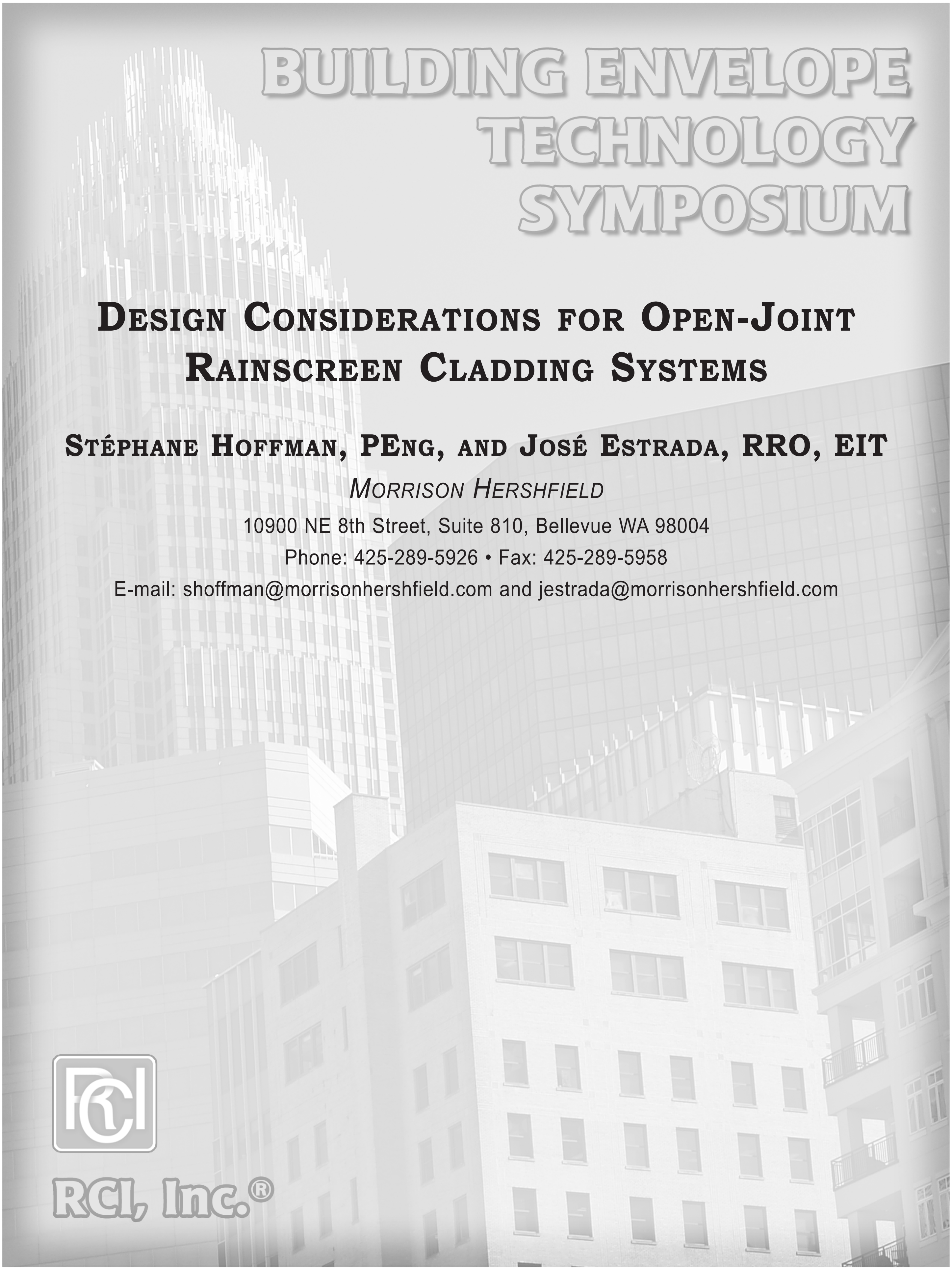

BUILDING ENVELOPE TECHNOLOGY SYMPOSIUM

Design Considerations for Open-Joint Rainscreen Cladding Systems

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ABSTRACT

Recent years have seen an increased trend toward rainscreen cladding systems for the benefits they offer in terms of rainwater management. These systems typically consist of an exterior cladding, a drainage cavity, and a back-up weather-resistive barrier. Traditionally in rainscreen cladding designs, the joints in the exterior cladding are sealed to minimize the potential for water intrusion into the drainage cavity, with the exceptions of weeps and pressure-equalization vents, which are generally sheltered from water ingress. However, recent trends in the design of exterior claddings have seen an increased use of open-jointed rainscreen cladding systems. In these systems, the joints between the cladding elements are intentionally left open. This paper will discuss the implications of open joints for the performance of rainscreen systems. Various approaches to the design of open-jointed rainscreen cladding systems will be discussed, and some case studies demonstrating the detailing of open-jointed cladding systems will be presented. The three case studies that are presented are newly constructed buildings; and, although no issues have been identified to date, the long-term performance of their open-joint cladding has yet to be established. Because of this constraint, this paper does not attempt to compare the performance of the different approaches outlined in the case studies.

SPEAKERS

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Design Considerations for Open-Joint Rainscreen Cladding Systems

INTRODUCTION

Rainscreen cladding has become common in building envelope design in North America because of its effective performance in mitigating moisture-related damage. This type of cladding includes three main components:

- A continuous water-shedding surface: cladding that acts as the first line of defense for direct precipitation.
- A drainage cavity: an open space to allow drainage of any water getting past the cladding and that is vented to encourage drying.
- A concealed air and weather barrier: a membrane that acts as a second line of defense for moisture intrusion further into the wall assembly and often also serves as the air barrier for the assembly.

In an increasing trend, architects are designing open-joint rainscreen cladding assemblies for new buildings. This is largely on account of the aesthetic appeal of this type of cladding. Such cladding assemblies can be defined as wall assemblies that employ the basic principles of a traditional rainscreen, with the exception that the joints between the cladding elements are left open–effectively compromising the continuity of the cladding as a water-shedding surface and increasing the burden of weathertightness on the underlying weather-resistive barrier (WRB).

Though several studies on the advantages of traditional rainscreen assemblies exist, there appears to be a lack of any scientifically based research into the performance of open-joint rainscreen assemblies. There are some unknowns that arise when introducing open joints into a rainscreen assembly. These variables include:

- **Water:** the influence of the open joints on increased water entry into the drainage cavity and, in some cases, the increased reliance on the weather-resistive barrier as the sole line of defense against water penetration
- **Air:** the influence on drying potential and on the limited thermal resistance of the air space as a result of the increased venting area and the increased potential for wind-washing effect on insulation installed in the drainage cavity
- **Light:** the effects of increased ultraviolet radiation on materials within the drainage cavity
- **Fire:** increased exposure to components within the cavity
- **Foreign Bodies:** the increased ease with which insects and debris can enter into the cavity

We have observed a number of approaches to use when it comes to the design and installation of this type of cladding. Each approach addresses these unknowns differently. These approaches can be largely broken down into two main categories. The first is to use open joints and modify the underlying assembly to accommodate the new demands identified above. The second is to modify the exterior cladding assembly itself, giving the cladding the appearance of open joints without actually leaving the joints completely open. Our observations have led us to identify five distinct installation methods that appear to be used when designing an open-joint rainscreen. We have defined them as:

- Open-cavity rainscreen
- Deep-cavity rainscreen
- Baffled-joint rainscreen
- Simulated open-joint rainscreen
- Dual WRB rainscreen

This paper briefly describes all of these methods and elaborates further on three examples we recently experienced. The case examples described include the open-cavity rainscreens, baffled-joint rainscreens, and the dual WRB rainscreens.

DESIGN APPROACHES

OPEN-CAVITY RAINSCREEN

The method that currently appears to be most commonly employed is the open-cavity rainscreen approach. This design is essentially a typical rainscreen assembly without sealant at the joints and with few or no modifications to account for the increased demand on the underlying assembly as a result of the open joints. In some installations, a secondary layer of WRB has been installed to coincide with the open joints of the cladding and conceal the main WRB. Although this has been largely done for the aesthetic reason of providing black-colored joints, it has the added benefit of protecting the main WRB at the most exposed locations from ultraviolet radiation and from direct exposure to the weather. *Figure 1* provides an example of a typical open-cavity rainscreen assembly where a strip of additional WRB was installed at the open joints.

Open-cavity rainscreens have also been installed at exterior-insulated wall assemblies. *Figure 2* shows examples of an exterior-insulated wall assembly where a weather- and UV-tolerant insulation such as rock wool has been installed on the exterior of the WRB and left exposed at the open joints.

To an extent, the performance of any wall in terms of moisture mitigation can be related to its level of exposure. For example, a wall under a large overhang is less likely to experience moisture-related failures than an exposed wall with no overhang. For instances with low exposure to wind-driven rain and under large overhangs, open-cavity rainscreen assemblies may be a viable option. However, the true performance of

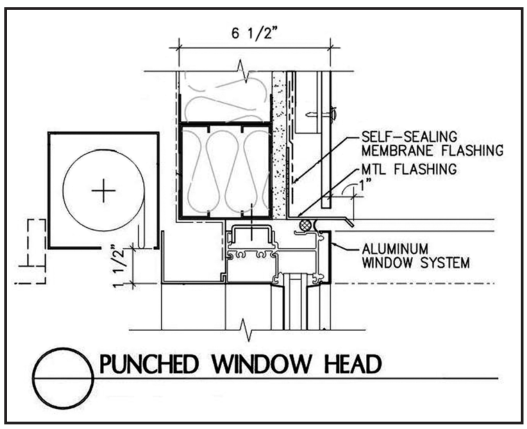


Figure 1 – Typical window head interface in an open-cavity rainscreen.

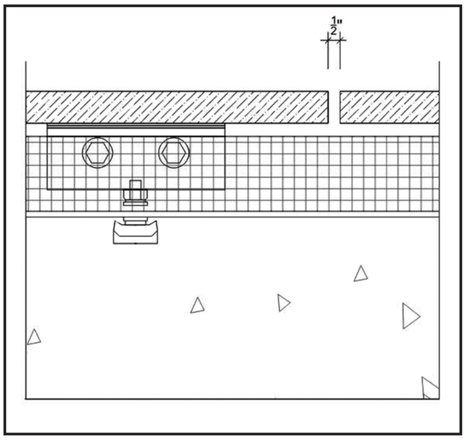
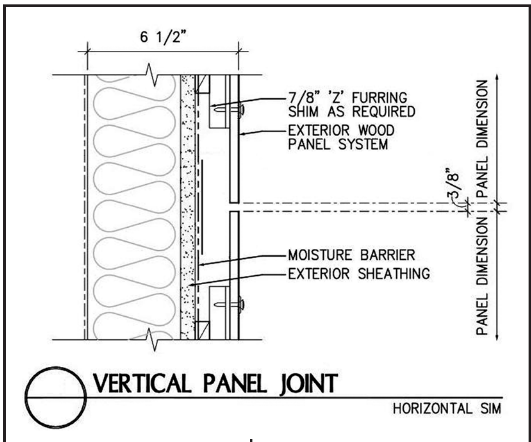


Figure 2 – View of typical half-inch joint in the exterior insulated open joint assembly.

these systems will not be fully understood until further observation of and research on existing systems have occurred. At the moment, owners and installers tend to use this method of installation because it offers the desired aesthetic appeal at a relatively low initial cost.



Figures 3A and 3B – Typical joint in cladding. Notice that a 3/8-in joint in the cladding is left open at the vertical and horizontal panel. In the field, "z" furring was installed at the vertical joints, as is shown in the photo.

Case Study of Open-Cavity Rainscreen

We were recently involved in two projects where differing variations on the open-cavity rainscreen were used over a significant portion of the wall area. In both cases, the joints in the cladding assembly were left open for aesthetic purposes, with minimal change in the underlying assembly to account for the increased loads that may be associated with open-joint cladding. The climate conditions in the area for both projects are considered temperate and humid, with rainfall distributed largely over the winter months in the form of low-intensity, long-lasting precipitation.

Open-Cavity Example

In one project, a high-rise medical building with moderate exposure to wind-driven rain used an open-joint panelized wood-panel cladding. The open-joint rainscreen panels at this project were used in conjunction with a number of other cladding and glazing assemblies. The main penetrations in the open-joint-clad walls were punch windows. See *Figures 1*, *3A,* and *3B*.

Design Intent:

The open joint cladding at this project included the following assembly from the exterior to the interior:

- Panelized wood cladding (with open 3/8-in joints)
- Drainage cavity (7/8 in)
- Sheet-applied vapor-permeable air- and weather-resistive barrier
- Vertical open joints; an additional strip of WRB was loosely attached
- Horizontal joints; a strip of sheet metal was installed
- Exterior sheathing
- Foil-faced batt insulation
- Interior sheathing

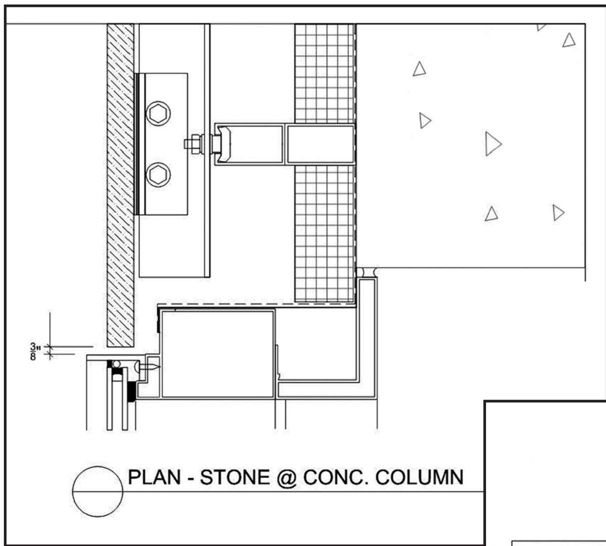
While this project was in the design phase, the design team, along with the WRB manufacturer, had originally recommended the addition of a secondary WRB to protect the field air and weather barrier from possible premature deterioration as a result of the open joints. Application of a secondary WRB would have essentially turned this open cavity rainscreen into a dual WRB open-joint rainscreen assembly. After discussion with the client and considering cost pressures on the project, a compromise was reached in which the addition of a secondary strip of WRB was applied only at the vertical open joints. Ultimately, the additional WRB at the joints was installed for aesthetic reasons, as the owner did not want the field WRB (which was orange) to be visible through the joints. The additional layer of WRB was black. At the horizontal joints, a black-colored sheet metal was installed to close the joint. This was done so that vertical fastening (z-girts) could be installed continuously, onto which the cladding was applied.

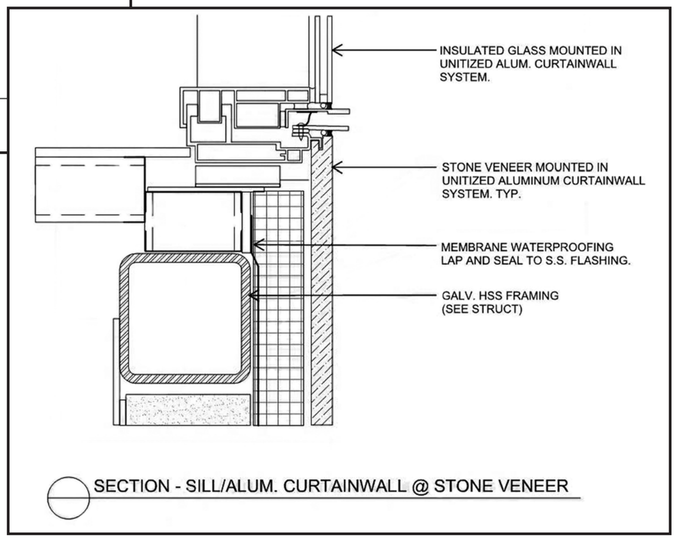
Detailing

Punch windows in the open-cavity rainscreen were detailed at the wall interfaces with a metal surround. At the head, this metal surround served an additional capacity as a through-wall head flashing. The joint between the metal flashing and the cladding was left open to maintain aesthetics, while the joint between the flashing and the window frame was sealed with caulking and backer rod. As designed and installed, this detailing relies heavily on the WRB, metal flashing, and the exterior seal at the window frame to deflect and resist moisture.

EXTERIOR INSULATED OPEN-CAVITY EXAMPLE

In another recent project, an open-cavity rainscreen system was installed at portions of a high-rise higher-education building in the Seattle area. Open-joint stone veneer panels were installed over an exterior insulated wall assembly. Penetrations in the open-joint-clad sections of this building were minimal; however, the wall does interface with a curtain wall system, with the wall membrane sealed to the frame of the glazing system. See *Figures 2* and *4*.





Figures 4A and 4B – Typical interface of thin-stone, open-joint cladding with curtain wall at jamb (top) and at the sill (below). Jamb: A 3/8-in joint has been left open at this interface. Sill: The thin-stone cladding has been mounted into the curtain wall frame at the sill and sealed to it. A joint in the frame itself with a flexible gasket allows for movement in the curtain wall and maintains the open-joint appearance.

Design Intent

The open-joint cladding portions of the building envelope included the following assembly from the exterior to the interior:

- Thin-stone panels (with open -in joints)
- Drainage cavity (-in)
- Rock wool exterior insulation (3 in)
- Liquid-applied membrane waterproofing (this membrane acts as the air/moisture and vapor barrier and is sealed to the curtain wall)
- Concrete masonry unit (CMU) wall

As an open-cavity assembly, this method of installation may be incrementally more durable than the nonexterior insulated open-cavity rainscreen mentioned previously. This is because the main WRB is also a waterproof membrane and is therefore more able to address extended wetting than a vapour-permeable WRB. During the design phase, as with the other examples of open-cavity rainscreens, we had originally recommended the addition of a secondary WRB layer to protect the insulation and other underlying assemblies; however, the client opted to simply use a relatively UV-stable exterior insulation and leave it exposed at the joints.

Detailing

Curtain wall sill: At the curtain wall sill, the thin-stone panels were mounted into the curtain wall frame and sealed to it. A joint within the curtain wall itself, which is baffled with a flexible gasket, served the dual purpose of allowing for deflection in the curtain wall and maintaining the open joint aesthetic of the thin-stone cladding. The decision to simulate the joint at this interface was made because of the critical nature of the sill interface. With a simulated open joint, water running down the surface of the window is less likely to drip into the drainage cavity at this joint.

Curtain wall jamb: At curtain wall jamb interfaces, the cladding was not mounted into the curtain wall as it was at the sill. Instead, a 8-in joint was left open between the cladding and the curtain wall frame. The open joint at the jamb exposes the framing of the curtain wall beyond, and a flexible membrane flashing was installed from the curtain wall frame to the field WRB to maintain the continuous air and weather barrier. The window jamb remains a critical joint, albeit slightly less critical than that at the sill; so to minimize water entry into the cavity at this interface, the size of the open joint was reduced to 8 in, which is smaller than the typical -in joint that is typical throughout.

DEEP-CAVITY RAINSCREEN

A method similar to the open-cavity rainscreen is the deep-cavity rainscreen with open joints. The main difference with this approach is that it includes a drainage cavity of 5 to 6 inches in depth. See *Figure 5*. This is much deeper than the drainage cavity in a typical rainscreen of approximately 1 inch or less. The intent of this design is to place the cladding out far enough from the WRB to reduce the exposure to wind-driven rain to the exterior sheathing, without overextending the clad-

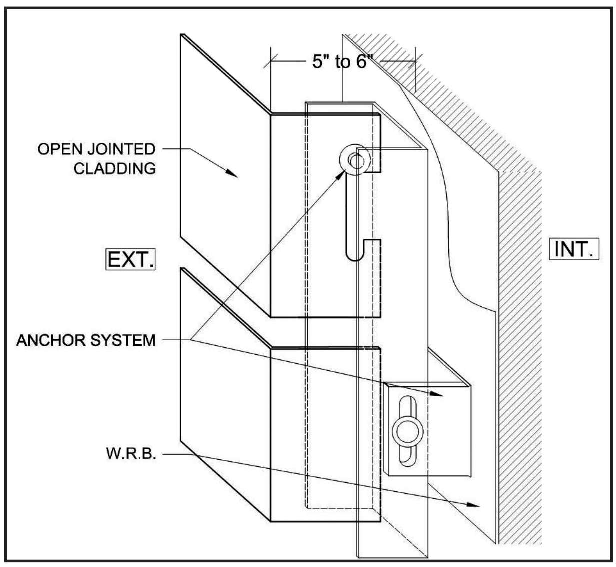


Figure 5 – Schematic of proposed deep cavity rainscreen.

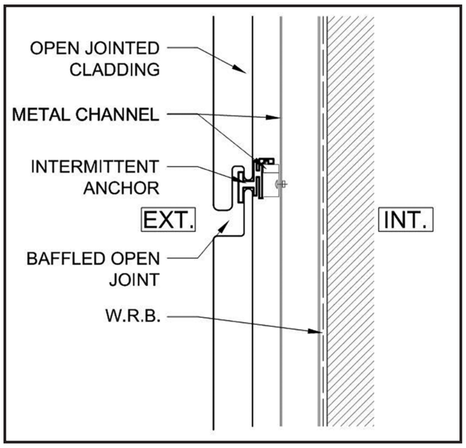


Figure 6 – Example of common baffled joint.

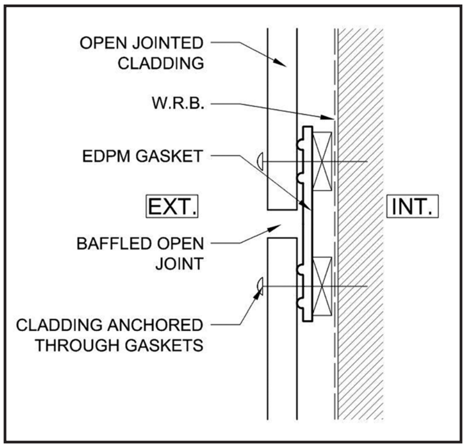


Figure 7 – Example of baffled-joint system with EDPM gasket at joint.

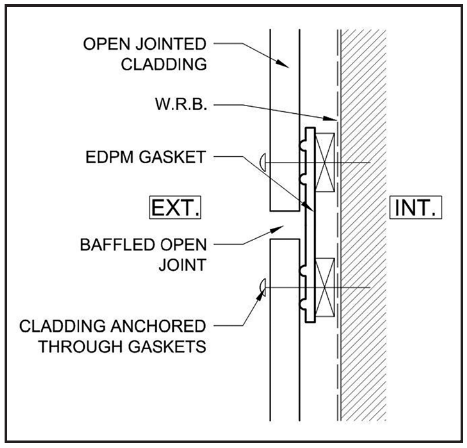


Figure 8 – Example of baffled-joint system with hat track and through-wall flashing at vertical joints.

ding to a point where a similar result could have been achieved with a smaller cavity. The theory in this method is that wind-driven rain is forced to travel a farther distance before encountering the WRB; this reduces the exposure of the WRB in most instances to wind-driven rain. At some level of wind speed, it is reasonable to assume that any benefit from the deeper cavity is diminished. To our knowledge, no scientifically derived relationship has been researched between the depth of cavity and the exposure of the WRB to rainwater.

Deep-cavity rainscreen systems are limited in the type of cladding that can be used, given that the anchors used to attach the cladding will be exposed to a larger moment arm than in a typical rainscreen system. Deeper cavities also tend to translate into thicker walls, which may reduce the usable floor areas and complicate through-wall penetrations such as windows and doors. Detailing at windows and other penetrations may also require special considerations in order to properly flash and align them with the insulation and avoid thermal bridging.

BAFFLED-JOINT RAINSCREEN

The appearance of an open-joint system can be achieved without using joints that are completely open; this type of design is considered a baffled-joint rainscreen system. Some common baffled-joint systems on the market include panels with offset joints that impede the entry of wind-driven rain into the drainage cavity. This option reduces the exposure of the WRB and drainage cavity to direct rain, wind, and light relative to a nonbaffled open joint. The joints remain open to air movement and thus have a reduced capability to achieve pressure equalization within the drainage cavity. Baffled panels are also constructed in a manner that is simple to install. These panels have a baffled end on two sides and a receiving end on the other two sides, making it possible for installers to slide panels into place. See *Figure 6*.

Another option for this method would be to create a baffle at the joints by installing a plate or flexible membrane at the perimeter of the cladding elements. This can be done with an EPDM membrane as depicted in *Figure 7*. In this option, the cladding elements can be fastened directly through the EPDM membrane. For cladding elements with smaller joints, an EDPM membrane works well to portray the impression of a completely open joint while concealing the drainage cavity; this illusion is lost, however, with larger joint sizes.

A metal hat track at vertical joints, combined with through-wall flashing at horizontal joints, can also be employed as a baffled-joint system. See *Figure 8*. The benefit in this option is that rainwater is expelled from the drainage cavity at the head of every cladding element. This option is best suited to large panels spanning floor to floor. Otherwise, with smaller cladding elements, this is a labor-intensive option. It requires careful detailing and workmanship at four-way intersections and at through-wall flashing. To maintain the aesthetic illusion of an open joint, it is also likely that the metal flashing and hat track will need to be finished with a dark color.

Case Study for Baffled-Joint Rainscreen

In a recent high-rise residential project in the Seattle area, we encountered an application of a terra cotta baffled-joint rainscreen installed within a curtain wall system. Spandrel panels within the curtain wall were typically detailed with furred-out, open-joint terra cotta panels over a glazed-in sheet metal plate. Penetrations through the open-joint cladding were typically avoided, and interfaces were limited to vision panels and at terminations. See *Figures 9A* and *9B*. The climate conditions in the area for this project are considered temperate and humid, with rainfall distributed largely over the winter months in the form of low-intensity, long-lasting precipitation.

Design Intent

The open-joint clad portions of this curtain wall consisted from the exterior to the interior of the following assembly:

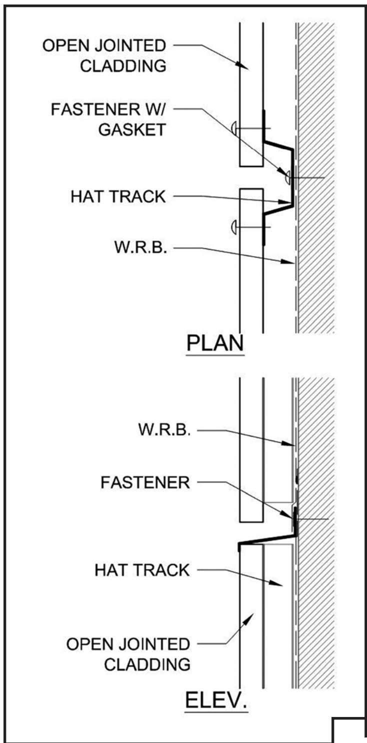
- Terra cotta panels (with -in baffled open joints)
- Drainage cavity (5 in)
- Glazed-in sheet metal
- Insulation with interior-facing vapor barrier
- Interior finish

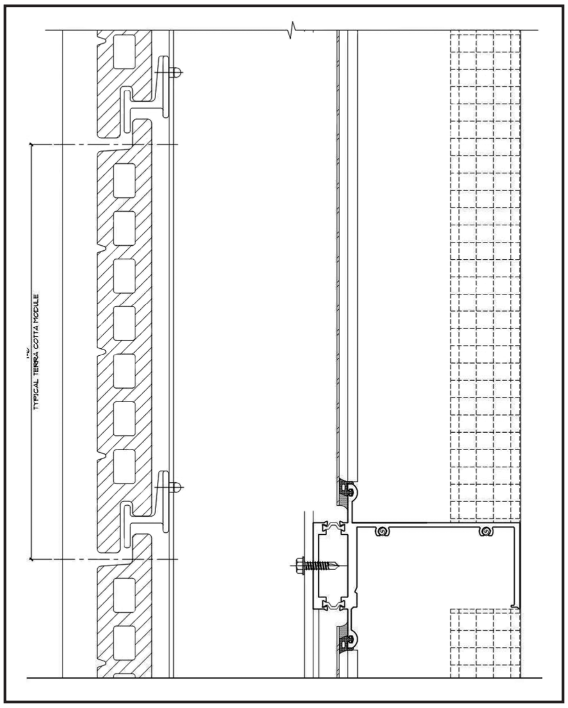
In this example, the open-joint cladding is installed over a durable underlying material (glazed-in sheet metal), which may increase the durability of the system. The system is also drained at expansion joints and typically sealed or baffled with flexible gaskets at interfaces.

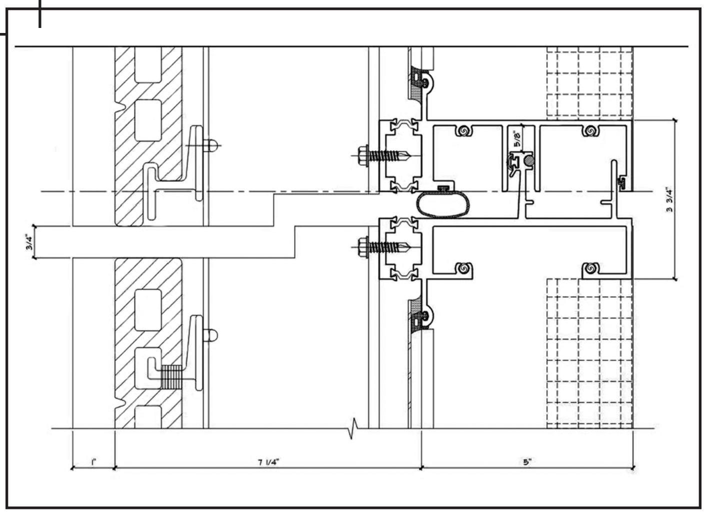
Detailing

Windows: The glazing was typically detailed with a protruding metal surround. At the window head, the cladding was sealed to the metal flashing and weeped to drain. At the windowsill, a flexible gasket was installed to function as a baffle in front of the open joint, and allow the windowsill to drain.

Expansion joints: At expansion joints in







Figures 9A and 9B – Example of baffled open-joint rainscreen used in a curtain wall. This detail illustrates the typical fastening mechanism and ½-in open joints. An expansion joint in the curtain wall with a ¾-in dynamic joint is also shown. At the expansion joint, a flexible gasket is installed at the curtain wall frame.

the curtain wall, a ¾-in joint in the cladding was left open to allow for movement in the system. A dual-compression gasket at the frame forms a rainscreen at this interface.

Simulated Open-Joint Rainscreen

One method of creating an appearance of an open-joint rainscreen assembly without necessarily creating open joints is to create an open-joint façade over a continuous substrate. See *Figure 10*. This method can be ideal if the cladding element panel sizes are relatively small, requiring many open joints. In this installation method, cladding elements, typically some form of cultured stone, can be glued or mechanically attached to the face of a cement board or some other robust substrate, such as a scratch layer of stucco on a wire mesh, and then installed over a typical rainscreen assembly. The joints between the cladding elements themselves are open, but their connection to the continuous substrate performs as if it were a closed-joint system. The joints of the substrate itself could then be sealed and treated as closed-joint while maintaining the appearance of an open-joint assembly. This method of installation provides a continuous water shedding surface and continuous protection for the drainage cavity while maintaining the desired open-joint appearance. One possible limitation of this approach is that the open joints in this assembly may be prone to efflorescence from dissolved salts, and in cold climates, they may be subject to freeze-thaw damage if water accumulates within the open joint.

Dual WRB Rainscreen

The creation of a two-stage WRB behind the cladding can be applied to help mitigate the increased demand of the underlying assembly. This dual barrier is constructed by installing an airtight second-line-of-defense layer under a primary water-shedding layer of WRB. The WRB is installed behind the cladding, separated from it with a drainage cavity. Of the observed "true open-joint rainscreen methods, this is our preferred method because of the continuity that it offers while providing the desired aesthetic effect. See *Figure 11*.

The theory behind this method of installation is that the primary water-shedding surface layer of WRB will perform the function of the cladding, particularly in areas near open joints. The cladding itself is assumed to function as a noncontinuous screen. The water-shedding WRB should be loose-laid to allow for drainage but anchored at regular intervals to prevent displacement. This design allows for a continuous water-shedding surface, a drainage medium, and a second

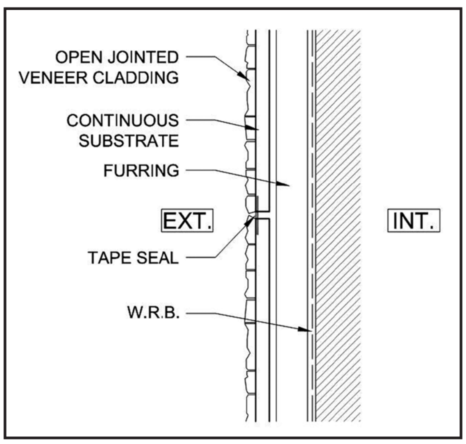


Figure 10 – Example of simulated open-joint rainscreen (section view).

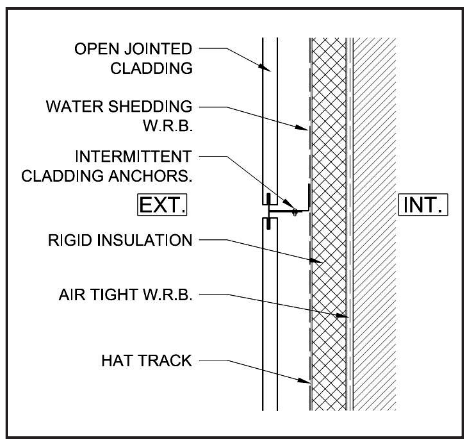


Figure 11 – Section view of proposed dual WRB rainscreen assembly.

line-of-defense WRB, while maintaining the appearance of an open-joint rainscreen assembly.

The cladding is then installed on the exterior of the water-shedding surface with a typically sized drainage cavity, separating it from the water-shedding surface. As with the deep-cavity rainscreen assembly, the cladding used in this method should be carefully considered, particularly when including a layer of rigid insulation. Though the drainage cavity itself is likely no deeper than a traditional rainscreen, the distance that any anchors span may increase with thicker insulation.

Case Study for Dual WRB Rainscreen

We were recently involved in a project that employed the dual WRB approach for the main open-joint rainscreen cladding. The project was a three-level office building with one level of below-grade parking and inset glazing. The ground floor of the building was mainly clad in aluminum-framed curtain wall that was in plane with the open-joint rainscreen cladding in the above floors. The climate conditions in this area are considered temperate and humid, with rainfall distributed largely over the winter months in the form of low-intensity, long-lasting precipitation.

Design Intent

The open-joint cladding portion of the building envelope included the following assembly, from the exterior to the interior:

- Thin-stone panels
- Drainage cavity ($1\frac{5}{8}$ in)
- Loose-laid, sheet-applied, WRB
- Exterior insulation (1 in)
- Liquid-applied air and WRB
- Exterior sheathing
- Foil-faced batt insulation
- Interior finish

The mechanically attached, sheet-applied WRB acted as the primary water-shedding surface and was taped at the seams to maintain continuity. The liquid-applied WRB behind the exterior insulation performed the function of the main air barrier and second line of defense for the envelope.

Interfaces and penetrations statistically tend to be more susceptible to instances of localized moisture-related failure, relative to the field envelope conditions in most building envelopes. As such, in developing the design of this type of cladding, a more conservative approach was taken near interfaces. Detailing at this project was largely simplified due to a number of factors, the most obvious of which was the lack of diverse penetrations within the open-joint cladding. Penetrations through the open-joint rainscreen consisted almost entirely of windows that were significantly inset. See *Figure 12* for schematic of assembly.

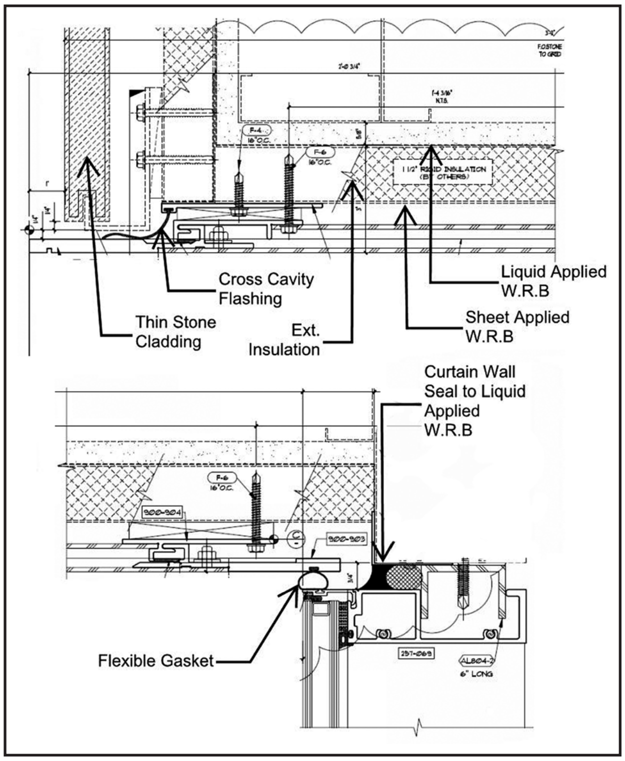


Figure 13 – Schematic of dual WRB system at project near Seattle, WA.

Detailing

Recessed Curtain Walls

The inset windows were generally separated from the cladding by a metal surround that ran perpendicular to the open-joint cladding and to the window frame at the sill, jambs, and head. This inset further simplified the detailing required to provide a seal from the window frame to the liquid-applied air and weather barrier.

At the interface of the windows, open joints were simulated with a black gasket. This created the appearance of an open joint while maintaining redundancies in water shedding at this often-difficult interface. The overhang formed by the soffit at the head of the window further protected the window interfaces. A cross-cavity flashing was installed at the soffit created by the metal surround at the head of the window bridging from the liquid-applied WRB to the exterior. *Figure 13* illustrates the detailing used at the window head in greater detail.

At the windowsill, gaskets were installed at the glazing interface with the metal surround and at the interface between the metal surround and the top of the thin-stone open-joint cladding. Below the metal surround, the sheet-applied WRB extended up to the window, and a waterproofing membrane was installed over the horizontal exterior sheathing below the exterior insulation. *Figure 14* illustrates the sill detailing.

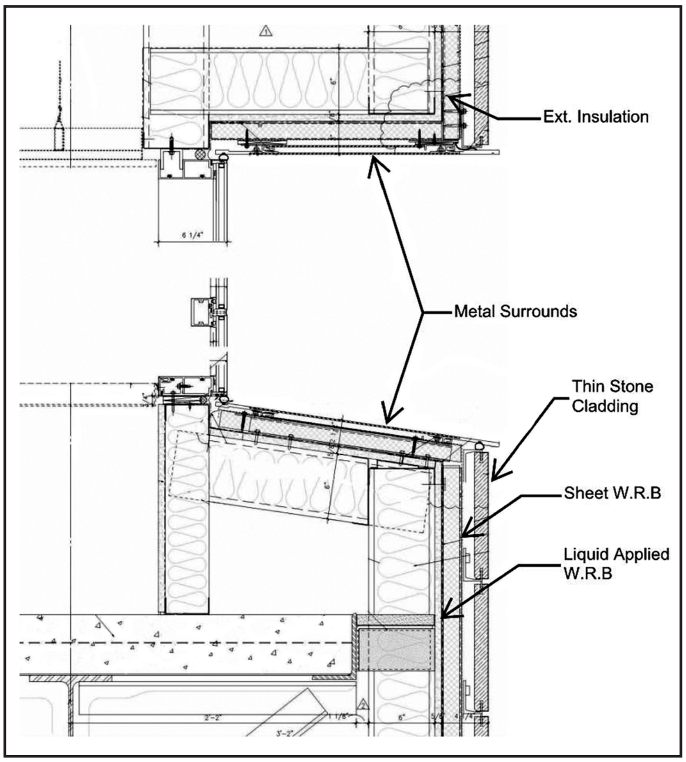


Figure 12 – Schematic of dual WRB system at project near Seattle, WA.

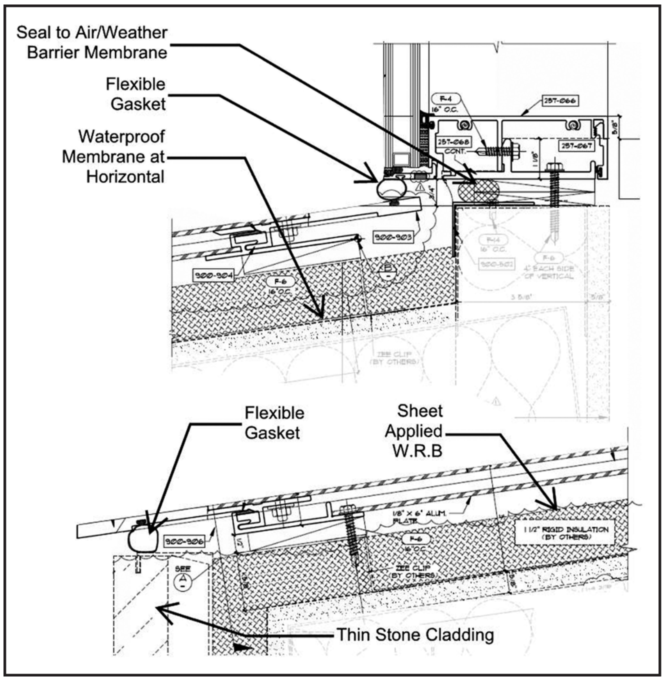


Figure 14 – Schematic of detailing at sill of recessed curtain wall.

CONCLUSION

Because the buildings in all three case studies presented herein are relatively new, their performance hasn t yet had a chance to be evaluated. Current building science theory suggests that best practice when designing and constructing a rainscreen assembly is to install a traditional closed-joint system. These systems have been used extensively in the North American market and have shown durability and reliability over other wall designs. This is not to say that open-joint rainscreen systems are poor practice, only that they require further research and observation before their true performance characteristics can be fully understood. Until further research and observation are done on a greater sampling of these cladding systems to understand their limitations, it is a good approach to consider designing them to incorporate the same characteristics of the better-understood typical rainscreen.

Simulating an open joint is perhaps the best way to benefit from the open-joint aesthetic while maintaining the performance characteristics of a traditional rainscreen. When a true (nonsimulated) open-joint cladding is preferred, the dual WRB approach appears to be the more conservative approach because it most closely resembles the traditional rainscreen system in design intent. Other approaches may be used; however, it is up to the design team to assess the risks and benefits of each method and determine the best approach for the given application.

Terminations

The bottom termination of the open-joint cladding interfaced with an in-plane curtain wall assembly at the ground level. The design intent at this interface was similar to that at the inset window. An extruded metal plate functioned as trim between the curtain wall and the thin-stone cladding and an open joint was simulated with a black gasket between the metal plate and the frame of the curtain wall. See *Figure 15*. Cross-cavity flashing was installed directly above the metal channel, extending from the liquid-applied WRB, to the exterior.

The top of the wall terminates at a parapet. The termination of the open-joint cladding at this condition was detailed with the use of a metal channel similar to the bottom termination. The sheet-applied WRB extended up behind the metal channel and lapped over the insulation. The liquid-applied WRB was capped at the top of the parapet with a self-adhesive membrane that bridged the air barrier from the WRB to the roofing membrane. In this project, the low slope roof was unvented. See *Figure 15*.

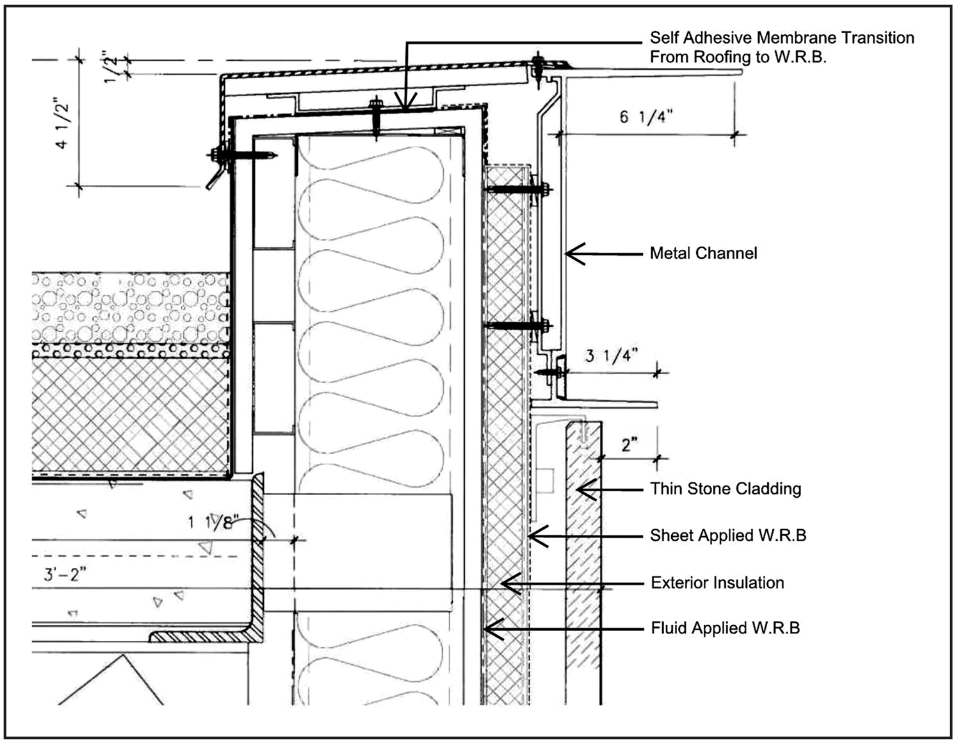


Figure 15 – This schematic illustrates the terminations of the thin-stone cladding. At the top of wall, the thin-stone cladding terminates at a metal channel at the parapet. At the bottom of wall, the cladding terminated at a curtain wall system.