

Got Shrinkage?

Why Wood Shrinkage Analysis Is Required by the Code

By Ray Wetherholt, F-IIBEC, RBEC, PE and Derek Hodgins, RBEC, PE, CCCA

While the two authors of this paper live at opposite ends of the United States (Seattle, Washington, and Clemson, South Carolina), both have first-hand experience regarding the importance of understanding and dealing with wood shrinkage in mid-rise wood-framed construction. Mid-rise wood-framed construction is typically four to six stories tall and may or may not include a concrete podium at the first floor. Both authors acknowledge that not dealing with wood shrinkage issues can have disastrous results, sometimes causing millions of dollars in damage.

What prompted the obvious need for this article is the fact that the experiences of the two authors occurred more than a decade apart from each other. Why is it taking so long for the construction industry to learn from early mid-rise wood failures that were documented so long ago? Once the West Coast folks figured out the importance of dealing with wood shrinkage, you would think that we would all have been able to benefit from their learning curve and not repeat the same mistakes on the East Coast. Not only has that not happened, but we also continue to design, approve, and construct mid-rise wood-framed buildings with predictable wood shrinkage problems. This opinion is based on the increasing volume of construction litigation that includes damages

related to this issue.

Since the *International Building Code* (IBC) requires that a shrinkage analysis be performed for wood buildings greater than three stories tall, starting with the 2003 edition,¹ it seems strange that there would be a need to discuss this issue in 2020. After all, since the building code establishes the bare minimum standards for construction, following the code is important if you expect to have a reasonably safe and durable building. However, for whatever reason, this issue is being completely ignored, misunderstood, and/or not properly dealt with by building officials, design professionals, and contractors, all of whom should be familiar with building code require-

ments, particularly requirements that have been around for 17 years.

This article is intended to provide some background regarding wood shrinkage; describe problems that can be caused by wood shrinkage; provide recommendations for design professionals, building officials, and contractors for dealing with wood shrinkage; describe problems with existing building code requirements; and provide recommendations for industry improvements. With any luck, the authors of this article, as well as those who read it, will experience fewer problems with wood shrinkage. For those who are not paying attention, we appreciate your business!

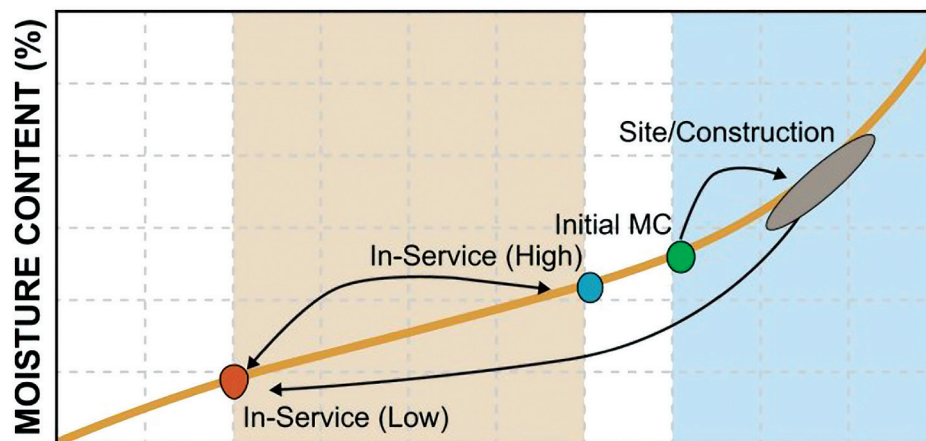


Figure 1 – This graphic showing the relative range of expected wood moisture content during a typical project. Source: RDH Building Science, Inc.

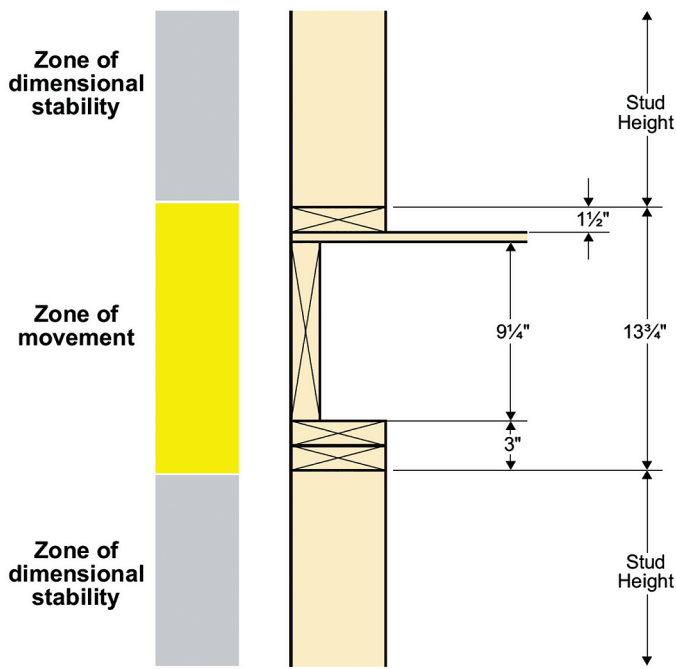


Figure 2 – This figure shows the zone of most significant wood shrinkage, located at the floor line.

BACKGROUND

Even before the 2003 IBC, there were references to wood shrinkage in building codes, but the requirement for an analysis to be performed

did not make it into the code until 2003, corresponding with the initial wave of mid-rise wood-framed buildings being constructed on the West Coast. According to Ray Wetherholt, “Seattle, Washington, was one of the hot spots for early mid-rise wood buildings.” However, it did not take long to realize that some of the first buildings of this type to be constructed were riddled with problems. Many of the problems were determined to be associated with wood shrinkage.

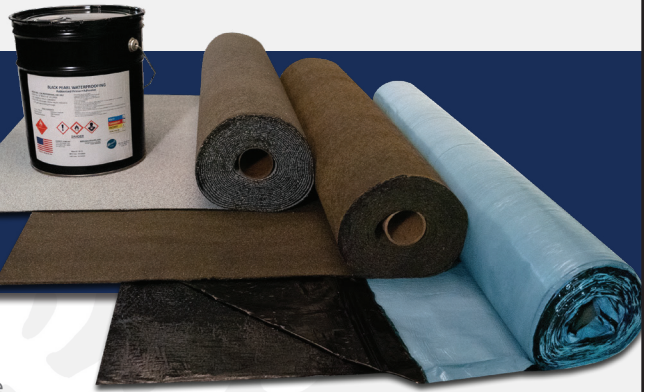
For those not familiar with the phrase, wood shrinkage is the

dimensional change in wood associated with a change in (loss of) moisture content. Figure 1 shows the relative range of wood moisture content that is expected during a typical construction project. Wood changes dimension in three directions: longitudinal (parallel to the grain), radial (perpendicular to the growth rings), and tangential (tangential to the growth rings). However, it is the tangential direction that is the most significant. Because the framing at floor lines often includes wood “bands” that are oriented such that the tangential shrinkage is vertical, the frame height is shortened. Figure 2 shows a typical floor construction configuration and the zone of most significant shrinkage. Obviously, the change in moisture content influences the extent of wood shrinkage. The wood species also influences the extent of wood shrinkage. On mid-rise wood-framed buildings that are four to six stories tall, wood shrinkage can be well over 1 in. The amount of time to experience the shrinkage related to moisture will be dependent on time of year and local climate. For instance, a desert location in summer should dry much faster than a location in Seattle built during the winter.

Combine shrinkage with frame compression (a separate issue that also contributes to a downward vertical movement), and the total movement can be closer to 2 in. These movements, while seemingly small, can wreak havoc on building components attached (or within)

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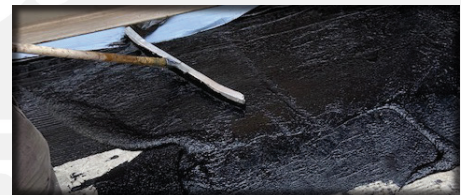
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Figure 3 – These two photos show the upward rotation of flashing caused by wood frame shrinkage.



the exterior walls. With basic design parameters, such as the wood framing design, the wood species, and the range of moisture content, the expected wood shrinkage can be calculated.²

Wood shrinkage is cumulative, from the bottom of the building to the top, with the most significant movement at the top floor.

PROBLEMS ASSOCIATED WITH WOOD SHRINKAGE

One of the most significant problems that arises when wood shrinkage is not accounted for is water intrusion related to deflection of

building components, such as flashing and balconies/walkways. As the wood framing of the exterior, load-bearing

walls shrink, the wall framing (and everything attached to it) is displaced vertically downward. If the vertical leg of through-wall flashing is attached to the exterior-wall framing, and extends over a somewhat independent cladding material, such as brick veneer or stucco, flashing rotation can result. Figure 3 shows two examples of this type of flashing damage.

Specifically, as the framing shrinks downward and the brick expands upward (do not forget that brick is the smallest it will ever be at the time of manufacture—it only grows in service), the flashing gets pulled into the wall cavity behind the brick veneer, causing the sloped leg of flashing to rotate upward.³ The flashing that you were counting on to direct water away from the building has now become a trough that holds water against the building, and if your flashing does not have end dams (which are not required by the IBC, but are required on housing by the NBCC), the flashing will direct concentrated flows of water into the exterior wall assembly. The concentrated areas' intrusion can result in significant

damage, including wood decay, mold, and corrosion of fasteners, among other issues. Figure 4 shows a typical example of concentrated water intrusion and associated damages.

When the exterior walls shrink, balcony/walkway framing will move as well. If the framing is supported by columns along the outer edge of the balcony/walkway, the movement can be significant. As the balcony/walkway rotates, any designed slope for drainage will be lost, and water will now be held on a giant horizontal shelf on the side of your building. Even worse, when these water shelves are rotated sufficiently to direct water *against* the building, even the best waterproofing efforts will be tested. You now have points of concentrated water intrusion into the building enclosure.⁴ With enough water, even well-intended and “code-compliant” wall designs can become overwhelmed. The term code-compliant is in quotes because buildings are often constructed with products and details that meet the *technical* aspects of the code, but fail to meet the reasonably safe and durable *intent* of the code. To add to the problem, the IBC did not require the waterproofed surface of balconies to be sloped until the 2018 IBC. Therefore, numerous projects have been constructed with flat balcony/walkway framing, requiring the waterproofing to be perfect, even though good practice was a slope of ¼ in. per ft.

There is often a detail to slope a porous concrete balcony/walkway surface for drainage. However, because the wood



Figure 4 – This figure shows concentrated water intrusion and associated damage.

Figure 5 – These photos show window and brick veneer damages caused by wood shrinkage.



shrinkage eliminates the designed slope, the flat (or reverse-sloped) balcony/walkway surface collects water that migrates through the concrete. Water is now held on top of the less-than-perfect waterproofing and possibly against the less-than-perfect exterior wall and/or the less-than-perfect door flashing. When these details are not perfect, damages will develop. By understanding the dynamics of the building assembly and incorporating more “best practices,” we can reduce the need for perfection. A good design should be able to accommodate reasonable workmanship; perfection is not required.

Probably the most common and easily identifiable issue related to wood shrinkage is the collision of brick veneer and windows. The fact is, if you terminate a few stories of brick veneer against (or even close to) the bottom of a window, damage will result if you have not considered the shrinkage. If this condition exists on a building—even one that is only a few years old—you are likely to find damage. When the damages are significant enough, this observation can be made while driving by in a car or during a casual stroll. The brick and window cannot avoid crashing into each other. The windows are attached to the wood-framed wall that is shrinking and moving downward. The brick veneer is attached to the wood-framed wall to provide lateral restraint, but is allowed to move vertically in a limited range. As the brick veneer expands, it pushes against the bottom of the window frame and everything else that is attached to the wall, and collides into the brick veneer. The photos in *Figure 5* show examples of window damage (crushing)

and brick veneer damage (cracking), both caused by the process described previously.

Another problem that can be caused by wood shrinkage is broken PVC plumbing pipes. Specifically, if a hole is cut through wood-wall framing to accommodate a plumbing pipe, the hole will need to be cut larger than the diameter of the pipe, such that a gap exists above the pipe that is equal to or greater than the shrinkage that is determined by the code-required analysis.⁵ Remember that shrinkage is cumulative, from the bottom of the building to the top, with the most significant movement at the top floor. It is important that, as the wood framing moves vertically downward, it does not come into contact with the PVC plumbing pipes. If a sufficient gap is not provided in the wood framing above the PVC plumbing, the wood framing can damage the plumbing, sometimes breaking a pipe clean off, as shown in *Figure 6*.

RECOMMENDATIONS FOR DEALING WITH WOOD SHRINKAGE

Design Professionals

Architects and structural engineers are the two types of design professionals that first come to mind regarding wood shrinkage. However, other design professionals, such as building enclosure consultants and mechanical, electrical, and plumbing (MEP) engineers, should

be aware of this issue to reduce the risk of damage to their designs, as described previously.

The architect is responsible for designing a building comprised of numerous parts and pieces. Each part and piece must fit together,



Figure 6 – This photo shows damages to PVC pipe caused by wood shrinkage.

06105: SHRINKAGE OF WOOD FRAMING

SHRINKAGE IN WOOD FRAMING IS DUE TO LOSS OF MOISTURE CONTENT AND TO COMPRESSION OF ASSEMBLIES OF WOOD COMPONENTS. PLUMBING, ELECTRICAL, AND MECHANICAL SYSTEMS, AS WELL AS EXTERIOR FINISHES, SHALL BE DESIGNED AND BUILT TO ACCOMMODATE ¼ INCH PER FLOOR WOOD SHRINKAGE. THE USE OF KILN-DRIED LUMBER AND PROVIDING A DRYING PROCESS TO THE FRAMING MEMBERS PRIOR TO APPLICATION OF FINISHES WILL HELP CONTROL BUT WILL NOT ELIMINATE SHRINKAGE.

Figure 7 – Example of wood shrinkage notes.

and stay together during the service life of the building. Because the parts and pieces are made of all types of materials, they behave differently. As with anything else, a building is only as good as its weakest link. Therefore, it is important to design and evaluate buildings as a system, and make sure that everything will “play nice” together over the long haul. Any potential for dimensional changes, loss of structural integrity, or functional compromise must be known, understood, and accounted for in the design process.⁶

Architect recommendations for dealing with wood shrinkage include:

1. Account for shrinkage at the floor line with slip joints in the sheathing and cladding.
2. Specify kiln-dried lumber and require it to remain dry and protected as part of the structural notes provided by the structural engineer of record.
3. Provide generous joints around dissimilar cladding materials.
4. Never terminate brick veneer against anything that is attached to the wood-framed wall, such as a window.
5. Exaggerate the slope on roof, balcony, and walkway framing (beyond code minimum) so that a positive slope for drainage is provided over the entire service life of the building, in coordination with the structural engineer.
6. Add notes on the plans and specifications regarding wood shrinkage potential.

A structural engineer who designs wood-framed buildings should be familiar with all properties of wood that may be relevant to the structural design of the building, not just the strength properties.⁷ In the world of wood-framed building problems, those properties include susceptibility to water damage, the potential for creep deflection, frame compression caused by workmanship issues, and dimensional changes related to changes in moisture content (that is, swelling and shrinkage). The

structural engineer would be expected to have the most direct knowledge of building code requirements related to wood structures. As such, a structural engineer should be familiar with the requirement for a shrinkage analysis for buildings greater than three stories. This analysis should be performed and shared with the architect, regardless of whether the local building official asks for it or not.

Structural engineer recommendations for dealing with wood shrinkage include:

1. Include a warning note on the drawings, to ensure the contractor is aware of the likelihood of shrinkage (see Figure 7).
2. Specify engineered lumber products when possible.
3. Do not allow “green” lumber. Dissimilar materials need to be accounted for, such as for steel framing, masonry, and concrete, compared to wood. These are called “hard points.”
4. Account for CMU walls that connect to wood framing. Wood shrinkage can result in a 1½- to 2-in. differential on a four- to six-story wood-framed building.⁸

Building Officials

A building official responsible for enforcing the building code should certainly be familiar with the requirement for wood shrinkage analysis. After being baffled by the extent of construction issues related to wood shrinkage, the East Coast author performed an informal survey of authorities having jurisdiction (AHJs) to determine why these issues were so common. The question was simply asked: “Has your office been enforcing the wood shrinkage analysis requirements as described by IBC Section 2304.3.3?” Some of the more revealing AHJ responses are generally summarized below.

1. “We were not aware of that building code requirement. Thank you for sharing this information. We will be sure to make our building officials aware of this issue.”
The most surprising aspect of this response was that this AHJ is associat-

ed with significant construction activity, including numerous mid-rise wood projects, some of which had experienced significant problems and associated repairs shortly after construction was completed.

2. “We are enforcing the wood shrinkage analysis requirements by requiring project plans to be signed and sealed.”

This is an interesting, but completely unacceptable response. It is not okay to ignore the code and to expect the design professional to prepare construction documents that adequately address all code-related issues. After all, the code requirement says that the shrinkage analysis is required to be performed in a manner that is “satisfactory to the building official.” How can code compliance be accomplished if the AHJ does not ask for the shrinkage analysis? If this AHJ enforced the code, they would at least know that this issue was being addressed. Assuming that design professionals will comply with this requirement without being asked to do so has resulted in problems.

3. “That has not been an issue that our office has enforced.”

It is unclear what is meant by this response. Perhaps it was not enforced in the past, but it is being enforced now? Maybe it has never been enforced, but it is being considered to be enforced now? It is possibly the nice way of saying the same as the first response of: “We were not aware of that building code requirement,” without admitting it.

Regardless of how building officials justify not enforcing this requirement, it needs to be enforced. At the very least, simply asking for the shrinkage analysis will put the design professional on notice of this requirement, and perhaps cause some discussion and/or consideration of this issue in the construction documents.

Building official recommendations for dealing with wood shrinkage include:

1. Enforce the building code requirement for wood shrinkage analysis, as the AHJ interprets.
2. Review the plans and specifications for indications that wood shrinkage has been considered.
3. Look for allowances for shrinkage during construction, such as elongated holes for plumbing, flexible plumbing joints, and slip joints at floor lines.

Contractors

As a contractor, it is reasonable to construct a building in accordance with project plans and specifications. It is also reasonable to rely on the design professionals to provide plans and specifications that meet or exceed building code requirements. However, a contractor also has an independent duty to know and comply with building code requirements. Certainly, a contractor is not expected to perform the required analysis, but should be familiar with the code requirements and know that wood shrinkage is an issue to be considered on tall wood buildings.

Contractor recommendations for dealing with wood shrinkage include:

1. Expect the building code requirement for wood shrinkage analysis to be enforced, and ask to see the results.
2. Review the plans and specifications for indications that wood shrinkage has been considered.
3. Provide allowances for shrinkage during construction, such as elongated holes for plumbing, flexible plumbing joints, and slip joints at floor lines.
4. Load the floors with materials to accelerate compression and shrinkage as each floor is constructed and before sheathing and exterior cladding.
5. Ventilate and dry down the moisture in the wood framing prior to sheathing and cladding.
6. Document the measures taken, and record the moisture contents of the various framing members. Have a third party (construction testing lab) do the testing and documentation if possible, paid for by the owner.

PROBLEMS WITH EXISTING CODE REQUIREMENTS

Section 2304.3.3 of the 2018 *International Building Code*⁹ stipulates when shrinkage consideration is required in wood-framed building design:

“Wood walls and bearing partitions shall not support more than two floors and a roof unless an analysis satisfactory to the building official shows that shrinkage of the wood framing will not have adverse effects on the structure or any plumbing, electrical or mechanical systems, or other equipment installed therein due to excessive shrinkage or differential movement caused by shrinkage. The analysis shall also show that the roof drainage system and the foregoing systems or equip-

ment will not be adversely affected or, as an alternative, such systems shall be designed to accommodate the differential shrinkage or movements.”

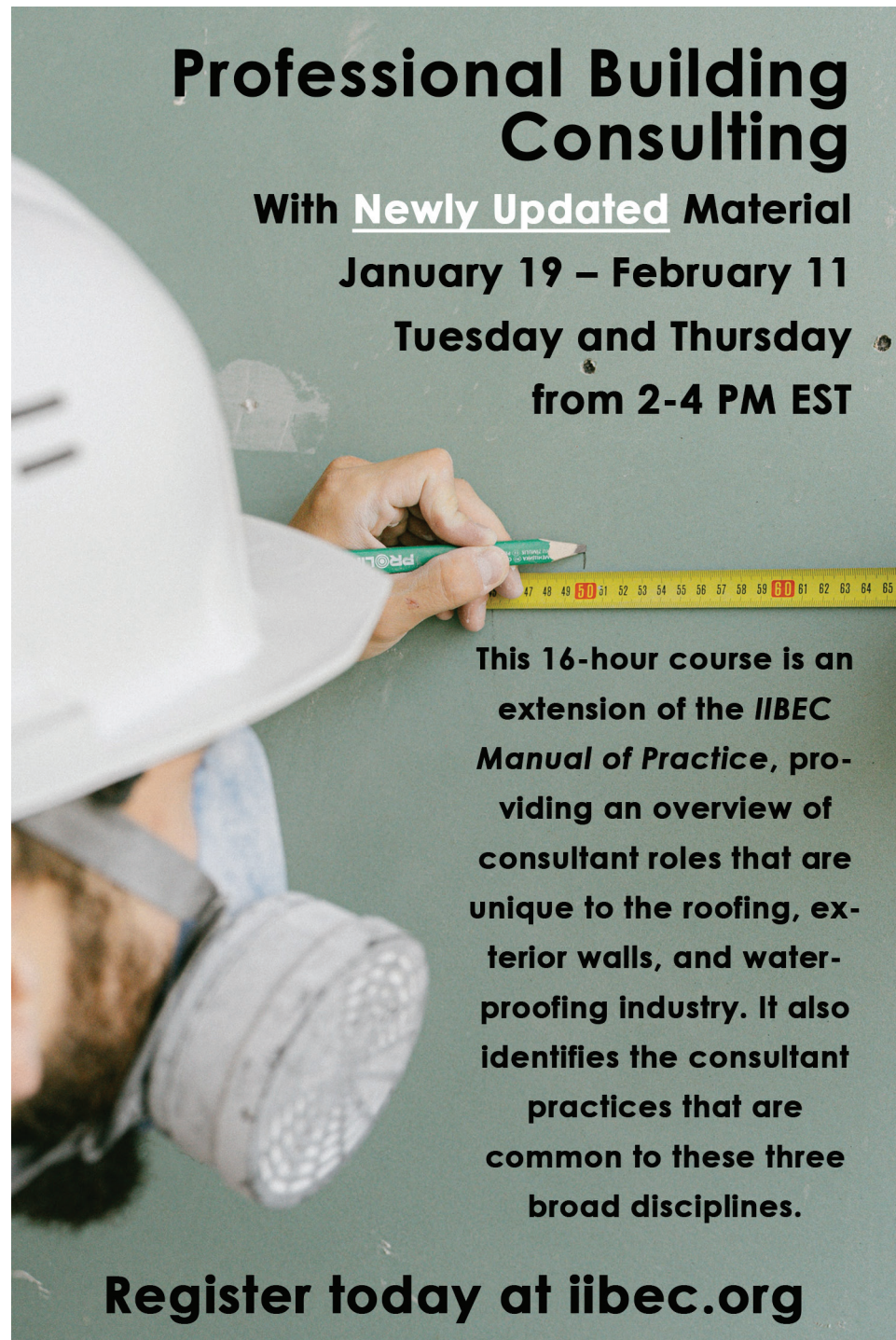
While it is great that the building code draws attention to this issue, the existing requirement falls short of delivering problem-free projects because it is not complete. While well intentioned, the building code does not go far enough. Specifically, the existing code requirement simply states that an “analysis satisfactory to the building official shows that

shrinkage of the wood framing will not have adverse effects” be performed. However, in order for the analysis to be of value to the project, the results of the analysis need to be shared with the entire construction team so that the design and construction details can accommodate the expected movement.

RECOMMENDATIONS FOR INDUSTRY IMPROVEMENTS

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the problem is accomplished by acknowledging and talking about the issue, from the design professionals, to the building officials, to the contractors. Also, because so many projects have already been constructed without proper consideration of wood shrinkage, we should consider educating owners, property managers, and repair contractors who will deal with these issues post construction for years to come.

The IIBEC Technical Advisory Committee is currently reviewing a Technical Advisory (TA) related to wood shrinkage issues. Once the bulletin passes through the peer-review process, it can be published and distributed to members of the construction industry. This will provide another educational opportunity to reduce future problems associated with wood shrinkage.

Building Code Revisions

As described previously, it is great that the code addresses wood shrinkage. However, because the current requirement is limited to simply performing an analysis to the satisfaction of the building official, it has not been adequate to eliminate significant building performance problems. One must verify that the results of the analysis have been provided to the entire construction team so that design and construction details are developed to accommodate the vertical movement. Perhaps a code revision that simply requires a statement on the project plans that summarizes the results of the wood shrinkage analysis, and that the analysis has been incorporated into the project design, would be sufficient to raise attention on this issue.

In summary, the AHJ, contractor and sub-contractors, and design team need to be aware of the shrinkage issues and account for them in the design and construction of the project to avoid problems after project completion. 

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Ray Wetherholt

Raymond Wetherholt, F-IIBEC, RBEC, PE, started Wetherholt and Associates in Redmond, WA, in 1984. Prior to that he worked for a commercial construction inspection and testing company as their inspection supervisor and special projects troubleshooter.

He has consulted on a broad array of projects throughout the Pacific Northwest, ranging from commercial projects to residential green roofs, manufacturing buildings, and the Experience Music Project. In 2013, he received IIBEC's Outstanding Educator Award, and he was named a Fellow of IIBEC the same year.



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In 1989, IIBEC Member Benjamin Scales, RRC, RRO, made the decision to drop out of the University of Kentucky (UK). Thirty years later, he finished his bachelor's degree. Scales was successful in business—as president of Scales Development—but always regretted not finishing his degree.

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