CWPA Proceedings, 205, pp 18-29

ENGINEERED WOOD STRUCTURES AND SUSTAINABLE CONSTRUCTION PRACTICES

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Summary

Sustainable design of buildings has drawn many traditional designers into a relatively new field in a very short period of time. There is a lack of technical information for designers when they need to make informed choices for the materials they specify. Preserved wood is no exception. Concerns such as recycling of preservative treated wood waste, reuse of treated material, avoiding chemical treatment at any cost, compatibility of preservative with metal fasteners, off-gassing and decay resistance are all intertwined in the decision-making process. A review of applicable elements of green design is provided, along with project examples. Recommendations are made on key research areas for the next 5 to 10 years.

1. Introduction

> "The future of everything we have accomplished since our intelligence evolved will depend on the wisdom of our actions over the next few years. Like all creatures, humans have made their way in the world so far by trial and error; unlike other creatures, we have a presence so colossal that error is a luxury we can no longer afford. The world has grown too small to forgive us any big mistakes."
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> \- *A Short History of Progress, Ronald Wright, 2004*

The doom and gloom predictions on the state of our environment appear to be holding true. Our buildings play a major role in shaping the environment. One the one hand, the built environment provides people with shelter from nature, thereby improving our quality of life and aiding in our ability to be productive. And, healthy buildings are commonly equated with healthy occupants, and healthy workplaces lead to increased productivity. But our buildings also shape the landscape, not only by their presence, but in their use of resources during their construction and over their operating lives. Architects and engineers directly impact the use of resources through their choices of site, water and energy use, and materials. While a well-educated and thoughtful designer is able to minimize the negatives effects on the environment that our buildings are known to produce, the sad truth is that, well-educated or not, short-sighted criteria normally guide the design process, such as maximizing building area, or locating on relatively inexpensive rural suburbs, or choosing cheap short-lived materials, inefficient building massing or inefficient heating/cooling and ventilation systems.

Add to this the fact that only 1 to 3 percent of new construction in North America falls into the relatively new category of sustainable or 'green' design, and we see a very negative trend. On the upside, green design is an emerging area that has gained tremendous momentum in the last five or so years. Energy use over the lifespan of a building is one of the key driving forces for this change. Statistics from the U.S. indicate that buildings use one-third of the total energy use, two-thirds of electricity production (US DOE, 2001), one-eighth of potable water (US Geological Service, 1995) and that buildings lead to destruction of the ecological land base. Similar numbers can be expected from Canada, possibly worst due to our climate. Air pollution from energy production and single-car-transportation-dependant cities increases smog, ground-level ozone, acid rain, health problems and contributes to global climate change.

Although energy use is a significant component of the problem, the choice of building materials is a key factor. Annually, building construction worldwide consumes roughly 3 billion tons of raw materials (Lenssen and Roodman, 1995). Of that, one-quarter of all harvested wood is used in buildings. How we use our wood resource has a tremendous impact on the well-being of our planet and our society.

The good news:
Wood preservatives have played a role in improving the life expectancy of this resource. If not for the use of preservative treatment to extend the life of our forest stock, "wood consumption was rising at a rate that would have completely depleted our forests resources [at the turn of the 19th century] (Morrell, 2004). Durability of a building or structure is an increasingly important aspect of construction in North America. As one architect put it "in a way, building something to last is one of the most sustainable things we can do" (Hartman, 2003).

The bad news:
Wood preservatives in wood products are an unknown for green builders when it comes to off-gassing and chemical transmission (including effects on building occupant health and local ecology), disposal of waste cuttings, future re-use of building components after disassembly, effects on wood composites, and effects on fasteners.

There are many environmental benefits to using wood in construction, and these will continue to influence designers and building owners as they choose wood in their structures. The introduction of preservative treatments puts all of this into question and may convince designers to switch to other materials.

2. Durability and Green Building

Among choices of building materials, timber provides architects and structural engineers with great benefits. It has long been purported that the so-called carbon sink of our forests more than makes up for the energy consumption required to harvest and process trees as well as the energy required to build structures from timber. In fact, the net carbon output is negative if one considers the stored carbon in the timber. The Canadian Wood Council recently presented results of a life-cycle analysis study which compared the environmental effects of a hypothetical three-storey office building built from timber, steel or concrete (CWC, 2003). The results were as follows.

In the manufacturing process:

1) Processing steel used 2 times the energy than timber, produced 1.5 times more carbon dioxide, 120 times more water pollution; and
2) Producing concrete used 1.5 times more energy than timber, produced 1.8 times more carbon dioxide, 1.9 times more water pollution.

In the construction process, no major energy use difference was found although concrete formwork was noted as creating 2 times as much construction waste than timber construction alone.

Once occupied, the building energy use for heating and cooling can far outweigh the initial energy input of the materials if not properly insulated. Timber has the advantage of being a better thermal insulator compared to steel, thereby requiring less additional insulation than steel.

Post-use deconstruction and disposal are normally overlooked in the design process and in all modern building codes. However, it is possible to design a building in timber or steel that can be easily disassembled so that its components can be reused in other applications – even though this is almost never considered at the design stage. And recycling facilities for steel are readily available, whereas recycling facilities for timber have only recently become more common. Although wood has the advantage of being biodegradable, structural composite lumber (including plywood, OSB, I-joists, parallel strand lumber, etc.), preservative-treated lumber and fire-retardant treated lumber pose significant problems with regard to disposal, recycling and reuse.

When building designers sell people on timber, they also sell them on the environment. Designers have to prove to building owners that timber is their best overall choice, from cradle to grave. The LEED® rating system was developed to provide owners and designers a tool for measuring the ‘greeness’ of their projects. Although other tools exist, in North America the LEED system currently stands out as the principal rating guide and has gained tremendous momentum in the last 4 years. It was developed through a grassroots volunteer movement of architects and building engineers by way of the US Green Building Council. They determined to make a change in the way buildings are designed and operated, with funding and assistance from the US Department of Energy. LEED has since been adopted in Canada. LEED addresses key areas of sustainability in construction including:

1) Choosing sustainable building sites,
2) Water efficiency,
3) Energy efficiency,
4) Indoor environmental quality, and
5) Materials and Resources.

In each category, a number of criteria are listed along with a point system. Projects that achieve a higher number of points rate higher from a sustainability perspective. In terms of structure, the choice of materials affects sustainability of the material resource, but also affects energy use in production (not currently a measurable item in this rating system) as well as possible energy savings in building operation. For example, choosing timber, as indicated earlier, may lead to improved thermal insulation characteristics of the building. Thus, there are synergistic relationships between choices that can be used to the designer's benefit.

All things considered, timber comes out on top in many categories in terms of the sustainable choice of building material.

3. Key Green Building Factors for Choosing Preservative Treatment

The ten (10) key areas specific to assessing timber as it relates to green construction are summarised as follows, and are based on the LEED document sources (LEED Canada 2004, McFarland 2003) with the author's additional comments regarding preservative treatments.

<u>1. Construction Waste Management</u>
This refers to diversion of at least 50% of construction waste from landfill to reuse or recycling facilities. For timber, recycling facilities do not always exist, although they have recently become more common. However, no facilities exist (to the author's knowledge) for handling wood that has been preservative-treated.

<u>2. Resource Re-use</u>
Reuse of materials from previous buildings into a new building for at least 5% of the new construction. Salvaged materials are becoming more accessible in the marketplace. Some are sold at a premium for their 'character.' However, if the salvaged timbers had preservative treatment, what identifying marks are there to know which type of treatment was applied? Is it obvious that that material was preserved, or is there a risk of putting a piece in a compromising location? Similarly, if one can not identify whether or not a piece was preserved and uses it in the interior of a building, off-gassing could pose a risk to occupants.

<u>3. Recycled Content</u>
At least 5% of the material content of new buildings is to be from recycled materials. An example might be particleboard containing material diverted from the waste stream of a wood processing plant. There is no current application for preserved wood content in other

materials, however, if it would be possible to recycle preserved wood into other products and then reuse them, then it would help.

4. Local Regional Materials

Minimum of 20% of building materials manufactured within 800 km of the new building site (or 2400 km if shipped by rail or water). In Canada, the forest industry is easily located within this distance; however, some preservative types are available only from US facilities, thereby increasing shipping requirements (e.g. shipping to Oregon for treatment then back to Toronto for installation).

5. Rapidly Renewable Materials

Provide a minimum 5% of total building materials in new construction from materials that harvest in 10 years or less from time of planting to reduce reliance on old growth stands. This would apply to poplar OSB, or bamboo. If preservatives were used on OSB or bamboo products, this would likely comply with this requirement.

6. Certified Wood

Use a minimum of 50% of wood based materials certified in accordance with the Forest Stewardship Council (FSC) Guidelines for wood building components. Raw material to be derived from managed forests per criteria of FSC. This applies regardless of treatment.

7. Durable Building (a new criterion initiated in Canada only)

Minimize material use and construction waste over a building's life resulting from premature failure of the building and its constituent components and assemblies. Assess durability criteria based on the standard CSA S478-95 (R2001) *Guideline on Durability in Buildings*. Use of careful detailing such as overhangs, shading from trees (natural), and sloping surfaces can improve life expectancy. Designers must also demonstrate life expectancy from design. Structural engineers have major role here as they can carefully detail to keep moisture away from critical areas, and, if not, they specify preservative treatment.

8. Low-emitting Materials

Americans spend between 80 and 90% of their time indoors (American College of Allergy, Asthma & Immunology). As a result, restrictions are placed on VOC limits for wood adhesives, sealants, paints and composite wood products. Ratings are based on adhesives for composite wood products, such as OSB, I-joists, glulam, LVL, LSL, PSL, but all without preservative treatment. What if preservatives are used? What are the VOC levels once preservatives are introduced? Essentially, the requirement is here to prevent the use of urea-formaldehyde (UF). Phenol-formaldehyde (PF) is allowed as it off-gasses much less than UF. Pmdi (polymeric methylene diisocyanate) is also allowed as it contains no formaldehyde. Although not currently addressed, what restrictions or allowances should be made for preservatives? As an indicator, it appears that well detailed and constructed buildings with Preserved Wood Foundations have similar favourable air quality (based on VOC's) to those constructed with concrete foundations (CWC, 1997).

A subset of the Low-emitting Materials category would be improving indoor air quality to improve occupant health. Off-gassing and airborne pollutants (inhaled substances which cause allergy or disease) can cause health problems that result in absenteeism and reduced productivity. Moulds (fungi and mildew) would fall under this category. Thus, designers must be aware of detailing to avoid creating musty, damp places such as basements or poorly ventilated spaces that could lead to toxic moulds. One might argue that wood preservatives prevent the growth of mould. (Although, the USDA Forest Product Lab Advanced Housing Research Center document "Common Questions and Answers About Molds [sic] 2003" indicates that there is little or no conclusive link between moulds that produce mycotoxins and microbial VOC's and health problems in buildings, and that these moulds do not necessarily grow on wood products but are generally found on cellulosic materials in wet conditions.)

9. Innovation & Design Process

This category is generic in that it allows the designers to suggest an improvement or target they wish to achieve that falls outside the standard guidelines. In terms of preservatives, the good news is that on one U.S. project, where the use of preservative treated wood was necessary, the designers restricted the use of CCA treated wood to 0% and were awarded with an extra point towards their green design designation.

10. Deconstruction (disassembly)

This category does not yet exist but is a concern at the end of the building life. Ease of disassembly and subsequent reuse of building materials is not yet a consideration. However, how can pieces of preservative treated wood be identified positively for presence of preservative and for type of preservative? What types of recycling facilities exist for these materials?

4. Project Examples

Preserved wood is only used in cases where no other options are viable for protecting structural timber. The exposure of engineered wood components changes during the life of a building. Initially, during construction of standard platform frame construction of houses, contractors typically leave all components exposed to the elements. This means that plywood, OSB walls, floors and roofs are left exposed – ironically, a very low-tech approach to building even though the engineered wood products in these buildings are relatively hi-tech. On the other hand, for very hi-tech structures using architectural grade glulam, exposure is never an option and temporary covers are mandatory, as shown in Figure 1.

Figure 1. Temporary tarps over architectural grade glue-laminated beams

There are structures where exposure is inevitable, such as bridges. However, the wood trusses on traditional covered bridges were not always treated with preservative. There was a reason for covering so-called “covered wood bridges” – the roof protected the structure. No preservative treatment of the timber trusses meant that deterioration could only be prevented by covering the structure to protect it from the elements – a simple yet effective approach to extending the life expectancy of the structure.

There are instances where wood is left exposed, for aesthetics, and requires protection. Normally, roof overhangs and cap flashings are chosen for simplicity, economy and aesthetics, as shown in Figure 2. Unfortunately, building owners tend to neglect their roofs, or do not re-stain or re-paint exposed timber on time, and untreated timbers normally suffer. The result is costly replacements of part or all of the structure, as was the case in this recent example shown in Figure 3. This structure had arches spanning nearly 40 m and was protected by a roof; however, poor detailing and lack of maintenance resulted in this structure lasting only 40 years as a result of significant rot. The result was a considerable loss of revenue for the building owner plus the added capital expense for replacement of almost the entire structure.

Figure 2. Cap flashings at exterior truss extensions

Figure 3. Neglected, untreated arch suffering rot through one-third of its depth

When no other option exists, preservative treatment provides an excellent opportunity for extending the life of a structure. The ferry terminal, shown in Figure 4, on the Pacific coast of British Columbia, has been in service for approximately 40 years and was only recently reviewed for possible replacement. In its lifetime, this structure was continually battered by the sea, sun (see Figure 5) and rain and regular impacts from sea-going vessels. An oil-borne preservative (type unknown) was used and was still apparent during a recent inspection. There are presently concerns with some parts of this structure and it will likely be replaced in the short-term. However, it has performed very well, in most part due to the use of preservatives.

Figure 4. Ferry terminal on Pacific coast

Figure 5. Ferry terminal overhead beams exposed to sun and rain

In existing structures, it is sometimes difficult to access areas with suspected decay and a non-destructive ultrasonic reading is necessary to detect rot. The Sylvatest hand-held ultrasonic probe, shown in Figure 6, provides this information. In one case, an 80-year old building in the historic district of Vancouver was assessed for the condition of existing columns. The columns were untreated. It was found that water leakage through masonry walls had led to internal rot in a number of columns. In this case, poor detailing of masonry butted against wood columns led to the deterioration, however, the building owner should have taken action years earlier when the leaks were first detected.

Figure 6. Hand-held ultrasonic testing

In exposed structures where aesthetics are important, CCA treatments are never used as they are water-borne and cause splits and checking in glulam. Treatments that have little effect on colouring and that do not impede choice of stains are preferable. Some examples follow.

The landmark arches at Roger's Pass, BC, have recently been replaced, as shown in Figure 7, 43 years after the initial opening ceremony. The original arches were rotting. Because of the park setting, the new arches were required to use a more environmentally-friendly preservative, Tim-bor, a borate preservative that is compatible with the Menco stain was used. It also minimizes the discolouration of the glulam.

Figure 7. Replacement arches at Roger's Pass, BC

Similarly, to avoid discolouring the glulam, a Hi-Clear II finish (anti-fungal and insecticide) from Permapost was used on the new Ali Shan railway terminal for Taiwan, shown in concept in Figure 8. The structure was shipped from BC to Taiwan where it will be prone to attack from insects/borers and fungi.

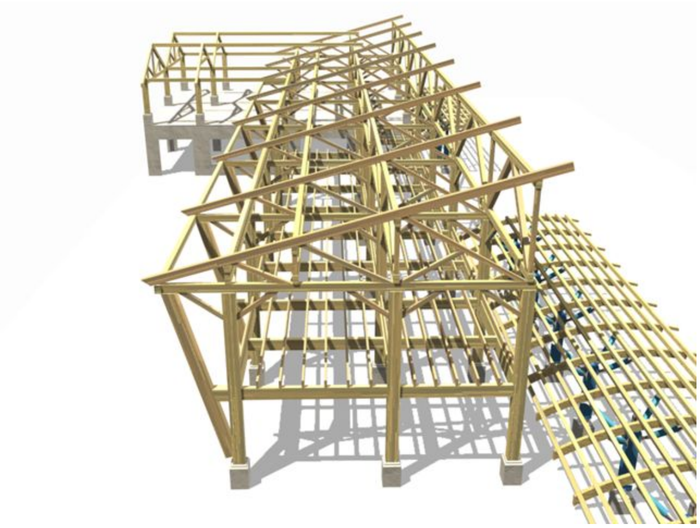

Figure 8. Ali Shan railway terminal, Taiwan

One final example is the recently opened McCulloch trestle bridge on the Kettle Valley Railway in BC, shown in Figure 9. This pedestrian bridge was completed in 2002 and spans roughly 70 m. All structural glulam was sloped to provide natural drainage. Pentachlorophenol was chosen, although the region is relatively dry, but the structure is exposed to the elements. Hem-fir decking was used for its compatibility with the treated substructure.

Figure 9. McCulloch Trestle, Kettle Valley Railway, BC

In all instances, the designers were confronted with many unknowns regarding treatment. How can the building design be changed to avoid using treatment entirely (construction practices, detailing, ventilation, etc.)? Which treatment to use? Local availability? How will the treatment affect the appearance? What are the toxic effects associated with the treatment? Will the treatment affect the metal connections? What are the long-term implications of choosing a treatment?

5. Conclusions

Recommended directions for future research are underlined in the following:

The decision to use preservatives treatments in building structures is not an easy one. From a practical standpoint, a designer's primary goal will be to eliminate the need for any preservative treatment in a structure by removing the source of moisture. If that is not possible, then the designer might choose another material option or structural system. Failing that, the designer is left with a difficult task of deciding on the type of preservative treatment, availability of treatment (and cost), effects on health and environment, compatibility of finishes (paints, sealants, etc.) with preservative, compatibility with steel hardware (expense of hot-dipped galvanizing or other metals), and spending the extra time to coordinate these options. Designers need better assessment tools and more up-to-date information on all current preservative treatment options and their positive and negative attributes.

There is a clear lack of information in the current literature to guide designers (and, it appears, researchers too) on suitable choices for sustainability. At present, perhaps the most pressing issue in forest products industry research should be that of wood preservatives - chemicals that linger in our environment and have become the focus of regulators (as they become legislated out of use) must be properly addressed. Some jurisdictions specify the use of certain treatments whereas others do not (e.g. the city of Vancouver prefers Borite treatment in residential wood frame; the State of Hawaii requires all wood to be preservative treated) – there is no uniform code of practice and no single reference that consolidates this information.

In the author's review of the literature for this paper, with particular regard to wood treatment, no recent papers were found to deal with genetically modifying common species using species with known decay resistance properties. In a similar vain, wood composites pose a problem as the 'green building' movement gains tremendous momentum in North America. This movement will eventually start pushing for methods of recycling or reusing composite wood products such as plywood, OSB, LVL, LSL, PSL, etc., to divert a known waste stream with chemical additives (from adhesives and preservatives) from landfill. There is little or no information on research aimed at reusing or recycling wood that has been treated with preservatives.

Finally, it is recommended that a 1-hour short course or lecture be developed to help designers navigate through the world of wood preservatives, perhaps in conjunction with a broader ranging one-day seminar series on timber design.

5. Literature

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