MITIGATING RISK WITH HIGH-PERFORMANCE structural wood panels

With the weather-resistant barrier integrated into each panel, the risk of loose laid wrap tearing during construction and increasing exposure to moisture is minimized.

PROVIDED BY HUBER ENGINEERED WOODS LLC

LEARNING OBJECTIVES

After reading this article, you should be able to:

+ DELINEATE the primary risks inherent in the design and construction of floor, wall, and roof systems in light-frame wood, low-rise multifamily construction.
+ EVALUATE the pros and cons of existing construction solutions to mitigate these risks and enhance the health and welfare of building occupants.
+ LIST potential failures associated with traditional floor, wall, and roof systems.
+ DISCUSS best practices to mitigate risk in the product specification and selection process for designing and building safe, sustainable multifamily dwellings.

The recent burst of activity in multifamily construction has magnified the financial risks to property owners, designers, and contractors, who must consider the potential liability of being involved with dozens, or even hundreds, of condominium owners or apartment renters on a project.

These risks have been heightened by the mass exodus of qualified skilled construction workers from the workforce during the Great Recession. The Associated General Contractors of America estimates that most of the two million construction workers who lost their jobs either retired or found other work. The remaining less experienced trades workers are being asked to build very sophisticated building envelopes with increasingly complex core structural elements.

Add to that heightened demand from cost-conscious developers focused on speed and volume of completed work, sometimes to the detriment of quality and attention to detail.

THREE BIG RISKS TO THE BUILDING ENVELOPE

There are three major risks to the key elements of the building envelope—floors, walls, and roofs—of light wood frame structures: **1) moisture management, 2) improper installation, and 3) potential structural failure.** These risks can have disastrous effects on the building and on the comfort and safety of its occupants. They can lead to expensive rework and even potential litigation.

1. Moisture and air management during construction and preventing the intrusion of unwanted moisture and air through the building envelope should be high priorities for Building Teams. High-performance panels provide solutions to these problems based on two factors: their ability to resist moisture absorption and intrusion and their ability to promote drying. These capabilities translate to superior performance from high-performance subfloor panels by minimizing damage to finished flooring due to moisture-related swelling and underfloor movement.

High-performance wall and roof panels manage moisture by creating a barrier that repels bulk water intrusion, yet allows water vapor to diffuse through the panel. Air/vapor leakage out of a structure, known a exfiltration, can lead to moisture condensation in wall cavities or other parts of the structure. Inadequate air barriers may allow heated or cooled air to leak to the outside, unnecessarily wasting energy and adding to the owner's costs.

2. Improper installation. Poorly installed roof coverings, improperly fastened structural wood sheathing, faulty flashing, open seams be-

tween sheathing or subfloor panels, poorly flashed windows, tape that fails to make a weathertight bond—all can contribute to improper functionality of a structure. Incorrect use of materials and lack of attention to detail in their installation can lead to more complex and expensive problems: floor bounce or squeaks, water condensation in wall cavities, air leakage, mold and mildew, and higher energy bills.

Building envelope and subfloor problems that lead to structural damage or impact the finished materials that rest upon the structural elements could result in millions of dollars of rework. The repair process costs the developer time and money, takes profit dollars out of the contractor's wallet, and can disrupt the property owner's business. Situations like these can end up in court.

3. Potential structural failure. According to ASHRAE, 90% of all building and building material failures involve moisture damage. Some industry watchers claim that as much as 80% of construction litigation can be traced to moisture failure. Structural failure can take the shape of an unhealthy living environment if mold is an issue, or it can disrupt occupant comfort due to an uneven floor with nail pops, squeaks, or bounce. While not all incidences of moisture intrusion or improper installation lead to severe damage, prolonged exposure to moisture can result in the weakening and decay of structural members. The potential for structural failure to floors, walls, and roofs must always be addressed.

THE ROLE OF SUBFLOORING IN THE FINISHED FLOOR

The finished floor is only as good as the subfloor it rests on. The ideal subfloor minimizes moisture absorption during construction. Exposure to snow and rain during construction constitutes a significant threat to the integrity of a subfloor. It can result in edge swell, thickness swell, and possible delamination in the subflooring.

Excessive moisture in flooring panels can also lead to a weakening in the holding strength of fasteners. The problem usually shows up in the form of swelling and buckling hardwood floors. Excessive moisture in the panel transfers to the unfinished backside of the hardwood, resulting in the hardwood floor moving and pulling away from the subfloor: the fasteners just don't have the strength to hold the flooring. Moisture absorption in the subfloor can lead to loss of structural strength that can diminish the safety, durability, and overall performance of the floor system, not to mention squeaking and cracking of the floor finish.

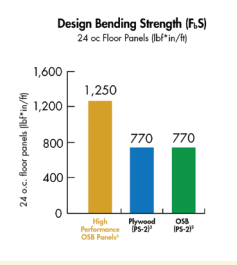
Unusually heavy materials such as marble or concrete countertop surfaces can create excessive loading on the subfloor that can lead to unwanted deflection over time, a phenomenon called *dead-load creep*. Most wood-framed floors are designed to resist 10–15 psf of material weight. A 1¼-inch-thick granite countertop exerts a force of 18 psf. This overstress can lead to movement over the life cycle of the floor system. Moisture absorption in subfloor panels can further weaken the panel. With the added weight of the materials, the floor will deflect (or "creep") over time, producing cracks in the floor surfaces.

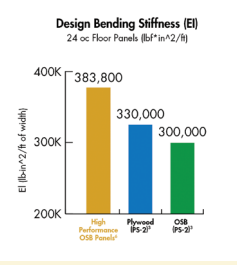
The likelihood and severity of subfloor problems is highly dependent on the type of subfloor used. The existing options are *oriented strandboard* (OSB), *plywood*, and *engineered high-performance panels*. OSB is particularly susceptible to moisture absorption through the face and edges of the panel. This can lead to edge swell and require additional sanding of the subfloor panels, driving up the cost of the finished flooring. Plywood may wick moisture at the seams and is prone to warping, cupping, and veneer delamination.

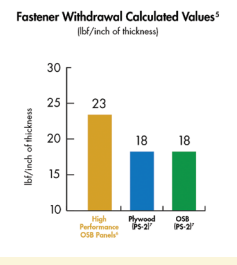
STANDARDS: PS 2 VS. ESR 1785
providing guidance for specifiers

Industry standards can help guide designers in specifying higher performing products that achieve durability, efficiency, and structural integrity in subfloors for multifamily projects. The minimum standard for structural wood panels is PS 2, a performance standard, now in its 10th edition (PS 2-10), that was developed by the Engineered Wood Association (www.apawood.org). PS 2 is published by the National Institute of Standards and Technology (nist.gov).

PS 2 establishes structural criteria for assessing the acceptability of wood-based structural use panels for sheathing and single-floor applications. Designers may consider selecting subfloor panels with design properties tested and proven to produce greater, more consistent levels of panel strength, stiffness, and fastener holding power than those required by minimum PS 2 standards. Doing so may add a layer of protection to the design and construction process.







The International Code Council Evaluation Service provides technical evaluations, called Evaluation Service Reports (ESR), for manufacturers that want to validate and qualify their products as having design properties superior to those that only meet the PS 2 standard. An ESR signifies that the high-performance panel product has passed a battery of testing protocols proving greater levels of panel strength, stiffness, and fastener holding power. ESRs for high-performance panels have been shown to have:

- > 60% better bending strength than OSB or plywood panels of the same dimension that meet only the minimum PS 2 standards
- > 25% better bending stiffness than OSB meeting PS 2 standards
- > 15% better bending stiffness than plywood meeting PS 2 standards
- Up to 10% better fastener holding power than plywood or OSB meeting PS 2 standards.

Tests reveal the high-performance subfloor product carrying the ESR-1785 designation to demonstrate higher strength, stiffness, and fastener-holding power design values than plywood and traditional OSB that only meet PS 2 code guidelines. See http://bit.ly/1pbG3HC for ICC-ES ESR-1785 Report.

High-performance panels are designed with advanced moisture-resistant resins and higher wood density than traditional OSB. They offer better moisture resistance than commodity OSB and plywood, come with longer warranties—in some cases, up to 500 days—and guarantee no sanding due to edge swell. Some high-performance panels are designed to offer up to 10% better calculated fastener holding power than plywood or OSB. According to ICC ESR-1785 (http://bit.ly/1pbG3HC), they are engineered to exceed design values of plywood and commodity OSB in strength and stiffness.

To help minimize installation defects, some manufacturers of high-performance panels offer precisely milled self-spacing tongue and groove profiles, plus a fastening guide for easier installation. In specifying high-performance panels, especially in high-traffic or weight-bearing areas, designers should consider subfloor products that have been tested and reported to have design values that exceed PS 2 standards (see box on opposite page for more on PS 2).

WALLS AND ROOFS—INTEGRATED SYSTEMS VS. BUILDING WRAPS

In designing moisture resistance into wall and roof systems, three factors must be considered:

1. Bulk water must be kept from getting inside the structure, where it can not only damage contents, but can lead to mold and structural failure if structural elements are not allowed to dry properly. A bulk water barrier can prevent this.
2. Vapor permeability allows airborne moisture from showers, kitchens, and occupants to migrate through the building envelope to the outside.
3. Exfiltration, which carries air out of the building, is just as important as infiltration. Air leakage can carry moisture into unwanted places, which can lead to rot, mold, energy loss, and poor indoor air quality. To be effective, an air barrier system must be continuous—no holes, openings, or penetrations—and resistant to air pressure differentials. Particular attention should be paid to inadequately sealed penetrations in the exterior wall, such as electrical outlets or mechanical openings.

Traditional methods of managing moisture and air intrusion—caulking, building felt, and traditional building wraps—have their shortcomings. They must be properly sealed at all penetrations, a complicated, time-consuming task. Building wraps are prone to tearing from mishandling or high winds. The adhesion between the flashing material and the tape is sometimes wanting. Installation details for some of these products can be hard to follow.

Some perforated wraps may result in the passage of water and air or have low abrasion and tear resistance. With macroporous perforated building wraps, the macro holes in the film provide vapor permeance but sacrifice air and water resistance. Some microporous products may not be sufficiently resistant to abrasion or tearing. Asphalt papers and felts may be more moisture resistant but less pliable.

The advantage of roll- or sprayed-on water-resistant barriers is that they will stay on the wall without ripping or tearing. However, they must be installed at a specific thickness. They require specific multi-step installation instructions for different substrates: achieving consistency is not easy. They must be applied to a completely dry surface, may require multiple coats and dry time, and have temperature restrictions.

To address these problems, one manufacturer is offering a new approach: high-performance panels with an integrated weather-resistant barrier that install easily with minimal environmental installation restrictions. With high-performance panels that have integrated weather-resistant barriers, there is no risk of water being trapped between the panel and the water-resistive layer as they are fused together. Further, integrated systems are specially engineered to allow permeability. To allow for outward drying, a water-resistive barrier must have a higher permeance, or permeability level, than the OSB panel behind it. A permeability of 12–16 perms is considered adequate to allow for outward drying of the system while also keeping excessive exterior moisture out.

Because the sheathing's weather-resistive barrier is permanently fused to each panel, there is little to no risk of it being ripped or torn. This ensures that the structure panel will not be exposed to physical damage or bad weather. By contrast, the wood surface of a traditional OSB and building wrap system can be compromised when the wrap is ripped or torn, exposing the underlying wood surface to rain, snow, or other moisture.

FLASHING TAPE—THE CRITICAL ELEMENT

All weather-resistant systems require fasteners to secure their positioning, sealing tape to seal the edges, and flashing tape to integrate with other building elements. Individual manufacturers will provide a compatible tape that seals the edges of its weather-resistant barrier system to

GET THE FLASHING DETAILS RIGHT

Flashing should be an important consideration in maintaining air tightness in multifamily buildings. Wall systems require flashing to integrate and maintain a continuous water-resistive barrier. In many cases, flashing is missing or poorly installed. In large-scale buildings, the effect of the resultant moisture and air leakage can add up, compromising occupant comfort and increasing utility bills. Well-respected building science organizations recommend that structures be built as tightly as possible, but with a properly designated ventilation path. ASHRAE stipulates that sealing, caulking, gasketing, or weather stripping is necessary for:

- Joints around fenestration and door frames
- Junctions between walls and foundations
- Walls and building corners
- Walls and structural floors and roofs
- Walls and roof and wall panels
- Joints, seams, and penetrations of vapor retarders
- All other openings in the envelope.

The type of flashing used should have a service life equal to that of the building.

each other. The main requirements are ease of use and durability when exposed to the elements and the effects of UV radiation. Where manufacturers differentiate themselves is in how their flexible flashing tapes integrate other building elements with the weather-resistant barrier.

There are two critical areas where the continuity of the weather-resistant barrier can be compromised by a poorly designed or incorrectly installed flashing system: windows and protrusions.

From metal flashing pans, to advanced sealants, to recent developments in flexible windowsill applications, windows and window flashing are now recognized as a significant area of risk for water intrusion. Stretchable acrylic-based sealant tape allows for one-piece window pans with no voids, easily solving the threat of water infiltration through windows.

Protrusions are most often the result of mechanical systems needing access between the interior and exterior of a structure. Here, too, stretchable acrylic-based sealant tapes provide a high-quality solution for preventing leaks between the building envelope and mechanical protrusions.

Stretchable flashing tape provides significant advantages over traditional metal flashings and nonflexible flashing tape. Today's acrylic tapes are engineered for superior durability and temperature range. They have been shown to perform so well that they are routinely used not only in construction but in high-performance automotive, marine, and aviation applications as well.

Tapes with acrylic adhesives—water-based, solvent-based, or "solid,"—are becoming increasingly popular. Water-based acrylic tape adhesive, while the least expensive, may not bond to as many types of substrates as the others. Solvent-based adhesives can become brittle over time.

According to BuildingGreen.com, "solid acrylic adhesives can form the strongest adhesive bonds at a wide range of temperatures and even achieve adhesion to damp or wet substrates." Solid adhesives contain no solvents and do not become brittle. Made of highly polar molecules that pull the adhesive into the substrate, these advanced acrylic tapes are formulated to flow into every crevice, increasing total contact area and producing a lasting seal that is considerably stronger than those of traditional asphalt and butyl tapes. With both robust adhesion and cohesion, advanced acrylic tapes are internally strong—intertwined polymer chains provide excellent internal strength, adding to the overall reliability of the seal.

LOOK FOR EASE OF INSTALLATION

Integrated sheathing and tape systems have a labor-saving edge over traditional building wraps by providing an all-in-one installation process versus the more labor-intensive two-step process required by loose-layered building wrap systems. In systems where the protective layer is permanently fused to each panel, the sheathing and tape can streamline the process, eliminating many windy-day installation problems and rips and tears from contractor mishandling.

Using high-performance panel sheathing with an integrated weather-resistive barrier minimizes exposure to the elements by providing quicker dry-in and shortening construction cycle times. Rough dry-in keeps the elements away from unprotected wood framing. Unlike loose-layered building wrap systems, integrated water-resistive barrier products do not require as many application steps to create a weather-resistant barrier: as soon as high-performance panels are installed and taped, other trades can begin work. A study by Home Innovation Research Labs found that integrated sheathing/tape systems installed more than 40% faster than a traditional sheathing/building wrap tape system.

Integrated sheathing and tape systems help protect against air leakage while allowing sufficient vapor permeability.

TOWARD A BEST PRACTICE SCENARIO

When it comes to achieving a structurally durable, weather-tight structure, the evidence points to specifying reliable, high-performance floor, wall, and roof sheathing products that have been third-party tested, meet standardized tests, and are easy to inspect for installation and quality by code officials.

For floors, walls, and roofs, high-performance panel systems offer increased reliability, provide building professionals with durable, energy-efficient systems that are easy to install, and yield superior resistance to water intrusion and air infiltration. High-performance panels also can carry superior warranties when installed according to the manufacturer's instructions—an indication of the manufacturer's confidence in these materials.

As building code performance standards become more stringent and condominium buyers and apartment renters become more demanding, a durable structure that mitigates the risks associated with inadequate moisture and air management, improper installation, or structural failure is an economic necessity. High-performance subfloor panels and exterior sheathing with integrated weather-resistive barriers are engineered to provide developers, architects, builders, and consumers an advantage in mitigating these risks. They are changing the way professionals build and manage risks in multifamily construction.

> EDITOR'S NOTE

Additional reading is required for this course.
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MEASURING THE TESTING SYSTEMS

Designers, contractors, developers, and property owners can benefit from an understanding of the major testing platforms used for vapor/air barrier systems:

ASTM E2273. Testing under ASTM E2273, the Standard Test Method for Determining the Drainage Efficiency of EIFS Clad Wall Assemblies, confirms that properly installed water-resistant panels and tape perform substantially better than traditional building wrap systems. Under third-party testing conducted by Architectural Testing, Inc., the integrated WRB sheathing/tape system achieved >90% drainage; the traditional sheathing/building wrap tape system achieved <10% drainage.

ASTM Water Penetration Test. Using modified ASTM E33 criteria, testers simulated a heavy 8-inch/hr rainfall with a constant wind of 35 mph on an integrated WRB and tape system and a traditional building wrap, both installed to manufacturer specifications. ASTM E331, the Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference, is commonly used on window openings. For this test, it was modified to spray directly on the wall systems to examine how the fastener penetrations held up against water intrusion. In one test, a traditional building wrap was secured using the 1-inch crown staples recommended in manufacturer instructions, while the sheathing and tape system was installed with the recommended pneumatic framing nails. A separate building wrap test also was run using button cap nails, an alternative manufacturer-recommended fastener.

In both tests, the high-performance panel with integrated WRB allowed less water to penetrate the WRB system compared to the fastener penetrations of the traditional building wrap system. Using manufacturer-recommended fasteners in the building wrap system, bulk water entered the staple holes created during the installation process, exposing the wood panel beneath the wrap to moisture. However, moisture exposure in the integrated WRB system was limited to the wood fibers directly around the nail heads and not the entire panel. Unlike the bulk water intrusion of the building wrap system, the integrated WRB managed the water exposure. In addition, no visible water entered the sheathing and tape-system wall cavity. Furthermore, in-the-field testing under ASTM E1105, Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference, confirmed the sheathing and tape system's water management capabilities, noting that even with over-driven fasteners, the sample wall passed the test at over 25 times the required pressure.

Many homes now require blower door air-leakage testing to confirm that their air-barrier assemblies meet code-recognized performance targets. Using ASTM E2357, a common, standardized test method for measuring the air leakage of air barrier assemblies, third-party testing indicates that sheathing and tape systems provide a tighter air barrier assembly than traditional building wrap which, in this test, did not pass the standard required for recognition as an air-barrier assembly. While the sheathing and tape system passed testing at seven different air pressure levels required under the code-recognized test methodology, the traditional residential building wrap failed at higher pressures, ripping or puncturing to expose the OSB surface beneath the wrap. Sturdier, more expensive commercial versions of the traditional building wrap were required to successfully pass the test.

DEALING WITH WARRANTIES: what you should look for

A product's warranty indicates the level of confidence the manufacturer has in its product. Industry warranties for subfloors range from no warranty to a limited lifetime, with the warranty highly variable between products and manufacturers. The unique density and advanced moisture-resistant resin technology used in high-performance panels enable their manufacturers to offer extended or limited lifetime warranties. Some subfloor manufacturers are able to offer, for example, no-sand warranties of up to 500 days because of the increased performance of their products. Specifying products backed by a high level of warranty against exposure damage protects the integrity of the building during construction and the life cycle of the structure.

In many cases, architects and builders use multiple systems from multiple manufacturers that require multiple layers of installation or application. For example, in traditional methods when sheathing is installed and the WRB installed at a later date, there is a gap in time where problems can occur, from overall exposure to covering misplaced protrusions or other openings in the structural sheathing. At best, this component or layered approach means there is a greater possibility of error among the systems; at worst, there is the potential for systems to work against one another to the point of voiding the warranty of one or more products. Each manufacturer of each different layer has a specific set of installation instructions. If they are not followed specifically, there is the possibility of voiding the warranty on that particular component of the layered system.

By contrast, in products where the WRB is integrated with the structural sheathing, a weather-tight seal is created simultaneously with the sheathing application when the tape is applied, minimizing the chance of errors. When it comes to considering warranties for roof or wall systems compared to two-step sheathing applications that require building wrap, there are great efficiencies in one warranty that covers moisture and air protection. Another point of differentiation is the warranty on various products—traditional building wraps typically carry a 10-year warranty, yet integrated systems can be warranted, for example, for 30 years, and may carry a 180-day exposure guarantee against extreme weather and UV exposure during construction.

THIRD-PARTY TEST CASE STUDY: integrated panels vs. traditional wrap

Third-party testing demonstrates the labor efficiency of integrated WRB panel and tape systems. Under observation by Home Innovation Research Labs, a professional framing crew was tasked with completing full-scale installations of an integrated WRB sheathing/tape system and a traditional sheathing/building wrap tape system. To ensure equivalent comparison, a three-man framing crew with in-the-field experience in the proper installation techniques of both systems was recruited to install both systems on a two-story mockup of a typical 1300-sf residential house. Recognizing that building site and weather conditions vary by location, testing was conducted in a controlled indoor environment to ensure that the two products were installed under similar conditions, as recommended by the manufacturers' instructions, with limited environmental influences. To reflect the typical mix of inside and outside wall corners of a new American home, the test structure featured 12 windows, two door openings, and walls with and without openings, alcoves, and bump-outs. The Home Innovation Research Labs third-party test confirmed that the integrated WRB sheathing/tape system installs substantially faster than a traditional sheathing/building wrap tape system.

While sheathing systems and traditional OSB install at a similar pace, the full-scale test found that significant time savings are gained in the time required to create a weather-resistant barrier: an integrated WRB sheathing/tape system installed more than 40% faster than a traditional sheathing/building wrap tape system. In addition to the overall labor savings found by Home Innovation Research Labs, the testing also found that installing windows and head flashing was easier with sheathing and tape than with traditional building wrap, requiring fewer steps and less time.

Multifamily construction is following this trend toward tighter air barrier requirements. Beginning with the 2012 International Energy Conservation Code (IECC), the 2012 International Green Construction Code (IgCC), ASHRAE 189.1-11, and ASHRAE 90.1-2010 all have requirements for air barriers. These codes and standards are all increasing the energy efficiency of buildings by requiring air barriers to seal a building from air infiltration and exfiltration.

IBHS Hurricane Effect on Integrated WRB and Taped Roof. Wind-driven water damage from hurricanes causes hundreds of millions of dollars in damage annually—a figure that can increase to billions when a hurricane makes landfall. In a first-of-its-kind test, the Insurance Institute for Business and Home Safety examined the comparative effects of a simulated hurricane on a roof deck that was sealed with tape and one that was not. Testing was performed on a fully furnished 1300-square-foot duplex house with construction features representative of houses in hurricane-prone areas of the U,S. The structures were transferred to the 21,000-sf IBHS lab where 105 350-hp fans subjected the structures to several tests, including high-speed multi-directional winds and prolonged exposure to rain typical of hurricanes. Once the roof cover on the units blew off, researchers conducted a wind-driven rainstorm test for just over an hour, which included rain in the amount of up to eight inches of water per hour, typical of a hurricane situation.

The difference between the unit with the sealed roof and the non-sealed roof was dramatic. In the non-sealed roof unit, in which there was no tape covering the seams between the layers of plywood or OSB sheathing, damage was substantial. The kitchen ceiling collapsed. The chandelier in the dining room fell from its mount and debris was widespread—in short, this unit experienced the level of damage that would render it uninhabitable for weeks, if not months. The unit with the taped roof deck suffered far less damage. This unit prevented substantial water from entering. As Julie Rochman, President and Chief Executive Office of IBHS, put it in a video presentation, "Sealing the roof deck will go a long way toward keeping wind and water out of the home."

Florida Building Code Housing Testing Application Standard 100-95. Another third-party test conducted by PRI Construction Materials Technologies of a modified Florida Building Code Housing Testing Application Standard 100-95, Test Procedure for Wind and Wind Driven Rain Resistance, showed that integrated systems and tape are more durable than traditional building wraps. The TAS-100 test as applied to roof application measures the ability of systems to resist water infiltration under wind. Modified for testing on walls, integrated weather-resistant barrier sheathing and tape systems remained intact and performed to the highest test setting, while the traditional building wrap system failed under wind speeds between 70 and 90 mph.

INSPECTABILITY OF WRB PANELS creates a smoother path to reliability

Inspectability leads to reliability. Without an integrated high-performance panel, a workable wall inspection is virtually impossible. Wall penetrations are often moved or duplicated and not repaired correctly. A layered system with faulty patching, or no patching at all, will be hidden behind the layered WRB, or masked by the liquid applied membrane, rendering a wall inspection essentially futile. If the structural layer is not inspected prior to the application of the WRB, what lies behind the WRB will remain unknown. With an integrated structural/WRB high-performance panel, both systems can be inspected simultaneously, with everything visible and potential problems can be easily identified. This results in a better constructed home or multifamily structure and an easier inspection process for both the builder and the code official.