Optimizing the Design of Mass Timber in Exterior Applications

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EXECUTIVE SUMMARY

The objective of this document is to assist architects, engineers and other specifiers in making decisions around design and maintenance of mass timber on the outside of buildings, focussing on glulam but also relevant to timbers, parallel strand lumber and cross laminated timber. With appropriate durability by design, durability by nature, durability by treatment and weather protection by coating mass timber can be durable and look good for the design life of the building. It will help to learn as much as possible about the properties of the material you are using before starting the design phase.

Critical Considerations in Design for Durability:

- Design the structure as much as possible to minimize exposure of wood components to rain, ground contact and masonry or concrete that will stay damp. Remember the 4Ds - Deflection, Drainage, Drying and Durable materials.
- Determine the exposure of each component – fully exposed, semi-exposed, or protected.
- Choose the appropriate natural durability or preservative treatment option for the anticipated decay and termite hazard allowing a factor of safety.
- Preservative-treated components need to be special ordered and may have limited availability.
- Take into account any preservative treatment applied when choosing the appropriate coating.
- Design any component with potential to fail prematurely to be easily replaced.

Critical Considerations in Design for Appearance:

- Protect material from rain during transport, storage and, as far as possible, during construction.
- Avoid iron stain using corrosion-resistant fasteners and not letting iron particles get near wood.
- Coatings are not preservatives. They are only designed to maintain the surface appearance.
- Design as much as possible to minimize exposure of wood to UV/visible light and rain.
- Determine the exposure of each component – fully exposed, semi-exposed, or protected
- Choose the appropriate coating for the desired appearance and performance in the anticipated exposure, taking into account the characteristics of the underlying material.
- Ask suppliers for information and choose coatings with a high concentration of organic and inorganic UV/visible light protection and an optimum compromise between liquid water exclusion and water vapour permeability.
- The best performance will come from a factory-applied coating. At minimum a surface sealer is recommended, even where the material is to end up in a protected environment.

Critical Considerations for Maintenance:

- Building owners should inspect exterior components every year and have them professionally inspected ever 5 years.
- Re-finish coatings on a regular basis, rather than after deterioration has been noticed.
- Any localized deterioration can be remedially treated using diffusible preservative and repaired.

1 INTRODUCTION

Modern Mass Timber Construction includes building systems otherwise known as post-and-beam, or heavy-timber, and cross laminated timber (CLT). Typical components include solid sawn timbers, glue-laminated timbers (glulam), parallel strand lumber (PSL) laminated veneer lumber (LVL) laminated strand (LSL), and CLT. Heavy-timber post and beam with infill walls of various materials is one of the oldest construction systems known to man. Historic examples still standing range from Europe through Asia to the long-houses of the Pacific Coastal first nations (Figure 1). Ancient temples in Japan and China dating back thousands of years are basically heavy timber construction with some components semi-exposed to the weather (Figure 2). Heavy-timber-frame warehouses with masonry walls dating back 100 years or more are still serviceable and sought-after as residences or office buildings in cities like Toronto, Montreal and Vancouver (Koo 2013). Besides their historic value, these old warehouses offer visually impressive wood structures, open plan floors and resultant flexibility of use and repurposing. Building on this legacy, modern mass timber construction is becoming increasingly popular in parts of Canada and the USA for non-residential construction, recreational properties and even multi-unit residential buildings. Owners and architects typically see a need to express these structural materials, particularly glulam, on the exterior of the building where they are at semi-exposed to the elements (Figure 3). In addition wood components are being increasingly used to soften the exterior look of non-wood buildings and make them more appealing (Figure 4). They are anticipated to remain structurally sound and visually appealing for the service life. However, putting wood outside creates a risk of deterioration that needs to be managed. Similar to wood used for landscaping, the major challenges to wood in these situations are decay, weathering and black-stain fungi. This document provides assistance to architects and specifiers in making the right decisions to maximize the durability and minimize maintenance requirements for glulam and other mass timber on the outside of residential and non-residential buildings. It focusses on general principles, rather than providing detailed recommendations. This is primarily focussed on a Canadian and secondarily on a North American audience.

Figure 1. Pacific coast first nations' longhouses with projecting cedar timbers (photo taken at the BC Museum of Anthropology at the University of British Columbia in Vancouver)

Figure 2. Ancient Chinese temple with exposed timbers

Figure 3. Rot in end of glulam beam with a wood end cap (Diagonal cut let in water and end-cap stopped end grain from drying out.)

Figure 4. Exterior glulam and soffit on modern post and beam building under overhang – well protected.

2 DURABILITY ISSUES ARISING FROM THE USE OF MASS TIMBER

Throughout this document the terms fully-exposed, semi-exposed and protected are used to delineate degrees of protection from sun and from rain.

- Fully-exposed: components or parts of them will be impacted by high-angle sun (over 45°) and by direct rain even in low-wind conditions. Typical uses would be uncovered bridge timbers.
- Semi-exposed: components of parts of them will only be impacted by low angle sun and by wind-driven rain. Typical uses would be columns and beams supporting glass canopies or roofs on the exterior of buildings.
- Protected: no part of the component is ever likely to be impacted by sun or by rain. Typical uses would be joists supporting glass canopies or roofs on the exterior of buildings.

General durability issues and solutions are well covered elsewhere and will not be repeated here. Issues specific to mass timber mainly arise from:

- Greater likelihood of pathways for moisture and consequently potential decay deep into the wood components due to:
    - Large areas of absorptive end-grain fully-exposed on tops of verticals and ends of horizontals
    - Combination of this end-grain with water traps at joints which are critical locations in structures
    - The potential for checking in sawn timbers and, to a lesser extent, in glulam
    - The potential for delamination of composites due to moisture stresses
    - Interconnecting voids between the strands in PSL
    - Gaps between boards in CLT
    - Slower drying rates once wood members have become wet due to:
        - Larger dimensions
        - Mass of wood at joints
        - Built-up members

3 HANDLING AND INSTALLATION OF EXTERIOR MASS TIMBER COMPONENTS

Mass-timber components, except those designed for fully-exposed exterior uses, should be protected from rain during transport, storage and installation. Some materials are more sensitive to wetting than others particularly materials composed of veneer or strands with interconnecting voids. Some materials are less sensitive particularly those composed of face glued, edge glued and end-glued solid wood laminations. A sealer may be applied by the manufacturer but this is designed to protect only against incidental and occasional wetting. The sealer should be compatible with the intended final coating and should not have to be removed prior to application of the final coating. Alternatively, one or two coats of an exterior semi-transparent coating may be applied by the manufacturer but this will not protect against full rain exposure without one or two further coats applied in situ. The primary protection will likely be a wrapping material which should be inspected and repaired immediately in case of puncture. If it is believed that moisture had got in, the wrapping should be removed and the component should be forced-air dried under cover. If further exterior storage is anticipated, the component should be rewrapped. More detail on moisture protection during construction is provided elsewhere (CWC 2004; Wang 2015). Mass-timber components should also be protected against staining due by iron dissolving from metal particles. Iron particles may come from machinery or from on-site reworking of metal components. If these iron particles get onto the wood, they may not be noticed until the surface gets wet and the iron dissolves and iron stain appears. Iron stain will be worst on uncoated wood, but it can also occur on wood under semi-transparent coatings when these are designed to be permeable to permit drying.

In order to check the condition of mass timber components when they arrive at the job site and make informed decisions on handling and installation, a hand-held moisture meter is an essential tool. Considering that we are dealing with appearance wood elements, a capacitance-based moisture meter is recommended because electrical resistance type moisture meters require hammering pins into the wood surface.

4 DURABILITY AND MAINTENANCE REDUCTION STRATEGIES

Methods to maximise wood durability and minimize maintenance requirements can be broken down into five major strategies:

- Durability by Design
- Durability by Nature
- Durability by Treatment
- UV/Visible Light Protection by Design (and possibly treatment)
- Maintaining Appearance by Coating

Durability by Design: Designing structures to minimize the exposure of wood components to moisture and UV should be the primary strategy to maximise durability and minimize maintenance requirements. Wood, even outdoors, does not decay unless it is fully-exposed to rain or other sources of liquid water for long periods of time. As with building enclosures, the 4Ds principle of managing precipitation – **deflection, drainage, drying** and **durable material** - can also be applied to exterior mass timber components.

> **Deflection** here means keeping as much rain as possible from ever touching the wood, particularly the more absorptive end-grain. When designing a structure, think like a falling raindrop and make sure you can't see the wood, particularly end grain. Avoid exposing the top of vertical wood columns and avoid beams projecting beyond the roof line (Figures 3,10).
>
> In priority order, use:
>
> 1. Overhangs,
> 2. Flashing, and
> 3. Drip edges.

Overhangs may take the form of a traditional pitched roof in recreational properties (Figure 4), however, in modern mass timber construction overhangs are typically made from glass to maintain the visual impact of the mass timber (Figure 5). Most importantly, designers need to consider wind-driven rain when determining the width of overhang. Too often overhangs are just too small to provide adequate protection to ends (Figure 6) and sides (Figure 7). In areas with high winds and/or small raindrop sizes, wind-driven rain can move horizontally or even upwards. As a general guide, wood components should not be installed lower and closer to the edge of an overhang than an imaginary line drawn at 60 degrees from vertical, as shown in Figure 8, unless they are pressure preservative treated or made of naturally durable species. Ends of beams should be cut at an angle of 45° or more such that the end-grain effectively faces the ground (Figures 5, 9). Take a look at newly installed beams with square ends below an inadequate overhang on a sunny day and you will see a diagonal shadow line. Take a look at older beams in the same situation and you will see a diagonal weathering line. Take a tip from nature and remove the part that will get weathered due to exposure to wind-driven rain (Figure 6). Cutting the other way so that the end-grain effectively faces up (or slanting the top of columns Figure 10) does not promote run-off and exposes even more end-grain to absorption of rain.

Figure 5. Exterior glulam on modern steel and concrete building protected by glass canopy, after 5 years without refinishing – well protected.

Figure 6. Inadequate overhang to protect beam from wind-driven rain leading to staining and coating failure on glulam ends

Figure 7. Inadequate overhang leading to coating failure on glulam side

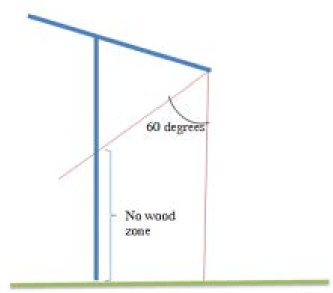

Figure 8. Wood components should not be installed less than 60 degrees from a vertical line

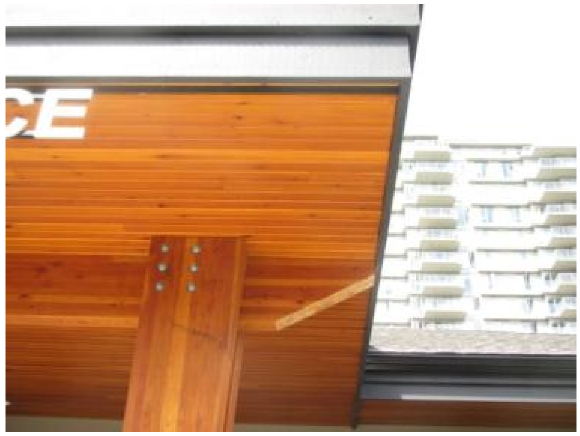

Figure 9. End of beams cut at an angle and wood soffit – well protected

Figure 10. Rot (growing grass) in top of creosoted timber column cut at an angle

Top-flashing (Figure 11) and end-flashing (Figure 12) are commonly used to protect beams projecting to or beyond the roof line. However, top flashing has extremely limited efficacy and poorly designed end caps can trap water and promote decay (Figure 3). Any defects in jointing or fastening metal flashing can create cupping and/or permit water penetration. Moisture can move by capillarity between the flashing and the wood if it is not gapped away from the wood at the top, sides and ends. Water simply flows down the side of the beam if the flashing does not have drip edges (Figure 11). Downward facing cracks can occur in the unprotected sides of beams permitting uptake of water and ingress of decay fungi. If, despite advice to the contrary above, the native west coast style of beams projecting beyond the roof line is desired, it can make sense to make the beam ends detachable and replaceable, with concealed connections. They can also be made from naturally durable or preservative treated wood. This will prevent decay in the exterior part of the beam progressing close to or through the building enclosure necessitating much higher repair costs.

Figure 11. Glulam with top flashing but still stained on sides

Figure 12. Glulam with end flashing and wood soffit – well protected

Also keep the base of the wood components well above ground to avoid splash-back and potential for direct soil contact as ground level inevitably rises (Figure 13). Never put wood components in direct contact with concrete less than 150mm above finished soil level because water wicks up concrete (Figure 14). Always slope concrete away from wood components.

If used to support a concrete slab from underneath, or in combination with concrete as a composite structural member, and the concrete will be exposed to rain, mass timber components should be separated from concrete by a durable water-proof membrane or should be preservative treated.

Figure 13. Rot in column base where soil level has risen.

Figure 14. Rot in column base in direct contact with concrete.

Drainage means avoiding water traps and encouraging water to run off, or drain between, components. Avoid creating anything like a bowl effect that will hold water. Eliminate strictly horizontal surfaces and slope surfaces away from the centre of the structure. Avoid using parallel beams appressed against each other creating a capillary to hold water (Figure 15) unless the beams are preservative treated. Crossing beams can create a similar but lesser capillary space (Figure 16). Spacing components to eliminate capillaries and encourage draining needs to be done with a view to ensuring effective load transfer between those components. Ensure adequate gaps between flashing, glass or other materials and the wood surface to prevent capillarity. Avoid using connectors that encase the wood components: metal boots to hold the base of wood columns are the worst example (Figure 17). If part of the structure will tend to collect water, make sure it does not shed that water onto another part of the structure. Create drip grooves on the underside of horizontals and the bottom of verticals to prevent water from flowing back underneath wicking up the end grain and causing growth of black-stain fungi and coating failure (Figure 18). Think like a raindrop and make sure it has as rapid a path as possible to the ground. End caps should be gapped away from the wood to permit drainage and drying.

Figure 15. Moisture trapped in nail-laminated timber deck and causing damage (courtesy of SMT Research)

Figure 16. Crossing beams trapping water by capillarity showing up as algal stain

Figure 17. Metal boot around the base of a column is like putting wood in a bucket of water

Figure 18. Column base without drip edge showing black-stain fungus and coating failure

Drying out after wetting will reduce the time the wood spends at suitable moisture contents for decay and growth of black-stain fungi. Many of the above measures for drainage will also encourage drying, as will any design features that promote airflow over and through the structure. End-grain dries more rapidly than side grain and is best left uncovered unless fully-exposed to rain. Bear in mind that exterior components have no heat from the building to assist in drying. Maximizing sun exposure will certainly aid drying but will adversely affect coating performance. Shady locations reduce drying and may encourage the growth of moss and algae which retain water after rain events (Figures 3, 16). Some climates are clearly more conducive to drying than others. Drying is difficult to do well in most climates. It is better to focus on keeping the wood from getting wet in the first place.

The risk of degradation can be reduced by taking another look at the structure once it is built and providing additional protection by design where necessary before deterioration begins. Additional information on durability by design is provided in AITC 104 (American Institute of Timber Construction 2003).

Durable materials are dealt with in the next two sections.

Durability by Nature: This means taking advantage of the natural durability of the heartwood of certain species, particularly western red cedar, eastern white cedar and yellow cypress (cedar). The heartwood of these three species all has similar decay resistance; the sapwood of all three is non-durable, just like other wood species. Western red cedar was the species of choice for the longhouses of first nations on the BC Coast for thousands of years (Figure 1). Eastern white cedar is not commonly used in the form of heavy timbers because it is only available in limited volumes and dimensions. Yellow cypress is considerably stronger than the other two and more suitable for uses where strength is critical, and using larger dimensions to compensate is not appropriate. It also has the best termite resistance among these three. Glulam made from yellow cypress has been used in several major infrastructure projects, such as bridges, where the owner or specifier did not want to use preservative treated wood (Figure 19). If, despite advice to the contrary above, the native west coast style of beams projecting beyond the roof line is desired, it can make sense to make the beam ends from western red cedar or yellow cypress and make them replaceable.

(Photo supplied by WEST 8 + DTAH, courtesy of the Wood *WORKS!* Awards Program)

Figure 19. Wavedeck in Toronto using yellow cedar glulam

Douglas-fir heartwood has some limited natural durability, much less than the cedars, and it has a much wider sapwood so it is more difficult to make beams out of 100% heartwood. In other than low-decay hazard climates (Scheffer Index values of less than 35 – see map, Figure 20, Morris and Wang 2008) and with considerable protection by design, Douglas-fir heartwood does not have sufficient natural durability for outdoor exposure to provide the service life desired from most massive timber construction projects.

Naturally durable woods can be allowed to weather to a natural grey patina (Figure 21) but this can be difficult to achieve rapidly and in a uniform way. UV and visible light delignify wood and expose cellulose and, with adequate moisture supply, promote the growth of fungi and algae that are pigmented for UV resistance. The grey colour is the combination silvery delignified cellulose and black-staining fungi and algae. Slight differences in sun and rain exposure, plus rainfall runoff from above can change the silver/black ratio creating a dark and light grey mottled or streaked effect. Iron stain often caused by inadequately corrosion-protected fasteners can also cause dark grey or black streaks when it reacts with phenolic compounds, particularly in naturally durable woods. Zinc from galvanized fasteners can cause white streaks. There are a number of weathering stains that can provide a more rapid and uniform grey colour.

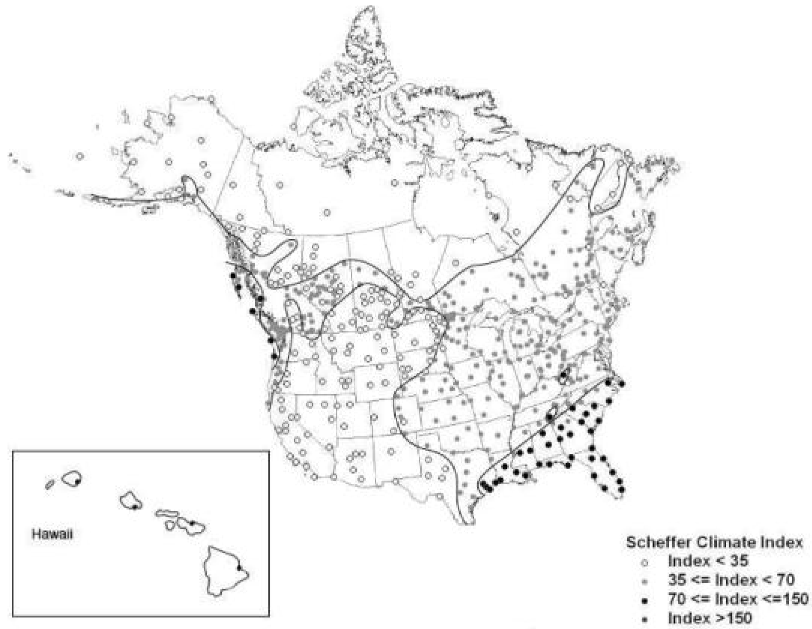

Figure 20. Decay hazard map of North America based on Scheffer Climate Index using climate data from 1971-2000

Figure 21. Weathered patina on naturally durable wood

Durability by Treatment: There may be situations where some degree of exposure to water and UV is unavoidable or desirable for a certain look. Where naturally durable woods may not provide adequate performance or will not be cost effective, then less durable woods will need to be preservative treated to provide the desired service life. To minimize costs and any potential for adverse environmental impact during or at the end of the service life, the choice of preservative and degree of treatment should be matched to the anticipated decay and termite hazard. This will be affected by the:

- climate (temperature and rainfall),
- local micro-climate, and
- design of the structure, particularly the degree of exposure to rainfall or water trapping.

Expert advice is usually needed on appropriate preservative treatments but some general guidance is provided here. Options for preservatives for pressure treatment of wood components in buildings for decay and termite resistance include:

- Robust copper/organic co-biocide
    - These are suitable for use in ground contact or above ground and generally include alkaline copper quaternary (ACQ), copper azole (CA) and micronized copper azole (MCA). The copper provides additional UV/visible light resistance so components treated with these preservatives can be left uncoated and allowed to weather to a grey green, or they can be coated. Micronized copper-based preservatives, such as MCA, are also now available tinted to a mid-brown with iron oxide pigments. Application of a high-quality transparent or semi-transparent coating will assist in retention of the pigment on the surface.
- Carbon-based (copper free, based on organic chemicals)
    - These should only be used on wood products ABOVE ground. These provide no UV/visible light resistance and must be combined with UV inhibitors or a UV/visible light-resistant coating.
- Sodium borate-based preservatives
    - These are primarily used on wood products which are protected from weather inside a building because they will leach out of wood when continuously exposed to liquid water. For use on the exterior of well-designed structures, a paint or 3-coat UV/visible light-resistant film forming coating is typically sufficient protection against leaching.

The above treatments are applied by pressure processes. However, pressure treatment provides only limited initial penetration into the wood leaving much of the cross section unpenetrated, particularly in larger members. Sodium borate will diffuse much deeper into the wood after the end of the pressure process.

All of these preservatives are water-borne so they will cause swelling during treatment and shrinkage upon drying. This speeds up the checking of large dimension wood components and causes stresses in composites such as glulam and CLT. It is not always practical to pressure treat larger timber products. Such composites are best manufactured from treated lamina but care must be taken to ensure good penetration in the lamina and compatibility between the preservative and the glue. The singular exception to this rule is PSL which treats very well due to the interstitial voids and shows only limited dimension change with careful preservative treatment processing.

Another option suitable for pre-treatment of components for use on the exterior of well-designed structures is a surface applied penetrating treatment using carbon-based preservatives (Ross 2011). Again this needs to be protected with a coating to prevent leaching.

Finally, there are diffusible surface-applied and depot (rods placed into drilled holes) treatments based on sodium borate (web page reference). As with borate pressure treatments, these are only suitable for use in buildings where the wood is protected from direct contact with liquid water, by design or by a film-forming coating. The surface-applied treatments included here are primarily those composed of borates with glycols to improve penetration into dry wood. They do not penetrate as deeply as the surface-applied penetrating treatments discussed above. The major advantage to this type of treatment is that they can be applied during construction, potentially to all surfaces, but also just in vulnerable locations. They will not penetrate mass timber components which are already coated with a factory-applied sealant. Depot treatments consist of borate and copper/borate rods which dissolve in water and diffuse within the wood.

Depot treatments are typically applied only in locations anticipated to be at least semi-exposed to moisture in service. The visual impact of capped holes and the cost of this type of treatment typically preclude full-length application except in emergency remedial treatment. The key to placing depot treatments is predicting where moisture will enter the wood so that the water will pick up borate and transport it to where it is needed. End grain and bolt holes (Figure 22) are obvious locations of moisture entry, existing checks are another, particularly checks in horizontal surfaces and the base of vertical checks. Later checking in service is more difficult to predict and is best dealt with by combining depot treatment with surface-applied treatment. The surface-applied treatment should have sufficient borate to move into newly developed checks and protect them.

The risk of degradation can be reduced by taking another look at the structure once it is built and providing additional in-situ treatment where necessary before deterioration begins.

Figure 22. Borate rod placement between end grain and bolt holes

UV/Visible Light Protection by Design: With both natural wood surfaces and coatings the biggest challenges are UV/visible light, rainfall and fungi, particularly the black-stain fungi that grow in and under coatings. Consequently, any efforts to reduce exposure to these elements will considerably increase the maintenance interval for re-finishing.

South walls clearly have the most exposure to light (in the Northern hemisphere) with West walls typically coming in a distant second. Focussing use of exterior wood components on North or East walls can go a long way to minimizing photo degradation but East walls may have other issues. Wind-driven rain may be directional (e.g. mostly from the East in Vancouver BC, from the south in Seattle WA). Understanding site-specific climate loads can play an important role in determining both the level of impacts and the nature of the impacts.

Many of the approaches to rain protection will also help reduce UV exposure but the same considerations are required as for durability protection by design. Glass canopies work very well in cutting down rain and UV exposure while maintaining the visual impact of the mass timber components (Figure 5). Soffits (cladding on the underside of overhangs) are a perfect way to accent with wood while virtually eliminating exposure to UV/visible light and rainfall (Figures 9, 12).

Maintaining Appearance by Coating: The difference between the functions of a coating and wood preservative need to be clearly understood. Coatings protect the surface appearance of the wood, while preservatives prevent decay and termite attack. Coatings will certainly reduce the surface uptake of water during rain events but they are rarely 100% continuous over the entire surface of every wood component in a structure, particularly if applied after the structure has been built. The parts that tend to be left uncoated under these circumstances are typically exactly those parts that are most vulnerable to moisture uptake, such as the end grain butted up against another component in joints.

Factory finishing is the ideal approach to ensure full coating coverage, particularly on the end-grain, and optimum coating adhesion. Oxidation and light exposure ruin the ability of wood to hold a coating. Therefore, wood should always be coated on a fresh surface – recently planed or lightly sanded (e.g., 85 Grit). Factory finishing means more than just one coat of a sealant. It means at least one priming coat and one top coat of a product designed for long-term performance in exterior uses. One or more additional top-coats can then be applied once any on-site fabrication has been done, i.e. the structure is complete and any moisture taken up during construction has dried out. Primer and top coats may need to be applied to cuts, daps or other site reworking that removes the original surface. Even this approach rarely provides 100% protection against precipitation due to the durability issues with mass timber components described above. Coatings can reduce the rate of wetting and drying of mass timber components but no coatings are capable of resisting the resulting stresses such that they can completely prevent checking. Once moisture has got into the wood, the coating may actually <u>slow</u> the rate of drying and thus promote decay. Typically coatings that are best at keeping water out also stop the wood from drying and coatings that are best at drying, don't keep liquid water out. Therefore, the best performing coatings are good at both keeping liquid water out and allowing water vapour to escape. Always ask the coating suppliers for such information to make informed decisions. The upshot is that the <u>need for durability must be a separate consideration from the need for coating, since coating primarily provides aesthetic appearance, not long-term wood durability.</u> However, there is no hard and fast line between coatings and preservatives. Several of the wood preservative treatments described above need to be used in combination with a coating. Some preservatives have trans-iron oxide pigments added which provide UV/visible light protection. If a weathered look (Figure 21) is tolerable or desirable, weathering stains can provide a more rapid and uniform grey colour.

Specifiers face a dilemma and a bewildering array of options in their choice of coatings. The dilemma is that the longest-life least-maintenance coatings are high-quality opaque paints that completely hide the colour and texture of the wood, negating one of the reasons for using wood in the first place. Any coatings that let people see the wood also let the sun "see" the wood. Transparent and semi-transparent coatings designed for exterior uses typically contain organic UV absorbers and light stabilizers that are pretty good in the short term (one or two years) at dealing with the light wavelengths most damaging to wood, the ones we can't see. However, they eventually break down and by definition, they cannot block visible light wavelengths which also cause damage to wood surfaces, albeit more slowly. Mixtures of red, yellow and black trans iron oxide (or carbon black) pigments provide semi-natural wood colours while blocking some of the visible light (Figure 5). These have the advantage of not breaking down with UV. Other light-stable non-coloured inorganic compounds may provide some visible light protection but they can also make the coating milky-looking. Due to the different functions of these organic and inorganic ingredients, when acquiring coating products, always consult with the suppliers to achieve the best protection against UV and visible light. Research is underway at FPInnovations to develop pre-treatments to improve the resistance of the underlying wood to visible light.

The bewildering array of options in semi-transparent coatings, each coating with its claims of special ingredients and better performance than the competition, makes coating choice very difficult. Most of the time, you get what you pay for. If it is cheap, then it probably does not contain the best performing resins and additives. Unfortunately, as of 2014, even good experiences with certain brands and long term tests of coatings in Canada are of little value since the formulations have changed in response to new VOC regulations. This is not readily apparent from reading the label. This means that performance claims are not necessarily based on hard data. Accelerated UV tests do not necessarily predict long term performance because they typically exclude biological effects. Where possible obtain objective independent field test data on current formulations before choosing a coating. Your wood material supplier may be able to recommend better-performing coatings.

Hierarchy of Glulam In Order of Increasing Durability

Wood Species	Preservative Treatment[1]	Protection by Design	Increased Inspection	Exposure		
				Above Ground		Ground Contact
				Overhang[2]	No overhang	
SPF, hem-fir, D-fir	None	Coating	No	✓	X	X
D-fir (No sapwood)	None	Coating, flashing	Yes	✓	✓[3]	X
All	Borate/glycol plus boron rods	Coating flashing	Yes	✓	✓	X
All	Surface-applied penetrating[4]	Coating flashing	Yes	✓	✓	X
Sapwood of red pine, amabilis fir	Pressure-treated[4] lamina, borate preservative	Coating flashing	No	✓	✓	X
Sapwood of red pine, amabilis fir	Pressure-treated[4] lamina, Carbon-based preservative	Coating flashing	No	✓	✓	X
Western red cedar, yellow cypress	None	Coating flashing	No	✓	✓	X
Sapwood of red pine, amabilis fir	Pressure-treated[4] lamina, Copper-based preservative	No	No	✓	✓	✓

1. PSL with any of the above preservative treatments will typically perform better than glulam with the same treatment due to the ability of the preservative to penetrate the interstitial voids.
2. Complete protection from moisture sources including damp concrete, masonry, wind-driven rain etc.
3. Dry climates only. Scheffer Index below 35 (Morris and Wang 2008).
4. Limited availability

5 MAINTENANCE OF EXTERIOR MASS TIMBER COMPONENTS

The maintenance requirements for these components can be reduced by taking another look at the structure once it is built and providing additional protection by design and in-situ treatment (see above) where necessary before deterioration begins.

Inspection: Exterior mass timber components should be inspected by the building owner every year and professionally every 5 years. The building owner should look for cracking, flaking or thinning of coatings, discolouration of the underlying wood and areas of softness or collapse that could indicate decay. Pay particular attention to end-grain, joints, upper horizontal surfaces, locations, which may receive water drips and places of contact with concrete and other moisture retentive building materials. Where there is any doubt about the structural capacity of the assembly, engineers should be called in to do the inspection. More detail on inspection is provided elsewhere (HPO 2007).

Coating Maintenance: Re-finishing should be done on a regular basis, rather than after deterioration has been noticed. Once the coating has failed to the point that the underlying wood has suffered photo degradation (bleaching) or black-stain (greying) fungus growth (Figures 6 and 16), re-coating will never achieve the same degree of adhesion and service life as a coating on fresh wood. The re-coating interval should be based on the manufacturers' recommendations, the climate and the degree of exposure. Typically transparent and semi-transparent coatings last from 6 months to 2 years. High solids opaque coatings can last 3 to 5 years and paints can last 6 to 10 years before refinishing.

Repair and Remedial Treatment: Exterior mass timber components are often designed more for decorative purposes than an integral part of the structure, consequently they are often over-engineered. This means that some decay can be tolerated if it is repaired and remedially treated. Repair is typically done with epoxy resin systems. Remedial treatment can use the same surface-applied and depot-type borate treatments as discussed above for new construction where a low decay hazard is anticipated.

6 RECOMMENDATIONS

- Design the structure as much as possible to minimize exposure of wood components to rain (including wind-driven rain), any ground contact, and UV/visible light.
- Carefully evaluate the degree of exposure of mass timber components in the final design before choosing durability and coating options.
- Choose the appropriate natural durability or preservative treatment option for the anticipated decay and termite hazard allowing a factor of safety.
- Wherever possible obtain material factory coated with at least one priming coat and one top coat of a product designed for long-term performance in exterior use.
- Choose the appropriate coating for the desired appearance and performance in the anticipated exposure, taking into account the characteristics of the underlying material and any treatment applied.
- Even if the material has been preservative treated and coated by the supplier, protect it from rain during transport, storage and, as far as possible, during construction.

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