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Surface checking of wood is increased by photodegradation caused by ultraviolet and visible light

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Abstract The aim of this research was to test the hypothesis that exposure to solar radiation increases the checking of wood exposed to the weather, and to examine the causes and spectral dependency of such an effect. Lodgepole pine decking samples were exposed outdoors under filters, which blocked selected regions of the solar spectrum while allowing other weathering factors to act on samples. Surface checking in samples was quantified after 12, 24 and 36 weeks of exposure, and the chemical and micro-structural changes occurring at weathered wood surfaces were examined. Check numbers and dimensions were greater in samples exposed under a filter to the full solar spectrum than in samples exposed under filters that blocked the transmission of UV, visible or infrared radiation. Samples that were shielded from more energetic wavelengths developed less checking and also showed less delignification at the exposed wood surfaces. Checks developed at the margins of rays and propagated at the interface between adjacent tracheids, close to the middle lamella. We conclude that exposure to UV and visible light increases the tendency of wood to check during exterior exposure. Our findings point to a link between changes in cell micro-structure as a result of photodegradation of lignin and the development of visible checks in wood exposed outdoors.

Introduction

Wood exposed outdoors is susceptible to surface degradation (weathering) caused by solar radiation, water and heat (Feist and Hon 1984). Solar radiation depolymerizes lignin and cellulose, and water leaches the resulting photodegraded

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fragments from wood (Derbyshire and Miller 1981; Evans et al. 1993). Water also swells wood and subsequent loss of moisture results in shrinkage. These cyclic changes in wood moisture content and dimensions occur frequently in wood exposed outdoors, and are most pronounced at the wood surface, which is directly exposed to rainwater and solar radiation (Zahora 1992). Wood beneath the surface dries more slowly and hence restrains shrinkage at the surface (McMillen 1955). Such restraint generates surface tensile stresses, whose magnitude depends on the moisture gradient between the surface and sub-surface layers of wood (Stamm and Loughborough 1942). When these stresses exceed the strength of wood perpendicular to the grain, the wood checks or cracks (Schniewind 1963; Stamm 1964).

It is well known that stresses are concentrated around voids resulting in the development of cracks, which propagate easily through brittle materials (Gordon 1976; Rahman et al. 2000). Both of these aspects of materials, which favor the development of checks, can be found at the surface of wood exposed to solar radiation. Such exposure causes rapid losses in the surface tensile strength and toughness of wood and creates numerous micro-checks in the cell walls of wood (Derbyshire and Miller 1981; Derbyshire et al. 1996; Evans 1989; Miniutti 1964, 1967; Raczkowski 1980; Turkulin and Sell 2002). Hence, it can be anticipated that exposure to solar radiation will increase the tendency of wood to check. In support of this suggestion, Sandberg (1999) mentioned that photochemical reactions, which take place at wood surfaces during outdoor exposure increase the checking of wood. Yata (2001) also suggested that the occurrence of small checks at wood surfaces was “attributable to the complex effect of photodegradation on wood components by short wavelength light and the stresses of repeated drying and wetting”. Most recently, Sandberg and Söderström (2006) stated that “visible cracks arise in the wood surface during weathering because of the growth of micro-cracks, photochemical reactions or moisture-induced stress fields”. Experimental evidence to support these suggestions, however, is lacking and, in particular, our understanding of how photochemical degradation influences the checking of wood exposed outdoors is limited. This is unfortunate because checking is an undesirable characteristic of wood that is partly responsible for its substitution by materials such as wood-plastic composites that are less susceptible to checking (Balatinecz and Woodhams 1993). Hence, there is a pressing need to better understand why checking occurs in wood and the factors that influence its development, so that solutions to the problem can be developed.

In this research we exposed lodgepole pine (*Pinus contorta var. latifolia Wats.*) decking samples under filters, which blocked selected regions of the solar spectrum while allowing other weathering factors to act on samples. Surface checking that developed in the samples was quantified and the chemical and micro-structural changes occurring at the weathered wood surfaces were examined. The aim was to test the hypothesis that exposure to solar radiation increases the tendency of wood to check when it is exposed outdoors to the weather, and examine the causes and spectral dependency (if any) of such an effect.

Materials and methods

Experimental design and statistical analysis

A factorial experiment was designed to examine the effect of two fixed factors: (a) wavelength of radiation in the solar spectrum and (b) exposure time, on the number and dimensions of checks that developed in lodgepole pine samples exposed outdoors under different filters for 12, 24 and 36 weeks. Decking boards cut from five different trees provided replication at the higher level. Samples cut from each of these decking boards were allocated to one of five different exposure racks, each containing five filters, which blocked selected wavelengths in the solar spectrum. The resulting experimental design accounted for random variation in wood properties of decking samples (growth ring orientation between samples cut from different trees) and that due to exposure of samples under various filters in different testing racks (spatial effects of location of samples between and within racks). Analysis of variance was used to examine the effects of fixed and random factors on the checking of wood. Statistical computation was performed using Genstat 5 (Genstat 2000). Before the final analysis, diagnostic checks were performed to determine whether data conformed to the underlying assumptions of analysis of variance, i.e., normality with constant variance, and as a result of such assessments, data for check dimensions and shape were transformed into natural logarithms before analysis. Significant results ($P < 0.05$) are presented graphically and least significant difference (LSD) bars ($P < 0.05$) on graphs can be used to compare differences between individual means. The significance of the effect of filter type on checking is also included on each graph.

Preparation of decking samples

Five mature lodgepole pine trees growing in the Alex Fraser Research Forest near Williams Lake (52°14′N, 122°12′W), British Columbia, Canada were felled in February 2004. A log approximately 3.05 m long in diameter was cut from the base of each tree and manually debarked. The logs varied in diameter from 33 to 39 cm and contained up to 94 growth rings (minimum 84). Each log was sawn through-and-through using a portable sawmill to produce five, 50 mm-thick, flat sawn boards. A board located 75 mm from the bark and containing mature, defect-free wood was selected from each log. These boards were kiln dried using a moderate low temperature (65–72°C) drying schedule for 14 days to attain a final moisture content of 13%. Each board was then planed on all four sides using a jointer and a thickness planer until it reached a final target size of 140 mm (width) × 40 mm (thickness). The longitudinal edges of each board were rounded to a 5 mm radius using a shaper, and each board was cross-cut to produce eight 32 cm long decking samples. The end grain of each sample was then coated with a paraffin wax sealant to minimize further drying of samples and reduce the development of checks in the end grain.

Exposure trial and measurement of checking

Five exposure racks were built, each of which contained five horizontal openings containing different polymethylmethacrylate filters (CRYO Industries, Rockaway, USA) that transmitted selected regions of the solar spectrum (Table 1). The different filters were randomly placed into the openings in the racks and matching filters on the sides and ends of the openings prevented unfiltered light from reaching the samples. One decking sample with growth rings, orientated convex to the upper surface was placed under each filter. The samples were orientated parallel to the long axis of the racks on 40 mm-wide spacer blocks (Fig. 1). Angled aluminum sheet was used to capture rain water and direct it onto the surface of samples (Fig. 1). This was necessary because wetting and drying of wood creates the stresses that are responsible for the surface checking of wood. Nevertheless, in practice we observed that samples exposed under filters did not become as wet as samples that were not shielded by filters (Urban 2005). They also developed less checking and were not as rapidly colonized by micro-organisms compared to samples that were fully exposed to the weather (Urban 2005). All of the sheeting and wooden members used to construct the frame of the racks were coated dark brown to minimize reflection of light onto samples. The racks were kept off the ground using concrete blocks and each rack was inspected daily to remove dust from the filters and keep the test area free of weeds.

Samples were exposed to the weather at Totem field at the University of British Columbia (UBC), Vancouver (49°11′N, 123°10 ′W) for three consecutive periods of 12 weeks as follows: one, 31 May–22 August 2004; two, 7 September–28 November 2004; three, 13 December 2004–6 March 2005. After each 12 week exposure period, the decking samples were removed from the racks and conditioned at 20 ± 1°C and 65 ± 5% relative humidity for 10 days. The number of visible checks at the surface of each sample was counted and the length and width of each check were measured using a transparent Perspex ruler and an optical magnifying glass containing a calibrated graticule, respectively. These measurements were used to calculate the total number, length, width and area of checks in each sample and their shape (length/width), as described previously (Evans et al. 2003).

Table 1 Wavelengths blocked and transmitted by the different filters used in the exterior weathering racks

Filter	Filter type	Wavelengths blocked (nm)	Wavelengths transmitted (nm)
1	Acrylite OP-4	None	UVB, UVA, visible, IR
2	Acrylite GP	UVB (260–345)	UVA, visible, IR
3	Acrylite OP-2	UVA (260–400)	Visible[a], IR
4	Acrylite GP Black 1146-0	UV/visible (260–760)	IR
5	Acrylite GP Black 199-0	All	None

[a] 98% of UV absorbed

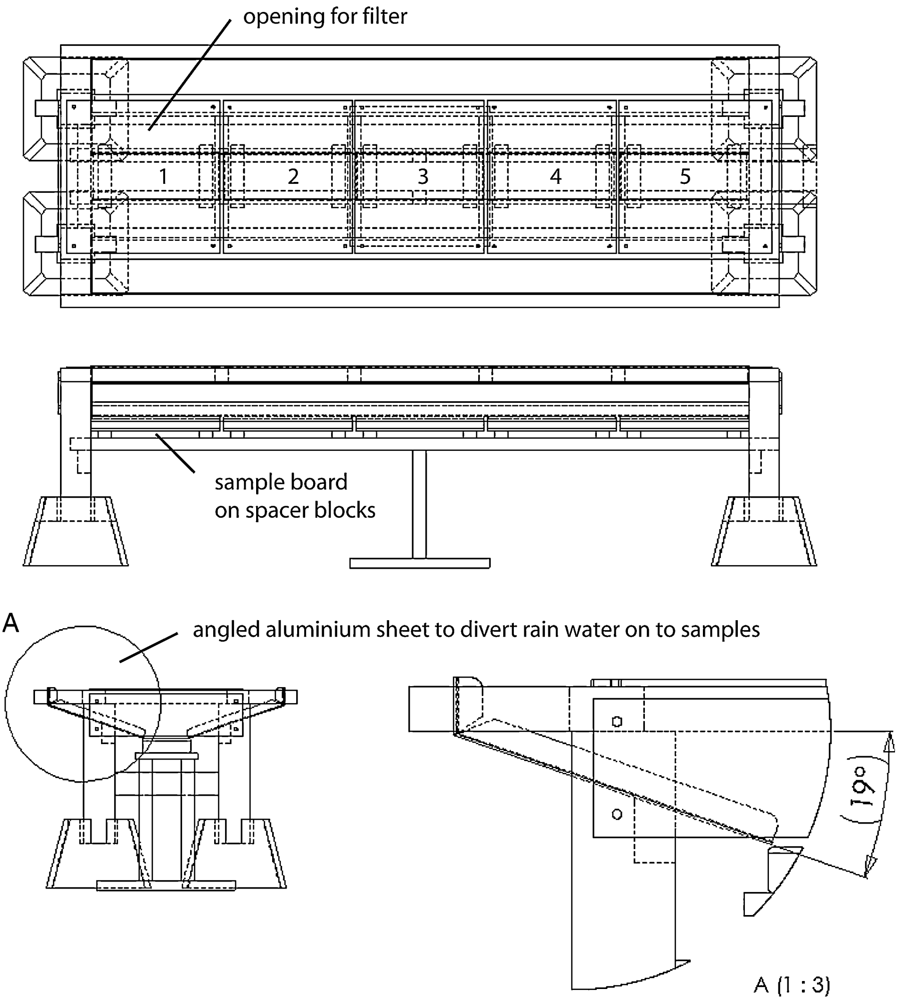

Fig. 1 One of five test racks used to expose deck board samples to the weather

Measurement of solar radiation

Information on the average temperature and total precipitation at the test site during the exposure trial were obtained from measurements made by the Faculty of Agriculture at UBC. The UVB and UVA radiation received by samples exposed under different filters during each exposure period was also measured using Viospor dosimeters (Furusawa et al. 1998). Dosimeters placed under the filter that transmitted all regions of the solar spectrum (Filter 1) were replaced every 2 to 3 days during the summer (June–August), and thereafter every week until the end of the exposure trial. Dosimeters placed under filter 2 that blocked UVB radiation were replaced every week during the summer and every 4 weeks thereafter. Dosimeters placed under the other filters were changed at the end of each 12 week exposure period.

Scanning electron microscopy and FTIR spectroscopy

It was difficult to see the cellular structure of wood at the surface of weathered decking samples. Therefore, a separate experiment was performed to examine the micro-structure of checking in wood exposed under different filters. Eighteen small wood samples measuring 6 mm (tangential) × 6 mm (longitudinal) × 15 mm (radial) were sawn from the same parent lodgepole pine material used to prepare decking samples. The tangential surfaces of these specimens were carefully prepared before they were exposed to the weather to minimize damage to specimens during surface preparation. The samples were placed in a beaker containing distilled water for 5 days until they became saturated with water, and they were then trimmed to a final size of 4 × 4 × 15 mm. Individual samples were clamped in a small vice located beneath the stage of a low-power binocular microscope and viewed at low (×10) magnification. A sharp single-edged razor blade was then used to manually slice thin (20–30 μm) sections from the tangential longitudinal face of each specimen until a clean, undamaged surface was obtained. Specimens were dried over silica gel at 20 ± 1°C in a dark room for 2 weeks. They were then attached to small crocodile clips, which were screwed into wooden backing plates measuring 80 mm (width) × 160 mm (length) × 8 mm (thickness). Five of these plates were prepared, each containing three specimens. One of these plates containing SEM specimens was placed under each of the five filters in a weathering rack (Fig. 1) where they were subjected to surface wetting as well as filtered solar radiation. Specimens were exposed outdoors to the weather for 50 days during August and September of 2006. They were removed from the racks and dried over silica gel, as above. They were then reduced in size to ~4 × 4 × 8 mm using a razor blade, and two samples exposed under each of the different filters and two unexposed samples were glued to separate aluminum stubs using Nylon nail polish as an adhesive. The stubs were sputter coated with a 10 nm layer of gold and they were then examined using a Hitachi S-2600 variable pressure scanning electron microscope at accelerating voltages of 7 or 15 kV. Secondary and back-scattered electron images of samples were obtained and saved as TIFF files.

Fourier transform infrared (FTIR) spectroscopy was used to examine chemical changes at the surface of wood samples exposed under the different filters. Six wood samples measuring 20 mm (width) × 60 mm (length) × 8 mm (thickness) were sawn from the same parent lodgepole pine material used to prepare decking samples. One sample was exposed for 50 days under each of the five different filters and one sample was retained as a control. After exposure, samples were stored for 5 days in a vacuum desiccator over silica gel and FTIR spectra of weathered surfaces were obtained using a single bounce attenuated total reflectance accessory (PikeMiracle) attached to a Perkin Elmer Spectrum One spectrometer. The penetration of infrared radiation into the wood sample was approximately 1.2 μm and each spectrum represented 16 accumulations at 8 cm^{-1} resolution.

Results

Surface checking

Exposure of decking samples to solar radiation had significant ($P < 0.01$) effects on the checking that developed at the surface of the samples. Figure 2 shows the number, dimensions and shape of checks in samples exposed outdoors under the different filters for 12, 24 and 36 weeks. It is apparent from this figure that check numbers and dimensions were greater in samples exposed to the full solar spectrum under filter 1 than in samples exposed under the other filters that blocked the transmission of UV, visible or infrared radiation. Blocking of UVB with wavelengths of 260–345 nm by filter 2 clearly reduced the numbers and dimensions of checks in samples, although it had no significant effect on the shape of the checks (Fig. 2). Further restriction of UV radiation by filter 3, which blocked wavelengths in the 260–400 nm range, reduced check numbers and their dimensions, particularly check width and area (not shown), where there was a significant overall difference ($P < 0.01$) in these parameters between samples exposed under filters 2 and 3. Additional reductions in the dimensions of checks occurred in samples exposed under filter 4, which blocked visible light, but not infrared radiation. However, there was no significant difference ($P > 0.05$) in the checking of these samples and those

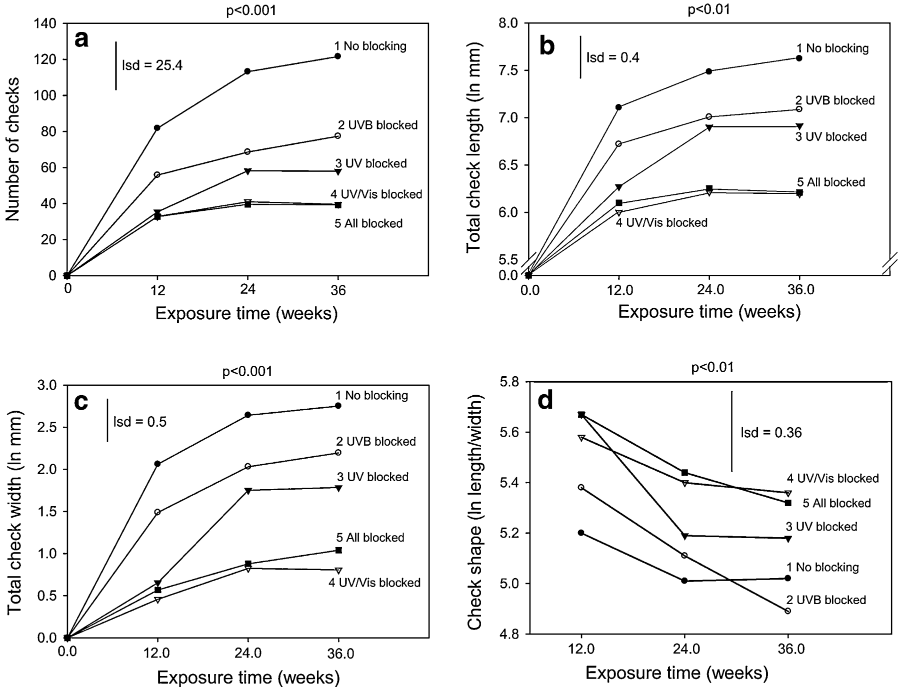

Fig. 2 Effect of blocking UV, visible and infrared radiation on the checking of lodgepole pine decking boards exposed under filters to the weather for 12, 24 and 36 weeks

exposed under filter 5 where infrared radiation was also prevented from reaching the surface of the samples.

Check numbers and their dimensions increased with exposure time as expected and the analysis of variance showed significant ($P < 0.01$) effects of exposure time on checking. These increases in checking were more pronounced initially in samples exposed to UV radiation under filters 1 and 2 than in the other samples. The shape of checks that developed at the surface of specimens also changed with increasing exposure time, and the decreases in the shape parameter in Fig. 2 reflect greater increases in width of checks with increasing exposure time compared to length.

The average temperature and total precipitation at the test site during the three 12 week exposure periods were 18.3°C and 78 mm (June–August), 10.5°C and 373 mm (September–November) and 5.1°C and 399 mm (Dec-Feb), respectively. Table 2 shows the UV radiation that samples were exposed to under the different filters. The UV radiation and average temperature were highest during the first period of exposure from June to August, as expected. Thereafter during subsequent exposure periods the UV radiation and average temperature declined, but total precipitation increased significantly. Samples exposed under filter 1 that transmitted all wavelengths received the greatest amount of UV radiation during each exposure period. In comparison, the levels of UV radiation received by samples under filter 2 were much smaller, particularly during the autumn and winter. UV radiation was also detected under filter 3, but the quantity received was low in comparison to that detected under filters 1 and 2. The levels of UV radiation detected under filters 4 and 5 were very low, particularly during the autumn and winter.

Chemical changes

Infrared spectra suggested substantial delignification at the surface of samples exposed under the filters that transmitted UV radiation (Fig. 3). The spectra for these samples showed substantial reductions in the peak at a wave number of 1505 cm^{-1} corresponding to C = C stretching vibration in aromatic rings of lignin (Harrington et al. 1964). The same peak was also reduced in samples exposed under filter 3 that transmitted visible light, but blocked most UV radiation (Fig. 3).

Table 2 Total UV radiation transmitted through the different filters during the three exposure periods

Filter	Total UV radiation (kJ/m^2)		
	June–August 2004	September–November 2004	December–February 2004/2005
1, No blocking	241	39.7	22.9
2, UVB blocked	29.8	5.6	3.0
3, UV blocked	14.8	3.6	1.5
4, UV/visible blocked	9.3	1.5	0.7
5, All blocked	8.3	1.5	0.7

Changes in the peak at 1505 cm^{-1} in samples exposed under the filters, which blocked UV and visible light (Filter 4) and all wavelengths (Filter 5) were small by comparison, indicating little surface delignification of these samples (Fig. 3).

Micro-structure of checking

Scanning electron microscopy of multiple samples revealed the presence of large checks in samples exposed to UV light and longer wavelengths under filters 1 and 2. Examples of such checking are shown in Fig. 4. Figure 4a shows one of the small specimens exposed for 50 days under the filter that transmitted all wavelengths (Filter 1). Two large checks are present on the left and right hand sides of the image (arrowed), measuring approximately 1 and 2 mm in length, respectively. Similar checks also developed in samples exposed under filter 2 that excluded UVB, but the checks were thinner than those in samples exposed to the full solar spectrum (arrowed in Fig. 4b). In contrast, large checks were absent in the small specimens exposed to only visible and/or infrared radiation (not shown) and in the unexposed control (Fig. 4c). Nevertheless, small voids developed in the unexposed control as a result of degradation of thin-walled parenchyma and epithelial cells within rays. The size of such voids or "ray micro-checks" reflects the dimensions of the parent rays and hence they were easier to see when they resulted from the degradation of large fusiform rays (arrowed in Fig. 4c). These voids developed despite the great care taken to prepare undamaged surfaces. During outdoor exposure, there was further degradation of ray tissue within rays, and the ray micro-checks became longer as a result of longitudinal separation of the tracheid wall at the margins of the rays.

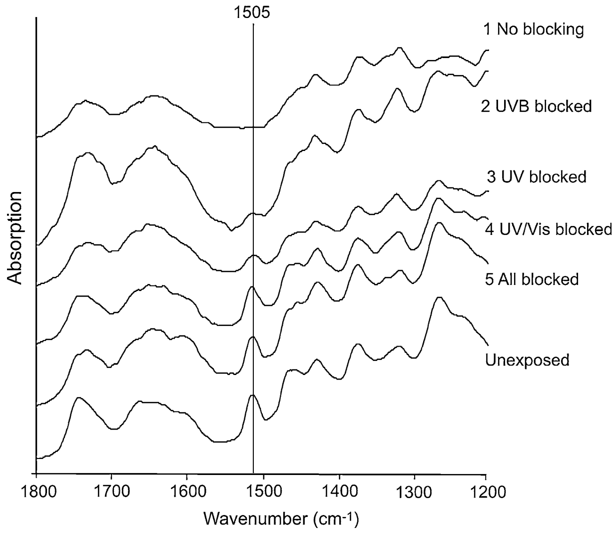

Fig. 3 Fourier transform infrared spectra of the surface of lodgepole pine wood samples exposed outdoors for 50 days under filters, which blocked selected regions of the solar spectrum

Figure 4d is an enlarged image of the large check on the left-hand side of Fig. 4a. This check extends above and below a degraded uniseriate ray as a result of separation of the cell wall at the interface between two tracheids. At its lower end, the check traverses one tracheid via a transverse micro-check and continues as a longitudinal separation of the cell wall in the adjacent tracheid (arrowed in Fig. 4d). Transverse micro-checks were observed frequently in specimens exposed to the full solar spectrum under filter 1, and provided a way for checks to propagate longitudinally from tracheid to tracheid. These transverse micro-checks were less frequent in samples exposed under the filter that blocked UVB radiation (Filter 2), and absent in specimens exposed under filters that blocked the transmission of all UV radiation. Nevertheless, large checks could still form in the absence of transverse micro-checks as a result of longitudinal separation of cell walls and propagation of checks formed in rays that were aligned vertically. The large check that formed on the right hand side of Fig. 4a and the one in the specimen exposed under filter 2, which excluded UVB (Fig. 4b), developed in this way (Figs. 4e, f). Longitudinal separation of cell walls appeared to occur at the interface close to the middle lamella in the double cell wall layer of two adjacent tracheids rather than within the middle lamella itself (Fig. 5a,b). Hence, one of the tracheids retained the middle lamella after it had separated from its adjacent partner (Fig. 5d, e). This effect was apparent in specimens exposed to UV and/or visible light (Fig. 5a–d) and could be observed in both secondary and back-scattered electron images, although in general, checking was easier to see in back-scattered images (compare Fig 5d, f). SEM samples under filters were not extensively colonized by micro-organisms, possibly because they were exposed outdoors during the late summer when Vancouver receives less rain than at other times of the year.

Discussion

Our results strongly suggest that photodegradation increases the tendency of lodgepole pine wood to check when it is exposed outdoors to the weather. Decking samples exposed outdoors for 36 weeks under a filter that transmitted all wavelengths in the solar spectrum developed three times as many visible checks as the control samples exposed under a filter that blocked UV and visible radiation. The checks that developed at the surface of samples exposed to the full solar spectrum were also larger than those found in samples exposed under filters that blocked UV and visible light. This was reflected by the lower length to width ratio of such checks and the greater total length, width and area of checks in samples exposed to the full solar spectrum compared to those in the controls. This contrast in the number and dimensions of checks in samples exposed to the full solar spectrum and those in samples that were shielded from UV and visible radiation provides compelling evidence that checking of wood is increased by photodegradation of the wood surface. Further support for this assertion was our finding that samples, which showed less surface chemical degradation as a result of being exposed under filters that progressively blocked photochemically active radiation developed less checking than samples exposed to the full solar spectrum. In particular, we noted

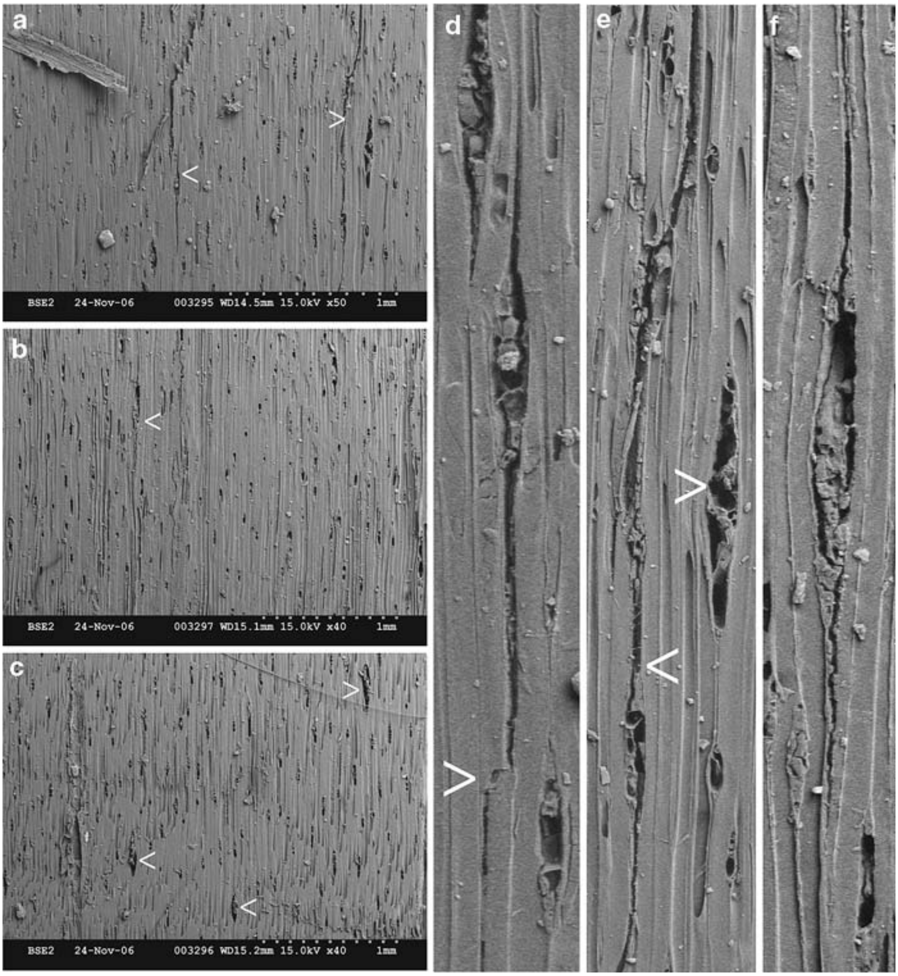

Fig. 4 Low-power scanning electron photomicrographs of tangential longitudinal surfaces of lodgepole pine samples exposed to the weather for 50 days under filters, which blocked selected regions of the solar spectrum. **a** Sample exposed to the full solar spectrum under a filter; **b** sample exposed under a filter, which blocked UVB radiation; **c** unexposed control containing microscopic voids (*arrowed*) caused by damage to rays during surface preparation; **d** visible check on the *left hand side* of **a**; **e** visible check on the *right hand side* of **a** (*arrowed left*) and a ray micro-check (*arrowed right*); **f** visible check on the *left hand side* of **b**

that shielding samples from UVB radiation (260–345 nm), which is the most energetic component of the solar spectrum at the earth's surface (Neale 1999), significantly reduced the numbers and dimensions of checks that developed in the samples during the exposure trial. A similar, but less pronounced, effect occurred as a result of shielding samples from UVA and visible radiation. This relationship between the wavelength of the light that samples were exposed to and severity of checking is similar to that found by Derbyshire and Miller (1981) for tensile strength losses of thin wood veneers exposed outdoors to filtered light. They

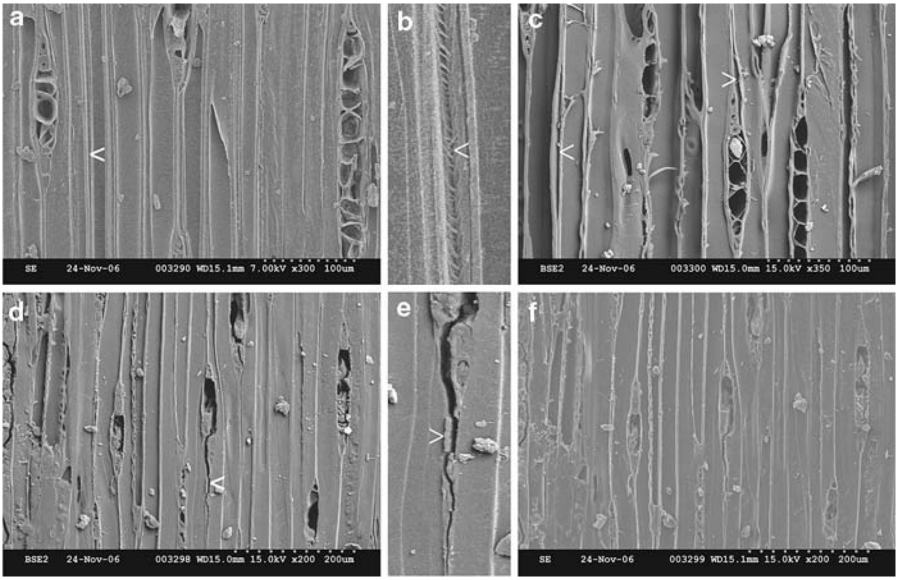

Fig. 5 High-power scanning electron photomicrographs of tangential longitudinal surfaces of lodgepole pine samples exposed to the weather for 50 days under filters, which blocked selected regions of the solar spectrum. **a** Sample exposed to the full solar spectrum under a filter; **b** enlargement of *arrowed part* of **a** showing separation of tracheids close to the middle lamella; **c** sample exposed under a filter that blocked UV radiation; **d** sample exposed under a filter, which blocked UVB radiation; **e** enlargement of *arrowed part* of **d** showing that adjacent tracheids separated at the interface between the middle lamella and, in this case, parts of the middle lamella are retained by the two adjoining tracheids; **f** sample exposed under a filter, which blocked UVB radiation as in **d**, but imaged using secondary rather than back-scattered electrons

concluded that wood exposed to visible light degraded at half the rate of samples exposed to the full solar spectrum. Our findings generally accord with their conclusion, since check numbers and total length and area of checking in samples exposed under a filter that was designed to block UV radiation and transmit only visible and infrared radiation (Filter 3) were approximately half those found in samples exposed to the full solar spectrum. Small levels of UV radiation, however, were detected under filter 3, if it is assumed that the levels received by samples exposed under filters 4 and 5 represent background radiation. Thus, it is possible that UV radiation contributed to some of the surface degradation and checking of samples exposed under filter 3. In contrast, checking in samples exposed under a filter that only transmitted infrared radiation was similar to that in samples exposed under a filter that blocked all wavelengths. Therefore, we conclude that UV, and to a lesser extent visible light, are the components of the solar spectrum that increase the tendency of wood samples to check during exterior exposure.

The relationship between surface degradation of samples and checking was subsequently examined to understand why checks were more numerous and larger in samples exposed to UV and visible radiation. Infrared spectroscopy suggested that surface degradation was more pronounced in samples exposed under filters that transmitted UV and visible light. In these samples, there were greater decreases in the absorption at a wave number of 1505 cm^{-1} in infrared spectra of weathered wood surfaces. This indicates that degradation of lignin was more pronounced in the samples exposed to UV and/or visible light, which were also the ones that developed greater checking during the weathering trial. Lignin reaches its highest concentration in the middle lamella that bonds adjacent tracheid walls together and it is particularly susceptible to photodegradation (Wood and Goring 1971; Kringstad and Lin 1970). Accordingly, scanning electron microscopy of samples exposed under the different filters revealed that this cell wall layer was degraded by exposure to UV and to a lesser extent visible light. This degradation manifested itself mainly as separation of tracheids at the interface between the middle lamella and the primary and secondary wall layers, which allowed micro-checks that developed at the margins of rays to propagate longitudinally and coalesce with other ray micro-checks forming checks that were visible to the naked eye. Occasionally, the micro-checks propagated via transverse cell wall micro-checks, which allowed them to develop more easily into visible checks. Transverse micro-checks were only observed in samples exposed to UV radiation and this may explain why checking was more pronounced in such samples. Overall, these findings point to a clear link between changes in cell wall micro-structure as a result of photodegradation of wood's molecular components and the development of visible checks in wood exposed outdoors. Checks may still develop in the absence of photodegradation, as was noted here, but they did not greatly increase in number or dimensions over time. This observation suggests that the progressive photodegradation of wood allows checks to increase in numbers and dimensions beyond that which would occur if such degradation were absent.

Accordingly, our findings suggest that treatments designed to prevent wood exposed outdoors from checking should attempt to restrict the surface photodegradation of wood. Traditionally, many of these treatments have simply reduced checking by minimizing moisture gradients and the magnitude of stresses that develop at wood surfaces (Borgin and Corbett 1970). Surface water repellent treatments and wood preservatives that contain hydrophobes such as oils or waxes work in this way and they are effective, especially in the short term, in preventing the surface checking of wood (Levi et al. 1970; Zahora 1992; Evans et al. 2003). Many water-repellent surface finishes for wood are now starting to incorporate photostabilizers to protect wood from photodegradation, but such compounds are generally not added to wood preservatives. Our findings suggest that the ability of wood preservatives to protect wood from checking could be improved further if they contained compounds that could prevent the photodegradation of lignin, as well as hydrophobic additives to increase the water repellency of the treated wood. In accord with this suggestion, it has been observed that wood preservatives that contain hydrophobic additives and chromium VI, which is particularly effective at photostabilizing lignin, are also very good at preventing wood exposed outdoors from checking (Zahora 1992; Evans et al. 2003). Chromium VI is toxic and cannot be used in many countries for wood protection, and therefore hydrophobic wood preservatives designed to prevent the surface checking of wood would need to incorporate other photostabilizing compounds, for example, UV absorbers or reflectors. Our results suggest that these additives should strongly absorb or reflect short-wavelength (UVB) radiation, but their effects should also extend into the visible region of the spectrum. The absorption of UV light by UV absorbers shows a Gaussian distribution (Hayoz et al. 2003) and therefore a single compound is unlikely to be able to absorb all of the wavelengths capable of delignifying the wood surface. It is more likely that combinations of UV-absorbing compounds, reflectors and pigments in a hydrophobic medium will be able to provide the protection that is needed. By itself, a chemical treatment may not be completely effective at preventing the surface checking of wood exposed outdoors. Careful selection of the wood used to make decking boards is also important. For example, previous research has shown that quarter-sawn boards check less than flat-sawn boards (Sandberg 1999), and some species also check less than others (Yata 2001). Hence, the development of wood products such as decking boards that are less susceptible to surface checking is likely to involve a holistic approach involving careful selection and preparation of wood raw material as well as a chemical treatment that can photostabilize the wood surface and make the wood more water-repellent.

Conclusions

Exposure to solar radiation increases the severity of checking that develops when wood is exposed outdoors. Ultraviolet light (particularly UVB) and, to a lesser extent, visible light are responsible for this effect. These components of the solar spectrum degrade lignin and weaken the wood cell wall, particularly the interface between tracheids. This allows micro-checks that initially form in the rays to propagate longitudinally and coalesce with similar checks creating visible checks. Hence, we conclude that there is a link between changes in cell micro-structure as a result of photodegradation of lignin and the development of visible checks in wood. Accordingly, protective treatments such as water-repellents and wood preservatives should contain photoprotective additives, in addition to hydrophobes (waxes and oils), to increase their ability to restrict the checking of wood exposed to the weather.

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