PROCEEDINGS

RCI INTERNATIONAL CONVENTION AND TRADE SHOW

Panelized Wall Systems – Joint Detailing for Success

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Abstract

Prefabricated exterior wall panels are becoming more popular for their potential to accelerate building construction schedules, better control fabrication quality in a shop setting, and reduce costs; however, without careful detailing, the joints between panels may increase maintenance requirements and prove to be the weak link within the system. These joints are potential vulnerabilities, as they often rely on gaskets, sealants, and foams as the primary weather barrier. All three typically require maintenance and make the integration of modern wall barriers (air, vapor, weather, and thermal) complicated. The joints also typically lack redundancy.

In this presentation, we discuss multiple panel joint options, which we have seen both in design and construction, and their advantages and disadvantages, including long-term durability and capability to accommodate building movement and deflection. We also discuss what features designers should focus on when reviewing prefabricated panel designs and how designers can work with the prefabricated exterior wall panel contractors to improve the wall barrier integration and provide redundancy in the joint detail design.

Speakers

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Panelized Wall Systems – Joint Detailing for Success

INTRODUCTION

Panelized wall systems are prefabricated panels, complete with exterior cladding, anchor systems, water/air/vapor barrier(s), insulation, and the structural framing. The panels are constructed in an enclosed facility, transported to the project site, and lifted into place, where they are anchored to the building's structural framing. Panelized wall systems are becoming increasingly popular for their potential to accelerate building construction schedules, improve control of fabrication quality in a shop setting, and reduce costs; however, without careful detailing and quality control, the joints between panels can become a source of leakage and prove to be the weak link within the panelized cladding system. The panelized wall system trades the reliability of continuous exterior wall membrane barriers for economy and speed in construction.

This presentation will describe design aspects of the panels, different panel joint materials and construction, and discuss considerations for the panel joints' watertightness, durability, and thermal resistance.

WHY USE PREFABRICATED PANELS?

Conventional exterior wall construction requires mobilizing multiple trades to work sequentially via staging, aerial lift, or swing stage; and much of the exterior façade work is dependent on temperatures and moisture.

For panelized wall systems, the trades work within the same enclosed facility to simultaneously fabricate multiple panels. Panel fabricators can have welders, waterproofers, glaziers, and cladding installers all working within the same place to streamline the fabrication process. Fabrication is not weather dependent, allowing weather-sensitive materials, like waterproofing membranes or spray-applied materials, to continue despite cold or hot temperatures, rain, and humid conditions outside. The panels can be easily inspected by a designated quality control manager as the layers of the façade are installed. Once the panels are complete, they can be stacked and stored at the facility until they are ready for installation, and then the timing of panel arrival to the project site can be staggered so that only enough space for a truck and a crane is needed. This accommodates sites with a small laydown area. Depending on the wall detailing, the exterior wall construction does not require stick-built staging or coordinating multiple aerial lifts.

Panelized wall systems can better accommodate tall buildings, shorter construction schedules, and construction sites with limited laydown space, and they can require minimal exterior access. These are the reasons to use prefabricated panels. So why not use them exclusively? The joints. The joints are the weak point in the system. If not designed and constructed correctly, they can allow water and air leakage, leading to premature deterioration.

PANEL DESIGN CONSIDERATIONS

In concept, prefabricated panels are similar to precast concrete panels that have been used for many years—precast concrete panels are constructed off-site, shipped to the project site, and anchored to the building structure. The joints between the precast concrete panels are commonly dual-stage sealant joints to maintain continuity of the weather barrier provided by the concrete to help overcome limitations of single-stage sealant joints. These wall systems typically perform well, until the sealant joints fail or the panels crack, requiring maintenance.

More modern panelized wall systems now incorporate a rainscreen cladding, air and water-resistive barrier membranes, and insulation within the panel, complicating the joint design. Designing a conventional veneer or rainscreen wall system requires consideration of the water/air/vapor and thermal barriers (depending on the climate at the building location). A successful exterior building envelope system incorporates a water barrier with flashing to contain and drain bulk water, an air barrier to minimize air flow, a thermal barrier to slow heat transfer, and a vapor retarder (where required) to minimize vapor diffusion from warm, moist air onto cold surfaces. These barriers should be continuous to provide the optimal performance.

The panelized wall systems are similar in some respects to conventionally constructed walls, with some modifications.

- **Structural framing:** The panels are typically constructed on a structural steel perimeter frame with light-framed metal stud infills. The structural frame is designed for the exterior wall dead and lateral loads and to provide the panel with rigidity to prevent racking when the panel is moved. Some frames have an interlocking mechanism along the edges to allow the panels to be stacked while allowing for in-plane deflection between floor slabs. If

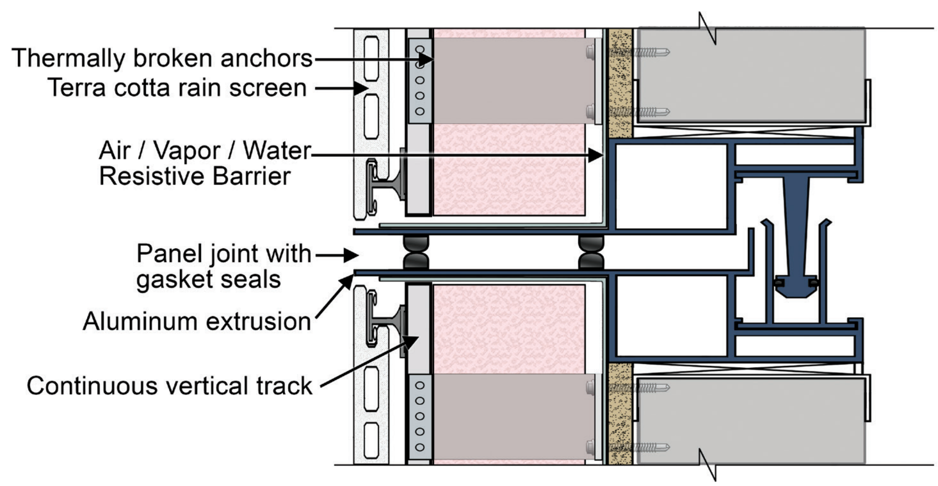

Figure 1 – Exterior wall section with interlocking metal frame.

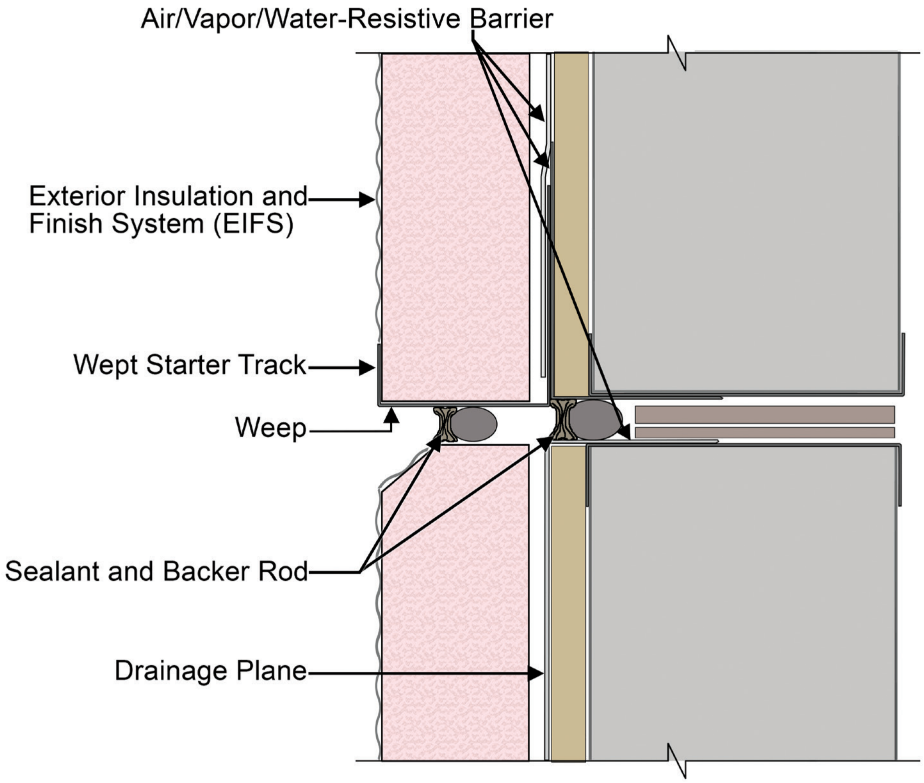

Figure 2 – Panel joint with dual-stage sealant joints.

this interlocking mechanism is continuous around the panels, it can also provide weather protection or an air barrier, similar to a unitized curtainwall system shown in *Figure 1*. The structural joint construction between panels can differ between panel fabricators.

- **Cladding:** The exterior wall cladding can vary, though typically panels incorporate a lightweight rain screen such as metal panels, exterior insulation and finish systems (EIFS), terra cotta, thin-brick, and glass fiber reinforced concrete (GFRC) panels. Panel sizes, and therefore the joint locations in the façade, are determined by floor height, column spacing, or often the shipping method between fabrication facility and job site (i.e., truck bed size). Façades with repetitive patterns naturally lend themselves to panelization, but façades with varying cladding types and offset joints can also be accommodated.
- **Flashing:** Through-wall metal flashing can be installed at the base of panels, allowing water to exit the façade at the horizontal panel joints, and further improving reliability and long-term performance against water intrusion. However, the flashing is difficult to install continuously across the façade. Instead, the metal flashing is typically end-dammed at edges of panels to isolate an individual panel from its surroundings, which prevents draining water at the panel joints, the weakest point of the wall system. Alternatively, adjacent pieces of the metal flashing can be sealed together at each vertical joint, which requires more field modifications and slows installation.
- **Windows:** Windows and curtainwall units, along with the perimeter flashing, are installed within the prefabricated panels, eliminating the window flashing and installation in the field. Windowsill pan flashing, head flashing, and perimeter seals are installed similarly to conventional construction.
- **Building transitions:** Transitions to other building envelope components, such as the roofs, parapets, bases of walls, or plazas still are field constructed. The panels need to be constructed to allow for this transition, or parts of the cladding need to be left off the façade to allow for the installation of these transitions in the field.

The water/air/vapor barrier and insulation within the field of the panel can be installed similar to conventional construction, but the material options at the joints can vary.

JOINT DESIGN CONSIDERATIONS

Material options to continue the water, air, and vapor retarder at panel joints include sealants, membranes, expandable foam tapes, and gaskets. The reliability (as determined by product material performance data and verifiable long-term track record) of the joint material is critical to the long-term performance of the wall system, as these joint materials can be difficult to replace without local deconstruction of the exterior cladding to access joints. Panel joints that rely on gaskets, sealants, and expandable foams will typically require maintenance during the anticipated life of the building. Since joint maintenance may be difficult or impractical, selection of durable seal material and proper installation are critical.

The following discusses some of the more common materials, along with their advantages and disadvantages. Some of these materials should only be considered when used in combination with other materials that have a history of performance.

Sealant Joints

Single-stage sealant joints alone should not be considered, as sealants are not a reliable long-term water-resistive barrier. Multiple-stage sealant joints are a common choice for joint construction, as they are straightforward and help overcome weaknesses of a single line of sealant. See *Figure 2,* where dual-stage sealant joints were installed between panelized EIFS.

Dual-stage sealant joints can provide an adequate barrier as long as they stay adhered to the bonding surfaces. As you can see in *Figure 2*, the exterior sealant joint (i.e., front sealant joint) is in line with the exterior cladding, and the rear sealant joint is in line with the air/vapor/water-resistive barrier. The panel system relies on the rear sealant joint being 100% continuous, integrated, and well adhered to the adjacent air/vapor/water-resistive barrier surfaces. The sealant and backer rod material selection must allow for proper cure of the sealant if the surrounding materials are impermeable, as air and/or moisture may be needed for the sealants to properly cure.

If the interior sealant joint should fail, replacing the interior sealant joint can be very difficult, if not impossible, if the front face of the cladding is deeper than a few inches, as proper replacement requires cleaning and preparing the joint surfaces, which are difficult to access. For this reason, it is important that the interior sealant joint—the primary weather seal—be inspected prior to the exterior sealant joint installation.

Membrane

Continuous membrane, such as self-adhered membrane or silicone membrane, forms a more reliable and durable water and air barrier and overcomes many limitations inherent with field-applied sealant joints. The membrane, when properly adhered and sealed on both panels, provides continuity of the air and water barrier, and of the vapor retarder, depending on the permeability of the membrane used. See *Figure 3* for an example of a horizontal panel joint with a self-adhered membrane over foam backer rod.

When the membrane is installed with a properly sized bellows, as shown in *Figure 3*, this joint is allowed to move (more than a sealant joint) without putting stress on the adhered surfaces. As such, this joint will typically have a longer life span before the membrane becomes unadhered or tears. The difficulty in installing membrane over the joints is that it requires access to the panel sheathing after the panel is installed on the façade, therefore requiring that the exterior cladding adjacent to joints be left off the walls until after the membrane transition is installed (reducing the benefit of using a panelized wall system), and this joint detailing may not be feasible for all types of exterior wall cladding types or aesthetic designs. In the case of Figure 3, the metal panels are installed afterwards, along with additional insulation.

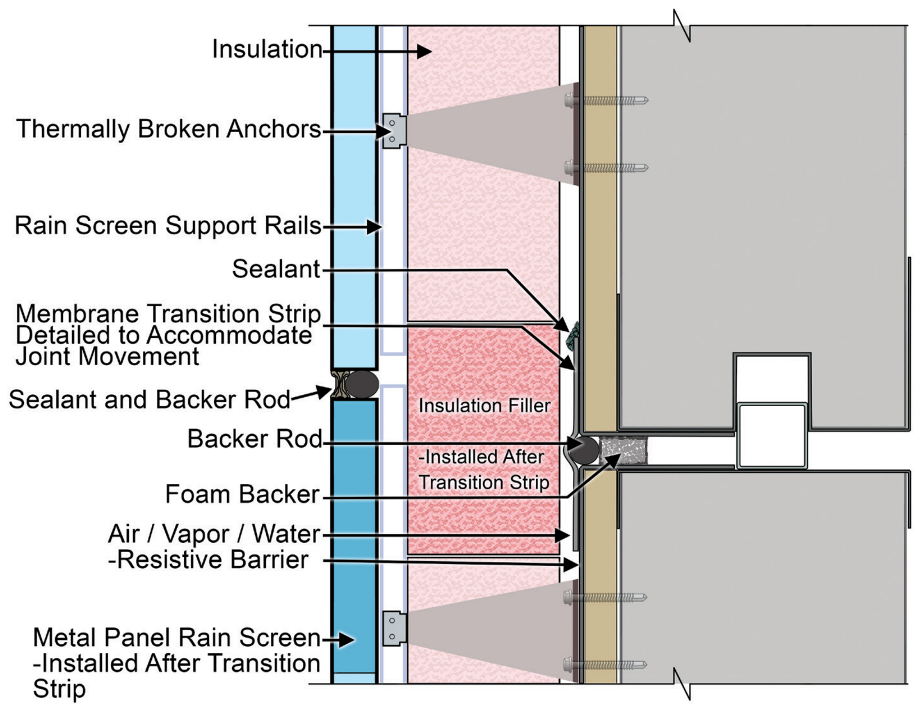

Figure 3 – Panel joint with membrane and insulation.

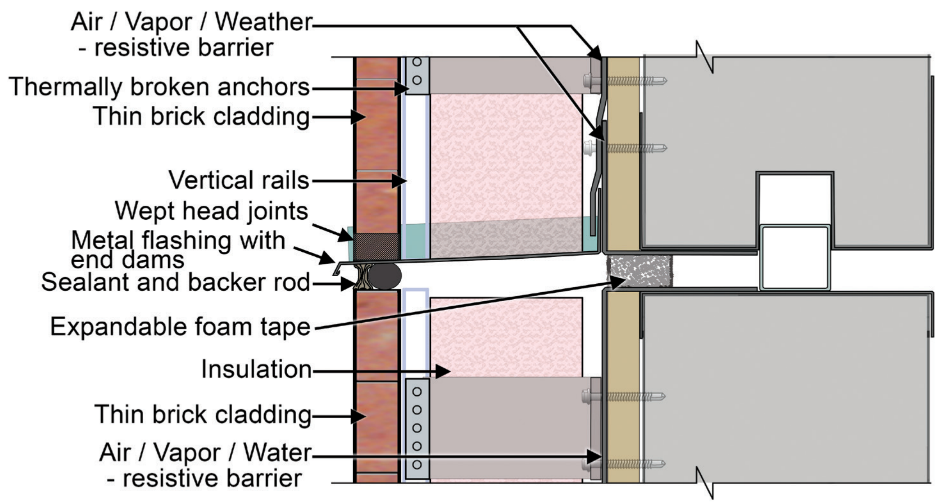

Figure 4 – Panel joint with expandable foam tape.

Expandable Foam Tapes

Expandable foam tapes are a time-efficient way to close the joints between panels, as the tape is adhered to the panel edges before the adjacent panel is installed. See *Figure 4*, where expandable foam is used to continue the air and water barrier at the joint, along with an exterior sealant joint at the face of the cladding. Many of these foams are vapor permeable, and therefore should not be considered where a vapor barrier is needed.

The reliability of the expandable foam tape depends on how well it bonds to the adjacent surfaces, which varies with the product and the installation requirements. Some expandable foam tapes rely on a thin, tacky surface (sometimes only on one side of the tape), along with the compressive nature of the material to compress against and bond to the panel edges and prevent water infiltration. These tacky surfaces can lose the adhesive bond if exposed to water for an extended period of time. Some foam tape manufacturers' installation instructions do not require sealing the edges and joints at the ends with sealant, so the extra step of sealing all gaps and butt joints between foam rolls should be specified. This is particularly important at the panel corners, as the foam tape cannot bend 90° at corners and instead must be cut at the corner, providing another weak point at a critical transition. See *Figure 5* showing sealant between cut edges of the expandable foam tape at the panel corner. Additionally, some foam tapes have limited expansion and compression capabilities, (i.e., less than that of a typical sealant joint that has up to 50% compression and 100% extension movement capabilities), so it may not be

Figure 5 – Expandable foam tape with sealant at the panel corner.

appropriate for all projects where the deflection at joints can add up due to temperature differential, loading movement, and long-term creep (concrete frames only).

Once installed between panels, the foam tape slowly expands until it fills the joint between solid surfaces. As it expands, force is exerted onto the panel surfaces, which must be solid, continuous without abrupt plane changes, and parallel. If the substrates are not solid, the foam will bulge through the unsupported surface. If the substrates are not continuous, the foam tape will not follow an abrupt plane change and will tent across the surfaces. If the substrates are not parallel, the expandable foam can roll itself out of the panel joint.

The track record on these expandable foam products is not as established as other joint products, such as self-adhered membrane or sealant, but is gaining popularity since the installation is quick and does not require immediately installing the exterior sealant joint to make the building façade watertight. The installation of the foam tape is extremely installer dependent, and it is beneficial to inspect 100% of the foam tape for gaps, foam defects, or unsealed cut edges if the façade is relying on the tape as the primary water barrier. In addition, this material should be used in combination with other materials with a proven track record.

Rubber Gaskets and Interlocking Joints

Similar to expandable foam joints described above, rubber gaskets offer another time-efficient way to provide a water, air, and vapor barrier at panel joints as the panel is being installed without much additional manpower. Rubber gaskets rely on the compression of the gasket against a hard substrate or another gasket to close off the joint and require the use of a metal extrusion to attach the gasket to the panels. See *Figure 1* where two lines of gaskets are used between aluminum extrusions, similar to a unitized curtainwall, and *Figure 6*, where the gasket is attached to a perimeter angle and is used in combination with the foam tape behind it.

Rubber gaskets can be an issue at the four-way panel joint corner, which has four 90° gaskets coming together. The gaskets should be stiffer at the panel corners to provide some rigidity at panel intersections to resist crushing from panel installation on the building. Even with perfect compression and alignment of panels, there will still be a small gap between the gaskets, so this method requires sealing at the panel intersections to ensure a continuous water barrier at the gasket corners. Long term, gaskets can become hard and brittle, making them less forgiving as the panels continue to move and deflect, and gasket replacement without deconstructing the panels is impossible.

Panel joints using continuous interlocking male–female extrusions, constructed similar to unitized curtainwalls, can provide an additional layer of weather protection at the joints beyond the gasketed seals. These panels are more expensive than panels with basic steel frames. The panels are sometimes smaller, so they can be hung from the building interior, eliminating the need for a site crane for installation, and more panels can be installed within a day as compared to larger panels.

The metal perimeter extrusions for the gaskets have to be integrated with the panel weather-resistive barrier for the panel to perform as intended. The metal perimeter extrusions provide a clean panel edge to hold the thermal insulation in place and protect the panel edges. However, metal extrusions have a high thermal conductivity, therefore

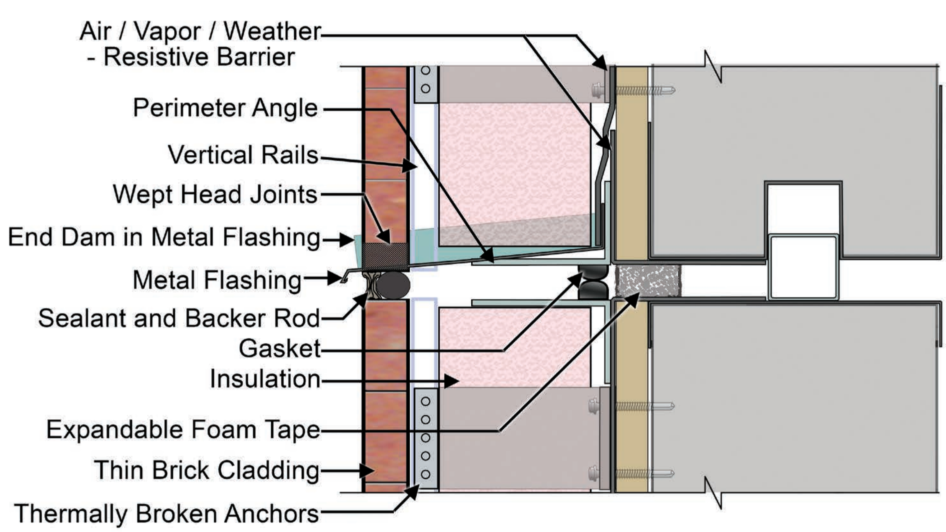

Figure 6 – Panel joint with rubber gasket.

reducing the overall thermal performance of the wall system. Additionally, the metal angles can increase the potential for interior condensation for buildings located in heating climates if they are not thermally broken. Models can simulate risk of condensation, depending on the building type and interior conditions during the winter. Though the perimeter metal extrusion is not ideal with respect to thermal performance, the extrusion may be needed to provide some rigidity to the panel or to provide a flat surface for a gasket, expandable foam tape, or sealant joint. The design team should weigh the benefits of the gasket with the reduction in thermal performance and potential for surface condensation as discussed below.

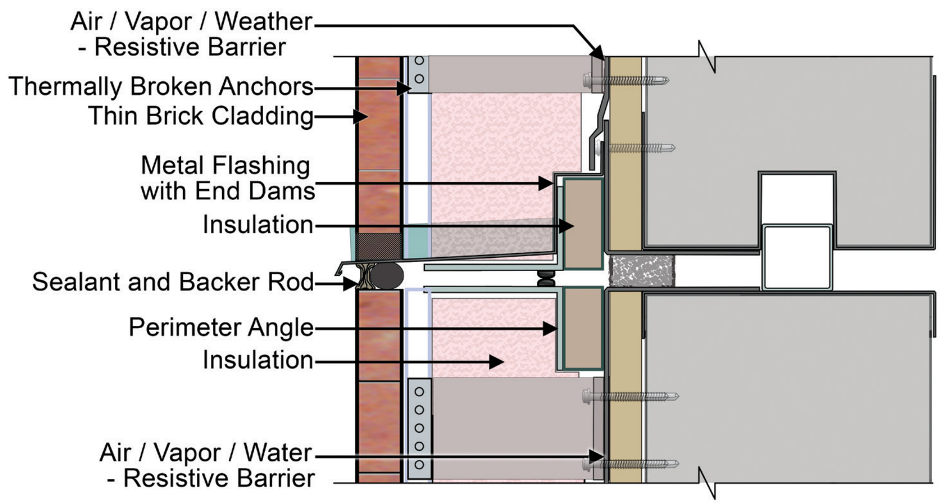

Figure 7 – Thermal break behind metal angle.

THERMAL PERFORMANCE

The exterior wall system must meet or exceed the energy code requirements while accounting for the thermal bridging at each panel joint that can increase likelihood of condensation on cold surfaces within the wall system.

Ideally, insulation would be placed in the joint after the panel installation for continuity as shown in *Figure 3*, but this may not be technically feasible due to the cladding type. The extent of the thermal impact on the overall wall performance depends on the joint detailing and panel size. The joint detailing shown in *Figures 1* and *6*, where aluminum extrusions span from the exterior cladding surface to inboard of the wall insulation, have the greatest potential to significantly decrease the overall wall U-factor or to create thermal bridging that increases the risk of interior surface condensation during cold weather for certain building types.

In these cases, a thermal break is beneficial within or behind the exterior metal extrusion. In the case of the metal angle, insulation behind the vertical leg of the angle can provide this thermal break as shown in *Figure 7*. In the case of the unitized frame, a thermal break can be provided in the metal framing. In both cases, developing a thermal model in a computer program such as THERM by Lawrence Berkeley National Laboratory, HEAT3 by BLOCON, or another thermal analysis software is necessary to show that the exterior wall system meets the code-required U-factor and will not cause interior surface condensation.

COORDINATION

Outside of the typical panel joints, issues often arise at the transitions to other building envelope systems, such as the roofs, parapets, soffits, or bases of walls. These joints still require field presence and coordination to integrate the water, air and thermal barriers, and vapor retarder.

All transitions to different envelope systems should be identified and addressed prior to the completion of panel shop drawings and coordinated with involved trades. With proper planning, transitions can be detailed to minimize the removal of the panel cladding. For example, the transition to a roofing system can be detailed with an oversized sheet of roofing membrane properly terminated to the panel weather barrier behind the cladding at the shop, and then welded or adhered to the main roofing system by the roofer once installed on the building; see *Figure 8*. A preconstruction coordination meeting highlighting the areas of concern can help avoid gaps in the four barriers, finger-pointing by responsible trades, and potential compatibility issues between dissimilar materials.

Figure 8 – Roof membrane transition to prefabricated panel.

Figure 9 – Laboratory testing the panelized wall system.

QUALITY CONTROL

With this type of wall design, the exterior wall performance is heavily dependent on the joint performance, and therefore, the joint performance should be verified through field inspection and testing. We recommend providing a designated specification section for the portion of the panelized façade in which the designer can specify inspection, and both laboratory and field performance testing to help mitigate the risk of air or water leakage at panel joints.

Sealant joint longevity relies on proper surface preparation, priming (if necessary), and joint geometry and tooling. Adhesion testing of the sealant joints in preconstruction and periodically during construction can mitigate some of the risk associated with installation issues. A detailed plan should be in place from the panel manufacturer for in-place field repairs prior to the start of installation. The panel manufacturer should also provide documentation of compatibility and adhesion testing for any materials that the sealant will contact in service.

Preconstruction mock-up panels can be tested in the laboratory or contractor's shop before they are brought onsite. The mock-up panels should include the interior steel studs, exterior sheathing, membranes, and cladding attachment system. The interior drywall should be excluded so that the interior face of the exterior sheathing is visible to document potential air and water leakage locations. We recommend initially excluding the exterior cladding from the mock-up performance testing to test the dedicated water and air membranes, flashing, and joint materials to better detect and address potential issues. The mock-up should include horizontal and vertical panel-to-panel joints (including an intersection joint of four panels and an intersection joint of three panels), each unique fenestration system, and transitions to other envelope systems (roofing, base of wall, etc.).

At a minimum, the testing specification should include water and air testing per the following standards at a minimum pressure of 6.24 psf, or higher to match the window or curtainwall test pressures:

- ASTM E283, *Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*
- ASTM E331, *Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference*

See *Figure 9* for an example of water testing on a mock-up. Currently, there is no standard for isolation testing for panel joints. We recommend specifying nozzle testing on the joint in general accordance with AAMA 501.2 (*Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls, and Sloped Glazing Systems*) with a modified pressure for field checks of panel joints. While the tests described above are for windows and doors, the same testing principles can be applied to check for continuity of the main seals between panels.

CONCLUSIONS

The panelized wall system approach represents a compromise between expediency in construction and reliability of the wall system. The panels themselves are constructed in a weather-controlled atmosphere with supervisors to check and double-check quality (thereby eliminating many limitations of conventional field-constructed façade systems), and the panels can be installed faster than a conventional wall system, but with the drawback of having many linear feet of field-constructed panel joints. The panel joint is the weakness in the wall system, and this approach for constructing the exterior walls is not without risks.

The panel joints should be designed to be weathertight using durable materials, as diagnosing performance problems with the joints after the fact is difficult, and repair or replacement of these materials may require removal of overlying cladding and insulation materials. The methods for constructing the joints presented above constitute a range of constructability, reliability, and risk. In many cases, jointing methods with lower risk (i.e., the continuous membrane across joints) are the most labor intensive, requiring more field presence by the contractors and greater exterior access, which will translate to higher cost. Faster and more efficient methods using sealants, tapes, and gaskets may be less reliable, although diligence and quality control during construction can help mitigate these risks to some extent. The owner, designer, and installers should be aware of the risks, benefits, and limitations of each approach to enable selection of the method best suited to meet the project goals and provide an acceptable level of performance and longevity.