant value, **Standard deviation, ***Duncan analysis group

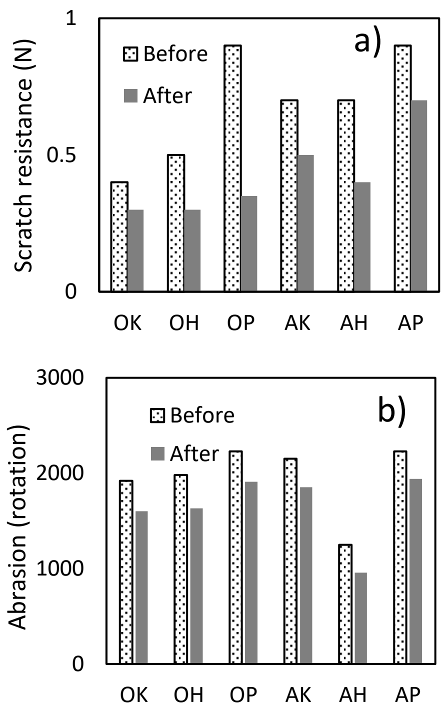


Figure 5. a) Scratch and b) Abrasion analysis results before and after weathering

When UF was used as a coating material on wooden surfaces, surface cracks appeared (Figure 6a). Although these cracks are not bothersome, they are unsightly visible on the surfaces. Although the use of wheat flour as a filler in UF reduced the hardness of the surfaces, it prevented the formation of surface cracks (Figure 6b). The WF used on the OSB covered up to 80% of the appearance of wood patterns (Figure 6b). With the use of WF in Black pine samples, the appearance of the wood pattern was only 20% (Figure 6b). When the Abrasion analysis results were examined, it was discovered that all samples met AC1 or AC2 abrasion wear classes according to DIN EN 13329 standards (Abrasion wear classes were given in Table 3).

WF weakened the sample surfaces against abrasion in the abrasion analysis, as in the scratch analysis. In terms of preventing surface cracks, this decrease could be overlooked (Figure 7b). CF reduced the number of cracks that formed on the sample surfaces but did not completely eliminate them as WF did (Figure 7a).

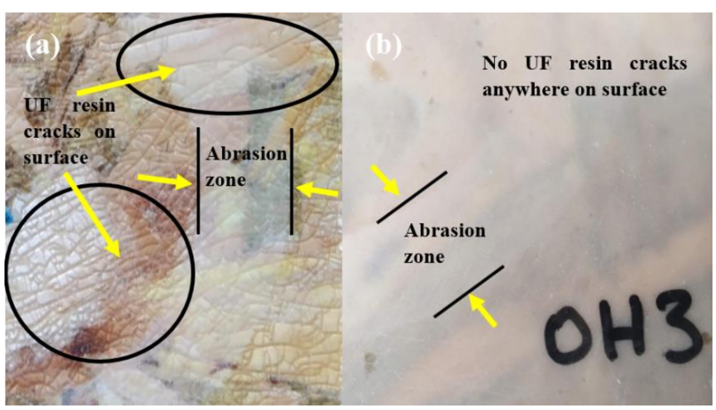


Figure 6. Crack and abrasion zone on samples surfaces before weathering, a) OK sample without filler, b) OH sample with WF filler

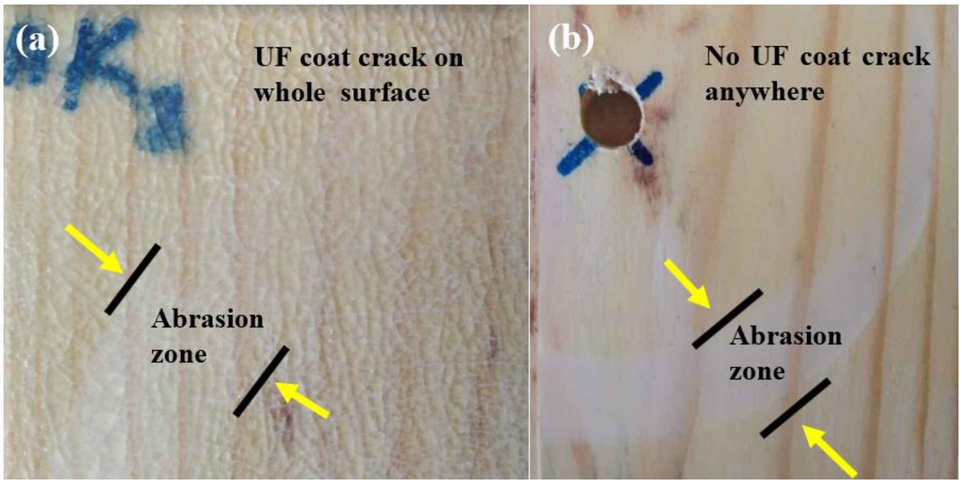


Figure 7. Crack and abrasion zone on samples surfaces before weathering, a) AK sample, b) AH sample

The scratch marks were clearly visible when the samples were viewed at a 45-degree angle under fluorescent light (Figure 8a). The samples coated with UF without filler had the brightest and smoothest surfaces. However, the cracks on the surfaces of the samples were cosmetic issues. The WF filler used to prevent these cracks reduced the abrasion and scratch resistance of the sample before weathering. According to the TSE standards, the scratch resistance of particleboard covered with decorative paper was 0.4 Newtons (TS EN 13329 + A 2021). Although the scratch resistance decreased with the addition of WF, it remained above the scratch standards for particleboards. The surfaces of the OSB samples were brighter when the surface glosses were visually examined. The scratch resistance of black pine samples (AK, AH, AP) was better than that of the OSB (OK, OH, OP) samples (Figure 8b). The lowest loss of scratch and abrasion resistance was observed in the AP sample after weathering. Coating wood surfaces with UF reinforced with CF can provide long-term protection for wood in semi-outdoor environments. After weathering, deep cracks were observed in the OH samples (Figure 8d). In the OK samples, instead of cracks, vein formation was observed after weathering. These veins created a distinct pattern on the wood surface (Figure 8c). These veins appeared to be visually appealing.

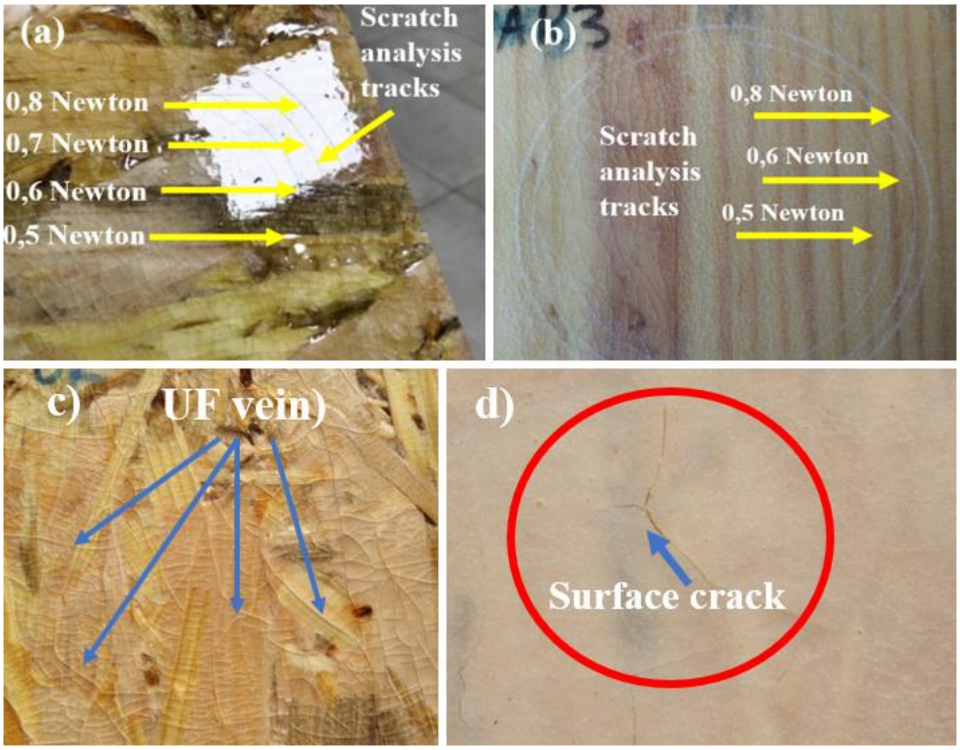


Figure 8. Scratch zone on samples surfaces, a) OK sample before weathering, b) AH sample before weathering, c) OK sample after weathering, d) OH sample after weathering.

Formaldehyde is a volatile organic compound that is toxic to humans when inhaled in large quantities. Consequently, researchers are developing water-based wood-coating materials. However, these coating materials are significantly more expensive than the UF coating materials. As a result, wood surfaces that are not in direct contact with humans and are not directly exposed to outdoor conditions can be protected and beautified with UF coatings.

For example, Li et al. (2021) investigated a waterborne wood coating that is environmentally friendly and has good mechanical properties and fast curing. This was accomplished by combining acrylated epoxidized soybean oil (AESO) and pentaerythritol triacrylate (PETA) with UV-curable waterborne polyurethane acrylate (PUA) resin. Even after 100 revolutions, the film exhibited favorable mechanical and thermal properties such as excellent hardness, strong adhesion, and low abrasion loss. However, the UF coating resulted in significantly higher abrasion resistance in our study.

Staining Analysis Results

The stain resistances of the samples were ordered from 0 to 5 (0: best, 5: worst). When no stain was observed, it was recorded as number “0.” When the stain resistance of the coated OSB and black pine samples was tested, it was discovered that only the coffee stain remained on the surface before weathering. Water, soap, acetone, and tea stains were found to leave no traces on the surface 24 h prior to weathering. Coffee staining was observed only in the WF-supplemented samples. WF not only reduced the samples' scratch and abrasion values, but also their stain-holding resistance. Visual examination revealed that the AH sample stained more than the OH sample (Figure 9b). This is thought to be due to the OH sample absorbing less UF than the AH sample (Figure 9a). Eye visibility analysis results showed that the OH and AH samples were in good condition (Table 6). After weathering, the stain resistance of all samples decreased.

The analysis of resistance to cigarette fire yielded similar results. Cigarette smoke damaged all the specimens (Figure 10 a, b, c, d, e, f). According to the visual examination results, it was determined that the most damaged samples were OH (Figure 10e) and AH (Figure 10b). In this case, it was discovered that incorporating WF into the UF resin reduces the coating's resistance values. However, it has been determined that if WF is not added, cracks on the UF surface will form. In this case, it would seem logical to conclude that adding WF would be beneficial. Because even though the surface resistance properties of the chipboard decrease with the addition of WF, they are still higher than the chipboard covered with decor paper.

After weathering, the stain resistance of the samples was also affected. The resistance to cigarette burns as well as to stains from water, soap, acetone, tea, and coffee has decreased. Since the stain resistance analyses were conducted visually, the extent of the decrease could not be quantified.

Water uptake is an important factor in the susceptibility of wood to fungal attack and decay. Moisture, on the other hand, not only affects the structural integrity of wood by promoting decay, but it also enters the cellular structure of wood, where it associates with cellulose, causing dimensional changes (Goodell et al. 2020). In this regard, it is expected that UF-coated wooden materials will be more resistant to insect and fungal pests.

Table 6. Staining analysis results

	Before weathering					After weathering				
Samples	Aceton stain (vis.*)	coffee stain (vis.*)	tea stain (vis.*)	Soap stain (vis.*)	water stain (vis.*)	Aceton stain (vis.*)	coffee stain (vis.*)	tea stain (vis.*)	Soap stain (vis.*)	water stain (vis.*)
OK	0	1	0	0	0	1	2	1	1	1
OH	0	3	0	0	0	1	4	1	1	1
OP	0	1	0	0	0	1	2	1	1	1
AK	0	1	0	0	0	1	2	1	1	1
AH	0	3	0	0	0	1	4	1	1	1
AP	0	1	0	0	0	1	2	1	1	1

* vis.: visibility (stain resistance of samples were ordered from 0 to 5 according to eye visibility. 0: best, 5: worst)

Figure 9. Coffee stain **a)** OH sample, **b)** AH sample

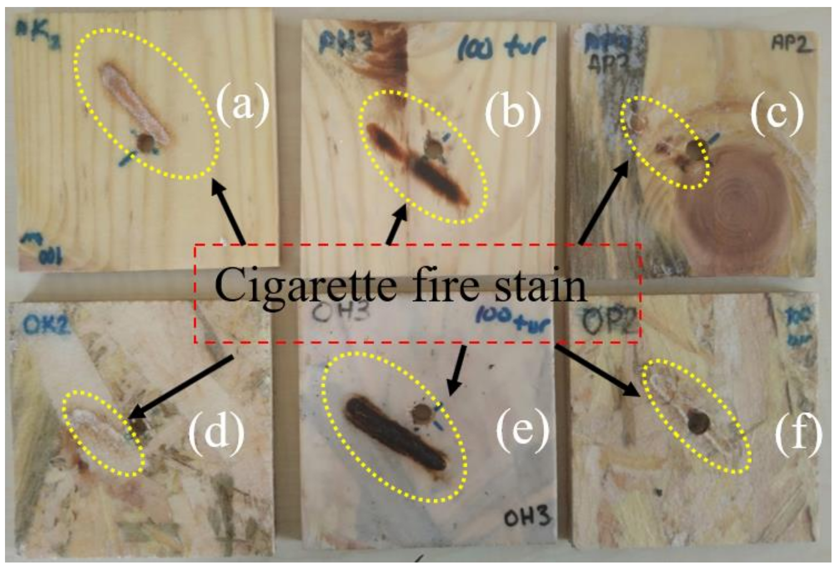


Figure 10. a) UF coating on Black pine (AK), b) UF + WF coating on Black pine (AH), c) UF + CF coating on Black pine (AP), d) UF coating on OSB (OK), e) UF + WF coating on OSB (OH), f) UF + CF coating on OSB (OP)

In this regard, the goal is to reduce water intake while increasing the mechanical resistance of wood surface coating materials. A new MUF resin formulation with high water tolerance and good physical and mechanical properties was developed in a study by adding sodium metabisulphite (MTBS) during the melamine condensation reaction, allowing the resin's water dilution capacity to be increased. Increased MTBS addition, on the other hand, resulted in lower internal bond strength and formaldehyde emissions (Paiva et al. 2016). According to current research, water is frequently the critical limiting factor in wood decay. Indeed, recent research has called into question long-held beliefs and shifted our understanding of the role of water in wood decay (Sandberg 2016, Jakes et al. 2020).

Silver nanoparticles were used by Mantanis and Papadopoulos (2010) to improve the water absorption properties of wood. They applied a nano-silver compound to pine wood and investigated its effect on the material's sorption characteristics. When appropriately modified to improve compatibility with the polymer, nano silica is another promising nanoparticle that can improve the sorption characteristics of wood (Nikolic et al. 2015).

CONCLUSIONS

In this study, the coating possibilities of urea formaldehyde (UF) resin on wooden surfaces were investigated. In the literature, it is known that thermoset resins were used to coat the wooden surfaces. UF is the cheapest thermoset resins among the other thermoset resins such as melamine and phenol. UF resin is not resistant to water and moisture, making it unsuitable for use in outdoor condition. In the present study, the coating of wood materials such as ceiling coverings or benches, which are used in semi-outdoor environments like partially covered verandas, with UF resin has been evaluated. The surfaces of the samples were moistened and then dried to simulate accelerated weathering. This process was repeated five times. In order to enhance the durability of the UF coating and prevent the formation of cracks on the surface, CF and WF fillers were added in UF resin. Organic fillers were used to prevent surface cracks.

According to the results, the addition of wheat flour (WF) into UF completely prevented crack formation before weathering. Adding cellulose fiber (CF) partially prevented crack formation before and after the weathering. But also, WF reduced abrasion and scratch resistance in all samples. The results showed that the solid wood surface covered with UF was more durable than OSB before the weathering. Stain removal analysis results of the coated surfaces showed that, apart from coffee stains, the surfaces were resistant to water, soap, acetone, and tea stains before the weathering. According to cigarette fire analysis the weakest samples were the WF filled before and after the weathering. After weathering, the scratch and abrasion resistance of the samples decreased by approximately 30-40%. It was concluded that, except for the WF addition, the samples could be used in semi-outdoor environments. Due to its affordability and widespread availability, UF can be considered as an inexpensive surface coating material for such semi-outdoor environments.

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