Over the past 25 years, I have investigated numerous issues that have been the subject of construction litigation. Some of the issues have been related to product failures, while others are associated more with a construction type and/or process. This paper is intended to provide an update on past issues, as well as identify issues that are currently being investigated and will likely be investigated for years to come.

UNREINFORCED PVC ROOF MEMBRANE FAILURES

Problem
In the 1980s, we discovered that loss of plasticizer in PVC roof membranes caused embrittlement that made roofs vulnerable to catastrophic failure. Specifically, what appeared to be an intact and functional roof membrane one day could be completely shattered by someone stepping on the roof during an early-morning visit. Although the colder early-morning temperatures were not required to cause a failure, that seemed to be a theme of many failure reports.

Solution
The recipe for PVC membranes was modified to limit plasticizer migration. Additionally, reinforcing mats—typically woven polyester—were added to the membrane to limit the extent of cracking (Figure 1). Because manufacturers were able to respond to the shortcomings in early membrane designs, PVC membranes continue to be a viable option in new construction and reroofing applications.

EIFS

Problem
Exterior Insulation and Finish System (EIFS) technology, aka “synthetic stucco,” was imported from Europe in the 1960s, where it had been successfully used to repair war-damaged masonry structures. (Using the proprietary name of Dryvit® to describe EIFS is similar to referring to facial tissue as Kleenex®. Dryvit® was simply one of several popular EIFS manufacturers on the market when problems were discovered.) The United States was quick to adapt this technology for use as an exterior cladding on wood-frame residential structures. However, EIFS was originally intended to function as a barrier system, with no provisions to protect the underlying wood framing in the event of incidental water penetration. We soon found out that if not
detailed adequately, incidental water penetration was common at roof/wall intersections, balcony and porch intersections, window and door openings (Figure 2), and most places that EIFS were penetrated and not perfectly sealed.\(^2\)

The conditions described above resulted in significant damages to wood framing at (and below) areas of water penetration. The damages were essentially hidden from view, behind the very attractive EIFS exterior skin. By the time water damage on the interior of the structure became visible to the occupant, the wood framing along the path of water intrusion had become significantly damaged. Over the many years of EIFS investigation and litigation, we learned the importance of diverter (aka kick-out) flashing, and that interior-side vapor barriers were a really bad idea in the hot/humid Southeast, or in any climate that is predominantly a cooling climate.

**Solution**

The concerns over EIFS performance were significant enough to cause a ban of its use in the state of North Carolina, the perceived epicenter of the problem. After much finger-pointing between various component manufacturers (EIFS, roofing, window, door, etc.), distributors, contractors, subcontractors, and design professionals, the original barrier design was changed to a drainage system that would manage incidental water penetration (Figure 3). While the design change has been very successful, with no significant issues since its reintroduction, there still seems to be a stigma surrounding the acronym "EIFS." There clearly remains

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*Figure 2 – Damage to wood wall framing behind a barrier EIFS installation.*

*Figure 3 – Illustration of a drainage EIFS cladding system (provided by the EIFS Industry Members Association [EIMA]).*

*Figure 4 – Brash failure of a wood truss member caused by fire-retardant-treated (FRT) wood.*
an association between EIFS (of any type) and past problems with the original barrier systems. However, among informed building envelope consultants, a properly installed drainage EIFS is considered to be a “state-of-the-art” system that has a proven track record. There simply needs to be more education provided to the consumer, insurance providers, and contractors that drainage EIFS is a viable cladding system that can be expected to perform trouble-free for many years.

**FIRE-RETARDANT-TREATED WOOD**

**Problem**

The United States construction industry first discovered fire-retardant-treated (FRT) wood problems in plywood roof decks on townhomes in the Virginia/Washington, D.C., area in the 1980s. Specifically, roofers were experiencing plywood embrittlement failures during the installation of composition shingles. While FRT formulas have been successful in terms of fire retardancy, problems with in-service strength loss were not fully understood. A process called acid-catalyzed dehydration (the very process that is triggered in the event of elevated temperature during a fire) was found to initiate at lower (i.e., in-service) attic temperatures. The strength loss impacted plywood roof decks most significantly due to the elevated temperatures. However, similar strength losses were later documented in dimensional framing members—primarily prefabricated metal-plate-connected wood roof trusses (Figure 4).

Before the in-service strength loss issues were recognized, design professionals relied on the National Design Standard (NDS) for wood construction for strength adjustment factors. Up until the 1991 NDS, a 10 percent strength reduction factor was used for FRT wood. This adjustment factor was considered necessary to account for the initial loss of strength associated with the kiln drying process that subjected the wood to elevated temperatures. However, it was later discovered that the strength loss associated with FRT is progressive and continuous. The 10 percent adjustment factor was removed from the NDS in 1991, and design professionals were directed to use strength adjustment factors provided directly from FRT manufacturers.

Many roofs constructed using earlier FRT formulations (mid-1980s or earlier) have been completely removed and replaced due to excessive strength loss and associated truss failures. The volume of reported problems (and associated litigation) has significantly decreased over time. However, occasional truss problems associated with older FRT formulations are still reported.

**Solution**

In response to the FRT problems, manufacturers made two primary changes. The first change was to the recipe of the FRT to make it less acidic. There is a direct relationship between the pH of the FRT formula and the rate of strength loss. Specifically, the strength loss is generally more significant with lower-pH (i.e., more-acidic) FRT formulas. Later FRT recipes added buffers (typically borax or borate) to raise the pH and retard the strength-loss process.

The second change was the publishing of more realistic strength adjustment factors. At first, most manufacturers stuck with the 10 percent reduction that was previously published by the NDS. However, manufacturers slowly increased strength adjustment factors to reflect in-situ and laboratory measurements of strength loss.
that occur in service. Published adjustment factors are now as high as 20 to 25 percent, depending on the manufacturer and wood property being considered (i.e., bending strength, shear strength, modulus of elasticity, etc.).

By changing the recipe and using more realistic adjustment factors, problems with FRT wood appear to have been adequately addressed such that it is now a viable and reliable product. For many years, the state of South Carolina banned the use of FRT in state projects because of documented strength loss and truss failures. Based on the improvements described above, that ban was recently removed.

**LIQUID-APPLIED FIRE RETARDANT ON OSB ROOF DECK / EXTERIOR WALL SHEATHING**

**Problem**

This is a recent issue that is related to a relatively new product line. While intumescent paints are not new, their use on oriented strand board (OSB) roof decks and wall sheathing to meet code-prescribed fire resistance requirements is relatively new and has been documented to be problematic. Unlike FRT products that provide fire resistance throughout the thickness of the pressure-treated wood component (typically plywood or dimensional lumber), the only thing that provides fire resistance on these products is a very thin coat of paint. If the paint falls off due to adhesion problems (Figure 5), is damaged by mechanical abrasion or is compromised by nail penetration (which is required by the building code) or water (Figure 6), the fire resistance of the OSB panel is unknown.

For a product to receive code approval, it must be determined to meet or exceed the performance of existing code-approved products; in this case, FRT. It is simply unreasonable to think that a thin coat of intumescent paint on the surface of highly combustible OSB will have the same or better performance than pressure-impregnated
FRT plywood. Already, in its short time on the market, this type of product has been documented to experience adhesive failure, mechanical damage, and water damage when exposed to typical and expected construction practices. The compromise of this product creates uncertainty regarding its performance and is a potential life-safety issue that should be taken very seriously.

The product investigated to date appeared to have code approval via a code evaluation report; however, the report was not issued by the International Code Council (ICC) or one of the accepted testing agencies that issues these reports. In 2017, the ICC approved Acceptance Criteria 479 (AC479), which will open the door for similar products to come into the market. Even after seven hours of testimony on why not to approve AC479, the ICC committee indicated that approval was based on local authorities having jurisdiction (AHJ) needing to determine code compliance via the alternate product provisions in Chapter 1 of the International Building Code (IBC). This is a very bad idea. The building officials do not have the benefit of seven hours of testimony regarding the shortcomings of AC479 and do not have time to perform a detailed evaluation of all proposed products. It is my experience that the existence of a code evaluation report is typically sufficient for AHJ approval; there is no time for an independent evaluation of the validity or sufficiency of the report provided.

**Solution**

In order for these types of products to be relied on to deliver the necessary and required fire protection, the test methods used to evaluate their performance must replicate in-service conditions. As it stands, products have been introduced into the stream of commerce that were not properly evaluated and are defective. The defective product(s) that are currently in the marketplace were not evaluated by ICC-approved Acceptance Criteria. While AC479 is an improvement from previous (non-ICC) evaluation protocols, it still falls short of adequately replicating the conditions that the product will be subjected to during construction and in service.

One of the most investigated issues in wood frame construction is water intrusion. To expect these OSB roof deck and wall sheathing panels to stay dry in service demonstrates a lack of understanding regarding the realities of wood frame construction. There are currently no tests that serve to demonstrate the fire retardancy of intumescent paint that is damaged by water. In intimate wall cross sections, water is routinely held against the OSB wall sheathing, with only a “breathable” weather-resistant barrier (WRB) to provide protection. Based on extensive observations of damages, these assemblies simply do not provide long-term protection of the OSB.

Other issues that need to be addressed more sufficiently by the evaluation process include the following:

1. The ¼-in.-wide gap that is required between adjacent OSB roof and wall panels
2. The damages caused by roofing and siding nails that “blow out” wood chips on the back side of OSB panels
3. The adhesion failure caused by heat in roof deck panels
4. The treatment of cut edges on OSB roof and wall panels

There are coated OSB panel products in the marketplace that provide fire resistance
and may perform adequately. This article only serves to highlight the issues that need to be reviewed before selecting/specifying/approving these types of products.

**NON-ASBESTOS-CONTAINING CEMENTITIOUS ROOF TILES**

**Problem**

Several building products have been made using fiber-reinforced cement. In many older products, asbestos was used to strengthen cement-based roofing and wall tiles. Transite® is the trade name generally associated with these types of products. When the EPA required the removal of asbestos from cement-based roofing tiles, the performance was compromised. Specifically, the non-asbestos roof tiles were observed to be vulnerable to cracking when installed with typical, code-compliant residential roof framing details (i.e., framing at 24 inches on center with ½-in.-thick plywood or OSB). (See Figure 7.)

**Solution**

After numerous failures and associated litigation, the manufacturers of non-asbestos fiber-cement roof tiles went out of business, discontinued their product line, or tried to make improvements to overcome the problems, with limited success. Eventually, these products seem to have been phased out and slowly replaced with composite material blends that include plastics, rubber compounds, resins, etc., that are used to create faux slate and tile products. Early versions of the composites also suffered some “learning curve” problems with shrinkage, cracking, and warping. However, due to the lack of recent investigations, perhaps these products are now serving their intended purpose without any known problems?

**MDF SIDING /TRIM**

**Problem**

Exterior siding and trim products made with medium-density fiberboard (MDF) are sensitive to elevated moisture conditions (Figure 8). The products are typically sold with a smooth and/or embossed woodgrain texture to resemble natural wood. However, the products primarily consist of finely chopped wood chips and glue. The most well-known siding product problems were associated with Masonite®; however, most early MDF siding manufacturers experienced similar problems with swelling and decay. The performance of MDF siding (aka hardboard) is governed by the code-referenced standard, ANSI 135.6.

Unfortunately, without proper testing and evaluation, many siding manufacturers expanded their product line to include MDF trim. At the time, the only standard that addressed exterior MDF was the 1994 version of ANSI A208.2. This standard included performance criteria that could not be met by any MDF siding or trim products. The reference to exterior MDF was removed from the next (2002) version of ANSI A208.2, reportedly due to confusion over what was meant by “exterior.”

Figure 7 – Non-asbestos-containing cementitious roof tiles that are susceptible to cracking.

Figure 8 – Water-damaged MDF trim.
Solution

An MDF trim standard (ANSI 135.7) was developed and published in late 2012, approximately 20 years after it was actually introduced into the market. However, the testing requirements in the trim standard are inadequate to predict product durability. Some MDF trim products have been removed from the marketplace. The products that remain available have been improved, but are still considered to be problematic. Specifically, the current MDF trim products typically include zinc borate as a rot inhibitor. Also, installation instructions have been modified to more directly address the moisture sensitivity issues.

MID-RISE WOOD FRAME CONSTRUCTION

Problem

In the world of construction litigation, mid-rise wood frame construction is quickly becoming the next big thing. Based on a number of factors, these projects have the perfect-storm recipe to be the next epidemic in the construction industry. Specifically, the rushed schedules typically associated with apartments (particularly student housing), the lack of skilled labor, the lack of understanding regarding building movements, the absence of building envelope inspections, the minimal requirements set forth by building codes, and the fact that wood is now allowed for taller and bigger buildings, have all contributed to this latest wave in construction defect litigation (Figure 9). Based on the sheer number of these projects that have been (or are currently being) constructed, this is a topic that we will be discussing for a long time to come.

Solution

In order to reduce the problems/risks with mid-rise wood buildings, the following should be considered:

- Provide education to building officials regarding Chapter 23 of the building code that requires a shrinkage analysis to be performed for wood framing more than three stories high.
- Provide the shrinkage analysis to the design professionals and contractors who are impacted by the vertical building movements (i.e., architects, structural engineers, waterproofing consultants, mechanical engineers, electrical engineers, etc.).
- Design professionals and contractors need to raise the bar and refuse to design and/or construct these types of buildings to minimum code standards. Minimum building code requirements may not be adequate and need to be addressed to reflect mid-rise wood frame construction.
- Project budgets should be modified to incorporate construction “best practices” and specialty consultants as needed.
- Mock-ups should be constructed to demonstrate the approved and expected details to be used throughout the project at critical locations.
Product manufacturers should be engaged as much as possible to review completed work and verify compliance with installation instructions.

PRESSURE-TREATED (PT) WOOD

Problem
One of the most effective preservative treatments for wood is copper chromium arsenate (CCA). However, because of concerns over environmental and health risks, the EPA caused the construction industry to convert from CCA to newer, lesser-known formulations, including alkaline copper quaternary (ACQ) and copper azole (CA).

Shortly after ACQ treatments were put into service, a significant corrosion issue was discovered. Industry members, such as the National Roofing Contractors Association (NRCA) and Simpson Strong Tie®, issued bulletins warning of corrosion problems associated with direct contact between metal components such as fasteners and connectors and wood treated with ACQ.

While the other, newer formulas appear to have better performance in regard to corrosion potential, there is a concern about their general effectiveness. Specifically, in the circle of forensic and industry experts, performance issues have been investigated, discussed, and dealt with over the past several years. It is too early to tell if this is an industry-wide problem or simply the case of some “bad batches” of treatment.

Solution
The industry response to performance issues has included the release of bulletins to distributors and end users regarding retention levels (the amount of preservative retained in the wood after treatment). (See Figure 10.) The bulletins suggest that end users have not been selecting the appropriate level of retention needed for exterior applications. To improve performance, it is recommended that “ground contact” retention levels should be used, even when the wood is not physically in contact with the ground. However, this is a situation that deserves to be monitored. Failures of fence posts, mailbox posts, deck boards, stair treads, stair stringers, and guardrails have all been observed—sometimes in as little as three or four years (Figure 11). If short-term failures continue to be documented, we will need to revisit the preservative treatment formulas and the standards that are used to predict their effectiveness.
CONCLUSION

The intent of this paper was to provide an update on past issues, as well as identify others that are currently being investigated. Several of these issues have been resolved over the years and are considered not to be as relevant for new construction. However, as construction continues to evolve, the industry is starting to see new issues that weren’t necessarily anticipated but need to be resolved before progressing further. Several of these issues will only worsen if the industry does not respond with reasonable solutions.

REFERENCES


Derek Hodgin, of Construction Science & Engineering, Inc., has more than 25 years of experience as an engineering consultant. A licensed professional engineer in 23 states, Hodgin is also registered through RCI as an RRO, RRC, RWC, REWC, and RBEC; and as a CDT and CCCA with CSI. He is currently at the forefront of investigations of building envelope and structural components of mid-rise wood-frame construction buildings. Hodgin has investigated and testified regarding the performance of various building products, including FRT wood, EIFS, hardboard siding, and trim.

First 3-D-printed Housing Project Planned in Netherlands

The city of Eindhoven, Netherlands, will be the site of what developers are claiming will be the first 3-D printed concrete homes. Project partners are the municipality of Eindhoven, Eindhoven University of Technology, contractor Van Wijnen, real estate manager Vesteda, materials company Saint Gobain-Weber Beamix, and engineering firm Witteveen+Bos.

The first, a single-floor house, is expected to be completed the first half of 2019. The designs are aiming for a high level of sustainability. The first home will be printed at the university and will be just over 1000 sq. ft. with walls just under 2 inches thick. Subsequent, larger homes will be built on site. By then the team hopes the printer can also be used to make drainage pipes and other building components.

Eindhoven is considered a “hot spot” for 3-D concrete printing. The group recently printed the world’s first 3D-printed concrete bridge for cyclists in the village of Gemert.

Rudy van Gurp, a project manager with Van Wijnen, said, “Eventually, people will be able to design their own homes and then print them out.”

Watch a video about the process here: https://www.youtube.com/watch?v=hL4Na-jHecQ.
— Eindhoven University of Technology

Artist impression of the five 3-D-printed concrete houses that will soon be under construction in the Netherlands. Courtesy Houben/Van Mierlo Architects.