

RAINSCREEN and BACK-VENTILATED DRAINED CAVITY WALL SYSTEMS: PRACTICAL APPLICATIONS for HIGH PERFORMANCE BUILDINGS

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INTRODUCTION:

High performance buildings must have exterior wall assemblies that provide a superior level of control and performance. Unfortunately, there is little quantifiable data to establish the performance of the enclosure. This paper provides recommendations for high performance exterior wall assemblies that are capable of providing the expected performance within current understandings of building science and practical application. It is the intent of the paper to assist Architects to understand the underlying building science and the practical application of that science to the design and detailing of exterior walls to deliver high performance. Proven, redundant, watertight, air tight, highly reliable, energy efficient walls are targeted. While many other wall assemblies may provide completely acceptable performance under normal expectations, this paper is intended to address the elevated expectations for high performance buildings. The concepts and features included apply to all building types, but the article is focused primarily on commercial construction. The wall assemblies included herein are generally more expensive than lower performing assemblies and the value decisions for performance versus cost must be made by project teams.

The recommendations in this paper are based on the experience and knowledge of the members of the AIA Technical Design for Building Performance Knowledge Community. This article uses “The Rain Screen Principle” by Mike Lough, also published by the TDBP for a foundational description of the principles for how these wall assemblies resist the passage of air and water. It is recommended to read “The Rain Screen Principle” before this article. The articles “Construction of Rainscreen Walls” by Drake Wauters and “Rain Screen—Getting Under the Skin of an Open Cladding Assembly” by Mark Perepelitza and Sean Scott covers issues related to actual construction of these wall assemblies. As a group, these articles by the TDBP KC represent one path for high performance enclosures.

Please see “The Rain Screen Principle” for a glossary of terms used in this article. The TDBP KC hopes that this glossary can bring clarity to the confusing lack of conformity now present in the industry.

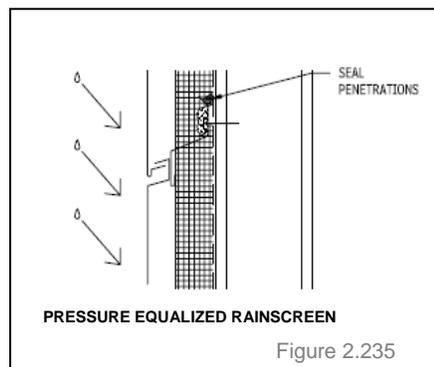
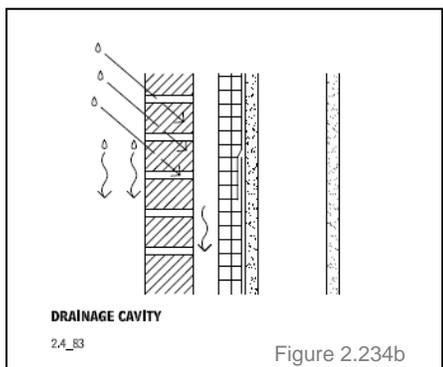
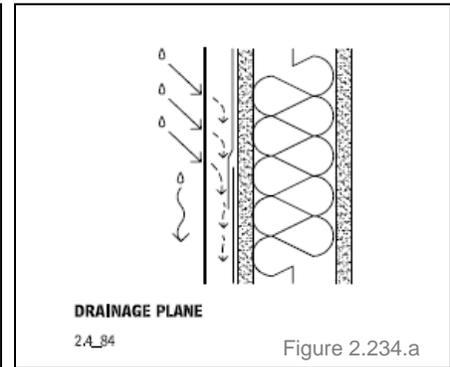
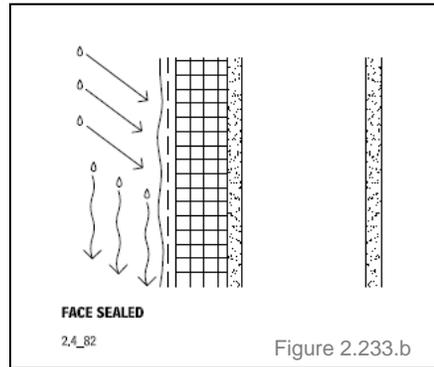
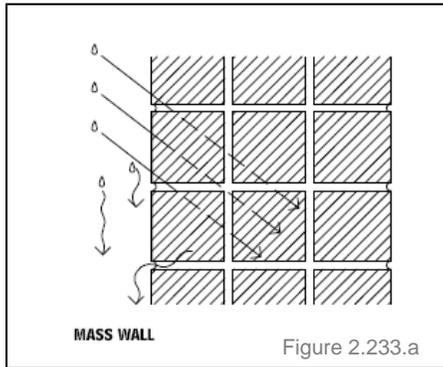
Illustrations used in this article are taken from AIA Architectural Graphic Standards, 11th edition, Element B – Shell and maintain that numbering system. AGS provides additional information on this subject and additional illustrations that may be helpful.

SELECTION OF THE EXTERIOR WALL SYSTEM:

Wall assemblies are classified into 5 major types related to the methodology to resist water penetration. (See AIA Architectural Graphic Standards, 11th edition, Element B, Shell, page 128 John Wiley and Sons, 2007 and “Designing the Exterior Wall” by Linda Brock, John Wiley and Sons, 2005 for additional information).

- Mass Barrier Wall Assemblies, figure 2.233.a.

- Face Sealed Barrier Wall Assemblies, figure 2.233.b.
- Drainage Plane Wall Assemblies, figure 2.234.a.
- Drained Cavity Wall Assemblies (DC) further defined as Back-Ventilated Drained Cavity Wall Assemblies (BVDC), figure 2.234.b.
- Pressure-Equalized Rainscreen Wall Assemblies (PER), figure 2.235.



Current descriptions and definitions of high performance buildings do not provide quantifiable criteria for wall performance. In order to meet with the spirit and intent of the goals for high performance buildings, wall assemblies of high-performance building should possess the following attributes: Other performance characteristics are necessary to fulfill the basic functions of walls and are not included here.

- Redundant protection against air and water infiltration.
- Control of water infiltration without dependence on absorption and drying to the interior.
- A continuous and easily installed air barrier (AB) and water resistant barrier (WRB).
- Continuous thermal insulation without major thermal breaks (approximately 1% of surface area).
- High levels of thermal insulation.
- Water vapor control with any potential condensation outside of the water control line.
- An installation process that allows for progressive quality management inspection and testing before covering by subsequent layers.
- A vented drainage cavity large enough to overcome water surface tension for a high drying capacity
- Ventilation towards the exterior side of the continuous insulation rather than behind.

- UV and thermal protection of sensitive membranes and seals.
- Shingling of layers of membranes, sheets, and flashing in the direction of water flow or mechanically anchored terminations at negative shingling.
- Accommodation of building structural movement.
- Durability for dependable service after years of in-situ service.
- The ability to effectively construct joints between the various wall systems and other enclosure components such as roofs, waterproofing and fenestration incorporating all of the criteria listed above.

Of the 5 wall assemblies listed, only Back-Ventilated Drained Cavity Wall Assemblies and Pressure-Equalized Rainscreen Wall Assemblies meet these heightened performance attributes.

In practical terms the difference between a BVDC wall assembly and a PER wall assembly is compartmentalization of the air cavity to provide for heightened control of water infiltration at the cladding by eliminating air pressure differential. In low-rise and smaller scale construction, the air pressure differentials between ambient and inside the cavity will frequently be low enough that a simple upturned leg in the cladding design can resist water penetration. As buildings get larger and in particular taller, the pressure-differentials are larger and present for much longer durations. Up turned legs would need to exceed 2 or more inches to control water penetration under common wind loads on tall buildings. Compartmentalization moderates the pressure differential, and allows for more consistent water infiltration control at the cladding without the large upturned leg. Compartmentalization can also help reduce air washing over the thermal insulation, improving the actual performance.

The most common credible method to verify that a wall assembly functions as a PER Wall Assembly is through successful testing according to AAMA 508-07, Voluntary Test Method and Specification for Pressure Equalized Rain Screen Wall Cladding Systems. It is recommended that only wall assemblies that have passed this test (or some similarly rigorous impartial test) be labeled as a “Pressure Equalized Rainscreen” or “Rainscreen”.

Unfortunately, the equivalent test method for a BVDC wall assembly, AAMA 509-09, Voluntary Test and Classification Method for Drained and Back Ventilated Rain Screen Wall Cladding Systems, has a pass threshold too low to establish an appropriate performance value. The test method places too much reliance on a near perfect waterproof air barrier.

There is great confusion within the industry over the term “rainscreen” and it can be difficult to determine the actual performance mechanisms claimed for materials and products. Clarity can be gained by studying the performance attributes of a product independent of any terminology and determining if the functional aspects are met. Some common clarifications:

- Simple open-jointed cladding that does not incorporate upturned legs, sloped surfaces, drips, and capillary breaks does not provide for all necessary cladding functions in BVDC or PER assemblies. Such cladding is more properly called “Open Cladding” (see “Rain Screen—Getting Under the Skin of an Open Cladding Assembly”). Without an additional layer for water shedding under the open cladding, the WRB must be nearly perfect as it is exposed to relatively large amounts of water.
- Cladding systems without a method to compartmentalize the air cavity are BVDC wall assemblies, not PER.

- Some cladding systems utilize BVDC or PER joints, but the panels themselves are a type of barrier wall. Common examples are insulated metal panels and precast concrete panels.
- Some cladding assemblies provide ventilation between the insulation layer and the interior, which degrades thermal performance even if truly a BVDC or PER.

MATERIAL SELECTION

Proper selection of materials for each component of a BVDC or PER wall assembly requires an understanding of the idealized function and the realities of practical applications. For example, in a perfect laboratory test, the air barrier need not be waterproof as all water penetration is stopped at the cladding. However, real-world experience proves this to not be true due to the vagaries of construction tolerances, quality control and unforeseen conditions. Therefore passing the single lab test for an air barrier is not enough to determine actual in-situ performance. Laboratory tests of products are also frequently based on new samples. UV exposure, heat, substrate movement, and chemical decay can all seriously degrade performance. Realistic performance may also be difficult to obtain if installation instructions require a level of care in the field that cannot be realistically performed. Architects are cautioned to carefully examine performance claims based only on lab tests.

Air Control and Water Control Layers: At the interior cavity face of BVDC and PER wall assemblies is the most important material for long-term performance (figure 2.236). This layer is the plane to control air infiltration and is the final limit to water penetration. It is not uncommon for this layer to also control vapor diffusion. Finally, this layer is deeply embedded in the wall assembly and will likely not be exposed for many years. Therefore the selection of the AB/WRB is crucial. While other methods can be used to provide for air and water control, such as sealed sheathing or rigid insulation, utilization of a membrane to provide this function is typically more durable and reliable. In order to perform long term the AB/WRB should be; thick enough to cover rough substrates when applied in the field, robust enough to resist damage from subsequent construction activities, fully adhered to the substrate to resist wind pressures, able to readily self-seal around penetrations for anchoring/supporting the cladding or be easily patched waterproof, shingled to drain or incorporate termination bars to mechanically anchor “uphill” edges. In parts of the country such as the Pacific northwest, where there is seldom a week without rain, the ability to apply the AB/WRB to damp substrates will be important. With the 2012 ICC there will a requirement for the AB/WRB to also comply with NFPA 285 testing for combustibility. Under earlier ICC codes the AB/WRB will have to match the NFPA tested assembly for most commercial buildings if there is foam plastic insulation in the air cavity.

Insulation: A portion of the air cavity will be filled with insulation to provide a continuous line of thermal control outside of the wall supports and main structure (figure 2.272 and figure 1a, 1b, and 1c). The insulation is typically either a rigid foam plastic or semi-rigid mineral wool. Rigid foam plastic

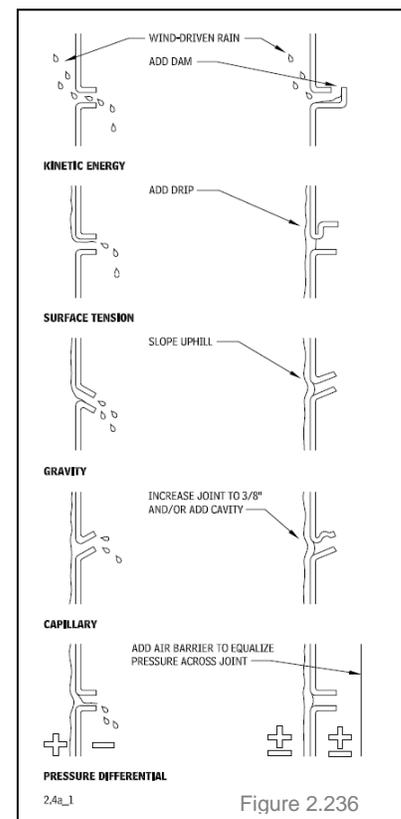


Figure 2.236

typically extruded polystyrene, polyisocyanurate or spray polyurethane foam provides the highest R-value for the cost but introduces a flammable material into a concealed cavity. The ICC has requirements that limit the use of foam plastic or requires compliance with a very restrictive and expensive large scale assembly test, NFPA 285. Note that the NFPA 285 test requires that the entire wall assembly be constructed in compliance with the test report, which restricts the selection of all other materials and influences detailing, particularly at window heads. The joints between rigid boards should be sealed with compatible spray foam or mastic for maximum performance. Spray polyurethane foam can be used as for the insulation and perhaps also for the AB/WRB and it solves the jointing problem. There are some questions about long term watertight sealing of the spray foam to all necessary penetrations. Carefully consider the qualifications of the applicator and the source of the raw products as the SPF is highly sensitive to numerous variables in the field. Semi-rigid mineral wool for cavity insulation has a lower embodied energy, is completely non-combustible and dries readily in the cavity, but typically requires a 50% increase in thickness for a comparable R-value. Because of its compressible nature, it is typically friction fit tightly together at joints.

In addition to the insulation in the air cavity, insulation may be added between the stud spaces of the back-up wall.

Girts and Shelf Angles: The cladding is always spaced away from the back-up wall to create the requisite cavity.

To support the cavity a system of clips, girts, and shelf angles must be detailed. Unfortunately, these must penetrate the insulation layer and create thermal bridges. The cross-sectional area of the bridges should be minimized for optimum thermal performance.

Shelf angles if needed for heavy cladding should be spaced off of the supporting structure to allow the insulation to pass behind. (figure 2.272) (See Thermal Bridging Solutions: Minimizing Structural Steel's Impact on Building Envelope Energy Transfer published by Structural Engineering Institute (SEI) /American Institute of Steel Construction (AISC)).

For lighter cladding use a network of girts, preferably aluminum or stainless steel as the penetrations and ends of galvanized material is subject to corrosion. Continuous zee girts should be avoided, instead provide small clips spaced approximately 4 feet apart which in turn support girts outside of the insulation (figure 1a, b, and c). The clips can be stainless or plastic to limit thermal bridging or can include a thermal break detail within the thickness of the insulation. Proprietary systems are available with the advantage of extensive engineering, but perhaps a loss of customization. Coordinate the location of the clips with the framing of the back-up wall framing to accommodate the more widely spaced and larger point loads. Note that every penetration of the AB/WRB should be detailed so that it can be properly sealed and inspected before installing the insulation. Be wary of anchors that supposedly seal through rigid insulation, the seal is frequently a gasket at the cavity face of the insulation, not

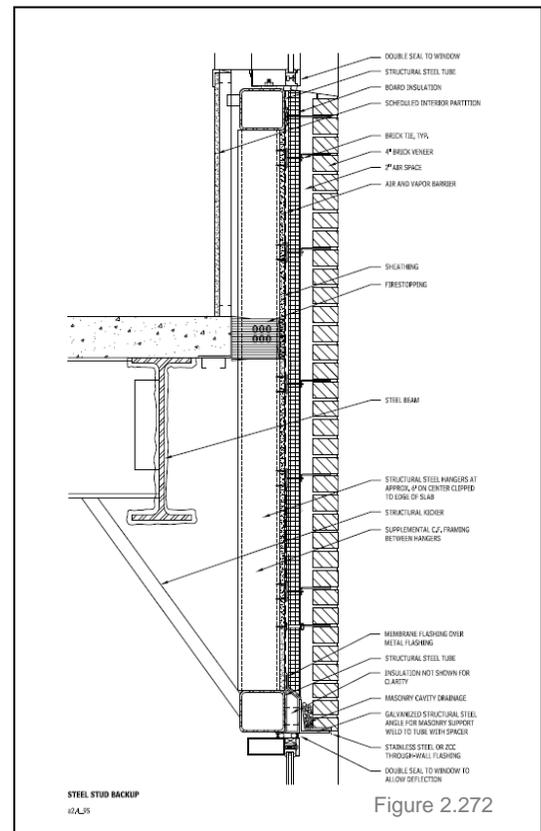
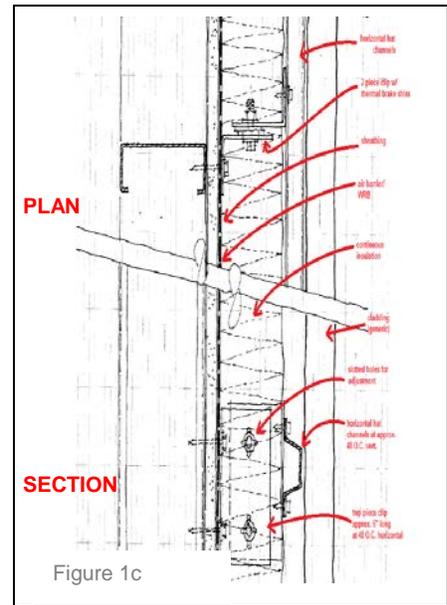
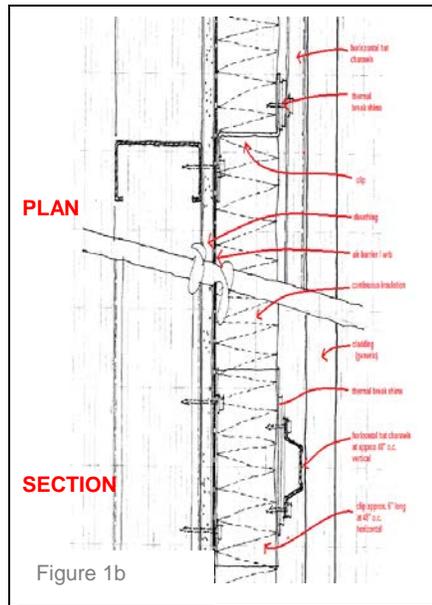
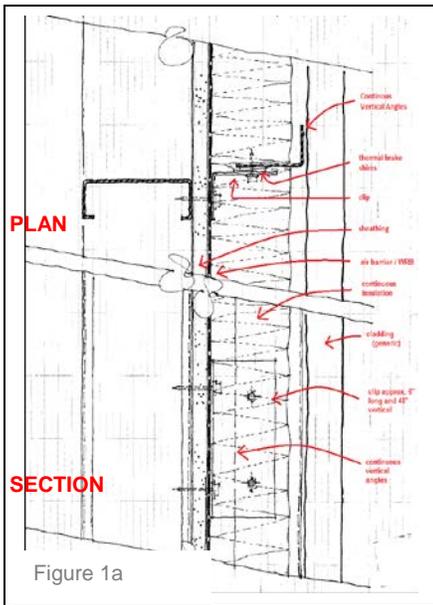


Figure 2.272

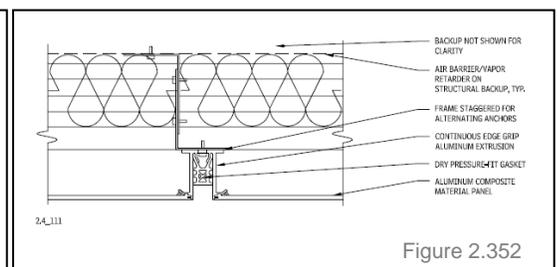
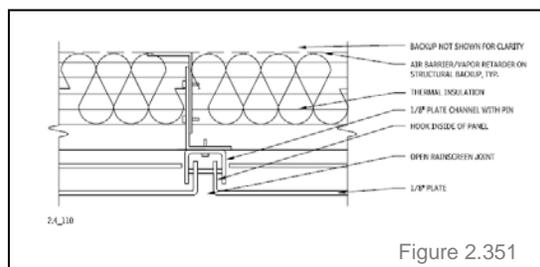
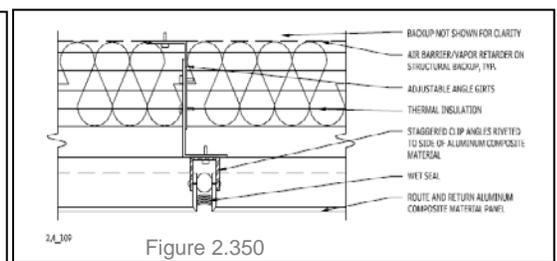
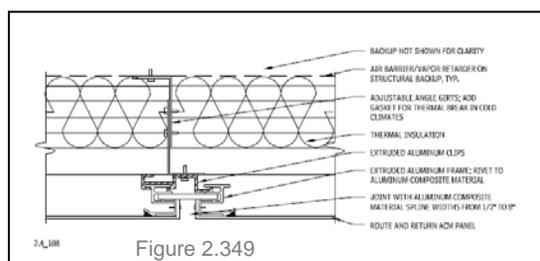
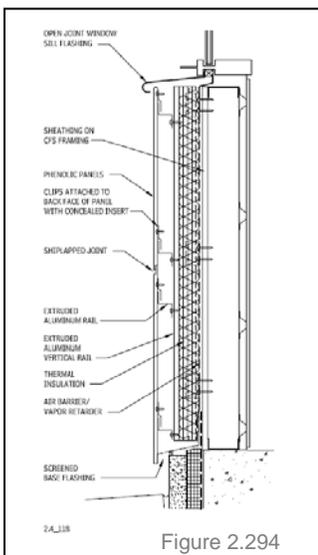
at the proper location at the surface of the AB/WRB.



Cladding: The outer cladding of the wall assembly can be a wide variety of materials. For the sake of clarity this layer is not referred to as the “rainscreen”. This name has created confusion and seemingly led to the idea that the cladding can be nearly anything, including open jointed systems, perforated materials, and literally screens. The cladding must be detailed to attempt to stop ALL water intrusion to qualify as a proper BVDC or PER system.

Masonry cladding may be stone, brick or CMU. Frequently mortar or sealant provides the primary sealing function of the cladding joints, and thus masonry cladding is rarely detailed as a true PER. Square jointed stone panels without joint fillers are open cladding and should be detailed as such. (figure 2.272).

Panel type cladding comes in nearly endless materials; wood, phenolic, cementitious, plastic, ceramics, metal composite materials, porcelain coated steel, sheet metal (aluminum, galvanized steel, zinc, titanium, etc.), metal plate (aluminum, steel), and more (figures 2.294, 2.341, 2.349, 2.350, 2.351 and 2.352).



Mounting typically falls into either exposed or concealed fastener types. Whichever fastener type, ensure that the

system will accommodate differential movement without distortion or degradation. Many of the cladding products can expand and contract more than 1/4" in common panel sizes with normal seasonal temperature changes. Systems that are rigidly screwed onto girts may fail very quickly. The jointing of the panels has to be detailed to stop water penetration. For thin panels that cannot provide sufficient ship-lapped edge profiles then metal zee flashing at horizontals and channels at vertical joints may be required. For any panel not inherently non-combustible verify if it is allowed on commercial projects. For any manufactured panel, verify long-term successful in-place service of the exact color and chemical make-up. Many variables can determine if the product

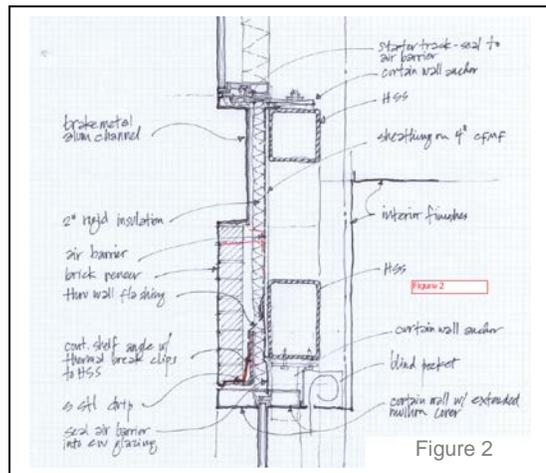
will perform, simply changing to a very dark panel can change temperatures sufficiently to cause failure.

Terra Cotta, ductile concrete, glass fiber reinforced concrete, fiberglass, and other products all have been used successfully if properly detailed. Again, open-joint systems such as terra cotta baguettes do not meet the requirements for cladding of a BVDC or PER wall assembly. Note that many aluminum and glass curtain wall systems are designed as pressure-equalized rainscreens. However, those systems are not included in the scope of this article.

DOCUMENTATION

Once the architectural team has properly selected a BVDC or PER wall assembly, the design must be fully described in the drawings and specs.

For the drawings, build from the most generic to the most specific in a logical fashion. It is recommended that the set of drawings include an assembly diagram of each individual system required to enclose the entire building.



Think of these assembly diagrams as exterior partition types. By showing every single layer of the assembly clearly defined and annotated with material callouts that exactly match the specs there is little room for mis-interpretation. These assemblies should be started early in Design Development and finalized BEFORE starting construction documents. It is also desirable to develop large scale details of the most common head/jamb/sill, parapet and base of wall conditions during DD phase (figure 2). During CDs the detailing can proceed from these typical assemblies into all of the special conditions. This rigor not only allows for proper time to complete the necessary details, it also helps offices maintain schedule and profitability.

Evaluate the details using the simple “pencil” test (figure 3). Trace the continuity of every control function; air, water, vapor, cladding, insulation, etc, around the entire perimeter of the building in plan and section without lifting the pencil. Gaps show areas that require study.

In particular for BVDC and PER wall assemblies, the drawings need to show the location of all movement joints, especially those in the back-up wall. These joints can get lost in panelization lines, so a separate diagram or larger line symbol is necessary. The extent should be shown on elevations with details for each condition. Make sure that no movement joints dead end.

For PER wall assemblies, the drawings should show the compartmentalization of the air cavity. Elevations should show extent with details showing methodology.

Detailing the BVDC or Rainscreen: Depending on the type of BVDC or PER Wall Assembly desired; the amount of detail required for compartmentalization, drainage, joints, weeping, ventilation and support varies. Some systems can be specified as a nearly complete assembly with relatively few details, others require that the architect detail every condition. Understand what the supplier or manufacture will provide and then detail missing elements accordingly. It is very rare that a product or system includes the full back-up wall, insulation and AB/WRB. Those layers of the wall assembly will need to be detailed by the architect.

Detailing Joints: The joint where a BVDC or PER wall assembly meets adjacent construction is crucial, especially at the interface to a different type of wall assembly or to barrier type fenestration. One must remember that water will likely be present some of the time in the cavity and the cavity is always open to ambient air conditions. At transitions the cavity must be blocked off.

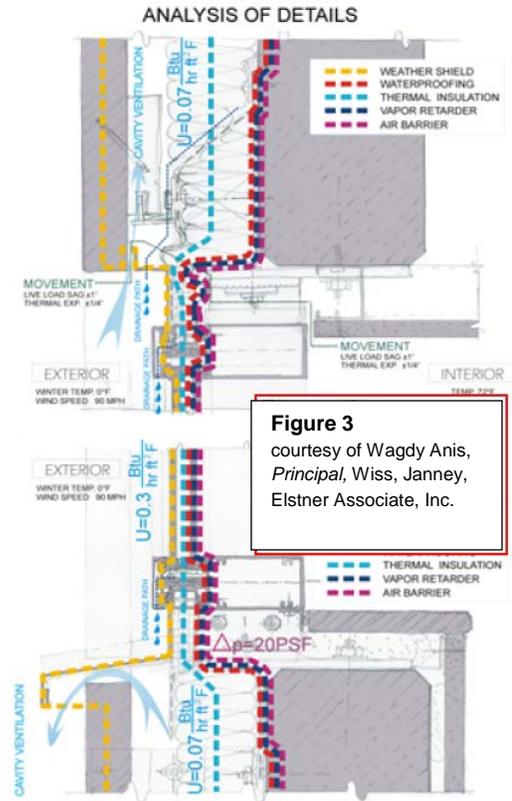
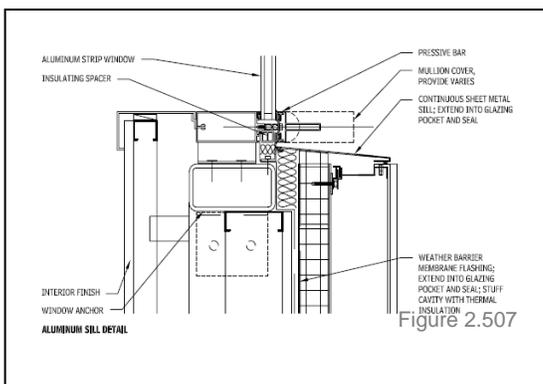


Figure 3
courtesy of Wagdy Anis,
Principal, Wiss, Janney,
Elstner Associate, Inc.



PER curtain wall: Bridge the AB/WRB line across to the back of the glazing pocket and maintain the thermal control layer. Connect the cladding to the curtain wall mullion covers. (figure 2.507)

Storefront: It is very difficult to seal cavity walls to storefront and many storefront systems do not provide strong thermal performance or water control. If possible, avoid using storefront framing on high performance walls. If unavoidable, it is important that there be a primary watertight seal from the storefront frame to the AB/WRB. An inner line of sealant can help provide some

redundancy and reduce air pressure differences across any gaps in the outer sealant.

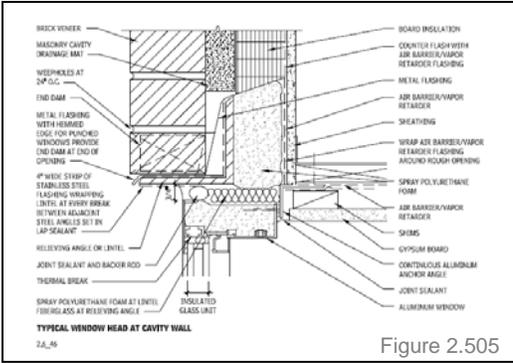


Figure 2.505

Windows: Similar to storefront, many older technology windows function as a face-sealed barrier and should be avoided or treated as listed above for storefront. If required provide a double line of sealant with inner air seals and outer weather seals (figure 2.505). More current window systems include provisions for sealing of the AB/WRB to the window frame itself. An outer seal at the cladding line should be provided.

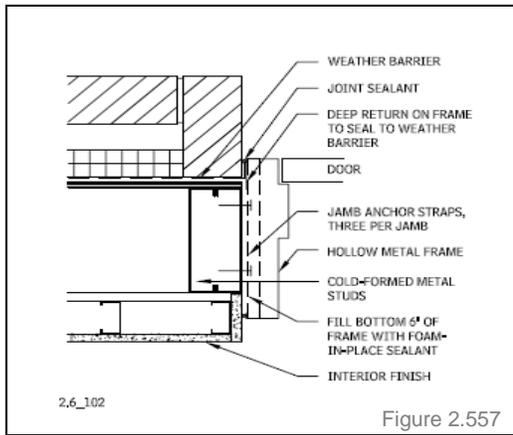


Figure 2.557

Hollow metal doors: Hollow metal doors are extremely difficult to properly seal into cavity walls. A flashing should close off the cavity to the exterior face of the hollow metal frame (figure 2.557). It is preferable to use aluminum curtain wall frames with aluminum doors and avoid the problem all together.

Barrier walls: At the joint between the BVDC/PER wall assembly, close the cavity with flashing, connecting the AB/WRB to the cladding. Seal the barrier wall to this closure. Note that the use of barrier walls in high-performance buildings is not recommended.

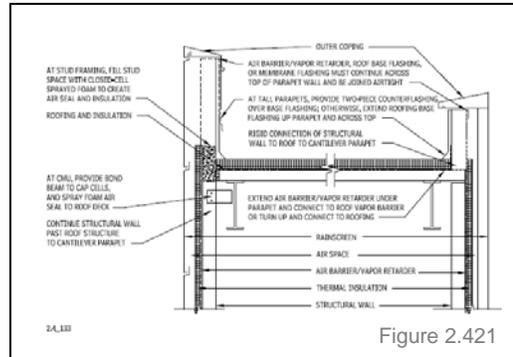


Figure 2.421

Roof Edge/Parapet: Detail a connection between the roofing membrane and the AB/WRB. At parapets it must be decided if the air barrier is to run up and over the parapet wall or if the air barrier is detailed to bridge the base of the parapet wall (figure 2.421). At gravel stop roof edges the roof membrane must extend to the air barrier (figure 2.424). If possible, utilize a protected membrane roof assembly, which more closely matches the layering of the BVDC or PER wall assembly. See Building Science Corp, "The Perfect Wall" for further explanation.

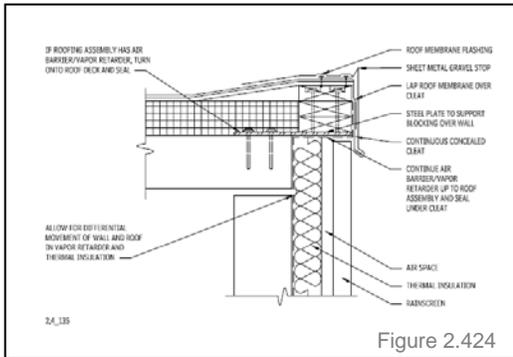


Figure 2.424

Overhangs and Soffits: The continuity of the double line of defense should be maintained across the soffits (figure 2.425a). Vented soffits are not recommended (figure 2.425b).

Foundation wall: Detail a connection of the AB/WRB to the foundation waterproofing system. Maintain continuity of the thermal control layer. For high performance buildings, true waterproofing is preferred over dampproofing. (figures 2.123, 2.294 and 2.328)

Slab-on-Grade condition: Provide a strip of waterproofing along the base of the wall, extending a short distance below grade. Maintain continuity of the thermal control layer if possible. Connect the below slab vapor barrier with to the AB/WRB if possible. (figure 2.294 and 2.328)

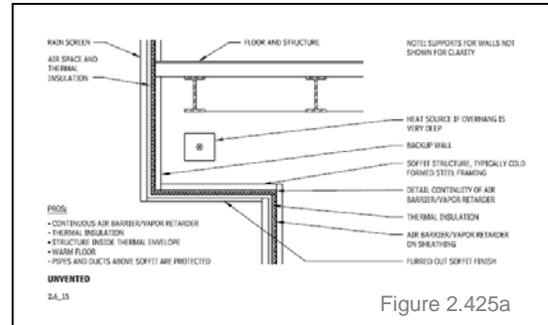


Figure 2.425a

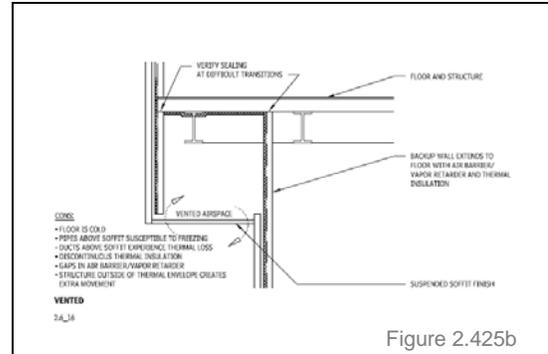
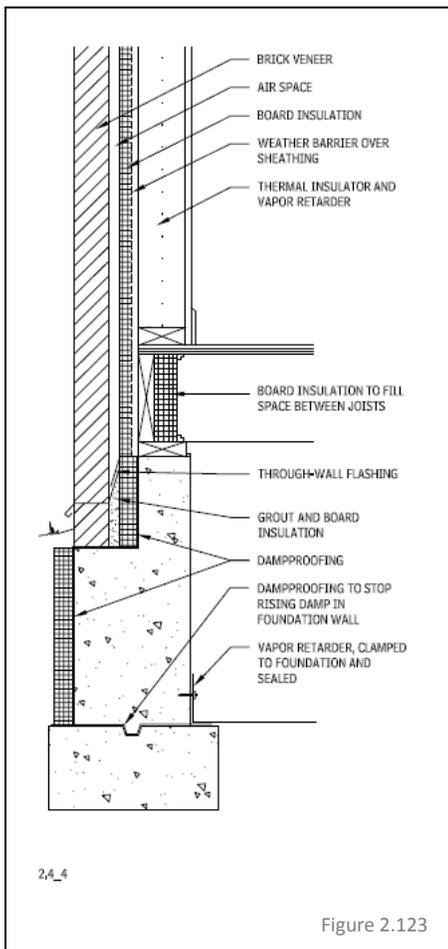


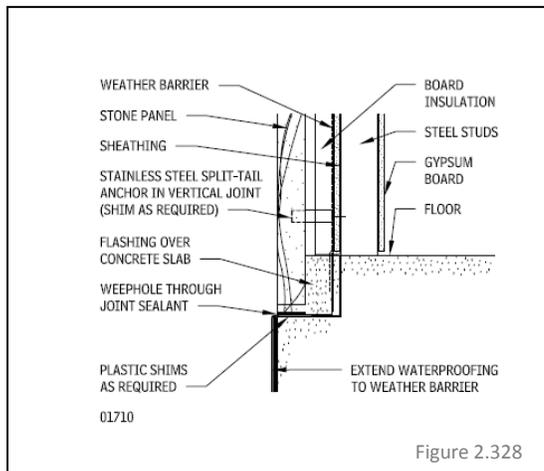
Figure 2.425b

Specifications:

Complete and coordinated specs will help deliver a functioning enclosure. The specs must be highly tailored to the specific project requirements, boilerplate will not do.



In many projects the BVDC or PER wall assembly is made up of many products specified in many technical sections. It is advisable to add an “Enclosure General Requirements” section in Division 1 or perhaps at the beginning of Division 7 that brings together all of the elements of the enclosure. Include a statement that the wall system is designed to function as a BVDC or PER wall along with a definition of that performance. Include performance criteria that is necessary for the entire assembly versus criteria that applies to only one layer such as air infiltration and water penetration. Include a rigorous quality process from the builders including requirements for coordinated enclosure drawings, coordination meetings, mock-ups, special testing, and site observations.



It is desirable for a single source to provide most if not all of the components required for the enclosure (most commonly available with all curtain wall buildings). Unfortunately, the construction industry is not prepared to address that desire when there are multiple trades involved. Work with local trade groups and CMs to establish if it is possible to find a contractor or sub-contractor who will provide all of the components of a BVDC or PER Wall Assembly before issuing a specification that includes a single source requirement.

Specify performance criteria with the product providing the performance, e.g. ACM panels frequently do not provide air tightness but it is common to see air tightness criteria included in

the ACM panel spec section. This inconsistency causes confusion with the construction team.

Specify each product with a unique name tied to the drawings so there is no question of what material is desired. For example, instead of “FLASHING” which can be specified in a dozen sections, use something more specific such as “AIR BARRIER TRANSITION FLASHING”.

Coordinate between the various technical spec sections, especially for products that bridge the cavity. For example, wall flashing speced in one section has to be connected to the AB/WRB speced elsewhere. Girts and girt anchorage must be coordinated with the cold formed metal framing spec to ensure proper structural support.

Ensure that outdated construction technology instructions, such as thru wall flashing embedded into CMU back-up wythes, are edited out for the more current AB/WRB membrane.

It is common for some aspects of a BVDC or PER wall assembly to be specified using delegated design. It is crucial that the documents clearly describe the extent of the delegated design (e.g. just the stud back-up wall or the entire wall) and must include all performance criteria and the method to validate compliance with the criteria (e.g. signed and sealed shop drawings with calcs and/or mock-ups with testing). If delegated design is utilized, then the drawings must represent a realistic solution to the delegated design in order for the architect to maintain sufficient control (e.g. the space allowed for internal girts must be deep enough for the required span conditions).

CONSTRUCTION

The drawings and specs are completed and a good team of contractor’s, subs and suppliers has been selected. Now it is time to actually get these high performance walls built. Please refer to “Construction of Rainscreen Walls” by Drake Wauters, part of this series of articles, for the next steps.