

Variables for Forensic Evaluation of Degradation of Structural OSB Panels Experiencing “Wet” Service



By Colin Murphy, RRC, FRCI, and Lonnie Haughton

Abstract

At many construction projects, the exterior wall and roof sheathing are comprised of oriented strandboard (OSB) panels produced by more than one manufacturer or produced by one manufacturer from more than one wood species. OSB typically consists of wood strands from one of many tree species (commonly aspen) that are hot-pressed, using one of two types of “binders,” into composite panels. OSB panels, however, also are manufactured from blended batches of wood strands from two or more tree species, including blended mixtures of hardwood and softwood species.

Wood-rotting fungi of the class *basidiomycetes* are classified as white rots and brown rots. In general terms, the brown rots preferentially feed upon softwood and the white rots target the hardwoods; however, some of the wood-rotting fungi have broadly diverse appetites, while others may favor only one or a few host species.

From the perspective of an invading fungus, wood is: a) structurally, a natural subway of interconnected tubes; b) nutritionally, a fast-food shop with limited choices; and c) environmentally, a desert without running water (paraphrasing Dr. Steven Miller of the University of Wyoming). The inadvertent introduction of water into dry structural lumber or engineered wood sheathing can lead to rapid fungal proliferation, if the wood meets the fungi’s nutritional requirements. The wood can be expected to satisfy the nutritional requirements of one or more of the different types of fungal spores that have been hanging around waiting for wetter environs.

Lack of appropriate weather protection of engineered wood sheathing during the initial construction process can be a key factor determining the speed and severity of later biodeterioration when the panels are re-wetted due to building envelope failures.

There is no readily available evidence to suggest that the use of a particular binder or wood (of those tree species commonly used to manufacture OSB) will provide greater overall resistance to the numerous species of wood decay fungi that may attack the panels; however, the authors document dramatic differences in the rate of deterioration by a specific white-rot fungus of two different OSB panels experiencing the same “wet” service.

The authors conclude that forensic evaluations of OSB sheathing damage must consider the potential for significantly varying rates of panel degradation due to differences in composition, even if all of the inspected panels are from the same manufacturer. Also, the rates of this structural degradation may have been further exacerbated

by pre-infection of the panels during the construction process due to deficient weather protection.

OSB Structural Panels

OSB panels now comprise a majority of the structural sheathing market in North America:

- “By 1973... plywood held a 99+ percent share of the U.S. domestic structural panels market. At this point, lumber had been totally displaced as a sheathing material.”
- “By 1983... waferboard shared the market with oriented strandboard (OSB), and together the two products accounted for 5.5 percent of the structural market in the United States.”
- “By 1993... OSB... accounted for one-third of the structural panels market.”
- “By 2000... North American production of OSB exceeded the production of softwood plywood.”¹

OSB structural panels are manufactured from thin wood strands² sliced from logs (in the direction of the wood grain) that are then dried, mixed with wax and binders, placed into a form in multiple layers, and hot-pressed into panels. Many tree species are used to manufacture OSB panels; however, commonly used species are southern pine, lodgepole pine, “aspen/poplar,”³ yellow poplar,⁴ sweetgum, and birch. The most commonly available OSB structural panels are manufactured from the aspen/poplar species.

- “The raw material for the original waferboard product, which was made from square wafers, was aspen. As this industry expanded and OSB became the predominant product manufactured, other species, such as southern pine, white birch, red maple, sweetgum, and yellow-poplar were found to be suitable raw materials as well. Small amounts of some other hardwoods can also be used for OSB.”⁵
- “Following development with aspen, a variety of other species have since been incorporated. Currently, mills can use almost any low-to-medium-density species that is widely available. Southern pine, spruce, birch, yellow poplar, sweetgum, sassafras, beech, and others are incorporated into OSB. Species of relatively high density, such as beech, are often mixed with species of relatively low density, such as aspen, to maintain acceptable board properties.”⁶

All OSB structural panels are manufactured to meet minimum voluntary performance standards⁷ when tested for three basic performance qualities: strength and stiffness, dimensional stability, and bond durability. The uniformity of these manufacturing standards has led many in the construction, repair, and consulting industries to assume that each brand of identically dimensioned OSB structural panel will provide the same general degree of both structural and weather-resistive performance, including similar levels of resistance to biodeteriorative attack by wood decay fungi.

- For most practical purposes, the first assumption is justified: due to industry-wide implementation of the voluntary performance standards in the manufacturing process, OSB sheathing panels by various manufacturers can, at a basic level, be considered structurally equivalent.
- However, the second assumption – equivalent OSB resistance to biodeterioration when encountering “wet” service – is demonstrably incorrect, as further discussed below.

Note: when properly installed as part of a properly designed and maintained roofing or cladding system, neither OSB nor plywood panels should be exposed to moisture extremes during the life of the structure.

For a review of moisture exchange performance differences between OSB and plywood panels, reference the authors’ article, “Moisture Exchange Performance of OSB and Plywood Structural Panels.”⁸

Wood Decay Fungi

The “wood decay fungi” (wood-rotting species of the class *basidiomycetes*) affecting above grade structures in North America are classified as white rots and brown rots. Wood decay fungi obtain nourishment by digesting the cell walls of the wood element, resulting in rapid and severe loss of structural properties.

- “The brown rots selectively attack the cellulose and hemicellulose of the cell and modify the lignin.... Brown rots cause dramatic strength loss in the early decay stages. Up to two-thirds of the total wood substance may eventually be consumed by brown rot fungi.”
“White-rot fungi have the ability to degrade both the lignin and cellulosic components of the cell, although the lignin is usually utilized at a somewhat faster rate. White rots may change the color of wood only slightly but more often give it a bleached or whitish color inherent to de-lignified cellulose. These fungi typically erode the cell outward from the cell lumen by decomposing successive layers of the cell wall, much as a river erodes its bank. Thus, the cell wall becomes progressively thinner, but the wood does not tend to shrink, check, or collapse, as is often the case with brown rots. White-rotted wood usually retains its shape, but may eventually become a fibrous, spongy mass.”⁹
- “Infection by spores of ‘wood-rotting basidiomycetes’ [WRB] probably does not occur at wood moisture contents below about 29%.... The mycelium and mycelial cords of WRB can colonize wood below the fibre [sic] saturation point, possibly down to 20% MC, provided they are growing from a substrate at a higher moisture content.”
“Once WRB are established, the minimum moisture content for decay to proceed is around 22-24%, so 20% is frequently quoted as a maximum safe moisture content for wood.

...WRB can survive for up to nine years in wood at moisture contents around 12%. If the wood wets up again, the decay process can restart.”¹⁰

Note that the initial infection by the fungal spores requires an initial spike of high moisture content (>28% MC), but subsequent proliferation of the established fungi only requires that the wood product is “wet” (>20% MC). This observation emphasizes the critical importance of protecting the sheathing prior to cladding or roofing. The authors have observed hundreds of construction projects in which the engineered wood sheathing remains exposed to inclement weather for weeks or months. Even if it is assumed that this saturated sheathing remains sound and will properly dry when the building is closed in, it is also reasonable to assume that some fungal sporulation either has occurred when the sheathing was exposed or will occur during the drying of the warmer, closed-in roof and walls. By allowing the sheathing to become initially saturated during construction, the builder has created a situation in which even relatively small future increases in moisture content of the dried panels can result in rapid biodeterioration and loss of structural integrity.

The sapwood lumber of all tree species has no inherent resistance to wood decay fungi. While the heartwood of some softwood lumber species (e.g., Douglas fir, western larch, and a few of the pine species) exhibit varying degrees of resistance to decay, the heartwood of most species used to manufacture OSB – including aspen, cottonwood, poplar, birch, and the remaining pines – has little or no decay resistance. Further, note that many trees harvested for OSB production are sufficiently young to have not produced a significant percentage of heartwood. Similar lack of heartwood production occurs with rapidly grown trees from commercial plantations.

- “When a tree or tree part is very young and growing vigorously, it contains no heartwood. After a number of years, however, heartwood typically begins to form near the center of a stem. The most common age at which transformation from heartwood occurs is reported to be fourteen to eighteen years. ...Some species, such as beech or European ash, may not begin to form heartwood until reaching sixty to one hundred years of age.”¹¹

In general terms, brown-rot fungi preferentially attack softwoods (e.g., Douglas fir, the true firs, larch, pine, and hemlock). Likewise, in general terms, white-rot decay fungi preferentially attack hardwoods (e.g., aspen, poplar, birch, and yellow poplar). A 1981 report identified 1,669 species that decay wood in forests or wood in use in North America. Six percent (113) of these species cause brown rots and 94 percent (1,556) cause white rots.¹² It is important to note that while some of the wood-rotting *basidiomycetes* are very selective about what they eat (some will infest only one tree species), others have a much broader appetite.

- “Brown-rot fungi commonly colonize softwoods, and white-rot fungi commonly occur on hardwoods, but both brown- and white-rot fungi occasionally colonize both types of wood.”¹³
- “Some fungi have a narrow host range, such as *boletus betulicola* on *betula* spp., while others have a very broad host range...”¹⁴
- “From a fungus point of view, wood is:

- a. structurally, a natural subway of interconnected tubes
- b. nutritionally, a fast-food shop with limited choices
- c. environmentally, a desert without running water.¹⁵

Typical wood structural members are manufactured from softwood species; thus, “brown-rot decay fungi have been the most common agents of decay in buildings,”¹⁶ including the biodeterioration of plywood sheathing.

Most commonly, OSB structural panels are manufactured from hardwood species. It is the authors’ experience that white-rot decay is the most prevalent form of fungal biodeterioration of OSB panels in buildings; however, we also have observed severe brown-rot damage of hardwood OSB sheathing.

- Where brown-rot deterioration of OSB sheathing is observed, these fungi often are found to be expanding into the panels from adjacent brown-rot decay occurring in softwood structural members.
- Similarly, where white-rot deterioration of softwood lumber or timbers is observed, the infestation commonly is found to have originated in adjacent white-rot decay occurring in the hardwood sheathing panels.

OSB Panel Manufacture - Type of Binder

In addition to the use of differing tree species and proprietary variables in the hot-press manufacturing process, the other major distinction between OSB brands is the type of synthetic “binder”

used to bond (with heat and pressure) the wood strands into a structural mass. The two major types of binder materials are: phenolic resins and methane di-isocyanate (“MDI”):

- “Phenolic resins are the most common binder used to manufacture Oriented Strand Board (OSB), as well as plywood, glass fibre [sic] insulation and other products. ...Phenolics are the oldest form of plastics. They have been used for a variety of applications for over 100 years and as wood based panel binders for over 60 years.”
- “Liquid polymeric diphenyl methane di-isocyanate (MDI) binders are an alternate binder system used by approximately 35% of the OSB mills (alone or in combination with phenolics) and bring to wood composites the same advanced polymer technology used in engineering thermoplastics and polyurethanes.”¹⁷

Biodeterioration of OSB Sheathing - Comparative Observations

Based upon the information provided above – that OSB panels are manufactured from differing tree species and typically use one of two different types of binders during the hot press manufacturing process – it is reasonable to hypothesize that one or both of these gross variables might significantly affect the potential risk for biodeterioration if a panel becomes wet.

In other words, the forensic consultant investigating the causes and extent of a building’s structural deterioration may find it useful to consider the possibility that the observed conditions have been selectively exacerbated by wood decay fungi that are targeting only some of the closely similar sheathing.



Photo 1 - Overview of the work area.



Photo 2 - Hardwood OSB sheathing with severe white-rot decay is surrounded by relatively undamaged hardwood OSB. The dashed line traces the upper limit of the migrating water. Note that the white-rot deterioration has spread upward from the water line. (The localized brown-rot decay at the upper right is spreading from underlying infestation of a softwood-framing member.)

The accompanying photos were taken by ERD in December 2002, at a condominium complex in Seattle, Washington, during a joint research project with the Forest Products Laboratory to study potential forensic uses of the “immunodiagnostic wood decay” (“IWD”) test¹⁸ developed by microbiologist Carol Clausen.

- The full results of the joint IWD study are published at <http://www.fpl.fs.fed.us/pubs.htm>: (C.A. Clausen, L. Haughton, and C. Murphy, “Evaluating Wood-Based Composites for Incipient Fungal Decay with the Immunodiagnostic Wood Decay Test.”)

Photo 1 shows an overview of the work area. In *Photo 2*, note the severe white-rot deterioration at one of the sections of hardwood OSB sheathing, while the surrounding hardwood OSB sections are relatively undamaged except for some localized brown-rot damage at the upper right corner. (The observed brown-rot decay has spread from an infested softwood-framing member behind the hardwood sheathing.)

The dramatic differences between the hardwood OSB panels are further highlighted in *Photo 3*. Note the water staining across the face of the otherwise undamaged middle section, tracing the route taken by the migrating moisture that promoted the severe white-rot damage at the OSB section at the right. Further, note that this moisture also has resulted in severe white-rot damage at the OSB section at the far left. Both damaged OSB sections are by the same manufacturer.

The severity of the white-rot deterioration at the left and right sections is advanced. As the panels became saturated and spongy, the fungi were able to spread vertically above the visible path of water flow denoted by the water stain. In striking contrast, the middle OSB section remains sound, firm, and undamaged.

- “The stain pattern from water infiltration that crossed three sheets of OSB revealed extensive damage to only two of the sheets. The middle sheet of OSB was not damaged.”¹⁹

Field inspection of mill stamps identified two manufacturers for the inspected OSB panels, which were manufactured in Minnesota and British Columbia.

- “Removal of the sheathing and subsequent analysis, including identification of “mill stamps” on the back of the panels, showed that two different types of OSB were installed at this area during construction. Inspection confirmed both types of OSB panels had been installed prior to siding installation and final inspection of the structure.”²⁰

The undamaged OSB sections were the panels manufactured in Minnesota.

Further evaluation at the Forest Products Laboratory, supported by review of online technical publications by the manufacturers, identified two major differences between the two panels: a) the British Columbia panels were found to be comprised of aspen (*populus sp.*) wood strands with an MDI binder; b) the Minnesota panels were comprised of birch (*betula sp.*) wood strands with a phenolic resin binder.

Unfortunately, the specific wood decay fungus could not be identified:

- “The visible decay fungus was not culturable from the mycelial sample ...”
- “Wood can be too decayed to recover a culture of viable fun-

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Photo 3 - Undamaged center panel is sandwiched by two white-rotted panels. (The dashed line traces the upper limit of the migrating water.)

gus or to give positive IWD results. In cases of advanced decay, where all wood components are utilized, growth of the decay fungus eventually stops ...²¹

Moisture readings with a Delmhorst meter, confirmed by laboratory testing, revealed moisture content levels typically less than 17% (13-15% for the damaged panels and 15-17% for the undamaged panels), indicating no recent conditions of water infiltration to the currently dry sheathing. The lack of viable decay fungi indicated a lengthy period had elapsed since the panels had last been wet. This situation likely was exacerbated by a dearth of appropriate food remaining within the ravaged panels, despite the mass of wood strands available in the adjacent undamaged panels.

- “The condominium complex was constructed in 1997. The winter of 1998-99 was the wettest on record for Seattle, with 34 inches of rain recorded between November 1 and February 28 (source: National Weather Service – Seattle). A forensic building envelope investigation discovered extensive decay in this complex in 1999.”²²

- Records for the 12-month period prior to the 2002 sampling indicate the total rainfall recorded in Seattle was 32 inches, more than 5 inches below normal. The summer months that preceded the sampling were the driest on record for Seattle, with less than 2 inches of rain recorded in a four-month period. Further, recorded rainfall during the year 2000 was more than 8 inches below normal, with the winter of 2000-2001 recorded as the second driest on record.²³

Summary Discussion

The OSB panels were installed at the same period of construction, as evidenced by the overlying steel strap seen in *Photo 2*. It is possible that the damaged panels had been infected with the white-rot fungi prior to installation, but the almost total absence of white-rot damage at the adjacent OSB sheathing is strong evidence that the OSB panels from Minnesota were highly resistant to this particular wood decay fungus.

The two major variables between the OSB brands were wood species (aspen vs. birch) and the binder (methane di-isocyanate vs.

phenolic resin). It is reasonable to assume that one or both of these variables caused the Minnesota panel to be deemed inedible by this particular specie of white-rotting *basidiomycetes*.

- Another potential variable, not explored in the joint ERD-FPL forensic analysis reported above, is the differing amounts of wax added to the binder during the proprietary manufacturing processes.²⁴ The potential effects of this added wax to the moisture exchange performance of wet OSB sheathing are discussed in “Moisture Exchange Performance of OSB and Plywood Structural Panels.”²⁵

These observations should not be construed as evidence that birch OSB sheathing manufactured with a phenolic resin binder can be expected to provide superior overall resistance to wood decay fungi; however, it is clear that under certain project-specific conditions, significantly varying decay-resistance performance will be afforded by some types of OSB panels. Further, the extent and severity of the deterioration may be exacerbated by the builder’s failure to properly weather-protect the panels prior to closing in the roof and walls.

This *ex post facto* information comes too late to benefit project design teams, but can be useful in various ways to forensic consultants evaluating building failures.

- For example, the two accompanying photos confirm that even a relatively small²⁶ amount of infiltrating water from one localized flashing failure can result in rapid total destruction of affected sheathing panels.
- Conversely, note that forensic sampling of only the middle OSB section could have led to a mistaken conclusion that the only results of the localized water infiltration had been simple water staining of the dry sheathing.

It should also be noted that the observed damage is strong evidence of the rapid rate of biodeterioration of structural wood products that can occur given the right conditions. Conditions of severe sheathing decay were observed throughout the project during the 1999 survey, only two years after construction. Given the near total bio-destruction of the dry OSB panels depicted in the photos, it must be assumed that:

- a. This damage also occurred primarily during the 1998-1999 period immediately following the project’s construction that included Seattle’s wettest winter on record; and
- b. Within the first year after project completion, the aspen OSB panels already had experienced significant and accelerating loss of structural integrity and performance. This one-year timeframe for structural failure can be an important factor in subsequent insurance claims analyses.

In summary, the building envelope consultant’s forensic analysis always must extend beyond a single point in time to evaluate the entirety of the possible conditions that could have led to the current problems. Clearly, a factor that may require consideration is the potential for significantly varying rates of panel degradation due to differences in the OSB composition, even if all of the inspected panels are from the same manufacturer. Rates of structural degradation can be further exacerbated if panels have been pre-infected during the construction process due to deficient weather protection. ■



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References

1. J.L. Bowyer, R. Shmulsky, and J.G. Haygreen, *Forest Products and Wood Science - An Introduction* (Fourth Edition), Iowa State Press, Ames, Iowa, 2003.
2. E.g., "Typical strand size is 4.5 to 6 inches long, 0.5 inches wide, and 0.023 to 0.027 inches thick (USDA 1999)." - Mackes, K. and Lynch, D., "The Effect of Aspen Wood Characteristics and Properties on Utilization," USDA Forest Service Proceedings RMRS-P-18, 2001. www.fs.fed.us/rm/pubs/rmrs_p018/rmrs_p018_429_440.pdf.
3. Various species belonging to the genus *populus* of the willow family (*salicaceae*). The poplar species native to North America is divided into three main groups: the cottonwoods, the aspens, and the balsam poplars.
4. *Liriodendron tulipifera* - not a true poplar.
5. *Wood Handbook - Wood As An Engineering Material*, Gen. Tech. Rep. FPL-GTR-113. Madison, WI, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, 1999. Chapter 10, p13.
6. Bowyer, Shmulsky, and Haygreen.
7. E.g., PS2-92 Performance Standard for Wood-base Structural-use Panels, National Institute of Standards and Technology, U.S. Department of Commerce, Gaithersburg, MD, 1992. www.apawood.org/pdfs/managed/S350D.pdf.
8. L. Haughton and C. Murphy, "Moisture Exchange' Performance of OSB and Plywood Structural Panels," *Interface* (Vol. XXI, No. 6), Roof Consultants Institute, Raleigh, NC, June 2003.
9. Bowyer, Shmulsky, and Haygreen.
10. Morris, P.I., "Understanding Biodeterioration of Wood in Structures," Forintek Canada Corp. / Canadian Wood Council, <http://www.durable-wood.com/pdfs/biodeterioration.pdf>.
11. Bowyer, Shmulsky, and Haygreen.
12. S. Miller, "Basidiomycota," University of Wyoming, 2001. <http://w3.uwyo.edu/~fungi/Basidios2001.pdf>.
13. *Wood Handbook - Wood As An Engineering Material*, Gen. Tech. Rep. FPL-GTR-113. Madison, WI, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, 1999. Chapter 13.
14. S. Miller, Basidiomycota, University of Wyoming, 2001. <http://w3.uwyo.edu/~fungi/Basidios2001.pdf>
15. Ibid.
16. Carll, C.G. and Highley, T.L., "Decay of Wood and Wood-Based Products Above Ground in Buildings," *Journal of Testing and Evaluation*, Vol. 27, No. 2, March 1999, pp. 150-158. <http://www.fpl.fs.fed.us/documnts/pdf1999/carll99a.pdf>.
17. "Binders and Waxes in OSB," Structural Board Association, 2002. www.osbguide.com/pdfs/TB114.pdf.
18. www.fpl.fs.fed.us/documnts/techline/II-3.pdf.
19. C.A. Clausen, L. Haughton, and C. Murphy, "Evaluating Wood-Based Composites for Incipient Fungal Decay with the Immunodiagnostic Wood Decay Test." General Technical Report FPL-GTR-142, Forest Products Laboratory, U.S. Department of Agriculture, Madison, WI, 2004. <http://www.fpl.fs.fed.us/pubs.htm>.
20. Ibid.
21. Ibid.
22. Ibid.
23. Source: National Weather Service - Seattle
24. "Binders and Waxes in OSB," Structural Board Association, 2002. www.osbguide.com/pdfs/TB114.pdf
25. L. Haughton and C. Murphy.
26. As evidenced by the total lack of damage to some of the OSB panels that had been wetted by the infiltrating water.

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Colin Murphy, RRC, FRCI, founded Trinity Group Fastening Systems in 1981. In 1986, he established Trinity Engineering, providing laboratory testing and forensic and material analyses of roof and building envelope components and systems. The firm, now known as Exterior Research & Design, LLC, is based in Seattle, WA, and has an office in Waterbury, CT.



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