Moisture Risks Associated with Current State of UFC Compliance Enforcement in ASHRAE Zone 7 and 8

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INTRODUCTION

Improving the thermal performance of the building envelope is a long-lasting, low-maintenance means of reducing energy consumption. However, design of the building envelope affects moisture migration dynamics as much as it affects thermal transfer, so any envelope design should include an analysis of the moisture balance through the various layers in building envelope assemblies. This is especially important in the subarctic climate, where exfiltration of vapor-laden air from the interior can represent a large, annual source of moisture accumulation in building envelope assemblies.

Any high-performance building enclosure must include proper control of air leakage and engineered vapor control to provide sufficient drying potential in order to prevent conditions favorable for corrosion, mold, structural rot, adhesion failure, reduction of insulation’s thermal resistance, and discoloration or frost damage to Architectural finishes.

This paper intends to demonstrate how building envelope assemblies designed to comply with recently-increased mandatory thermal performance standards can lead to building envelope failures if they are not properly designed. Review of moisture management dynamics is an important, and often overlooked, strategy for USACE to ensure that they are building truly high-performing buildings.

BACKGROUND

Building Science

The building envelope consists of the water, air, thermal and vapor control layers that exist across all surfaces of the building, including the floor, walls, doors, windows and roof. The function of the building envelope is to separate the outdoor environment from the indoor environment. As a result, the building envelope is subject to a variety of stresses that range from UV degradation and pests to wind-driven rain and air pressure gradients that can drive gallons of water into the envelope in a given winter.

While the building envelope is keeping environmental conditions on their “proper side”, the envelope itself has to withstand the impacts of these environmental loads. A building envelope needs to be designed to survive these “damage functions,” including all sources of potential moisture migration into the different assemblies that comprise the building envelope. Generally speaking, the four greatest sources of moisture damage in building envelope assemblies are, in order of significance: bulk water intrusion, capillary action, infiltration of vapor-laden air, and water vapor diffusion.

In the subarctic climate, exfiltration of vapor-laden air from the interior can often surpass capillary action in overall contribution to moisture loading. In arid climates such as the Interior of Alaska, exfiltration can pose a greater threat than even bulk water intrusion. Exfiltration is driven by the extreme temperature and air pressure gradients across the building envelope during the winter. As the warm interior air is driven through gaps and cracks in the building envelope, the air makes contact with a material that is cold enough to cause the vapor in the air to condense into liquid form. This typically occurs on the interior face of the wall sheathing or the studs. Vapor diffusion, on the other hand, is the migration of water vapor molecules through the actual building materials of the assembly (not the air spaces around the materials). This process is much slower, so the amount of moisture that is caused by vapor diffusion typically orders of magnitude smaller than that caused by exfiltration.

The process of exfiltration is driven by the air pressure gradient across the building envelope (from wind, stack effect, and mechanical pressurization) and is resisted by the air permeance ("air tightness") of the building envelope system as a whole. The process of vapor diffusion is driven by the vapor pressure gradient across the building envelope and is resisted by the vapor permeance (or vapor diffusion resistance) of each material in the assembly. The moisture flow associated with exfiltration is concentrated in areas of weak air resistance, but the moisture flow associated with vapor diffusion does not magnify at areas of weak vapor diffusion resistance.

Moisture flows through building envelope assemblies are similar to many other engineering situations – it is a matter of demand and capacity. If the wetting potential of an assembly (demand) exceeds the drying potential of the assembly (capacity), then moisture accumulation occurs. If there are hygroscopic materials in the assembly, then some of that moisture can be stored in those materials, providing a "hygric buffer", where moisture can later be released when there is a net drying trend in the assembly. However, if the material's safe storage capacity is exceeded (or if the assembly's materials are not hygroscopic, such as steel or plastics), then conditions become favorable for corrosion and the growth of decay organisms, such as mold and rot. Excessive water content of materials can also cause other undesirable effects, such as timber strength reduction, adhesion failure, frost damage to concrete and finishes, reduction of insulation's thermal resistance and discoloration of finishes.

Water intrusion is inevitable (improper water resistive barrier (WRB)/flashing design and/or installation, plumbing leaks, moisture accumulation from vapor diffusion and exfiltration, etc.), so building envelopes need to be designed to allow for drying. Since drying occurs primarily via vapor diffusion, at least one side of the wall should have low vapor diffusion resistance. As a result, the location of vapor-retarding layers within an assembly is critical to its hygrothermal performance. Convection also aids in drying, so ventilated cladding such as a drained/back-ventilated rainscreen is a key component of building envelope design in our climate, even though our precipitation loads are relatively small.

United Facilities Criteria summary

The Unified Facilities Criteria (UFC) that govern all building designs on military facilities require compliance with several different thermal envelope performance standards. Per UFC 3-101-01, Air Force projects are required to conform to ASHRAE 90.1 building envelope U-factors. All other projects must comply with ASHRAE 189.1, which is roughly a 10% improvement over ASHRAE 90.1. Per UFC 1-200-02, renovation projects that meet certain size and cost parameters, must improve whole building energy consumption by at least 20% from the ASHRAE 90.1 baseline. And new projects over 10,000 GSF and $3M in construction cost (which includes the majority of new military construction projects in Alaska), are required to improve energy consumption by at least 30% beyond ASHRAE 90.1 standards. Since the building envelope is largely responsible for dictating HVAC loads (and therefore energy consumption), this requirement is generally taken as a requirement to improve the building envelope thermal resistance by 20% (for renovations) or 30% (for new construction). So, based on the type of project and military installation, UFC thermal envelope requirements range from 0 – 30% improvement over ASHRAE 90.1 minimum U-factors.

However, UFC 3-101-01 also requires compliance with ASHRAE 160 for moisture control in building envelope assemblies. ASHRAE 160 prescribes moisture performance criteria, as well as methods to assess the performance of building envelope assemblies given site-specific interior and exterior climate parameters, and hygrothermal properties of building materials. The moisture performance of an assembly is evaluated based on the prevalence of ambient conditions conducive to the growth of decay organisms within the assembly's materials. This process is described in detail later in this report.

UFC compliance challenges in Zone 7 & 8

Condensation risk is significantly increased by two major trends that we are seeing in military RFPs: (1) increased R-value requirements (driven by recent revision to ASHRAE 90.1 and 189.1); and (2) increased use of building humidification (common on Air Force projects to protect sensitive electronic or life-safety equipment). Nowhere in the world is this issue more challenging than in the arctic and subarctic climates.

Meeting ASHRAE 90.1 thermal envelope criteria has become more challenging in recent years, with recent versions of the standard introducing significant increases in the thermal envelope performance requirements. ASHRAE 90.1-2013 reduced the allowable thermal conductivity of below-grade walls by over 40% (compared to the 2010 version). Reductions for above-grade walls range from 11 – 42%, depending on the type of construction. For example, ASHRAE 90.1-2010 required mass walls to have a maximum U-factor of 0.071, but that figure dropped to 0.048 in the 2013 version. Roof, slab, and fenestration U-values decreased by similar amounts for Zone 8 in the 2013 standard.

Even though the thermal performance requirements have become more stringent, complying with them is fairly straight-forward, and is consistently reviewed by military project administrators. But the moisture control component of building envelope design is far less understood by both designers and project managers, and isn't typically given the appropriate level of consideration in plan reviews. As a result, there are accepted building envelope designs that meet the rigorous energy requirements of ASHRAE 90.1 and 189.1, but fail significantly in meeting the moisture performance requirements of ASHRAE 160. Therefore, military projects in Zone 7 and 8 are especially vulnerable to the unintended consequences of poor moisture management, including unhealthy indoor air quality, future repair costs, and reductions in the thermal resistance of the building's insulation.

To demonstrate the risk of moisture damage from thermally-compliant assemblies in Zone 7 and 8 that are not properly evaluated against ASHRAE 160 criteria, this paper will present two pairs of two different wall assemblies. Each assembly complies with the given thermal performance requirement (ASHRAE 189.1 and ASHRAE 90.1 +30%). However, one assembly in each pair is poorly designed for moisture conditions and, as a result, fails to comply with ASHRAE 160.

ANALYSIS METHODOLOGY

Hygrothermal Analysis Methods

General Information

ASHRAE Standard 160 provides several methodologies for assessing the hygrothermal performance of building envelope assemblies, ranging from simplified calculations to complex parametric computation. This paper utilizes a hygrothermal modeling software to perform the parametric computations, thereby offering the most accurate and robust approximation of expected conditions. This software, called WUFI, was created by the Fraunhofer Institute for Building Physics (IBP), and is recognized by the industry as the best platform for evaluating the complexities of hygrothermal phenomenon, going beyond many of the simplified assumptions in ASHRAE Handbook of Fundamentals and ASHRAE Standard 160. WUFI has the capability of modeling all of the major damage functions mentioned above, and takes hygric buffering, solar radiation, and night-sky cooling into account. Several renowned laboratories across the globe have field-verified WUFI model results by comparing actual test conditions to WUFI model results.

The WUFI-VTT program was also used to model potential mold growth. This program analyzes mold growth based on the material sensitivity class, mold index decline coefficient, water content, temperature, and relative humidity, in accordance with a 2016 addendum to ASHRAE 160. WUFI-VTT takes into account die off of decay organisms during cold and dry conditions, and provides a mold index value representative of the expected amount of mold coverage of any material.

Climate Parameters

WUFI uses ASHRAE climate files as hourly inputs for exterior boundary conditions, including temperature, relative humidity, wind, rain, and solar radiation. The climate file utilized in this analysis is the third most severe year concerning moisture damage to the building envelope in a 30-year analysis, according to ASHRAE Research Project 1325, “Environmental Weather Loads for Hygrothermal Analysis and Design of Buildings.”

Interior boundary conditions are based on user inputs, with the option to use several international standard protocols for simulating indoor conditions. An indoor climate file was created using ASHRAE Standard 160 procedures to determine indoor humidity conditions based on ambient outdoor climate. This hourly climate file was modified to represent a building humidification scenario typical for recent Air Force projects on Eielson Air Force Base (minimum 30% relative humidity).

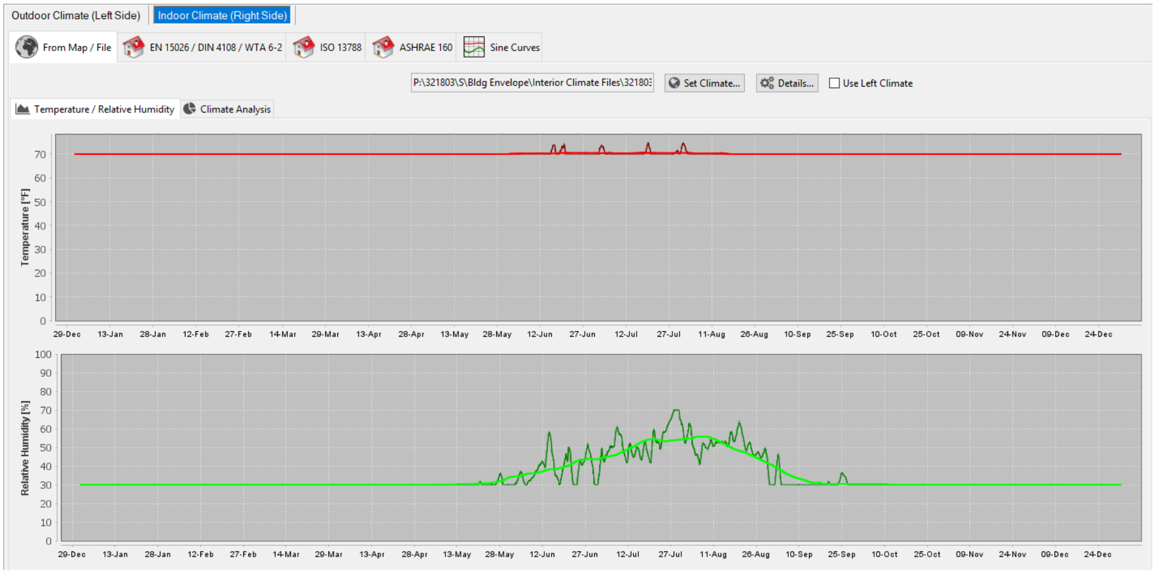

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Figure 1: Indoor Climate data used to simulate humidification to a minimum of 30% relative humidity.

Fairbanks, AK; ASHRAE Year 1

Figure 2: Exterior Climate data used to simulate Fairbanks conditions (wind, solar insolation, and night-sky cooling not shown)

Since solar radiation and wind-driven rain vary by compass direction, the worst-case orientation needs to be established. The two different wall orientations that are typically suspected to be the worst-case scenario in our climate are the north exposure (due to minimal solar drying) and the southwest exposure (due to maximum driving rain, as determined by ASHRAE climate data). Models of both orientations indicated that they both performed almost identical, with the north exposure being slightly worse. Therefore, North was chosen as the modeled wall's orientation.

Material Properties

WUFI utilizes hygrothermal properties of building materials, as determined by ASHRAE and other research sources. These material properties include: moisture- and temperature-dependent thermal conductivity (R-value as a function of temperature and water content), liquid transport coefficients (capillary action), moisture-dependent vapor diffusion resistance (permeance as a function of relative humidity), and moisture storage function (water content as a function of relative humidity). Some of these properties can vary significantly between product manufacturers, however for this analysis, the models utilize standard data provided in the WUFI database.

The initial moisture content of most building materials is assumed to be twice the equilibrium moisture content at 80% relative humidity ("ECM80"), per ASHRAE 160. This boundary condition represents the high moisture levels that are typically built-in to building materials during construction, due to weather exposure and high-moisture construction practices (concrete cutting, slab curing, application of liquid coatings, etc.). For concrete, the initial moisture content is twice the equilibrium moisture content at 90% ("ECM90"), due to its very high moisture content during the curing phase. This approach is consistent with typical construction sequencing for sub-arctic projects, where building envelope assemblies are often closed in soon after the period of heaviest rain exposure (September-October).

Hygrothermal Sources & Sinks

This analysis utilizes advanced WUFI modeling protocols, as specified by ASHRAE 160 and the Fraunhofer Institute. Among these protocols is the application of 1% of driving rain for the particular wall orientation to the porous material nearest to the exterior face of the Water Resistive Barrier (WRB). This simulates typical water penetration past the envelope's deflection layer (siding).

Exfiltration of interior air into the wall cavity is also simulated in WUFI, and is dependent upon stack effect, mechanical over-pressurization and the air-tightness of the building envelope. For the modeled assemblies, the envelope was classified as Air Tightness Class B. Even though the air barrier inspection and testing requirements in UFC 3-101-01 are rigorous and typically provide an overall tight air barrier, localized areas are often subject to imperfections and damages that are lost "in the noise" in a whole building air leakage test. Therefore, we analyze wall assemblies under these imperfect conditions, which are likely to experience air leakage at a typical rate for common buildings (i.e. Class B), instead of the very high-performance assumptions associated with Air Tightness Class A. This is a conservative approach that provides a resilient building envelope, capable of withstanding unforeseen conditions.

The WUFI models also simulate the natural air exchange that occurs in the cavity between the siding and the exterior insulation in rainscreen assemblies. The model accomplishes this by exchanging the air behind the siding with the exterior air, which has the effect of improving the wall's drying during the summer (WUFI refers to this as an "air change source").

Hygrothermal Evaluation Factors

Until 2016, simplified hygrothermal performance criteria were prescribed in ASHRAE 160, where it was recommended to avoid conditions that were expected to cause the average relative humidity within a building envelope assembly to be above 80% for 30 days while the temperature is above 40 degrees Fahrenheit in order to avoid mold growth. 98% relative humidity for 7 days and 100% relative humidity for 24 hours were also identified as conditions to avoid in order to minimize mold growth. Corrosion of metals is expected when average relative humidity is above 80% for 30 days.

In 2016, ASHRAE 160 updated the hygrothermal performance criteria to recommend avoiding conditions that are expected to cause a Mold Index greater than 3.0. The mold index is determined by a series of calculations based on material parameters, and ambient environmental conditions. ASHRAE has not changed the corrosion criteria since the original publication of ASHRAE 160 in 2009.

The WUFI models used for this report perform hourly calculations of the temperature, humidity, and water content of a tight grid of elements within each material layer that comprises the simulated assembly. The WUFI-VTT program takes this analysis a step further and assigns a Mold Index value to the chosen element based on hygrothermal conditions and how bio-utilizable the material is. Mold index values indicate expected amount of mold coverage, ranging from zero (no mold growth) and one (some microscopic coverage of mold growth) to six (100% visible coverage of mold growth).

In all assemblies analyzed herein, a critical layer is selected for mold growth analysis and comparison. The critical layers are selected based on exposure to moisture, susceptibility to mold, and potential for impacting human health and building damage. The attached WUFI model results summary table indicates the water content during the last simulated winter and the Mold Index value during the last simulated summer of this element. The water content of the critical layer is reported at the beginning and the end of the model period as an indication of the wetting or drying trend of the assembly. An assembly that shows a wetting trend from its initial conditions is typically considered a failure. Mold Index values that indicate visible coverage of mold growth (MI=3.0) indicate failure, per ASHRAE 160.

HYGROTHERMAL ANALYSIS

This analysis evaluates wall assemblies for a theoretical 20,000 square foot military facility near Fairbanks, Alaska. Typical conditions (including building humidification at 30%RH, a 25' stack height, and a 12.5 Pascal mechanical over-pressurization) are applied equally to all assemblies. All assemblies are also modeled as north-facing walls under a low-sloped roof, with medium weather exposure.

The assemblies do, however, differ in the targeted thermal performance category. Two assemblies are designed to meet ASHRAE 189.1 U-factor requirements for a wood-framed wall. The other two assemblies are designed to be 30% better than the ASHRAE 90.1 U-factor requirements for a mass wall.

Within each energy target scenario, there is one assembly that was designed without moisture performance in mind. The other assembly is engineered for moisture management, including proper selection of the type and location of insulating materials, and the addition of a ventilated rainscreen.

Descriptions of the wall assemblies are as follows:

ASHRAE 189.1 Compliant Assemblies – Wood-Framed

Wall Type '189.1-WET"

From interior to exterior:

- 5/8-inch Gypsum wallboard
- Polyethylene sheeting (air/vapor barrier)
- 2x6 wood stud @ 24" o.c. with R-21 fiberglass batt
- 1/2-inch OSB
- Spun-bonded Polyolefin membrane (WRB, e.g. Tyvek Commercial Wrap)
- 2-1/2" Expanded Polystyrene (EPS) with polypropylene or foil-facing

- 5/8” Fiber-Cement siding board

U-factor = 0.029 (R-34.8).
Assembly complies with ASHRAE 189.1 for Wood-Framed Walls (max U-factor = 0.029)

Wall Type ‘189.1-DRY”

From interior to exterior:

- 5/8-inch Gypsum wallboard
- Polyethylene sheeting (air/vapor barrier)
- 2x6 wood stud @ 24” o.c. with R-21 fiberglass batt
- 1/2-inch OSB
- Spun-bonded Polyolefin membrane (WRB, e.g. Tyvek Commercial Wrap)
- (2) layers of 2” rigid Mineral Wool
- 3/4” air gap (ventilated rain screen)
- 5/8” Fiber-Cement siding board

U-factor = 0.029 (R-34.8).
Assembly complies with ASHRAE 189.1 for Wood-Framed Walls (max U-factor = 0.029)

ASHRAE 90.1 + 30% Compliant Assemblies – Concrete Masonry

Wall Type ‘189.1-WET”

From interior to exterior:

- 5/8-inch Gypsum wallboard
- Polyethylene sheeting (air/vapor barrier)
- 3-5/8” metal stud @ 24” o.c. with R-21 fiberglass batt
- 5” open-cell Spray Polyurethane Foam (ocSPF)
- Liquid-applied air barrier (Backstop NT or similar)
- 8” grout-filled split-face Concrete Masonry Unit (CMU)

U-factor = 0.032 (R-31.5).
Assembly complies with ASHRAE 90.1+30% for Mass Walls (max U-factor = 0.037)

Wall Type ‘189.1-DRY”

From interior to exterior:

- 5/8-inch Gypsum wallboard
- 3-5/8” metal stud @ 24” o.c. – no batt insulation
- 8” grout-filled Concrete Masonry Unit (CMU)
- Exterior Insulation Finish System (EIFS):
    - Liquid-applied air barrier (Backstop NT or similar)
    - 7” unfaced Expanded Polystyrene (EPS)
    - Acrylic Stucco finish

U-factor = 0.032 (R-31.5).
Assembly complies with ASHRAE 90.1+30% for Mass Walls (max U-factor = 0.037)

ANALYSIS RESULTS

ASHRAE 189.1 Compliant Assemblies – Wood-Framed

For these assemblies, the critical layer is considered to be the Oriented Strand Board (OSB). This material is very sensitive to moisture and provides a good growth medium for mold under the right conditions. Since the OSB is a structural member, providing shear resistance for wind and seismic loads, it is critical to keep it dry enough to avoid strength loss and potential corrosion of structural fasteners. Finally, since there is a potential air pathway from the interior face of the OSB to the building occupants, preventing mold growth on the OSB is a significant indoor air quality concern.

The OSB in the “189.1-WET” assembly experiences fairly severe moisture accumulation. The EPS insulation (and especially the facing materials typically adhered to this type of insulation) have a very low vapor permeance, which restricts the potential for moisture in the OSB to diffuse toward the exterior. Similarly, the polyethylene vapor barrier on the interior face of the wall’s studs restrict the wall’s drying potential toward the interior. This double vapor barrier condition is a common pitfall in extreme cold climate construction, and the result is moisture getting trapped inside the wall cavity. In this case, the moisture is coming from interstitial condensation (caused mostly by air leakage) during the winter months.

The “189.1-WET” assembly demonstrated an overall wetting trend, with all of the moisture accumulation concentrated in the OSB layer. At the beginning of the modeled period, the wall assembly had 0.68 pounds per square foot of water (including the construction moisture). By the end of the 5-year modeled period, the wall assembly had 1.06 pounds per square foot of water. The OSB layer started at 5.2 pounds per cubic foot, but ended up with 15.05 pounds of water per cubic foot. Moisture content levels in the OSB rose above 19% (the point at which structural strength reductions are expected) during the first fall, and kept increasing thereafter. Since the OSB was not able to dry out sufficiently in the summer months, the VTT model displayed significant mold growth each summer (when the temperatures support growth), with ever-increasing coverage of mold growth. By the end of the 5 years, the VTT Mold Index reached 4.0, and was continuing to increase. This mold index value represents visible mold growth exceeding 10% of the OSB surface.

The ”189.1-DRY” assembly, on the other hand, demonstrated a drying trend for both the entire assembly and the critical OSB layer. By using highly-permeable mineral wool for the exterior insulation, any condensation that would occur on the OSB during the winter months was able to diffuse quickly through the mineral wool insulation and disperse to the atmosphere. The addition of a ventilation cavity behind the siding improves the OSB’s moisture balance by providing convective drying immediately outboard of the mineral wool insulation. The whole assembly went from 0.67 pounds of water per square foot to 0.54 pounds per square foot during the model period. The water content in the OSB layer went from 5.2 pounds per cubic foot to 3.23 pounds per cubic foot, which was dry enough to prevent even microscopic mold growth, as indicated by the layer’s 0.0 VTT Mold Index.

ASHRAE 90.1+30% Compliant Assemblies – Concrete Masonry

For these assemblies, the critical layer is considered to be the interior face of the CMU. While cementitious materials, themselves, are not considered good mold growth media, the dust that accumulates on the rough surfaces can support mold growth, and any mold growing on this surface has the potential to impact indoor air quality. However, given the type of material that it is, mold growth is not considered the main concern for moisture accumulation in CMU. For the poorly-designed assembly, this surface is the condensation plane, and accumulation of moisture on this surface can have several detrimental impacts. Excessive moisture accumulation in the CMU causes efflorescence, which would impact the aesthetic appearance of the exposed exterior finish. Frost damage from excessive moisture in masonry is also possible. Liquid condensate on the surface of the CMU migrated to the adjacent insulation, thereby reducing the wall's thermal performance. Portions of the insulation were saturated for long periods of time during the winter, indicating a likelihood of extreme hoar frost accumulation, which often leads to bulk water damage to adjacent wall and floor materials.

Overall, the "90.1+30%-WET" assembly appears to have maintained a steady moisture content, however this may have been caused by the model "ejecting" moisture beyond the holding capacity of the insulation (i.e. hoar frost accumulation or liquid water leaking down the wall cavity). Even with this consideration, however, the interior portion of the CMU was shown to increase its moisture content significantly. Water content in the interior face of CMU started at 5.31 pounds per cubic foot, but ended up with 12.62 pounds per cubic foot.

Since CMU is not a great media for mold growth, and the CMU was able to store lots of the condensation and slowly dry to the exterior, the VTT model displayed only marginal mold growth, although the rate of growth was ever-increasing through the model period. By the end of the 5 years, the VTT Mold Index reached 0.9, and was continuing to increase. This mold index value is below the threshold for being able to see mold under a microscope, and it is considered a passing result. However, the polyurethane insulation reached a VTT Mold Index of 5.5, which represents visible mold coverage of more than 50%. Between the high mold growth in the insulation, potential efflorescence and frost damage to the CMU, and likely accumulation of hoar frost or bulk water, this assembly is considered to fail.

The "90.1+30%-DRY" assembly, on the other hand, demonstrated a drying trend for both the entire assembly and the critical CMU layer due to the exterior placement of all the insulation, which keeps the critical materials warm and dry. The whole assembly went from 3.59 pounds of water per square foot to 1.32 pounds of water per square foot during the model period. Water content in the interior face of the CMU layer went from 5.31 pounds per cubic foot to 1.66 pounds per cubic foot, which was dry enough to prevent even microscopic mold growth, as indicated by the layer's 0.0 VTT Mold Index.

A summary of the key metrics described in this section is attached to this report. A graphical representation of the Mold Index values for each assembly throughout the model period is also attached.

Limitations of Analysis

This analysis was performed on the conditions that exist in a typical cross-section of the walls. While this represents the majority of the wall's area, it ignores the more vulnerable areas that are typically constructed with reduced continuity of the water, air, thermal and vapor control layers. These areas are the transitions from floor to wall, wall to wall, and wall to roof, as well as around doors, windows and other penetrations. Also, since WUFI is only a one-dimensional model, the interactions between bridging elements, such as studs, and the adjacent non-bridging materials, such as fiberglass insulation, cannot be accounted for. In addition to these challenging areas, there are likely to be some areas of the basic wall assembly that are more vulnerable to moisture damage due to faulty construction or post-construction damage. These portions of the building envelope could perform worse than the performance indicated by the WUFI model results.

CONCLUSION

The United States Army Corps of Engineers has taken great strides in improving the thermal performance of its new facilities by adopting and enforcing several UFCs that mandate minimum building envelope assembly R-values. UFC 3-101-01 also requires building envelopes to be designed for proper moisture performance to avoid mold growth, structural rot, corrosion, and other moisture damage. Unfortunately, the design principles and analysis methodologies are not well understood by the design community at large, and is not clearly enforced by the Corps during plan reviews.

As we increase the required thermal performance of our buildings, we also increase the hygrothermal stresses on our building envelope assemblies. This adds complexity to the design and construction process, and introduces higher risks to indoor air quality and building durability.

Achieving the proper moisture balance in building envelope assemblies is especially important in Zones 7 and 8 due to extreme temperature, air-, and vapor-pressure gradients across the building envelope. This paper demonstrates how it is possible to succeed in accomplishing both energy and moisture performance goals in the sub-arctic climate. It also shows how easy it is to cause moisture damage with an “energy efficient” wall in this climate. In order to ensure long-term thermal performance and avoid harm to building occupants and materials, moisture performance standards such as ASHRAE 160 should be embraced and applied as consistently as energy performance standards such as ASHRAE 90.1 and 189.1.