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Natural Weathering of Bio-Based Façade Materials

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Abstract: Although there is a global awareness that the exploitation of non-renewable materials is unsustainable, there has been limited interest in fully utilizing natural, renewable resources like wood and its products because of the service durability concerns. One such issue is the aesthetical degradation of wooden facades due to the impact of weathering. This research was carried out as an international cooperation project to ascertain the weathering resistance of bio-based façade materials under the Estonian climate. In total, 120 bio-based façade materials obtained from 31 different companies, universities and research institutions from 17 countries were investigated. The specimens were placed on an exposure rack, inclined at an angle of 45° located at 59°23′50.6″ N 24°39′24.0″ E and then subjected to accelerated natural weathering for 2 years. Parameters such as precipitation, UV index, temperature and relative humidity were measured during the period of the natural weathering. The influence of the weathering on the colour change and cracks on the surface of test specimens was evaluated using Minolta Chroma Meter CR-121 (Konica Minolta INC, Tokyo, Japan) and Avongard Check Width Gauge (Avongard Ltd, Gloucestershire, United Kingdom), respectively. The results showed that the untreated natural wood façade materials presented the least resistance to weathering, while 63 of the tested materials developed checks. The outcome of this study is essential to the optimization of software-simulating changes in the appearance of façade materials in outdoor conditions.

Keywords: natural weathering; bio-based materials; wood; colour change; checks

1. Introduction

Forestry accounts for 30% of the Earth's land resources in Europe, but only about 1.6% of wood is used as a construction material [1]. This limited application of wood is traced to the issue of durability during service [2]. Through further research, innovation and development of a new approach, wood properties have been enhanced to provide a significant increase in their strength. However, there is a lack of awareness or sufficient information available [3]. Recent publications present the benefits that can be achieved by using bio-based materials [4,5]. For changing the consumer's behaviour, more information about the service life prediction, cost of service and aesthetical performance of wooden façade materials is collected and provided in several recent research papers [2,5,6]. The major factor affecting wooden façade material during service is weathering that causes the deterioration affecting the aesthetics and structural integrity of the covering. Weathering of wood material is influenced by parameters such as solar radiation, water, atmospheric temperature, humidity, oxygen, microorganisms and so on that can alter the material appearance [7]. However, the rate of weathering depends on the durability of the wood species [8], finishing type, technical design, climatic conditions, duration and direction of exposure as well as the inclination of the material surface [6,9]. It is essential to adopt proper construction design and adequate protection from water entrapment to minimise the effect of weathering. Moreover, coatings,

impregnation, chemical and thermal modification of wood or wood with higher natural durability should be used for outdoor construction [3,8,10–14].

Our study aimed to evaluate the accelerated 2-years weathering resistance of 120 bio-based façade materials in the Estonian climate. There was international collaboration in this research to provide knowledge about the fundamental properties of novel bio-based building materials. Furthermore, the obtained results could be used to develop optimised simulation software and validate the developed models of the weathering of building façades.

2. Materials and Methods

2.1. Façade Materials

The 120 façade specimens were obtained from 31 companies and 17 countries, the majority of which are in Europe with some from Central America and New Zealand. The samples measured 150 mm × 75 mm × 20 mm in length, width and thickness, respectively. Specimens were categorised based on the type of modification into 7 groups (Figure 1). The bulk of the samples were from impregnated wood materials (Beech and Beech chips (4), Fir (3), Poplar (6), Spruce (6), and Pine (10)), which were treated with either AATMOS (3-(2-Aminoethylamino) propyl trimethoxysilane), TA (Timbercare Aqua), Fluorosilane, DMDHEU (1.3-dimethylol-4.5-dihydroxyethyleneurea), Knittex, Madurit (aqueous unetherefied and etherified melamine resins for impregnation—amine salt) or Fixapret (modified dimethyloldihydroxyethylene urea) impregnation. The 25 hybrid modified materials used were either chemically impregnated or thermally modified before surface coating or further impregnation. Examples of such materials in this group are Accoya (acetylated and surface-coated wood [15]), impregnated softwood coated with biofilms, thermally modified wood (oak) coated with wax and so on. Only 7 composite materials Tricoya (coated, acetylated medium density fibre (MDF) board [16]), wood–plastic composite (WPC), ceramics and bamboo (*Bambuseae)*-coated particleboards and 5 chemically modified samples were provided for the test.

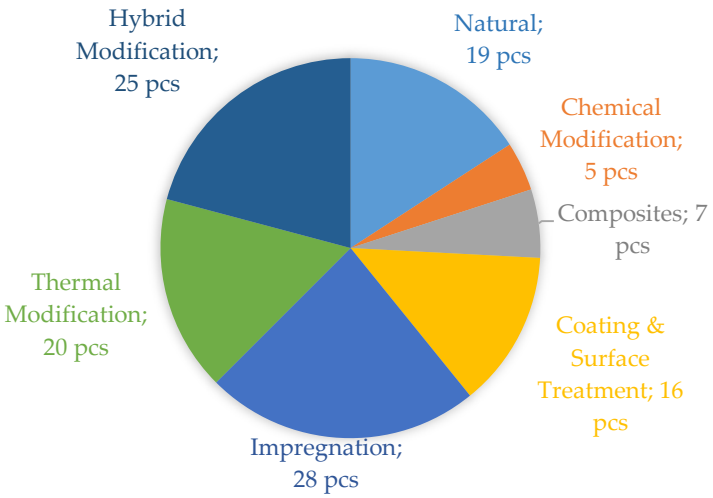


Figure 1. Groups of materials evaluated. [4,17].

2.2. Site Description

The effect of weathering on the materials was evaluated in Tallinn. We commenced the experiment in Tallinn on March 14th in 2017 and concluded on March 26th in 2019 (2 years). The weathering site was at Laboratory of Wood Technology in Tallinn University of Technology (59°23′50.6″ N 24°39′24.0″ E) on an exposure rack inclined at a 45° angle (according to EN ISO 2810 [**18**]) and facing the south (Figure 2), to aid water drainage and good exposure to the sun, respectively.

Figure 2. Specimen set-up (southern exposure, 59°23′50.6″ N 24°39′24.0″ E).

2.3. Evaluation Method

Material assessment was done in accordance with the guidelines stipulated by COST FP1303 [2] for colour change and formation of checks, which are in line with EN ISO/CIE 11664-4 [**19**] and EN ISO 4628 [20], respectively. The colour measurement was performed using Minolta Chroma Meter CR-121 based on the International Commission of Illumination (CIE—Commission Internationale de l'éclairage) L*a*b* (Lab) colour space method, also known as CIELAB. The L* axis represents the light and dark scale of a specimen (i.e., L = 100 and L = 0, respectively). Axis a* shows specimen colour in the scale of red (a = 100) and green (a = −100), while axis b* shows the scale of yellow (b = 100) and blue (b = −100) [21]. The colour coordinates were measured from three predefined points on the surface of the specimens to ensure uniformity. The mean value was then used to characterise the colour change for each of the samples. In addition, all of the specimens were captured every month using a Canon EOS 450D camera, while Checks were evaluated using Avongard Check Width Gauge. Checks were evaluated after the first 3 months of weathering. Equation (1) below shows the mathematical expression for determining the colour change in the colour space referred to as Units of Measure (U/M).

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \quad (1)$$

Where ΔL, Δa and Δb are the colour change in L*, a* and b* axes, respectively. For reference, $\Delta L = (L_1 - L_2)$, where L_1 is colour coordinate after latest measurements in the L*axis and L_2 is colour coordinate before the exposure in the L*axis.

3. Results

3.1. Weather Conditions

Estonian Weather Service Station situated in Harku provided the weather data during the tests. The considered parameters were precipitation, UV index, average, maximum and minimum air temperature and average relative humidity (RH), all changing with the four seasons. The precipitation and relative humidity data presented in Figure 3 shows, on the average, low amounts of precipitation during the spring and summer of both years. However, the highest monthly value (180 mm) was in August of 2017, while the lowest was in May 2018 (5.5 mm), which corresponds to 57.3% of RH, the lowest for both years. On average, the highest RH (82.7%) in the first year of weathering was more than that in the second (77.3%).

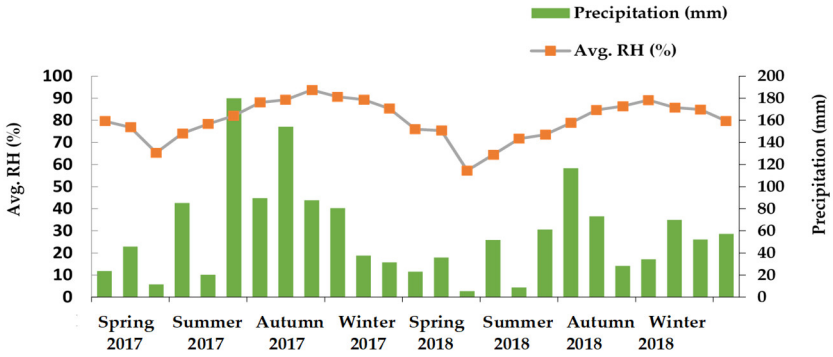


Figure 3. Precipitation and relative humidity during 2-year weathering.

The lowest air temperature recorded was −17.5 °C in February 2018, while the highest was 34.2 °C in July of the same year (Figure 4(a))The average temperature ranged from −6 °C (February 2018) to 20.4 °C (July 2018). The UV index (Figure 4(b)) was highest in the summer period of both years (6.8 and 7.1 in 2017 and 2018, respectively) while the lowest recorded index was in December 2018 (0.2).

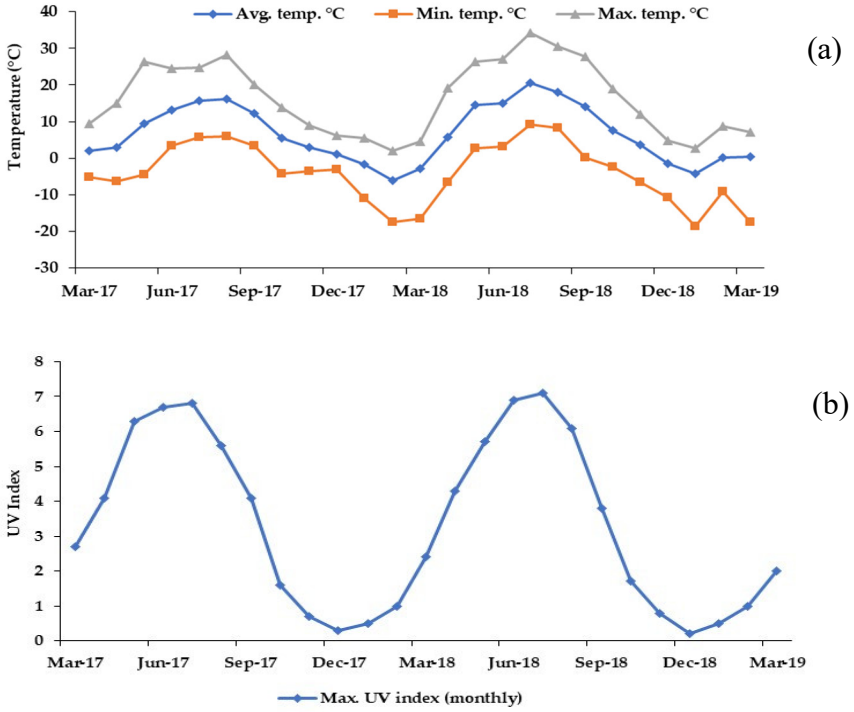


Figure 4. The air temperature (**a**); UV index (**b**) during the 2-year weathering as obtained from Estonian Weather Service Station situated in Harku.

3.2. Appearance and Colour Change of Specimens After 2 years of Weathering.

Figure 5 shows how the 120 test specimens' appearances changed during the 2-year weathering period. It can be seen that the effect of weathering was severe for those materials under the Estonian climate. Visually, only about 20 of the materials appeared to maintain their original colour at the end of the study.

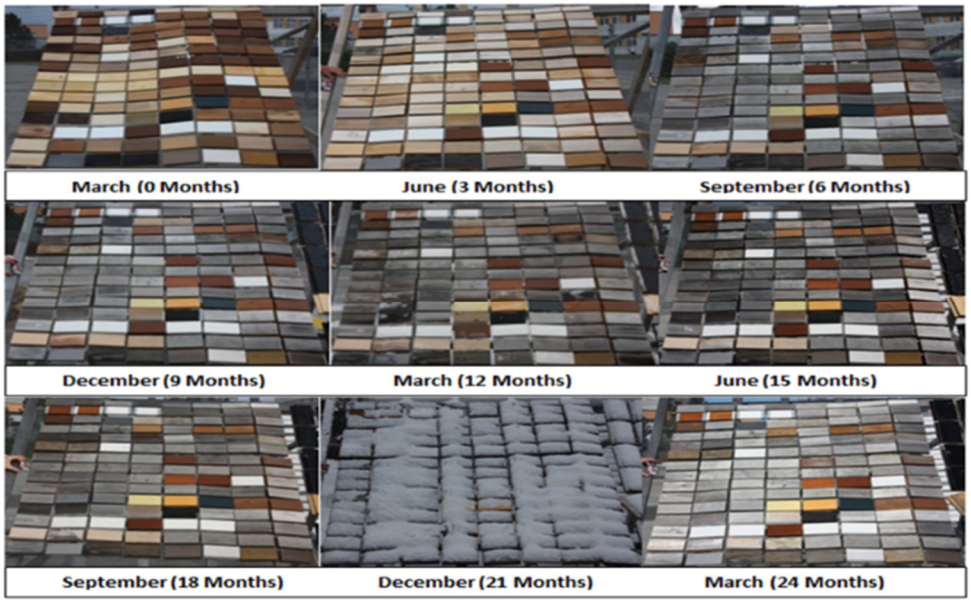


Figure 5. Experimental samples during natural weathering in Tallinn (2 years).

Table 1 shows the colour changes of all the natural wood and bamboo specimens at the end of the 2-year weathering period. It can be seen from Table 1 that all test specimens showed relatively low resistance to colour change with an overall mean outcome of 25 ± 7 U/M. However, the average colour change of the bamboo specimens was 17 ± 3 U/M, which was significantly lower than that of the wood specimens (26 ± 7 U/M). Additionally, the hardwood species appear to show better colour retention with an average ΔE of 21 ± 5 U/M compared to 32 ± 1 U/M of the softwood samples.

Table 1. Colour changes of natural specimens.

Wood Specimens	Scientific Name	ΔE (U/M) After 2 Years
Norway Spruce	*Picea abies*	35.7 ± 1.7
Pine (Heartwood, dried 50 – 70 °C)	*Pinus radiata*	33.6 ± 3.7
Pine	*Pinus radiata*	31.3 ± 4.6
Larch with Laser Graver	*Larix* sp.	31.0 ± 2.9
Southern Yellow Pine	*Pinus echinata*	30.7 ± 3.4
Natural Pine	*Pinus sylvestris*	30.4 ± 2.8
Silver Fir	*Abies alba*	30.0 ± 1.4
Softwood	-	29.0 ± 1.5
Plantation Teak (Class P_B)	*Tectona grandis*	28.6 ± 2.3
Plantation Teak (Class A)	*Tectona grandis*	26.9 ± 2.0
Plantation Teak (Class B)	*Tectona grandis*	24.2 ± 0.7
Plantation Teak (Class C)	*Tectona grandis*	21.8 ± 3.7
Oak	*Quercus petraea*	20.8 ± 4.1
Beech	*Fagus sylvatica*	19.4 ± 2.9
Bamboo Cladding	*Bambuseae*	18.9 ± 4.7
Natural Beech	*Fagus* sp.	18.5 ± 2.7
Bamboo Decking	*Bambuseae*	15.3 ± 0.8
Poplar	*Populus tremula*	14.6 ± 1.6
Ceris Oak	*Quercus cerris*	13.8 ± 2.2

In the results shown in Table 2 for the chemically modified specimens, the overall average was 13 ± 4 U/M. It can be seen that the type of chemical treatment influences the material performance more than the type of wood species. There was no significant difference for acetylated pine and alder, but acetylated beech appears to show a better outcome. Furfurylation treatment showed a

significantly better outcome (10 ± 4 U/M) than acetylation (16 ± 1 U/M). Diverse composite samples were compared. Hence, it will be inaccurate to present an overall outcome. Nonetheless, the results show that composites of wood and plastics are 3 times more likely to retain the original colour compared to those of only wood-based materials (average ΔE = 21 ± 3 U/M). Coated, acetylated medium-density fibreboard and bio-ceramics specimens showed very good colour retention after weathering, with mean values of 4 ± 0.3 U/M and 5 ± 1 U/M, respectively.

Table 2. Colour change of chemically modified and composite specimens.

Chemically Modified Specimens	ΔE (U/M) After 2 Years	Composites	ΔE (U/M) After 2 Years
Acetylated Radiata Pine	16.5 ± 1.3	Particleboard and Bamboo	23.2 ± 1.4
Acetylated Alder	16.4 ± 0.8	Fiberboard	18.5 ± 5.3
Acetylated Beech	14.3 ± 1.0	Wood Plastic Composites	7.4 ± 1.2
Kebony (Furfurylated)	12.4 ± 1.1	Bio-Ceramics	4.5 ± 1.0
Scots Pine Kebony (Furfurylated)	6.8 ± 3.4	Tricoya. Opti finish	4.5 ± 0.3
		Tricoya for cladding. Pigmented White	4.1 ± 1.0
		Tricoya White	4.0 ± 1.5

Table 3 presents the results for the surface-coated and impregnated materials. Similarly, the different types of treatment and specimens offer different outcomes, leading to high error margins (± 8) for the coated specimens. The average colour change was 13 U/M. Overall, spruce coated material showed better colour stability (6 ± 0.7 U/M) compared to the other coated wood-based materials (pine and oak). For the outcome of impregnated materials, three groupings were made according to the type of wood and the similarity of the impregnating chemicals. The result was significantly better for impregnated pine, with an average value of 30 ± 4 U/M, compared to impregnated spruce (32 ± 4 U/M) and poplar (34 ± 4 U/M). Additionally, when we compared the method of chemical penetration, forced impregnation produced a better result than soaking. Considering the type of chemicals, copper ethanolamide (CEA)-impregnated softwood presented the best outcome (10 ± 2 U/M).

Table 3. Colour change of surface coated and impregnated wood-based specimens

Surface Coated Specimens	ΔE (U/M) After 2 Years	Impregnated Specimens	ΔE (U/M) After 2 Years
Pine. nanocoated	27.4 ± 1.2	Spruce. AATMOS soaked	39.0 ± 1.3
Natural Oak. Waxed	22.9 ± 0.6	Spruce. TA Impregnated. + Fluorosilane	38.8 ± 4.0
Larch Lightly Burned	18.4 ± 4.2	Poplar. TA Impregnated. + Fluorosilane	37.5 ± 3.1
Pine. Aqua Coating	17.9 ± 2.4	Poplar Soaked AATMOS	37.1 ± 0.8
Natural Oak Coated	17.4 ± 3.7	Spruce. TA Fluorosilane soaked	34.2 ± 1.6
White Treatment Solas	14.0 ± 0.2	Spruce. Impregnated. AATMOS	33.9 ± 1.6
Softwood. Coated	12.1 ± 2.6	Pine. Soaked AATMOS	33.5 ± 1.9
Pine. Grey Coating	9.3 ± 1.4	Pine. Impregnated + Soaking in Fluorosilane	32.6 ± 1.7
Pine. White Coating	9.3 ± 2.6	Poplar. Impregnated AATMOS	32.2 ± 3.4

Natural Spruce. Oiled	9.3 ± 0.5	Pine. Impregnated AATMOS	31.6 ± 4.6
Hardwood. for Windows (coated)	9.1 ± 1.2	Spruce. Fluorosilane	30 ± 1.5
Larch Carbonised	8.8 ± 4.0	Beech. Silicone	29.8 ± 3.9
Softwood. Water Base	8.5 ± 1.7	Poplar. Impregnated + Fluorosilane	29.6 ± 2.5
Softwood. Solvent Base	7.9 ± 0.3	Poplar. Fluorosilane	28.6 ± 1.7
Spruce. Coated	5.5 ± 0.7	Spruce. Impregnated + Fluorosilane	28.6 ± 2.7
Softwood. for Windows	1.6 ± 0.3	Poplar. Impregnated. + Soaking in Fluorosilane	28.5 ± 1.4
		Pine. DMDHEU	27.8 ± 1.6
		Fixapret	25.0 ± 3.2
		Pine. TiO2	24.2 ± 0.2
		Silver Fir	23.4 ± 4.2
		Silver Fir. treated	21.5 ± 0.9
		Beech. impregnated	20.7 ± 3.1
		Silver Fir	20.5 ± 1.6
		Madurit	20.3 ± 3.1
		Beech. PBS	19.6 ± 1.7
		Knittex	18.3 ± 0.2
		Beech. PLA	11.3 ± 0.9
		CEA impregnated Softwood	10.1 ± 1.7

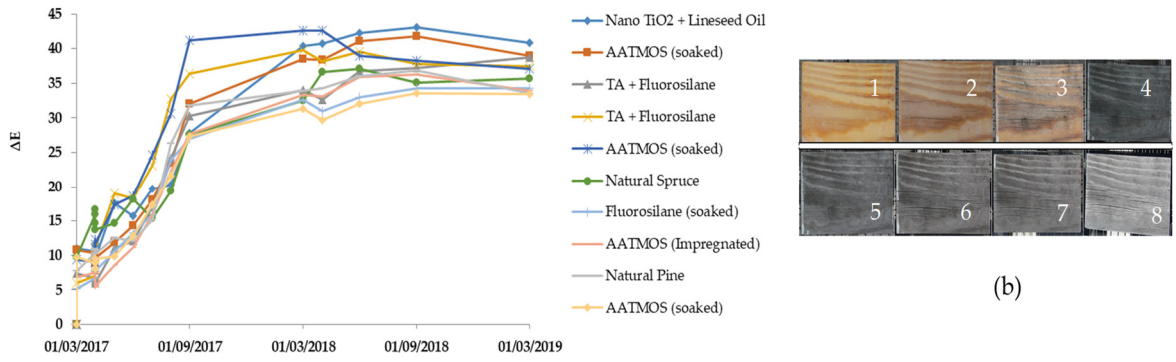
Table 4 shows the values of the colour change for thermally modified, and hybrid treated specimens. The mean value of the colour change (18 ± 5 U/M) was the second highest of all the groups of material after that of samples from natural wood. Many of the samples observed were from thermally modified spruce and pine. Although there was no significant difference in test results between these two wood types, the test results showed that overtreatment with heat could enhance colour stability as we can see from the outcome presented by overtreated spruce (7 ± 2 U/M). The samples from thermally modified poplar also showed similar results to those of the aforementioned wood types. The weakest colour stability was from thermally modified wood frakes (22 ± 4), while TM oak and ash showed comparable outcomes with ΔE values of 13 ± 0.2 U/M and 13 ± 3 U/M, respectively. On the contrary, the average outcome presented by hybrid samples was 13 ± 9 U/M, with the acetylated + surface coated wood (pigmented white) displaying the optimum colour stability (1.3 ± 0.3 U/M) of all the 120 samples examined. It appears that the type of hybrid treatment influenced the colour stability more than the kind of material used. For illustration, ΔE varies from 1 to 18 U/M for the acetylated wood with different types of coatings and from 7 to 41 U/M for pine with a different combination of solution/coatings treatment. In comparison, no significant difference can be seen between spruce (14 ± 2 U/M) and pine (14 ± 4) test pieces having similar treatments (TM + coating).

Table 4. Colour change of thermally modified and hybrid treatment specimens.

Thermally Modified Specimens	ΔE (U/M) After 2 Years	Hybrid Modified Specimens	ΔE (U/M) After 2 Years
Frake. TM	25.4 ± 2.2	Pine. Nano TiO2 + Linseed Oil	40.8 ± 2.2
Radiata Pine. TM	24.2 ± 1.9	Spruce. TM + Oil	25.2 ± 1.9
Pine. TM	23.8 ± 3.1	Poplar. Madurit + TM	22.9 ± 1.8
Spruce. TM	23.1 ± 1.2	Accoya (Poseidon)	20.8 ± 3.0
Spruce. TM	22.0 ± 1.4	TM Oak + Coated	19.7 ± 5.6

Spruce. TM	21.9 ± 2.6	Accoya (Hydro-Oil)	17.9 ± 1.4
Poplar. TM	20.0 ± 1.1	Softwood. TM + Wax	14.8 ± 1.6
Ayous. TM	19.3 ± 1.8	Pine. TM + Coating	14.3 ± 4.0
Frake. TM	19.2 ± 1.7	Spruce. TM + Coating	14.2 ± 2.3
Pine Thermo D 212 °C	18.7 ± 2.1	Oak. TM + Wax	13.4 ± 0.5
Spruce Thermo D 212 °C	18.6 ± 4.9	Radiata Pine. Silicate	13.2 ± 2.5
Sycamore. TM	17.4 ± 1.4	Radiate Pine. TM + Coating	12.1 ± 0.8
Pine. TM	17.0 ± 0.4	Pine. Treated + Triazole	11.1 ± 1.6
Poplar. TM	16.7 ± 2.3	Spruce TM + FeSo4	10.4 ± 1.8
Thermally Treated Obeche	15.4 ± 2.3	Ayous TM + Coating	10.3 ± 0.8
Pine. OHT	14.8 ± 2.2	Accoya (Dark)	10.2 ± 0.7
Ash Thermally Treated	13.5 ± 2.6	Accoya (Matt)	9.2 ± 3.8
Thermally Modified Oak	12.6 ± 0.2	Radiata Pine. Water	8.6 ± 0.5
Softwood. TM	12.0 ± 1.3	Frake. TM + Coating	7.8 ± 0.8
TM Spruce. Over treated	7.1 ± 1.8	Pine. Triazole + Treated	7.0 ± 4.0
		TM Spruce. Coated	4.8 ± 1.0
		Accoya (Aqua)	4.0 ± 0.9
		Softwood. Biofilm	3.3 ± 0.4
		Accoya (White)	3.0 ± 0.2
		Accoya (Pigmented White)	1.3 ± 0.3

Figure 6(a) shows the colour change for the 10 most weathered specimens. Mostly affected were natural wood (pine and spruce) and chemically (AATMOS and Fluorosilane) impregnated materials. Image of Nano TiO2 + linseed oil impregnated wood taken during 3-month intervals is presented in Figure 6(b) with Pallet 1 and 8 showing the pictures taken before weathering in March 2017 and after in March 2019. As can be seen from Figure 6, the colour was fairly stable in the first 3 months, followed by a more rapid change in the latter stages (October 2017 (pallet 4) to March 2018). Figure 6(c) displays the results of the 10 most colour-stable samples, which consist principally of acetylated + surface coated wood, coated + acetylated medium density fibreboard, surface-coated woods, ceramic material and hybrid (TM and coated spruce). Figure 6(d) presents a more explicit image of the colour change of accoya (matt and pigmented white) taken during 6-month intervals (Pallet 1, the first image before weathering and Pallet 5, the image after weathering in March 2019), very good colour stability is observed throughout the weathering period.



(a) (b)

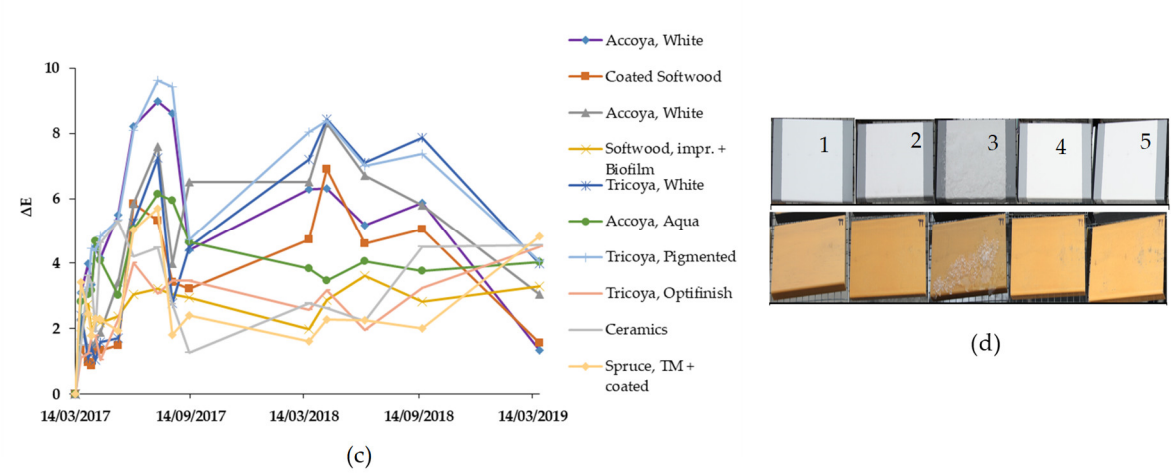


Figure 6. (**a**) Ten specimens with the most colour changes, (**b**) image of titanium dioxide (TiO_2)-impregnated + linseed-oil-treated wood taken at 3-month intervals, (**c**) 10 specimens with the least colour changes and (**d**) image of accoya (matt and pigmented white) taken at intervals of 6-month until the end of weathering [17].

3.3. Material Surface Checks

Figure 7 presents the materials with the longest total checks obtained from aggregates of widths exceeding 0.1 mm, while Figure 8 shows an image of the noticeable splits that occurred on the surface of pine nano TiO_2 impregnated pine after the 2-year weathering time. Before the weathering, 21 of the samples, especially oak and some tropical hardwood, previously showed some amounts of visible checks on the surface that were not counted during the evaluation. After 3 months, there were 40 materials with surface checks, and at the end of the research, most checks were from natural wood and impregnated and thermally modified specimens.

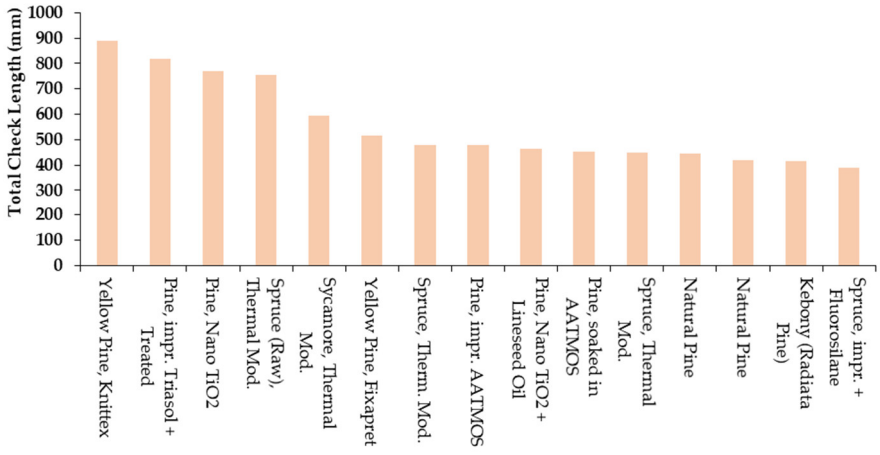


Figure 7. Materials with the longest total checks after 24 months of weathering.

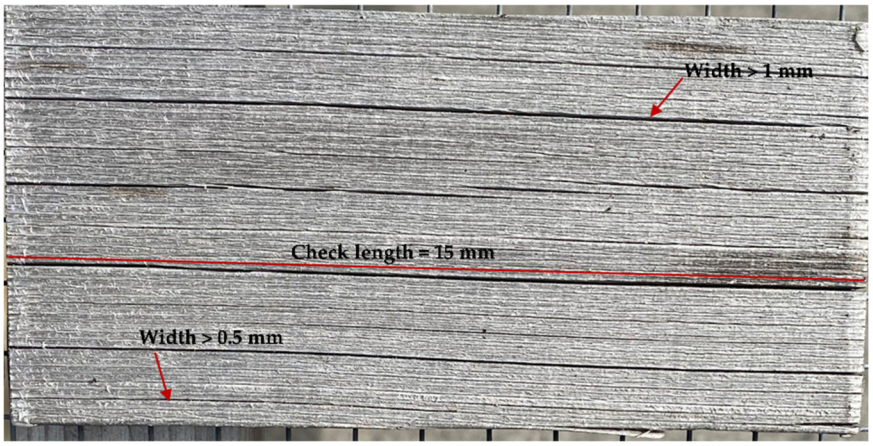


Figure 8. Visible cracks of nano TiO_2-impregnated pine after 2 years of weathering.

4. Discussion

The fluctuation in climatic conditions makes it problematic for materials to maintain their original condition. Material degradation during weathering is increased by almost two times by the set-up of the specimens on the exposure rack (45°) compared to a vertical (90°) set-up [9]. Overall, results showed that the use of untreated wood as façade material should be discouraged. Spruce, larch and pine showed low colour stability during weathering tests [22]. This outcome was expected because these wood species are naturally classified as moderate to low durability [8]. The colour change (ΔE) result for spruce (34.1 U/M) obtained after 1 year of weathering was like the 36 ± 2 U/M obtained in our study. However, it may be difficult to relate results from different studies because of the distinct geographic location and environmental conditions. A major reason for the colour changes in natural wood is attributed to delignification [22]. For TM wood façade materials, resistance to colour change of TM spruce (7 U/M) was the best, while 11 out of the 20 TM façade test specimens also showed good colour stability (below the measured average of 18 ± 5 U/M). When comparing untreated wood and TM wood, past research confirms that thermal modification enhances colour stability [11]. Impregnated materials showed higher colour degradation, with just three of the 28 specimens, CEA-impregnated softwood, poly-lactic acid (PLA)-treated beech and Knittex-treated yellow pine, presenting some resistance to colour deterioration. Copper-based preservatives are known to decrease photodegradation of wood [23], which is attributed to a reduction in delignification during weathering [24]. Although PLA-treated beech and Knittex-treated pine showed some measure of resistance to colour change, there was a stable shift in the b* axis with the material becoming bluish (by −10 U/M), which is assumed to be due to leaching of decomposed lignin and extractives [22]. Chemical impregnation of wood by AATMOS and flourosilane primarily resists biological degradation (insects and fungi), decay and water damage, but they do not give as much improvement to colour stability [25,26]. This may be the reason for their slightly poor performance. All the chemically modified specimens offered better outcomes than previously mentioned samples with Kebony modified materials that showed the best stability. This result is in accordance with Rowell et al. [7] and Temiz et al. [24], whose studies have shown that chemical modification by acetylation promotes colour stability. Nanocoated pine (27 U/M) and waxed oak (23 U/M) were the only two surface-painted materials of the 16 examined exhibiting above-average colour degradation. Oil and water-based solvent coatings showed no significant variation. The film thickness, covering the biomaterial, plays an important role in its ability to resist colour change [**27**]. Since no information about the thickness of the various coatings was provided, it is difficult to draw a direct comparison between the performances of the coated samples. Composite materials from particleboard and fibreboards covered with bamboo presented minimal colour stability. The exposure of a wood-based composite material to both light and water, as well as a high wood content (no information given about composite fractions), aid deterioration in colour [**7**]. The favourable result from coated,

acetylated, medium-density fibreboard is due to the acetylation [24,25], followed by surface-coating of the medium density fibre boards. Hybrid modification, on the other hand, generally enhanced colour stability except for nano TiO_2- and linseed-oil-modified pine. The hybrid modification combining a series of treatment (Chemical, impregnation or thermal) with material surface coating are most suitable. Specimens of the Accoya like the coated + acetylated medium density fibreboards showed outstanding resistance to colour change. The least colour-stable specimen was Poseidon-coated acetylated wood (21 ± 3 U/M), while the most resistant to change was pigmented white (1.3 U/M). The poor outcome by nano TiO_2 (an ultraviolent screen) and linseed-oil-modified pine could be due to the use of TiO_2, which does not show much integration with pine wood, and, though it is confirmed to improve colour stability when used alone, no particular improvement is obtained when combined with other methods [28,29]. Even linseed oil is proven to reduce colour changes in the wood [29]. Assessment of the degree of cracking on the test specimens showed that development of surface checks was more rapid during the first year. This is due to the moisture-induced swelling of photodegraded wood particles on the surface of the material [7]. Sixty-three (63) of the tested materials, mainly natural, impregnated and thermally modified wood developed checks after the experimental period. Knittex-impregnated yellow pine developed the longest total checks (890 mm), while pine, spruce and oak samples showed significant amounts of surface checks as well. Although impregnation with chemicals reduces water uptake and enhances dimensional stability in wood, It often increases susceptibility to checking [13].

5. Conclusions

In the weathering resistance test, 120 bio-based materials were assessed. Due to the high colour degradation and cracking the untreated wood is not the best alternative material for façades. Additionally, impregnation and thermal modification of natural wood do not significantly improve resistance to the weathering when compared with results obtained from untreated wood. However, a combination of methods like thermal modification or other forms of wood modification with subsequent surface coating should be considered to enhance the colour stability of façade materials. Consequently, the successful approach to maintain the aesthetical conditions of wood building façade details is to use hybrid treatment of wood materials involving acetylation and surface coats or to use wood–plastic composites where the wood content does not significantly limit the colour stability of the material.

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