Structural Performance

performance issues relative to extreme events

Engineered Wood Products Exposed to Floodwaters

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There have been a number of significant flooding events in recent years, ranging from the Nashville flood in May 2010 to Hurricane Irene in August 2011. Floods are one of the leading natural disasters in the United States. Average annual U.S. flood losses for each of the past 10 years (2001-2010) exceeded $2.7 billion (National Flood Insurance Program). Fortunately, engineered wood products can be considered relatively durable when temporarily exposed to floodwaters. Many of the losses involving engineered wood products can be reduced if proper measures are taken.

Dry It Out

If a building or home is flooded, it is imperative to get the structure dried out as soon as possible. This is necessary to prevent mold growth and fungal decay – the latter can lead to permanent strength loss (Kirby, Wiggins).

After floodwaters have receded, any standing water in a basement or crawl space should be removed. Any insulation, gypsum board, carpet and padding, or other interior finish materials that are wet should be removed. Ceramic tile floors should also be removed, as concrete topping or backer boards used underneath ceramic tiles often retain moisture. This will speed up the drying process and allow for visual inspection of the structure. Fans and dehumidifiers should be used when possible to circulate air. As stated by APA in a publication on assessing flood damage, "*Depending on conditions, the drying process can take from a week or two to several months.*" While the building is being dried out, temporary shoring of any wood products may be necessary to prevent permanent set, especially for primary support members that are heavily loaded.

Engineered wood products should be dried out to a moisture content less than 16%, returning it to the assumed "dry use" conditions, as specified in Section 8.1.4 of the 2005 *National Design Specification® (NDS®) for Wood Construction*. While not a structural concern, any mold on wood should be cleaned by a detergent and water solution, as recommended by the EPA, or a 1 cup bleach per 1 gallon water solution as recommended by the CDC. The CDC also recommends that large mold infestations should be addressed by a professional who has experience with cleaning mold in buildings and homes.

A moisture meter will be necessary to determine if wood members are properly dried. A handheld electrical resistance meter with pins is the most common type of moisture meter used in the field. For engineered wood products, the pins of the meter should be put in the wide face of the beam or panel. They should be inserted parallel to the grain. It should be noted that the resins in engineered wood products affect the electrical resistance and often cause readings to be higher than the actual moisture content. Rather than attempting to account for this potential difference, it is recommended that the moisture meter output be used directly with knowledge that it may be slightly conservative.

Moisture meter with pins inserted into bottom of I-joist.

Adhesives in Engineered Wood Products

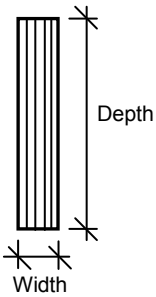
Engineered wood products are manufactured by taking a tree apart, removing inconsistencies inherent in the lumber, and putting its fibers back together to take full advantage of its natural strengths. This results in high-quality products that have higher allowable design properties, and more dimensional stability than sawn lumber. Examples of engineered wood products include I-joists, structural composite lumber, oriented strand board (OSB), and plywood. Structural composite lumber (SCL) products include laminated veneer lumber (LVL), parallel strand lumber (PSL), and laminated strand lumber (LSL).

One of the most common concerns about engineered wood products exposed to extreme moisture conditions such as flooding is whether the adhesive bond will be compromised, leading to delamination of individual wood veneers or strands. Engineered wood products use adhesives that are rated for exterior use, although this use category is intended for temporary moisture exposure during construction, not long-term exposure. Structural composite lumber and I-joists use adhesives adhering to ASTM D 2559 requirements while plywood and OSB meet the Exposure 1 classification required in the U.S. Department of Commerce PS-1 and PS-2 standards, respectively.

The most common adhesives used to manufacture engineered wood products are phenol formaldehyde (PF), phenol resorcinol formaldehyde (PRF) and diphenylmethane diisocyanate (MDI). During the manufacturing process, bonding is caused by a chemical reaction in the adhesive. In that reaction, the adhesive becomes

SCL Dimensional Change at Different Moisture Exposures.

Product	% Thickness (Width) Swell		% Depth Swell		% Length Swell	
	Wet (>30% MC)	Recovery from Wet	Wet (>30% MC)	Recovery from Wet	Wet (>30% MC)	Recovery from Wet
LSL	18%	9%	1%	0.3%	Negligible	
LVL	6-8%	3-4%	4-6%	1-1.5%	Negligible	
PSL	10-15%	5-8%	5-6%	2-2.5%	Negligible	



1) From 'as manufactured' dimensions and moisture content.
2) 'Wet' assumes MC > 30% throughout the cross-section. Partially wetted product will exhibit lower percentage swell than shown in this table.
3) 'Recovery from wet' assumes original manufactured moisture content.

chemically inert. Once the reaction is complete, the adhesives are more resistant to moisture than the wood and there is no concern over the adhesives breaking down and causing delamination.

Strength and Dimensional Stability

Most wood strength properties decrease as moisture content increases beyond dry use conditions, until fiber saturation (roughly 30% moisture content) is reached. Beyond fiber saturation, these properties remain relatively constant. The NDS provides guidance for reducing design values in wet use applications. When temporarily wet wood members are dried back to normal equilibrium moisture content (< 16%), it is typical to assume no change in allowable strength properties, though a small loss may occur in relative ultimate strength due to wetting.

Elevated moisture contents can also affect the stiffness and creep performance of wood members. Creep is an increase in deflection that occurs over time under sustained load or exposure to moisture; this increase is typically only applied to dead load deflection because the live load applied is considered too transient to produce creep. Raising the moisture content from dry in-service conditions to fiber saturation decreases stiffness up to 25%, thereby causing an additional deflection of about one-third more than calculated. For this reason, it is good practice to temporarily shore primary support members and joists supporting offset bearing walls until the wood members are dried.

Moisture content for sawn lumber at time of fabrication varies from 15% to more than 20% depending on whether it is kiln-dried or shipped green. Equilibrium moisture content for wood in buildings typically ranges from 6 to 15%, depending on the building location, climate, and season. This is why sawn lumber typically shrinks as it equilibrates to the in-service moisture content of the structure.

Conversely, engineered wood products are typically manufactured at a moisture content of 5 to 7%. If wood products are exposed to flooding, the moisture content will likely be elevated to more than 15%, which could result in substantial swelling. Thus, it is important to give consideration to potential dimensional stability issues. SCL products swell more in the thickness direction than the depth direction, because this is the orientation of pressing during the manufacturing process. After significant exposure to moisture, a SCL beam can be expected to shrink back to approximately half of its swollen dimension upon redrying, also known as springback. For example, a 3½-inch x 16-inch PSL beam that has swollen to 16½ inches can be expected to shrink back to 16¼ inches when it is properly redried to its original manufactured moisture content. An example of dimensional changes SCL products experience when exposed to varying moisture contents is shown in the *Table*.

I-joists will follow the same general rules as SCL products in regards to swelling, including springback when the joists are properly redried. If I-joists are submerged or exposed to moisture for extended periods of time, the web-flange connection should be closely inspected to ensure that the web has not swollen and split the flange or been otherwise compromised.

Panel Products

OSB and plywood panels exposed to flooding will likely experience swelling along the panel edges. After drying, the swollen edges can typically be sanded down to maintain a flat floor surface. If panels become very saturated, they may expand and buckle along the panel edges. APA's publication on assessing water damage after a flood is an excellent reference for OSB and plywood panels. In particular, they provide two ways to remedy panel buckling. One option is to run a circular saw (set to the panel thickness) along the panel joints. This is called "kerfing," and will help relieve the pressure that causes buckling. If tongue-and-groove edges are cut, they must be blocked from underneath or a layer of underlayment must be installed over the top with underlayment joints offset from subfloor joints. However, kerfing and drying may not completely remedy buckling. The other option involves blocking under buckled portions of the floor to push panels flat again. Depending on the degree of flood damage, it may be necessary to add a second layer of sheathing or to replace panels to ensure subfloor integrity.

If hardwood flooring is to be installed over flooded OSB or plywood panels, it is critical that panels be allowed to dry. *The National Wood Flooring Association® (NWFA) Installation Guidelines* state that the moisture content of properly acclimated solid strip flooring less than 3 inches wide should be within 4% of the subfloor moisture content at time of installation. For 3 inches or wider solid flooring, that difference should not exceed 2%. High moisture content in hardwood flooring or subfloor panels can lead to poor fastener retention, which is one of the most common causes of "popping" with hardwood floors.

Laminated strand lumber (LSL) sill plates show post-flood swelling from 3 inches to 3¼ inches.

Conclusion

Taking appropriate measures may lessen the impact of flood damage on sawn lumber and engineered wood components in a structure. In all cases of flood damage, it is recommended that an engineer or design professional with knowledge of wood products and engineered wood products assess the unique conditions of each structure and provide specific recommendations for remediation and/or replacement procedures. In many cases, the engineered wood product manufacturer can provide guidance to the design professional on how to evaluate their specific products.▪

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