Case Studies: The Perils of Poor Rim Joist Closure Construction

Introduction

In 1999, renowned building envelope guru Joseph Lstiburek, PhD, PE, of the Building Science Corporation in Westford, MA, published a lengthy study, "Air Pressure and Building Envelopes", demonstrating that: "*Control of air pressure is key to several important performance aspects of the building system*."[1]

Dr. Lstiburek's informative analysis includes performance comparisons of "*well-defined*" and "*poorly-defined*" air-pressure boundaries, including the "*wind tunnel effect*" produced by "*leaky*" rim joists (aka, band joists) at multistory buildings. As depicted at Figure 1 below (closely derived from Figure 18 of Dr. Lstiburek's report), rim joists enclose the semi-conditioned interstitial floor space between the conditioned levels of a building.[2]

At the four sides of a building, these potentially problematic rims are both *parallel* and *perpendicular* to the interstitial floor joists. When air pressure boundaries are not contiguous with building envelope thermal boundaries due to poor rim closure practices, pressure differentials readily can convey warm humid interior air to the colder back side of cladding/sheathing assemblies, causing highly damaging condensation and ensuing decay and degradation.[3]

Despite widespread recognition by modern designers and consultants of the importance of "air barriers", our firm continues to see litigation claims where cladding subcontractors are being solely faulted for hidden decay, degradation, and fungal growth that instead should have been attributed (in full or in part) to the problematic effects of pressurized interior air leakage caused by poor rim enclosure practices at buildings with both traditional and "open web" (as seen in Photo 1) floor joists.

Case Study 1 – Telltale Evidence of Damaging Condensation of Interior Water Vapor

Consider a large apartment complex in Sacramento, CA with 26 two-story, wood-framed multiunit buildings clad with traditional stucco and fiber-cement lap siding, at which decay and fungal growth have been found within exterior wall cavities at first-floor units. The ceilings at these lower apartments are attached to the bottom side of the open web floor joists structurally supporting the upper units.

At many of these first-floor apartments, widespread decay and damage were found *within* the cavities of certain exterior walls; however, such damage did not extend above the rim joist transitions to the upper units. For the following reasons, we concluded that these conditions generally resulted from cold-weather vapor condensation, as opposed to the effects of localized rainwater infiltration:

- The pervasive and uniform nature of the damage;
- The primary location (only at the first-floor units) and primary positioning (at *interior* face of the building paper or the engineered wood sheathing panels) of these conditions;
- Water spray testing of the stucco cladding at severely damaged walls produced no interior leakage; and
- As further reviewed below, our investigation revealed grossly deficient rim closure practices that certainly created the discontiguous pressure/thermal boundaries decried by Dr. Lstiburek.

Per Photos 1 to 3, the stucco cladding at some buildings was backed only with "line wire" – i.e., without any underlying sheathing. As seen at Photo 1 (after removal of loosely laid insulation batts atop the ceiling boards), the thermal boundary at the open rim, perpendicular to the floor joists between the semi-conditioned interstitial air and the inner face of the cold-in-winter stucco plaster, consisted of nothing more than asphaltic building paper, which has minimal insulative properties and does not function as an air barrier.

Upon preliminary investigation, we concluded that the marginal rim closure found at these first-floor units (all of which had only one *parallel* and one *perpendicular* rim – differing from generalized Figure 1) most likely had promoted air pressure differentials that conveyed humid air from the semi-conditioned interstitial spaces above the ceilings down into the cold-in-winter stud bays. We noted the many remnants of fiberglass insulation that remained stuck to the building paper, indicating that it had been excessively wet at times in a manner consistent with water vapor condensation during cold weather.

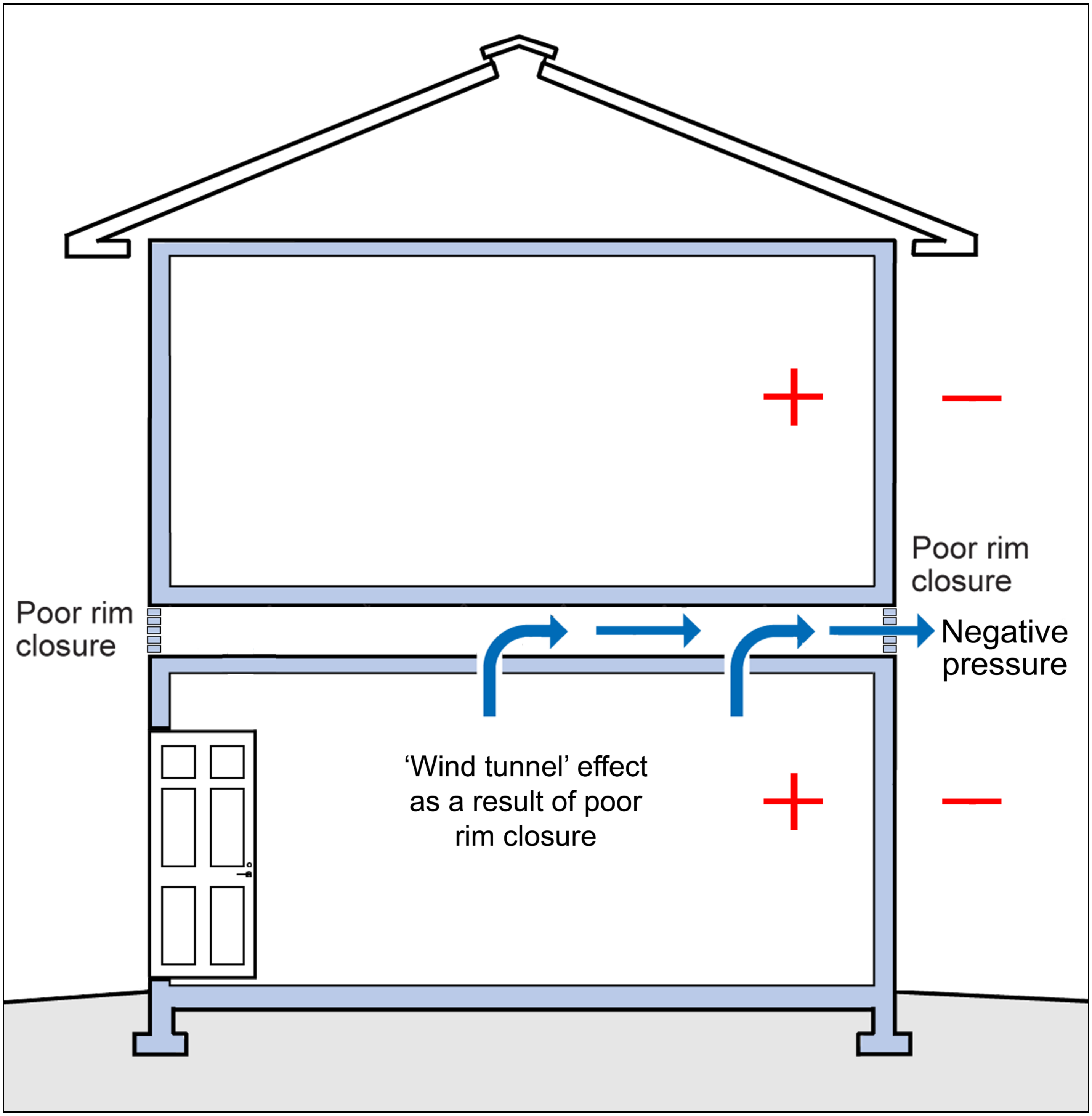

Figure 1 (closely derived from Dr. Lstiburek's "Air Pressure" report) – When air pressure boundaries are not contiguous with building envelope thermal boundaries, pressure differentials readily can convey warm humid interior air to the colder back side of cladding/sheathing assemblies, causing highly damaging condensation and ensuing decay and degradation.

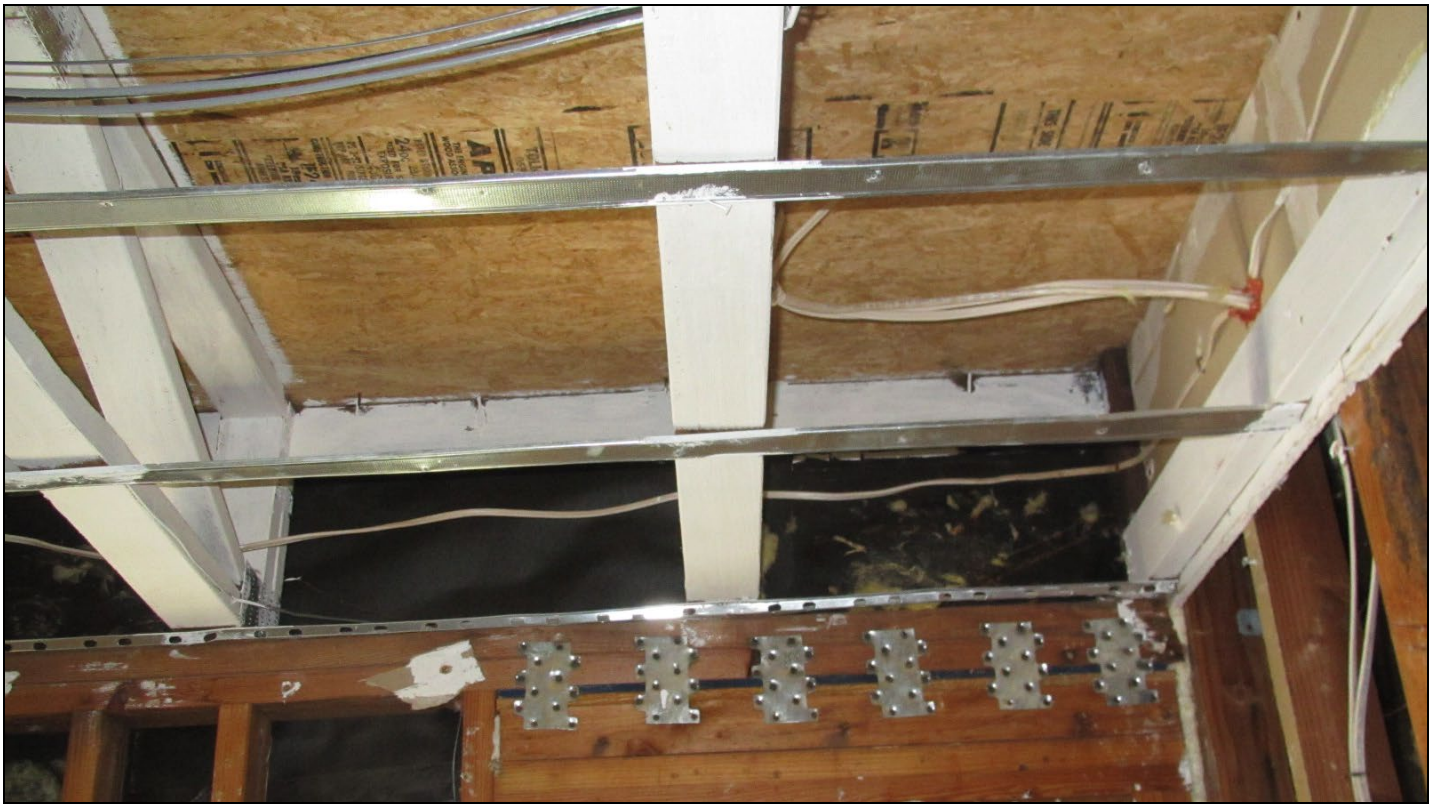

Photo 1 – No rim/band joist or exterior sheathing provided at the "open web" floor joists. Instead, upon insulation removal, we found the inside face of the asphaltic building paper serving the stucco cladding (installed over steel line wire per Photo 2).

Photo 2 – The steel line wire that backed the stucco was extensively rusted and remnants of the fiberglass insulation remained stuck to the inside face of building paper. These conditions are consistent with condensation of warm humid interior air.

Photo 3 – These pervasive conditions (rusty line wire and remnants of the batt insulation stuck to the inside face of the building paper) indicated that the paper had been uniformly wet at times in a manner consistent with vapor condensation.

Investigation at all other buildings found oriented strandboard ("OSB") sheathing panels under both cladding types. However, as demonstrated by Photos 4 to 14, the vast extent of the moisture damage exposed at these exterior walls similarly was located *within* the stud bays – typically at the inside face of the sheathing.

At Photos 4 to 6, the close correlation between the areas of prolific fungal growth and the adhered insulation remnants again are indicative of interaction between warm humid interior air and a cold-weather "condensation plane" where the surface temperature is less than the ambient "dew point". (Note at Photo 4 the relative lack of damage at the single stud bay warmed by the AC heating lines serving both the lower and upper apartments.)

The follow-up exterior sampling at Photos 7 and 8 revealed similar fungal proliferation at the inner face of the sheathing, while the outer faces of the OSB panels exhibited no evidence of rainwater leakage.

Then, our test openings at Photos 8 and 9 were targeted at rim transitions at exterior walls that paralleled the interstitial floor joists (as opposed to the open perpendicular rim seen in Photo 1). At these parallel walls, the wood stud framing was found to be enclosed with an interior layer of gypsum wallboard (see Photo 10) that, in theory, should have provided the airtight pressure boundary recommended by Dr. Lstiburek (and required by the California Building Code for such 1-hour fire-rated apartment buildings). Even so, we still found evidence of damaging water vapor condensation at the inside face of the OSB.

After review, we noted that the stud bays at these parallel walls extended down ten feet, with no blocking, from the doubled wood plates supporting the upper apartment. In other words, per Photo 11, these continuous wall cavities encompassed the lower unit <u>and</u> the interstitial space at the floor joists.

Further, upon closer inspection, we observed that the gypsum wallboard joints in Photos 10 and 11 were never fire-taped, contrary to code, thereby providing direct pathways for air transfer into these cold-in-winter exterior wall cavities. Compare again Photos 9 and 10 of the same test opening. At these parallel rims, how else but pressurized air leakage through the open joints could such excess moisture have reached the inner face of the OSB sheathing?[4]

This conclusion can be confirmed by comparing Photos 11 and 12. Note in Photo 11 the relatively small patch of fungal growth at the interior wallboard, directly below the un-taped joint at the semi-conditioned interstitial space above the ceiling. Because we found no evidence of external leakage at the cladding and sheathing and no alternate routes of moisture migration into this wall cavity, the remarkable damage seen in Photo 12 (looking down into this wall cavity) at the inside face of the OSB could only have resulted from condensation of warm, humid air conveyed into this wall by the poorly sealed rim closure.

Finally, consider the test cut documented at Photos 13 and 14 at an open perpendicular rim. The damage seen at Photo 14 clearly demonstrates vapor condensation at the interface between the semi-conditioned interstitial air and the cold-in-winter OSB panel. Despite the presence of the loosely laid insulation atop the ceiling boards, this design certainly does not provide a code-compliant thermal boundary, much less the code-required 1-hour fire rating. As seen at the Photo 7 test cut (taken lower down the same wall), similar moisture damage and fungal proliferation extends throughout the inside face of the sheathing.

In summary, we informed our client that the conditions documented within the first-floor exterior walls resulted from the deleterious effects of poor rim closure construction and associated code violations that also threatened the health and safety of the occupants. As further reviewed below, these findings subsequently were disputed by certain consultants (with a vested interest in skewing the litigation settlement process) seeking to pin the damage solely on the two cladding contractors.

Photo 4 – At this wall, the remnants of batt insulation stuck to the inside face of the OSB sheathing indicate it has been uniformly wet at times – except at the one stud bay warmed by AC heating lines (serving both the lower and upper units).

Photo 5 – Prolific fungal growth and fiberglass insulation remnants within stud bay at a different exterior wall.

Photo 6 – Fungal growth and insulation remnants at condensation plane within stud bay at yet another exterior wall.

Photo 7 – The clean and bright exterior face of this OSB sheathing shows no evidence of rainwater leakage.

Photo 8 – Even though this OSB was dry (9.4% and 7.4% moisture content) during our summer testing, the close correlation between the fungal growth and sticky insulation is indicative of cold-weather condensation.

Photo 9 (same test location as Photo 10) – Fungal growth and sticky insulation remnants at inner face of the OSB panel. Again, the clean and bright exterior face of this sheathing shows no evidence of rainwater leakage.

Photo 10 (same test location as Photo 9) – Because this joint was not fire-taped, contrary to code, pressurized air from the semi-conditioned interstitial space can flow (via Dr. Lstiburek's "wind tunnel" effect) down into the cold-in-winter stud bays.

Photo 11 – The failure to fire-tape these joints between the interstitial spaces and the units below negated the code-mandated air pressure boundary. The resulting "wind-tunnel" effect produced condensation and fungal growth at the OSB panels.

Photo 12 – Prolific fungal growth at "condensation plane" at inner face of the OSB sheathing.

Photo 13 – While some evidence of moisture damage was found at the exterior face of this OSB sheathing, which spans the rim, far greater degradation was found at the interior face (compare with Photo 14).

Photo 14 – In conjunction with Photo 13, this photograph conclusively demonstrates the deleterious effects of vapor condensation at the interface between the semi-conditioned interstitial air and the cold-in-winter rim.

Case Study 1 – Defense Efforts to Pin this Damage Solely on the Cladding Contractors

For their findings to be considered substantive, building envelope experts should avoid biased advocacy that hides, distorts, or selectively interprets the information revealed during the investigation. The mantra of the forensic professional should be: "***It is what it is***." In other words, the data reveals the story, even when this story differs from the desired or expected findings.[5]

Even so, despite empirical evidence to the contrary, some of the opposing consultants continued to inform their clients that the pervasive in-wall damage and fungal growth being exposed at these first-floor apartments could only have been caused by rainwater leakage due to cladding installation errors. In short, these folks rejected our analysis of poor rim joist closure construction as being, at best, simply speculative.

Case Study 1 – Collection and Analysis of Ambient Moisture Content Data

To forestall a potential "consultant vs. consultant" stalemate during the eventual litigation settlement process, our client authorized deployment of 100 humidity/temperature dataloggers into 24 first-floor apartments.[6]

- Over a 160-day period, we simultaneously recorded (every 10 minutes) a total of 4,500,000 temperature and relative humidity readings that, in combination, generated 2,250,000 psychrometric[7] calculations of ongoing "humidity ratio" fluctuations within three Test Areas: #1) conditioned bedrooms, #2) the semi-conditioned interstitial space above, and #3) exterior wall cavities.
- In a manner similar to using standard pin-style meters to determine moisture content ("MC") percentages within a piece of wood, the humidity ratio simply represents ambient MC percentages (the ratio of grains of water vapor per pound of dry air).[8]

We then compared this massive compilation of humidity ratio readings with official National Weather Service data for the same 160-day period (November to April). This time-consuming analysis produced the following remarkable findings:

a. Extended periods of wintertime rain <u>did not</u> tend to cause increased ambient MC levels within any of the three Test Areas;
b. However, on sunny days immediately following such winter rainstorms, dramatically increased (by 20-40%) levels of average ambient MC did appear within Area #2 (interstitial space) and Area #3 (exterior wall cavity) at the tested units, while far lesser increases (typically 2-6%) were recorded in the bedrooms below;
c. Further, as we described in published articles in 2014 and 2015,[9] the cyclic daily patterns of these increased levels of interior humidity conclusively demonstrated that such excess moisture inside these residential units resulted from "solar heating" of the recently rain-wetted cladding assemblies and
d. In particular, the compiled data strongly supported our conclusion that excessive levels of moisture intrusion (as solar-heated water vapor) through the poorly enclosed rims (e.g., Photos 1 and 14) into the interstitial space above the ceilings subsequently migrated (in part, via Dr. Lstiburek's wind-tunnel effect) into cold-in-winter exterior wall cavities, causing damaging "dew point" condensation during certain periods of the year.

These findings, supported by a voluminous amount of graphed data, helped ensure that an equitable settlement was reached in the litigation mediation process. In addition to various legitimate claims being made against the cladding subcontractors, the separate parties responsible for these poor rim enclosure practices also significantly contributed to the joint agreement.

Case Study 1 – Summary Finding

Without doubt, poor rim joist enclosure practices were the primary cause of the widespread building envelope degradation and damage found *within* the first-floor wall assemblies at this residential complex.

Case Study 2 – Similar Summary Findings

Similarly, consider the comparably deficient rim joist enclosure practices and resulting damage documented in the annotated photographs below (from a different residential complex in Northern California):

Photo 15 – Our team's inspection in 2012 of this stucco-clad wall revealed no evidence of rainwater infiltration or decay.

Photo 16 – However, despite the dry sunny weather, free moisture still was found *behind* the asphaltic building paper.

Photo 17 – Further, the deterioration and damage were most severe where these OSB shear panels spanned the 18-inch-high interstitial joist bays above the first-floor apartments.

Photo 18 – In particular, the exposed deterioration and damage corresponded to poor rim joist enclosure practices.

Photo 19 – At all buildings, the most severe damage was found at the poorly enclosed rim joists at the interstitial space above the first-floor apartments.

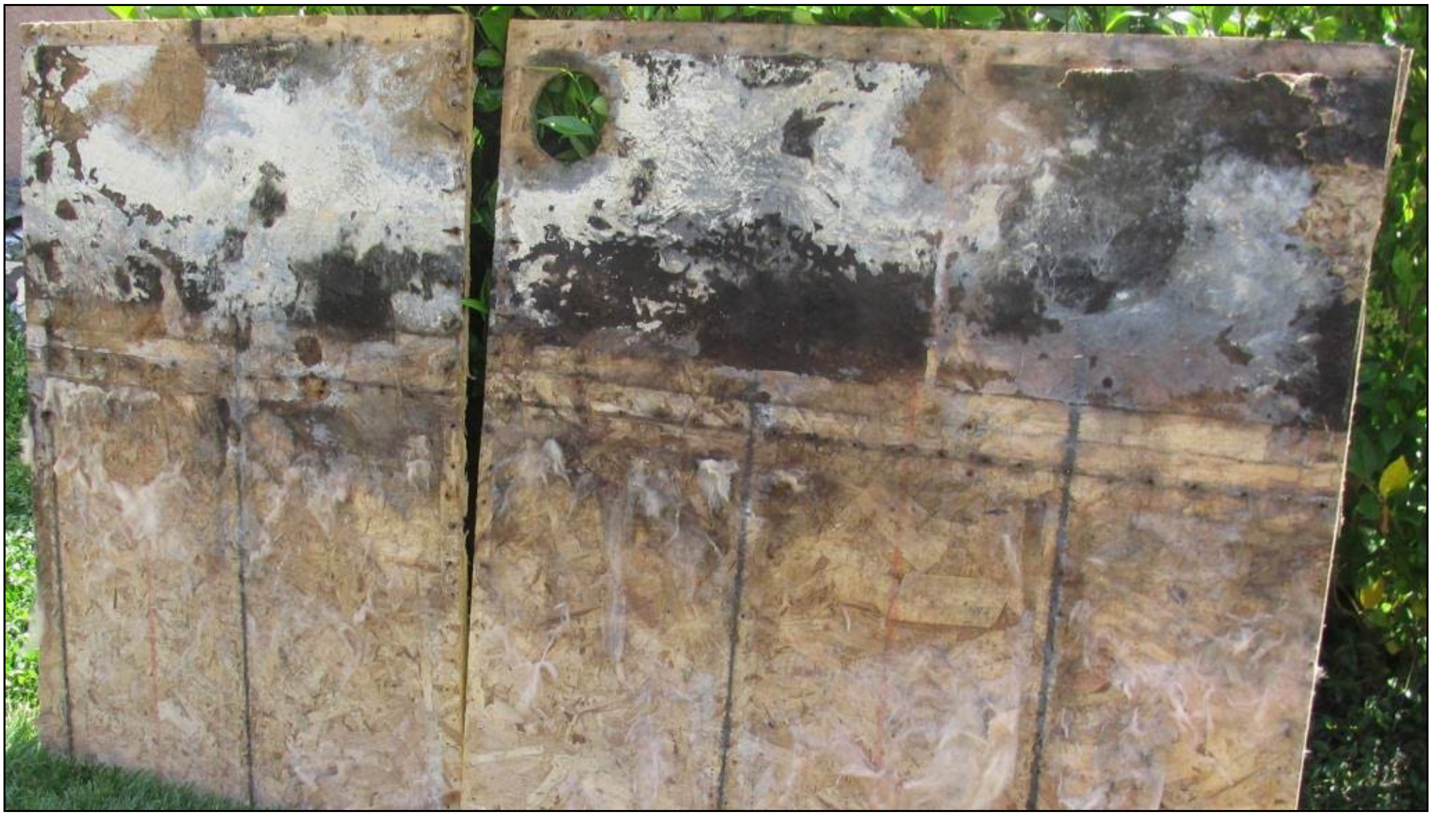

Photo 20 – Extensive fungal growth was observed at the *interior* face of the OSB panels where they spanned the poorly enclosed interstitial joist bays.

Case Studies 1 and 2 – Summary Discussion

At both of these projects, defense consultants representing the insurance carriers for the contractors responsible for the improperly enclosed interstitial rim joists sought to blame alleged cladding installation deficiencies and purported exterior leakage for the damage observed within the first-floor exterior walls. In contrast, our firm's forensic teams compiled sufficient data and evidence to conclusively demonstrate that these poorly enclosed rims not only violated controlling building and fire code requirements for "fire-blocking",[10] but also provided direct routes for highly damaging migration of warm humid interior air into the cold-in-winter exterior walls.

*****

Lonnie Haughton is a senior partner with AVELAR (ex-Richard Avelar & Associates) in Walnut Creek, CA. He is a licensed general contractor and one of about 1,100 individuals worldwide who are certified by the International Code Council as active Master Code Professionals. His many additional ICC certifications include California Building Inspector, Building Plans Examiner, Fire Inspector I, and Certified Building Code Official.

Timothy Stokes is a managing partner at AVELAR and its separate general contracting arm, Reconstruction Services. He joined the firm in 1997 after more than 25 years of construction/consulting experience and advanced to the AVELAR leadership team in 2000. He has a Bachelor of Science degree in Conservation and Resource Studies from University of California Berkeley.

Bobby Whitworth, Jr., REWC, is a licensed general contractor, an IIBEC Registered Exterior Wall Consultant, and an ICC-certified Residential Building Inspector.

*****

---

[1] https://buildingscience.com/documents/reports/rr-9905-air-pressure-and-building-envelopes/view

[2] "Conditioned" space in a building is directly heated and cooled as needed to serve occupants' comfort levels. "Semi-conditioned" space (e.g., an attic) commonly is indirectly heated and cooled by adjoining conditioned spaces. "Unconditioned" spaces (e.g., a garage) are not mechanically heated or cooled.

[3] https://buildingscience.com/documents/information-sheets/critical-seal-spray-foam-at-rim-joist. In 2009, BSC published Information Sheet 408, "Critical Seal (Spray Foam at Rim Joist)" advising that "*the interior side of the rim joist is a cold surface in wintertime, and has associated risks of condensation*."

[4] William A. Rose, Water in Buildings – An Architect's Guide to Moisture and Mold, John Wiley & Sons, Inc., 2005: "*Most moisture problems can be diagnosed by looking at the condition and asking how much water it took to create that problem. Solving the problem amounts to asking where that amount of water could have come from and where it should go*."

[5] L. Haughton and C. Murphy, "Qualitative Sampling of the Building Envelope for Water Leakage," *Journal of ASTM International*, Vol. 4, No. 9, 2007 (www.astm.org/DIGITAL_LIBRARY/JOURNALS/JAI/PAGES/JAI100815.htm):

[6] L. Haughton, "Using Humidity/Temperature Loggers for Moisture Investigations – Case Studies", presented at RCI Building Envelope Technology Symposium Proceedings, San Diego, CA (October 26, 2009)

[7] Donald P. Gatley, Understanding Psychrometrics, Second Edition, ASHRAE, Inc., Atlanta, GA 2005: "…*psychrometrics is defined as the science that involves the properties of moist air (a mixture of dry air and water vapour) and the process in which the temperature and/or the water vapour content of the mixture are changed*."

[8] Ibid.: "*Humidity ratios provide a simple, effective, and most convenient means of accounting for the mass of water vapour in a psychrometric process …by relating it to the nonvarying mass of dry air*."

[9] L. Haughton, *Interface* magazine: "Solar-Driven Waves of Water Vapor within Exterior Wall Cavities" (https://avelar.net/solar-driven-waves-of-water-vapor-within-exterior-wall-cavities/) and "Analyzing Increased Solar-Driven Moisture through Two Rain-Wetted Cladding Assemblies" (http://iibec.org/wp-content/uploads/2015-07-haughton.pdf).

[10] L. Haughton, *Interface* magazine: "A Brief History of Code-Required "Fireblocking" at Concealed Spaces" (http://iibec.org/wp-content/uploads/2017-02-haughton.pdf).