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Effects of design configuration on decay initiation and progression in non-durable wood

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Abstract:
Wood used above ground and exposed to moisture may be vulnerable to decay. The initiation and rate of decay are influenced by several factors, including substrate type, moisture and temperature. The design and geometry of wood components affect moisture dynamics and may therefore influence both the initiation and progression of decay. This study evaluated the impact of nine different design configurations on the durability of wood components in a field experiment conducted at three North America sites with distinct climates. The tested variables included specimen volume, the presence of impermeable surface coatings, and the arrangement of appressed boards. Significant effects on both decay initiation and severity were observed, with water-trapping features such as appressed boards and sealed surfaces associated with earlier onset and more extensive decay over a fixed period. The results suggest that longer service life may be achieved by avoiding design features that retain moisture or inhibit drying.

Keywords: Aboveground exposure, field testing, moisture content, design configuration, service life, *Tsuga heterophylla*, western hemlock, wood decay

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Introduction

In temperate climates, the service life of above-ground wood assemblies exposed to moisture is primarily limited by fungal decay (Van Niekerk *et al.* 2021). Decay fungi require temperature and moisture conditions suitable for growth, as well as a supply of oxygen and a nutrient source (Carll and Highley 1999, Bari *et al.* 2020). Temperature and moisture generally have the greatest impact on the progression of decay over time (Meyer and Brischke 2015).

Estimation of the service life of wood components is becoming increasingly important to refine performance models and to compare the cost and environmental impact of various materials (Brischke and Thelandersson 2014). Accurate data are needed to substantiate wood's environmental profile and to facilitate its specification in construction projects. The service life of wood products is difficult to predict as it depends on many factors including climate, local biological hazards, material properties and design configuration (Brischke *et al.* 2006). Furthermore, design configuration is an important consideration when developing durable wood structures and components such as cladding, fencing or laminated assemblies.

Van Niekerk *et al.* (2021) illustrate a framework showing the steps required to model the service life of a wood component. This includes material resistance, material properties, and indirect variables such as climate and design. One of the least studied variables listed is design, which can impact decay rate through various means such as shading, condensation, water trapping, or facilitation of accumulation of leaf litter (Clausen and Lindner 2011, Isaksson and Thelandersson 2013, Kirker *et al.* 2020). As durability by design is frequently referenced in architectural literature and building code guidance, the ability to maximize service life by minimizing the duration and severity of moisture ingress is of considerable practical relevance.

The design features or component geometry of wood assemblies can influence decay susceptibility in many applications. As buildings evolve and the use of mass timber increases, understanding how specific design choices affect the service life of wood components becomes increasingly important. The present work investigates the impact of specimen size, sealed faces, and water trapping configurations on the initiation and progression of decay at three North America sites with different climates.

Areas of inhibited drying on wood surfaces are associated with increased decay (Morris and Stirling 2016, Stirling *et al.* 2017). Inhibited drying can result from surface coatings or from contact with adjacent components (wood or other materials). Coatings that reduce drying have been shown to increase decay (Norton and Francis 2008, Schauwecker *et al.* 2010). Water trapping caused by placing components in close contact is the basis of accelerated decay tests such as the bundle test (Brischke *et al.* 2023). In Mississippi, DeGroot (1992) found design influenced both onset and severity of decay at 48 months, with specimen size and moisture retaining features being critical factors. In Panama, under tropic conditions, he reported little variation in decay rate and severity among designs. These results suggest that design considerations may have a stronger effect on service life under temperate, fluctuating decay hazards than under tropical conditions with consistently high decay hazard.

The present study generates data specifically for the purpose of improving service life prediction models, aiding in evaluating potential test methods, and assisting designers to make durable wood structures by understanding the potential impacts of inhibiting drying surfaces on wood components. Three hypotheses were developed. Decay was hypothesized to begin sooner and develop faster at sites with higher Scheffer Index (SI). Water trapping from the presence of appressed boards or coated faces was hypothesized to be associated with decreased time to infection and increased rate of decay. Larger specimens were hypothesized to decay more slowly.

Materials and methods

Test materials

Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) was selected for this study as it has heartwood with low natural durability (Clark 1957) and was commercially available. Consistently low natural durability was a requirement to produce rapid results with minimal variation related to the material itself. Two hundred 2,44 m long 105 mm green hem-fir squares were obtained from Teal Jones (Surrey, British Columbia, Canada). From this species group, western hemlock boards were selected by microscopy. The material was primarily heartwood. Selected boards were kiln dried in a conventional batch kiln to below fiber saturation point and crosscut into 450 mm long end-matched specimens.

Boards were further planed and sawn to produce the material specified in Table 1. Material with loose knots or defects was excluded. Grain orientation was mixed. Twenty replicate specimens were prepared for each configuration type and for each test site. Design configurations were selected to examine potential impacts of specimen volume (comparing units 1, 5 and 9), appressed boards (comparing units 4 and 5, and 7 and 9) and impermeable coatings (comparing units 1, 2 and 3, and 5 and 6). All units were used to examine the effects of exposure site.

Units 2, 3 and 6 include coated faces. Only specified major faces were coated. These were prepared by brush-applying two coats of a two pack, high gloss white epoxy resin (Intergard 740, International Marine Coatings). The initial coat was allowed to cure at room temperature for approximately 24h before application of the second coat. Units 4, 7 and 8 were clipped together using stainless steel U-shaped clamps on each end. Stainless steel identification tags were affixed to each specimen.

Several comparisons were made in this study with different configurations acting as controls.

Table 1: Description of design configuration test units.

Unit Number	Configuration Description
1	Single 25 mm wide specimen
2	Single 25 mm wide specimen, coated one face
3	Single 25 mm wide specimen, coated two faces
4	Two 25 mm specimens clipped together
5	Single 50 mm wide specimen
6	Single 50 mm wide specimen, coated one face
7	Three 25 mm wide specimens clipped together
8	25 mm wide and 50 mm wide specimens clipped together
9	Single 75 mm wide specimen

Installations

Test materials were installed on aluminum frames approximately 1 m above the ground. Specimens had holes drilled on the underside of either end and sat fitted atop bolts protruding upward from the frame. All specimens were oriented on edge. Contact with the frame was limited to two points near either end of the specimen. In configurations with appressed boards the gap between boards was vertical to create a water trap. An aluminum bar was placed above each rack of specimens to hold each unit in place without touching the specimens (Figure 1).

Figure 1: Design configuration test specimens in Petawawa, Ontario (top left) and Maple Ridge, British Columbia (top right) after exposure, Saucier, Mississippi (lower left) at time of installation, and close up to show the rack design (lower right).

Selected test sites were in the Petawawa Research Forest near Chalk River, Ontario, Canada (latitude: 45,997168 longitude: -77,426108), the University of British Columbia's Malcolm Knapp Research Forest in Maple Ridge, British Columbia, Canada (latitude: 49,266712 longitude: -122,570828), and the Harrison Experimental Forest near Saucier, Mississippi, USA (latitude: 30,625609 longitude: -89,054657). All sites have a history of being used for above ground decay testing (DeGroot 1992, Morris *et al.* 2016). Test materials were installed in September 2018 in Petawawa and Maple Ridge and in April 2019 in Saucier. The Scheffer Index (SI) was calculated for each site over a thirty-year period from 1991 to 2020. SI values were 55 for Petawawa, 60 for Maple Ridge and 87 for Saucier. The Saucier site also has native subterranean termites (*Reticulitermes* spp.), though no termite damage was observed in these materials in this study.

Public health restrictions prevented inspection in 2020. Test materials in Petawawa were inspected September 2021, September 2022, July 2023 and September 2024. Test materials in Maple Ridge were inspected September 2021, October 2022, July 2023 and September 2024. Test materials in Saucier, Mississippi were inspected April 2022 and February 2024. Inspections evaluated extent of decay on a 10 to 0 scale based on AWPA deck board evaluation methods (AWPA 2023). Each 25 mm section of a specimen was given a decay rating. For specimens with multiple ratings, the lowest rating was used. In the AWPA decay rating scale, a rating of 9 is the highest rating with confirmed decay (AWPA 2023). A rating of 9,5 is only a trace or suspicion of decay. For this reason, ratings of 9 or less were as the basis for calculating time to decay initiation.

Statistical analysis

Time to decay initiation data was reported as the percentage of specimens with ratings of 9 or less at each inspection. The *Z*-test was used to evaluate the statistical significance of differences in proportions between treatment groups. This was calculated using an online calculator (Social Science Statistics 2025). To assess extent of decay, mean, standard deviation, median, skewness and kurtosis were calculated for each treatment group. Box and whisker plots were prepared to visualize ratings distribution. Despite decay ratings being ordinal data, replication was high, and skewness and kurtosis were within generally acceptable limits, so parametric tests were used. Student *t*-tests and one-way and two-way ANOVAs were used to compare selected groups. Groups were considered to be statistically different if p values were less than 0,05. Except where noted, all calculations and statistical analyses were completed in Microsoft Excel.

Results

Time to decay initiation

For the purposes of this study, the time to decay initiation was the first time a rating of 9 or lower was recorded. The percentages of specimens rated 9 or lower at each inspection are reported in Table 2. If a specimen previously rated 9, was rated 9,5 or 10 in a future inspection, the most recent value was taken. This explains some of the observed decreases in the percentage of specimens with ratings of 9 or less and is a consequence of the error associated with decay ratings. After 72 months, decay was observed in 81% of specimens in Maple Ridge and 62 % of specimens in Petawawa across all configurations. Decay initiation was much more rapid in Saucier with decay observed in 76 % of specimens after only 36 months and in 92 % of specimens after 58 months.

Table 2: Percentage of specimens with ratings of 9 or less at each inspection.

Configuration	Petawawa				Maple Ridge				Saucier	
	36 mo.	49 mo.	58 mo.	72 mo.	36 mo.	48 mo.	58 mo.	72 mo.	36 mo.	58 mo.
1	0	10	5	30	5	10	60	75	10	65
2	0	5	15	70	0	15	70	75	60	100
3	0	10	20	95	0	40	90	100	100	100
4	0	15	65	90	5	60	70	95	100	100
5	0	5	10	15	0	10	15	55	85	95
6	0	0	10	45	0	30	45	65	95	80
7	0	25	80	95	25	80	85	95	100	100
8	0	5	80	95	5	35	65	85	100	100
9	0	5	10	25	5	35	70	80	35	85
Total	0	9	33	62	5	35	63	81	76	92

Association with site

The proportion of specimens in all configurations rated 9 or less at each inspection interval differed between sites (Figure 2). The number of specimens with signs of decay increased with each inspection at each site. Decay was observed much earlier in Saucier than in Petawawa and Maple Ridge. Direct comparison between sites was possible at 36 and 58 months. Statistically significant differences were observed between proportions of specimens with ratings of 9 or less at each site at these times ($p < 0,05$).

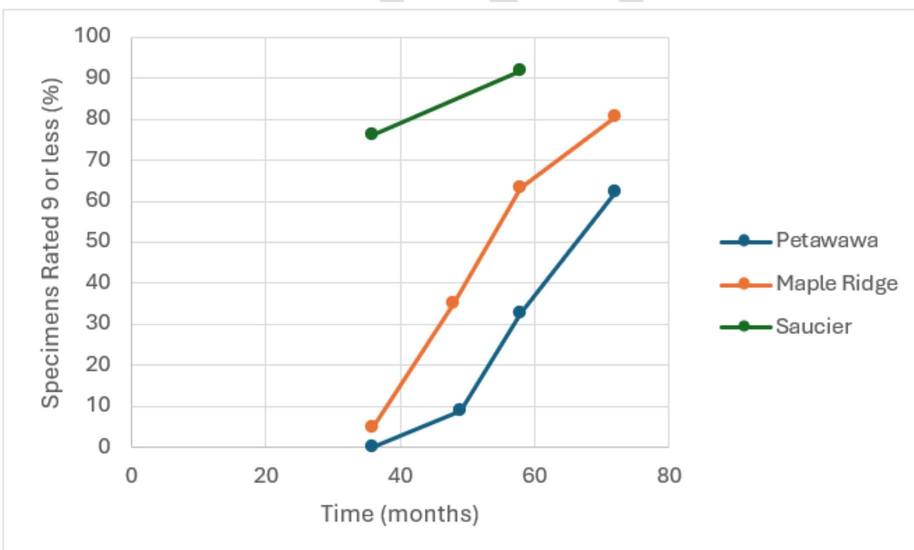

Figure 2: Percentage of specimens with decay ratings of 9 or less at each test site.

Association with water trapping

Two comparisons were made to evaluate the hypothesis that water trapping from appressed boards was associated with decreased time to infection (Table 3 and Table 4). Design configuration 4 consists of two appressed boards, while design configuration 5 is one solid piece with the same overall volume of wood. Configuration 7 consists of three appressed boards, while configuration 9 is one solid piece with the same overall volume of wood. The incidence of decay was greater in groups comprised of appressed boards than in groups comprised of solid boards of the same volume, except in Petawawa at the 36-month inspection where there was no confirmed decay in any of these groups. The observed differences were significant when the incidence of decay was moderate.

At both low and high incidence, these differences were no longer significant. Overall, these data confirm the association between the presence of a water trap and earlier observable decay. Under the conditions of this experiment, time to a rating of 9 was shortened when water traps created by the appressed boards were present. The difference was greatest in Petawawa, where the rate of decay was slowest, suggesting that water trapping may have a greater impact on incidence of decay in environments with lower decay hazards.

Table 3: Comparison of incidence of decay in design configurations 4 and 5.

Site	Petawawa				Maple Ridge				Saucier	
Exposure time (mo.)	36	49	58	72	36	48	58	72	36	58
Configuration 4, n ≤ 9	0	3	13	18	1	12	14	19	20	20
Configuration 5, n ≤ 9	0	1	2	3	0	2	3	11	17	19
Z	N/A	1,05	3,59	4,75	1,01	2,94	3,52	2,92	1,80	1,01
p	N/A	0,29	<0,001	<0,001	0,31	0,003	<0,001	0,004	0,072	0,31

Table 4: Comparison of incidence of decay in design configurations 7 and 9.

Site	Petawawa				Maple Ridge				Saucier	
Exposure time (mo.)	36	49	58	72	36	48	58	72	36	58
Configuration 7, n ≤ 9	0	5	16	19	5	16	17	19	20	20
Configuration 9, n ≤ 9	0	1	2	5	1	7	14	16	7	17
Z	N/A	1,77	4,45	4,52	1,77	2,88	1,13	1,43	4,39	1,80
p	N/A	0,077	<0,001	<0,001	0,077	0,004	0,25	0,15	<0,001	0,072

Association with presence of impermeable coated faces

The epoxy coatings remained in good condition throughout the duration of the test, though some minor cracking was observed in some specimens. Two comparisons were made to evaluate the hypothesis that impermeable coatings were associated with decreased time to infection. Configurations 1, 2 and 3 were compared (Table 5). Configuration 1 had no coatings. Configuration 2 had one major face coated. Configuration 3 had two major faces coated. Configurations 5 and 6 were also compared (Table 6). These were thicker specimens with and without one major face coated. Statistical differences between 36-month data from Petawawa and Maple Ridge were not evaluated as the incidence of decay was either 0 or 1.

In Petawawa, there was a low incidence of decay after 49 and 58 months of exposure and no statistically significant differences between groups. After 72 months of exposure, incidence of decay increased, and statistically significant differences were observed. In Maple Ridge, differences in the proportion of specimens with ratings of 9 or less were statistically significant between configurations 1 and 3 after 48 months. Incidence of decay was similar in most cases between uncoated configurations and configurations with only one coated face.

In Saucier, statistically significant differences were observed between configurations 1, 2 and 3 after 36 months. After 58 months, the incidence of decay in configuration 1 was significantly lower than in configurations 2 and 3, which both exhibited decay in all specimens. Statistically significant differences were not observed between configuration 5 and 6. Overall, the impact of having one coated face appeared to be greater when the proportion of surface area covered was greater.

Progression of the incidence of decay was observed in most specimens over time. Configuration 6 exposed in Saucier exhibited a decreasing incidence of decay. This was due to four specimens being rated 9 in 2022 and 10 in 2024. Ratings are made without prior knowledge and there is some subjectivity related to the environmental conditions at the time of inspection and differences between raters. Such variations are typical in this type of inspection (AWPA 2021).

Table 5: Comparison of incidence of decay between design configurations 1, 2 and 3.

Site	Petawawa			Maple Ridge			Saucier	
Exposure time (mo.)	49	58	72	48	58	72	36	58
Configuration 1, n ≤ 9	2	1	6	2	12	15	2	13
Configuration 2, n ≤ 9	1	3	14	3	14	15	12	20
Configuration 3, n ≤ 9	2	4	19	8	18	20	20	20
Z (1,2)	0,60	1,05	-2,53	-0,48	-0,66	0	-3,32	-2,91
p (1,2)	0,55	0,29	0,011	0,63	0,51	1	<0,001	0,004
Z (1,3)	0	-1,43	-4,25	-2,19	-2,19	-2,39	-5,72	-2,91
p (1,3)	1	0,15	<0,001	0,029	0,029	0,017	<0,001	0,004
Z (2,3)	0,60	-0,42	-2,08	-1,77	-1,58	-2,39	-3,16	N/A
p (2,3)	0,55	0,67	0,038	0,077	0,11	0,017	0,002	N/A

Table 6: Comparison of incidence of decay between design configurations 5 and 6.

Site	Petawawa			Maple Ridge			Saucier	
Exposure time (mo.)	49	58	72	48	58	72	36	58
Configuration 5, n ≤ 9	1	2	3	2	3	11	17	19
Configuration 6, n ≤ 9	0	2	9	6	9	13	19	16
Z (5,6)	1,01	0	-2,07	-1,58	-2,07	-0,65	-1,05	1,43
p (5,6)	0,31	1	0,039	0,11	0,039	0,52	0,29	0,15

Extent of decay

Box and whisker plots were developed to show the progression of decay at each site across all configurations (Figure 3, Figure 4, Figure 5). Mean and median values decreased with time as decay progressed. Standard deviation also increased as some specimens decayed more rapidly than others, resulting in greater variability. The data were negatively skewed at each inspection by the presence of outliers which decayed more rapidly. The 58-month inspection data from Saucier were an exception; with a high incidence and degree of decay there was minimal skewness.

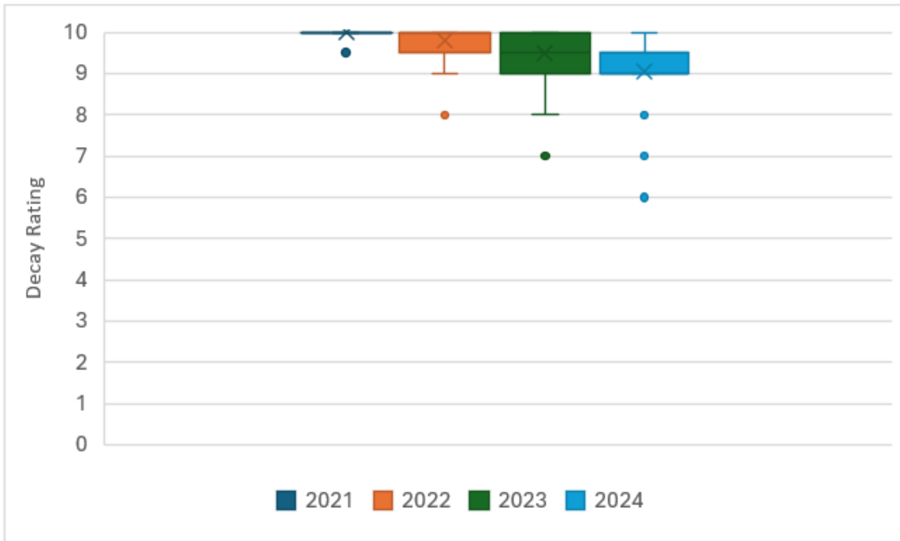

Figure 3: Box and whisker plot for decay ratings in Petawawa, Ontario.

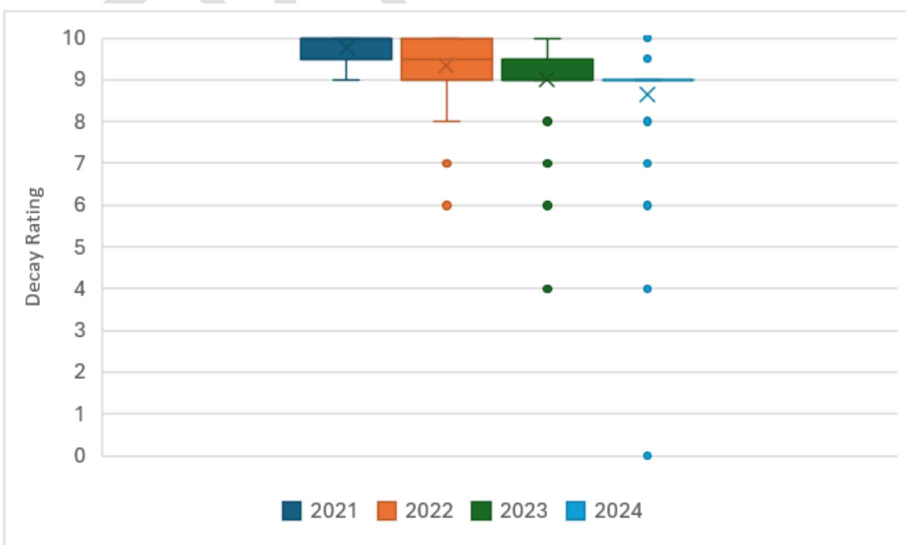

Figure 4: Box and whisker plot for decay ratings in Maple Ridge, British Columbia.

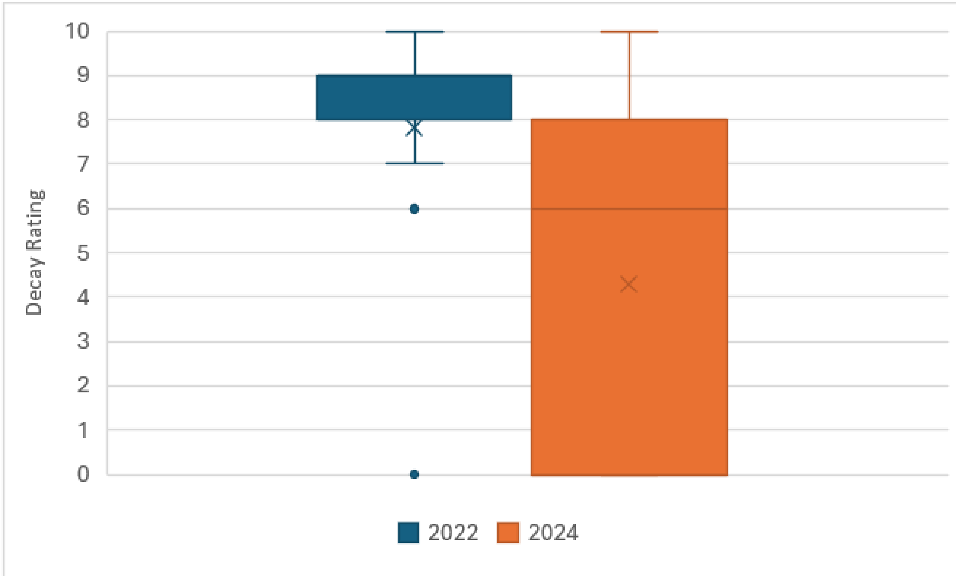

Figure 5: Box and whisker plot for decay ratings in Saucier, Mississippi.

To understand the impact of design configuration on extent of decay at selected times, box and whisker plots were prepared for each figuration at each site. These included the 72-month data from Petawawa and Maple Ridge, and the 36- and 58-month data from Saucier (Figure 6, Figure 7, Figure 8, Figure 9). Similar trends were observed at all sites, with extent of decay greatest in configurations 3, 4, 7 and 8. This corresponds with the clipped board configurations and the configuration which had two coated sides.

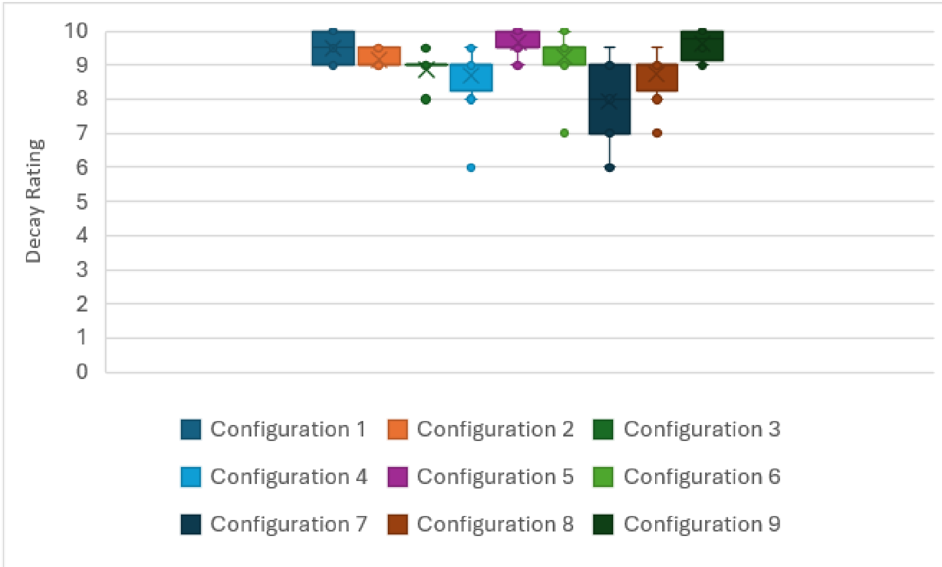

Figure 6: Box and whisker plot for 72-month decay ratings for each configuration in Petawawa, Ontario.

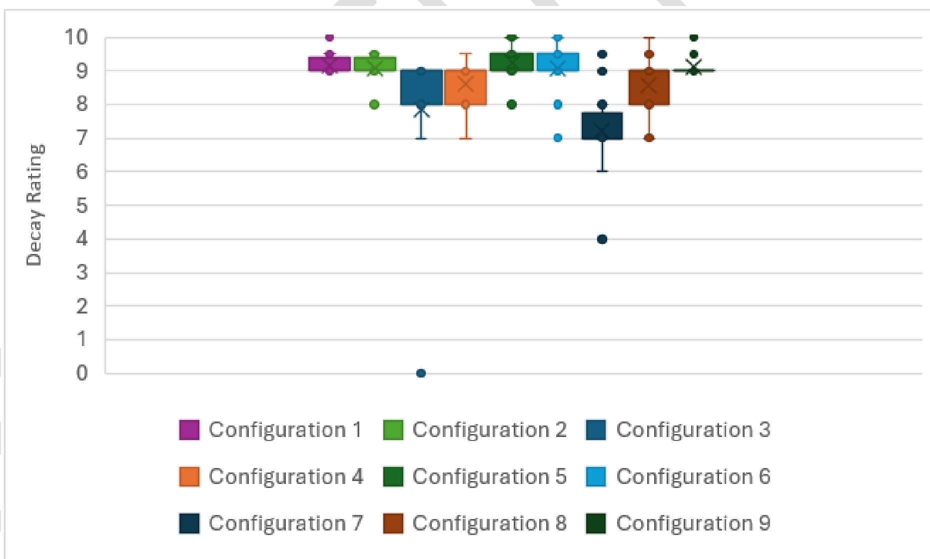

Figure 7: Box and whisker plot for 72-month decay ratings for each configuration in Maple Ridge, British Columbia.

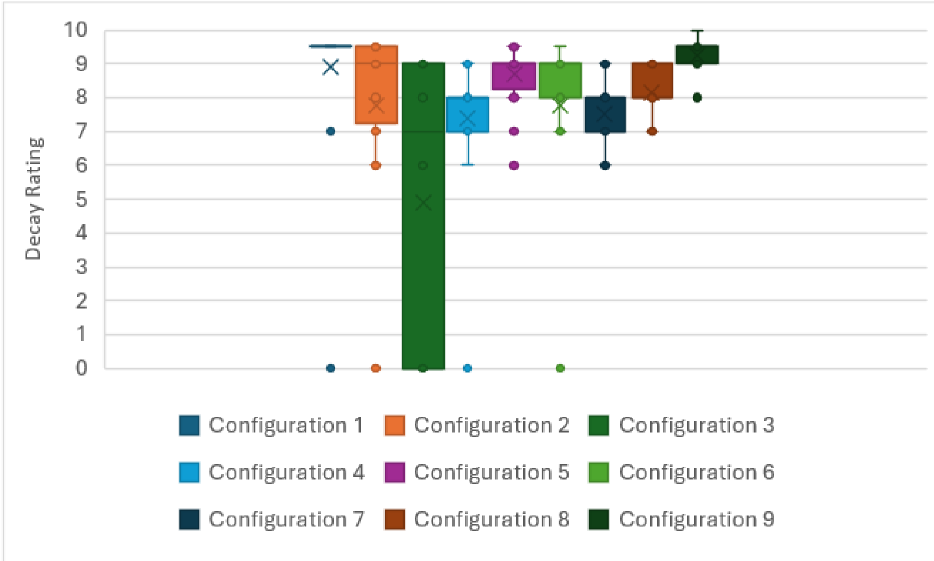

Figure 8: Box and whisker plot for 36-month decay ratings for each configuration in Saucier, Mississippi.

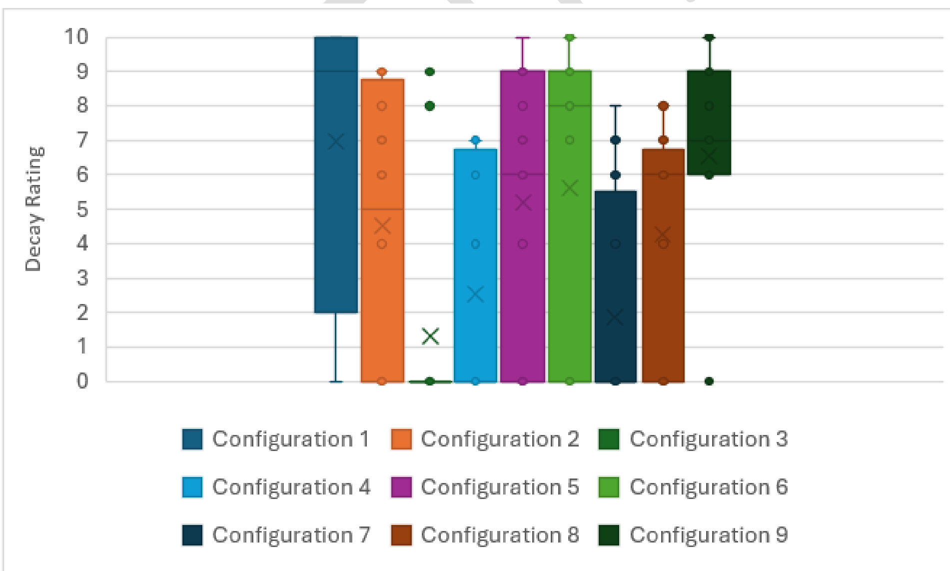

Figure 9: Box and whisker plot for 58-month decay ratings for each configuration in Saucier, Mississippi.

Associations with site and design configuration

Decay ratings from 58-month inspections were common to all sites and thus selected for comparison. A two-way ANOVA with replication was conducted to evaluate the association between site, design configuration, their interaction and decay ratings (Table 7). Statistically significant ($p < 0,05$) effects were observed for each factor and their interaction.

Table 7: Two-way analysis of variance for decay ratings from all sites and configurations.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample (Site)	2960,901	2	1480,45	325,7767	4,73E-92	3,013295
Columns (Configuration)	390,2426	8	48,78032	10,73423	5,22E-14	1,956442
Interaction (Site x configuration)	331,9324	16	20,74578	4,565158	1,37E-08	1,663249
Within	2331,263	513	4,544371			
Total	6014,338	539				

Association with water trapping

Two comparisons were made to evaluate the hypothesis that water trapping from appressed boards was associated with more rapid decay progression (Table 8). Configurations 4 and 5 were compared. Configuration 4 consists of two appressed boards, while configuration 5 is one solid piece with the same overall volume of wood. Similarly, configurations 7 and 9 were also compared.

Configuration 7 consists of three appressed boards, while configuration 9 is one solid piece with the same overall volume of wood. For this comparison, data from 72-month inspections in Petawawa and Maple Ridge, and the 58-month inspection in Saucier were selected as the extent of decay was greatest at this time. Statistically significant differences ($p < 0{,}05$) were observed for all comparisons indicating that the appressed board configurations decayed faster than equivalent volumes of solid wood.

Table 8: Comparison of decay rating means for selected groups with water traps.

Site	Configuration	Mean	Standard deviation	*p*
Petawawa	4	8,7	0,8	< 0,001
	5	9,7	0,4	
	7	7,9	1,2	< 0,001
	9	9,6	0,4	
Maple Ridge	4	8,6	0,6	0,001
	5	9,3	0,5	
	7	7,2	1,2	< 0,001
	9	9,1	0,3	
Saucier	4	2,6	3,3	0,0241
	5	5,2	3,8	
	7	1,9	3,0	< 0,001
	9	6,6	3,2	

Association with presence of impermeable coated faces

Two comparisons were made to evaluate the hypothesis that presence of impermeable coatings would be associated with greater extent of decay. Configurations 1, 2 and 3 were compared. Configuration 1 had no coatings. Configuration 2 had one major face coated. Configuration 3 had two major faces coated. Configurations 5 and 6 were also compared. These were thicker specimens with and without one major face coated. Comparisons were only made for data from the most recent inspections as extent of decay was greatest at this time (Table 9).

One-way ANOVAs based on data from each site showed statistically significant associations between configurations with zero, one and two coated faces ($p < 0,05$). Student t-tests were used to compare thicker specimens with zero and one coated face (configurations 5 and 6). A statistically significant difference ($p < 0,05$) was observed in Petawawa (Table 10). However, no significant differences were observed in data from Maple Ridge and Saucier.

Table 9: One-way analysis of variance for decay ratings from design configurations with zero, one and two coated faces.

Site	Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Petawawa	Between Groups	3,925	2	1,9625	16,00894	3,04E-06	3,158843
	Within Groups	6,9875	57	0,122588			
	Total	10,9125	59				
Maple Ridge	Between Groups	21,30833	2	10,65417	4,152748	0,020719	3,158843
	Within Groups	146,2375	57	2,56557			
	Total	167,5458	59				
Saucier	Between Groups	321,1	2	160,55	10,99724	9,14E-05	3,158843
	Within Groups	832,15	57	14,59912			
	Total	1153,25	59				

Table 10: Comparison of decay rating means for selected groups with impermeable coatings.

Site	Configuration	Mean	Standard deviation	*p*
Petawawa	5	9,7	0,4	0,011
	6	9,2	0,6	
Maple Ridge	5	9,3	0,5	0,338
	6	9,1	0,7	
Saucier	5	5,2	3,8	0,758
	6	5,6	4,3	

Association between specimen volume and extent of decay

The association between specimen volume and extent of decay was evaluated by comparing the most recent decay ratings from design configurations 1, 5 and 9 (Table 11). Design 1, 5 and 9 were standalone configurations without appressed boards or coatings. Design configuration 5 had twice the volume of configuration 1, while configuration 9 had three times the volume of configuration 1. One-way ANOVAs from each site showed no statistically significant associations between specimen volume and extent of decay ($p < 0,05$).

Table 11: One-way analysis of variance for decay ratings from design configurations with differing volume.

Site	Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Petawawa	Between Groups	0,258333	2	0,129167	0,819193	0,445909	3,158843
	Within Groups	8,9875	57	0,157675			
	Total	9,245833	59				
Maple Ridge	Between Groups	0,175	2	0,0875	0,689119	0,506151	3,158843
	Within Groups	7,2375	57	0,126974			
	Total	7,4125	59				
Saucier	Between Groups	33,63333	2	16,81667	1,193562	0,310601	3,158843
	Within Groups	803,1	57	14,08947			
	Total	836,7333	59				

There were significant differences in both time for decay initiation and rate of decay associated with field test site. These sites have different climates, and climate is well known to affect decay rate (Scheffer 1971). Saucier had the highest SI and decay rates. The Maple Ridge site has a higher SI than Petawawa and was associated with more rapid and extensive decay than Petawawa (Scheffer 1971, Setliff 1986, Morris and Wang 2008). Nevertheless, climate is only one of the differences between the sites. It is possible that local site effects, microclimatic factors, or differences in fungal communities may also be underlying causes (Råberg *et al.* 2005, Brischke and Rapp 2008, Zahora 2008, Hiscox *et al.* 2016).

Appressed board configurations were designed to create a water trap that would facilitate more rapid wetting and slow drying of the specimens. Keeping the wood wet for longer was expected to result in more rapid decay initiation and an increased rate of decay (Meyer *et al.* 2014). This was observed with significant differences found between two sets of groups at all sites. DeGroot (1992) observed similar increased decay in stacked specimens, with similar water traps created by appressed boards, exposed in an earlier experiment in Saucier, Mississippi. The appressed board configurations are similar to the embedded test reported by Cookson *et al.* (2014), which was also reported to accelerate decay. In this study, the appressed board configuration resulted in the most rapid decay. This is likely due to its ability to trap water combined with protection from wind and sun that would reduce the rate of drying.

The appressed board configuration mimics some common fence panel designs. These data suggest that designs that avoid this type of water trap may be able to achieve longer service life. The appressed board configuration also mimics nail laminated timber. These data suggest that nail laminated timber may be particularly susceptible to decay if made from non-durable materials and exposed outside without protection by design. The material in this study exhibited only limited checking. However, the appressed board configuration mimics a deep check or crack suggesting that the presence of such checks or cracks could also lead to greater decay (Brischke and Meyer-Veltrup 2015).

Previous studies have noted the association between incomplete or defective coatings and increased decay (Fougerousse 1976, Norton and Francis 2008, Schauwecker *et al.* 2010, Meyer *et al.* 2014). This was evaluated in the present study by comparing 25 mm thick specimens with zero, one and two major faces sealed with epoxy, and by comparing 50 mm thick specimens with zero or one major face sealed with epoxy. Epoxy has very low water vapor transmission (Miklečić and Jirouš-Rajković 2021). There were statistically significant differences in some of these comparisons but not others. Time to decay data varied by year of inspection. Differences were minimal when the incidence of decay was low, or high.

Differences between configurations were more likely to be observed when the incidences were moderate. The presence of an impermeable coating reduces the ability of the wood to dry. This increase in surface area where drying is inhibited is likely the cause of observed increases in extent of decay. These data highlight the importance of vapour permeability in coatings that are exposed to precipitation, and further caution against employing configurations that inhibit drying.

The hypothesis that larger specimens would decay more slowly was not supported by these data. This contrasts with earlier work where small specimens were found to dry too quickly and thus decayed more slowly than larger specimens (Fougerousse 1976, DeGroot 1992, Cookson *et al.* 2014). In treated materials, preservatives may deplete more rapidly from smaller specimens thus accelerating decay (Zahora 2008). The absence of an effect in this study may be due to differences in climate or other site factors, or due to the relatively small range evaluated. The volume varied only threefold and only in thickness. Within this thickness range (25 to 75 mm) we did not observe differing rates of decay. The specimens were largely clear wood with minimal checking. If large checks or cracks were present, the specimen may behave more like the appressed boards, and a greater rate of decay might be expected.

The concept of a drying inhibited surface area is useful for evaluating how wood components are installed and connected to each other in exterior above ground applications. In addition to specifying durable materials for exterior above ground use, designers should also seek to avoid water traps and detailing that trap moisture. This is a critical element to realize the maximum service life achievable.

The opposite advice may be employed to accelerate decay in field exposures, i.e., exposure in an aggressive climate with water traps and limited drying capability. Many above ground tests methods have employed these techniques (Fougerousse 1976, DeGroot 1992, Zahora 2008, Cookson *et al.* 2014, Meyer *et al.* 2014). While such accelerations may lead to more rapid data, they may not represent realistic service lives. Such data are best used for screening and comparative purposes. Use in service life prediction may yield biased or less precise results than data from long-term, unaccelerated commodity sized tests.

Data reported here were limited to three sites with moderate to high Scheffer Indices, indicating a moderate to high above-ground decay hazard. It's not known whether the significance of the configurations observed in this study would extend to climates with much greater decay hazards. Previous research found little impact of test unit configuration under tropical conditions where decay progressed rapidly and relatively uniformly (DeGroot 1992), and we see this trend in the progression of decay in Saucier.

This study only investigated the performance of a non-durable material. This was selected to provide rapid results. The interaction between material durability and physical configuration was beyond the scope of this work. It's unclear if the same effects would be observed if more durable materials (e.g., naturally durable woods, modified woods, or preserved woods) were used.

Maintenance was also beyond the scope of this study. This has previously been associated with extended service life (Grüll *et al.* 2010). It's unclear how physical configuration and maintenance would interact, as some configurations would be more difficult to maintain than others.

Finally, moisture content was not monitored in the test specimens in this study. Inclusion of long-term moisture monitoring would provide a more comprehensive understanding of how physical configuration impacts moisture dynamics and biodegradation.

Conclusions

The design configuration of non-durable softwood exposed above ground at three sites in North America had significant impacts on both decay initiation time and extent of decay. Time to decay initiation was negatively correlated with SI, and decay developed more rapidly at sites with higher SI. Water trapping from the presence of appressed boards or impermeable coatings was associated with decreased time to infection, and increased rate of decay. Specimen volume was not associated with faster decay. Longer service life may be achieved by avoiding designs that trap water or inhibit drying. These criteria should be considered when designing wood assemblies for durability.

Authorship contributions

R.S.: Conceptualization, methodology, investigation, formal analysis, project administration and writing – original draft preparation. G.T.K.: Investigation, validation, and writing – review and editing.

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Declaration of interest

The authors declare no conflict of interest.

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