Building Green with Wood Construction

By Jim DeStefano, P.E., AIA

Sustainable design is a tough issue for structural engineers to get their arms around. While the sustainable design movement has taken the architecture and engineering world by storm in the past few years, it is often unclear what role the structural engineer can play.

Essentially, "sustainable" or "green" buildings are buildings which are energy efficient and which minimize the adverse environmental impacts associated with their construction and operation. There are multiple aspects to sustainability, including site selection, energy efficiency, durability, water consumption, indoor air quality, reuse of recycled materials and construction waste management.

It seems as though every building materials group and every product manufacturer has been touting the green aspects of their material or product, while downplaying the not so green aspects. Of course, there is no perfectly green building material. They all have some adverse impacts, or "brown" aspects associated with their use that must be balanced against the green benefits.

Wood is the most commonly used structural building material in the world, although most engineers are far more familiar with structural steel and reinforced concrete. There are some inherently green aspects to wood construction.

Wood is a bio-based material and is renewable. Trees extract carbon dioxide from the atmosphere and the carbon is stored in wood building products. Wood has low embodied energy compared to most other structural materials. The energy consumed in managing forests, harvesting trees, milling timber and transporting lumber to job sites is relatively small. Wood fares exceptionally well when comparing the manufacturing impacts of building materials such as solid waste generation, air and water quality impacts, and greenhouse gas creation.

Sustainable Forestry

Responsible forest management is the key to preventing potential adverse environmental impacts associated with the harvesting of timber from forests. In the past, there have been instances of environmental degradation of forests from irresponsible logging practices. In recent decades forest owners have become more environmentally sensitive, and there has been a trend towards managing forests in a more sustainable manner. Forest management has evolved into not just maximizing timber yield, but also protecting streams and rivers, minimizing erosion, protecting natural ecosystems, and enhancing wildlife habitats.

So how does a structural engineer know if the lumber on his or her project came from a responsibly managed forest? There are certification programs for wood products that verify that a particular board, joist, or beam was produced following specific sustainable forestry criteria.

There are four prominent forest certification programs certifying approximately one-fourth of the forest lands in North America. They are the *Forest Stewardship Council* (FSC), the *Sustainable Forestry Initiative®* (SFI), the *American Tree Farm System* (ATFS) and the *Canadian Standards Association* (CAN/CSA-Z809). While there has been considerable debate over which certification program is best, all four are recognized and credible programs.

Green building starts with sustainable forestry.

Less than 20% of the structural wood products available today come from certified forests. Wood that is not certified by one of the four sustainable forestry programs may not necessarily have been grown and harvested in the most sustainable manner. While the LEED rating system only recognizes FSC certification of wood products, the Green Globes and NAHB rating systems recognize all four prominent North American certification programs.

Carbon Sequestration

Increasing levels of carbon dioxide in the atmosphere from the consumption of fossil fuels has been recognized as a cause of accelerated climate change. The only practical technology currently available for extracting carbon dioxide from the atmosphere is the cultivation and harvesting of trees and other crops.

A well managed forest or woodlot will extract a considerable amount of carbon dioxide from the atmosphere. For every pound of wood grown, 1.47 pounds of carbon dioxide is removed from the atmosphere and replaced with 1.07 pounds of oxygen. However, if a forest is not managed and trees are not thinned and harvested, the forest will mature to a point where the carbon dioxide returned to the atmosphere by the decay of dead trees and forest fires balances that extracted from the atmosphere.

To effectively remove carbon dioxide from the atmosphere on a sustainable basis, mature trees must be periodically harvested and milled into building products that will endure for many decades. This is referred to as "carbon sequestration" since carbon becomes a permanent and integral part of the building products. When trees are harvested for short duration uses, such as paper pulp or in the construction of buildings with a relatively short service life, the carbon dioxide may soon be returned to the atmosphere with less sustained environmental benefit. The key to effective carbon sequestration is building wood structures that will endure for many decades, or even centuries.

Wood Product Selection

Each type of wood product available to the engineer will have its own environmental advantages and disadvantages that need to be considered.

Solid sawn lumber, and particularly dimension lumber, is commonly used in building construction. A major advantage of sawn lumber is its extremely low embodied energy.

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Transportation impacts and the associated embodied energy can be minimized by specifying locally or regionally grown species. Typically the dominant structural wood species in various regions of the county are: Douglas fir in the West, Southern Yellow Pine in the Southeast, and Spruce-Pine-Fir (SPF) in the Northeast and Midwest.

The popularity of *Engineered Wood Products* (EWP) for structural applications has grown significantly in recent decades. The primary advantage of EWPs is their ability to efficiently use smaller trees and underutilized species with very little manufacturing waste. Another advantage of EWPs is their ability to span further and use fiber more efficiently. Offsetting these advantages is their somewhat higher embodied energy when compared to solid sawn lumber.

EWPs are manufactured using petro-chemical based adhesives and resins. There are valid toxicity and air-quality concerns related to off-gassing from urea-formaldehyde resin in wood products. Urea-formaldehyde resin is no longer used in the manufacture of structural EWPs, since it does not perform well when exposed to the weather. EWPs primarily utilize phenol-formaldehyde resins which are not subject to any significant detectable off-gassing. However, urea-formaldehyde is still commonly used in non-structural wood products for architectural millwork.

Precut and prefabricated building components are assembled more efficiently and with less waste than site-built construction. Prefabricated components include:

- Metal plate connected wood trusses
- Panelized framing
- Structural Insulated Panels (SIPs)
- Timber framing

Fabricating wood building components in a factory environment, unimpeded by adverse weather conditions, has proven to result in greater efficiency and productivity which translates into reduced embodied energy.

Structural Insulated Panels

Structural Insulated Panels (SIPs) have a rigid foam core sandwiched between Oriented Strand Board (OSB) skins. Expanded Polystyrene (EPS) and urethane are the most common core materials. SIPs can be used as a cladding system on a timber frame structure or as a stand alone structural system.

Engineered wood products utilize wood fiber efficiently.

SIPs result in a very energy efficient structure. They have a high R-value and provide a very low air infiltration rate. With proper sealing of the panel joints, infiltration rates are typically less than 0.10 air changes per hour. As with any "tight" structural system, SIP enclosed structures must be mechanically ventilated to prevent indoor air quality problems.

Advanced Framing

Advanced framing techniques, also referred to as *Optimum Value Engineering* (OVE), involve framing structures with less lumber than would be used with traditional wood framing methods. Advanced wood framing uses wood most effectively when wall studs, joists and rafters are spaced at 24 inches on center, rather than the more common spacing of 16 inches on center. Joists and rafters are aligned with wall studs and wall studs are aligned from floor to floor. This alignment of horizontal framing members with studs allows the use of single member top plates. Headers are sized for actual loading conditions at structural and non-structural walls, and redundant studs and floor joists are eliminated on typical details.

Advanced framing allows for more effective insulation of exterior walls with fewer studs to interrupt the insulation.

Advanced framing results in fewer pieces of lumber, but often an increase in lumber size. For instance, when wall stud spacing is increased from 16 inches to 24 inches, the stud size will usually increase from 2x4 to 2x6. The wall sheathing and drywall will also often increase in thickness from ½ inch to ⅝ inch.

Implementing advanced framing techniques requires some retraining of carpentry crews. It has been estimated that it takes framing as many as ten house structures for a framing crew to become proficient at executing advanced framing techniques.

Advanced framing results in a more efficient structure than a conventionally framed wood structure. It also results in a less redundant structure, which can be a disadvantage when a structure is altered or adapted to a different use.

Design for Durability

All efforts to design an efficient structure are of limited sustainable value if the structure has a short service life and is demolished or destroyed after a few decades. If a wood frame structure does not stand for as long a time as it took the trees that went into its construction to grow, then it can be hardly classified as a sustainable building. Sometimes a robust structure that can be easily adapted to new building uses and loading conditions will be the most sustainable design.

Wood waste is processed into landscape mulch.

The natural durability of wood has been proven by the multitude of buildings that have stood for centuries. While wood's natural bio-based attributes make it a sustainable building material, it also makes wood vulnerable to decay and wood destroying insects. Proper design, installation and detailing are critical to ensure long-term durability.

When wood is used in exposed applications, or in areas where it is subjected to moisture and insects, it must be protected with mechanical barriers, coatings and, in some instances, preservative treatments.

Preservative Treatment

Wood can be impregnated with preservative chemicals to protect it from decay and insect damage. Many preservative compounds are toxic and protect the wood by poisoning decay fungi and insects. Common preservative treatment compounds such as CCA, ACQ, Copper Azole and pentachlorophenol, require special handling during manufacture and disposal after use. (CCA treatment is no longer available for residential construction but is still available for timber pilings, marine structures and other engineering applications.) The advantage of an extended service life must be balanced against chemical toxicity concerns. Although in most cases the chemicals are fixed within the wood, preservative-treated wood can result in adverse environmental impacts if not properly handled and disposed of.

Borates are not toxic to humans and other mammals, although they are toxic to termites and decay fungus. Most borate treatments are susceptible to leaching and are not suitable for applications where they are exposed to the weather. Their use is limited to applications such as sill plates, crawlspace framing, and other protected framing.

Naturally occurring decay-resistant species contain extractives in their heartwood that are resistant to decay and wood eating insects. Redwood, Cedar and Cypress are commonly used when natural decay resistance is desired.

Deconstruction and Recycling

Within the manufacturing environment, wood waste is either recycled into the production process or used as process fuel.

At the jobsite, wood waste along with drywall scraps can be processed into landscape mulch. Studies have shown that mulch made from engineered wood products is suitable for landscape applications. Mulch is beneficial to plantings due to its ability to retain moisture in the soil and retard weed growth. Eventually, the mulch decays and contributes organic material to the soil.

Demolition debris can be sorted and recycled. Larger structural timbers can be salvaged during deconstruction for re-use in other structures. Sorting and nail removal from light wood framing can be very labor intensive and impractical unless specialized tools are used.

Wood waste can also be used as a boiler fuel. Jobsite waste, demolition debris, manufacturing scraps and slash (branches and tree crowns) from logging operations can all be chipped and used as bio-fuel, displacing the consumption of fossil fuels.

Summary

A structural engineer endeavoring to design responsibly with wood should consider the following sustainable initiatives:

- Specify wood products that come from sustainably managed forests.
- Specify wood species that are grown in the same region as the project.
- Utilize wood efficiently. Consider using prefabricated building components, engineered wood products and advanced framing techniques.
- Design durable structures that are resistant to deterioration, and can be altered and adapted to new uses and loading conditions.
- Specify non-toxic preservative treatments when appropriate.
- Require that construction site waste and demolition debris be sorted and recycled, or used as biofuel.▪

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This article contains excerpts from *SEI Sustainability Guidelines for the Structural Engineer*, which is scheduled to be released later this year.