Building Science Forum

Importance of Condensation Control in Cold Climate Wall Assemblies

Water in liquid and vapor states, coupled with temperature changes, building operating settings, and/or usage, create potentially damaging conditions for exterior wall assemblies. To address the counterproductive effects of these environmental elements, the designers of exterior building envelopes incorporate design strategies for the control of rain water, as well as air and vapor flow through the wall assembly. Previous *RRJ Insight* articles have discussed problems in building envelopes associated with wind-driven rain; however, condensation and frost formation within the exterior wall can also lead to grave consequences including deterioration of interior finishes, corrosion of metal components, wetting of insulation, and development of unwanted biological growth.

Condensation occurs when the temperature of a surface of a building component reaches the dew point temperature (DPT) of the surrounding ambient air or air stream. Frost forms when the surface temperature is not only at the DPT but also at or below freezing (32°F, 0°C). The DPT (or saturation temperature of water vapor) is the temperature at which the water vapor and liquid water phases of air are in equilibrium and is dependent on air temperature, air pressure, and the amount of water vapor in the air. Modifications to any of these variables alter the equilibrium and may create conditions which foster condensation. For example, increasing the moisture of the interior air (relative humidity) in a building, while maintaining a steady air temperature, will raise the DPT and therefore increase the potential for condensation in some wall assemblies as the surface temperatures of some materials exposed to the vapor-ladened air may now be below the DPT.

Condensation and frost formation in cold climates are influenced by many factors including building details, air and vapor flow, interior operating conditions, and occupant usage. Common building details that can affect heat loss and promote condensation include exposure of wall components to cold cavity air due to air barrier breaches, cold wall components that span over the thermal isolators or thermal breaks of the building products, (see Figure 2), inadequate interior heat supply, and improper installation and usage of relatively vapor-impermeable materials. Air and vapor move in response to pressures created by wind, the mechanical HVAC system, and intrinsic tendencies for vapor pressure equilibrium. Essentially, air and vapor move from warm, humid, high-pressure conditions to cold, dry, low-pressure conditions. Mechanical systems can also induce pressures across the plane of the wall that can draw cold air into wall cavities or force warm humid air into them. Increased humidity levels to accommodate building occupancy or contents create even more vulnerable conditions. It is important to recognize that in northern climates where wintertime temperatures can dip below 0°F and interior ambient air can be maintained at 70°F and 30 percent relative humidity, liquid water can condense in an exterior wall assembly from vapor drive alone. Forced airflow into the wall cavity can substantially increase the problem in some circumstances depending on the wall design.

In conclusion, designers of exterior wall assemblies should consider performing an analysis of the permeability or thermal characteristics of the various wall components to assess how air and vapor are intended to be controlled throughout the wall, as well as how well the materials can dry should any water accumulate in the system. In addition, air and vapor retarders should be reviewed for adequacy, and mechanical systems should be balanced to achieve the design humidity and air temperatures, to provide necessary air flow over specific exterior wall components, and to prevent unwanted air flows. Thermal modeling and laboratory testing can also be used to evaluate the integration of the various wall systems and to identify potential problem areas.

- Robert J. Kudder

Figure 2—Condensation has formed on these exposed metal window surfaces due to wall construction that has compromised the window's design features.

Project Profile

Installation Details and Condensation Performance

Condensation and frost formation on window frames are common problems that have led to the development of industry standard tests and calculation methods to determine the condensation resistance of these products. The Condensation Resistance Factor (CRF) is one of several performance parameters that have been developed and used by the window industry to rate window and door products. Originally, CRF unit values were determined from the results of laboratory tests on specific samples, but currently, computer modeling is used to assist in obtaining these values. A higher CRF is typically recommended in climates with colder temperatures and elevated interior humidity. However, installing a window unit with a higher CRF does not ensure that the window will resist interior surface condensation because the CRF rating does not compensate for improper installation details and surrounding wall components.

RRJ was recently asked to investigate continued incidences of condensation associated with thermally broken aluminum window units installed at a healthcare facility located in southern Minnesota. The product literature for the installed windows indicated a CRF of 59 based on laboratory test results. The American Architectural Manufacturer's Association (AAMA) provides design guidelines for selection of window units by climatic conditions, and the table in AAMA 1503 indicates that window systems with CRF values between 50 and 54 should be suitable for usage in southern Minnesota. Because the window design itself appeared to be suitable with a CRF of 59, which exceeded AAMA's representations, it became necessary to consider the interfacing building details and interior operating conditions to determine the cause of the condensation.

The adjoining wall construction, from exterior to interior, consists of brick veneer, an air cavity, rigid insulation board, a weather-resistive membrane, exterior gypsum sheathing, metal stud framing, and interior drywall. A wood stool set on solid blocking was installed at the interior of the window frame, and a metal sill pan was installed beneath the window sill and extended over the exterior edge of the brick.

To provide an effective and easily adaptable method for evaluating the wall system, existing conditions were modeled

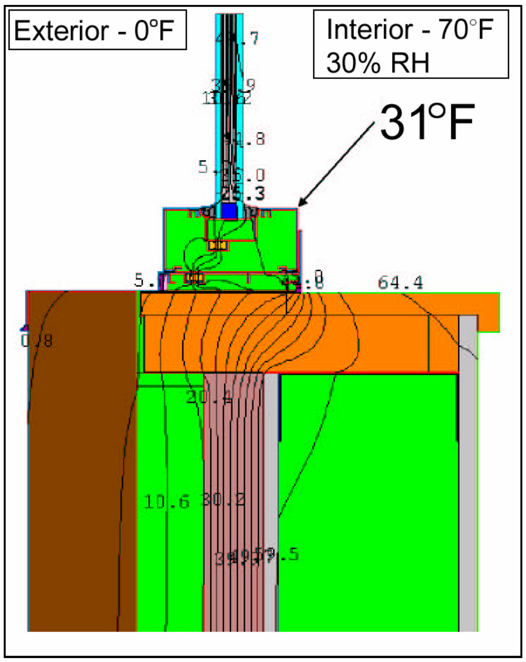

Figure 3—Existing conditions.

in THERM, a steady state, two-dimensional heat transfer program that is used to obtain CRF values for AAMA 1503 parameters (see Figure 3). The computer model incorporates interior temperatures of 70°F and exterior temperature of 0°F even though the wintertime design temperatures for southern Minnesota are -5°F. These temperature variations were not considered detrimental to the study since our intent was to identify troublesome areas. The modeling results revealed that for the as-built conditions, frame temperatures were well below the dew point range of 41°F that could be expected with an interior air temperature of 70°F and 40% relative humidity.

Several repair scenarios were then modeled that focused on insulating and isolating the window frame, but these options did not provide any significant benefit. Instead, the models did highlight the disadvantages of isolating any part of the window frame from the heat provided by the interior air. By removing the solid blocking below the wood stool and installing intermittent shims, interior air could reach the window frame and significantly reduced the heat loss experienced by the existing conditions. However, due to the limited interior access and an inability to alter interior conditions with sensitive occupancies, additional scenarios were modeled for evaluation. One scenario included an exterior metal closure filled with batt insulation installed without any alterations to the interior conditions. The Therm model predicted a frame temperature slightly above dew point. However, a repair of this type was installed and monitored throughout the winter months, interior condensation still formed at the window due to closed blinds that prevented direct access to the heat supply. Further changes were made to the mechanical system to alleviate this problem.

Though CRFs can be a useful indicator of the condensation performance and are established with prescribed testing parameters, they may not accurately predict in-situ performance. Actual exterior temperatures of northern regions may be lower than laboratory conditions and installation details can create further heat losses not addressed in CRF testing. Therefore, it is necessary to consider project-specific details when evaluating condensation concerns, including a complete understanding of laboratory and modeling parameters. Furthermore, this example demonstrates the usefulness of component modeling to efficiently and effectively evaluate repair scenarios and options prior to implementation on a larger scale.

-Robert J. Kudder
- Dennis K. Johnson
- Sarah K. Flock

RATHS, RATHS & JOHNSON, INC.
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RRJ INSIGHTS NEWSLETTER Reprint
500 JOLIET ROAD · SUITE 200 · WILLOWBROOK, IL · 60527
630.325.6160 | WWW.RRJ.COM