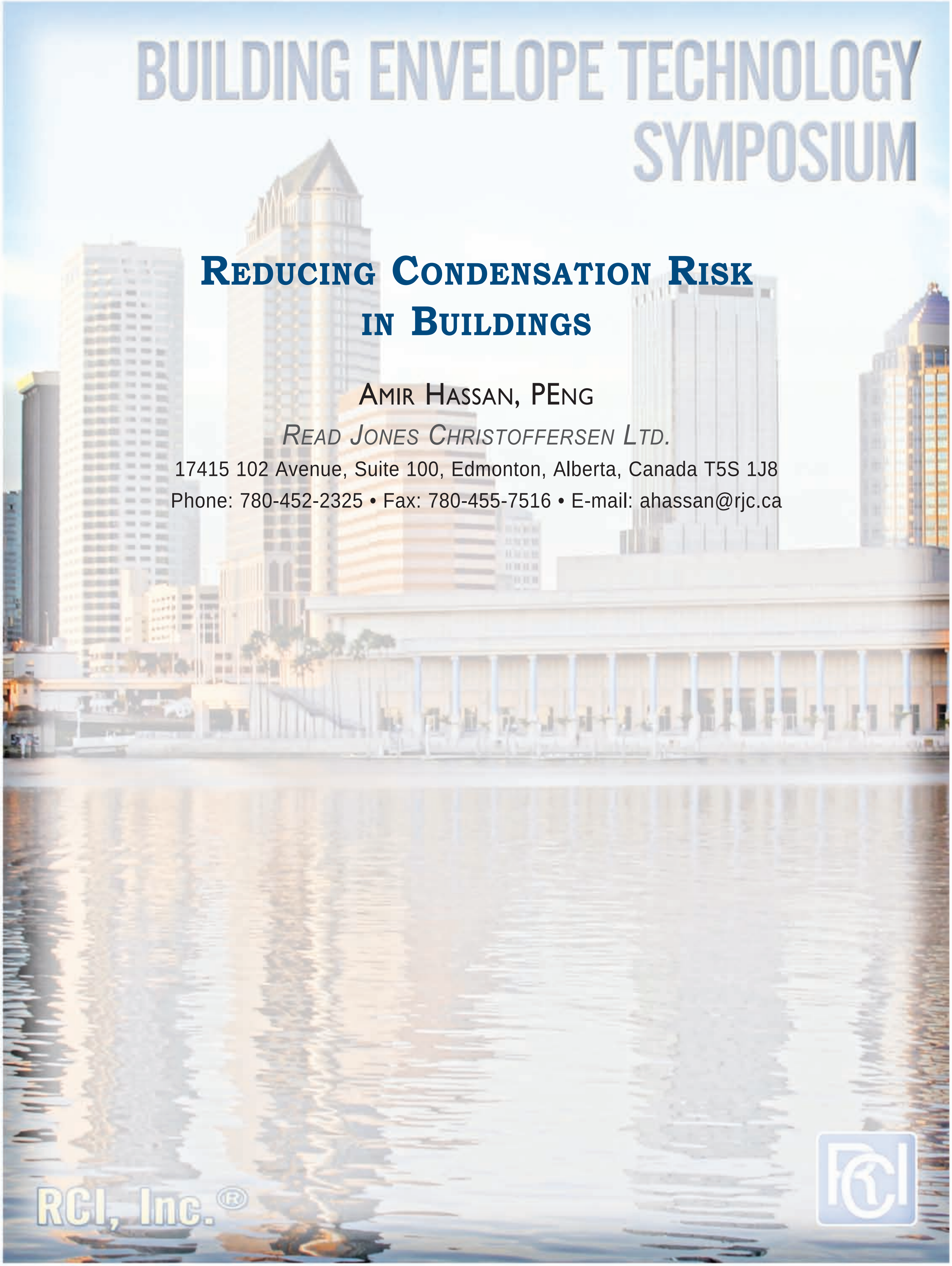

REDUCING CONDENSATION RISK IN BUILDINGS

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ABSTRACT

We have successfully made our modern buildings tighter and much more thermally insulated. However, we are now challenged to deal with side effects concerning condensation, circulation, and air quality. Condensation is a form of dampness on and in building components, where it can cause many unwelcome problems.

Condensation risk can be controlled through full understanding and analysis of anticipated problems, using temperature-gradient calculation, WUFI modeling, and finite-elements simulation. Using case studies, this presentation will shed light on the causes and some of the ways to mitigate condensation in new and restoration projects.

Additionally, some questions will be answered, such as: Would an additional layer of insulation reduce the condensation risk? Where should we add breathable membrane? What are the differences in building envelope design in cold and hot climates? What's the best way to reduce ice damming?

SPEAKER

Amir Hassan, PEng – Read Jones Christoffersen Ltd.

AMIR HASSAN has 20 years of experience in façade engineering in the Middle East, Europe, and North America. He has worked on complex projects for both existing buildings and new construction, garnering a wealth of valuable knowledge in many areas within the field. He has a BS degree in civil engineering and an MS in façade engineering. His education and practice include many areas such as the building envelope, structural glass, curtain wall design and evaluation, frameless and skylight systems, structural assessment, weathertightness, thermal performance, and thermography. Hassan is also very versatile due to his knowledge of Therm, WUFI, FEA, and other widely utilized engineering programs.

Reducing Condensation Risk in Buildings

Condensation in buildings can have a significant impact on the performance of the building envelope. Understanding the principles of condensation, its types, and practical ways to mitigate its formation can reduce the risk of damage to a building's components and the health hazards associated with mold growth and poor indoor air quality. Modern building envelope construction can be complex, with many layers of different products joining together to create adequate seals. Whether with new construction or restoration, consultants must deal diligently with these new double-edged-sword smart assemblies by using building science, testing, computer modeling, and thermography.

INTRODUCTION

We have been successful in making our modern buildings tighter and improving their thermal performance. We are now challenged, however, to deal with some side effects such as condensation, circulation, and air quality. Additionally, contemporary construction is smarter and more efficient; yet, in some cases, it can be less durable. We use products in building envelopes that are less forgiving of water, such as gypsum board and wood sheathing (*Figure 1*). In general, we expect the main structure of a building to serve for 75 years or more, while various components of the building envelope are designed to serve considerably less than that, depending on the assembly's construction and maintenance.

Besides the supporting structure (load-bearing masonry, stud wall, metal deck roof, etc.) and the outer finish layer (brick veneer, vinyl siding, stucco, metal cladding, etc.), which serves as the weather shield, the building skin consists of three main layers: the thermal barrier, the water barrier, and the air barrier. The key to good design is understanding how these layers interact with one another and—most importantly—with the surrounding environment.

Generally, building wall systems can be categorized into two types, depending on the position of the insulation layer. The first is an interior insulated wall assembly (such as an insulated stud-wall assembly) where

Figure 1 – Wood-framed building.

insulation can be inserted into the cavity between studs and commonly secured by friction. The second is an exterior insulated wall assembly (such as a basement wall or exterior insulation finishing system [EIFS]), where insulation is usually installed on the outside and secured by bonding agents or fasteners.

Figure 2 – Surface condensation on glass.

CONDENSATION IN BUILDINGS

Condensation is a form of dampness on building components (surface condensation) and in building components (interstitial condensation), and it's caused by precipitation of water vapor from air onto colder surfaces. **Surface condensation** is readily visible, with misting of windows as an example (*Figure 2*), and can be managed by providing sufficient ventilation and heat, or even accepting the results—like the use of condensation gutters in some skylight

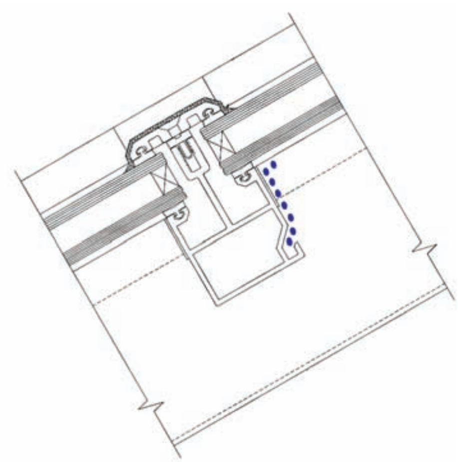

Figure 3 – Condensation gutter in skylight system.

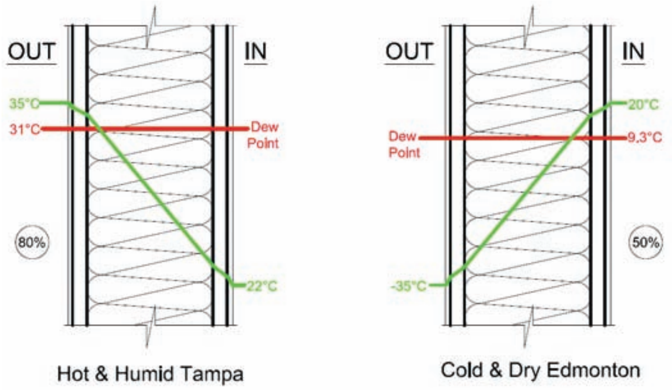

Figure 4 – Temperature gradients and dew point temperature lines in two wall assemblies.

systems (*Figure 3*). Simply put, the surface condensation will eventually dry off. That's why it's recommended, in humidified spaces when it's cold outside, to leave window curtains open in order to allow the heat from the interior to increase the inner surface temperature, thereby reducing condensation risk, as well as to let the condensed water evaporate.

In hot, humid climates, condensation can form on the outside surface of the wall system. This is not as critical to the building performance, provided that moisture does not condense within the building's assemblies. In high-rise towers, however, condensation on exterior glazing poses some challenges, as it is hard to wipe off and attracts dust.

Interstitial condensation (formation of moisture within the exterior cladding assemblies) is more problematic because it attacks the wall assembly from within; and by the time it is detected, the assembly could be at a late stage of deterioration. In buildings, interstitial condensation can cause:

- Premature failure of insulated glass panels
- Beads of water on surfaces
- Damage to interior finishes
- Dampness of absorbent materials
- Mold growth
- Unhealthy living conditions
- Corrosion and rot to building components
- Structural concerns

Water within the supporting structure can rot wood, corrode metal, and deteriorate concrete. This compromises the structural integrity of the building and leads to very costly and inconvenient repair. Mold is a growing problem within our building industry. There are many species of mold that are known to cause adverse health effects to people. Mold needs four essentials to survive: food (cellulose in most building materials), oxygen, appropriate temperature, and water. So eliminating water (both liquid and vapor) in the wall assembly is the only viable way to have a mold-free building.

PRINCIPLES OF CONDENSATION

Condensation happens simply when hot, humid air comes in contact with a cold surface where the temperature is below the dew point. In typical residential spaces, the indoor temperature is usually 68-72˚F (20-22˚C), with humidity around 30-50%. In cold climates, and with insufficient insulation, surface condensation will occur because of the cold inner surface. Adding insulation will transfer this risk to the assembly's core. This assessment can be determined quite accurately by superimposing dew point temperature's line of the warm side over temperature's gradient line of the assembly. The latter can be calculated manually or by using computer-modelling software, such as WUFI or finite-elements simulation programs.

If vapor is allowed to penetrate the wall cavity, it will hit the cold plane at the dew point and transform from gaseous water to liquid water, which is called interstitial condensation. Therefore, the vapor barrier has to be on the warm side, whether the warm side is on the outside or the inside of the building (*Figure 4*).

Even in the same geographic region, the building skin has to accommodate the differences in temperature and humidity on both sides throughout the entire year. So, the same wall that works in Edmonton, Canada's winter has to perform in summertime when the outside is the warm side. Moreover, what if the wall has to accommodate a cold hockey arena in summertime and a cozy concert in winter? The use of the building is an important factor in analyzing the condensation risk, as special requirements have to be considered when dealing with high-humidity spaces such as kitchens, bathrooms, and especially, indoor swimming pools. Furthermore, some suppliers specify minimum relative humidity (RH) for their products, such as hardwood flooring.

Vapor is gaseous-state water and can be carried from hot to cold surfaces by air convection (circulation). Another way for vapor to transfer is by diffusion through permeable materials. Therefore, air-seal can be divided into two types: air/vapor membrane, which allows neither air nor water to pass through; and vapor-permeable membrane, which retards air and allows vapor to pass through. Depending on permeance value and deriving from the Canadian General Standards Board's approach, vapor barriers can be classified into three types (*Table 1*).

To clarify terminology: Some prefer to call the membrane a vapor/air retarder instead of a vapor/air barrier, while keeping the water barrier's name as is. There's a logic behind this, as water barriers allow zero water through, while air retarders allow some air through (equal or less than 0.02 L/s•m^2 at an air pressure difference of 75 Pa, in accordance with the National Building Code of Canada [NBCC:5.4.4.2.1.a]). To keep up with the market's vocabulary, however, the term "barrier" will be used throughout this paper.

The most commonly used vapor barrier is a 6-mil-thick polyethylene sheet (poly) with a 0.06 perm rating. This value categorizes it as a Type-1 vapor barrier. Type 1 is required when there is a high difference in vapor pressure. The high difference in tem-

Type 1	Type 2	Type 3
VB ≤ 0.1 perm	0.1 perm < VB ≤ 1.0 perm	1.0 perm < VB ≤ 10.0 perm
• Glass & metal sheet • Polyethylene film • Aluminum foil • Rubber membrane	• Oil-based paints • Vinyl wall coverings • Plywood • Building paper (A&B)	• Latex-based paints • Gypsum board • Oriented strand board (OSB) • Concrete block masonry

Table 1– Different types of vapor barriers.

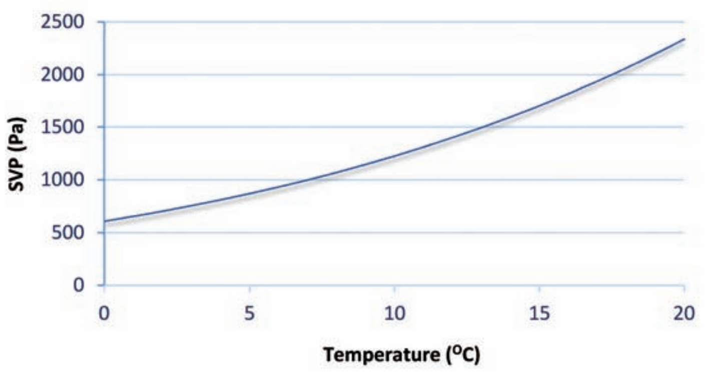

Figure 5 – Hot air can carry more vapor than cold air.

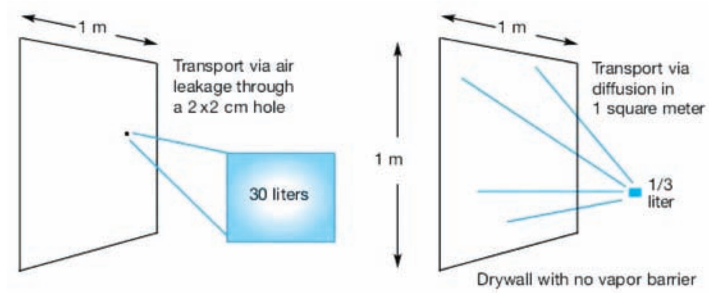

Figure 6 – Moisture transport over one heating season in central Canada (graphic courtesy of Ecohome).

perature across the separator creates that difference in vapor pressure, since warm air can hold more moisture than cold air (*Figure 5*).

For mild climates when we have a smaller difference in vapor pressure, Type 2 membranes will suffice. This can be achieved by applying oil-based paint on interior plaster. The perm rating depends on the brand, the number of coats, and the use of primer.

So if we have an air/vapor barrier, no vapor can go through it easily. Consequently, no interstitial condensation will occur. However, if there is a small hole in that membrane, then vapor will be carried through the hole by convection and liquefied on any cold surface with a temperature less than the dew point. Actually, the scale of the problem is much larger if there is a small hole in a wall than if the entire wall has a higher perm rating (*Figure 6*).

It is important to understand that when the membrane is watertight, it means it doesn't allow water through. Contrastingly, air barriers allow a specified amount of air in, which should be less than that specified in the referenced rating system. This means that the potential risk of interstitial condensation always exists.

Therefore, consultants should specify a layer with low permeability against air and vapor in order to mitigate interstitial condensation. On the contrary, if there is vapor trapped in dead space and we want to allow it to dry out, then we should use a breathable membrane that doesn't allow for air movement and yet permits vapor to escape.

CONDENSATION AND INSULATION

Mother Earth wants to sustain balance always. Therefore, heat transfers from higher to lower temperatures. There are three modes of heat transfer:

- Conduction, within solids (negligible in fluids)
- Convection, in fluids
- Radiation, without any medium

To reduce conduction, layers of material with high thermal resistivity (wood frame) should be used to construct the structural part of the skin assembly as much as possible. Reducing radiation can be achieved by using material with low emissivity (poor absorbers and good reflectors of long-wave radiation), such as applying a very thin layer of metal film on low-emissivity glass and laminating aluminium foil to sheathing board.

Air has the highest thermal resistivity among naturally existing materials, with 38.8 m•OC/W, but circulation of air in big voids reduces its resistivity due to convection. Therefore, creating smaller compartments within the large one would produce a good insulator. The insulation would rank in thermal performance depending on the arrangement of those compartments and the materials used.

Many types of insulating materials are available and used in buildings. The most commonly used types are fibrous insulation, such as rock wool; rigid insulation, such as expanded polystyrene (EPS) and extruded polystyrene (XEPS); and spray polyurethane foam (SPF), which consists of isocyanate and resin (*Figure 7*).

Fibrous insulation (batt or semi-rigid formation and fiberglass or rock wool material) is used in cavity walls with the air/vapor barrier on the warm side and the breathable membrane on the cold side. Rockwool and fiberglass are moisture- and fire-resistant. Condensation water within the cavity can dry out through the breathable membrane. Otherwise, water will get trapped, reducing the wall's thermal resistivity dramatically (thermal resistivity of air is 23 times more than that of water). Besides a decline in thermal performance, there will be a risk of rot to wood studs, rust to steel studs, and mold growth (*Figure 8*).

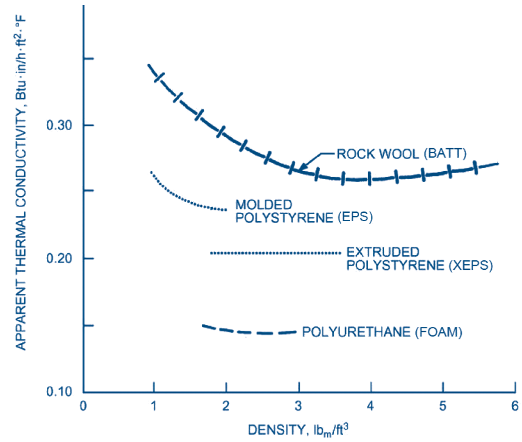

Figure 7 – Thermal performances of different types of insulation.

Figure 8 – Mold due to interstitial condensation.

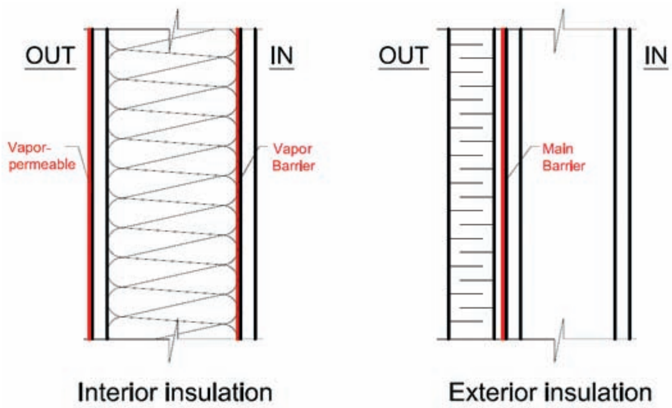

Figure 9 – Interior insulation versus EIFS.

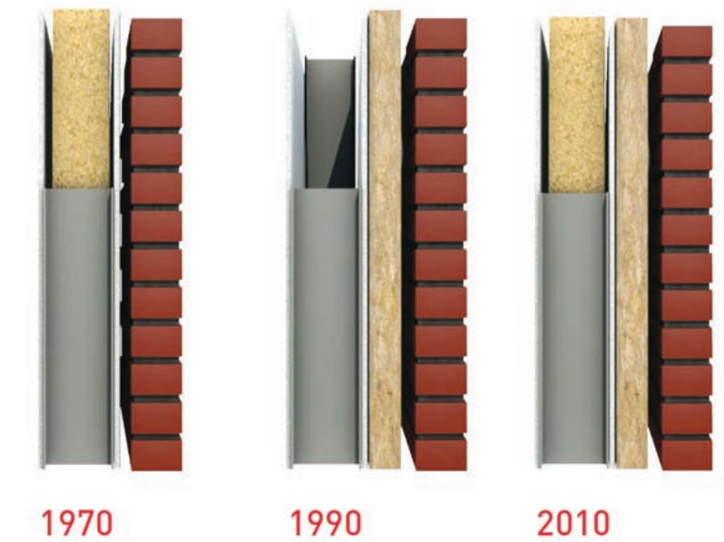

Figure 10 – Development of wall systems by Roxul.

EIFS incorporate EPS insulation (molded/expanded polystyrene). EIFS are lightweight and can be bonded or mechanically fastened to the substrate. This gives the great advantage of reducing thermal bridging through the studs and providing ample room within the stud cavity for building service lines. The only membrane in EIFS is usually responsible for separating the wall against water, air, and vapor. The drainage plane is located between the membrane and the back of the EPS board. In cold climates, the membrane can be breathable, since diffused vapor would condense on the back of EPS and drain down in the drainage plane. EPS boards may crack and house condensed rainwater. Therefore, weep holes should be provided at sill and intermediate joints.

XEPS is often used on the outside of a concrete/brick wall, especially undersoil (foundation wall and under slab-on-grade) because of its high durability and low water absorption properties. The wall section commonly consists of concrete wall on the inside, water/air/vapor membrane, drainage matt, and then XEPS board. Its closed-cellular structure makes it more resistive to water and water vapor penetration. However, it cannot be considered as a vapor barrier.

Unlike fibrous insulation, plastic insulations are resistant to fungal growth. As a result, there have been some attempts to use them on the cold side. Their drawback versus fibrous insulation, however, is their combustibility. Therefore, when plastic insulation is used on the inside, it must be covered with a minimum of ½-in.-thick gypsum board. Alternatively, fibrous insulations have been used on the outside in the form of semi-rigid insulation. Regardless, interstitial condensation occurrence would be the same whether fibrous or plastic board were used.

The golden rule for any insulated wall system is to have a vapor barrier while allowing any humidity to escape from the insulation. In interior insulation, the vapor barrier must be on the warm side. The greatest advantage in using exterior over interior insulation is that the plane of condensation is located on the outside of the water membrane. Therefore, there is less risk of interstitial condensation, and the same system (unlike interior insulation) will work in both hot and frigid temperatures (*Figure 9*).

EVOLUTION OF INSULATION

When it comes to increasing the thermal resistance of the wall by adding insulation, some believe the more, the better (*Figure 10*). This is true not only for new construction; the same approach has been employed to enhance the performance of existing buildings' skin in order to meet current codes. It is important to understand that the definite enhancements are in thermal and acoustic performances. Condensation occurrence within the new wall has to be analyzed carefully.

Actually, in some cases, it is quite damaging. Take the example of an existing building with EIFS walls. Adding batt insulation in the wall cavity would reduce the surface temperature of the main membrane because insulation performance depends on the difference in temperatures across the thickness. In this example, without a vapor-permeable membrane, condensation will occur in the new wall (*Figure 11*). Therefore, if the existing building consists of a cavity wall with batt insulation and build-

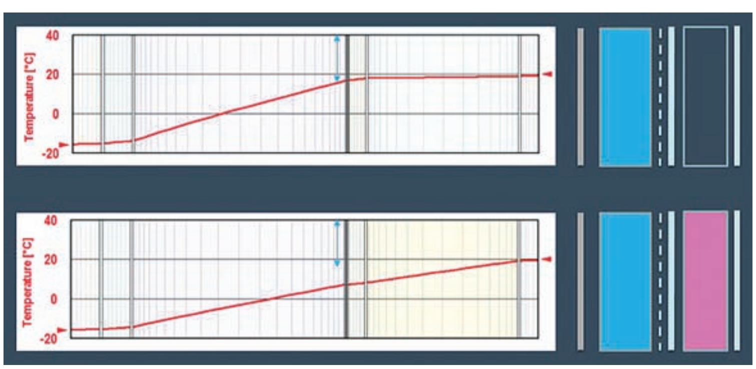

Figure 11 – Additional insulation may increase condensation risk (per WUFI).

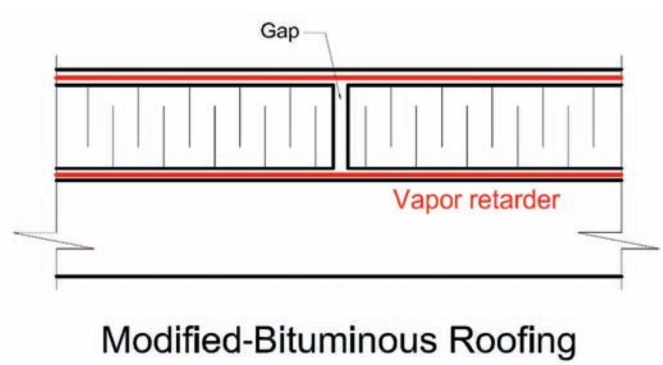

Figure 12 – Gap between rigid insulation panels.

ing paper, the wall's greatest thermal and acoustic enhancements can be achieved by adding external insulation and replacing building paper with breathable membrane.

CONDENSATION IN SEALED CAVITIES

Styrene-butadiene-styrene (SBS) roofing systems break that golden rule where there are two vapor barriers sandwiching rigid insulation with no ability to breathe. There are no connected channels in rigid insulation for air to travel between cold and warm membranes. That is why there is no risk of interstitial condensation within the insulation boards. As for the gaps, if the air pockets are small, then air won't circulate and work as a bad conductor for heat; since it acts as still air, there is less risk of interstitial condensation (*Figure 12*). Most of the roofing manuals specify board joints to be equal or less than 6 mm (¼ in.) wide. If greater, gaps shall be filled with insulation. Similar guidelines are recommended in EIFS systems (*Figure 13*).

Figure 13 – Filling large gaps with SPF in EIFS assembly.

So the question is: What's the cavity width that allows convection and, subsequently, condensation? From glazing technologies, we know that a 12-mm (½-in.) gap between two panes of glass is the optimum width for thermal insulation. More than that and we won't gain any significant increase in thermal performance because the air will have more room for convection (*Figure 14*). With vigilance, we can apply that concept to any sealed cavity. A computation fluid dynamics (CFD) simulation can be utilized to determine air circulation for specific gap geometry and anticipated differences in temperature.

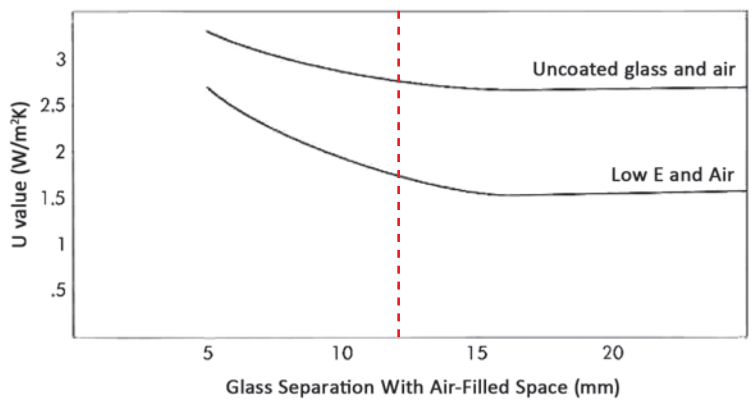

Figure 14 – The effect of an air gap between panes in IGU.

The same notion can be applied to the cavity between glazing system and adjacent wall. The lines of insulation of the glazing system and the wall don't usually meet. The gap creates a thermal bridge, and the membrane gets cold in frigid climates. If we leave the gap unsealed from the inside, humid, warm air can travel and condense on the cold membrane, causing damage to the interior components and finishes. So if the gap is small (less than 12 mm or ½ in., depending on temperature difference), then interior caulking should be sufficient (*Figure 15*).

If the gap is bigger and exterior insulation is not achievable, then insulation should be used from the inside. Low-expansion foam is commonly used to avoid any distortion to the window frame, such that the sash fails to open and close easily. However, using low-expansion, open-cell, low-density foam insulation would create indentations in the cavity and must be treated as fibrous insulation—i.e. by applying interior caulking after cutting the foam back (*Figure 16*).

Figure 16 – Low-expansion foam insulation.

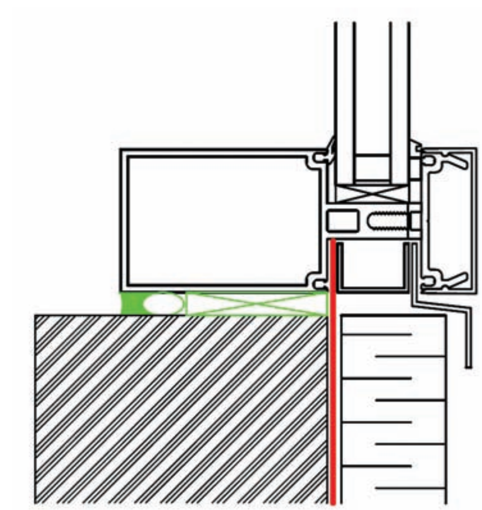

Figure 15 – Perimeter joint around glazing.

Figure 17 – Pull test for foam insulation.

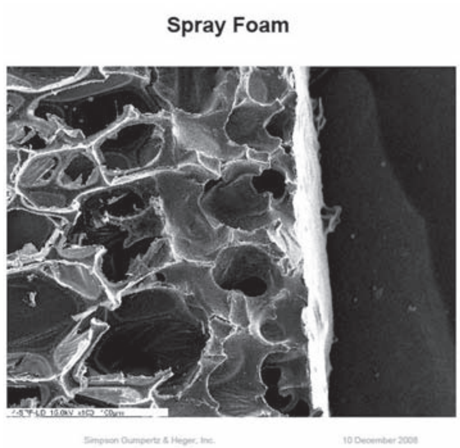

Figure 18 – Structure of spray foam.

SPRAY POLYURETHANE FOAM

The use of closed-cell foam insulation has been escalating in building envelope construction in recent years. Any complicated three-dimensional cavity may be sprayed. SPF is formed by mixing two chemical agents (isocyanate and aminoplast resin). The final volume is around 20-40 times the original combined volume. It has very similar characteristics to plastic insulation. In a scenario where there is a wall with two air/vapor barriers, neither fibrous insulation (needs to breathe) nor rigid insulation (buildability issues) can be used, so the best feasible solution is using closed-cell foam insulation.

Like any plastic insulation, SPF has poor fire resistance, so if it is used as interior insulation, a ½-in. gypsum board must be used for up to 4 in. of insulation, and ⅝-in. gypsum board for insulation thicker than 4 in. Alternatively, thermal barrier (ignition barrier) can be sprayed on the inside. One type of thermal barrier is a cementitious fire/heat protective coating formulated specifically for application over plastic insulation. The thickness depends on the product and the thickness of the insulation. With some exceptions, the use of thermal barrier can be eliminated in crawl spaces and attics.

Moreover, the foam is brittle, with very minimum tolerances to movement. Consequently, air can penetrate through movement cracks. Therefore, air/vapor membrane should be used on the warm side.

Besides resistance to mildew, fungi, and bacteria, foam insulation has good bonding attributes. In old, uninsulated buildings, foam-in-place insulation can be used alone on the inside regardless of the climate. First, it can adhere to the substrate where pull tests can verify that (*Figure 17*); second, with minimum thickness, depending on the brand name (generally, 3.5-in. thick is considered air-impermeable; ASTM E283 can be referenced), it can work as an air/vapor barrier; and third, there is no risk of interstitial condensation due to its closed-cell structure.

Both common types of foam-in-place insulation (low-density, open-cell and medium-density, closed-cell) have cellular structures (*Figure 18*) that consist of gas bubbles. In closed-cell foam (*Figure 19*), the gas bubbles trap the blowing agent (air or hydrochlorofluorocarbons [HCFC]) permanently during expansion and cure, making closed-cell foam vapor barriers at a specified thickness (this thickness can usually be found in the product's data sheet). Contrastingly, open-cell foam's bubbles cannot retain the blowing agent, and it escapes during expansion and cure, creating connecting channels within the insulation. Those channels will be filled with atmospheric air (*Figure 20*). Thus, open-cell foam acts similarly to EPS insulation. The market recognizes a density of 2.0 lb/ft^3 as the threshold to consider a foam as closed-cell insulation.

Moreover, because of all-in-one characteristics, spray foam insulation can be applied in underground parking garages (including ceilings), any wall types, attics, and even roofs (whether on the inside or on the outside).

CONDENSATION IN SPANDREL PANEL

Some curtain wall designers have employed a similar approach by replacing semi-rigid insulation in metal backpans (*Figure 21*) with foam insulation. Using semi-rigid insulation requires having an integrated air/vapor barrier behind it. This is done by having one piece of backpan or applying membrane on the fabricated backpan's seams (*Figure 22*). Foam insulation can be used without membrane on the fabricated backpan if the insulation foam creates a proper air seal. Regardless of insulation, the space between the insulation's exterior face and the pane's interior face has to be ventilated and drained (*Figure 23*).

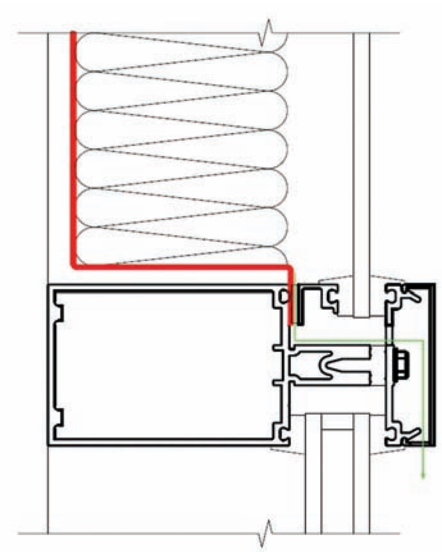

Figure 21 – Typical detail of spandrel panel.

Figure 19 – Closed-cell foam insulation.

Figure 20 – Open-cell foam insulation.

Figure 22 – Using membrane to create vapor seal at nonwelded joints.

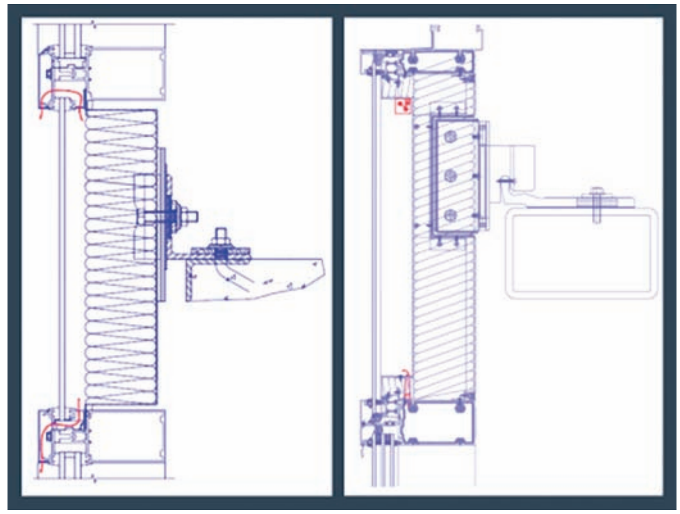

Figure 23 – Ventilation openings in curtain wall systems.

THERMAL BRIDGING

It is hard to fully avoid thermal bridging in buildings. In general, exterior insulation systems offer better coverage from the environment for a building's components. Besides the loss in energy, condensation is a serious issue in cold climates, where these components attract humidity and cause condensation (*Figure 24*).

Leaving cold components unfinished exposes them to inside heat and circulation, leading to a lower risk of surface condensation. Alternatively, insulating these components and providing an air/vapor barrier would be the optimum solution. In hot, humid climates, the condensation occurs on the outside, and the element should be designed to stand against the weather (such as specifying the use of stainless steel fasteners for weather durability). Special attention should be given to closed and nondrained finishes around the thermal bridges.

UNDERGROUND ASSEMBLY

The best way to insulate underground concrete walls and slabs is by using exterior insulation after the waterproofing membrane. However, that might not be the case when dealing with older buildings or with new buildings where insulation layers have been overlooked. As an example: Sometimes part of a parking garage's slab is under heated space, while the rest is not, and yet the entire slab could be uninsulated. The latter part would create a very cold surface in winter and cause condensation and frost (*Figure 25*). Removing landscaping plus soil to add that layer is very expensive and disruptive. Also, building a fully insulated wall on the inside would reduce the usable square footage.

Therefore, using foam insulation is very practical since it is one layer that acts as an air, vapor, and heat retarder. Proper surface preparation and testing for bonding and density are crucial. Again, adding a thermal barrier satisfies the fire code (*Figure 26*). Some rigid insulation systems are available on the market (*Figure 27*).

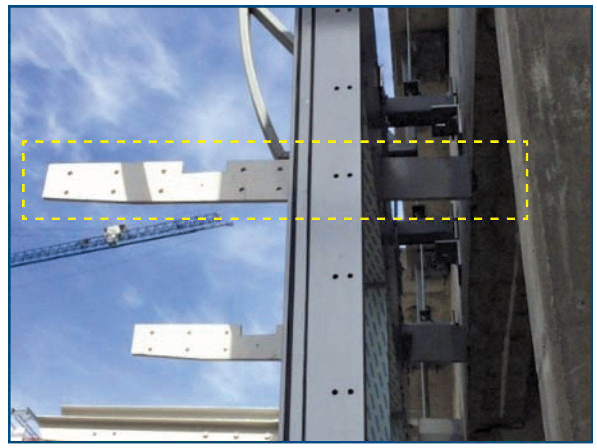

Figure 24 – Thermal bridge via steel bracket through curtain wall.

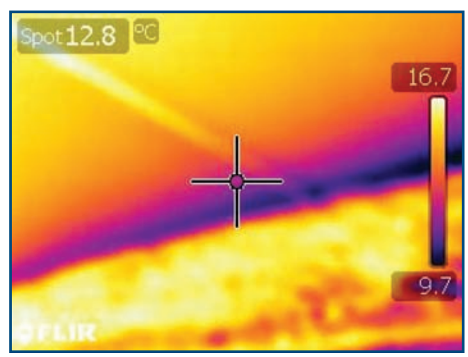

Figure 25 – Infrared image of underground slab.

Figure 26 – Insulated parking garage slab.

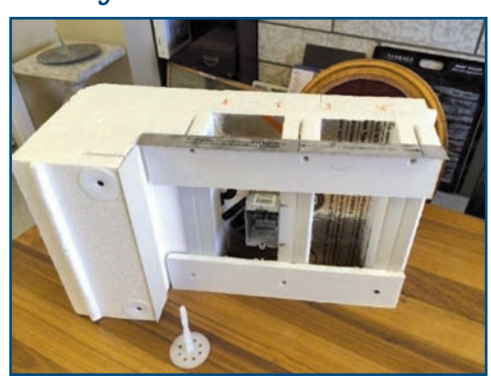

Figure 27 – Interior insulation system for existing structure.

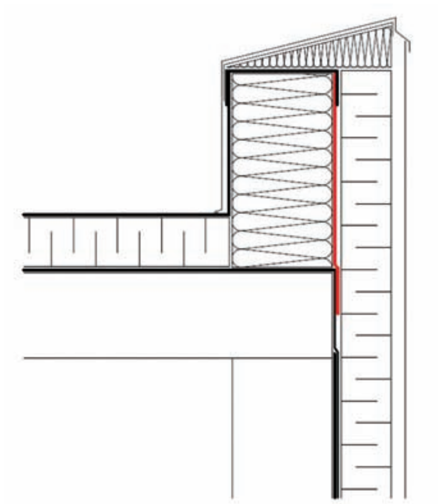

Figure 28 – Common parapet detail.

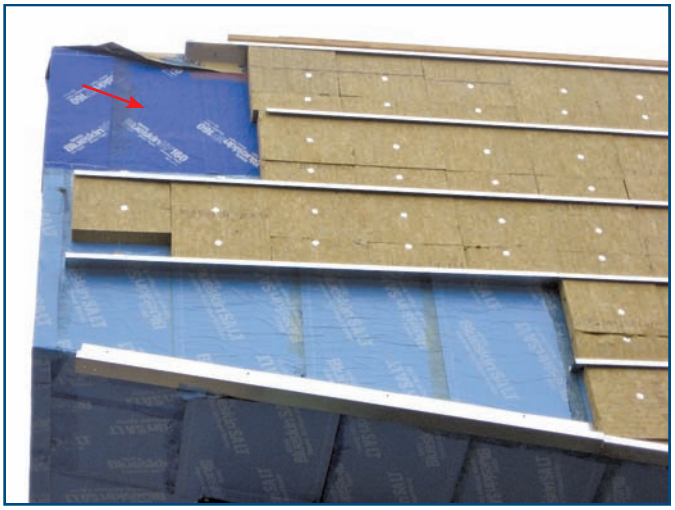

Figure 29 – Using breathable membrane at parapet wall.

PARAPET DETAIL

Another weak joint is located at the meeting line between the wall and the roof parapet. In high-rise buildings, a combination of interior hot air (gets elevated by the heat-stack effect) and high wind suction creates the perfect recipe for air leakage and a high risk of condensation in cold climates. Both wall and roof assemblies are insulated and sealed. But what about the interface? One of the recommended details—used commonly in commercial buildings—can be achieved by running the vapor barrier of the roof assembly under the parapet wall, then connecting it to the wall's membrane in shingle fashion to reduce the risk of water ingression behind the wall's membrane (*Figure 28*). The exposed flap should be temporarily secured to the wall until it gets connected to the wall membrane.

Complex 3-D geometry and different adjoining materials cause some confusion. The common mistake is trapping vapor in the parapet space, which leads to interstitial condensation. Using breathable membrane would solve this problem (*Figure 29*). Alternatively, closed-cell foam insulation can be used in the parapet wall when it's fully enclosed by vapor barrier membranes.

Additionally, curtain wall mullions at parapet joints act as miniature chimneys, where the humid hot air can travel upward, hit the cold surface, and condense (*Figure 30*). Full extension of the air/vapor barrier mitigates any condensation risk caused by imperfection in the curtain walls' air barrier. Also, to reduce thermal bridging through the curtain wall's mullions and the parapet wall's steel studs, insulation should be added on the top ledge (*Figure 31*).

ATTIC DESIGN

An attic is technically a wall assembly with a large air space. The greatest challenge lies in constructing and maintaining the air/vapor barrier. In cold climates, the stack effect pushes hot, humid air to the enclosed cold space. Where there is insulation on the dividing slab, unsealed ducting that penetrates through that slab, and any thermal bridging (*Figure 32*), an imperfection in the air/vapor barrier (if any) could create the recipe for imminent condensation on the cold roof of the attic structure (*Figure 33*).

In addition, seeping of hot air can melt snow on the roof and create ice damming (*Figure 34*). Besides trying to perfect the airtightness of the slab, attic ventilation has proven to be the most practical and efficient solution. Ventilation will keep both sides of the attic roof cold and reduce the RH value within. As for hot climates, ventilation will reduce the temperature of the attic air, which can be very high due to solar heating.

Spray foam insulation can be applied as the thermal air vapor barrier (*Figure 35*). Special attention has to be given to fire codes and accommodation of building movements within the plastic insulation.

Thermal simulation and building science assessments of an attic during design, or even during restoration, may steer the assembly away from ventilation and take it as far as an external insulation system.

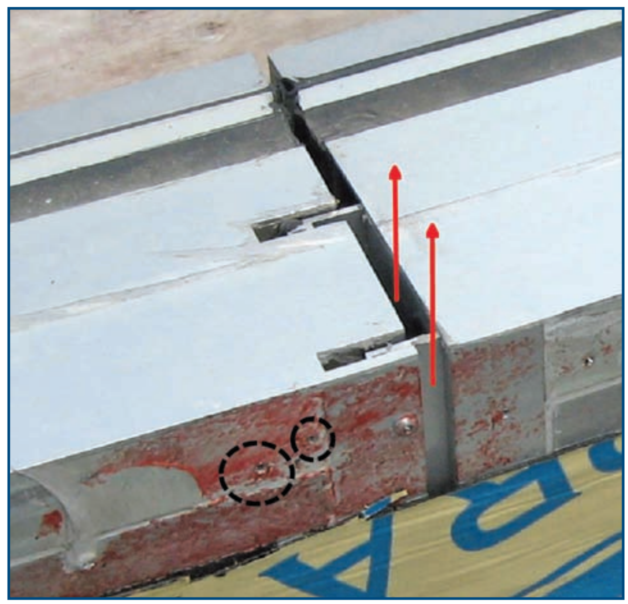

Figure 30 – Air leakage through mullions.

Figure 31 – Unfinished parapet ledge.

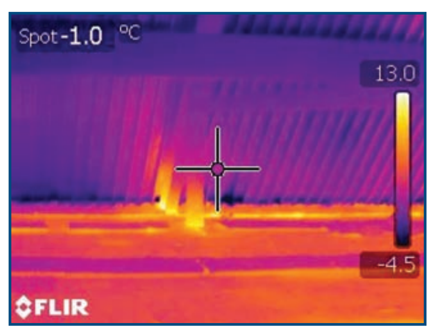

Figure 32 – Thermal bridging to the attic space.

Figure 33 – Condensation and frost on the attic wall.

Figure 34 – Ice damming.

Figure 35 – Foam insulation as prime barrier in attic.

CONCLUSION

Buildings incur condensation, and the consequences can be devastating—from the degradation of finishes to mold growth and even structural deterioration. Whether dealing with condensation issues in an existing building or in new development, analyzing the building envelope and understanding water vapor's behavior is vital to achieving effective enclosures. Educating the building owner/user on condensation risk and his or her role in reducing the ramifications is necessary to reach required performances.

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