



National Masonry Systems Guide

NATIONAL MASONRY SYSTEMS GUIDE

NORTHWEST EDITION - 2024

MASONRY INSTITUTE OF WASHINGTON

NATIONAL MASONRY SYSTEMS GUIDE NORTHWEST EDITION

**FIRST EDITION - 2016
SECOND EDITION - 2018
THIRD EDITION - 2024**



**MASONRY INSTITUTE OF WASHINGTON
Washington, Oregon, and Idaho
www.masonrystemsguide.com**

NATIONAL MASONRY SYSTEMS GUIDE NORTHWEST EDITION

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MASONRY INSTITUTE OF WASHINGTON

14900 Interurban Ave. S
Suite 275, Seattle, WA 98168

(206) 674-4562

Printed in the U.S.A.

FIRST EDITION – 2016
SECOND EDITION – 2018
THIRD EDITION – 2024

ISBN: 978-0-578-17514-0

FOREWORD

One definition of *inspect* is “to examine closely and critically.” In building construction, the term *inspections* can imply other definitions: *completeness*, *code compliance*, *quality assurance*, and *as-specified* are a few examples. For the purposes of this guide, inspection will be discussed as actions performed by a building owner, product manufacturer, code official, and others. Construction observations for quality assurance and assessment are typically performed by professional, credentialed construction observers and consultants such as a Certified Mason Contractor (CMC) as recognized by the Washington State Conference of Mason Contractors; however, these services may be provided by individuals with extensive experience in design and construction of building enclosure components.

This guide has been compiled to provide assistance regarding the design, engineering, and construction of components of masonry building enclosure systems, including exterior walls, accessories, membranes, penetrations and transition flashings. The guidelines included cover these systems during their design, specification, and initial construction. The purpose of this guide is to assist quality assurance observers and owners who may have limited knowledge and experience in the specifics of masonry system component installation or evaluation. This guide also serves as a procedural reference for experienced professionals who review masonry systems regularly.

During construction, quality assurance observers can review the masonry systems as they are installed to confirm that they comply with the project specifications, industry standards, and recognized guidelines for the work being performed. Following construction and throughout the service life of the system, visual assessments can determine if maintenance is required beyond cleaning debris from elements of a masonry system or replacing sealant or pointing that has aged to the point of failure. If more detailed and involved maintenance is required, a credentialed, professional building enclosure consultant experienced in masonry design and restoration or a CMC should be engaged.

References and resources for information contained in this guide may be found at the end of each chapter and resources may be found near the end of this guide.

This publication was created with the oversight of experienced professional building enclosure consultants, engineers, architects, experienced commercial masonry contractors, and other masonry specialists. Therefore, the information presented here comes directly from consultants and contractors with decades of in-the-field masonry experience.

This guide should be considered a supplement to other masonry industry publications that describe many details and alternative construction methods and applications. Where project specifications may be inadequate, many of the details within this publication are subject to interpretation by professional building enclosure consultants or the judgment and experience of a commercial mason contractor.

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INTRODUCTION

Masonry has been used successfully in building construction in the Northwest region (Washington, Oregon, and Idaho) for many decades as both the primary structural system and as a cladding material. Masonry has withstood the test of time not only because of its natural resistance to fire, water, impact, and organic growth but also because of its design versatility.

Historically, structural mass masonry wall systems such as that shown in Fig. i-1 were commonplace, primarily due to their superior fire-resistance, durability, and weatherability. Over time, such systems have given way to alternative structural/ framing materials and separate cladding elements. By definition, mass structures inherently address the many above-grade functions of walls, including control of water, air, heat, sound, and fire. Thus, replacing the mass structure increases the complexity of the wall design as follows:



Fig. i-1 Historic Masonry Structure: Maple Leaf Gate, Seattle 1911

- Wall cavity and/or exterior insulation may be necessary for thermal and sound control.
- An air barrier is necessary to limit the uncontrolled exchange of air—and consequently the uncontrolled exchange of moisture (primarily vapor), heat, sound, and pollutants that move with air—between the interior and exterior environments.
- Moisture control is rethought to ensure that moisture-sensitive structural and insulation components are protected.

Traditional decorative and durable cornice and cornerstone elements and strategically located built-in drip edges were typical of mass masonry structures. These were also responsible for deflecting much of the water cascading down the face of these buildings. These design elements have been either eliminated or

traded for more modularized and economized veneer units that, while reminiscent of historic mass masonry construction detailing, do not have the same water-deflecting characteristics. Fortunately, most veneer wall assemblies are able to accommodate the added moisture ingress due to a concealed drainage plane and flashings. The result is a similar material aesthetic, fire-resistance, and durability, yet a flatter and simpler appearance, such as that shown in Fig. i-2, that lacks the intrinsic ability to deflect water away from the masonry-clad wall face and away from areas most sensitive to water entry, e.g., wall penetrations such as vents, windows, and doors.

Though the evolution of the above-grade wall design has led to more complex overall systems, product selection, and code compliance than in previous years, it has also demonstrated the durable and accommodating nature of modern above-grade masonry wall systems to the local climate conditions of the Northwest region.



Fig. i-2 Contemporary masonry veneer structure, Wenatchee Valley College Music and Art Center, constructed in 2012

As a result, the focus of this guide is to provide comprehensive design and construction detailing information for 8 primary above-grade wall systems successfully used in the Northwest climate that are composed of clay or concrete masonry as an adhered or anchored veneer or single-wythe concrete masonry unit (CMU) wall application. The focus for each system is to clarify the overall above-grade wall building enclosure design as it relates to managing moisture (both liquid water and vapor), air, and heat transfer between the interior environment and exterior environment and to demonstrate the constructibility of these systems to provide long-term durability. Cladding considerations including attachment and installation methods are also addressed.

Each system within this guide is addressed specific to the Northwest region, including Washington, Oregon, and Idaho and considers local climate, codes, and building preferences and practices. The systems included within this guide have also been developed for application to occupied multistory, multifamily residential or commercial structures with typical indoor environments (e.g., ASHRAE 55¹-compliant spaces) in the Northwest region. Multistory applications of each system are recommended in the "Masonry Systems Comparison Matrix" beginning on page i-8. Although, some of the systems discussed within this

guide may be applicable to structures with atypical indoor environments (e.g., natatoriums, fridge and freezer warehouses, unconditioned spaces, etc.), these applications are not the intended scope of the guide.

The information presented within this guide is not meant to be exhaustive of all system variations, product performance properties, or detailing approaches but rather represents a selection of the successful enclosure design and construction practices used in the Northwest region.

This guide is not intended to replace professional advice. When information presented here is incorporated into specification building projects, it must be reviewed by the design team and reflect the unique conditions and design parameters of each building in addition to conforming with local building codes, standards, and by-laws.

How to Use This Guide

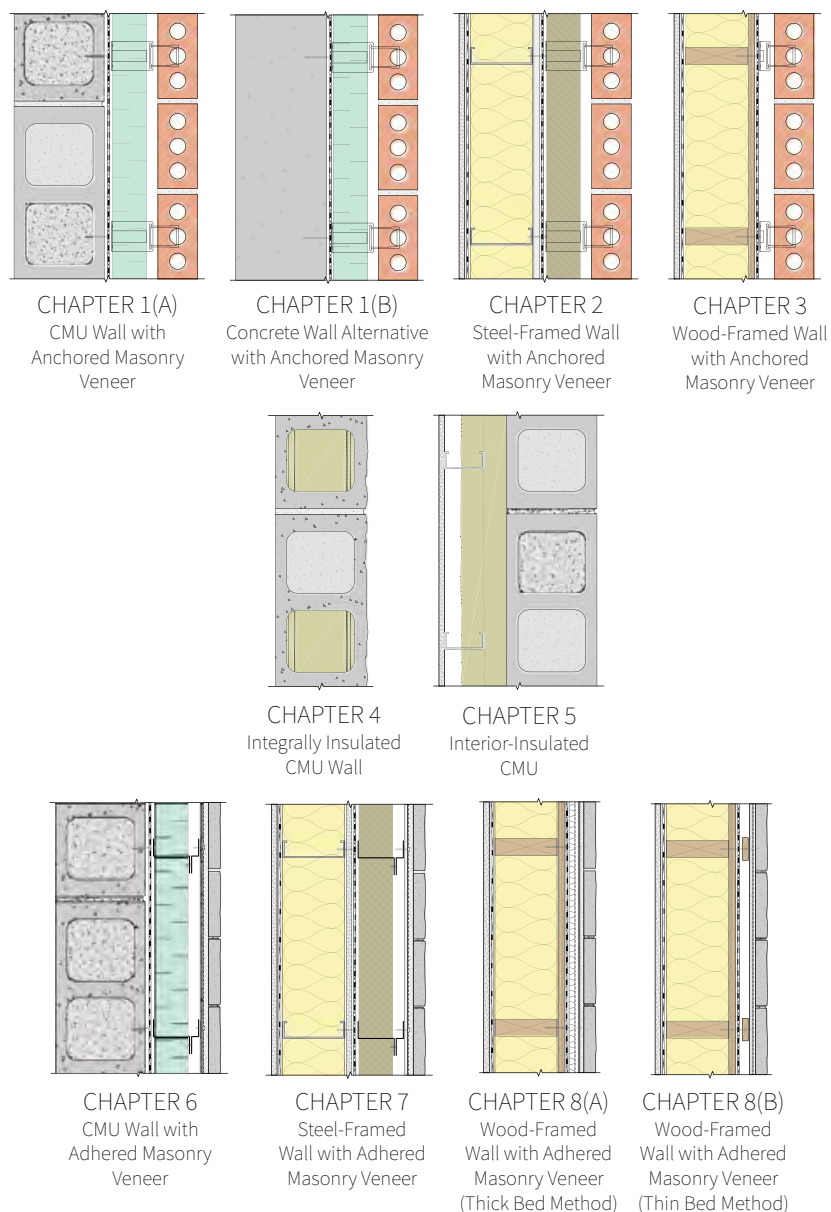
This introductory chapter showcases the 8 primary above-grade wall systems that are the focus of this guide. This introduction also contains technical references and supporting information for general topics that apply to the featured above-grade wall systems.

Each subsequent chapter is dedicated to one of the primary above-grade wall systems and provides system-specific discussion, guidance, photos, and/or diagrammatic illustrations. Two- and three-dimensional details and cutaway wall sections are provided at the end of each chapter, summarizing the chapter content and illustrating its use in real-world-like applications.

The sections following the 8 system chapters contain additional information regarding thermal modeling parameters, product resources, and a glossary of terms.

Online Availability

The content of this guide and additional information may be accessed online at www.masonrysystemsguide.com. Also available online are downloadable digital versions of two- and three-dimensional system details and cutaway sections and sample project specifications. Ongoing additions to the references and resources included within this guide can also be accessed.



Guide Systems

The 8 primary above-grade wall systems featured within this guide are shown in Fig. i-3 and are summarized in the "Masonry Systems Comparison Matrix" beginning on page i-8. These systems and their respective chapters include:

- Chapter 1: CMU (or Concrete Alternative) Wall with Anchored Masonry Veneer
- Chapter 2: Steel-Framed Wall with Anchored Masonry Veneer
- Chapter 3: Wood-Framed Wall with Anchored Masonry Veneer
- Chapter 4: Integrally Insulated CMU Wall
- Chapter 5: Interior-Insulated CMU Wall
- Chapter 6: CMU Wall with Adhered Masonry Veneer
- Chapter 7: Steel-Framed Wall with Adhered Masonry Veneer
- Chapter 8: Wood-Framed Wall with Adhered Masonry Veneer (Thick or Thin Bed Methods)

Fig. i-3 Chapters 1 through 8 system summary. Systems are depicted in plan view with interior located at left and exterior located at right.

Expected Cladding Service Life

As shown in Fig. i-4, the expected service life for various drained and mass wall systems will vary. A drained cladding system assumes that a drainage cavity exists between the back of the cladding and the water-resistive barrier (WRB) membrane and that exit pathways are provided to divert water within the cavity back to the exterior environment. Undrained cladding systems are not addressed in this table due to the decreased expected service life of such assemblies, which in turn reduces the effective service life of the cladding. We acknowledge decades-old undrained systems exist, but modern undrained assemblies in weather exposed conditions are at a higher risk of failure than modern drained systems.

The actual cladding service life within the depicted ranges will depend on cladding exposure, the quality of the original installation (including appropriate detailing at details and interfaces, etc.), and a continuous maintenance program. However, general field observations performed by RDH Building Science Inc. identify that concrete masonry unit walls (either coated or uncoated) and anchored clay masonry veneer walls can provide similar or greater expected cladding service life than other systems. This performance is primarily due to the lack of moisture-sensitive components of CMU wall systems or the inclusion of drainage provisions of veneer walls.

The following can help achieve average or greater service life of the masonry veneer-based cladding systems described above:

- Develop a building form with features that provide a continuous water-shedding surface and promote deflection of water away from the building, particularly at details and interfaces (see page i-18). Confirm that water-shedding elements are constructed continuously in the field.
- Design and construct continuous water and air control layers (see page i-24 and page i-26). Use a moisture-tolerant and durable water-resistive barrier system and air barrier system as well as insulation materials that exist within the drained and vented (where applicable) air space behind the cladding.
- During design, select cladding attachment materials such as ties, girts, and fasteners and metal components such as sheet-metal trim and counterflashing elements whose service lives are similar to that of the cladding material. For example, stainless-steel components parallel the expected longevity of masonry wall systems (see page i-46 and the Corrosion Resistance sections of each system chapter).

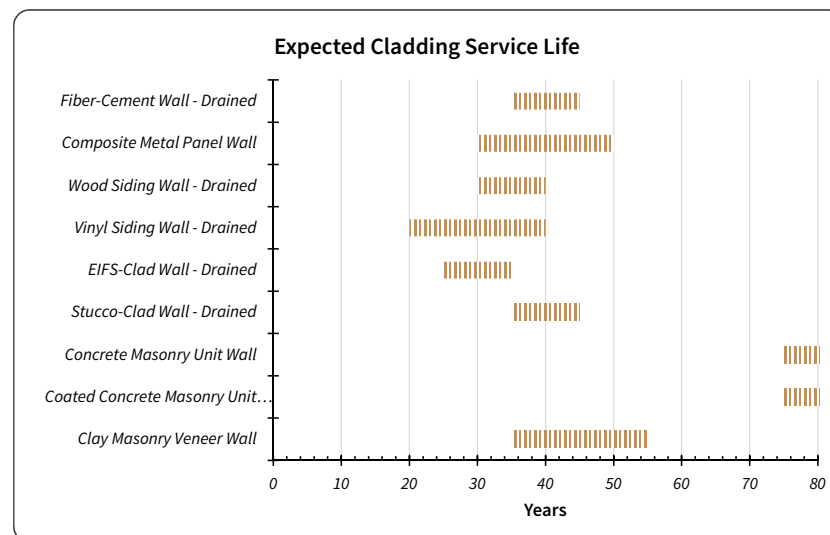


Fig. i-4 Expected cladding service life, based on a combination of manufacturer warranties and RDH staff professional opinions and experience

- Implement a comprehensive maintenance program that is specific to the building. In general, the following outline recommends frequencies for maintenance events:
 - ☑ Immediately: Correct water diversion mechanisms that may have become disconnected or failed, such as scupper, gutters, or downspouts.
 - ☑ As Needed: Repair localized cladding and cladding component damage or failure.
 - ☑ Every 2 to 5 Years: Review cladding for signs of distress or wear such as cracks/spalling, efflorescence (see page i-66), organic growth development, or sealant joint failures and repair or clean as needed. Repair moisture sources that may be causing efflorescence.
 - ☑ Every 5 to 10 Years: Review the condition of mortar in masonry veneer walls; repoint mortar as necessary. Perform a comprehensive condition assessment of cladding and cladding components including sounding of adhered veneer components.
 - ☑ Every 5 to 20 Years: Reapply masonry sealers based upon sealer manufacturer-recommended intervals (see page i-59).

Masonry Systems Comparison Matrix

For the purposes of this guide, a masonry system is an above-grade exterior wall assembly that includes masonry as the primary cladding element and is designed for the local climate or microclimate where the system will be installed. A masonry system considers how all wall components (e.g., water control and air control layers, cladding attachment and supports, veneer products, etc.) are integrated and made continuous with all other wall elements, including the field-of-wall area and its relationship to penetration and transition details.

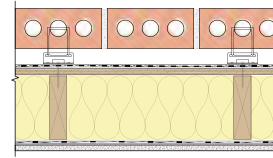
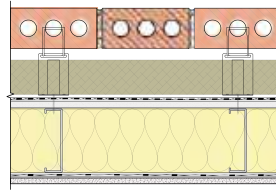
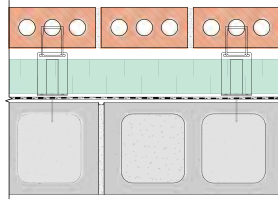
Selecting a Masonry System

The system comparison matrix assists with the selection of appropriate masonry system(s) for a particular project. On the following fold-out pages, each system is described and compared according to the categories described on this page (below) and page i-13.

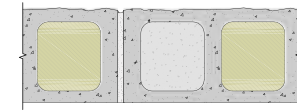
Recommended Occupancy | Residential occupancy includes multifamily structures with dwelling and/or sleep units. Commercial occupancy includes all other occupancy types. Both residential and commercial occupancies assume normal indoor environmental conditions as discussed on page i-2.

































Maximum Building Height | The maximum building height recommended for each system is determined by typical wind pressures, common building shape/form, and accessibility for installation and maintenance. Building height definitions vary throughout the industry; however, for the purpose of this guide, building height is classified as either low-, mid-, or high-rise. Some systems may be used for buildings of greater height, but these applications should be carefully evaluated by the project's design team.

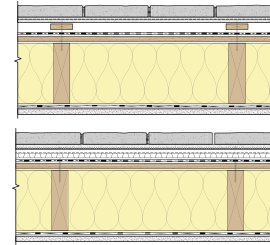
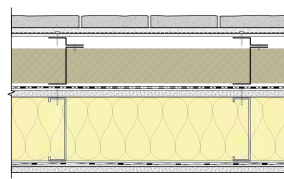
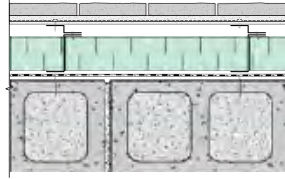
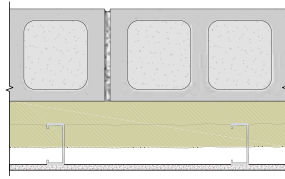
Maximum Annual Rainfall Level | Defines the maximum annual rainfall level for each system as it correlates to the annual rainfall levels described in Fig. i-8 on page i-17. The recommended system level assumes high exposure of the cladding (minimal overhangs, canopies, or dense surroundings such as heavily treed areas or taller adjacent buildings). Note that the severity of regional rainfall can be minimized by implementing building form and feature practices that minimize exposure to rainfall (see page i-18). For example, a system designated with a maximum moderate level could be appropriate in extreme rainfall areas if roof overhangs are provided. Each building's location and form are unique and should be considered when selecting a system.



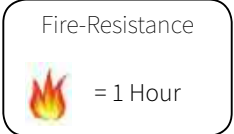
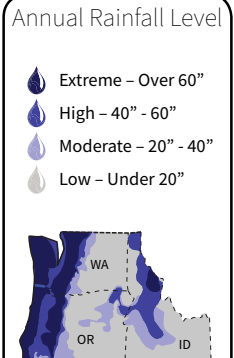
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COMPARISON CATEGORY	System 1A and 1B	System 2	System 3	System 4
Structure + Cladding	CMU + Anchored Veneer	Steel-Framed + Anchored Veneer	Wood-Framed + Anchored Veneer	Exposed CMU (Integrally Insulated)
Recommended Occupancy	Residential or Commercial	Residential or Commercial	Residential or Commercial	Commercial
Maximum Building Height	  	  	  	
Maximum Annual Rainfall Level	   	   	   	 
Typical System Thermal Performance	R-10 - R-20+ Exterior insulation typical where grouted cells limit integral insulation. See page 1-12 for thermal performance tables.	R-15 - R-20+ Exterior insulation typical to compensate for highly conductive steel framing. See page 2-12 for thermal performance tables.	R-18 - R-20+ For a greater system effective R-value, exterior insulation may be added to this system. See page 3-12 for thermal performance tables.	≤R-10 R-value will vary based on percentage of cell area available for core insulation. System may qualify for energy code exceptions in some jurisdictions. See page 4-7 for additional discussion.
Cladding Attachment (Lateral Loads)	Anchored Cavity depths are limited to 6%" per TMS 402-16 ² . See page 1-8 for tie options.	Anchored Cavity depths are limited to 6%" per TMS 402-16 ² . See page 1-8 for tie options.	Anchored Cavity depths are limited to 6%" per TMS 402-16 ² . See page 3-9 for tie options.	N/A Independent cladding design not applicable; wall structure provides cladding element.
Cladding Support (Gravity Loads)	Bearing Elements Requires TMS-402 ² required bearing elements such as footings, shelf angles, and floor slabs.	Bearing Elements Requires TMS-402 ² required bearing elements such as footings, shelf angles, and floor slabs.	Bearing Elements Requires TMS-402 ² required bearing elements such as footings, shelf angles, and floor slabs.	Bearing Elements Single-wythe system is the cladding and is supported by footings and floor slabs.
Fire-Resistance	   			 
Price per Square Foot (Low-High Baseline Cost)	\$33.50 - \$42.30	\$33.50 - \$42.30	\$30.75 - \$39.05	\$25.75 - \$39.50



	System 5	System 6	System 7	System 8A and 8B	Graphics Key
	Exposed CMU (Interior Insulated)	CMU + Adhered Veneer	Steel-Framed + Adhered Veneer	Wood-Framed + Adhered Veneer	Maximum Building Height
	Residential or Commercial	Residential or Commercial	Residential or Commercial	Residential or Commercial	Low ≤ 3 stories
					Mid 4 - 8 stories
					High ≥ 9 stories
	R-7 - R-20+ Interior continuous insulation unbridged by highly conductive steel framing provides greatest effective R-value. See page 5-2 for thermal performance tables and additional configurations.	R-12 - R-15+ Exterior insulation typical where grouted cells limit integral insulation. See page 6-10 for thermal performance tables.	R-15 - R-20+ Exterior insulation typical to compensate for highly conductive steel framing. See page 7-11 for thermal performance tables.	R-10 - R-20+ For a greater assembly effective R-value, exterior insulation may be added to this assembly. See page 8-12 for thermal performance tables.	Annual Rainfall Level
	NA Independent cladding design not applicable; wall structure provides cladding element.	Clip/Girt Cladding system to be engineered by manufacturer of proprietary clip system or project structural engineer.	Clip/Girt Cladding system to be engineered by manufacturer of proprietary clip system or project structural engineer.	Clip/Girt or Fastener Attachment/fastener frequency to be engineered by project structural engineer.	Extreme – Over 60"
	Bearing Elements Single-wythe system is the cladding and is supported by footings and floor slabs.	Clip/Girt Cladding supported by clip/girt cladding support system.	Clip/Girt Cladding supported by clip/girt cladding support system.	Clip/Girt or Fastener Cladding supported by clip/girt cladding support system or fasteners.	High – 40" - 60"
					Moderate – 20" - 40"
	\$27.75 - \$34.25	\$49.50 - \$64.60	\$51.25 - \$66.50	\$39.50 - \$56.25 (8A) \$46.00 - \$53.50 (8B)	Low – Under 20"
					Fire-Resistance
					= 1 Hour



Typical System R-value | Defines the typical effective R-value for the field of wall area. For veneer systems, this assumes that framed wall cavities contain insulation and that exterior insulation is installed at thicknesses necessary to maintain prescriptive energy code compliance as further clarified in thermal modeling results of each chapter. For single-wythe masonry systems, typical assumes an 8-inch concrete masonry unit (CMU) wall and either integral or interior insulation commonly installed in the Northwest region. Thermal performance can vary with wall depth, insulation type and thickness and cladding attachment methods. Refer to the chapter thermal performance tables referenced in the matrix for additional discussion.

Cladding Attachment (Lateral Loads) | Defines the attachment method used to laterally support the masonry veneer (where applicable).

Cladding Support (Gravity Loads) | Defines the attachment method used to support the gravity loads of the masonry component of the system.

Fire-Resistance Rating | Defines the ability of a building element or assembly to withstand exposure to a fire without passage of excessive heat, hot gases, or flames while continuing to provide sufficient structural stability. Typical ratings are shown. Chapter 4 and Chapter 5 ratings assume an 8-inch-wide CMU wall. Thicker CMU walls may achieve a higher rating.

Price Per Square Foot | Defines the relative price per square foot for components outboard of the wall sheathing (framed systems) or CMU backup wall structure. For single-wythe CMU without a veneer, pricing includes all components except interior finishes and interior framing (where it occurs). Pricing is based on a 10,000-square-foot wall area and is valid for the 2018 calendar year. Current pricing is also available at masonrystemsguide.com.

The remaining sections within this introduction serve as a reference for topics discussed within many of the system chapters. These topics include the building enclosure and loads; building enclosure control layers; system rain control strategies; thermal performance and energy code compliance; sheet-metal components; movement joints; cleaning, repellents, and coatings; and minimizing freeze-thaw cycles and efflorescence.

Building Enclosure

The building enclosure (i.e., building envelope) is a system of materials, components, and assemblies physically separating the interior environment(s) from the exterior environment. As an environmental separator, the enclosure must control the flow of heat, air, water (liquid water and water vapor), sound, and much more. The building enclosure must also provide support against physical loads on the building (e.g. air pressures, gravity loads, impact, etc.) and, in most, but not all cases, is required to provide an acceptable interior and exterior finish and help distribute utilities through the building.

An appropriately designed building enclosure benefits a building's heating and cooling energy use, comfort, durability, and serviceability. It also contributes to a healthy indoor environment.

The elements of the building enclosure include roofs, above- and below-grade walls, windows, doors, skylights, exposed floors, the basement/slab-on-grade floor, and all of the interfaces and details in between. Many typical building enclosure elements are depicted in Fig. i-5. Because the focus of this guide is specific to the 8 primary masonry systems described in the previous sections, only design considerations for above-grade wall systems are addressed here. Where appropriate, roof, floor-line, foundation, and fenestration transition details, in addition to typical wall penetration details, are also discussed.



Fig. i-5 Many building enclosure elements are visible in this photo, including a roof, above-grade walls, windows, doors, and floors (i.e., soffits).

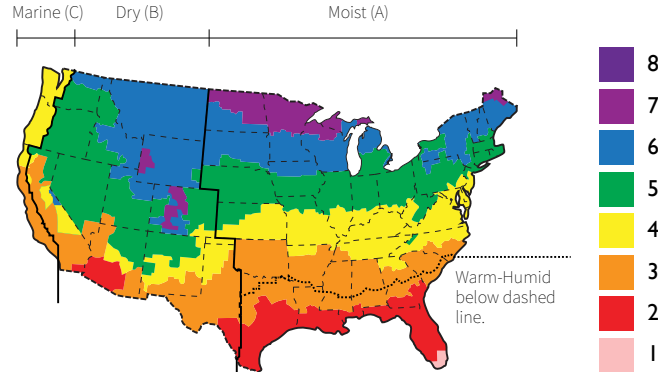


Fig. i-6 United States climate zone map as referenced from Figure C301.1 of the 2015 International Energy Conservation Code.³

Determining Building Enclosure Loads

Over the life of a building, the building enclosure is subjected to a wide range of interior and exterior environmental loads. The impact of rain (liquid water) falling on and flowing over the exterior surface of the building—as well as differences in temperature, water-vapor content, and air pressures between the interior and exterior environments—creates the most critical loads acting on the enclosure.

Interior environmental loads include building pressures, temperature, relative humidity, and water vapor condensation as well as liquid water and water vapor associated with the operation of heating/cooling and ventilation systems, human activities, and potential defects in appliances, sprinklers, and interior plumbing.

Exterior environmental loads include solar radiation, rain, snow, ice, hail, vapor condensation, wind, temperature, relative humidity, insects, pests, and organic growth. The climate zone in which the building is constructed, in

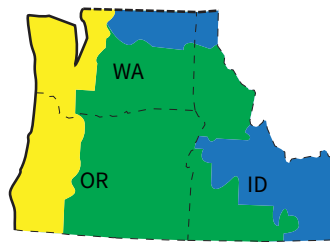


Fig. i-7 Northwest region (Washington, Oregon, and Idaho) Climate zones including Zone Marine 4, Zone 5, and Zone 6 as references from Figure C301.1 of the 2015 International Energy Conservation Code³ (see Fig. i-6).

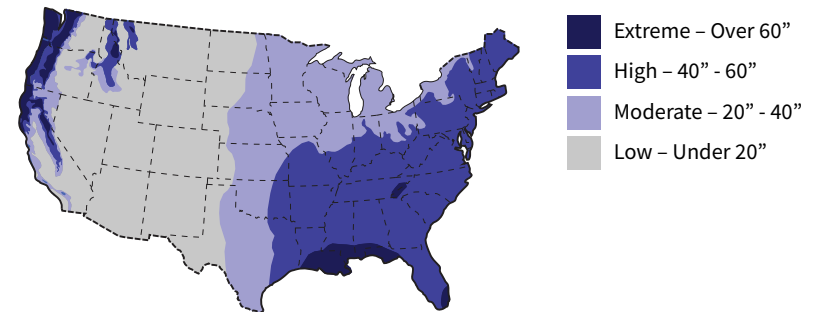


Fig. i-8 United States Total Annual Rainfall Levels. Map by RDH Building Science Inc. Data courtesy of National Oceanic and Atmospheric Administration.⁴

addition to its site-specific features, dictates the magnitude and duration of these environmental loads.

As depicted in Fig. i-7, three climate zones exist in the Northwest: Marine Zone 4, Zone 5, and Zone 6. These climate zones impose a wide range of environmental loads, including rainfall ranging from low to extreme levels as shown in Fig. i-8 and Fig. i-9. In the Northwest, high and extreme rainfall loads occur near the western Washington peninsula, the Oregon coast, and the higher elevations of Idaho.

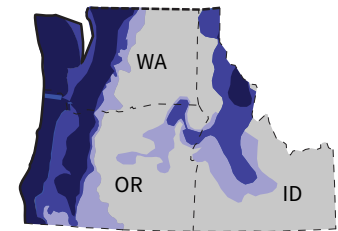


Fig. i-9 Annual rainfall levels of the Northwest region. Figure excerpted from Fig. i-8.

Site-specific features, including the local terrain, can further vary the properties of the regional exterior climate by creating a microclimate specific to a building site. For example, whereas a project may be located in a regional high-wind area, the site's features such as adjacent buildings or heavily wooded areas could reduce the wind exposure on the building.

Building Form and Features

Region and site-specific climate determine the potential for water (e.g., rain, snow, hail), solar, and wind loads on the building enclosure. However, a building's form and features dictate to what degree these loads act on the building enclosure. On a larger scale, building form and features include the building height as well as geometry inclusive of canopies, balconies, and roof overhangs. On a smaller scale, form and features include cladding, fenestrations, cornice elements, counterflashings, and drip edges all act as part of the water-shedding surface.

Specific to above-grade wall systems, exterior architectural elements such as balconies, canopies, or roof overhangs can deflect large amounts of water away from fenestration systems, cladding elements, and building entrances. Examples of beneficial building form and features are shown in Fig. i-10, Fig. i-11, and Fig. i-12. Conversely, building form and features can increase the severity of loads such as water by concentrating runoff at specific areas of the building enclosure. For example, a canopy that drains water runoff onto the wall cladding could cause staining, cladding damage, or worse: water intrusion into the building. In the Northwest region, it is especially critical in moderate to extreme rainfall areas that a building's form and features are consciously designed for water control.



Fig. i-10 ICHS Shoreline Medical and Dental Clinic, constructed in 2014, features large roof overhangs and canopies above entrances to deflect rain away from the above-grade enclosure components and shade the interior environment from the sun.



Fig. i-11 (above) Baker Middle School (opened in 2012) showcases roof overhangs that assist in deflecting rainwater away from the building enclosure below. Sun shades over windows also assist with controlling solar loads and reducing rain exposure.



Fig. i-12 (right) At Station 38, Hawthorne Hills, sheet-metal drip edges above windows, projected precast concrete windowsills, roof gutters, downspouts, and window canopies all help reduce the amount of water on the building enclosure.

Water-Shedding Surface

The water-shedding surface is the outer surface of the masonry system: the anchored or adhered veneer or CMU wall face at the field-of-wall area. The water-shedding surface also extends to the details and transitions shown throughout this guide and includes sheet-metal flashings, the face of fenestrations (e.g., windows), the roof membrane of a conventional roof assembly, and the top surface of the insulation of an inverted roof assembly.

The water-shedding surface will deflect and/or drain the vast majority of the exterior water from the system; thus, the water-shedding surface reduces the water load on the underlying elements of the system. Due to its importance, the water-shedding surface is depicted on the system figures and details throughout this guide as shown in Fig. i-14 and Fig. i-15 on page i-22.

In summary, interior climate, exterior climate (both regional and site-specific microclimate), and a building's form and features, including the water-shedding surface, all determine the overall water, air, heat, and vapor loads that act on the building enclosure. Together these factors may be referred to as load-determining factors and are graphically summarized in Fig. i-13 on page i-21.

Building Enclosure Loads and Control Layers

As discussed, a function of the building enclosure is to control (i.e. appropriately manage) building enclosure loads such as water (precipitation and ground), water vapor, air, heat, sound, fire, light, and contaminants. For the purpose of this guide, water, air, heat, and water vapor (i.e. vapor) are addressed in greater detail. Consideration of sound, fire, light, and contaminants may be related to the concepts discussed within this guide but are not covered in detail.

Water, air, heat, and vapor are controlled by various layers including the water control layer, air control layer, thermal control layer, and vapor control layer, respectively. These layers may include systems of materials or stand-alone materials that are intentionally selected and located within the enclosure to control a specific enclosure load. Fig. i-13 depicts the relationship between the concept of load-determining factors, building enclosure loads, control layers, and the systems and materials that make up each control layer.

As an example, the building enclosure load of air—more specifically air pressure—is controlled by the air control layer (the primary relationship). This layer comprises the air barrier system. The air control layer also has secondary relationships: it assists with controlling water, heat, water vapor, sound and fire.

When control layers are intentionally designed to control a specific load, they are said to have a primary relationship with the building enclosure load. Primary relationships are shown in Fig. i-13 with a solid line connecting the building enclosure load and control layer. Some control layers will also assist with the control of other loads. This relationship is shown in Fig. i-13 as a dashed line connecting the building enclosure load and control layer.

Using the control layer concept to evaluate assemblies and details (e.g. masonry systems) is consistent with industry best practices and can be useful to assess specific assemblies and details being considered for a project. The application of the control layer concept can help all parties better understand the role and importance of the systems and materials associated with each layer and can help identify areas where control layers may be missing or are discontinuous (if required to be continuous). Throughout this guide, the control layers are shown on system figures similar to those shown in Fig. i-14 and Fig. i-15 on page i-22. Placement and continuity of these systems and materials are also shown for each 2-dimensional detail in the system chapters.

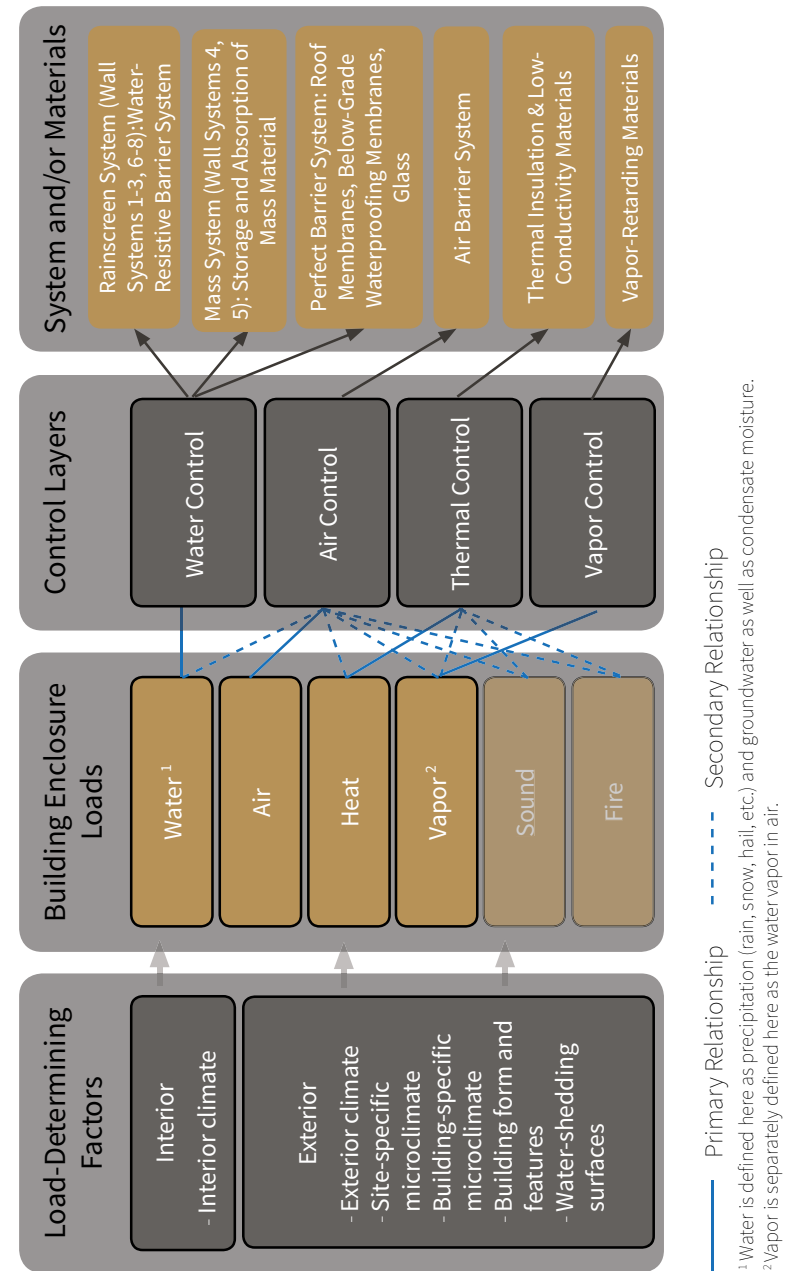
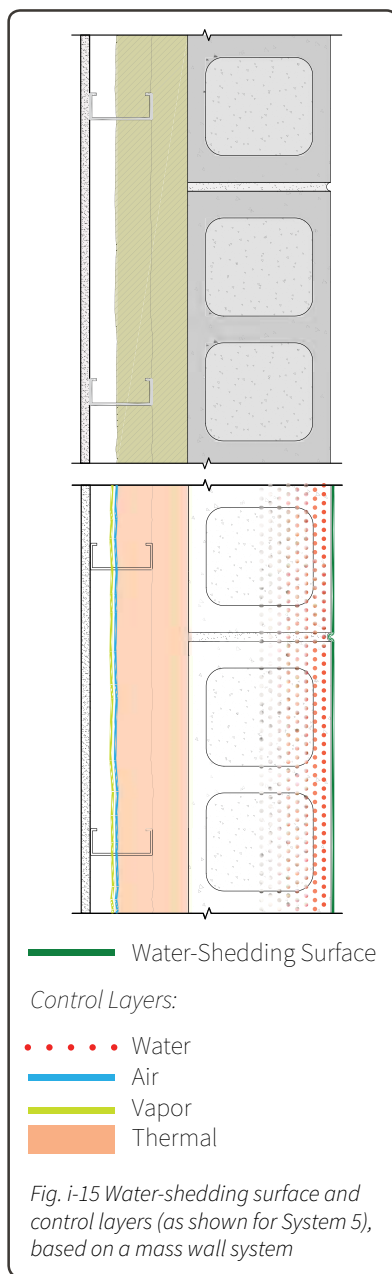
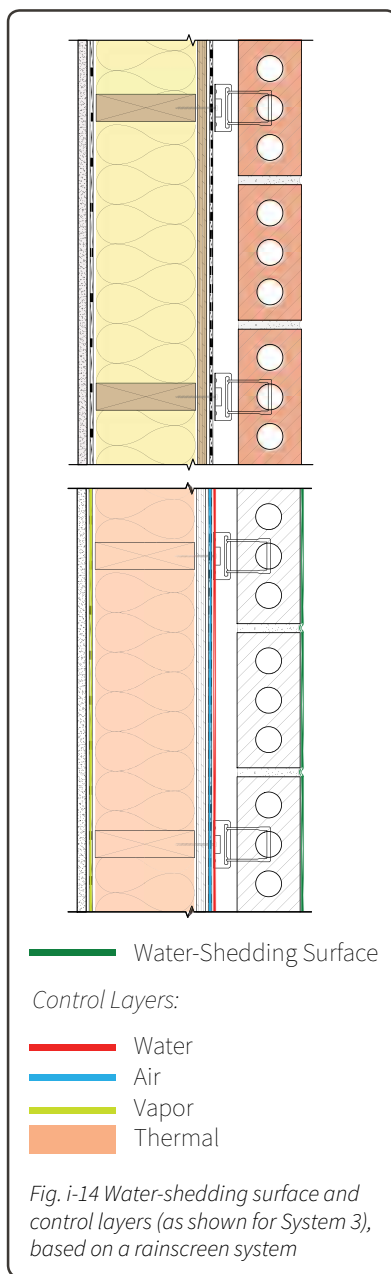


Fig. i-13 Building enclosure load and control layer relationships, specific to the above-grade wall systems and details depicted in this guide.



System Rain Control

There are three categories of rain control available for above-grade walls: screened and drained (i.e., rainscreen), storage (i.e., mass), or perfect barrier.⁵ The systems within this guide include either rainscreen or mass walls. Perfect barrier walls are not included; however, perfect barrier assemblies or materials such as a conventional roof membrane assembly or window glass occur in some details. Further discussion of the perfect barrier category of rain control is beyond the scope of this guide, though a definition of a perfect barrier system may be found in the glossary.

A rainscreen wall is shown in Fig. i-14. This rain control category assumes that some water makes its way through the cladding plane while the building is in-service. For the purpose of this guide, a rainscreen wall assumes the following characteristics:

- A cladding system (the rainscreen).
- An air cavity (i.e., drainage gap) behind the cladding system to allow for drainage. In some cases this cavity may be vented, ventilated, or pressure-equalized to improve rain control.
- Drain holes or gaps through the cladding system so that drained water can leave the air cavity. Flashings are typically placed at drain hole or drainage gap locations (e.g., base-of-wall, doors, windows, etc.) to direct draining water to the exterior environment.
- A drainage plane, commonly the outer face of a water-resistive barrier membrane. This membrane acts as a drainage plane within the air cavity behind the cladding.

A continuous air control layer is not a requirement of the rainscreen wall but is typically provided in the Northwest region to improve rain control and meet energy code requirements.

It is important to note that rainscreen wall systems can exhibit good resistance to water penetration and are less sensitive to water ingress than other rain control categories; however, good performance is reliant on implementing proper details and ensuring acceptable construction practices are followed. Improperly executed details are frequently sources of water intrusion, critically affecting the moisture performance of the assembly and contributing to premature weathering or efflorescence on the masonry veneer system.

The masonry systems in Chapters 1, 2, 3, 6, 7, and 8 are rainscreen walls with respect to rain control and are referred to as rainscreen wall systems in this guide.

A mass wall is shown in Fig. i-15 on page i-22. In recent years, the mass wall rain control strategy has evolved to allow for thinner mass wall systems that further control water through the use of clear surface-applied water repellents and water-repellent admixtures.

The systems in Chapters 4 and 5 are mass walls with respect to rain control and are referred to as mass wall systems.

Control Layers

As described in Fig. i-13 on page i-21, each control layer is primarily responsible for managing a specific building enclosure load. The control layers and the systems and/or materials that make up each system are described in detail in this section and summarized in each system chapter and depicted on the typical wall assembly figures and 2-dimensional details throughout this guide (as shown similarly on Fig. i-16).

Water Control Layer

The water control layer is a continuous control layer that is designed, installed, and/or acts to form the innermost boundary against water intrusion.

In a rainscreen wall system, the water-resistive barrier (WRB) system is the last line of defense against water intrusion. A WRB system includes a WRB field membrane and accessories such as fluid-applied and flexible flashing membranes, sheet-metal flashings, sealants, tapes, and fasteners. To be effective, these materials are continuous and shingle-lapped to promote water-shedding. Where the WRB system is also part of the air-barrier system, it will be sealed for airtightness using

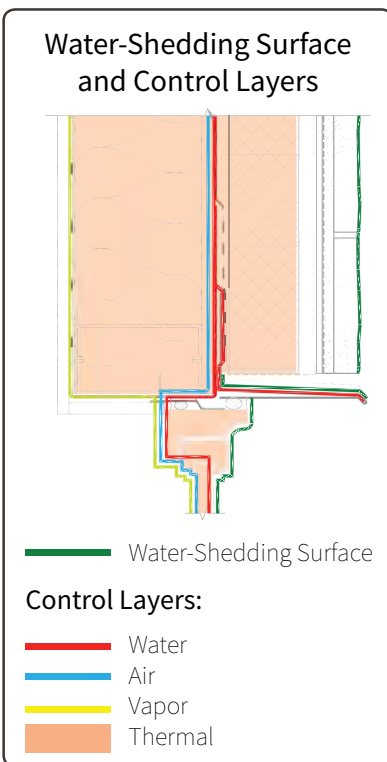


Fig. i-16 Typical window head two-dimensional detail. Each colored line or shaded area corresponds to the control layer identified in the legend below the detail.

tapes, sealants, gaskets, and other components.

A WRB system generally has the following properties:

- **Water-Resistive** – Resistant to the passage of liquid water when applied to a vertical, drained surface.
- **Durable** – Durable and resistant to moisture, microbial growth, and wind pressures in addition to ultraviolet (UV) exposure either during installation or as anticipated during the building service life.
- **Compatible** – Known chemical and adhesion compatibility with all accessory products such as self-adhered flashing membranes, fluid-applied membranes, sealants, and tapes.
- **Air Barrier Properties** – Where the WRB system also performs as the air barrier system (i.e. the air barrier and WRB system). For more information refer to the Air Control Layer discussion on page i-26.
- **Water Vapor Transmission** (i.e., vapor permeance) – Such that the WRB system does not contribute to the development of condensation within the system that could damage enclosure layers or other elements. For more information refer to the Vapor Control Layer discussion on page i-28.

For the rainscreen wall systems discussed in this guide, the WRB field membrane may be either a sheet- or fluid-applied membrane installed over the wall sheathing/structure as shown similarly in Fig. i-17. The field membrane may also be the face of fully taped or sealed exterior insulation that exists outboard of the wall sheathing or structure. In this guide, two WRB field membrane types are discussed and demonstrated in details; these include sheet-applied (either mechanically attached or self-adhered) and fluid-applied membranes. Examples of each system are shown in Fig. i-17 and in Fig. i-18 on page i-27.

For the mass wall systems included within this guide, the WRB system is the single-wythe CMU wall structure inclusive of a surface-applied clear water repellent and integral water-repellent admixtures within the block and mortar.



Fig. i-17 Sheet-applied air barrier and water-resistive barrier membrane example

Air Control Layer

The air control layer is provided by the air barrier system and is responsible for controlling the flow of air through the building enclosure, either inward or outward. Air flow is significant as it impacts heat flow (space conditioning), water vapor transport, and rain penetration control.

The air barrier system should be impermeable to air flow, continuous across the building enclosure, strong enough to transfer the forces that act upon them (e.g., mechanical pressures, wind pressures, and stack effect) back to the structure, durable over the life expectancy of the building enclosure, and stiff enough to resist air flow without altering its other performance characteristics.⁶ Additional discussion on the degree of air impermeability of the air barrier system is further discussed in Code Airtightness Requirements discussion on page i-43.

For a rainscreen wall system, there are many types of air barrier systems available on the market today. A typical practice within the Northwest is to use the wall system's WRB system as the air barrier system. If implemented, the WRB system must have the properties of an air barrier system and must be taped and/or sealed continuously for airtightness.

Where the air barrier system is a mechanically attached sheet membrane, it is secured to the structure with furring strips, masonry ties, cladding support clips, or washer head fasteners as approved by the air barrier membrane manufacturer. This attachment assists with long-term resistance to the pillowing effects of air pressure differentials. Where a self-adhered sheet membrane or fluid-applied membrane is used, the membrane bonds directly to the exterior sheathing or substrate for continuous support.

Other types of air barrier systems include:

- **Sealed Sheathing:** This option uses exterior gypsum board or plywood sheathing with sealed seams (either joint sealant or tape) to provide the air barrier field membrane (i.e. the membrane within the field of wall area). The air barrier at the sheathing is transferred to rough openings, to penetrations, and across shelf-angle attachments with self-adhered or fluid-applied flashing membranes. A separate WRB field membrane is required when using this air barrier system.
- **Closed-Cell Spray Polyurethane Foam (CCSPF):** Spray foam insulation may be installed over the exterior wall sheathing to form the air barrier system. This system relies on self-adhered or fluid-applied flashing membranes at rough openings and transitions to complete the air barrier system. Exterior



Fig. i-18 Fluid-applied air barrier and WRB membrane example

CCSPF insulation also provides the WRB system and assists with thermal and vapor control.

- **Rigid Exterior Insulation:** This option includes exterior rigid board insulation such as extruded polystyrene (XPS) or foil-faced expanded polystyrene (EPS) or polyisocyanurate. Board seams are sealed and/or taped to form the air barrier system as well as the WRB field membrane. Self-adhered or fluid-applied flashing membranes are used to complete the air barrier and WRB system at transitions. This system also assists with thermal and vapor control.
- **Airtight Drywall Approach (ADA):** This option relies on interior gypsum board and additional air-sealing strategies to form an air barrier system at the interior plane of the enclosure. This approach is traditionally a single-family residential air-sealing strategy and can be difficult to execute successfully at transitions such as wall-to-roof lines, complex framing structures, partition walls, and service penetrations. Air-sealing strategies for this approach are typically concealed, making quality control review and system repair difficult. This approach is not recommended for the commercial or multifamily structures to which this guide applies.

For the mass wall systems within this guide, the single-wythe CMU wall structure may provide the air barrier system as further discussed in the Air Control Layer on page 4-3 or may use other products as discussed in the Air Control Layer discussion on page i-26.

The air barrier system extends to the details and transitions shown throughout

this guide and includes fenestration systems, the air barrier membrane of a conventional roof system, and the roof membrane of an inverted roof membrane system as well as spray foam (of a minimum thickness, often determined by manufacturer testing) and sealant joints necessary to transition between assemblies.

Code-required air barrier system performance targets specific to the Northwest region are discussed in the Code Airtightness Requirements discussion on page i-43.

Vapor Control Layer

The vapor control layer retards or greatly reduces the flow of water vapor due to vapor pressure differences across the building enclosure. The ease with which water molecules diffuse through a layer is known as vapor permeance. The 2015 International Building Code (IBC)⁸ defines three classes of vapor permeance:

- Class I: Materials that have a permeance ≤ 0.1 perm (i.e., vapor barrier)
- Class II: Materials that have a permeance > 0.1 perm and ≤ 1.0 perm (i.e., vapor retarder)
- Class III: Materials that have a permeance > 1.0 perm and < 10 perms

Although not defined by the IBC, a Class IV vapor permeance designation is often used for materials that have a vapor permeance > 10 perms.

A vapor control layer may not be necessary for some masonry wall systems (such as Systems 1, 4, and 6) in the Northwest region and is further discussed in each system chapter. Perfect continuity of the vapor control layer is also not necessary to adequately control vapor diffusion in most cases. Small holes, gaps, or tears are not critical, unlike with the air barrier system. Section 1405.3 of the 2015 IBC defines code requirements for vapor control in Northwest Climate Zones 5, 6, and Marine 4. In the Northwest region, a vapor retarder (Class II vapor permeance) material is commonly installed on the interior (warm in winter) side of the insulation (high vapor pressure side), such as inboard of framing in Systems 2, 3, 7, and 8. Common vapor retarder products include:

- *Polyvinyl Acetate (PVA) Vapor-Retarding Primer*: This applied coating requires a substrate for application. It is typically applied to the face of interior gypsum board prior to the finish paint.
- *Asphalt-Coated Kraft Paper*: This sheet good is typically a facer to the wall cavity batt insulation and is located behind the interior gypsum board.

- *Polyamide Film*: This sheet good product is located between the interior gypsum board and insulated wall cavity; it is installed after wall cavity batt installation. This material is engineered to change its permeability due to ambient humidity conditions. The material permeability increases in the presence of higher relative humidity environments, allowing the system to dry inward during warmer months.

Note that for Systems 2, 3, 7, and 8, the use of a polyethylene sheet (Class I vapor permeance material) is not generally recommended for vapor control in the Northwest region because it significantly reduces the inward drying ability of the wall system which can be beneficial to some systems during warmer seasons.



Fig. i-19 Polyamide film vapor retarder installed over a wood-framed wall with cavity batt insulation

Whereas all materials fall into a class of vapor permeance, it is important to consider the vapor permeance of each material within the wall system relative to the building's thermal control layer (e.g., the vapor permeance of the air barrier and WRB system relative to cavity and/or exterior insulation).

In the Northwest region, it is generally acceptable to locate:

- Class I or Class II vapor permeance materials interior (on the warm side) of $\frac{1}{2}$ to $\frac{2}{3}$ of the wall system's total nominal thermal insulation (i.e., the total R-value the wall's thermal insulation) to minimize the risk of condensation within the wall system.
- Class IV vapor permeance materials outboard of the wall systems thermal enclosure.

Class III permeance materials and their placement within the wall system should be carefully considered on a case-by-case basis. The locations for each class permeance described above assume typical interior conditions as described in introductory text of this chapter.

For above-grade wall assemblies in the Northwest, low-permeance exterior insulation and air barrier and WRB systems may be used when all insulation is located exterior of the air barrier and WRB system or when the exterior insulation is 1/2 to 2/3 of the total nominal insulation R-value of the system. This helps reduce the risk that condensation will develop inboard of the air barrier and WRB system. In all cases, the use of low-permeance products and their placement relative to thermal control layer elements should be carefully evaluated based on project-specific characteristics.

Thermal Control Layer

The thermal control layer is responsible for controlling the heat flow across the building enclosure. The placement and continuity of the thermal control layer is an important factor of a thermally efficient building enclosure. While all materials within the building enclosure contribute to the thermal control layer, some materials may actually increase heat flow (such as highly conductive framing elements). Identification of high-conductivity materials helps identify thermal bridges or any thermal discontinuities that should be addressed by design.

Materials that contribute most to slowing the rate of heat flow across the wall system include thermal insulation, low-conductivity framing elements, and thermally improved glazing systems. These materials are identified in the control layer diagrams found throughout this guide.

For a rainscreen wall system, the primary resistance to heat flow is provided by thermal insulation within the framed wall cavity (if applicable) or by exterior insulation within the air cavity between the air barrier and WRB system and the cladding. Wood framing components will provide some insulating value, whereas steel stud framing will not.

For the mass wall systems in this guide, the thermal insulation is either interior of the CMU structure or integral at CMU cores.

Insulation Products

A variety of insulation products exist on the market for wall cavities, integral insulation, and continuous (interior or exterior) insulation.

For wall cavities, unfaced fiberglass or mineral fiber batt are most common. High-density versions of either batt can be found and assist with achieving a greater effective R-value without increasing wall depth, especially in wood-framed wall systems. Due to the significant reduction in effective thermal performance for steel-framed wall

systems (typically 40 to 60%), a high-density batt provides little benefit over lower-density batt products in steel-framed systems. Batt insulation widths and thicknesses range in size to accommodate most standard wood and steel framing depths. Wall cavity insulation may also include sprayed polyurethane foam insulation, which is available in both open- and closed-cell varieties and varies in thermal resistance and vapor permeance.

Where split insulation occurs (e.g., both wall cavity and exterior insulation) it is important to consider both the air and vapor permeance of the insulating material and the air barrier and WRB system. These considerations are discussed in each system chapter.

Where continuous insulation is used, several types of insulation products are available:

- **Semi-Rigid Mineral Fiber (R-4.2/inch):** Hydrophobic, tolerates moisture, and has free draining capabilities. This insulation is vapor-permeable, making it acceptable for use exterior of both vapor-permeable and vapor-impermeable air barrier and WRB systems. The semi-rigid properties of this insulation facilitate a snug fit at board joints and around penetrations such as masonry ties and cladding support clips without requiring notching. The density of the semi-rigid insulation should be considered for cladding attachment designs where insulation compression is necessary to support cladding attachment methods. An example of this insulation product type is shown in Fig. i-20.



Fig. i-20 Semi-rigid mineral fiber insulation prior to anchored masonry veneer installation

- **Rigid Extruded Polystyrene (XPS) (R-5 per inch):** Moisture-resistant and suitable for wet environments, XPS is a rigid insulation and has a vapor permeance less than 1.0. As a result, XPS may be used where cavity insulation does not exist or when the cavity stud nominal insulation R-value is $\frac{1}{2}$ to $\frac{1}{3}$ of the total nominal insulation R-value of the wall system. Rigid board insulation may require notching around intermittent cladding supports or ties to create a snug fit. An example of this insulation product type is shown in Fig. i-21.
- **Rigid Polyisocyanurate (R-5.0 to 5.7 per inch):** When used as continuous exterior insulation, typically includes a foil facer or moisture-tolerant facing to protect the insulation core. Faced polyisocyanurate rigid insulation has a vapor permeance of approximately 0.1. As a result, polyisocyanurate may be used where cavity insulation does not exist or when the cavity stud nominal insulation R-value is $\frac{1}{2}$ to $\frac{1}{3}$ of the total nominal insulation R-value of the wall system. Rigid board insulation may require notching around intermittent cladding supports or ties to create a snug fit.
- **Closed-Cell Spray Foam Insulation (R-5.5 to R-6 per inch):** May be used as exterior or interior insulation and eliminates the need for separate air and vapor control layers. This insulation option should be installed after all wall penetrations and cladding supports are in place. Closed-cell spray foam insulation typically has a vapor permeance less than 1.0 at 2-inch or greater thicknesses. As a result, closed-cell spray foam insulation may be used where cavity insulation does not exist or when the cavity stud nominal insulation R-value is $\frac{1}{2}$ to $\frac{1}{3}$ of the total nominal insulation R-value of the wall system.



Fig. i-21 XPS insulation behind anchored masonry veneer

Although masonry is defined as a noncombustible cladding material, the use of combustible air barrier and WRB system products or foam plastic insulation products within a wall cavity can trigger fire propagation considerations and requirements. Depending on the local jurisdiction, IBC Section 1403.5 regarding vertical and lateral flame propagation as it relates to a combustible air barrier and WRB system may require acceptance criteria for NFPA 285⁸. The use of foam plastic insulation within a wall cavity should also be addressed for IBC Chapter 26 provisions.

Integral insulation, which may be used within the CMU systems of this guide, may be loose-fill such as perlite but is commonly provided by a foam-in-place insulation product. Foam-in-place insulation is typically injected through ports within the CMU mortar joints. An example of foam-in-place insulation is shown in Fig. i-22.

Thermal Performance and Energy Code Compliance

At the time of publication, the energy performance of buildings in the Northwest is governed by:

- State of Washington (except Seattle) – *2015 Washington State Energy Code⁹ (WSEC)*, based on the 2015 International Energy Conservation Code (IECC) with amendments, effective July 1, 2016.
- City of Seattle, Washington – *2015 Seattle Energy Code¹⁰ (SEC)*, based on the 2015 WSEC with amendments, effective January 1, 2017.
- State of Oregon – *2014 Oregon Energy Efficiency Specialty Code¹¹ (OEESC)*, based on the 2009 IECC with amendments, effective July 1, 2014.
- State of Idaho – *2012 International Energy Conservation Code¹² (IECC)* without amendments, effective January 1, 2015.

In general, these energy codes address the *minimum* requirements for both the air and thermal control layers of the opaque above-grade wall systems.

In this guide, discussions related to the energy code compliance focus on the above-listed codes and their commercial energy code compliance provisions; residential provisions are not addressed. Definitions of residential and



Fig. i-22 Foam-in-place CMU core insulation

commercial buildings may be found within the Definitions chapter of the codes listed above.

Under commercial provisions, the prescriptive performance requirements for opaque above-grade wall systems are differentiated by:

- Climate zone (Zone Marine 4, Zone 5, or Zone 6), as shown in Fig. i-23
- Occupancy (All Other or Group R)
- Classification (e.g., mass, metal-framed, wood-framed, or other)

Table i-1 on page i-38 summarizes the prescriptive opaque above-grade wall thermal envelope insulation requirements as they apply to the wall systems in this guide. Requirements for both the *minimum R-value method* and *maximum U-factor method* are included. In Table i-1:

- R-values are for the minimum nominal insulation R-value within the system and may include continuous insulation (ci), which is further discussed in Continuous Insulation on page i-40.
- Maximum U-factors define the maximum thermal transmittance of the system when insulation and other bridging elements are considered—such as framing members and, in some cases, cladding attachments and supports. *For the purpose of this guide and for ease of reference, the prescriptive U-factor is also provided as an equivalent effective R-value and is shown in parentheses ().* For simplicity, the R-value is the inverse of the U-factor.

Fig. i-26 on page i-39 describes the typical process for navigating the opaque above-grade wall system thermal envelope energy code compliance options and strategies. It also describes how this process relates to the system-specific thermal performance results and discussions included within each system chapter of this guide.

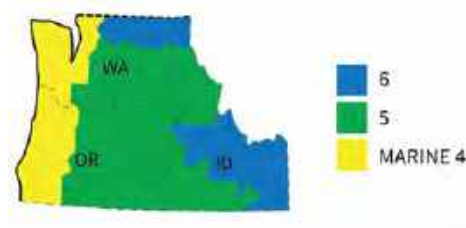


Fig. i-23 Northwest region climate zones as referenced from Fig. i-17

Prescriptive Compliance Option

Refer to Fig. i-26 on page i-39, which identifies the *prescriptive compliance options* for energy code compliance. Where a project seeks this compliance option, the above-grade wall system must meet one of the following strategies:

- **Insulation R-Value Method:** The wall assembly thermal insulation R-value must meet or exceed the minimum nominal insulation R-value(s) listed in Table i-1. For example, in Washington State (2015 WSEC), a multifamily residential (Group R) project with a wood-framed wall (such as System 3 or 8) requires at least a nominal R-21 wall cavity insulation to meet this compliance strategy. Where continuous insulation is denoted, follow jurisdiction specific definitions for continuous insulation.
- **Assembly U-Factor Method:** The wall assembly U-factor must be less than or equal to that listed in Table i-1. For this strategy, the project-specific wall assembly U-factor will need to be determined either through calculations or by using table values.
- **Component Performance Alternative:** The wall assembly U-factor may exceed that listed in Table i-1; however, the summation of the area-weighted U-factors for all components (at the thermal envelope) must be less than that required by the code.

An *exception* to the compliance strategies listed above is denoted in Footnote 2 of Table i-1 on page i-38. Refer to Chapter 4 for more information regarding this exception.

The IECC³ defines the building thermal envelope as “the basement walls, exterior walls, floor, roof, and any other building elements that enclose conditioned space or provide a boundary between conditioned space and exempt or unconditioned spaces.” Note that the thermal envelope may not always occur at the building enclosure.

Project-specific thermal performance values for an opaque above-grade wall should be used for energy code compliance and determined from a source that is approved by the authority having jurisdiction. Thermal performance sources may include the Appendices of the 2015 WSEC,³ ASHRAE 90.1,⁴ COMcheck,⁵ thermal modeling and calculation exercises, or other industry resources.

Non-Prescriptive Compliance Option

Refer to Fig. i-26 on page i-39, which identifies the *non-prescriptive compliance option* (e.g., whole-building modeling strategies). When a project seeks this compliance option, an above-grade wall assembly's thermal performance is determined as a U-factor; however, it may or may not be required to meet the prescriptive values shown in Table i-1.

Determining System Effective Thermal Performance

Various thermal performance tables are available in the Northwest energy codes and ASHRAE 90.1¹³ to assist with determining the U-factors of above-grade wall assemblies. Where the wall assemblies are not representative of a project specific application, alternative methods are available for calculating the effective thermal performance of the wall and are discussed below. Appropriate calculation methods should be confirmed with the authority having jurisdiction because not all of these methods may be accepted:

- *Parallel Path and Isothermal Planes* (refer to the ASHRAE Handbook of Fundamentals¹⁴): Typically used for assemblies with low-conductivity materials. Where material conductivity varies minimally, a parallel path method is typically used, such as with a wood-framed wall. When material conductivities within a wall assembly vary moderately, such as in a CMU wall, the isothermal planes method is typically used. These methods are not reliable for assemblies with highly conductive materials (e.g., steel studs) or intermittent components

such as fasteners or ties through exterior insulation.

- *Zone Method and Modified Zone Method* (refer to the ASHRAE Handbook of Fundamentals¹⁴): Typically used for assemblies with highly conductive elements such as steel studs. These methods are not recommended for determining the performance of assemblies with intermittent fasteners or ties through exterior insulation.
- *Two-Dimensional Computer Modeling*: Programs such as Lawrence Berkley National Laboratory's THERM¹⁵ calculate two-dimensional heat transfer. This method may be used for most above-grade wall assemblies; however, it is not appropriate for assemblies where intermittent fasteners, ties, or cladding supports bridge exterior insulation. An example of a two-dimensional thermal image is shown in Fig. i-24.
- *Three-Dimensional Computer Modeling*: Programs such as HEAT3¹⁶ calculate three-dimensional heat transfer. This method may be used for all above-grade assemblies, including those with exterior insulation bridged by fasteners. An example of a three-dimensional thermal image is shown in Fig. i-25.

Within this guide, three-dimensional computer modeling was employed for all wall systems, except System 4, to demonstrate how typical thermal bridges—like masonry ties, shelf angles, and cladding support clips of various types—contribute to the effective thermal performance of each system. Based on modeling results, insulation thicknesses and types as well as cladding support materials and types may be estimated for project-specific systems. Through evaluation of the results, numerous options for thermally optimizing each wall system are discussed. Modeling results and discussions are demonstrated in each chapter as an effective R-value but may be converted to a U-factor by dividing 1 by the R-value.

When performing heat loss calculations (e.g., mechanical equipment sizing or energy modeling) the system's U-factor, inclusive of all thermal bridges, should be considered.

Thermal modeling was undertaken using HEAT3.¹⁶ Modeling specifics and additional information used to complete the modeling within this guide are provided in the Appendix. Modeling does not account for the impact of thermal mass.

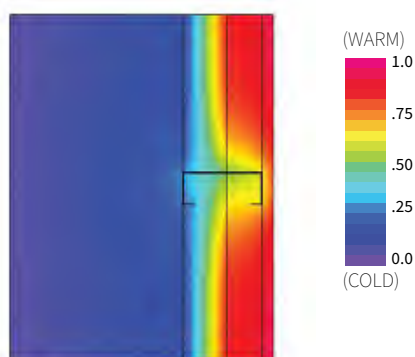


Fig. i-24 Two-dimensional thermal modeling of a mass wall with interior steel studs and cavity insulation

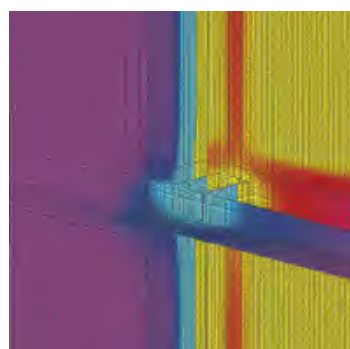


Fig. i-25 Three-dimensional thermal model of a masonry veneer floor line standoff shelf angle

Table i-1 Northwest energy codes – prescriptive compliance values for opaque above-grade wall systems within this guide

OPAQUE ABOVE-GRADE WALL – THERMAL ENVELOPE REQUIREMENTS												
Energy Code		2015 SEC		2015 WSEC		2014 OEESC		2012 IECC				
Climate Zone		5 and Marine 4		5, 6 and Marine 4		5 and Marine 4		5 and Marine 4		6		
Guide Assembly #		Classification		All Other		Group R		All Other		Group R		
1A 1B	CMU (or Concrete) Wall	Mass	Exterior: R-16c ⁽¹⁾ U-0.057 (R-17.5)		Group R		Group R		All Other		Group R	
			R-13 + R-19 + R-10c ⁽¹⁾ U-0.055 (R-18.2)	R-13 + R-8.5c ⁽¹⁾ U-0.055 (R-18.2)	R-21 int	R-21 int	R-13.3c ⁽²⁾ U-0.104 ⁽²⁾ (R-9.6)	R-13.3c ⁽²⁾ U-0.078 (R-11.1)	R-13.3c ⁽²⁾ U-0.078 (R-11.1)	R-13.3c ⁽²⁾ U-0.078 (R-11.1)	R-13.3c ⁽²⁾ U-0.078 (R-11.1)	R-13.3c ⁽²⁾ U-0.078 (R-11.1)
2	Steel-Framed Wall	Steel-Framed	U-0.055 (R-18.2)		U-0.055 (R-18.2)	R-10c ⁽¹⁾ U-0.055 (R-18.2)	R-13 + R-8.5c ⁽¹⁾ U-0.055 (R-18.2)	U-0.064 (R-15.6)	U-0.064 (R-15.6)	U-0.064 (R-15.6)	U-0.064 (R-15.6)	U-0.057 (R-17.5)
3	Wood-Framed Wall	Wood-Framed and Other	R-13 + R-10c ⁽¹⁾ U-0.057 (R-17.5)		R-21 int	R-21 int	R-13 + R-8.5c ⁽¹⁾ U-0.055 (R-18.2)	R-13 + R-8.5c ⁽¹⁾ U-0.055 (R-18.2)	R-13 + R-8.5c ⁽¹⁾ U-0.055 (R-18.2)	R-13 + R-8.5c ⁽¹⁾ U-0.055 (R-18.2)	R-13 + R-8.5c ⁽¹⁾ U-0.055 (R-18.2)	R-13 + R-8.5c ⁽¹⁾ U-0.055 (R-18.2)
4	Integrally Insulated	Mass	U-0.057 (R-17.5)		U-0.057 (R-17.5)	U-0.057 (R-17.5)	U-0.057 (R-17.5)	U-0.057 (R-17.5)	U-0.057 (R-17.5)	U-0.057 (R-17.5)	U-0.057 (R-17.5)	U-0.057 (R-17.5)
5	Interior Insulated	Mass	Interior: R-13 + R-6c _i , or R-13 + R-10c ⁽¹⁾ U-0.057 (R-17.5)		Interior: R-13 + R-6c _i , or R-13 + R-10c ⁽¹⁾ U-0.057 (R-17.5)	Interior: R-13 + R-6c _i , or R-13 + R-10c ⁽¹⁾ U-0.057 (R-17.5)	Interior: R-13 + R-6c _i , or R-13 + R-10c ⁽¹⁾ U-0.057 (R-17.5)	Interior: R-13 + R-6c _i , or R-13 + R-10c ⁽¹⁾ U-0.057 (R-17.5)	Interior: R-13 + R-6c _i , or R-13 + R-10c ⁽¹⁾ U-0.057 (R-17.5)	Interior: R-13 + R-6c _i , or R-13 + R-10c ⁽¹⁾ U-0.057 (R-17.5)	Interior: R-13 + R-6c _i , or R-13 + R-10c ⁽¹⁾ U-0.057 (R-17.5)	Interior: R-13 + R-6c _i , or R-13 + R-10c ⁽¹⁾ U-0.057 (R-17.5)
6	CMU Wall	Mass	Exterior: R-16c ⁽¹⁾ U-0.057 (R-17.5)		Exterior: R-16c ⁽¹⁾ U-0.057 (R-17.5)	Exterior: R-16c ⁽¹⁾ U-0.057 (R-17.5)	Exterior: R-16c ⁽¹⁾ U-0.057 (R-17.5)	Exterior: R-16c ⁽¹⁾ U-0.057 (R-17.5)	Exterior: R-16c ⁽¹⁾ U-0.057 (R-17.5)	Exterior: R-16c ⁽¹⁾ U-0.057 (R-17.5)	Exterior: R-16c ⁽¹⁾ U-0.057 (R-17.5)	Exterior: R-16c ⁽¹⁾ U-0.057 (R-17.5)
7	Steel-Framed Wall	Steel-Framed	U-0.055 (R-18.2)		U-0.055 (R-18.2)	U-0.055 (R-18.2)	U-0.055 (R-18.2)	U-0.055 (R-18.2)	U-0.055 (R-18.2)	U-0.055 (R-18.2)	U-0.055 (R-18.2)	U-0.055 (R-18.2)
8A 8B	Wood-Framed Wall	Wood-Framed and Other	R-13 + R-10c ⁽¹⁾ U-0.057 (R-17.5)		R-21 int	R-21 int	R-13 + R-8.5c ⁽¹⁾ U-0.055 (R-18.2)	R-13 + R-8.5c ⁽¹⁾ U-0.055 (R-18.2)	R-13 + R-8.5c ⁽¹⁾ U-0.055 (R-18.2)	R-13 + R-8.5c ⁽¹⁾ U-0.055 (R-18.2)	R-13 + R-8.5c ⁽¹⁾ U-0.055 (R-18.2)	R-13 + R-8.5c ⁽¹⁾ U-0.055 (R-18.2)

⁽¹⁾ When using interior insulation: R-13 + R-6 c for wood studs or R-13 + R-10 c for metal stud; when using exterior insulation: R-16 c

⁽²⁾ Exception: integrally insulated concrete block complying with ASTM C90 with all cores filled, with at least 50% of block cores are filled with vermiculite (or equivalent fill insulation), and enclosing one of the following uses: gymnasium, auditorium, church chapel, arena, kennel, manufacturing plant, indoor swimming pool, pump station, water and wastewater treatment facility, storage facility, warehouse (storage and retail), motor vehicle service facility, mechanical/electrical structures (OEESC only), and restroom/concessions (OEESC only). Under the WSEC, where additional uses not listed (such as office, retail, etc.) are contained within the building, the exterior walls that enclose these areas may not utilize this exception.

Step 1: Determine	Determine Governing Energy Code: 2015 WSEC, 2015 SEC, 2014 OEESC, or 2012 IECC				Determine Project Climate Zone: Zone: Marine 4, Zone 5, or Zone 6				Determine Project Occupancy: Group R or All Other			
	Prescriptive Compliance Options:				Non-Prescriptive Compliance Option:				Whole-Building Modeling Strategies			
Step 2: Select an Option	Use when a whole-building energy model will not be performed to demonstrate energy code compliance. Typically, whole-building energy modeling methods are required if assembly R-value or U-factors cannot meet code requirements, when the U-factor component performance alternative cannot be used to demonstrate compliance, or when glazing areas exceed the maximum glazing area percentages set by the energy code.				Use when prescriptive compliance options cannot be used to demonstrate energy code compliance.				Use when enclosure components, lighting, and HVAC performance will all be traded off to meet energy code compliance. This strategy is typically used when a project will exceed maximum glazing area ratios set by the energy code.			
	Insulation R-Value Method				Assembly U-Factor Method/U-Factor Alternative				Component Performance Alternative, Area Weighted U-Factor, Simplified Trade-Off Strategy			
Step 3: Select a Strategy	Provide opaque above-grade wall insulation with an R-value equivalent to or greater than that described in Table i-1.				Provide an opaque above-grade wall assembly with an assembly U-factor less than or equal to that described in Table i-1.				Use when enclosure components that meet prescriptive R-value and U-factor requirements will be used to offset those that do not meet prescriptive R-value and U-factor requirements. This strategy is typically not successful when a project exceeds maximum glazing area percentages set by the energy code.			
	Provide insulation that meets or exceeds the R-values listed in Table i-1. If using Footnote (2), see Chapter 4 discussion.				For all wall systems in this guide (except system 4), use thermal modeling result tables and figures within each chapter to estimate the insulation thickness and R-value per inch and masonry tie or cladding support clip material type. System thermal performance results are depicted in each chapter as effective R-values and can be compared to the Table i-1 equivalent R-value shown in parenthesis (). Also see the Modeling Results section of each chapter for additional information on optimizing thermal performance. For Chapter 4, and when using Footnote (2), see Chapter 4 discussion.				Use thermal modeling result tables and figures within each chapter to estimate the insulation thickness and R-value per inch and masonry tie or cladding support clip material type. System thermal performance results are depicted in each chapter as effective R-values and can be compared to the Table i-1 equivalent R-value shown in parenthesis (). Also see the Modeling Results section of each chapter for additional information on optimizing thermal performance. For Chapter 4, and when using Footnote (2), see Chapter 4 discussion.			
Step 4: Determine System	Provide insulation that meets or exceeds the R-values listed in Table i-1. If using Footnote (2), see Chapter 4 discussion.				For all wall systems in this guide (except system 4), use thermal modeling result tables and figures within each chapter to estimate the insulation thickness and R-value per inch and masonry tie or cladding support clip material type. System thermal performance results are depicted in each chapter as effective R-values and can be compared to the Table i-1 equivalent R-value shown in parenthesis (). Also see the Modeling Results section of each chapter for additional information on optimizing thermal performance. For Chapter 4, and when using Footnote (2), see Chapter 4 discussion.				Use thermal modeling result tables and figures within each chapter to estimate the insulation thickness and R-value per inch and masonry tie or cladding support clip material type. System thermal performance results are depicted in each chapter as effective R-values and can be compared to the Table i-1 equivalent R-value shown in parenthesis (). Also see the Modeling Results section of each chapter for additional information on optimizing thermal performance. For Chapter 4, and when using Footnote (2), see Chapter 4 discussion.			
	Provide insulation that meets or exceeds the R-values listed in Table i-1. If using Footnote (2), see Chapter 4 discussion.				For all wall systems in this guide (except system 4), use thermal modeling result tables and figures within each chapter to estimate the insulation thickness and R-value per inch and masonry tie or cladding support clip material type. System thermal performance results are depicted in each chapter as effective R-values and can be compared to the Table i-1 equivalent R-value shown in parenthesis (). Also see the Modeling Results section of each chapter for additional information on optimizing thermal performance. For Chapter 4, and when using Footnote (2), see Chapter 4 discussion.				Use thermal modeling result tables and figures within each chapter to estimate the insulation thickness and R-value per inch and masonry tie or cladding support clip material type. System thermal performance results are depicted in each chapter as effective R-values and can be compared to the Table i-1 equivalent R-value shown in parenthesis (). Also see the Modeling Results section of each chapter for additional information on optimizing thermal performance. For Chapter 4, and when using Footnote (2), see Chapter 4 discussion.			

Fig. i-26 Energy Code Compliance Chart. Use this chart to navigate selection of an energy code compliance strategy and use of the modeling results within this guide.

Continuous Insulation

Continuous insulation is referenced in the prescriptive requirements for many of the wall systems in this guide. Where continuous insulation is required or used to meet code compliance, the definitions of continuous insulation should be carefully considered; definitions vary by jurisdiction within the Northwest region and include:

- **2012 IECC¹²:** No definition provided. This guide recommends confirming local requirements with the governing jurisdiction.
- **2015 SEC¹⁰:** “Insulating material that is continuous across all structural members without thermal bridges other than fasteners that have a total cross-sectional area not greater than 0.04 percent of the envelope surface through which they penetrate and service openings. It is installed on the interior or exterior or is integral to any opaque surface of the building envelope.”
- **2014 OEESC¹¹:** “Insulation that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior or is integral to any opaque surface of the building.”
- **2015 IECC³ and 2015 WSEC⁹:** “Insulating material that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior or is integral to any opaque surface of the building envelope.”

Based on the above definitions:

- ☑ Continuous insulation can be interior, exterior, or integral to the building envelope, for example, continuous insulation interior of a CMU wall as shown in the System 5.
- ☑ Insulation bridged by structural members (e.g., framing or anchored veneer shelf angles) may not be considered continuous. This guide recommends clarifying this requirement with the governing jurisdiction on a project-specific basis.
- ☑ Service openings (e.g., doors, ducts, etc.) have no impact on whether insulation is classified as continuous or not.
- ☑ Fastener or metal fastener considerations vary by jurisdiction and are further discussed in the next section.

Metal Fasteners

The thermal performance of exterior insulation is reduced when penetrated by fasteners (metal or otherwise). Continuous insulation with no fasteners will perform near its nominal R-value. However, when fasteners—especially metal fasteners, which are highly conductive—penetrate the insulation, the nominal R-value is reduced.

The interpretation of a fastener or metal fastener may vary by code and jurisdiction. As a result, the local governing jurisdiction should be contacted for determining when fasteners are to be considered. Below, some general clarifications are provided for assistance.

The term “thermal bridging” is not defined by the energy codes that govern the Northwest region. However, the ASHRAE Handbook of Fundamentals¹⁵ recognizes thermal bridging as “passing highly conductive materials through insulation layers.”

Under the **2015 SEC¹⁰**, the fasteners’ cross-sectional area of penetration (as measured in the plane of the insulation surface and as calculated as a percentage of opaque wall area) should be considered. Where this area of penetration exceeds 0.04%, the penetrated insulation is not considered continuous or “continuous insulation equivalents” tables located within the code may be referenced. For example, if exterior insulation is bridged by a 2-inch-wide double eye and pintle masonry tie at 24-inches on-center vertically and 16-inches on-center horizontally, the cross-sectional penetration area as a percentage is:

- 0.04% for a 14-gauge backup plate: this option meets 0.04% and the exterior insulation is considered continuous by definition.
- 0.06% for a 12-gauge backup plate: this option exceeds 0.04% and the exterior insulation is not considered continuous, thus, (1) an alternative nominal R-value as found for metal penetrations between 0.04% and 0.12% can be selected from Table C402.1.3(g) of the **2015 SEC¹⁰** and **2015 WSEC⁹**, or (2) the effective thermal performance of the wall is calculated and designated as a U-factor to meet the prescriptive U-factor requirements.

Note that if the tie spacing was reduced to 16-inches on-center vertically and 16-inches on-center horizontally, the cross-section penetration area of 14-gauge backup plate tie would be greater than 0.04%. In this case, guidance provided for the 0.06% case above would be considered.

Under the **2014 OEESC¹¹** and the **2015 WSEC⁹**, fasteners that penetrate continuous

insulation have no impact on whether exterior insulation is considered continuous or not for code compliance purposes. Table C402.1.3, Footnote (g) of the 2015 SEC¹⁰ and 2015 WSEC⁹ codes provides continuous insulation equivalent R-values for penetration areas exceeding 0.04% area.

When complying under the 2012 IECC¹², contact the local governing jurisdiction to confirm metal fastener and continuous insulation requirements.

Mass Wall Considerations

A mass wall has the ability to store thermal energy (i.e., heat) that can be released at a later time, reducing peak heating and cooling loads and increasing occupant thermal comfort. The benefit of thermal mass varies with climate zone and is more beneficial in warmer climates; however, thermal mass can still provide some benefit in cooler climates. Some energy codes within the Northwest allow mass wall systems to meet lesser prescriptive thermal performance requirements than framed wall types. When complying with the energy code through a whole-building modeling approach, any effects of thermal mass are directly considered within the building model.

The 2012 IECC¹², 2015 WSEC⁹, 2015 SEC¹⁰ and 2014 OEESC¹¹ in general define mass wall as weighing more than 35 psf of wall surface area or weighing more than 25 psf of wall surface area when the material weighs more than 120 pcf. Furthermore, the 2015 WSEC⁹ and the 2015 SEC¹⁰ clarify that mass walls may also include walls having a heat capacity that exceeds 7 Btu/ft²-deg F or walls having a heat capacity greater than 5 Btu/ft²-deg F when the material weight is not more than 120 pcf.

The classification of a mass wall typically encompasses the backup wall structure; veneer inclusions should be confirmed with the local governing jurisdiction. The masonry systems in Chapters 1, 4, 5, and 6—which have CMU backup wall structures—typically qualify as mass walls.

In the states of Oregon and Washington (excluding the City of Seattle), integrally insulated CMU walls such as the masonry system in Chapter 4 system are exempt from some prescriptive performance R-values and U-factors when specific conditions are met. See the discussion in Chapter 4 for more information on this exception.

Code Airtightness Requirements

Energy codes within the Northwest have mandatory air leakage requirements. Requirements include a continuous air barrier throughout the building thermal envelope (i.e., surrounding conditioned and semi-heated spaces) that is continuously sealed and supported by the structure (e.g., with fasteners or adhesion). Air barrier system compliance options for each Northwest code are provided below. This guide recommends that all members of the design and construction team are familiar with the air barrier system requirements specific to their jurisdiction.



Fig. i-27 Blower door setup during whole-building air leakage testing of a building with an anchored masonry veneer above-grade wall system

- Under the 2015 WSEC⁹ and the 2015 SEC¹⁰, once the whole-building air barrier system is complete, the rate of air leakage must be determined by performing a whole-building air leakage test such as that shown in Fig. i-27. The maximum allowable air leakage rate is 0.30 cfm/ft² at 0.3 in-H₂O (75 Pa) for the 2015 SEC and 0.40 cfm/ft² at 0.3 in-H₂O (75 Pa) for the 2015 WSEC⁹ when tested to ASTM E779.¹⁷ Failure to comply with the maximum leakage rate requires a visual inspection and repair of the discontinuous air barrier system areas to the extent practicable. Industry research has demonstrated these code-maximum air leakage targets are not prohibitively difficult to meet.¹⁸
- Under the 2015 WSEC⁹ and 2015 SEC¹⁰ Additional Efficiency Package Options, if the reduced air infiltration option is selected the maximum allowable air leakage rate when tested to ASTM E779 is 0.25 cfm/ft² at 0.3 in-H₂O (75 Pa) for the 2015 WSEC⁹ and 2015 SEC¹⁰ (Group R occupancy) and 0.22 cfm/ft² at 0.3 in-H₂O (75 Pa) for 2015 SEC¹⁰ (All Other occupancy).
- Under the 2012 IECC¹² and the 2014 OEESC¹¹, air leakage testing is one of three air barrier compliance options. The remaining two options require that air barrier materials or air barrier assemblies meet specific air permeance performance and meet specific installation requirements.

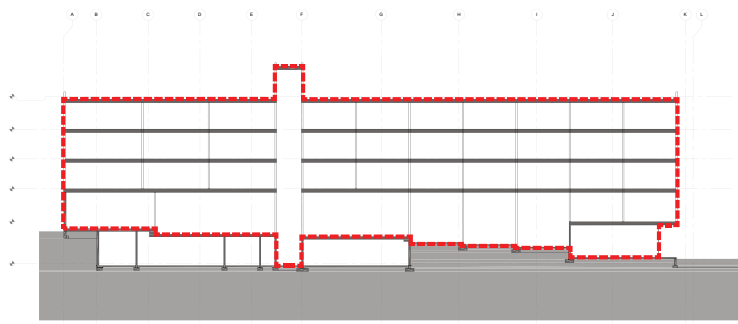


Fig. i-28 Whole-building section with the continuous air barrier system pressure boundary denoted in red

The following checklist items can increase the success of the design and installation of a continuous air barrier in all jurisdictions.

Design Checklist

- ☑ Select appropriate air barrier system materials and assemblies. Per the IECC,³ an air barrier material has an air permeance less than 0.004 cfm/ft² at 1.57 psf (75 Pa) when tested to ASTM E2178.¹⁹ An air barrier assembly has an air permeance of less than 0.04 cfm/ft² at 1.57 psf (75 Pa) when tested to ASTM E2357.²⁰ Section C402.4 of the 2012 IECC and Section 502.4 of the 2014 OEESC¹¹ include a number of air barrier materials and assemblies that meet these requirements. The Air Barrier Association of American (ABAA) also lists several commercially available compliant air barrier membrane products and systems at www.airbarrier.org.
- ☑ Ensure that a continuous line representing the plane of airtightness can be drawn across building enclosure assemblies, details, and transitions between assemblies. This includes in both plan and section perspectives. Details included within this guide demonstrate this practice, and an example is shown in Fig. i-16 on page i-24.
- ☑ Clearly delineate the air barrier system's pressure boundary on the construction documents. This practice is typically performed on the floor plans for each building level and on each building section as shown in Fig. i-28. This delineation, in addition to the calculation of the air barrier pressure boundary surface area, is required by the 2015 WSEC⁹ and the 2015 SEC¹⁰ for compliance.
- ☑ Identify air barrier system installation, testing, and installer qualification

requirements in Divisions 1 and 7 of the project manual. Air barrier master specifications related to Divisions 1 and 7 are available from ABAA's website and may be modified to meet local code and project specific requirements.

Construction/Installation Checklist

- ☑ Use installers with air barrier system installation experience to perform air barrier-related installations.
- ☑ Designate an air barrier/building enclosure foreman or superintendent from the construction team to oversee all trades involved in installations related to the air barrier.
- ☑ Build freestanding mock-ups of all project-specific typical and unique air barrier details. Retain building mock-ups for training and reference purposes throughout construction.
- ☑ Perform qualitative diagnostic air leakage testing of mock-up installations to identify deficiencies. Correct deficiencies and retest to demonstrate that deficiencies have been resolved. Refer to ASTM E1186²¹ for air leakage site detection practices. An example of diagnostic air leakage testing is demonstrated in Fig. i-29.
- ☑ Implement a quality control program. Develop a checklist of items requiring review prior to covering the air barrier system with additional elements such as exterior insulation and cladding.
- ☑ Provide third-party quality assurance reviews of installed air barrier detailing and provide periodic diagnostic air leakage testing to confirm airtight transitions, especially between roof-to-wall, roof-to-foundation, floor line, and window perimeter detailing.
- ☑ Execute whole-building air leakage testing prior to covering (when possible). This limits the need to remove building elements, such as cladding, to correct deficiencies.



Fig. i-29 A smoke pencil is used to conduct diagnostic air leakage testing while a building is under positive air pressure; the smoke exits the building through a discontinuity at the head of the window rough opening.

Sheet-Metal Flashing Components

Sheet-metal flashing components are used in both rainscreen and mass wall systems and typically occur above and below wall penetrations, at parapet tops, and as counterflashing elements. Sheet-metal flashings deflect rain water and protect underlying components among many other functions.

Design Considerations

The location of sheet-metal flashings should be carefully planned for each project, but—at minimum—they should be located:

- Above and below wall penetrations such as windows, doors, and service penetrations. This applies to rainscreen wall systems and where practicable in mass wall systems.
- At perpendicular wall interfaces such as parapet-to-wall or roof-to-wall saddle conditions and at parapet tops. This applies to both rainscreen and mass wall systems.
- For a rainscreen wall system, it is best practice to provide flashings at every floor line, especially for buildings three stories or greater in height. Examples are depicted in Fig. i-30 and Fig. i-31.
- At vertical support elements of anchored masonry veneer systems and often at movement joints designed to accommodate vertical differential movement in a rainscreen wall system.

It is best practice to provide sheet-metal flashing profiles which include a projected hemmed drip edge, positive slope, and a minimum 4-inch-tall back leg where the flashing is shingle lapped into the WRB system. Where serving as a counterflashing, it is best practice to counterflash cladding a minimum of 1.5-inches (where possible) and project a minimum of a half an inch beyond the

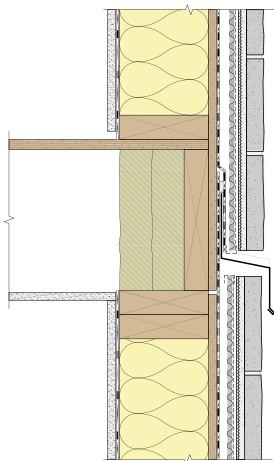


Fig. i-30 System 8, Detail 8b-D. Typical floor line cross-cavity sheet-metal flashing. The flashing helps drain the rainscreen cavity above and deflects water away from the top of the cavity below, while still allowing for drainage and ventilation in each cavity. Space above and below the sheet-metal flashing also allows for movement within the veneer as well as differential movement between the veneer and wall structure.

A cross-cavity flashing and **through-wall flashing** are commonly used interchangeably; however, there is a technical difference. A cross-cavity flashing is integrated with the WRB system and extends through the rainscreen cavity. A through-wall flashing extends through the entire depth of the wall, such as one might find at the base of a CMU wall.

cladding face to avoid blocking ventilation. The vertical location of the sheet-metal flashing in relation to the masonry veneer should be considered; adequate spacing between the sheet metal and the veneer above and below will ensure building movement does not adversely affect the sheet-metal flashing profile or its function.

In a rainscreen wall system, folded end dams assist with deflecting water away from the rainscreen cavity and are recommended at all flashing terminations (e.g., at the ends of a window head flashing).

Where sheet-metal laps occur, laps are either fully sealed with a high-quality silicone or butyl-based sealant or may be soldered.

It is a best practice to construct masonry veneer sheet-metal flashings from stainless steel. Stainless steel is relatively inert to the corrosiveness of mortar and provides a similar level of durability and longevity as the masonry veneer. Prefinished galvanized sheet-metal products may be used in masonry veneer applications; however, they may require replacement before the masonry veneer does.

This guide recommends consulting the Architectural Sheet Metal Manual²² published by the Sheet Metal and Air Conditioning Contractor's National Association (SMACNA) for additional discussion on the design and installation of sheet-metal components.

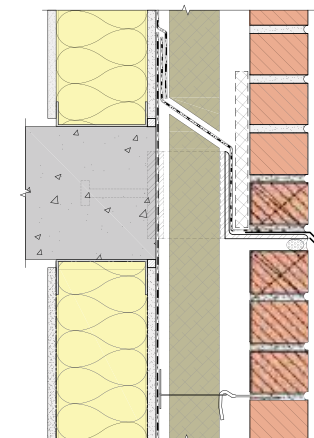


Fig. i-31 System 2, Detail 2-D. Typical floor line condition at standoff shelf angle. This alternative detail approach includes a flexible self-adhered membrane in lieu of sheet metal to drain the rainscreen cavity.

Cross-Cavity Alternative

Where exterior insulation is used, cross-cavity sheet-metal flashings create a thermal bridge. An alternative to a sheet-metal flashing at anchored veneer systems is to provide a flexible self-adhered flashing membrane that is fully supported by the exterior insulation and lapped into the WRB system as shown in page i-47. This flexible membrane is shingle-lapped over the bearing element (typically a standoff shelf angle) and under the sheet-metal drip flashing.



Fig. i-32 Cross-cavity sheet-metal flashing displacement as a result of wood-framed wall shrinkage and brick anchored clay masonry veneer expansion

Movement Joints

Over time, volumetric changes will occur within any above-grade wall system and can be the result of changes in temperature, moisture, elastic deformation, settlement, and creep. The amount of movement that occurs will depend on the building materials used within the wall system as well as on the intensity of the influencing mechanism (e.g., temperature change). In general, wood frame members, concrete, CMU, and stone will shrink, whereas clay masonry will expand. If steel studs or a CMU backup wall are used and are properly protected, minimal volume change is expected, except where specifically designed for.

Different materials within each wall system may move differently in relation to one another as shown by the example in Fig. i-32. If not properly designed for, differential movement can cause unwanted cracking, spalling, buckling, settlement, or separation within the building structure or veneer.

For the purpose of this guide, discussion and design of movement joints are considered as they relate to differential movement between the veneer and wall structure and also include control and expansion joints. The consideration for locating and sizing building expansion joints that occur within the wall structure is beyond the scope of this guide but must be appropriately designed for and integrated into the above-grade wall system where they occur.

The discussion of building movement in this guide is meant to be a general reference; it is the responsibility of the Designer of Record to appropriately design for all building movement.

Locating Movement Joints

This section identifies general rules for locating movement (expansion or control) joints as they relate to the 8 primary wall systems in this guide.

- For anchored clay masonry veneer, provide expansion joints such that long wall sections do not exceed 25 feet apart at occupied space and 15 feet apart at parapet wall conditions. Joint locations may be reduced to 20 feet at wall sections that have openings. Additional guidance on brick veneer expansion joints may be referenced from BIA Technical Notes 18²³ and 18A.²⁴
- For anchored concrete masonry veneer, provide control joints such that the length between control joints in long walls do not exceed 1.5 times the height or a maximum of 26 feet. Additional guidance on concrete masonry veneer control joints may be referenced from the Northwest Concrete Masonry Association (NWCMA) Tek Note on Design of Concrete Masonry Veneer for Crack Control.²⁵
- For CMU wall structures, control joints should be spaced every 40 feet or where needed to minimize wall sections to a 3:1 ratio of length to height, whichever is less. Additional guidance on control joints may be referenced from the NWCMA Tek Note on Control Joints for Concrete Masonry Crack Control.²⁶ An example of CMU control joint locations is shown in Fig. i-33 on page i-50.
- For adhered veneers, joint location recommendations vary throughout the industry and should be confirmed with the veneer unit manufacturer for the project-specific application. In general, this guide recommends joints are provided such that each panel of adhered veneer does not exceed 144 square feet, each panel has a maximum height/width or width/height ratio of 2.5 to 1, and spacing between joints does not exceed 15 feet in any direction. Refer to Brick Industry Association (BIA) Technical Note 28C²⁷ and the Laticrete Direct-Adhered Ceramic Tile, Stone, and Thin Brick Facades Technical Design Manual²⁸ for additional information.

There is no single set of recommendations for the placement and design of movement joints that will work for all projects. Additionally, joints may be added more frequently than is necessary for aesthetic purposes. In general, the following locations for movement joints are recommended within a masonry veneer or structure in addition to the above.



Fig. i-33 Example of vertical CMU control joint locations (shown in green)

Vertical Joint Placement

- Throughout long walls with no openings as described in the previous section
- At wall offsets and setbacks
- At or within 10 feet of corners
- Around openings such as windows and doors
- At intersections and junctions (at intersections of walls that serve different functions or are different heights/thicknesses or cladding types)
- At parapets, aligned with joint placement at the wall area below
- Where framing methods or materials change (e.g., where a concrete meets steel-framed backup wall)

Horizontal Joint Placement

- At floor lines, typically aligned with the top-of-wall and floor interface.
- Below structural support elements such as shelf angles
- Between cladding material changes
- At anchored and adhered veneer cross-cavity wall penetrations such as those discussed in Masonry Veneer Penetrations on page i-54.

Note that placement of horizontal joints is also recommended at various locations on a rainscreen wall system to allow for cavity drainage and building movement.

As discussed in Chapters 6, 7, and 8, the use of a crack isolation membrane within an adhered veneer system does not reduce or replace the need for appropriately designed and installed movement joints.

The location of joints for the purposes of accommodating movement, drainage, and/or veneer air cavity ventilation are further discussed and identified within each chapter and with an asterisk (*) in chapter details.

Joint Design

Joints that accommodate vertical movement either include a sheet-metal flashing or a backer rod and sealant joint. Joints that accommodate horizontal movement typically receive a backer rod and sealant joint. Movement joints are typically designed and constructed to accommodate 3 to 4 times the amount of anticipated movement but are no narrower than $\frac{3}{8}$ of an inch. All allow for unobstructed movement, movement joints should be free of debris, reinforcing, or other elements that may inhibit movement over the life of the building.

Joint sealants are a critical component of a movement joint and allow the joint to open and close mostly uninhibited while providing a continuous water-shedding surface. Sealant products ideal for use at masonry movement joints have the following properties:

- ☑ **Movement Capabilities:** A sealant that allows for expansion or compression of the sealant joint without permanent deformation. The sealant product selected should be classified as a Class 100/50 sealant per ASTM C920.²⁹ This sealant has joint movement capabilities of a minimum 100% extension and 50% compression when tested to ASTM C719.³⁰
- ☑ **Adhesion to Substrate:** The sealant selected should have demonstrated adhesion to porous substrates such as masonry and concrete. Where differing substrates occur at either side of the movement joint (e.g., at metal panel-to-masonry veneer interfaces), the sealant should have acceptable adhesion to both substrates. Sealant adhesion testing prior to and during field installation is highly recommended and should result in cohesive sealant failure (rather than adhesive failure to the substrate).
- ☑ **Durability:** Movement joints at cladding should be UV-stable as well as durable when exposed to moisture and temperature fluctuations.
- ☑ **Longevity:** Masonry is a long-lasting cladding option and will likely outlive the sealant joint. To match the durability of the masonry cladding and reduce the

replacement frequency of the joint, this guide recommends a quality silicone sealant. When properly installed and maintained as needed, silicone sealants will exhibit 20+ years of acceptable performance. Other sealant options such as hybrid or polyurethane sealants may provide acceptable performance for 10+ years before replacement is required.

Best Practices

The following joint design best practices will encourage long-term performance of a movement joint:

- ☑ Select a quality sealant based on the criteria described in the Joint Design discussion on page i-51.
- ☑ Follow industry-standard best practices for sealant joint installation. This includes joint design and substrate cleaning and priming. As a useful resource, refer to the Dow Corning Americas Technical Manual³¹ as well as the joint dimensioning described in Fig. i-34.
- ☑ Provide an annual review and repair of joints one year after installation and biannual reviews thereafter. Areas of adhesive failure or damage should be repaired.

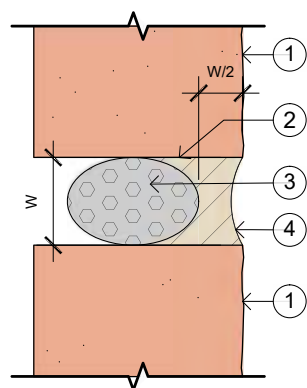


Fig. i-34 Typical sealant joint design

(1) Substrate (masonry or other)

(2) Clean substrate per sealant manufacturer's instructions, primed as needed for adhesion

(3) Foam backer rod with **bond breaker** jacket, oversize rod 25% larger than width of joint to achieve hourglass profile after tooling.

(4) Sealant, sand joint surface where desired

Architectural Considerations

Where there is a desire to minimize the visual appearance of masonry veneer movement joints, the following may be considered:

- ☑ Select a sealant joint color that is similar to the anchored veneer mortar or adhered veneer grout color.
- ☑ Opt for a sanded joint in which mason's sand is bed into the sealant following tooling as shown in Fig. i-35.
- ☑ Consider details that minimize the visible area of the joint while still accommodating movement, such as that shown in Fig. i-36 and Fig. i-37.
- ☑ Include a provision in the project manual for field mock-ups of typical horizontal and vertical movement joints. Review the mock-ups for joint installation quality, adhesion, and appearance.
- ☑ Hide movement joints at inside building corners.



Fig. i-35 Typical sanded sealant joint below a window opening

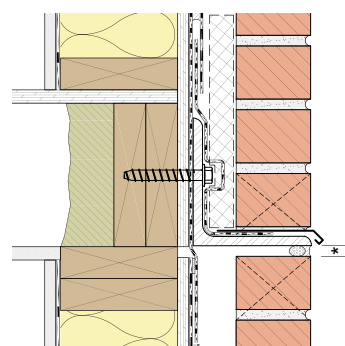


Fig. i-36 Typical anchored masonry veneer horizontal floor-line movement joint example. * Identifies the minimum joint dimension.

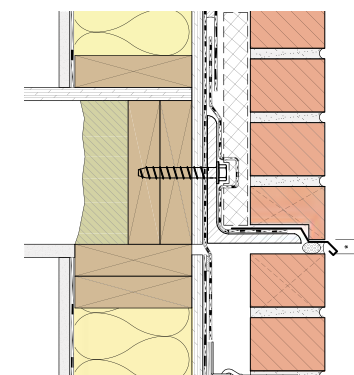


Fig. i-37 Anchored masonry veneer horizontal floor-line movement joint example with lip brick. * Identifies the minimum joint dimension.

Masonry Veneer Penetrations

Penetrations through masonry systems are common, including service penetrations, temporary scaffold tie-back supports, or structural penetrations such as knife plate connections as shown in Fig. i-38—which are a common method of supporting canopies, balcony structures, and building signs on new structures in the Northwest region. These penetrations are typically anchored to the building structure and penetrate the air and water control layers as shown in Fig. i-39; they may also penetrate the thermal control layer. In anchored masonry veneer applications, the veneer and wall structure move independent of one another. This movement must be accounted for in the design while maintaining continuity of the water-shedding surface and the air and water control layers.



Fig. i-38 Typical structural knife plate penetrations through an anchored masonry veneer prior to installation of exterior sealant joints or final cleaning

Water, Air, and Thermal Control Detail Considerations

Penetrations through the air and water control layers need to be detailed to prevent water intrusion and air leakage and to allow for an unobstructed drainage pathway around the penetration (behind the cladding). Two common practices for detailing around penetrations are shown in the flashing sequences in Fig. i-40 and Fig. i-41 on page i-57: a self-adhered flashing membrane and a fluid-applied flashing membrane, both applied around and onto the penetration. Pre-formed, gasketed boots may also be used and are typically detailed similarly to Fig. i-40.

Although Fig. i-40 and Fig. i-41 show a knife plate penetration, the flashing sequences may be used for most discreet penetrations through the masonry veneer. Large penetrations through the veneer (e.g., a continuous steel channel support, a unit exhaust vent, etc.) may require alterations to the sequence, such as a sheet-metal head flashing, to ensure adequate cladding support and unobstructed drainage at the face of the WRB system.

While detailing around penetrations is important, continuity of the air and water control layer at the penetration is equally important. This may require sealing holes and wire penetrations within electrical boxes or installing sealant between sleeves and pipes.

Penetrations that extend through thermal insulation layers should also be evaluated on a case-by-case basis for thermal bridging effects and condensation. These risks can be minimized by using lower-conductivity penetration materials (e.g., PVC in lieu of steel for sleeves or pipes).

Differential Movement

Care must be taken when designing and detailing penetrations projecting through anchored masonry veneer. As discussed in "Locating Movement Joints" on page i-49, differential movement between the backup wall structure and veneer needs to be accommodated. Anticipate expansion of a clay masonry veneer and shrinkage of concrete and wood-framed structures. Additionally, weight applied to some connections (e.g., a balcony placed on a knife plate connection after the masonry veneer is in place) can also introduce movement.

Sequencing

This guide recommends that penetrations through the water, air, and thermal control layers, or masonry veneer, are secured before the mason contractor begins work. Preplanning penetration locations and detailing can avoid schedule delays and cladding removals due to out-of-sequence installations.



Fig. i-39 Typical structural knife plate penetrations flashed with a foil-faced self-adhered flashing membrane similar to the sequence in Fig. i-40 on page i-57. Also visible is a pre-formed penetration boot for a pipe penetration.

LEGEND

Sheet-Applied Air Barrier and WRB System - Flashing Sequence (Fig. i-40)

1. Framed wall sheathing (shown) or backup wall structure face (e.g., CMU)
 2. Hot-dipped galvanized knife plate (shown), or other penetration, secured to structure
 3. Air barrier and WRB target sheet notched around penetration
 4. Air barrier and WRB field membrane, lapped below target sheet
 5. Air barrier and WRB system tape (typically not required with self-adhered air barrier and WRB systems)
 6. Self-adhered flashing membrane, notched and fit tightly onto penetration
 7. Continuous sealant at flashing membrane leading edges around penetration
 8. Air barrier and WRB field membrane, lapped over target sheet
 9. Continuous air barrier and WRB system tape (typically not required with self-adhered air and WRB systems)
 10. Masonry veneer
 11. Continuous sealant over backer rod around penetration
- * Size joint for project-specific building movement (minimum $\frac{3}{8}$ -inch wide). See "Movement Joints" on page i-48 for more information.

Fluid-Applied Air Barrier and WRB System - Flashing Sequence (Fig. i-41)

1. Framed wall sheathing (shown) or backup wall structure face (e.g., CMU)
 2. Hot-dipped galvanized knife plate (shown), or other penetration, secured to structure
 3. Air barrier and WRB field membrane
 4. Air barrier and WRB flashing membrane over field membrane and onto penetration
 5. Exterior insulation, tight to penetration
 6. Masonry veneer
 7. Continuous sealant over backer rod around penetration
- * Size joint for project-specific building movement (minimum $\frac{3}{8}$ -inch wide). See "Movement Joints" on page i-48 for more information.

Detail Discussion

- Two typical flashing sequences are shown. Other detail options may include a pre-formed boot or a hybrid air barrier and WRB system that includes a sheet-applied air barrier and WRB field membrane and fluid-applied air barrier and WRB flashing membrane. Regardless of the system selected, consult with the system manufacturer or the building enclosure consultant for product- and project-specific detail recommendations.
- Penetrations through the air barrier and WRB system are also part of the air barrier and WRB system. Additional sealing may be necessary for penetration types such as electrical boxes or pipe penetration to maintain air and water control layer continuity.
- Anchored masonry veneer is shown in the figures at the right; however, the flashing sequences shown also apply to adhered veneer systems.
- Further promote water diversion at the penetration by forming wire drip loops and sloping pipe penetrations away from the structure.

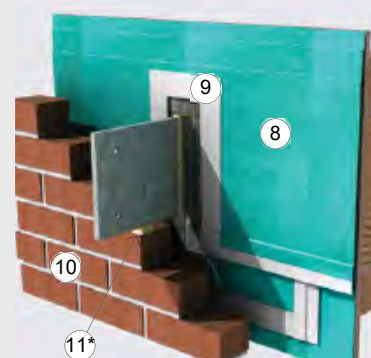
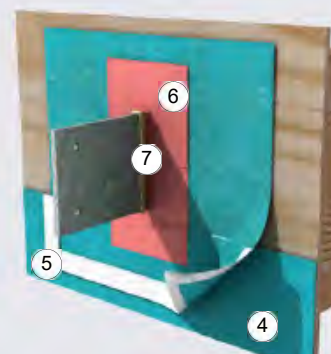


Fig. i-40 Sheet-Applied Membrane Flashing Sequence

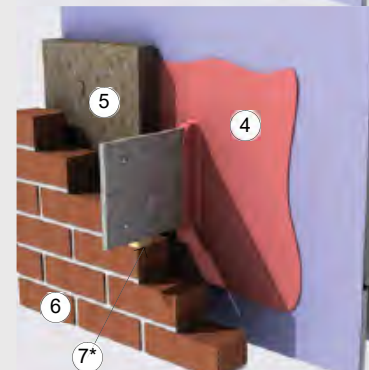
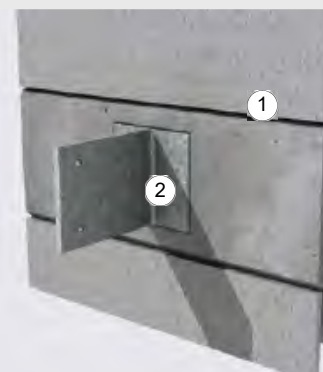


Fig. i-41 Fluid-Applied Membrane Flashing Sequence

Cleaners, Repellents, and Coatings

In the Northwest region, surface-applied clear water repellents are commonly applied to the surface of masonry veneer claddings and exposed CMU walls for the systems featured within this guide. Elastomeric coatings may also be used in targeted applications. The success of a clear water repellent or elastomeric coating is reliant on appropriate product selection, cleaning procedures, and application methods. Although these products have a number of uses, as described below, their use does not make up for poor masonry workmanship or detailing. This section covers cleaning and best practices for selection and application of clear water sealers and elastomeric coatings.

Cleaning Methods

Cleaning of any mortar on grout smears, construction dirt, staining, contaminants, and possibly efflorescence from the construction phase is required prior to the application of clear water-repellent coatings. When masonry surfaces are to be opaque-coated, cleaning is only necessary to provide adequate adhesion between the coating and the masonry wall. A number of cleaning methods are available including hand, water, chemical, and abrasive.

Select cleaning procedures based on masonry unit and mortar colors, texture, and the type of existing debris or contaminants. In general, select the least-aggressive cleaning method necessary to remove debris and contaminants and to effectively clean the wall. Over-cleaning masonry products or using excessive abrasion can alter the appearance of the masonry veneer or CMU and can encourage premature weathering.

For all cleaning methods, test-clean an inconspicuous area of the wall to confirm the effectiveness and acceptability of the cleaning method. Water-clean only when surface and ambient temperatures exceed 40° F; even warmer temperatures may be required for applications of chemical cleaning products that rely on a chemical reaction to be effective.

ASTM D5703³² and BIA Technical Note 20³³ are helpful resources for determining appropriate cleaning procedures for clay masonry units, whereas NCMA TEK 8-4A³⁴ provides helpful discussion on cleaning CMU block of various types and finishes. Also consult the masonry unit or CMU manufacturer and cleaning product manufacturer (where applicable) prior to cleaning.

Surface-Applied Clear Water Repellents

A surface-applied clear water repellent is recommended for the systems in this guide that include adhered or anchored unglazed veneer or exterior-exposed CMU. Application of a clear water repellent can reduce water absorption of the veneer and CMU, as demonstrated in Fig. i-42, while preserving or enhancing natural appearance and minimizing the need for cleaning frequency. By reducing how much water the masonry cladding absorbs, less frequent wetting/drying and freezing/thawing cycles are expected to occur, reducing the likelihood of premature weathering and water-related damage and staining.

There are two primary types of repellents: penetrating or film-forming.

- *Penetrating repellents* have the ability to penetrate into the pores of the masonry while still allowing water vapor to diffuse through the masonry veneer. Common penetrating repellents include silicone resins, silanes, and siloxanes.
- *Film-forming repellents*, such as acrylics, stearates, and urethanes, form a thin film on the surface of the masonry face and across smaller pores. As a result, film-forming repellents can reduce the drying ability of the masonry cladding.

Of the two repellent types, penetrating repellents are recommended for use within the Northwest.

For unglazed clay masonry and CMU in the Northwest, a silane/siloxane blend clear water repellent is common. Silanes penetrate deep into the pores of clay masonry, while siloxanes are deposited closer to the masonry surface.

Both silanes and siloxanes chemically bond to clay masonry, CMU, and mortar in the presence of moisture and alkalinity. As a result, silane/siloxane-based repellents can provide 5 to 20 years of protection, making such blends a durable and relatively longer-lasting water repellent option.

Clear water repellent application to glazed masonry veneers is not recommended. Glazed surfaces reduce the penetrating ability of clear water



Fig. i-42 Water droplets form on a brick veneer on which clear water repellent has been applied

repellent products, limiting the effectiveness of the application.

When selecting a clear water repellent, the following are characteristics and/or properties that are desirable for long-term performance:

- **Suitability for Substrate/Finish:** Products are suited for vertical above-grade wall applications and project-specific masonry cladding types. Manufacturer-published literature indicates that the product is acceptable for the type of masonry substrate and finish (e.g., split-faced CMU, fired clay brick, etc.).
- **High Vapor Permeance:** Water repellence test results indicate 90% or more of the untreated masonry product vapor permeance is retained when tested to ASTM E96.³⁵
- **Effective Water Penetration Resistance:** ASTM E514³⁶ results indicate an 85% or more reduction in maximum leakage rate when compared to an untreated wall.
- **Water-Repellent Admixture Compatibility:** Clear water repellents that are compatible with any water-repellent admixture within the CMU or mortar. Incompatible clear water repellents may be less durable.

Where anti-graffiti repellent properties are desired, consider using a vapor-permeable silicone-based or fluorosiloxane-based repellent with penetrating properties that is marked as an anti-graffiti repellent. The anti-graffiti repellent should provide similar vapor permeance and water penetration resistance to that listed above. The effectiveness of anti-graffiti properties is demonstrated through ASTM D7089³⁷ results, which may be used to compare the ease of graffiti removal.

Clear water repellents should not be used as a replacement for a water-resistive barrier or air barrier within a masonry system. Water repellents are also not effective at bridging cracks or filling voids that result from poor joint design/installation or from long-term building movement. Although clear water repellents will increase the masonry's ability to shed water, a repellent will not prevent efflorescence as a result of water intrusion behind a masonry veneer and will require reapplication to be effective over the long-term service life of the building.

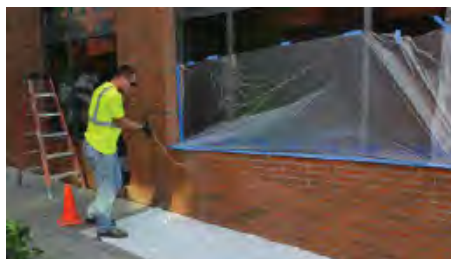


Fig. i-43 Clear water repellent application at an anchored masonry veneer

Best Practices

The following general procedures and considerations are the best practices for clear water repellent application:

- ☑ Complete cladding sealant joints (e.g. around window and door perimeters and at expansion/control joints) prior to application. Sealant joints should be fully cured (typically 14-21 days) prior to cleaning and application.
- ☑ Clean masonry substrates to remove debris and surface contaminants prior to water repellent application.
- ☑ Protect areas that are not to receive water repellent. Prevent contact between clear water repellents and non-masonry products such as asphalt-based products, window glazing, and landscaping.
- ☑ Avoid applying sealant when rain threatens, when windy, and when minimum water repellent application temperatures are not met.
- ☑ Perform a mock-up to demonstrate protection, cleaning, and water repellent application procedures and for review of final masonry appearance.
- ☑ Plan application extents to determine start and stop application locations; avoid overlap.
- ☑ Apply water repellent in accordance with the repellent manufacturer's installation instructions, including the application rate. General application requirements may include the following:
 - Begin water repellent application on a dry substrate at lower surfaces, working upward as shown in Fig. i-43 on page i-60. Fully saturate brushes and rollers, and provide a continuous stream for spray application. Brush away drips and runs.
 - Where wet-on-wet application is required by the manufacturer, allow individual coats to penetrate a minimum of 5 to 15 minutes prior to reapplication.
 - Schedule reapplication of clear water repellent as prescribed by the manufacturer. Perform reapplication with the same or similarly formulated clear water repellent.

A clear water repellent will not prevent efflorescence as a result of water intrusion behind a masonry veneer and will require reapplication to be effective over the long-term service life of the building.

Elastomeric Coatings

Elastomeric coatings reduce the amount of water absorbed by masonry substrates and also provide crack-bridging properties that help reduce water leaks. Elastomeric coatings are typically installed where additional water penetration resistance is desired and where a painted surface is visually acceptable. An example of an elastomeric-coated CMU wall is shown in Fig. i-44. Elastomeric coatings can serve as a water-shedding surface, water-resistive barrier, and air barrier on the exterior face of a masonry substrate when a UV-stable coating is used.



Fig. i-44 Exposed CMU wall coated with elastomeric coating

A vapor-permeable silicone or acrylic elastomeric coating with UV resistance and high elongation properties is recommended for a good coating. A vapor-permeable coating will allow the masonry substrate to dry and reduces the likelihood of salt buildup and bubbling or blistering of the coating.

When selecting an elastomeric coating, the following characteristics/properties are desirable for long-term performance:

- **Product Suitability:** Products suited for vertical above-grade wall applications with UV resistance
- **Water Penetration Resistance:** No leaks occur at the field of wall area when tested to ASTM D6904.³⁸
- **Vapor Permeance:** A minimum vapor permeance of 8 perms when measured per ASTM E96³⁵ wet cup method at the manufacturer-recommended dry film thickness.
- **High Elongation Properties:** Elongation properties that exceed 300% when tested per ASTM D412.³⁹
- **Crack-Bridging Ability:** No cracking occurs when tested to ASTM C1305.⁴⁰

- **Validation:** Products that include an “SWR Institute Validation Program” label on the product data sheet.⁴¹ This label validates performance properties and can be helpful for comparing product options with the program label.

Elastomeric coatings can exhibit staining and may be difficult to clean. Surface staining is largely attributed to surface wetting as a result of runoff below horizontal or sloped surfaces and penetrations including flashings, windows, and parapets. Therefore, staining can largely be reduced by minimizing water runoff onto coated wall areas. Sheet-metal drip edges (such as at window and door sills) are recommended to deflect water away from the surface of the masonry coating to help reduce staining.

Best Practices

The following general application procedures and considerations are the best practices for elastomeric coating application:

- ☑ Include consideration for water-shedding and deflection in above-grade wall design. Use minimum ½-inch projected drip edges to minimize coating staining and runoff.
- ☑ Provide a minimum 28-day cure for masonry grouts and adjacent concrete surfaces prior to application.
- ☑ Seal all cracks and cladding joints as recommended by the coating manufacturer. Use appropriate joint design and backing at movement joints. Typically, cracks or holes ¼-inch wide or larger require treatment.
- ☑ Use block filler when required by the manufacturer. Some manufacturers may allow an additional application of coating in lieu of block filler.
- ☑ Test the coating adhesion to confirm cleaning procedures and priming requirements to the masonry substrate and joint sealants. Use a mock-up for coating review prior to full-scale application.

Designing to Minimize Freeze-Thaw Damage and Efflorescence

The long-term durability and performance (including aesthetic performance) of masonry cladding starts with good design, is implemented with sound construction practices, and is preserved with regular maintenance over the service life of the building. Because the focus of this guide is design and construction, this

section addresses how good design can minimize the risk of two occurrences in masonry cladding: freeze-thaw cycles and efflorescence.

Freeze-Thaw Cycles

Freeze-thaw cycles can be described as repeated freezing and thawing of moisture within masonry pores as a result of temperature fluctuations. The occurrence of freeze-thaw cycles does not always result in damage but can if enough moisture exists within the masonry component to cause damage and the occurrence of these conditions are frequent. Eliminating either the moisture source or the occurrence of freezing temperatures can eliminate the risk of freeze-thaw damage.

The factors impacting both the occurrence of freeze-thaw cycles and the likelihood of resulting damage include climate, material properties, and building-specific design features and are described in the following sections.

Climate

Wet climates prone to rapid temperature swings and marine climates that experience freezing temperatures have a greater risk of freeze-thaw occurrence. Freeze-thaw occurrence is atypical in the Northwest region; however, it is more likely to occur in areas that experience freezing temperatures and experience high-to-extreme rainfall (see the Determining Building Enclosure Loads discussion on page i-16), particularly those areas of the Cascade Range and the Rocky Mountains.

Climate is a factor beyond the control of the designer and mason contractor; thus, material properties and building-specific design are of greater focus for minimizing freeze-thaw damage in higher-risk areas of the Northwest region.

Material Properties

Porosity, pore structure/size, material strength, and saturation coefficient of the masonry material may affect the occurrence of and subsequent damage due to freeze-thaw cycles. While the direct relationships between these material properties and freeze-thaw occurrence is highly debated and not described here, the discussion within each system's chapter provides recommendations for specifying masonry components that are appropriate for exterior applications and limit the risk of freeze-thaw damage.

Historically, freeze-thaw occurrence, has not been a problem with well-designed and properly constructed masonry structures in the Northwest region.

In-depth discussion of sound construction practices in the field and long-term maintenance of masonry cladding is beyond the focus on this guide; however, we remind the reader to seek qualified mason contractors to perform work within the Northwest region to ensure quality installation of masonry materials. Additional numerous resources addressing the long-term care and maintenance of masonry veneer and wall systems are available through the organizations listed in the References section at the end of this guide.

Building-Specific Design

Building-specific design concepts of masonry systems are within the control of the designer and can greatly reduce freeze-thaw occurrence and related damage. The following building-specific design concepts should be considered, especially within higher-risk areas of the Northwest region:

- Building-specific form and features that reduce the cladding exposure to liquid water and snow accumulation. See Building Form and Features discussion on page i-18 for more.
- Site design that locates water sources such as irrigation and outdoor water features away from the building enclosure.
- Drainage behind the masonry veneer, such as that shown in the masonry systems in Chapters 1 through 3 and 6 through 8, which minimizes water buildup behind the masonry cladding. Venting/ventilating behind the veneer, which further reduces the amount of moisture within the veneer.
- Appropriate selection of air barrier materials and design of air barrier transition details as discussed throughout all chapters of this guide. Excessive air leakage condensation on masonry materials can increase the moisture within the masonry and freeze-thaw risk.
- Use of vapor-permeable water repellents and coatings such as those discussed in Cleaners, Repellents, and Coatings on page i-58.

Note that many of the building-specific design concepts beneficial for ensuring the long-term durability of the masonry wall or veneer are also beneficial for the long-term performance of the system as a whole. The above-noted concepts also serve to reduce the likelihood of water leaks and heat loss/energy consumption and can improve the long-term durability of the structure and masonry cladding.

Efflorescence

Efflorescence occurs when water-soluble alkali salts within the masonry unit, mortar, and/or grout are dissolved by water and migrate to the surface of the masonry wall or veneer. Water evaporates when it reaches the exposed surface of the masonry, leaving the salts behind—which typically appear as a white residue. Minimizing wetting of the cladding through good design, sound construction practices, and regular long-term maintenance can help prevent efflorescence. Refer to the Building-Specific Design discussion of this section and the recommended details at the end of each system chapter.

It is typical for some efflorescence to form on masonry veneer and walls systems immediately following installation due to moisture within the grout and mortar materials during placement. Should efflorescence be observed following the final cleaning of the masonry veneer after installation, a source of moisture may be present and should be investigated and repaired as needed.



Fig. i-45 Example of efflorescence on anchored masonry veneer

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CHAPTER 1:**CMU WALL WITH ANCHORED MASONRY VENEER**

Masonry system 1 is a rainscreen wall system with concrete masonry unit (CMU) or concrete wall structure and anchored masonry veneer. The components of this system, from interior to exterior, are described in Fig. 1-1. This system is appropriate for many applications including low-, mid-, or high-rise residential or commercial structures. An example project application of this system is shown in Fig. 1-2 on page 1-2. This system with a concrete backup wall alternative is also depicted in Fig. 1-3 on page 1-2 and contains similar typical components to that described in Fig. 1-1.

Building Enclosure Control Layers

As noted in the Introduction, an above-grade wall system controls liquid water, air, heat, and possibly water vapor to function as an effective and durable environmental separator. Control of these elements, specific to this wall system, is provided by the following control layer systems and/or materials:

- The water control layer, comprising the water-resistive barrier (WRB) system
- The air control layer, comprising the air barrier system

INTERIOR

- Single-wythe CMU (or concrete) wall
- Air and water-resistive barrier membrane
- Exterior insulation
- Air cavity
- Anchored masonry veneer with
- Clear water repellent

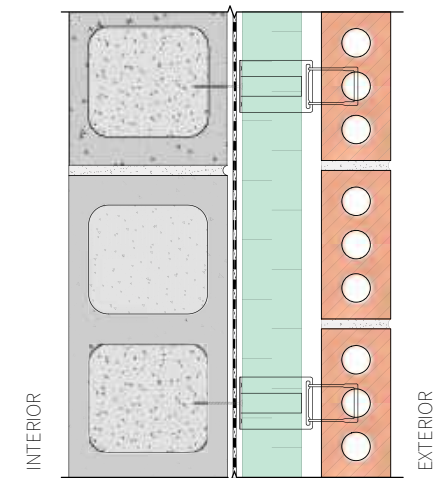
EXTERIOR

Fig. 1-1 Typical System 1 components from interior to exterior

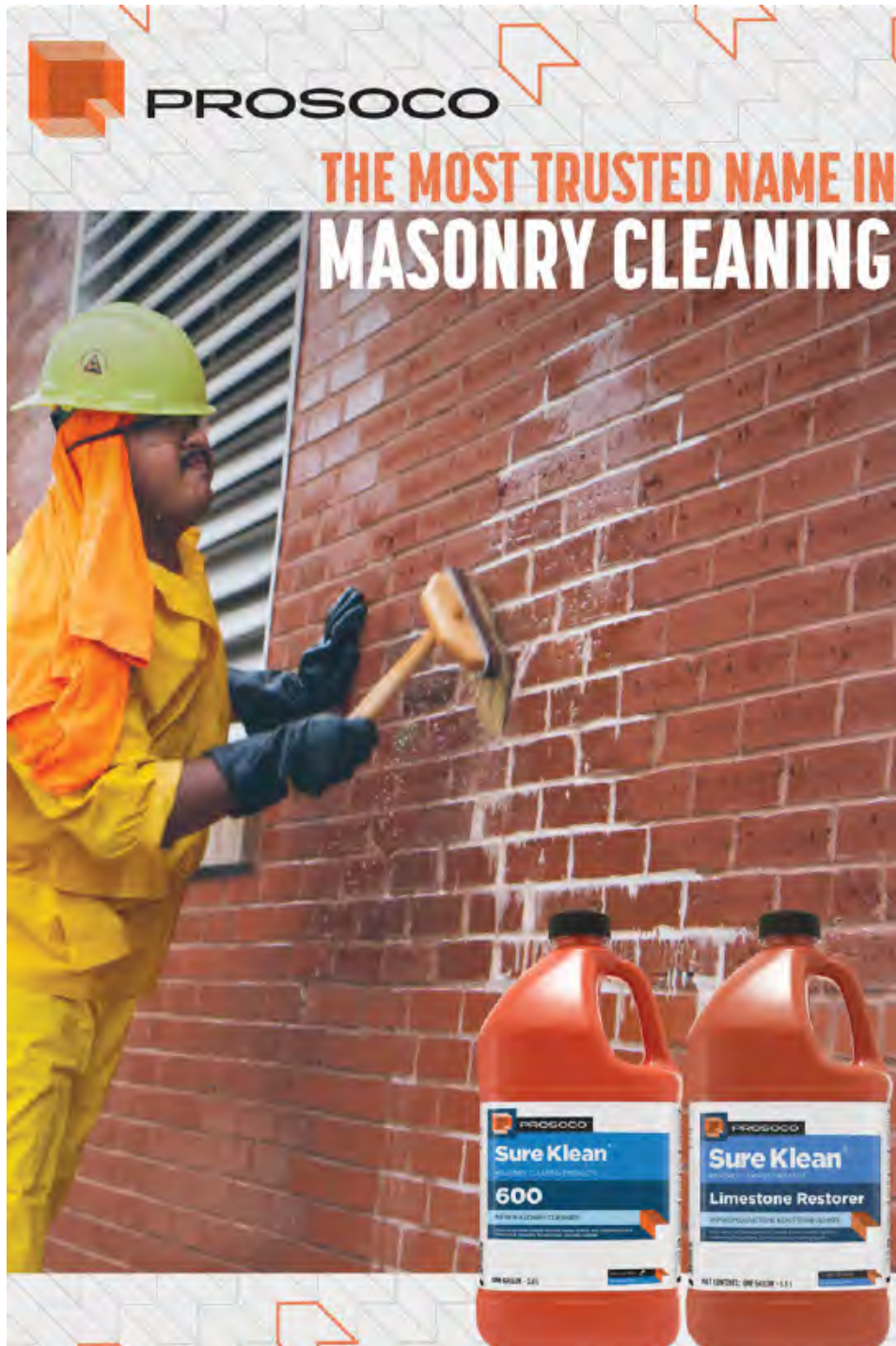




Fig. 1-2 CMU wall with anchored masonry veneer example project application

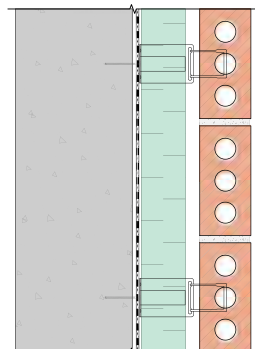


Fig. 1-3 System 1 with concrete backup wall alternative

- Thermal control layer, comprising thermal insulation and other low-conductivity materials
- Vapor control layer, comprising vapor retarding materials

For a summary of the relationship between building enclosure loads, control layers, and associated systems and materials, refer to Fig. i-13 on page i-21 of the introductory chapter.

Fig. 1-4 and the typical system details provided adjacent to each detail at the end of this chapter illustrate the water-shedding surface and control layer locations for this system.

As shown in Fig. 1-4, the water-shedding surface occurs at the anchored masonry veneer, with most water-shedding occurring at the wall face while some water will be stored within the masonry veneer to be released at a later time. The water control layer, the air control layer, and the vapor control layer occur at the same location at the exterior face of the CMU wall structure. The thermal control is mostly provided by the exterior insulation.

Water-Shedding Surface

The water-shedding surface reduces the water load on the enclosure layers. A general discussion of the water-shedding surface is provided in the Water-Shedding Surface discussion on page i-19.

The anchored masonry veneer cladding, including both mortar joints and masonry veneer units, is the primary water-shedding surface of the wall system. Additional water-shedding surface components include sheet-metal flashings and drip edges, sealant joints, and fenestration systems as shown in the details at the end of this chapter.

To promote water-shedding at the masonry veneer face, mortar joints should be installed with a tooled concave (preferred) or V shape.

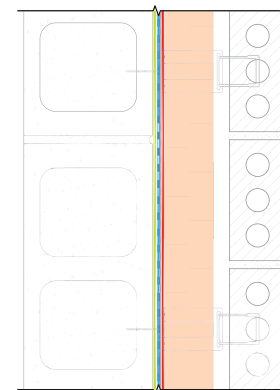
The water-shedding surface is most effective when free of gaps except where providing drainage and/or ventilation. Movement joints and joints around fenestrations and penetrations are recommended to be continuously sealed with backer rod and sealant or counterflashed with a sheet-metal flashing to deflect wind-driven rain and shed water away from the rainscreen cavity.

Water Control Layer

The water control layer is a continuous control layer that is designed and installed to act as the innermost boundary against water intrusion. In a rainscreen wall system, the WRB system is the last line of defense against water intrusion. A general discussion of the WRB system is provided in the Water Control Layer discussion on page i-24.

In this wall system, the WRB system is typically a self-adhered sheet or fluid-applied system that also functions as the air barrier system; thus the WRB system is often referred to as the air barrier and WRB system. Either a self-adhered sheet or fluid-applied system is depicted in the details at the end of this chapter. An example of a fluid-applied air barrier and WRB system over a concrete backup wall is shown in Fig. 1-5 on page 1-4. This membrane may have Class I, Class II, Class III, or Class IV vapor permeance properties because it is located interior

Water-Shedding Surface and Control Layers



— Water-Shedding Surface

Control Layers:

- Water
- Air
- Vapor
- Thermal

Fig. 1-4 System 1 (CMU wall structure) water-shedding surface and control layer locations

of the system's thermal insulation. Physical properties of the WRB system products are discussed in detail in the Water Control Layer discussion on page i-24. Vapor permeability of materials is addressed in the Vapor Control Layer discussion on page i-28.

The WRB system must be continuous across the wall system to provide effective water control. In addition to the field membrane, the WRB system includes fluid-applied or self-adhered flashing membranes, sealants, sheet-metal flashings, and penetrations such as windows and doors as shown in the detail drawings that follow this chapter discussion. Where sheet-metal flashing components occur within the system, the back leg of the sheet-metal flashing is shingle-lapped into the WRB system to facilitate drainage at the face of the WRB system and to the exterior of the cladding.

Masonry veneer ties in this system will penetrate the WRB system and should be sealed as required by the WRB system manufacturer's installation requirements. Typically, plate ties are bed in a compatible sealant or fluid-applied flashing product or are attached through a self-adhered membrane patch, whereas screw ties with gasketing washers are typically not required to be sealed.

Where a ladder eye-wire masonry veneer attachment method is used, a fluid-applied WRB system is recommended; each wire penetration through the membrane should be sealed with a sealant, fluid-applied flashing material, or liberal application of fluid-applied field membrane as recommended by the membrane manufacturer.

Air Control Layer

The air barrier system serves as the air control layer. By controlling air, this layer also assists with controlling liquid water, heat, and water vapor.



Fig. 1-5 Fluid-applied air barrier and WRB system field membrane over a concrete backup wall. Double eye and pintle masonry veneer ties penetrate through the exterior semi-rigid mineral fiber insulation.

A mechanically attached air barrier and WRB membrane may be used for this wall system where recommended by the manufacturer for installation over a CMU or concrete wall substrate.

For this wall system, the air barrier system is the same field membrane and many of the components that serve as the WRB system. A general discussion of the air control layer and the air barrier system is provided in the Air Control Layer discussion on page i-26.

As discussed in the Introduction, the air barrier system must be continuous and fully sealed to resist air flow, whereas the WRB system is not required to be continuously sealed to be effective, but merely shingle-lapped.

Vapor Control Layer

The vapor control layer retards or greatly reduces (e.g., vapor barrier) the flow of water vapor due to vapor pressure differences across enclosure assemblies. Unlike the other control layers presented in this guide, the vapor control layer is not always necessary or required to be continuous.

For this system, a vapor control layer is not necessary; the risk of condensation development or damage to the structure due to outward vapor drive and condensation is unlikely due to all of the system's thermal insulation being located exterior of the wall structure and the air barrier and WRB system.

Note that Fig. 1-4 identifies the vapor control layer at the exterior face of the CMU wall. This represents the exterior-most plane of the CMU wall structure, which has some vapor resistance. It would also represent the location of a vapor control layer if relatively low vapor permeance (Class I or II) air barrier and WRB systems were used.

Thermal Control Layer

The thermal control layer controls heat flow and assists with controlling water vapor.

In this wall system, the exterior insulation is the primary material that forms the thermal control layer. At transition details, the thermal control layer includes the exterior insulation across bond beams; peripheral floor lines; and insulation at the roof assembly, slab, and foundation elements. Windows and doors that penetrate this system are also part of the thermal control layer.

The location of the insulation in this wall system, exterior of the wall structure:

1. Allows for the exterior insulation to extend across floor lines (which are typically required to meet similar energy code compliance requirements as this wall system).

2. Keeps the structure warm, which reduces the risk that condensation may develop inboard of the WRB system.
3. Protects the air barrier and WRB systems from extreme temperature cycles and damage during veneer installation.

The CMU (or concrete) in this system is also a thermal mass, thus it may provide some thermal mass benefit.

Additional thermal control layer information is provided in the Thermal Control Layer discussion on page i-30 of the Introduction.

Insulation Selection

In the Northwest region, the exterior insulation for this system is typically semi-rigid mineral fiber board insulation; moisture-tolerant rigid board insulation (e.g., polyisocyanurate or XPS as shown in Fig. 1-6) may also be used. Refer to the Insulation Products discussion on page i-30 for a discussion on various insulation types and additional considerations.



Fig. 1-6 XPS rigid board exterior insulation behind an anchored masonry veneer

Although masonry is defined as a noncombustible cladding material, the use of a combustible air barrier and WRB system or foam plastic insulation within a wall cavity can trigger fire propagation considerations and requirements. Depending on the local jurisdiction, IBC Section 1403.5¹ (regarding vertical and lateral flame propagation as it relates to a combustible WRB system) may require acceptance criteria for NFPA 285.² The use of foam plastic insulation within a wall cavity should also be addressed for IBC Chapter 26 provisions.

Thermal Performance and Energy Code Compliance

This wall system is typically classified as a mass above-grade opaque wall system for energy code compliance purposes. Prescriptive energy code compliance values for this wall system are summarized in Table 1-2 on page 1-13 and describe:

- Minimum insulation R-values for a *prescriptive insulation R-value method* strategy.

- Maximum system U-factors for a *prescriptive assembly U-factor method* strategy. Note that the equivalent effective R-value of this U-factor has been calculated and is denoted in parenthesis () for easy comparison to thermal modeling results included within this chapter.
- Footnote (2) for compliance by *exception*. The ability to use this option depends on the jurisdiction, building's use, and availability of CMU cores to be filled with insulation. If this exception is to be used, refer to the Chapter 4 Thermal Performance and Energy Code Compliance discussion on page 4-5.

For all energy code compliance strategies except the *prescriptive insulation R-value method strategy*, the system's thermal performance will need to be determined as a U-factor through either calculation or from tables; however, it may or may not be required to be less than the prescriptive U-factors shown in Table 1-2.

The Thermal Performance and Energy Code Compliance discussion on page i-33 and Fig. i-26 on page i-39 of the introductory chapter describes the typical process of navigating energy code compliance options. Additionally, the thermal modeling results demonstrated in this chapter may be used to assist with selecting wall system components (e.g., tie type, insulation R-value/inch, etc.) to achieve a target U-factor. Options for thermally optimizing this wall system, as determined through the modeling results, are also discussed.

Project-specific thermal performance values for an opaque above-grade wall should be used for energy code compliance and determined from a source that is approved by the authority having jurisdiction. Thermal performance sources may include ASHRAE 90.1,³ COMcheck,⁴ the appendices of the 2015 WSEC,⁵ thermal modeling and calculation exercises, or other industry resources.

System Effective Thermal Performance

Masonry ties and floor line shelf angles penetrate the exterior insulation in this system and create areas of thermal bridging; thermal bridging reduces the system's actual thermal performance.

Examples of typical anchored masonry veneer ties and a standoff shelf angle support are shown in Fig. 1-7 and Fig. 1-8 on page 1-8; examples of the relative thermal bridging that these components can have when penetrating exterior insulation are described by Fig. 1-9 through Fig. 1-14 on page 1-9.

Where shown in Fig. 1-10, Fig. 1-12, and Fig. 1-14, the lighter blue thermal gradient color at the attachment locations describes a warmer temperature than the



Fig. 1-7 Masonry tie types used for modeling—from left to right: ladder eye-wire tie, thermally optimized screw tie, double-eye and pintle plate tie

adjacent darker blue insulation face—an indicator of heat loss at the penetration through the insulation. This thermal bridging reduces the system's effective thermal performance.

Three-dimensional thermal modeling demonstrates this system's effective thermal performance with various insulation thicknesses, insulation R-values, masonry veneer ties, and standoff shelf angle options. A discussion on the modeling performed for this guide is included in the Appendix.

Thermal Modeling: Variables

The following are modeling variables specific to this wall system:

- **Wall Structure** – An 8-inch medium-weight block. Modeling results are not presented for a concrete backup wall structure; however, similar results would be expected for this alternative backup wall type because the overall performance is driven by the insulation and thermal bridging. Modeling results consider a concrete slab bypass condition with and without a shelf angle.



Fig. 1-8 Hot-dipped galvanized standoff shelf angle

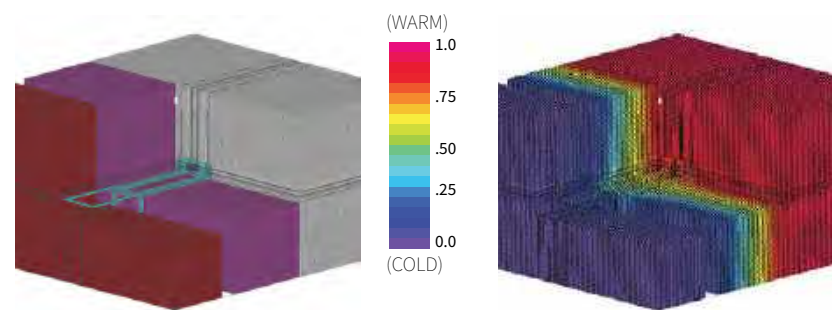


Fig. 1-9 Three-dimensional model of a galvanized-steel masonry tie through exterior insulation

Fig. 1-10 Three-dimensional thermal image of the galvanized-steel masonry tie through exterior insulation shown in Fig. 1-9



Fig. 1-11 Three-dimensional model of a continuous floor line shelf angle bridging exterior insulation

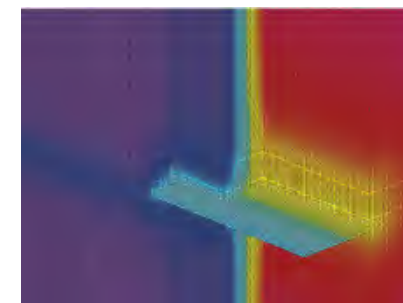


Fig. 1-12 Three-dimensional thermal image of the continuous floor line shelf angle shown in Fig. 1-11

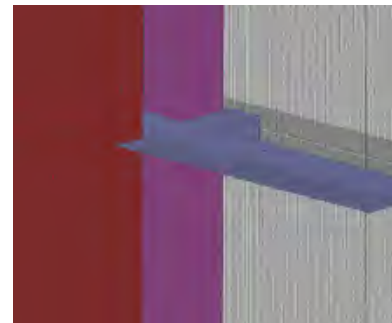


Fig. 1-13 Three-dimensional model of a floor line standoff shelf angle bridging exterior insulation

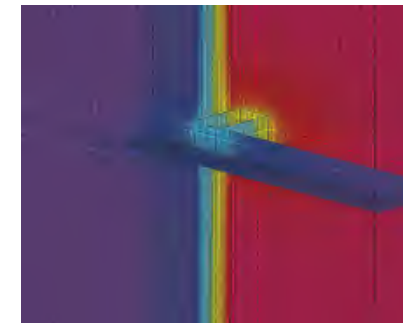


Fig. 1-14 Three-dimensional thermal image of floor line standoff shelf angle shown in Fig. 1-13

- **Masonry Ties** – Tie types are considered at 16-inch-by-16-inch spacing. Tie types are shown in Fig. 1-7 and include:
 - Ladder eye-wire tie ($\frac{3}{16}$ -inch diameter) with cross-rods at 16-inches on-center made of hot-dipped galvanized steel or Type 304 stainless steel. Hooks are either hot-dipped galvanized steel or Type 304 stainless steel to match the ladder wire.
 - Thermally optimized screw tie with stainless steel barrel and carbon steel fastener. Hooks are either hot-dipped galvanized steel or Type 304 stainless steel.
 - Double eye and pintle plate tie (14-gauge). Hooks are either hot-dipped galvanized steel or Type 304 stainless steel to match the tie plate.
- **Exterior Insulation** – R-4.2/inch or R-6/inch insulation product. Insulation thicknesses of 3-, 4-, and 5-inches are considered. The R-values selected demonstrate the lower and upper thermal resistance of typical exterior insulation products.
- **Shelf Angle Supports** – Hot-dipped galvanized steel shelf angles. Either attached tight to the floor line structure (i.e., continuous shelf angle) as shown similar in Fig. 1-11 and Fig. 1-12 or offset to the depth of the exterior insulation and supported by intermittent hollow steel sections (HSS) at 4 feet on-center (i.e., standoff shelf angle) as shown similar in Fig. 1-13 and Fig. 1-14.

Thermal Modeling: Results

Modeling results are shown in Table 1-1, Fig. 1-15, and Fig. 1-16 on page 1-12 and page 1-13 and demonstrate the system's effective R-value under various conditions. Fig. 1-15, and Fig. 1-16 graphically represent the results summarized in Table 1-1.

Below is a discussion of the results. Where reductions in the system's effective R-value are discussed, these values are as compared to the system's effective R-value "Without Penetrations" such as ties and shelf angles.

- As determined from Table 1-1 for ties only, masonry ties of any cross-sectional area reduce the system's effective R-value by 7 to 38%. Galvanized steel masonry plate ties provide the greatest reduction in the system's effective R-value at 23 and 38%. *The most thermally efficient option modeled is the stainless-steel ladder wire tie, followed by the thermally improved screw tie and the stainless-steel plate tie.* Note that a 16-inch-by-16-inch on-center

spacing is modeled for this guide; *greater spacing of non-ladder eye wire ties can increase the system's effective R-value; however, spacing needs to be coordinated with structural requirements.*

- Table 1-1 and Fig. 1-16 demonstrate that the system's effective R-value with ties only is similar for both thermally optimized screw tie and stainless-steel plate tie options. *Performance targets can be met without proprietary cladding attachment systems. Stainless-steel tie options provide a highly corrosion-resistant attachment and may prove to be cost-effective.*
- As determined from Table 1-1 with ties only, an R-19 wall target could be provided by one of the scenarios listed below when using R-6/inch exterior insulation. *As a result, the tie used can effect the wall thickness without compromising the system's effective R-value.*
 - 3-inches of insulation with a stainless-steel ladder wire
 - 4-inches with a stainless-steel plate tie or thermally optimized screw tie
 - 5-inches with a galvanized-steel plate tie
- A continuous shelf angle support reduces the system's effective R-value significantly, as shown in Fig. 1-15. When considered with galvanized-steel plate ties, a continuous shelf angle support reduces the systems' effective R-value by 47 to 65%. When a standoff angle support is considered, a lesser reduction of 31 to 48% is achieved. *As shown in Fig. 1-15, a standoff shelf angle support performs better thermally than a continuous shelf angle support.*

Drainage, Ventilation, and Water Deflection

The anchored masonry veneer is expected to shed most water it is exposed to; however, some moisture is expected to penetrate the cladding and enter the air cavity. This moisture is drained through the air cavity and exits the cladding system where cross-cavity flashings are provided.

Drainage and Ventilation

In this system, the air cavity between the anchored masonry veneer and the exterior insulation provides drainage behind the cladding as well as ventilation when vent ports are provided at the top and bottom of the air cavity. The code-minimum air cavity depth is 1-inch as required per TMS 402-16;⁶ however, the risk that mortar droppings will block the air cavity increases with smaller cavities. A 1-inch cavity may be considered where a strict quality control program is

Table 1-1 System 1 thermal modeling results

8" CMU Wall with Anchored Masonry Veneer, R-4.2/in - R-6/in Exterior Insulation					
Tie Type	Tie Penetration Area	Exterior Insulation Thickness	Nominal Exterior Insulation R-Value	3D Thermal Modeling Effective R-Value of System (ft ² ·°F·hr/Btu)	
				Without Penetrations (Through Exterior Insulation)	
				Ties Only	Ties + Standoff Shelf Angle
Embedded Wire Tie (e.g., ladder style) – Stainless Steel	0.02%	3"	12.6–18	14.9–19.3	13.1–16.2
		4"	16.8–24	18.7–24.6	16.0–19.9
		5"	21–30	22.4–29.7	18.8–23.4
Embedded Wire Tie (e.g., ladder style) – Galvanized Steel	0.02%	3"	12.6–18	13.2–16.4	11.8–14.1
		4"	16.8–24	16.3–20.4	14.2–17.1
		5"	21–30	19.3–24.2	16.5–19.8
Thermally Optimized Screw Tie – Stainless-Steel Hook	0.05%	3"	12.6–18	15.9–21.3	12.4–15.2
		4"	16.8–24	20.2–27.5	15.1–18.4
		5"	21–30	24.4–33.4	17.4–21.2
Thermally Optimized Screw Tie – Galvanized-Steel Hook	0.05%	3"	12.6–18	15.9–21.3	12.4–15.1
		4"	16.8–24	20.2–27.5	15.0–18.3
		5"	21–30	24.4–33.4	17.4–21.2
Plate Tie (14 ga) – Stainless Steel	0.05%	3"	12.6–18	14.1–18.0	12.5–15.3
		4"	16.8–24	17.7–22.8	15.3–18.7
		5"	21–30	21.1–27.2	17.8–21.8
Plate Tie (14 ga) – Galvanized Steel	0.05%	3"	12.6–18	12.2–14.8	11.0–12.9
		4"	16.8–24	14.8–17.9	13.0–15.3
		5"	21–30	17.1–20.7	14.9–17.4

Table 1-2 System 1 prescriptive energy code compliance values excerpted from Table i-1 of the introductory chapter

OPAQUE ABOVE-GRADE WALL – THERMAL ENVELOPE REQUIREMENTS									
Energy Code		2012 SEC		2012 WSEC		2014 DEESC		2012 IECC	
Climate Zone		5 and Marine 4		5, 6 and Marine 4		5 and Marine 4		6	
Guide Assembly #		All Other		All Other		All Other		All Other	
Classification		Group R		Group R		Group R		Group R	
Mass		Exterior: R-16cl ⁽¹⁾ U-0.057 (R-17.5)		Exterior: R-16cl ⁽¹⁾ U-0.057 (R-17.5)		Exterior: R-16cl ⁽¹⁾ U-0.057 (R-17.5)		Exterior: R-16cl ⁽¹⁾ U-0.057 (R-17.5)	
1A 1B		Exterior: R-16cl ⁽¹⁾ U-0.057 (R-17.5)		Exterior: R-16cl ⁽¹⁾ U-0.057 (R-17.5)		Exterior: R-16cl ⁽¹⁾ U-0.057 (R-17.5)		Exterior: R-16cl ⁽¹⁾ U-0.057 (R-17.5)	

⁽¹⁾ When using interior insulation: R-13 + R-6 cl for wood studs or R-13 + R-10 cl for metal stud; when using exterior insulation: R-16 cl

⁽²⁾ Exception: integrally insulated concrete block complying with ASTM C90 with all cores filled, with at least 50% of block cores are filled with vermiculite (or equivalent fill insulation), and enclosing one of the following uses: gymnasium, auditorium, church chapel, arena, kennel, manufacturing plant, indoor swimming pool, pump station, water and wastewater treatment facility, warehouse (storage and retail), motor vehicle service facility, mechanical/electrical structures (OEESC only), and restroom/concessions (OEESC only). Under the WSEC, where additional uses not listed (such as office, retail, etc.) are contained within the building, the exterior walls that enclose these areas may not utilize this exception.

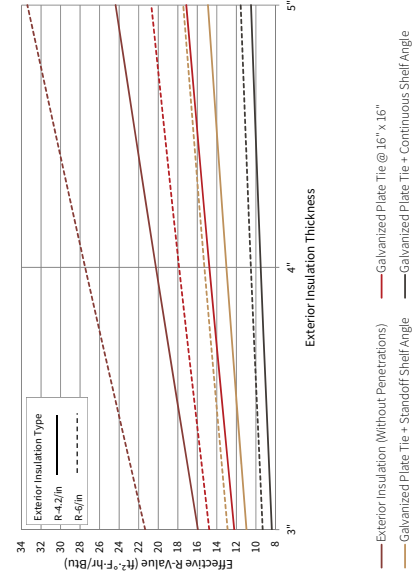


Fig. 1-15 System 1 effective R-value comparison of galvanized steel plate tie and shelf angle options

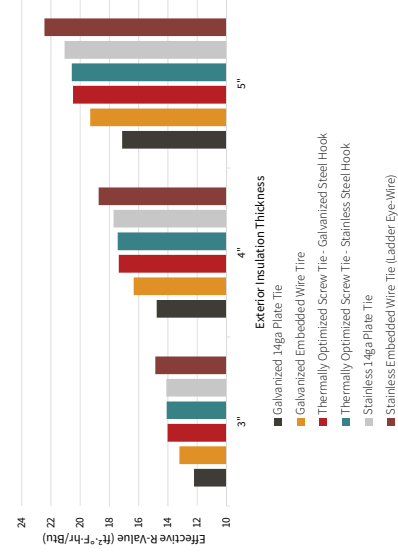


Fig. 1-16 System 1 effective R-values for R-4.2/inch insulation, various tie types, and without shelf angles

implemented to minimize the likelihood that mortar droppings block the cavity; however, a 2-inch air cavity is best practice. Fig. 1-17 on page 1-14 demonstrates a typical air cavity for this system.

Where the air cavity is reduced, which commonly occurs at fenestration rough openings with return brick, a compressible free-draining filler is recommended such as semi-rigid mineral fiber insulation. Mortar should not be packed within these cavities.

The air cavity is ventilated through vents located at the top and bottom coursing of each wall section. Top vents typically occur just below the parapet blocking and below intermittent bearing elements such as floor line shelf angles. Bottom vents, which also serve as **weeps** and may be referred to as weep/vents, also assist with draining moisture within the air cavity. These weep/vents are typically located just above bearing elements such as loose-lintels, floor line shelf-angles, or foundation walls.

Vents and weep/vents are recommended to be spaced a maximum of 24-inches on-center (i.e., every two to three masonry units) and filled with a cellular or mesh product that fills the head joint of a standard brick unit. It is important that weep fillers extend into the bed joint of the course to facilitate drainage. Weep tubes are avoided as they provide far less ventilation and are blocked easily with debris.

Mortar collection nets are recommended at all veneer-bearing locations to prevent mortar from blocking the rainscreen cavity and weep/vents. Generally, a trapezoidal open-weave, moisture-tolerant net is used.



Fig. 1-17 Typical rainscreen cavity at CMU wall with anchored masonry veneer

Sheet-Metal Components

Sheet-metal components used with this system are reflected throughout the details at the end of this chapter. Cross-cavity sheet-metal components are typically located at all bearing elements such as the head of a penetration (e.g., window head), the floor line shelf-angles, and the foundation. These flashings assist with draining the rainscreen cavity and also serve to protect fluid-applied or self-adhered flashing membranes that may exist beneath them. Counterflashing sheet-metal components assist with water shedding and are typically located at windowsill and parapet top conditions; they protect the cavity from water ingress while allowing ventilation of the air cavity.

Refer to the Sheet-Metal Flashing Components discussion on page i-46 for general recommendations on sheet-metal flashing products, including design considerations and materials.

Movement Joints

For this system, anchored clay masonry will expand over time as a result of irreversible moisture gain, and mortar joints will shrink slightly overtime. In the CMU wall structure, shrinkage will occur over time due to initial drying and carbonation. To minimize the risk of damage to the veneer or other wall components, differential movement between the wall structure and veneer must be considered. Expansion joints must also be provided to allow for overall expansion of the clay masonry veneer; control joints must be provided for shrinkage where concrete masonry veneer units are used.

Differential vertical movement between the structure and the veneer is accommodated with a horizontal gap between the veneer and elements that are directly attached to the wall structure, such as shelf angle supports, parapet blocking, and windows. Either a backer rod and sealant joint or cross-cavity sheet-metal flashing is placed at each horizontal gap. The sizing and location of joints will vary depending on the expected differential movement between the wall and veneer.

Expansion/shrinkage of the veneer or differential movement between the veneer, penetrations, and different cladding materials is accommodated with vertical joints in the veneer system as shown similar in Fig. 1-18 on page 1-16. Vertical gaps minimize stresses between

Expansion joints (clay masonry veneer) or control joints (concrete masonry veneer) minimize stresses within the veneer, between dissimilar materials such as at window jamb to veneer interfaces.

the veneer and other components to provide crack control for the masonry veneer. Vertical gaps are typically sealed with a backer rod and sealant.

Typical locations of joints for the purposes of accommodating movement, drainage, and/or rainscreen cavity ventilation are identified with an asterisk (*) in chapter details. In general, a minimum gap dimension of $\frac{3}{8}$ -inch is recommended; however, it is the Designer of Record's responsibility to appropriately locate and size all movement joints.

Refer to the Movement Joints discussion on page i-48 for more information on locating veneer joints and sealant joint best practices.



Fig. 1-18 Typical vertical brick expansion joint aligned with window jambs. Each joint continues the full height of the building and is awaiting backer rod and sealant joint installation.

Structural Considerations

The CMU block (or concrete) wall of this system provides the primary structure of this system. It is the responsibility of the Designer of Record to ensure that all structural elements of the backup wall and veneer are designed to meet project-specific loads and local governing building codes. Generic placement of the grout, reinforced elements, and supports/ties are demonstrated within the details of this chapter and are provided for diagrammatic purposes only.

Masonry Ties

Masonry ties (i.e., masonry anchors) are used to connect the veneer to the masonry (or concrete) wall structure. They are designed to resist the out-of-plane loads applied to the wall, typically wind and seismic loads. At the same time, ties must be flexible to allow the veneer to move in-plane relative to the backing wall.

Building codes provide prescriptive requirements for masonry ties secured to concrete or masonry that include spacing, size, placement, and tie type. These requirements are summarized in Table 1-3 and are based on TMS 402-

Table 1-3 Prescriptive spacing requirements for anchored masonry veneer ties based on TMS 402-16² provisions

Prescriptive Spacing for Adjustable Two-Piece Masonry Veneer Ties			
Spacing Designation	Requirement Category (use more stringent spacing requirement where applies)		
	General	Seismic Design Categories D, E, and F ⁽¹⁾	High Wind ⁽²⁾
Maximum Wall Area per Anchor	2.67 ft²	2.00 ft² (75% of General Requirement Max.)	1.87 ft² (70% of General Requirement Max.)
Maximum Horizontal Spacing	32 inches	32 inches	18 inches
Maximum Vertical Spacing	25 inches	25 inches	18 inches
Maximum Spacing at Opening ⁽³⁾	36 inches	36 inches	24 inches
Maximum Distance from Openings	12 inches	12 inches	12 inches

⁽¹⁾ Seismic design categories as determined by ASCE 7

⁽²⁾ High wind includes wind velocity pressures between 40 psf and 55 psf as determined by ASCE 7 and when the building's mean roof height is less than or equal to 60 feet

⁽³⁾ For openings larger than 16 inches in either dimension

16⁶ provisions for adjustable ties (i.e., anchors). The use of these prescriptive requirements are limited to masonry veneer assemblies with a weight less than 40 psf, with a cavity depth no more than $\frac{6}{8}$ -inches, and where the ASCE-7⁷ wind velocity pressure (q_z) is less than 55 psf (previously wind speed less than 130 mph). Wall assemblies that exceed these criteria require the design professional to evaluate the building loads and materials and rationally design the anchorage system accordingly. The majority of masonry tie manufacturers have empirical testing data available to support the use of their anchorage systems when the cavity depth or loads exceed these criteria.

Included in Table 1-3 are TMS 402-16⁶ prescriptive spacing requirements for anchored masonry veneers with special requirements for Seismic Design Categories D, E, and F and high wind zones with velocity pressures (q_z) between 40 and 55 psf. These higher seismicity and wind speed areas are common to some parts of the Northwest and are dependent on the geography and building occupancy category. Refer to local building code requirements to ensure seismicity and wind speed criteria are properly evaluated for the building occupancy and site conditions.

Common tie types for reference are shown in Fig. 1-19 on page 1-18. For masonry and concrete walls, adjustable ties are required and may include embedded wire or joint reinforcement or surface-mounted connectors with adjustable ties.



Fig. 1-19 Masonry veneer tie types. Top row, left to right: standard double eye and pintle plate tie, thermally optimized double eye and pintle screw tie, ladder eye-wire tie. Bottom row, left to right: corrugated masonry ties, adjustable L-bracket, nonadjustable surface-mounted tie.

- Based on local preference, double eye and pintle type ties (whether a plate or screw type) are commonly used. Double eye and pintle ties are available from a number of manufacturers in a variety of sizes to meet project requirements in the Northwest.
- Embedded joint reinforcement ties (i.e., ladder eye-wire) may also be used with masonry backup walls. The joint reinforcement includes two eye wires that protrude out from the face of the backup wall at a nominal spacing, extending through the exterior insulation. This tie type is common with CMU backup walls but offers less adjustability and additional coordination for successful placement and use.
- Adjustable L-bracket triangular wire ties are acceptable but may not be preferred by installers because the vertical tie orientation can complicate the exterior insulation installation process by requiring vertical insulation boards.
- Corrugated masonry ties and nonadjustable surface-mounted ties are not allowed by TMS 402-16 for this system.

To prevent pull-out or push-through of the tie, TMS 402-16⁶ requires ties to be embedded a minimum of 1½-inches into the veneer, with at least ⅝-inch mortar

or grout cover at the outside face. The mortar bed thickness is to be at least twice the thickness of the tie. To prevent excess movement between connecting parts of adjustable tie systems, the clearance between components is limited to a maximum ¼-inch. The vertical offset of adjustable pintle-type ties may not exceed 1¼-inches.

Vertical Support

Anchored masonry veneers are supported vertically by the building's foundation or other structural components such as shelf-angle and lintels. An example of both structural-bearing and loose lintel vertical support elements is shown in Fig. 1-20 on page 1-20. Vertical supports are designed to minimize the possibility of cracking and deflection within the veneer; the support design considers the design loads, material type, moisture control, movement provisions, and constructibility.

Per TMS 402-16⁶, anchored masonry veneer with concrete and masonry backings should be supported vertically by noncombustible construction. Best practice for concrete- and masonry-backed veneers is to support the lowest portion of the masonry cladding directly on the concrete foundation.

TMS 402-16⁶ does not place any height restrictions or requirements for intermediate support of masonry with concrete or masonry backings, with the exception of Seismic Design Categories D, E, and F where the veneer is to be supported at each floor line. However, the design should provide intermediate support to accommodate movement and prevent cracking of the veneer associated with differential movement of the veneer, ties, building structure, and other building components. Unless dictated by the code, this guide recommends that intermediate supports are provided every 20 feet or every 2 floors, whichever is greater, for structural considerations and to facilitate drainage and ventilation of the rainscreen cavity.

This guide recommends that intermediate supports for masonry are provided with galvanized-steel shelf angles anchored to the structure as needed to limit deflection to less than L/600 as required by TMS 402-16.⁶ As noted in the Movement Joints sections in this chapter and the introductory chapter, a joint is recommended beneath the angle and closed off from the rainscreen cavity with elastomeric sealant.

Where masonry is supported at openings within the veneer (e.g., windows and doors), shelf angles for larger openings or loose lintels at smaller openings are typically provided. Galvanized-steel loose lintels are recommended except where architectural design dictates reinforced masonry or precast concrete lintels for

appearance. Steel angle lintels span the opening; TMS 402-16⁶ requires the lintel bear a minimum of 4-inches onto the adjacent masonry at the **jamb**s of the opening.

Refer to the details at the end of this chapter for detailing of typical support elements.

Corrosion Resistance

It is best practice to match the durability and longevity of metal components within this system to that expected of the masonry veneer. Metal components within this system include veneer ties, vertical support ledgers and lintels, sheet-metal flashings, and fasteners. This guide includes discussion for common corrosion-resistant materials; however, it is the Designer of Records' responsibility to select a level of corrosion resistance appropriate for project-specific application/exposure and the expected longevity of the masonry system.

It is common to provide hot-dipped galvanized carbon steel masonry veneer ties that comply with ASTM A 153⁸ Class B-2 or AISI Type 304 or 316 stainless steel per ASTM A580,⁹ such as that shown in Fig. 1-21. At minimum, steel support angles such as shelf angle supports and loose lintels are hot-dipped, galvanized, and comply with ASTM A123.¹⁰

Best practice is to use sheet-metal flashing components of ASTM A666¹¹ Type 304 or 316 stainless steel, which is nonstaining and resistant to the alkaline content of mortar materials. Whereas the use of stainless steel sheet-metal flashing components is not always economically feasible or aesthetically desirable, prefinishing sheet-metal may be considered. Where used, this guide recommends the base sheet metal is a minimum G90 hot-dipped, galvanized coating in conformance with ASTM A653¹² or minimum AZ50 galvalume coating in conformance with ASTM A792.¹³ This guide also recommends that the exposed top



Fig. 1-20 Masonry veneer bears on concrete foundation elements below and loose lintel elements above openings as indicated

finish of the sheet metal be coated with an architectural-grade coating conforming to AAMA 621¹⁴ is recommended.

Fasteners used with all metal components should be corrosion-resistant, either hot-dipped galvanized steel or stainless steel to match adjacent metal components.

Masonry Veneer

There are several types of anchored masonry veneer products that may be used with this system. Those most typical within the Northwest include facing brick made of clay or shale. Concrete facing brick and concrete masonry units are also used.

For facing brick made from clay or shale, use anchored veneer units that comply with ASTM C216¹⁵ and are severe weather (SW) grade. When using concrete facing brick, anchored veneer units are to comply with ASTM C1634.¹⁶ Hollow concrete masonry units used for veneer applications are typically 4-inches deep and comply with ASTM C90.¹⁷

Mortar designed for the anchored masonry veneer units is to conform to ASTM C270;¹⁸ the type selected should be appropriate for the veneer application. Type N mortar is acceptable for most anchored masonry veneer applications. When selecting mortar, the lowest compressive strength (softest) mortar that satisfies the project requirements should be used.



Fig. 1-21 Thermally optimized screw tie with stainless-steel hook and barrel as observed at a freestanding mock-up

Appropriate product selection of masonry veneer unit and mortar materials is necessary to provide a durable and water-resistive cladding system. Install the masonry veneer units and mortar joints in conformance with industry standard best practices and manufacturer requirements. Have the specifics of architectural characteristics and structural properties of the masonry veneer units, mortar, and reinforcing designed and reviewed by a qualified Designer of Record.

Various industry resources are available to assist with veneer design and are listed in the Resources section at the back of this guide.

Clear Water Repellents

Application of a clear water repellent to the anchored masonry veneer of this system is common in the Northwest. Refer to the Surface-Applied Clear Water Repellents discussion on page i-59 for more information on selecting an appropriate clear water repellent and for best practice installation guidelines.

Pricing Summary

A pricing summary for this system is provided in Table 1-4 on page 1-24 of this chapter. Pricing demonstrates the relative price per square foot and is based on a 10,000 square foot wall area with easy drive-up access. Pricing includes all components outboard of the CMU wall structure and provides no evaluation for interior finishes or CMU wall structure. Pricing for this system is for a CMU backup wall structure; a concrete backup wall structure is expected to be comparable. Pricing is valid for the 2018 calendar year. Current pricing is also available at www.masonrysystemsguide.com.

Online Availability

The content of this guide and additional resources may be accessed at www.masonrysystemsguide.com, along with downloadable versions of two- and three-dimensional system details and cutaway sections as well as sample project specifications and ongoing updates to references and resources included within this guide.

Chapter References

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7. American Society of Civil Engineers. *Minimum Design Loads for Buildings and Other Structures*, ASCE/SEI 7-10. (Reston, VA: ASCE Press, 2013).

8. ASTM International. *ASTM A153/A153M-16a Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*. (West Conshohocken, PA: ASTM International, 2016).

9. ASTM International. *ASTM A580/580M-16 Standard Specification for Stainless Steel Wire*. (West Conshohocken, PA: ASTM International, 2016).

10. ASTM International. *ASTM A123/A123M-15 Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products*. (West Conshohocken, PA: ASTM International, 2015).

11. ASTM International. *ASTM A666-15 Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar*. (West Conshohocken, PA: ASTM International, 2015).

12. ASTM International. *ASTM A653/A653M-15e1 Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process*. (West Conshohocken, PA: ASTM International, 2015).

13. ASTM International. *ASTM A792 /A792M-10(2015) Standard Specification for Steel Sheet, 55% Aluminum-Zinc Alloy-Coated by the Hot-Dip Process*. (West Conshohocken, PA: ASTM International, 2015).

14. American Architectural Manufacturers Association. *AAMA 621-02 Voluntary Specification for High-Performance Organic Coatings in Coil-Coated Architectural Hot-Dipped Galvanized (HDG) and Zinc-Aluminum Coated Steel Substrates*. (Schaumburg, IL: American Architectural Manufacturers Association, 2002).

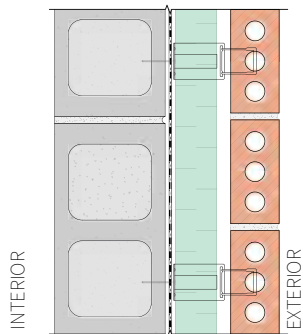
15. ASTM International. *ASTM C216-17 Standard Specification for Facing Brick (Solid Masonry Units Made from Clay or Shale)*. (West Conshohocken, PA: ASTM International, 2017).

16. ASTM International. *ASTM C1634-16 Standard Specification for Concrete Facing Brick*. (West Conshohocken, PA: ASTM International, 2016).

17. ASTM International. *ASTM C90-16a Standard Specification for Loadbearing Concrete Masonry Units*. (West Conshohocken, PA: ASTM International, 2016).

18. ASTM International. *ASTM C270-14a Standard Specification for Mortar for Unit Masonry*. (West Conshohocken, PA: ASTM International, 2014).

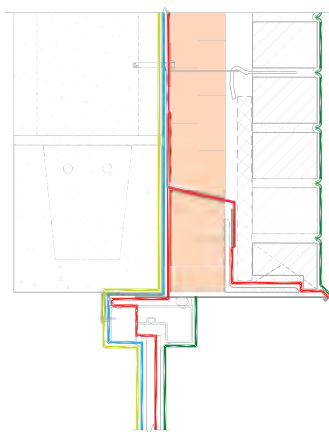
Table 1-4 System 1A and System 1B CMU (or concrete alternative) wall with anchored masonry veneer pricing summary

System 1A and 1B: CMU (or concrete) Wall with Anchored Masonry Veneer					
System Component	Baseline Product	Alternate (call for estimate)	Baseline Cost/ft ² (incl. labor)		
			Low	High	
INTERIOR					
1	Structural CMU (or concrete) wall	No evaluation of these components provided.			
2*	Air and water-resistant system	Fully adhered sheet-applied membrane system	Fluid-applied membrane system	\$1.50	\$3.75
3*	Exterior insulation	Rigid XPS board insulation; 2-inch thickness	No specified alternate	\$2.75	\$3.25
4	Air cavity	Not applicable	Not applicable		
5*	Anchored masonry veneer (without ties)	SW brick masonry modular unit (3-5/8" x 2-1/4" x 7-5/8") FBX, running bond; Type S or N mortar	No specified alternate	\$25.00	\$27.80
6*	Anchored masonry veneer ties	14 ga hot-dipped galvanized or stainless-steel plate tie, including fasteners	Thermally optimized screw tie with stainless or hot-dipped galvanized hook	\$2.50	\$5.00
7*	Clear water repellent	Silane/siloxane blend	Antigraffiti clear water repellent	\$1.75	\$2.50
EXTERIOR					
Total cost to install 10,000 sq ft wall area w/easy drive-up access -->				\$33.50	\$42.30
Pricing Summary Discussion			System Plan View		
<ul style="list-style-type: none">- Low and high baseline costs are based on baseline products and installed labor costs. Call for an estimate for alternative product pricing.- Baseline costs provided will vary based on product-specific conditions as well as project location and should be used as an estimate only.- Veneer unit prices is for typical units as noted. Pricing will vary based on size, color, and finish and should be confirmed with the unit manufacturer.- *See the Resources Section of this guide for product recommendation					

LEGEND

1. Typical Assembly:
 - Single-wythe CMU wall
 - Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
 - Exterior insulation
 - Air cavity
 - Anchored masonry veneer with
 - Clear water repellent
2. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per air barrier and WRB system manufacturer recommendations
3. Continuous mortar collection mesh
4. Self-adhered sheet or fluid-applied air barrier and WRB prestrip membrane
5. Hot-dipped galvanized-steel loose lintel
6. Vent/weep at maximum 24-inches on-center
7. Two-piece sheet-metal head flashing with hemmed drip edge and end dams (beyond)
8. Sheet-metal trim
9. Sealant over backer rod
10. Continuous air barrier sealant tied to continuous seal at window perimeter
11. Continuous back dam angle at rough opening perimeter, minimum 1-inch tall with window fastened through back dam angle per window manufacturer recommendations
12. Storefront window

Water-Shedding Surface and Control Layers

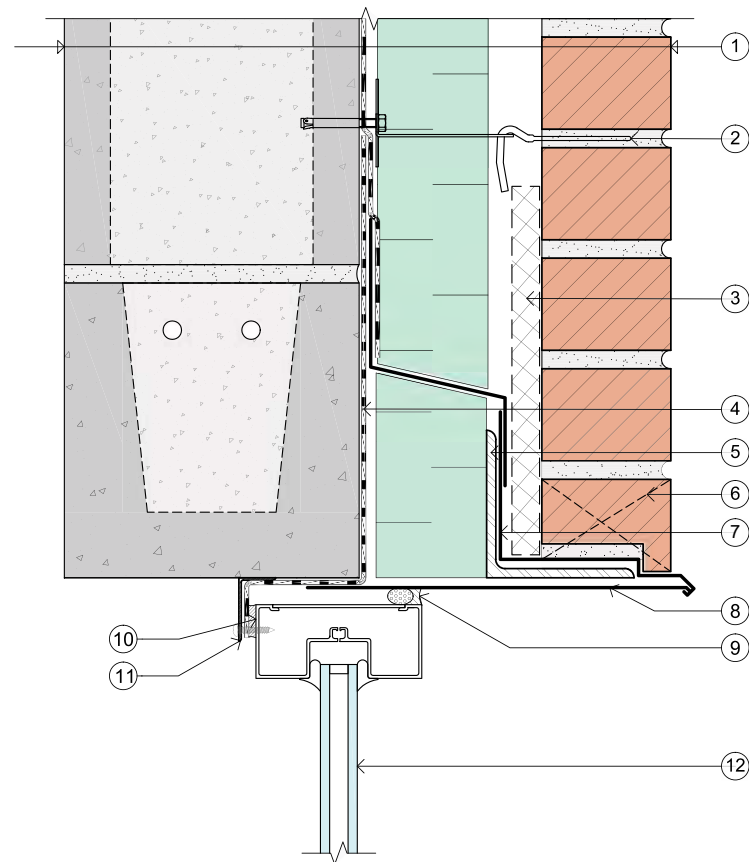


Water-Shedding Surface

Control Layers:*

- Water
- Air
- Vapor
- Thermal

* Where a Class I or II permeance (and sometimes Class III permeance) air barrier and WRB field and prestrip membrane exist



Detail Discussion

- Air and water control layer continuity is provided by the self-adhered sheet- or fluid-applied air barrier and WRB field membrane, prestrip membrane, and air barrier sealant transition to the storefront window.
- The hot-dipped galvanized-steel loose lintel location allows exterior insulation to be continuous up to the rough opening. It may be replaced with a standoff shelf angle support where vertical support is required (such as at a floor line).
- For a thermal improvement, the two-piece sheet-metal flashing may be replaced with a self-adhered flashing membrane as shown similarly in Fig. i-31 on page i-47. Where replaced, the self-adhered flashing membrane should be compatible with the air barrier and WRB system.
- The hemmed drip edge of the sheet-metal head flashing sheds water from the anchored masonry veneer above before it reaches the window and sill.

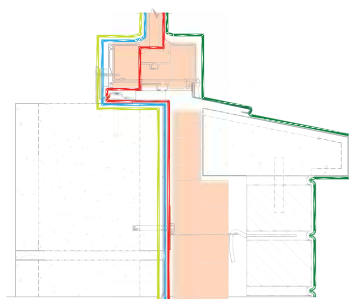
Typical Loose Lintel at Window Head

Detail 1-A

LEGEND

1. Typical Assembly:
 - Single-wythe CMU wall
 - Self-adhered sheet or fluid-applied air barrier and WRB field membrane
 - Exterior insulation
 - Air cavity
 - Anchored masonry veneer with
 - Clear water repellent
2. Storefront window on minimum ¼-inch-thick intermittent shims
3. Sealant over backer rod
4. Sloped sheet-metal sill flashing with hemmed edge and end dams (beyond)
5. Sloped precast sill, sealant over backer rod (beyond), where applicable
6. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
7. Continuous air barrier sealant tied to continuous seal at window perimeter
8. Continuous back dam angle at rough opening perimeter, minimum 1-inch tall, with window fastened through back dam angle per window manufacturer recommendations
9. Fluid-applied or self-adhered flashing membrane

Water-Shedding Surface and Control Layers

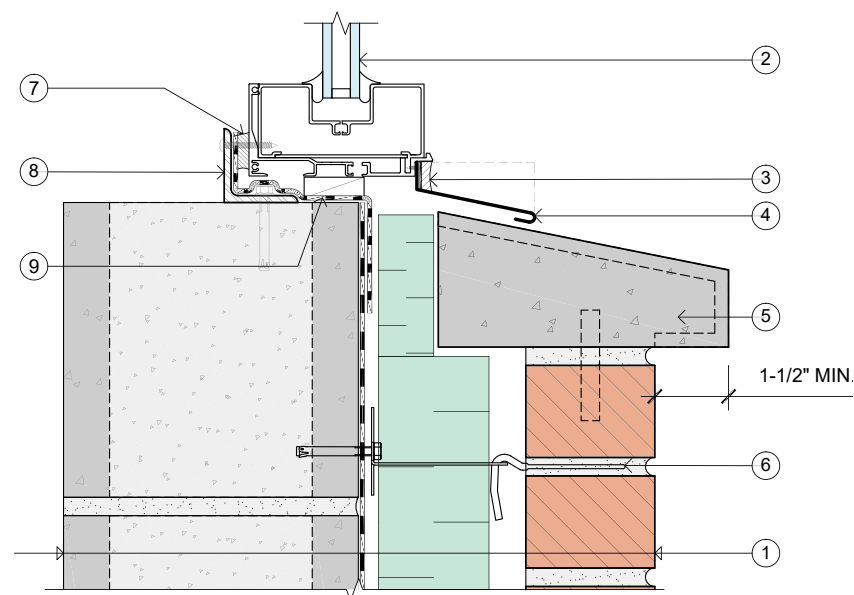


Water-Shedding Surface

Control Layers:*

Water
Air
Vapor
Thermal

* Where a Class I or II permeance (and sometimes Class III permeance) air barrier and WRB field and prestrip membrane exist



Detail Discussion

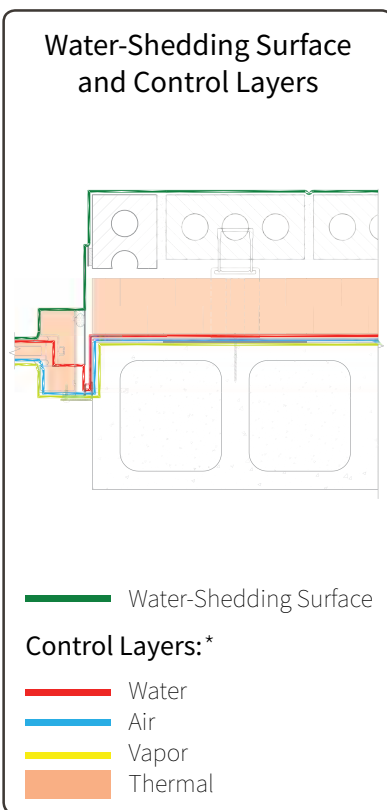
- Air and water control layer continuity is provided by the self-adhered sheet- or fluid-applied air barrier and WRB field membrane, fluid-applied or self-adhered flashing membrane at the sill, and air barrier sealant transition to the storefront window.
- The sheet-metal sill flashing conceals the rainscreen cavity and protects the cavity insulation from UV exposure. Terminate the sheet-metal sill flashing with end dams at each jamb and counterflash each end dam with the sheet-metal jamb trim to close off the rainscreen cavity and complete the water-shedding surface.
- This guide recommends that a sheet-metal flashing is **not** placed below the precast sill. It can prematurely degrade the mortar bed beneath the precast element.

Typical Precast and Sheet-Metal Windowsill

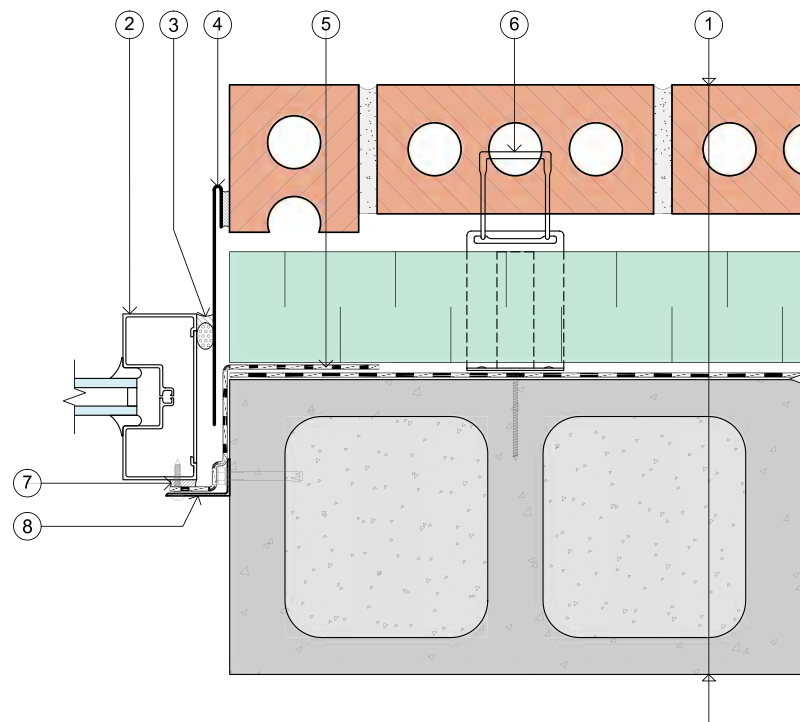
Detail 1-B

LEGEND

1. Typical Assembly:
 - Single-wythe CMU wall
 - Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
 - Exterior insulation
 - Air cavity
 - Anchored masonry veneer with
 - Clear water repellent
2. Storefront window
3. Sealant over bond breaker
4. Sheet-metal jamb trim, attached to intermittent L-angles at window per manufacturer recommendations. Counterflash sheet-metal sill flashing end dams (beyond). Bed sheet-metal trim in sealant at anchored masonry veneer return.
5. Self-adhered or fluid-applied sheet air barrier and WRB prestrip membrane
6. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
7. Continuous air barrier sealant, tie to continuous seal at window perimeter
8. Continuous back dam angle at rough opening perimeter, minimum 1-inch tall. Fasten window through back dam angle per window manufacturer recommendations



* Where a Class I or II permeance (and sometimes Class III permeance) air barrier and WRB field and prestrip membrane exist



Detail Discussion

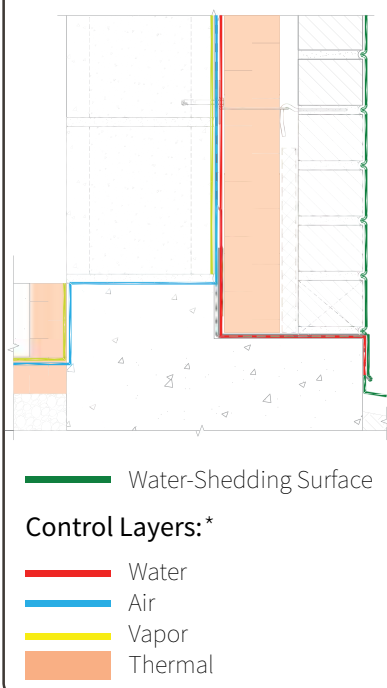
- Air and water control layer continuity is provided by the self-adhered sheet- or fluid-applied air barrier and WRB field membrane, prestrip membrane, and air barrier sealant transition to the storefront window.
- The sheet-metal jamb trim is bed in continuous sealant against the anchored masonry veneer to provide water-shedding surface continuity.
- Exterior insulation should be tightly installed around all penetrations including masonry ties.

Typical Window Jamb
Detail 1-C

LEGEND

1. Typical Assembly:
 - Single-wythe CMU wall
 - Self-adhered sheet or fluid-applied air barrier and WRB field membrane
 - Exterior insulation
 - Air cavity
 - Anchored masonry veneer with
 - Clear water repellent
2. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
3. Continuous mortar collection mesh
4. Sheet-metal flashing with hemmed drip edge and end dams beyond
5. Fluid-applied or high temperature self-adhered flashing membrane
6. Vent/weep at maximum 24-inches on-center
7. Typical Assembly:
 - Concrete floor slab
 - Vapor barrier
 - Rigid XPS insulation
 - Capillary break
8. Rigid XPS insulation thermal break

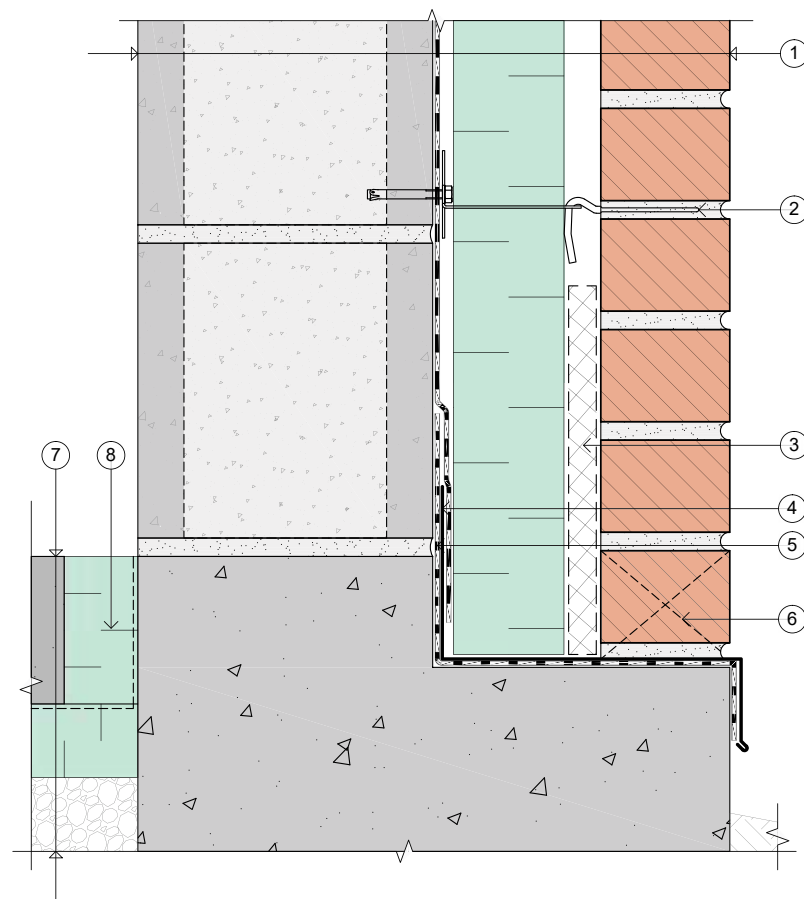
Water-Shedding Surface and Control Layers



* Where a Class I or II permeance (and sometimes Class III permeance) air barrier and WRB field and prestrip membrane exist

Detail Discussion

- A significant thermal bridge occurs at the foundation element. The insulation between the concrete floor slab and concrete foundation wall is typically referred to as a thermal break and helps reduce the amount of heat loss at the floor slab perimeter and concrete foundation element.
- Vents/weeps at the wall base drain the rainscreen cavity and assist with air cavity ventilation. The mortar collection mesh helps keep vents/weeps clear of mortar droppings.



Typical Foundation Detail

Detail 1-D

LEGEND

1. Typical Assembly
 - Single-wythe CMU wall
 - Self-adhered sheet or fluid-applied air barrier and WRB field membrane
 - Exterior insulation
 - Air cavity
 - Anchored masonry veneer with
 - Clear water repellent
2. Inverted roof membrane assembly
3. Sloped standing-seam sheet-metal coping with gasketed washer fasteners
4. High-temperature self-adhered membrane
5. Preservative-treated wood blocking
6. Compressible filler
7. Vents at maximum 24-inches on-center
8. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations

* Size gap for project specific movement, minimum 3/8-inch

Water-Shedding Surface and Control Layers



Water-Shedding Surface

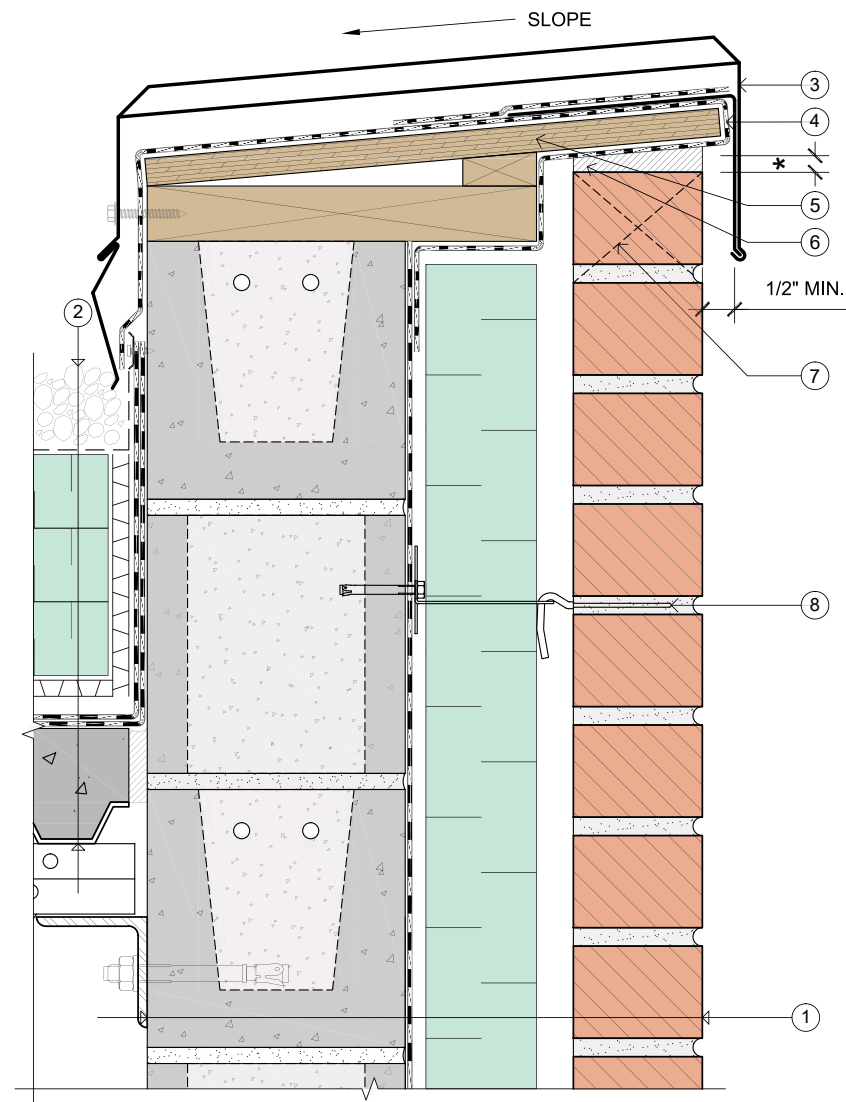
Control Layers:[†]

- Water
- Air
- Vapor
- Thermal

[†] Where a Class I or II permeance (and sometimes Class III permeance) air barrier and WRB field and prestrip membrane exist

Detail Discussion

- The sheet-metal parapet coping with hemmed drip edge is held off the anchored masonry veneer face to minimize disruption of air flow through the vents. A 1/2-inch gap is recommended.
- The self-adhered sheet or fluid-applied air barrier and WRB field membrane, high temperature self-adhered membrane, and roof membrane provide the air and water control layers in this detail.
- A compressible filler is used between the anchored masonry veneer and parapet blocking to allow building movement while preventing insects and debris from entering the rainscreen cavity.
- This detail may be thermally improved by framing the parapet on top of the roof structure and insulating the parapet cavity similar to Detail 2-E.



Typical Parapet at Inverted Roof Membrane Assembly

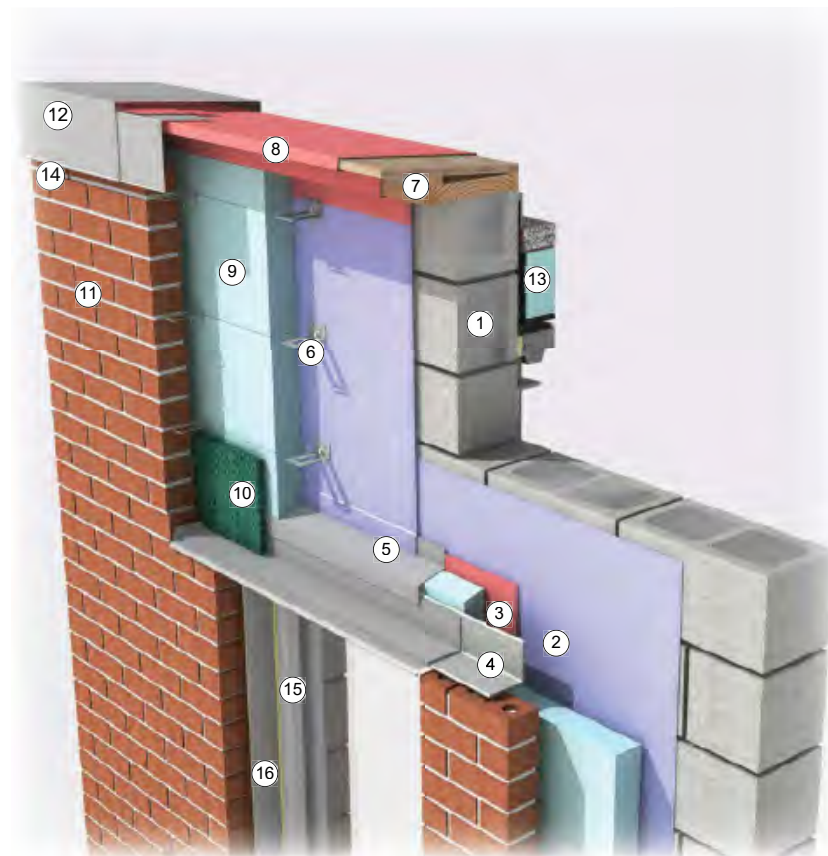
Detail 1-E

LEGEND

1. Single-wythe CMU wall
2. Self-adhered sheet or fluid-applied air barrier and WRB field membrane
3. Self-adhered sheet or fluid-applied air barrier and WRB prestrip membranes
4. Hot-dipped galvanized-steel loose lintel
5. Two-piece sheet-metal head flashing with hemmed drip edge and end dams
6. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
7. Sloped preservative-treated wood blocking
8. High-temperature self-adhered membrane
9. Exterior insulation
10. Continuous mortar collection mesh
11. Anchored masonry veneer
12. Sloped standing-seam sheet-metal coping with gasketed washer fasteners
13. Inverted roof membrane assembly and roof structure
14. Vents at maximum 24-inches on-center
15. Storefront window
16. Sheet-metal jamb trim and sealant over bond breaker

3-D Detail Discussion

- Three-dimensional cutaway sections on the next three pages represent two-dimensional details of this system.
- In all details, water control layer elements are shingle-lapped to encourage liquid water drainage.
- As shown in Detail 1-F, horizontally oriented ties, such as a double eye and pintle plate ties, allow exterior insulation to be installed in horizontal strips between ties. This orientation can improve the efficiency of the anchored masonry veneer installation.
- The two-piece sheet-metal flashing at the window head, as shown in Detail 1-F, allows the upper flashing to be installed and integrated into the air barrier and WRB system prior to installation of the lower sheet-metal flashing and hot-dipped galvanized-steel loose lintel.
- As shown in Detail 1-F, the sheet-metal flashing above the lintel ends at a head joint. This location allows the sheet-metal head flashing to terminate with an end dam.
- Vents/weepers at the wall base, as shown in Detail 1-G provide both drainage and ventilation of the rainscreen cavity. Mortar collection mesh helps keep the vents/weepers and base flashing area free of mortar droppings.
- Detail 1-H describes a typical rough opening with continuous back dam angle. The back dam angle creates a sill pan below the window; intermittent shims below the storefront window promote drainage at the sill and into the rainscreen cavity.
- The sheet-metal jamb trim shown in all details conceals the rainscreen cavity from water exposure and protects the insulation from UV exposure.
- Exterior insulation should be tightly installed around all penetrations, including masonry ties.

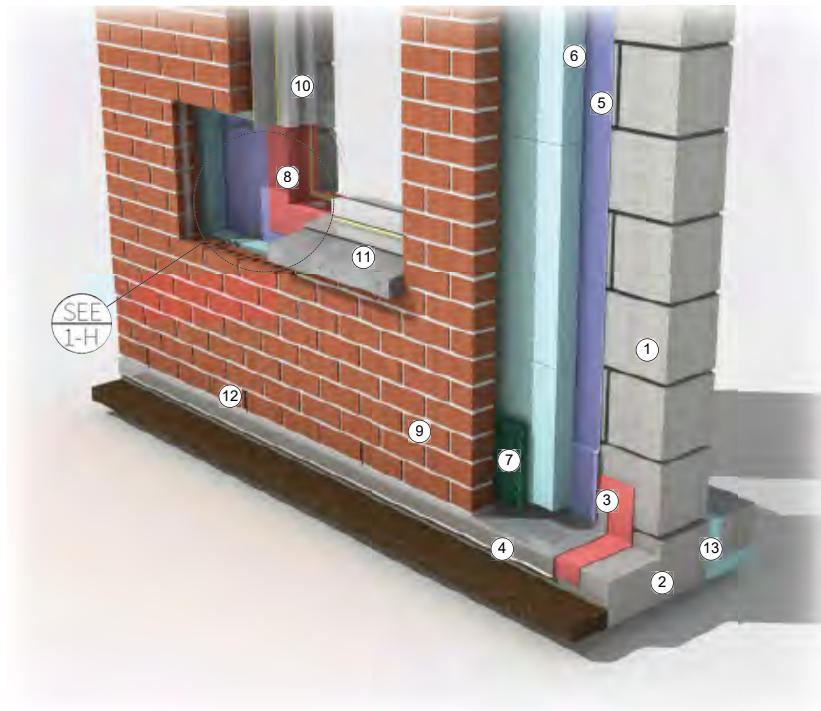


Parapet Cutaway Section

Detail 1-F

LEGEND

1. Single-wythe CMU wall
2. Concrete foundation element
3. Fluid-applied or self-adhered flashing membrane
4. Sheet-metal base flashing with hemmed drip edge and end dams (beyond)
5. Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
6. Exterior insulation
7. Continuous mortar collection mesh
8. Self-adhered sheet- or fluid-applied air barrier and WRB prestrip membrane and fluid-applied or self-adhered flashing sill membrane
9. Anchored masonry veneer
10. Storefront window
11. Sloped precast concrete sill with sloped sheet-metal sill flashing
12. Vent/weep at maximum 24-inches on-center
13. Rigid XPS insulation thermal break

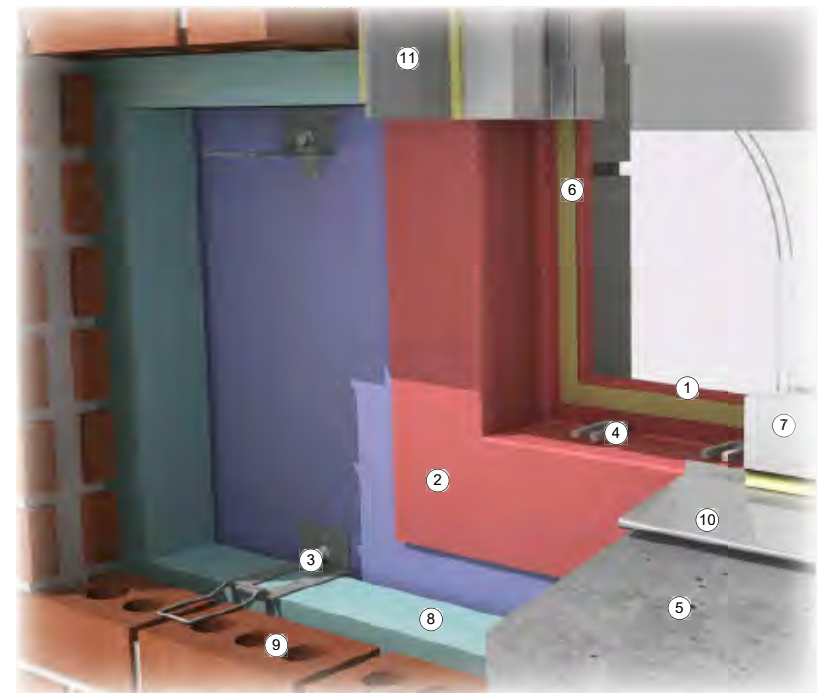


Base of Wall Cutaway Section

Detail 1-G

LEGEND

1. Continuous back dam angle at rough opening perimeter, minimum 1-inch tall, with window fastened through back dam angle per window manufacturer recommendations
2. Self-adhered sheet- or fluid-applied air barrier and WRB prestrip membranes at jamb and sill
3. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
4. Minimum 1/4-inch thick intermittent shims
5. Sloped precast concrete sill
6. Continuous air barrier sealant tied to continuous seal at window perimeter
7. Storefront window
8. Exterior insulation
9. Anchored masonry veneer
10. Sloped sheet-metal sill flashing with hemmed edge
11. Sheet-metal jamb trim with hemmed edge, bed in sealant against anchored masonry veneer



Typical Window and Jamb Cutaway Section

Detail 1-H

CHAPTER 2:**STEEL-FRAMED WALL WITH ANCHORED MASONRY VENEER**

Masonry system 2 is a rainscreen wall system with steel-framed wall structure and anchored masonry veneer. The typical components of this system, from interior to exterior, are described below in Fig. 2-1. This system is appropriate for many applications including low-, mid-, or high-rise residential or commercial buildings. An example project application of this system is shown in Fig. 2-2 on page 2-2.

Building Enclosure & Control layers

As noted in the Introduction, an above-grade wall system controls liquid water, air, heat, and possibly water vapor to function as an effective and durable environmental separator. Control of these elements, specific to this wall system, is provided by the following control layer systems and/or materials:

- The water control layer, comprising the water-resistive barrier (WRB) system.
- The air control layer, comprising the air barrier system.

INTERIOR

- Interior gypsum board
- Vapor retarder
- Steel-framed wall with batt insulation
- Exterior sheathing
- Air and water-resistive barrier membrane
- Semi-rigid exterior insulation
- Air cavity
- Anchored masonry veneer with
- Clear water repellent

EXTERIOR

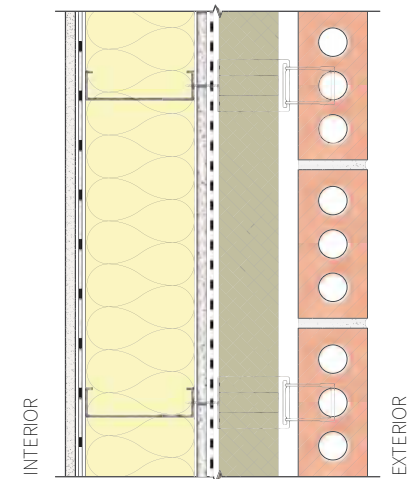


Fig. 2-1 Typical System 2 components from interior to exterior

- The thermal control layer, comprising thermal insulation and other low-conductivity materials.
- The vapor control layer, comprising vapor retarding materials.

For a summary of the relationship between building enclosure loads, control layers, and associated systems and materials, refer to Fig. i-13 on page i-21 of the introductory chapter.

Fig. 2-3 illustrates the water-shedding surface and control layer locations for this system. The water-shedding surface and control layers for typical system details are also provided adjacent to each detail at the end of this chapter.



Fig. 2-2 Steel-framed wall with anchored masonry veneer example project application

As shown in Fig. 2-3, the water-shedding surface is located at the anchored masonry veneer, with most water-shedding occurring at the wall face while some water will be stored within the masonry veneer to be released at a later time. The water control layer and the air control layer occur at the same location exterior of the wall sheathing. The thermal control layer occurs at the framed wall cavity insulation and exterior insulation. The vapor control layer occurs at the interior (warm-in-winter side) of the steel-framed structure.

Water-Shedding Surface

The water-shedding surface reduces the water load on the enclosure. A general discussion of the water shedding surface is provided in the Water-Shedding Surface discussion on page i-19.

The anchored masonry veneer cladding, including both mortar joints and masonry veneer units, is the primary water-shedding surface of the wall system. Additional water-shedding surface components within the wall system include sheet-metal flashings, drip edges, sealant joints, and fenestration systems as shown in the details at the end of this chapter.

To promote water shedding at the masonry veneer face, install mortar joints with a tooled concave (preferred) or “V” shape.

The water-shedding surface is most effective when free of gaps other than those providing drainage and/or ventilation. Movement joints and joints around fenestrations and penetrations should be continuously sealed with backer rod and sealant or counterflashed with a sheet-metal flashing to deflect wind-driven rain and shed water away from the rainscreen cavity.

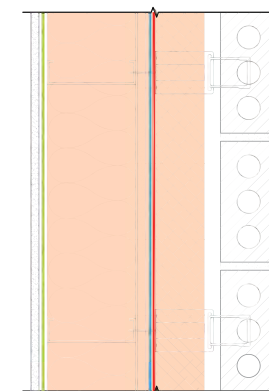
Water Control Layer

The water control layer is a continuous control layer that is designed and installed to act as the innermost boundary against water intrusion. In a rainscreen wall system, the WRB system is the last line of defense against water intrusion. A general discussion of the WRB system is provided in the Water Control Layer discussion on page i-24.

In this wall system, the WRB system is typically a self-adhered sheet or fluid-applied system that also functions as the air barrier system; thus, the WRB system is often referred to as the air barrier and WRB system. Either a self-adhered sheet or fluid-applied system is depicted in the details at the end of this chapter. An example of a fluid-applied air barrier and WRB system field membrane is shown in Fig. 2-4 on page 2-4. The air barrier and WRB system for this wall system may have:

- Class IV vapor permeance properties regardless of the insulation R-value placed within the wall cavity relative to the insulation placed exterior of the air barrier and WRB system.
- Class I and II vapor permeance properties when at least $\frac{1}{2}$ to $\frac{3}{4}$ the total nominal insulation R-value of the wall system is placed exterior of the air barrier and WRB system. For this case, the air barrier and WRB system will also function as the vapor control layer. As a result, a separate vapor retarder

Water-Shedding Surface and Control Layers



— Water-Shedding Surface

Control Layers:

— Water
— Air
— Vapor
— Thermal

Fig. 2-3 System 2 water-shedding surface and control layer locations



Fig. 2-4 Double eye and pintle plate ties are attached through self-adhered membrane patches over top of the fluid-applied air barrier and WRB systems. Ties penetrate the continuous rigid insulation.

membrane (as shown typical on page 1 of this chapter at the interior side of the framing) may be omitted.

- Class III vapor permeance properties when carefully evaluated against other system material properties and the thermal control layer.

Physical properties of the WRB system products, are discussed in detail in the Water Control Layer discussion on page i-24. Vapor permeability of materials is addressed in the Vapor Control Layer discussion on page i-28.

The air barrier and WRB system must be continuous across the wall system to provide effective water control. In addition to the field membrane, the WRB system includes fluid-applied or self-adhered flashing membranes, sealants, sheet-metal flashings, and penetrations such as windows and doors as shown in the detail drawings that follow this chapter discussion. Where sheet-metal flashing components occur within the system, the back leg of the sheet-metal flashing is shingle-lapped into the WRB system to facilitate drainage at the face of the WRB system and to the exterior of the cladding.

Masonry veneer ties in this system will penetrate the WRB system and should be sealed as required by the WRB system manufacturer's installation requirements. Typically, plate ties are bed in a compatible sealant or fluid-applied flashing product or are attached through a self-adhered membrane patch, whereas screw ties with gasketing washers are typically not required to be sealed.

Air Control Layer

The air barrier system serves as the air control layer. In addition to controlling air, this layer also assists with controlling liquid water, heat, and water vapor.

For this wall system, the air barrier system consists of the same field membrane and many of the components that also serve as the WRB system. A general discussion of the air control layer and the air barrier system is provided in the Air Control Layer discussion on page i-26.

As discussed in the Introduction, the air barrier system must be continuous and fully sealed to resist air flow, whereas the WRB system need not be continuously sealed to be effective, merely shingle lapped.

Vapor Control Layer

The vapor control layer retards or greatly reduces (e.g., vapor barrier) the flow of water vapor due to vapor pressure differences across enclosure assemblies. Unlike the other control layers presented in this guide, the vapor control layer is not always necessary or required to be continuous.

When a Class IV permeance air barrier and WRB system is used within this wall system, typically a vapor retarder (Class II) is located at the face of or just behind the interior gypsum board. The vapor retarder for this system should comply with Section 1405.3 of the governing International Building Code (IBC).¹ In the Northwest, typical vapor retarder products include PVA vapor-retarding primer, asphalt-coated kraft paper, or a polyamide film retarder membrane. Refer to the Vapor Control Layer discussion on page i-28 for additional information.

When a Class I or II permeance air barrier and WRB system is used within this wall system, the WRB system becomes the vapor control layer and a separate vapor control layer (as shown in Fig. 2-1) is not necessary. Note that in this case, the thermal insulation R-value within the framed wall cavity is recommended by this guide to be $\frac{1}{2}$ to $\frac{1}{3}$ the total nominal insulation R-value of the wall system.

Thermal Control Layer

The thermal control layer controls heat flow and assists with controlling water vapor.

In this wall system, the framed cavity and exterior insulation are the primary materials that form the thermal control layer. At transition details the thermal control layer also includes exterior insulation across floor lines; parapet cavity insulation; and insulation at the roof assembly, slab, and foundation elements. Windows and doors that penetrate this system are also part of the thermal control layer.

Additional thermal control layers information is provided in the Thermal Control Layer discussion on page i-30 of the introductory chapter.



Fig. 2-5 Semi-rigid mineral fiber insulation with thermally optimized masonry ties

Insulation Selection

The cavity insulation in this system is typically a fiberglass or mineral fiber batt insulation product.

The exterior insulation in this wall system is typically semi-rigid mineral fiber board insulation (R-4.2/inch)—which is hydrophobic, tolerates moisture, and has free-draining capabilities. Its vapor permeance makes it acceptable for use exterior of a high-permanence air barrier and WRB system without inhibiting assembly drying. An example of this insulation is shown in Fig. 2-5 on page 2-6. The semi-rigid properties of the insulation allow it to fit tightly around penetrations such as masonry veneer ties.

Exterior insulation such as XPS or moisture-resistant polyisocyanurate may be appropriate when a Class I or II permeance air barrier and WRB system is used. Refer to the Insulation Products discussion on page i-30 for a discussion on various insulation types and additional considerations.

Although masonry is defined as a noncombustible cladding material, the use of a combustible air barrier and WRB system or foam plastic insulation within a wall cavity can trigger fire propagation considerations and requirements. Depending on the local jurisdiction, IBC Section 1403.5¹ regarding vertical and lateral flame propagation as it relates to a combustible WRB system may require acceptance criteria for NFPA 285.² The use of foam plastic insulation within a wall cavity should also be addressed for IBC Chapter 26 provisions.

Thermal Performance and Energy Code Compliance

This wall system is typically classified as a metal-framed (or steel-framed) above-grade wall for energy code compliance purposes. Prescriptive energy code compliance values for this wall system are summarized in Table 2-3 on page 2-13 and describe:

- Minimum insulation R-values for a *prescriptive insulation R-value method* strategy.
- Maximum system U-factors for a *prescriptive assembly U-factor method* strategy. Note that the equivalent effective R-value of this U-factor has been calculated and is denoted in parenthesis () for easy comparison to thermal modeling results included within this chapter.

For cavity insulation, steel stud walls are typically constructed with 16-inch on-center stud spacing and can accommodate up to an R-15 batt insulation for 3-5/8-inch studs or R-21 batt insulation for 6-inch studs. Alternative insulation products may also be used to fill the cavity. Because of its high thermal conductivity, steel framing can reduce the nominal R-value of the stud cavity insulation by approximately 40 to 60%. For this reason, continuous insulation is typically needed to meet prescriptive energy code compliance strategies.

For all energy code compliance strategies except the *prescriptive insulation R-value method strategy*, the system's thermal performance will need to be determined as a U-factor either through calculation or from tables; however, it may or may not be required to be less than the prescriptive U-factors shown in Table 2-3 on page 2-13.

Project-specific thermal performance values for an opaque above-grade wall should be used for energy code compliance and determined from a source that is approved by the authority having jurisdiction. Thermal performance sources may include ASHRAE 90.1,³ COMcheck,⁴ the appendices of the 2015 WSEC,⁵ thermal modeling and calculation exercises, or other industry resources.

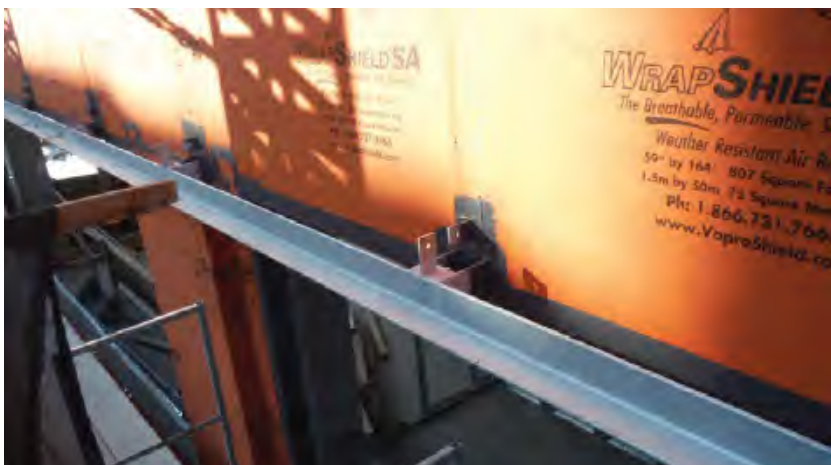


Fig. 2-6 Hot-dipped galvanized standoff shelf angle

The Thermal Performance and Energy Code Compliance discussion on page i-33 and Fig. i-26 on page i-39 of the introductory chapter describes the typical process of navigating energy code compliance options. Additionally, the thermal modeling results demonstrated in this chapter may be used to assist with selecting wall system components (e.g., tie type, insulation R-value/inch, etc.) to achieve a target U-factor. Options for thermally optimizing this system, as determined through the modeling results, are also discussed.

System Effective Thermal Performance

Masonry ties and floorline shelf angles penetrate the exterior insulation in this system and create areas of thermal bridging; thermal bridging reduces the system's actual thermal performance.

Examples of typical anchored masonry veneer ties and a standoff shelf angle support are shown in Fig. 2-6 and Fig. 2-7; the relative thermal bridging that these components can have when penetrating exterior insulation is illustrated in Fig. 2-8 through Fig. 2-13 on page 2-10. Where shown in Fig. 2-9, Fig. 2-11, and Fig. 2-13 the lighter blue thermal gradient color at the attachment describes a warmer temperature than the adjacent darker blue insulation face, which is an indicator of heat loss at the penetration through the insulation. Thermal bridging of the steel studs and concrete slabs are also depicted where the thermal gradient is orange (warmer) at studs and transitions to yellow (cooler) where cavity insulation occurs. This thermal bridging reduces the system's effective thermal performance.

Three-dimensional thermal modeling demonstrates this system's effective thermal performance with various insulation thicknesses, insulation R-values, masonry veneer ties, and standoff shelf angle support options. A discussion on the modeling performed for this guide is included in the Appendix.

Thermal Modeling: Variables

The following are modeling variables specific to this wall system:

- **Framing and Cavity Insulation:** 3½-inch steel stud wall with R-15 batt insulation or 6-inch steel stud with R-21 batt insulation. A full-height steel stud wall includes the top and bottom track adjacent to a concrete slab but does not include the wall area at the slab edge.

- **Masonry Ties:** Various tie types are considered at 16-inches by 16-inches on-center spacing. Tie types are shown in Fig. 2-7 and include:

- Thermally optimized screw tie with stainless steel barrel and carbon steel fastener. Hooks are either hot-dipped galvanized steel or Type 304 stainless steel.
- Double eye and pintle plate tie (14-gauge). Hooks are either hot-dipped galvanized steel or Type 304 stainless steel to match the tie plate.

- **Exterior Insulation:** R-4.2/inch or R-6/inch insulation product. Insulation thicknesses of 2-, 3-, and 4-inches are considered. The R-values selected demonstrate the lower and upper thermal resistance of typical exterior insulation products.

- **Shelf Angle Supports:** For energy code compliance purposes, the peripheral concrete slab edges that typically occur on a building with this system are classified as a mass above-grade wall; opaque mass wall thermal envelope requirements may be found in tables within Chapters 1, 4, 5, and 6. As a result, the influence the slab edge has on the steel stud system's effective R-value is not included within the system modeling results but is presented separately. Shelf angle supports are either attached tight to the floor line structure (i.e., continuous shelf angle) as shown in Fig. 2-10 and Fig. 2-11 or offset to the



Fig. 2-7 Brick tie types used for modeling—from top to bottom: thermally optimized screw tie and double eye and pintle plate tie

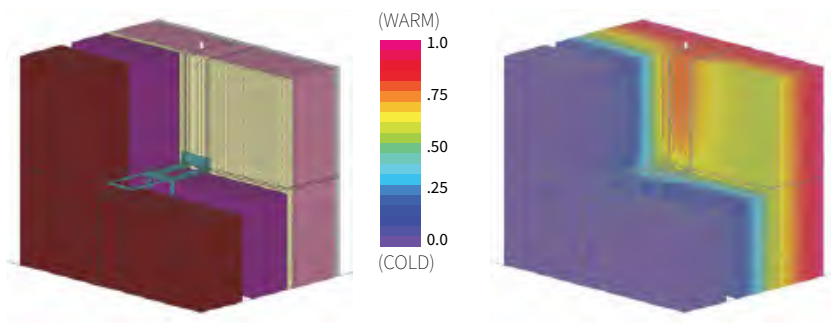


Fig. 2-8 Three-dimensional section of a galvanized steel masonry tie through exterior insulation

Fig. 2-9 Three-dimensional thermal image of the galvanized-steel masonry tie depicted in Fig. 2-8



Fig. 2-10 Three-dimensional section of a continuous floor line shelf angle supporting anchored masonry veneer

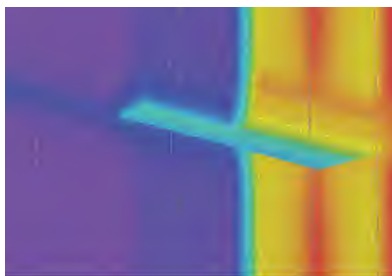


Fig. 2-11 Three-dimensional thermal image of the continuous floor line shelf angle shown in Fig. 2-10

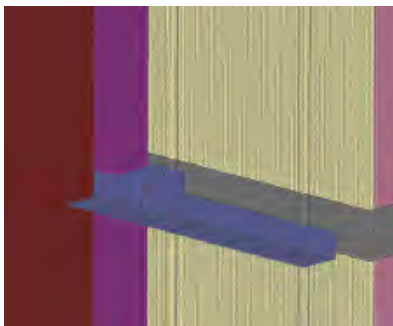


Fig. 2-12 Three-dimensional section of a standoff floor line shelf angle supporting anchored masonry veneer

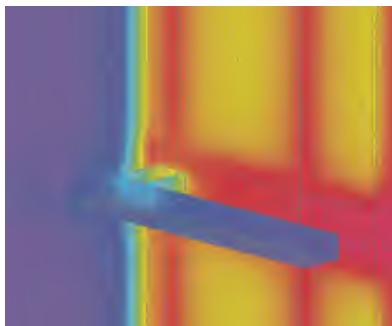


Fig. 2-13 Three-dimensional thermal image of the standoff floor line shelf angle shown in Fig. 2-12

depth of the exterior insulation and supported by intermittent hollow steel sections (HSS) at 4 feet on-center (i.e., standoff shelf angle) as shown similar in Fig. 2-12 and Fig. 2-13. Slab edge modeling results consider the effects of the steel stud system above and below.

Thermal Modeling: Results

Modeling results are shown in Table 2-1, Table 2-2, Fig. 2-14, and Fig. 2-15 (see page 2-12 and page 2-13) for 3½-inch steel stud walls and Table 2-4, Table 2-5, Fig. 2-16, and Fig. 2-17 (see page 2-14 and page 2-15) for 6-inch steel stud walls demonstrate the system's effective R-value. Figure references graphically represent the results summarized in each table.

Below is a discussion of the results. Where reductions in the system's effective R-value are discussed, these values are as compared to the system's effective R-value "Without Penetrations" such as ties and shelf angles.

- As determined from Table 2-1 and Table 2-4, the system's effective R-value is reduced by 9 to 33% when considering tie penetrations. Note that a 16-inch by 16-inch on-center spacing is modeled for this guide; *reducing the frequency of ties can increase the system effective R-value; however, spacing needs to be coordinated with structural requirements.*
- As determined from Table 2-1 and Table 2-4, stainless-steel plate ties reduce the system's effective R-value by 8 to 16%, while galvanized-steel plate ties reduce the effective R-value by 18 to 33%. Stainless-steel plate ties reduce the effective R-value less than both galvanized-steel and thermally optimized tie options as shown in Fig. 2-14 through Fig. 2-17. *Use of a stainless-steel plate tie may prove to be a cost-effective option compared to thermally improved proprietary tie options and also provides a highly corrosion-resistant attachment method.*
- As determined from Fig. 2-15, an R-24 target could be provided by one of the scenarios listed below when using R-6/inch exterior insulation. *As a result, the tie used can effect the wall thickness without compromising the system's effective R-value.*
 - 2¾-inches of insulation with a stainless-steel plate tie
 - 3¾-inches of insulation with a thermally optimized screw tie (with stainless-steel hook)
 - 4-inches of insulation with a galvanized-steel plate tie.

Table 2-1 System 2 thermal modeling results – 3%-inch steel stud wall

3-5/8" Steel-Framed Wall with Anchored Masonry Veneer, R-15 Batt Insulation, R-4.2/in - R-6/in Exterior Insulation						
Tie Type	Tie Penetration Area	Exterior Insulation Thickness	Nominal Insulation R-value (Cavity + Exterior Insulation)	3D Thermal Modeling Effective R-Value of System (ft²·°F·hr/Btu)		
				Without Penetrations (Through Exterior Insulation)	With Masonry Tie Penetrations @ 16" x 16" O.C.	
					Stainless Steel Tie and/or Hook	Galvanized Steel Tie and/or Hook
Plate Tie (14ga)	0.05%	2"	15 + 8.4-12	19.4-22.9	17.7-20.3	15.7-17.4
		3"	15 + 12.6-18	23.4-29.0	20.9-24.9	18.0-20.6
		4"	15 + 16.8-24	27.7-35.2	24.4-29.6	20.6-23.7
Thermally Optimized Screw Tie	0.05%	2"	15 + 8.4-12	19.4-22.9	17.0-19.3	16.9-19.2
		3"	15 + 12.6-18	23.4-29.0	19.9-23.3	19.8-23.3
		4"	15 + 16.8-24	27.7-35.2	23.1-27.5	23.0-27.4

Table 2-2 System 2 concrete floor line thermal modeling results – 3%-inch steel stud wall above and below

Concrete Slab Edge with Anchored Masonry				
Exterior Insulation Thickness	Nominal Exterior Insulation R-Value	3D Thermal Modeling Effective R-Value (ft ² ·°F·hr/Btu)		
		Exterior Insulation (Without Penetrations)	Standoff Shelf Angle	Continuous Shelf Angle
2"	8.4-12	12.4-16.2	6.6-6.8	2.8
3"	12.6-18	16.8-22.3	7.2-7.3	2.9
4"	16.8-24	21.3-28.7	7.6-8.2	3.1

Table 2-3 System 2 prescriptive energy code compliance values excerpted from Table i-1 of the introductory chapter

OPAQUE ABOVE-GRADE WALL - THERMAL ENVELOPE REQUIREMENTS									
Guide Assembly #	Energy Code Climate Zone	2012 SEC		2012 WSEC		2014 OEESC		2012 IECC	
		All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R
2	Steel-Framed Wall with Anchored Masonry Veneer	R-13 + R-10ci U-0.055 (R-18.2)	R-19 + R-8.5ci U-0.055 (R-18.2)	R-13 + R-10ci U-0.055 (R-18.2)	R-13 + R-7.5ci U-0.064 (R-15.6)	R-13 + R-7.5ci U-0.064 (R-15.6)	R-13 + R-7.5ci U-0.064 (R-15.6)	R-13 + R-7.5ci U-0.064 (R-15.6)	R-13 + R-7.5ci U-0.057 (R-17.5)

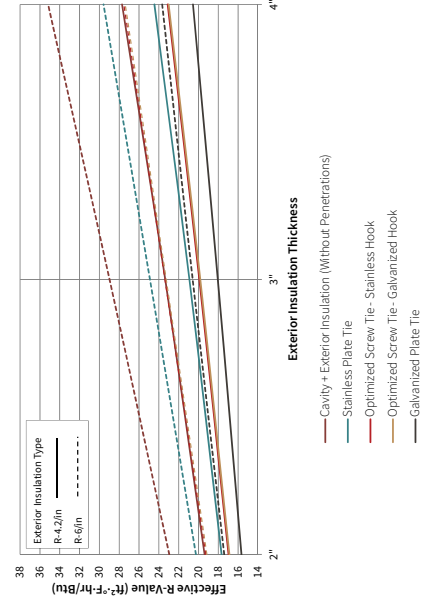


Fig. 2-15 System 2 (3%-inch steel stud) effective R-value comparison of different tie types. A range of insulation R-value per inch is represented.

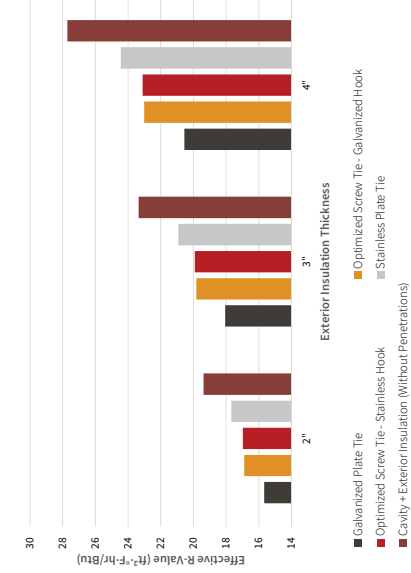


Fig. 2-14 System 2 (3%-inch steel stud) effective R-value modeling results for R-4.2/inch exterior insulation, various insulation thicknesses and various tie types

Table 2-4 System 2 thermal modeling results – 6-inch steel stud wall

6" Steel-Framed Wall with Anchored Masonry Veneer, R-21 Batt Insulation, R-4.2/in - R-6/in Exterior Insulation						
Tie Type	Tie Penetration Area	Exterior Insulation Thickness	System Nominal Insulation R-value (Cavity + Exterior Insulation)	3D Thermal Modeling Effective R-Value of System (ft ² ·F·hr/Btu)		
				Without Penetrations (Through Exterior Insulation)	With Masonry Tie Penetrations @ 16" x 16" O.C.	
					Stainless Steel Tie and/or Hook	Galvanized Steel Tie and/or Hook
Plate Tie (14 ga)	0.05%	2"	21 + 8.4–12	20.4–24.4	18.7–21.6	16.7–18.7
		3"	21 + 12.6–18	24.7–30.4	22.3–26.3	19.3–21.8
		4"	21 + 16.8–24	29.1–36.6	25.8–31.0	21.8–24.9
Thermally Optimized Screw Tie	0.05%	2"	21 + 8.4–12	20.4–24.4	18.0–20.6	17.9–20.5
		3"	21 + 12.6–18	24.7–30.4	21.2–24.7	21.1–24.6
		4"	21 + 16.8–24	29.1–36.6	24.4–28.9	24.3–28.7

Table 2-5 System 2 concrete floor line thermal modeling results – 6-inch steel stud wall above and below

Concrete Slab Edge with Anchored Masonry and 3				
Exterior Insulation Depth	System Nominal Exterior Insulation R-Value	3D Thermal Modeling Effective R-Value		
		Cavity + Exterior Insulation (Without Penetrations)	Standoff Shelf Angle	Continuous Shelf Angle
2"	8.4–12	12.8–16.6	5.9–6.4	3.9–4.1
3"	12.6–18	17.2–22.7	6.8–7.3	4.0–4.3
4"	16.8–24	21.7–29.1	7.6–8.2	4.2–4.5

Table 2-6 System 2 prescriptive energy code compliance values excerpted from Table i-1 of the introductory chapter

OPAQUE ABOVE-GRADE WALL - THERMAL ENVELOPE REQUIREMENTS									
Guide Assembly #	Energy Code Climate Zone	2012 SEC		2012 WSEC		2014 OEESC		2012 IECC	
		All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R
2 Steel-Framed Wall with Anchored Masonry Veneer	Steel-Framed	R-13 + R-10ci U-0.055 (R-18.2)	R-19 + R-8.5ci U-0.055 (R-18.2)	R-13 + R-10ci U-0.055 (R-18.2)	R-13 + R-7.5ci U-0.064 (R-15.6)	R-13 + R-7.5ci U-0.064 (R-15.6)	R-13 + R-7.5ci U-0.064 (R-15.6)	R-13 + R-7.5ci U-0.064 (R-15.6)	R-13 + R-7.5ci U-0.057 (R-17.5)

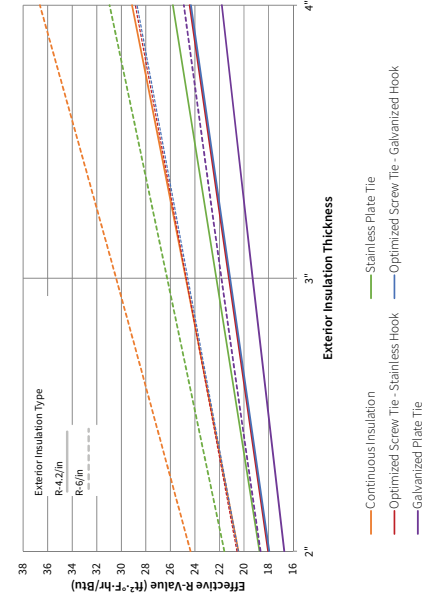


Fig. 2-16 System 2 effective (6-inch steel stud) R-value comparison of different tie types. A range of insulation R-value per inch is represented.

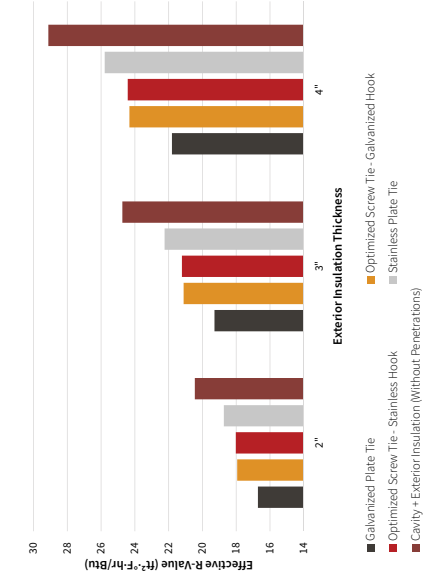


Fig. 2-17 System 2 (6-inch steel stud) effective R-value modeling results for R-4.2/inch exterior insulation, various insulation thicknesses and various tie types

- Table 2-2 and Table 2-5 demonstrate the effective R-value of exterior insulation at two shelf angle options: standoff and continuous. As shown, a continuous shelf angle provides a lower effective R-value than a standoff shelf angle. When compared to the effective R-value of the slab edge without a shelf-angle, the system's effective R-value is reduced by 70 to 89% with a continuous shelf angle and 47 to 72% with a standoff shelf angle. *When shelf angle supports are needed for this system, a standoff angle will provide a greater effective R-value at the slab edge condition.*

Sheathing Selection

Exterior sheathing on this system is typically a gypsum-based product and should be a product resistant to organic growth and moisture. Fiberglass-faced products are commonly used; avoid paper face products.

Drainage, Ventilation, and Water Deflection

The anchored masonry veneer is expected to shed most water it is exposed to; however, some moisture is expected to penetrate the cladding and enter the air cavity. This moisture is drained through the air cavity and exits the cladding system where cross-cavity flashings are provided.

Drainage and Ventilation

In this system, the air cavity between the anchored masonry veneer and the exterior insulation provides drainage behind the cladding and also ventilation when vent ports are provided at the top and bottom of the air cavity. The code-minimum air cavity depth is 1-inch, as required per TMS 402-16;⁶ however, the risk that mortar droppings will block the air cavity is increased with smaller cavities. A 1-inch cavity may be considered where a strict quality control program is implemented to minimize the risk that mortar droppings will block the cavity; however, a 2-inch air cavity is best practice. Fig. 2-18 demonstrates a typical rainscreen cavity for this system.

Where the air cavity is reduced, which commonly occurs at fenestration rough openings with return brick, a compressible free-draining filler is recommended such as semi-rigid mineral fiber insulation. Mortar should not be packed within these cavities.

The air cavity is ventilated through vents located at the top and bottom coursing of each wall section. Top vents typically occur just below parapet blocking and below intermittent bearing elements such as floor-line shelf angles. Bottom vents, which also serve as weeps and may be referred to as weep/vents, also assist

with draining moisture within the air cavity. These weep/vents are typically located just above bearing elements such as loose-lintels, floor line shelf-angles, or foundation walls.

Vents and weep/vents are recommended to be spaced a maximum of 24-inches on-center (e.g., every two to three masonry units) and filled with a cellular or mesh product that fills the head joint of a standard brick unit. It is important that weep fillers extend into the bed joint of the course to facilitate drainage. Avoid weep tubes because they provide far less ventilation and are blocked easily with debris.

Use mortar collection nets at all veneer-bearing locations to prevent mortar from blocking the rainscreen cavity and weeps/vents. Generally, a trapezoidal open-weave, moisture-tolerant net is used.

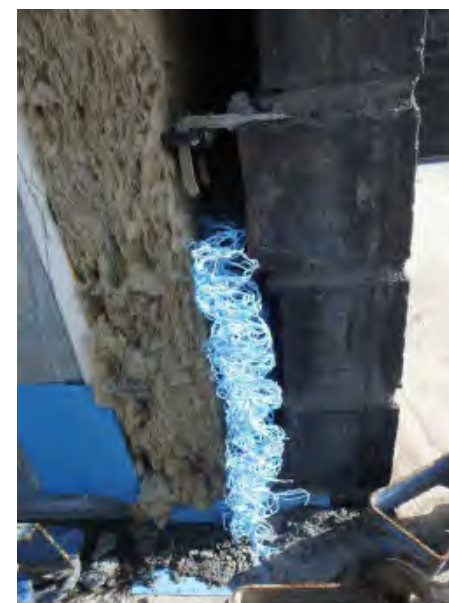


Fig. 2-18 Mock-up wall section of System 2; thermally optimized screw ties penetrate the semi-rigid mineral fiber board exterior insulation. A mortar collection net is visible at the base of the air cavity.

Sheet-Metal Components

Sheet-metal components used with this system are reflected throughout the details at the end of this chapter. Cross-cavity sheet-metal components are typically located at all bearing elements such as penetration heads (e.g., window head), floor line shelf-angles, and foundations. These flashings assist with draining the rainscreen cavity and serve to protect fluid-applied or self-adhered flashing membranes that may exist beneath them. Counterflashing sheet-metal components assist with water shedding and are typically located at windowsill and parapet top conditions; they protect the cavity from water ingress while allowing ventilation of the air cavity. Fig. 2-19 on page 2-18 shows an example of sheet-metal components.



Fig. 2-19 A sheet-metal flashing conceals the top of the rainscreen air cavity and masonry at this windowsill area. The sheet-metal flashing extends beyond the masonry veneer face to deflect water away from the veneer. At the window jamb condition beyond, sheet-metal trim is also used to close off the rainscreen air cavity.

Refer to the Sheet-Metal Flashing Components discussion on page i-46 for general recommendations on sheet-metal flashing products, including design considerations and materials.

Movement Joints

For this system, anchored clay masonry will expand over time as a result of irreversible moisture gain, and mortar joints will shrink slightly over time. In the support system, the steel-framed backup wall will experience little volume change; however, some movement may occur where studs interface with floor and roof lines. To avoid veneer damage, breaks must be provided in the veneer to compensate for differential movement between the cladding and the support wall. Expansion joints must also be provided to allow for overall expansion of the clay masonry veneer; control joints must be provided for shrinkage where concrete masonry veneer units are used.

Expansion joints (clay masonry veneer) or control joints (concrete masonry veneer) minimize stresses within the veneer between dissimilar materials such as at window jamb to veneer interfaces.

Differential vertical movement between the structure and the veneer is accommodated with a horizontal gap between the veneer and elements that are directly attached to the wall structure, such as shelf angle supports, parapet blocking, and windows. Either a backer rod and sealant joint or cross-cavity

sheet-metal flashing is placed at each horizontal gap. The size and location of joints will vary depending on the expected differential movement between the wall and veneer.

Expansion/shrinkage of the veneer or differential movement between the veneer, penetrations, and different cladding materials is accommodated with vertical joints in the veneer system as shown similar in Fig. 1-18 on page 1-16. Vertical gaps minimize stresses between the veneer and other components to provide crack control for the masonry veneer. Vertical gaps are typically sealed with a backer rod and sealant.

Typical locations of joints for the purposes of accommodating movement, drainage, and/or rainscreen cavity ventilation are identified with an asterisk (*) in chapter details. In general, a minimum gap dimension of $\frac{3}{8}$ -inch is recommended; however, it is the Designer of Record's responsibility to appropriately locate and size all movement joints.

Refer to the Movement Joints discussion on page i-48 for more information on locating veneer joints and sealant joint best practices.

Structural Considerations

The steel frame walls and concrete floor slabs of this wall system provide the primary structure of this system. It is the responsibility of the Designer of Record to ensure that all structural elements of the backup wall and veneer are designed to meet project-specific loads and local governing building codes. Generic placement of the reinforced elements and supports/ties is demonstrated within the details of this chapter and is provided for diagrammatic purposes only.



Fig. 2-20 Expansion joints (where indicated by red arrows) are located on this veneer where transitions occur at window steps and wall projections. Joints are continuous from the foundation-bearing element to the full height of the veneer.

Masonry Ties

Masonry ties (i.e., masonry anchors) are used to connect the veneer to the steel-framed backup wall. They are designed to resist the out-of-plane loads applied to the wall, typically wind and seismic. At the same time, these ties must be flexible to allow the veneer to move in-plane relative to the metal stud-framed wall.

Building codes provide prescriptive requirements for masonry ties secured to concrete or masonry that includes spacing, size, placement, and tie type. These requirements are summarized in Table 2-7 and are based on TMS 402-16⁶ provisions for adjustable ties (i.e., anchors). Use of these prescriptive requirements is limited to masonry veneer assemblies with a weight less than 40 psf, with a cavity depth no more than 6 $\frac{5}{8}$ -inches, and where the ASCE-7⁷ wind velocity pressure (q_z) is less than 55 psf (previously wind speed less than 130 mph). Wall assemblies that exceed these criteria require the design professional to evaluate the building loads and materials and rationally design the anchorage system accordingly. The majority of masonry tie manufacturers have empirical testing data available to support the use of their anchorage systems when the cavity depth or loads exceed these criteria.

Prescriptive spacing requirements for anchored masonry veneers are included in Table 2-7 for special requirements for Seismic Design Categories D, E, and F and



Fig. 2-21 Masonry veneer tie types. Top row, left to right: standard double eye and pintle plate tie and thermally optimized double eye and pintle screw tie. Bottom row, left to right: corrugated masonry ties, adjustable L-bracket, nonadjustable surface-mounted tie.

high-wind zones with velocity pressures (q_z) between 40 and 55 psf. These higher seismicity and wind speed areas are common to some parts of the Northwest and are dependent on the geography and building occupancy category. Refer to local building code requirements to ensure seismicity and wind speed criteria are properly evaluated for the building occupancy and site conditions.

Common tie types for reference are shown in Fig. 2-21. For steel-stud framed walls, adjustable ties are required by the code.

- Based on local preference, double eye and pintle type ties (whether a plate or screw type) are commonly used. Double eye and pintle ties are available from a number of manufacturers in a variety of sizes to meet project requirements in the Northwest.
- Adjustable L-bracket triangular wire ties are acceptable but may not be preferred by installers because the vertical tie orientation can complicate exterior insulation installation by requiring vertical orientation of insulation boards.
- Corrugated masonry ties and nonadjustable surface-mounted ties are not allowed by TMS 402-16⁶ for this system.

Table 2-7 Prescriptive spacing requirements for anchored masonry veneer ties based on TMS 402-16⁶ provisions

Prescriptive Spacing for Adjustable Two-Piece Masonry Veneer Ties			
Spacing Designation	Requirement Category (use more stringent spacing requirement where applies)		
	General	Seismic Design Categories D, E, and F ⁽¹⁾	High Wind ⁽²⁾
Maximum Wall Area per Anchor	2.67 ft²	2.00 ft² (75% of General Requirement Max.)	1.87 ft² (70% of General Requirement Max.)
Maximum Horizontal Spacing	32 inches	32 inches	18 inches
Maximum Vertical Spacing	25 inches	25 inches	18 inches
Maximum Spacing at Opening ⁽³⁾	36 inches	36 inches	24 inches
Maximum Distance from Openings	12 inches	12 inches	12 inches

⁽¹⁾ Seismic design categories as determined by ASCE 7

⁽²⁾ High wind includes wind velocity pressures between 40 psf and 55 psf as determined by ASCE 7 and when the building's mean roof height is less than or equal to 60 feet

⁽³⁾ For openings larger than 16 inches in either dimension

To prevent pull-out or push-through of the tie, TMS 402-16⁶ requires ties be embedded a minimum of 1½-inches into the veneer, with at least ⅝-inch mortar or grout cover at the outside face. The mortar bed thickness is to be at least twice the thickness of the tie. To prevent excess movement between connecting parts of adjustable tie systems, the clearance between components is limited to a maximum ⅛-inch. The vertical offset of adjustable pintle-type ties may not exceed 1¼-inches.

TMS 402-16⁶ requires that masonry ties are fastened directly to the steel stud framing through the exterior sheathing with minimum #10 corrosion-resistant screws (0.190-inch shank diameter). They should not be fastened to the sheathing alone. *While the code may allow a horizontal anchor spacing up to 32-inches on-center, it is recommended that anchors be spaced horizontally to align with the typical stud spacing, typically 16-inches on-center.*



Fig. 2-22 Loose lintel supports (with a sheet-metal flashing) occur at small window head conditions on this elevation.

Vertical Support

Anchored masonry veneers are supported vertically by the building's foundation or other structural components such as shelf angles and lintels. Vertical supports are designed to minimize cracking and deflection within the veneer; the support design considers the design loads, material type, moisture control, movement provisions, and constructibility.

For steel stud-framed wall systems, TMS 402-16⁶ requires the anchored masonry veneer to be supported by noncombustible construction; any veneer that exceeds 30 feet in height must be supported at each story above 30 feet. Masonry below 30 feet in height must also be supported at each floor when used in Seismic Design Categories D, E, and F. Best practice for commercial construction is to support the lowest portion of the masonry cladding directly on the concrete foundation wall.

This guide recommends that intermediate supports for masonry are provided

with galvanized-steel shelf angles anchored to the structure as needed to limit deflection to less than $L/600$ as required by TMS 402-16.⁶ As noted in the Movement Joints sections in this chapter and the introductory chapter, a joint is recommended beneath the angle and closed off from the rainscreen cavity with elastomeric sealant.

Where masonry is supported at openings within the veneer (e.g., windows and doors), shelf angles for larger openings or loose lintels at smaller openings are typically provided. Galvanized-steel loose lintels are recommended except where architectural design dictates reinforced masonry or precast concrete lintels for appearance. Steel angle lintels span the opening; TMS 402-16⁶ requires the lintel bear a minimum of 4-inches onto the adjacent masonry at the jambs of the opening. An example of lintel supports is shown in Fig. 2-22.

Refer to the details at the end of this chapter for detailing of typical support elements.

Corrosion Resistance

It is best practice to match the durability and longevity of metal components within this system to that expected of the masonry veneer. Metal components within this system include veneer ties, vertical support ledgers and lintels, sheet-metal flashings, and fasteners. This guide includes discussion for common corrosion-resistant materials; however, it is the Designer of Records' responsibility to appropriate select a level of corrosion resistance for project-specific application/exposure and the expected longevity of the masonry system.

It is common to provide hot-dipped galvanized carbon steel masonry veneer ties that comply with ASTM A 153⁸ Class B-2, AISI Type 304, or AISI Type 316 stainless steel per ASTM A580.⁹ Steel support angles such as shelf angle supports and loose lintels are at minimum hot-dipped galvanized and comply with ASTM A123.¹⁰

Best practice is to use sheet-metal flashing components of ASTM A666¹¹ Type 304 or 316 stainless steel, which is nonstaining and resistant to the alkaline content of mortar materials. Whereas the use of stainless steel sheet-metal flashing components is not always economically feasible or aesthetically desirable, prefinishing sheet-metal may be considered. Where used, this guide recommends the base sheet metal is a minimum G90 hot-dipped galvanized coating in conformance with ASTM A653¹² or minimum AZ50 galvalume coating in conformance with ASTM A792.¹³ Coating the exposed top finish of the sheet metal with an architectural-grade coating conforming to AAMA 621¹⁴ is recommended.

Fasteners used with all metal components should be corrosion-resistant, either hot-dipped galvanized steel or stainless steel to match adjacent metal components.

Masonry Veneer

There are several types of anchored masonry veneer products that may be used with this system. Those most typical within the Northwest include facing brick made of clay or shale. Concrete facing brick and concrete masonry units are also used.

For facing brick made from clay or shale, use anchored veneer units that comply with ASTM C216¹⁵ and are severe weather (SW) grade. When using concrete facing brick, anchored veneer units are to comply with ASTM C1634.¹⁶ Hollow concrete masonry units used for veneer applications are typically 4-inches deep and comply with ASTM C90.¹⁷

Mortar designed for the anchored masonry veneer units is to conform to ASTM C270;¹⁸ the type selected should be appropriate for the veneer application. Type N mortar is acceptable for most anchored masonry veneer applications. When selecting mortar, the lowest compressive strength (softest) mortar that satisfies the project requirements should be used.

Appropriate product selection of masonry veneer unit and mortar materials is necessary to provide a durable and water-resistive cladding system. The masonry veneer units and mortar joints should also be installed in conformance with industry standard best practices and manufacturer requirements. The specifics of architectural characteristics and structural properties of the masonry veneer units, mortar, and reinforcing should be designed and reviewed by a qualified Designer of Record.

Various industry resources are available to assist with veneer design and are listed in the Resources section at the back of this guide.

Clear Water Repellents

Application of a clear water repellent to the anchored masonry veneer of this system is common in the Northwest. Refer to the Surface-Applied Clear Water Repellents discussion on page i-59 for more information on selecting an appropriate clear water repellent and for best practice installation guidelines.

Pricing Summary

A pricing summary for this system is provided on Table 2-8 on page 2-27. Pricing demonstrates the relative price per square foot and is based on a 10,000-square-foot wall area with easy drive-up access. Pricing includes all components outboard of the exterior wall sheathing and provides no evaluation for interior finishes (including vapor retarder), framing/sheathing, or cavity insulation. Pricing is valid for the 2018 calendar year. Current pricing is also available at www.masonrysystemsguide.com.

Online Availability

The content of this guide and additional resources may be accessed at www.masonrysystemsguide.com as well as downloadable versions of two- and three-dimensional system details and cutaway sections and sample project specifications. Ongoing updates to references and resources included within this guide can also be accessed.

Chapter References

1. International Code Council. *2015 International Building Code*. (Country Club Hills, IL: International Code Council, Inc., 2014).
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3. American Society of Heating, Refrigerating, and Air-Conditioning Engineers. *ANSI/ASHRAE/IES Standard 90.1-2016 Energy Standard for Buildings Except Low-Rise Residential Buildings*, IP ed. (Atlanta: ASHRAE, 2016).
4. U.S. Department of Energy. *COMcheck* (version 4.0.7). Windows or Online. Washington, D.C.: U.S. Department of Energy, 2017, <https://www.energycodes.gov/comcheck>
5. 2015 Washington State Energy Code, Commercial Provisions. Chapter 51-11C WAC (filed by Washington State Legislature, January 19, 2016).
6. The Masonry Society. *TMS-402/602-16 Building Code Requirements and Specification for Masonry Structures* (n.p.: The Masonry Society, 2016).
7. American Society of Civil Engineers. *Minimum Design Loads for Buildings and Other Structures*, ASCE/SEI 7-10. (Reston, VA: ASCE Press, 2013).
8. ASTM International. *ASTM A153/A153M-16a Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*. (West Conshohocken, PA: ASTM International, 2016).

9. ASTM International. *ASTM A580/580M-16 Standard Specification for Stainless-Steel Wire*. (West Conshohocken, PA: ASTM International, 2016).

10. ASTM International. *ASTM A123/A123M-15 Standard Specification for Zinc (Hot-Dip Galvanized) on Iron and Steel Products*. (West Conshohocken, PA: ASTM International, 2015).

11. ASTM International. *ASTM A666-15 Standard Specification for Annealed or Cold-Worked Austenitic Stainless-Steel Sheet, Strip, Plate, and Flat Bar*. (West Conshohocken, PA: ASTM International, 2015).

12. ASTM International. *ASTM A653/A653M-15e1 Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process*. (West Conshohocken, PA: ASTM International, 2015).

13. ASTM International. *ASTM A792/A792M-10(2015) Standard Specification for Steel Sheet, 55% Aluminum-Zinc Alloy-Coated by the Hot-Dip Process*. (West Conshohocken, PA: ASTM International, 2015).

14. American Architectural Manufacturers Association. *AAMA 621-02 Voluntary Specification for High-Performance Organic Coatings in Coil-Coated Architectural Hot-Dipped Galvanized (HDG) and Zinc-Aluminum Coated Steel Substrates*. (Schaumburg, IL: American Architectural Manufacturers Association, 2002).

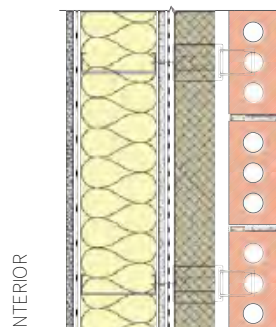
15. ASTM International. *ASTM C216-17 Standard Specification for Facing Brick (Solid Masonry Units Made from Clay or Shale)*. (West Conshohocken, PA: ASTM International, 2017).

16. ASTM International. *ASTM C1634-16 Standard Specification for Concrete Facing Brick*. (West Conshohocken, PA: ASTM International, 2016).

17. ASTM International. *ASTM C90-16a Standard Specification for Loadbearing Concrete Masonry Units*. (West Conshohocken, PA: ASTM International, 2016).

18. ASTM International. *ASTM C270-14a Standard Specification for Mortar for Unit Masonry*. (West Conshohocken, PA: ASTM International, 2014).

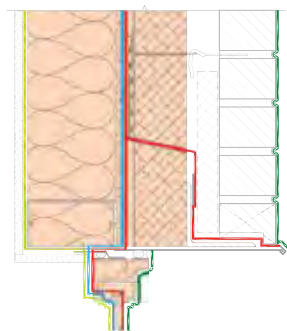
Table 2-8 System 2 steel-framed wall with anchored masonry veneer pricing summary

System 2: Steel-Framed Wall with Anchored Masonry Veneer					
System Component	Baseline Product	Alternate (call for estimate)	Baseline Cost/ft ² (incl. labor)		
			Low	High	
INTERIOR					
1	Interior gypsum board	No evaluation of these components provided.			
2	Vapor retarder				
3	Steel-framed wall with batt insulation				
4	Exterior sheathing				
5*	Air and water-resistive barrier	Fully adhered or mechanically attached sheet-applied membrane	Fluid-applied membrane system	\$1.50	\$3.75
6*	Semi-rigid insulation	Semi-rigid mineral fiber board; 2-inch thickness	No specified alternate	\$2.75	\$3.25
7	Air cavity	Not applicable	Not applicable	-	-
8*	Anchored masonry veneer (without ties)	SW brick masonry modular unit (3-5/8" x 2-1/4" x 7-5/8") FBX, running bond; Type S or N mortar	No specified alternate	\$25.00	\$27.80
9*	Anchored masonry veneer ties	14-gauge hot-dipped galvanized or stainless-steel plate tie, including fasteners	Thermally optimized screw tie with stainless or hot-dipped galvanized hook	\$2.50	\$5.00
10*	Clear water repellent	Silane/siloxane blend	Antigraffiti clear water repellent	\$1.75	\$2.50
EXTERIOR					
Total cost to install 10,000 sq ft wall area w/easy drive-up access -->				\$33.50	\$42.30
Pricing Summary Discussion			System Plan View		
<ul style="list-style-type: none">- Low and high baseline costs are based on baseline products and installed labor costs. Call for an estimate for alternative product pricing.- Baseline costs provided will vary based on product-specific conditions as well as project location and should be used as an estimate only.- Veneer unit prices are for typical units as noted. Pricing can vary based on size, color, and finish and should be confirmed with the unit manufacturer.- *See the Resources section of this guide for a list of resources related to this component.					

LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Vapor retarder
 - Steel-framed wall with batt insulation
 - Exterior sheathing
 - Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
 - Semi-rigid exterior insulation
 - Air cavity
 - Anchored masonry veneer with
 - Clear water repellent
2. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
3. Continuous mortar collection mesh
4. Self-adhered sheet- or fluid-applied air barrier and WRB prestrip membrane
5. Hot-dipped galvanized-steel loose lintel
6. Weep/vent at maximum 24-inches on-center
7. Two-piece sheet-metal head flashing with hemmed drip edge and end dams (beyond)
8. Sheet-metal trim
9. Sealant over backer rod
10. Window strap anchor, bed in air barrier sealant at continuous air barrier sealant joint plane
11. Non-flanged window
12. Air barrier sealant over backer rod tied to continuous seal at window perimeter

Water-Shedding Surface and Control Layers

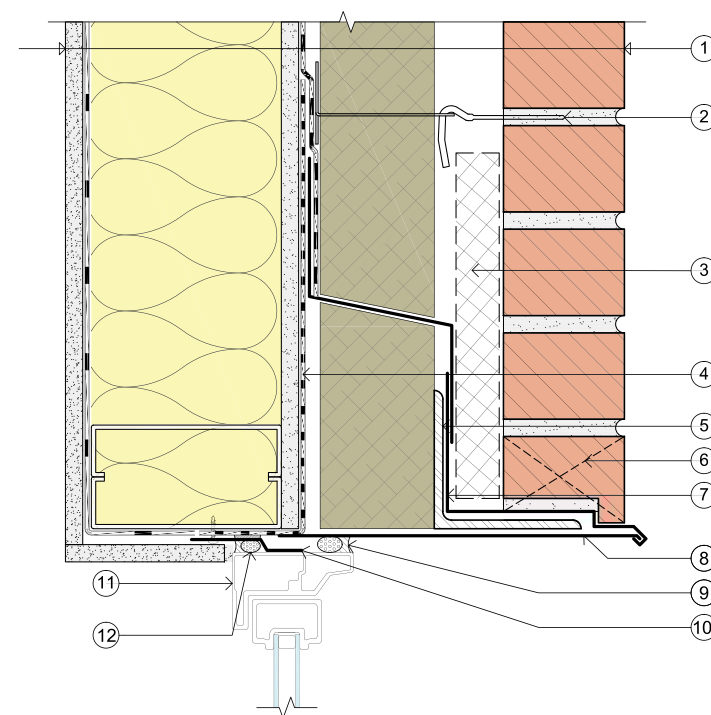


— Water-Shedding Surface

Control Layers:*

— Water
— Air
— Vapor
— Thermal

* Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing



Detail Discussion

- Air and water control layer continuity is provided by the self-adhered sheet- or fluid-applied air barrier and WRB field membrane, prestrip membrane, and air barrier sealant transition to the window. Window strap anchors are bed in sealant during fastening to eliminate an air barrier discontinuity behind the strap anchor that could otherwise lead to both air leakage and/or water intrusion.
- A non-flanged window is shown in Detail 2-A and facilitates future window repair and replacement without the need to remove the anchored masonry veneer.
- The hot-dipped galvanized-steel loose lintel location allows the exterior insulation to be continuous up to the rough opening. The two-piece sheet-metal flashing may be replaced with a self-adhered flashing membrane for a thermal improvement, as shown similarly in Fig. i-31 on page i-47. Where replaced, the self-adhered flashing membrane should be compatible with the air barrier and WRB system. Also see Detail 2-D for an example of this detail approach.

Typical Loose Lintel at Window Head

Detail 2-A

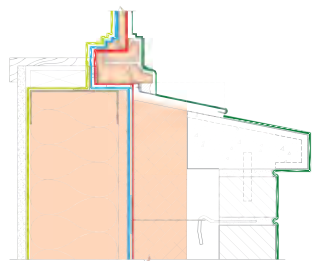
LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Vapor retarder
 - Steel-framed wall with batt insulation
 - Exterior sheathing
 - Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
 - Semi-rigid exterior insulation
 - Air cavity
 - Anchored masonry veneer with
 - Clear water repellent
2. Non-flanged window on minimum 1/4-inch-thick intermittent shims
3. Sealant over bond breaker
4. Sloped sheet-metal sill flashing with hemmed edge and end dams (beyond), attached to intermittent L-angle at window per window manufacturer recommendations
5. Sloped precast sill, sealant over backer rod (beyond), where applicable
6. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
7. Continuous air barrier sealant tied to continuous seal at window perimeter
8. Continuous back dam angle at rough opening sill, minimum 1-inch tall. Fasten window through back dam angle per window manufacturer recommendations.
9. Self-adhered sheet- or fluid-applied air barrier and WRB prestrip membrane

Detail Discussion

- Air and water control layer continuity is provided by the self-adhered sheet- or fluid-applied air barrier and WRB field membrane, self-adhered sheet- or fluid-applied flashing membrane at the sill, and the air barrier sealant transition to the window.
- The sheet-metal sill flashing conceals the rainscreen cavity; counterflash each end dam of the sill flashing with the sheet-metal jamb trim to close off the rainscreen cavity and complete the water-shedding surface.
- This guide recommends that a sheet-metal flashing is **not** placed below the precast sill. It can prematurely degrade the mortar bed beneath the precast element.

Water-Shedding Surface and Control Layers

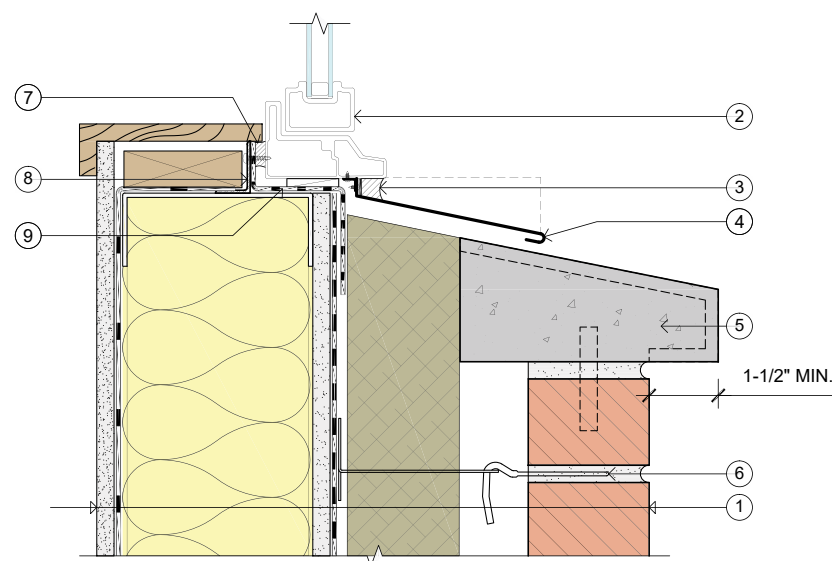


— Water-Shedding Surface

Control Layers:*

— Water
— Air
— Vapor
— Thermal

* Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing



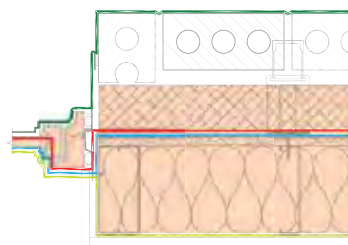
Typical Precast and Sheet-Metal Windowsill

Detail 2-B

LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Vapor retarder
 - Steel-framed wall with batt insulation
 - Exterior sheathing
 - Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
 - Semi-rigid exterior insulation
 - Air cavity
 - Anchored masonry veneer with
 - Clear water repellent
2. Non-flanged window
3. Sealant over bond breaker
4. Sheet-metal jamb trim, attached to intermittent L-angles at window per manufacturer recommendations. Counterflash sheet-metal sill flashing end dams (beyond). Bed sheet-metal trim in sealant at anchored masonry veneer return.
5. Self-adhered or fluid-applied sheet air barrier and WRB prestrip membrane
6. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
7. Air barrier sealant over backer rod, tied to continuous seal at window perimeter
8. Window strap anchor, bed in air barrier sealant at continuous air barrier sealant joint plane

Water-Shedding Surface and Control Layers

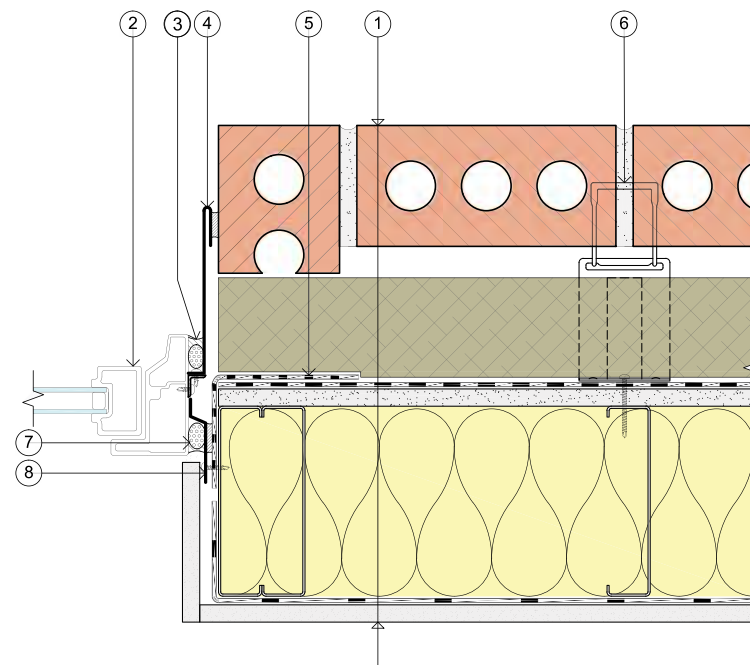


Water-Shedding Surface

Control Layers:*

- Water
- Air
- Vapor
- Thermal

* Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing



Detail Discussion

- Air and water control layer continuity is provided by the self-adhered sheet- or fluid-applied air barrier and WRB field membrane, prestrip membrane, and air barrier sealant transition to the window. Window strap anchors are bed in sealant during fastening to eliminate a discontinuity in the control layers behind the strap anchor that could otherwise lead to both air leakage and/or water intrusion.
- This detail allows the exterior insulation to continue up to the rough opening. The sheet-metal attachment to the intermittent angle, exterior of the window's thermal break, improves thermal performance of the jamb condition.
- The sheet-metal jamb trim is bed in continuous sealant against the anchored masonry veneer to provide water-shedding surface continuity.
- Exterior insulation should be tightly installed around all penetrations, including masonry ties.

Typical Sheet Metal and Brick Return Window Jamb

Detail 2-C

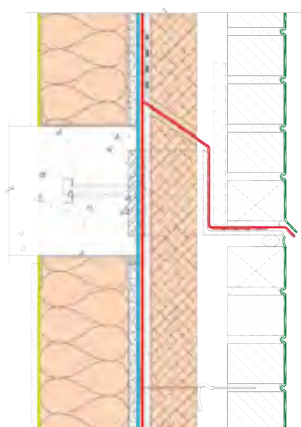
LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Vapor retarder
 - Steel-framed wall with batt insulation
 - Exterior sheathing
 - Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
 - Semi-rigid exterior insulation
 - Air cavity
 - Anchored masonry veneer with
 - Clear water repellent
 2. Self-adhered flashing membrane over semi-rigid insulation and shelf angle
 3. Continuous mortar collection net
 4. Hot-dipped galvanized-steel standoff shelf angle support anchored on intermittent knife plates
 5. Weep/vent at maximum 24-inches on-center
 6. Sheet-metal flashing with hemmed drip edge
 7. Sealant over backer rod
 8. Vent at maximum 24-inches on-center
 9. Self-adhered or fluid-applied flashing membrane, extend onto intermittent knife plate.
See Fig. i-40 and Fig. i-41 on page i-57 of the introductory chapter for additional detailing discussion.
 10. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
- * Size joint for project-specific movement, minimum 3/8-inch.

Detail Discussion

- A self-adhered flashing membrane over the semi-rigid insulation provides drainage of the rainscreen cavity at the floor line. It is a thermally improved alternative detail to a two-piece sheet-metal flashing as shown similar in Detail 2-A. When installing the self-adhered membrane, provide a tight fit to the substrate and slope to drain.
- The hot-dipped galvanized-steel standoff shelf angle support reduces the amount of thermal bridging at the floor line when compared to a continuous shelf angle mounted tight to the concrete slab face.

Water-Shedding Surface and Control Layers



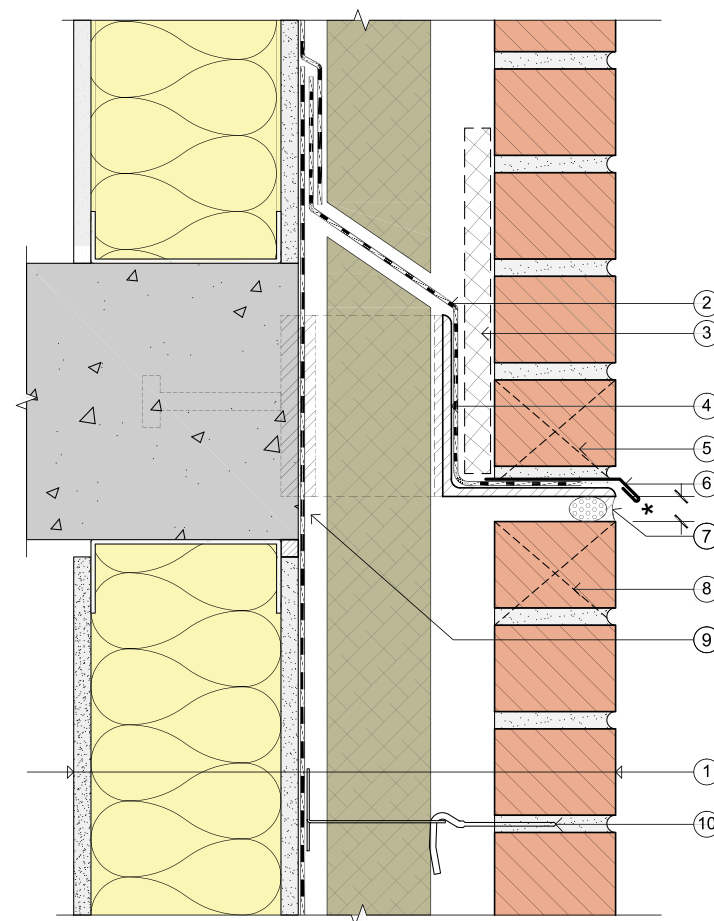
Water-Shedding Surface

Control Layers:[†]

- Water
- Air
- Vapor
- Thermal

[†] Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing

Refer to Fig. i-31 on page i-47 for an alternative lip brick detail that reduces the visibility of the backer rod and sealant movement joint. Note, this joint is necessary for differential movement that will occur between the structure and anchored masonry veneer.



Typical Standoff Shelf Angle Support at Floor Line

Detail 2-D

LEGEND

1. Parapet Assembly
 - Roofing membrane over sheathing
 - Steel-framed wall with cavity insulation as shown
 - Exterior sheathing
 - Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
 - Semi-rigid exterior insulation
 - Air cavity
 - Anchored masonry veneer with
 - Clear water repellent
 2. Inverted roof membrane assembly
 3. Sloped standing-seam sheet-metal coping with gasketed washer fasteners
 4. Compressible filler
 5. Preservative-treated blocking
 6. High-temperature self-adhered membrane
 7. Vent at maximum 24-inches on-center
 8. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
 9. Closed-cell spray foam insulation plug
- * Size gap for project-specific movement, minimum 3/8-inch wide.

Water-Shedding Surface and Control Layers



Water-Shedding Surface

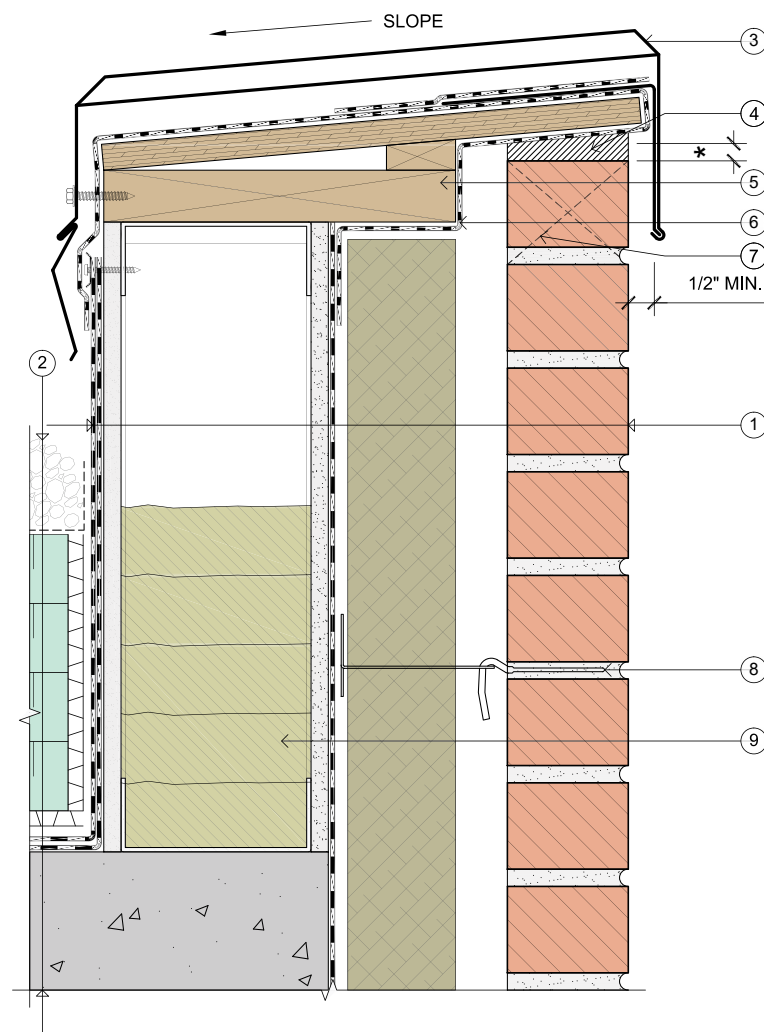
Control Layers:[†]

- Water
- Air
- Vapor
- Thermal

[†] Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing

Detail Discussion

- The concrete roof structure provides the vapor control layer at this detail.
- Vents are located at the top masonry course to encourage ventilation of the rainscreen cavity. The sheet-metal parapet coping with hemmed drip edge is held off the anchored masonry veneer face to minimize blocking air flow through the vents. The sheet-metal coping also protects the vent opening from wind-driven rain.
- A compressible filler is used between the anchored masonry veneer and parapet blocking to allow building movement while preventing insects and debris from entering the rainscreen cavity.
- Parapet cavity insulation provides continuity of the thermal control layer at the roof-to-wall transition.



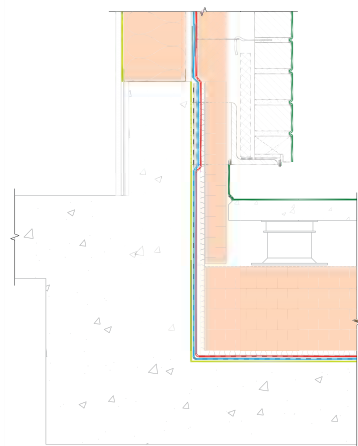
Typical Parapet at Inverted Roof System

Detail 2-E

LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Vapor retarder
 - Steel-framed wall with batt insulation
 - Exterior sheathing
 - Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
 - Semi-rigid exterior insulation
 - Air cavity
 - Anchored masonry veneer with
 - Clear water repellent
2. Typical inverted roof assembly with overburden
3. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
4. Self-adhered or fluid-applied flashing membrane, lapped over roof membrane termination
5. XPS insulation
6. Continuous mortar collection mesh
7. Interior furring for interior gypsum board attachment
8. Weep/vent at maximum 24-inches on-center
9. Sheet-metal flashing with hemmed drip edge
10. Hot-dipped galvanized stand off shelf angle support
11. Roof penetration flashing membrane (per roof membrane manufacturer), extend onto shelf angle support knife plates and lap into WRB system

Water-Shedding Surface and Control Layers



Water-Shedding Surface

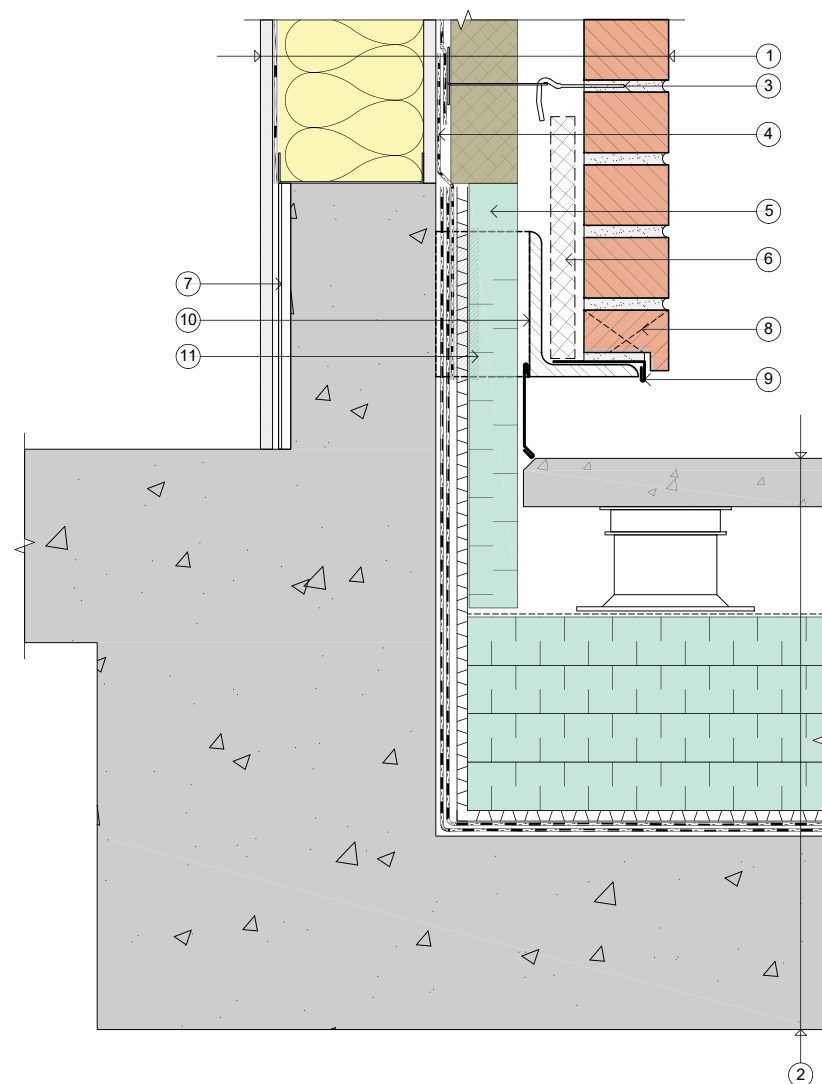
Control Layers: *

- Water
- Air
- Vapor
- Thermal

* Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing

Detail Discussion

- The standoff shelf angle support at this transition allows for continuous thermal insulation to occur between the roof and wall assemblies.
- Use of a lip brick at the wall base hides the sheet-metal counterflashing.
- Masonry wall system installation often precedes roof membrane installation and restricts future access for installation of the roof membrane and flashing components behind the standoff shelf angle support. As a result, installation of a roof membrane prestrip and roof penetration flashing membrane at the concrete wall is needed prior to masonry wall system installation.



Inverted Roof Assembly-to-Wall Interface

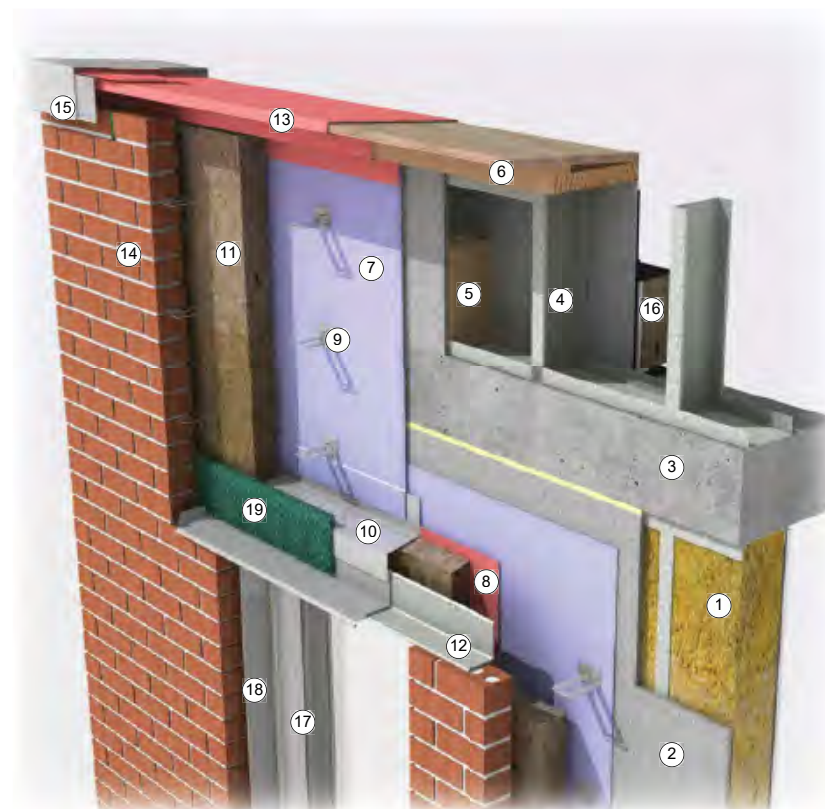
Detail 2-F

LEGEND

1. Steel-framed wall with batt insulation
2. Exterior sheathing
3. Concrete roof structure
4. Steel stud parapet framing
5. Closed-cell spray foam insulation plug
6. Sloped preservative-treated blocking
7. Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
8. Self-adhered sheet- or fluid-applied air barrier and WRB prestrip membranes
9. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
10. Two-piece sheet-metal head flashing with hemmed drip edge and end dams
11. Semi-rigid exterior insulation
12. Hot-dipped galvanized-steel loose lintel
13. High-temperature self-adhered membrane
14. Anchored masonry veneer
15. Sloped standing-seam sheet-metal coping with gasketed washer fasteners
16. Inverted roof membrane assembly
17. Non-flanged window
18. Sheet-metal jamb trim
19. Continuous mortar collection mesh

3-D Detail Discussion (Details 2-G, 2-H, 2-I)

- Three-dimensional cutaway sections on the next four pages represent two-dimensional details of this system.
- In all details, water control layer elements are shingle-lapped to encourage drainage in the rainscreen cavity.
- As shown in Detail 2-F, horizontally oriented ties, such as a double eye and pintle plate tie, allow exterior insulation to be installed in horizontal strips between ties. This orientation can improve the efficiency of the anchored masonry veneer installation.
- The two-piece sheet-metal flashing at the window head, as shown in Detail 2-F, allows the upper flashing to be installed and integrated into the air barrier and WRB system prior to installation of the lower sheet-metal flashing and hot-dipped galvanized-steel loose lintel. As shown, the sheet-metal flashing above the lintel ends at a head joint. This location allows the sheet-metal head flashing to terminate with an end dam.
- Weep/vents at the floor line above the lintel, as shown in Detail 2-G, provide both drainage and ventilation of the rainscreen cavity above. Mortar collection mesh helps keep the weeps and the base of the rainscreen cavity free of mortar droppings. Vents below the floor line lintel encourage ventilation of the rainscreen cavity.
- Detail 2-H describes a typical rough opening with sill back dam angle. The back dam angle creates a sill pan below the window; intermittent shims below the window promote drainage at the sill and into the rainscreen cavity.

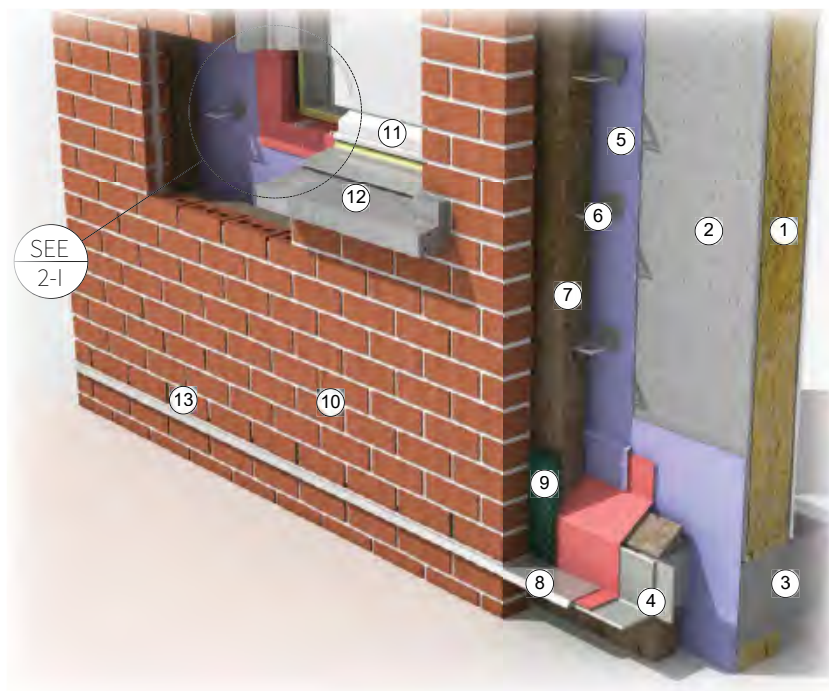


Parapet Assembly Cutaway Section

Detail 2-G

LEGEND

1. Steel-framed wall with batt insulation
2. Exterior sheathing
3. Concrete floor slab
4. Hot-dipped galvanized-steel standoff shelf angle support anchored on intermittent knife plates
5. Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
6. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
7. Semi-rigid exterior insulation
8. Sheet-metal flashing with hemmed drip edge
9. Continuous mortar collection mesh
10. Anchored masonry veneer
11. Non-flanged window
12. Sloped precast concrete sill with sloped sheet-metal sill flashing
13. Weep/vents at maximum 24-inches on-center

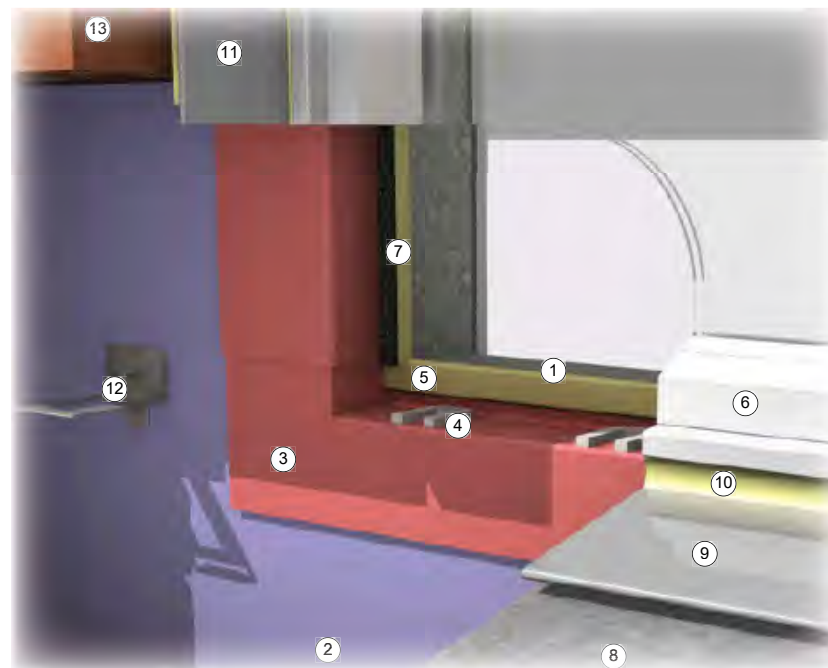


Floor Line Cutaway Section

Detail 2-H

LEGEND

1. Continuous back dam angle at rough opening sill, minimum 1-inch tall. Fasten window through back dam angle per window manufacturer recommendations.
2. Self-adhered sheet or fluid-applied air barrier and WRB field membrane
3. Self-adhered sheet or fluid applied air barrier and WRB prestrip membrane and fluid-applied or self-adhered flashing sill membrane
4. Minimum 1/4-inch-thick intermittent shims
5. Continuous air barrier sealant, tied to continuous seal at window perimeter
6. Non-flanged window
7. Air barrier sealant over backer rod, tied to continuous seal at window perimeter
8. Sloped precast concrete sill
9. Sloped sheet-metal sill flashing with hemmed edge
10. Sealant over bond breaker tape between window frame and sheet-metal sill flashing
11. Sheet-metal jamb trim with hemmed edge
12. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
13. Anchored masonry veneer



Typical Windowsill and Jamb Cutaway Section

Detail 2-I

LEGEND

1. Inverted roof membrane assembly over concrete roof structure
2. Inverted roof membrane
3. Self-adhered or fluid-applied flashing membrane, lap over roof membrane termination and parapet saddle flashing membrane
4. Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
5. Parapet saddle flashing membrane, extend onto sloped parapet blocking beyond brick face and over wall beyond
6. Semi-rigid mineral fiber exterior insulation
7. Hot-dipped galvanized-steel standoff shelf angle support on intermittent knife plates
8. Shelf angle knife plate support with flashing membrane (per roof membrane manufacturer)
9. Continuous mortar collection mesh
10. Sheet-metal flashing with hemmed drip edge
11. Anchored masonry veneer
12. High-temperature self-adhered membrane, lap membrane over parapet saddle flashing membrane and roof membrane termination
13. Exterior sheathing
14. Closed-cell spray foam insulation within framed parapet
15. Sloped standing-seam sheet-metal coping, end dam at anchored masonry veneer face beyond
16. Sheet-metal counterflashing with spring lock inserted into mortar bed beyond, seal with a sanded sealant over backer rod
17. Sheet-metal flashing with hemmed drip edge and end dam, see Detail 2-D similar
18. Sloped, preservative-treated blocking

3-D Detail Discussion (Detail 2-J)

- The saddle flashing in this detail is often a fluid-applied flashing membrane. A self-adhered saddle flashing membrane may be difficult to form continuously at the parapet-to-wall interface.
- The hot-dipped galvanized-steel standoff shelf angle support is shown anchored on intermittent knife plates; however, other standoff support options may be used. Welding activities necessary to attach the ledger to the support can damage waterproofing. Protect waterproofing during welding activities or sequence waterproofing components following ledger installation if accessibility and clearance allow.
- The ledger is located above the parapet blocking. The separation between the blocking and ledger is sized to accommodate any anticipated building movement during construction or occupancy.
- The sloped parapet below the ledger encourages drainage of water away from the parapet saddle transition. The standing-seam sheet-metal coping is end-dammed at the anchored masonry veneer face and deflects water away from the parapet saddle transitions.
- The sheet-metal counterflashing with spring-lock is inserted into a mortar bed joint at the anchored masonry veneer and is sealed with a sanded sealant joint. Installation of the counterflashing can occur following installation of the anchored masonry veneer. The sanded sealant joint may be cut and counterflashing removed as needed for roof and parapet membrane repair and replacement.
- The anchored masonry veneer transitions to Detail 2-D at the outside wall corner. An end dam is recommended where Detail 2-D terminates at the parapet. Refer to Detail 3-K in Chapter 3 for a similar cutaway section at the exterior parapet face.



Saddle Flashing Cutaway Section

Detail 2-J

CHAPTER 3:**WOOD-FRAMED WALL WITH ANCHORED MASONRY VENEER**

Masonry system 3 is a rainscreen wall with wood-framed wall structure and anchored masonry veneer. The components of this system, from interior to exterior, are described in Fig. 3-1. This system is appropriate for many applications including low- or mid-rise residential or commercial buildings. An example project application of this system is shown in Fig. 3-2 on page 3-2.

Building Enclosure and Control layers

As noted in the Introduction, an above-grade wall system controls liquid water, air, heat, and possibly water vapor to function as an effective and durable environmental separator. Control of these elements, specific to this wall system, is provided by the following control layer systems and/or materials:

- Water control layer, comprising the water-resistive barrier (WRB) system
- Air control layer, comprising the air barrier system
- Thermal control layer, comprising thermal insulation and other low conductivity materials

INTERIOR

- Interior gypsum board
- Vapor retarder
- Wood-framed wall with batt insulation
- Exterior sheathing
- Air and water-resistive barrier membrane
- Air cavity
- Anchored masonry veneer with
- Clear water repellent

EXTERIOR

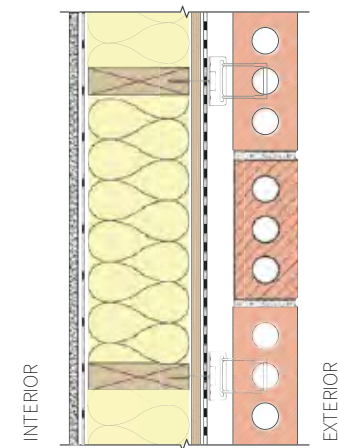


Fig. 3-1 Typical System 3 components from interior to exterior

- Vapor control layer, comprising vapor retarding materials

For a summary of the relationship between building enclosure loads, control layers, and associated systems and materials, refer to Fig. i-13 on page i-21 of the introductory chapter.

Fig. 3-3 illustrates the water-shedding surface and control layer locations for this system. The water-shedding surface and control layers are also shown on typical system details provided adjacent to each detail at the end of this chapter.



Fig. 3-2 Wood-framed wall with anchored masonry veneer example project application

As shown in Fig. 3-3, the water-shedding surface occurs at the anchored masonry veneer, with most water-shedding occurring at the wall face while some water will be stored within the masonry veneer to be released later. The water control layer and air control layer occur at the same location exterior of the wall sheathing. The thermal control layer occurs at the framed wall cavity insulation. The vapor control layer is located at the interior (warm-in-winter side) of the wood-framed structure.

Water-Shedding Surface

The water-shedding surface is a system that serves to reduce the water load on the enclosure. A general discussion of the water-shedding surface is provided in the Water-Shedding Surface discussion on page i-19.

The anchored masonry veneer cladding, including both mortar joints and masonry veneer units, is the primary water-shedding surface of the wall system. Additional water-shedding surface components within the wall system include sheet-metal flashings and drip edges, sealant joints, and fenestration systems as shown on the details included at the end of this chapter.

To promote water shedding at the masonry veneer face, mortar joints should be installed with a tooled concave (preferred) or “V” shape.

The water-shedding surface is most effective when free of gaps except where providing drainage and/or ventilation. Continuously seal movement joints and joints around fenestrations and penetrations with backer rod and sealant or

counterflash them with a sheet-metal flashing to deflect wind-driven rain and shed water away from the rainscreen cavity.

Water Control Layer

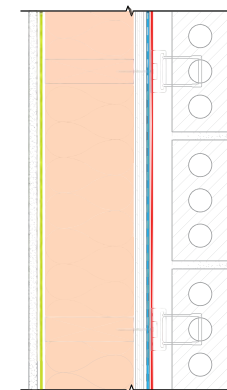
The water control layer is a continuous control layer that is designed and installed to act as the innermost boundary against water intrusion. In a rainscreen wall system, the water-resistive barrier (WRB) system is the last line of defense against water intrusion. A general discussion of the WRB system is provided in the Water Control Layer discussion on page i-24.

In this wall system, the WRB system typically has Class IV vapor permeance properties and may be a mechanically attached sheet membrane, a self-adhered sheet membrane, or a fluid-applied system that also functions as the air barrier system; thus, the WRB system is often referred to as the air barrier and WRB system. An air barrier and WRB system with a Class IV vapor permeance allows this wall system to dry to the exterior. Drying ability to the exterior is not only beneficial during the service life of the building but also helps relieve any construction-related moisture in the wood framing or wood-based sheathing products. A vapor-permeable air barrier and WRB system with mechanically attached field membrane is depicted in the details at the end of this chapter. An example of this system is shown in Fig. 3-4 on page 3-4.

Physical properties of WRB system products, are discussed in the Water Control Layer discussion on page i-24. Vapor permeability of materials is addressed in the Vapor Control Layer discussion on page i-28.

The WRB system must be continuous across the wall system to provide effective water control. In addition to the field membrane, the WRB system includes fluid-

Water-Shedding Surface and Control Layers



— Water-Shedding Surface

Control Layers:

— Water
— Air
— Vapor
— Thermal

Fig. 3-3 System 3 water-shedding surface and control layer locations



Fig. 3-4 Double eye and pintle plate ties are fastened through compatible self-adhered membrane patches over a mechanically attached sheet air and water barrier membrane.

applied or self-adhered flashing membranes, sealants, sheet-metal flashings, and penetrations such as windows and doors as shown in the detail drawings that follow this chapter discussion. Where sheet-metal flashing components occur within the system, the back leg of the sheet-metal flashing is shingle-lapped into the WRB system to facilitate drainage at the face of the WRB system and to the exterior of the cladding.

Masonry veneer ties in this system will penetrate the WRB system; seal them as required by the WRB system manufacturer's installation requirements. Typically, plate ties are bed in a compatible sealant or fluid-applied flashing product or are attached through a self-adhered membrane patch, whereas screw ties with gasketing washers are typically not required to be sealed.

Low-permeance (Class I, Class II, and sometimes Class III vapor permeance) flashing membranes are commonly used in WRB systems that have vapor-permeable WRB system field membranes. These flashing membranes can be effective on horizontal or low-slope transitions such as window and door rough opening sills or to detail around penetrations and other transitions; however, it is recommended that the use of such membranes is minimized when a vapor-permeable WRB system field membrane is used. This may be achieved by reducing the installation of low-permeance membranes to less than 10 percent of the wall area and by avoiding concentrated areas of low-permeance membranes at wall areas that would otherwise benefit from drying to the exterior (such as in wood-framed systems).

Air Barrier System

The air barrier system provides the air control layer. In addition to controlling air, this layer assists with controlling liquid water, heat, and water vapor. A general overview of the air control layer and the air barrier system is provided in the Air Control Layer discussion on page i-26.

For this wall system, the air barrier system is the same field membrane and many of the components that also serve as the WRB system. As discussed in the introductory chapter, the air barrier system must be continuous and fully sealed to resist air flow, whereas the WRB system is not required to be continuously sealed to be effective, merely shingle-lapped.

Mechanically attached sheet-applied air barrier and WRB system materials should be attached per manufacturer recommendations to minimize the risk of membrane displacement and damage during wind events. Often masonry ties are relied upon to provide this membrane support; however, other manufacturer-approved fasteners such as washer head nails or fasteners may be necessary to secure the membrane until ties are placed. It is recommended that any temporary fasteners remain in place or that holes at any evacuated fasteners are repaired as required by the membrane manufacturer.

Vapor Control Layer

The vapor control layer retards or greatly reduces (e.g., vapor barrier) the flow of water vapor due to vapor pressure differences across enclosure assemblies. Unlike the other control layers presented in this guide, the vapor control layer is not always necessary or required to be continuous.

The vapor control layer of this system is located on the interior (warm-in-winter side) of the wall and is typically at the face of or just behind the interior gypsum board. The vapor retarder for this wall system should comply with Section 1405.3 of the governing International Building Code (IBC).¹ In the Northwest, typical vapor retarder products include PVA vapor-retarding primer, asphalt-coated kraft paper, or a polyamide film retarder membrane. Refer to the Vapor Control Layer discussion on page i-28 for additional information on vapor retarder products.

Thermal Control Layer

The thermal control layer controls heat flow and assists with controlling water vapor.

In this wall system, the low-conductivity wood framing and wall cavity insulation form the thermal control layer. At transition details, the thermal control layer also includes parapet cavity insulation and insulation at the roof assembly, slab, and foundation elements. Windows and doors that penetrate this wall system are also part of the thermal control layer. Exterior insulation may also be used with this system as shown in Fig. 3-5 to improve thermal performance.

Additional thermal insulation information is provided in the Thermal Control Layer discussion on page i-30 of the introductory chapter.

Insulation Selection

The cavity insulation in this system is typically fiberglass or mineral fiber batt insulation product.

The exterior insulation in this system is typically semi-rigid mineral fiber board insulation (R-4.2/inch), which is hydrophobic, tolerates moisture, and has free-draining capabilities. Its vapor permeance allows it to be acceptable for use exterior of a the Class IV vapor-permeable WRB system. The semi-rigid properties of the insulation allow it to be fit tightly around penetrations such as masonry veneer ties.

Exterior insulation with relatively low vapor permeance properties (e.g., XPS or polyisocyanurate) may be avoided in this wall system because it can limit system drying to the exterior.

Refer to the Insulation Products discussion on page i-30 for information on various insulation types and additional considerations.

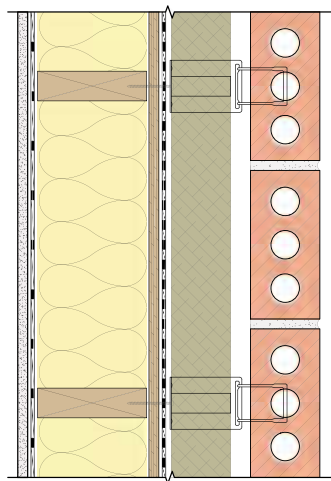


Fig. 3-5 System 3 with exterior semi-rigid mineral fiber insulation

Although masonry is defined as a noncombustible cladding material, the use of a combustible air barrier and WRB system or foam plastic insulation within a wall cavity can trigger fire propagation considerations and requirements. Depending on the local jurisdiction, IBC Section 1403.5¹ regarding vertical and lateral flame propagation as it relates to a combustible WRB system may require acceptance criteria for NFPA 285.² The use of foam plastic insulation within a wall cavity should also be addressed for IBC Chapter 26¹ provisions.

Thermal Performance and Energy Code Compliance

This chapter system is typically classified as a “wood-framed and other” above-grade wall for energy code compliance purposes. Prescriptive energy code compliance values for this system are summarized in Table 3-2 on page 3-13 and describe:

- Minimum insulation R-values for a *prescriptive insulation R-value method* strategy.
- Maximum system U-factors for a *prescriptive assembly U-factor method* strategy. Note, the equivalent effective R-value of this U-factor has been calculated and is denoted in parenthesis () for easy comparison to thermal modeling results in this chapter.

Wood-framed walls are typically constructed with 16-inch on-center stud spacing for standard framing or 24-inch on-center stud spacing for advanced framing methods. Nominal 2x6 framing accommodates up to an R-21 fiberglass or R-23 mineral fiber batt insulation and nominal 2x8 framing up to an R-30 mineral fiber batt insulation. When continuous insulation requirements are to be met, this system will have insulation exterior of the wood frame structure, wall sheathing, and Class IV vapor permeance air barrier and WRB system, as shown in Fig. 3-5.

For all energy code compliance strategies except the *prescriptive insulation R-value method strategy*, this wall system’s U-factor will need to be calculated or determined from table values; however, it may or may not be required to be less

Project-specific thermal performance values for an opaque above-grade wall should be used for energy code compliance and determined from a source that is approved by the authority having jurisdiction. Thermal performance sources may include ASHRAE 90.1,³ COMcheck,⁴ the appendices of the 2015 WSEC,⁵ thermal modeling and calculation exercises, or other industry resources.

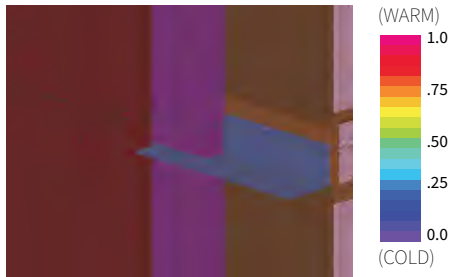


Fig. 3-6 Three-dimensional section of a continuous floor line shelf angle supporting anchored masonry veneer



Fig. 3-8 Three-dimensional section of a standoff shelf angle supporting anchored masonry veneer



Fig. 3-7 Three-dimensional thermal image of the continuous floor line shelf angle shown in Fig. 3-7



Fig. 3-9 Three-dimensional thermal image of the standoff shelf angle shown in Fig. 3-8

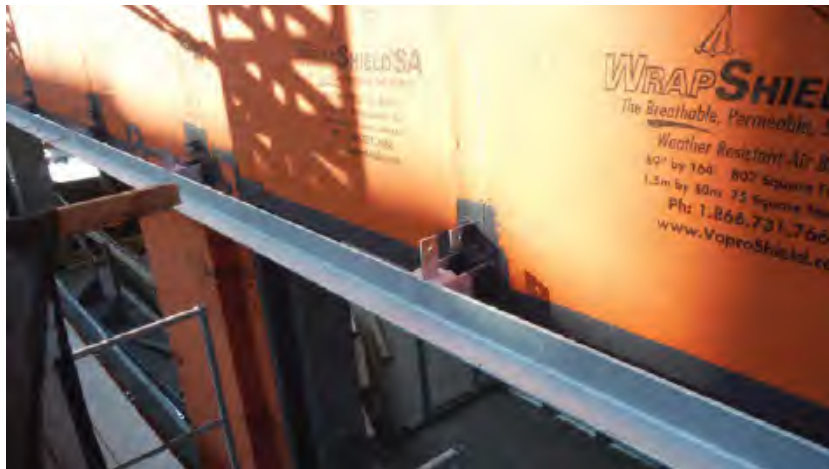


Fig. 3-10 Hot-dipped galvanized standoff shelf angle

than the prescriptive U-factors in Table 3-2.

The Thermal Performance and Energy Code Compliance discussion on page i-33 and Fig. i-26 on page i-39 of the introductory chapter describes the typical process of navigating energy code compliance options. Additionally, the thermal modeling results demonstrated in this chapter may be used to assist with selecting wall system components (e.g., tie type, insulation R-value/inch, etc.) to achieve a target U-factor. Options for thermally optimizing this system, as determined through the modeling results, are also discussed.

System Effective Thermal Performance

Exterior insulation in this system may or may not be required to meet project-specific energy targets; however, when exterior insulation is used, cladding attachments and supports (e.g., masonry ties and shelf angle supports) will penetrate the exterior insulation and create areas of thermal bridging (i.e., heat loss).

Examples of typical standoff shelf angle and anchored masonry veneer ties are shown in Fig. 3-10 and Fig. 3-11.

An example of the thermal bridging created by shelf angle supports, whether continuous or stand-off, is described by Fig. 3-6 through Fig. 3-9. Fig. 3-7 shows dark blue (colder temperature) at the floor line edge for the continuous floor line shelf angle, whereas the floor line with a standoff shelf angle is light blue and yellow, indicating warmer temperatures. This thermal bridging reduces the system's effective thermal performance.

Three-dimensional thermal modeling demonstrates this system's effective thermal performance with various insulation thicknesses, insulation R-values, masonry veneer ties, and standoff shelf angle support options. A discussion on the modeling performed for this guide is included in the Appendix.



Fig. 3-11 Brick tie types used for modeling
From top to bottom: thermally optimized screw tie and double eye and pintle plate tie

Thermal Modeling: Variables

The following are modeling variables specific to this system:

- **Framing and Cavity Insulation:** 2x6 with R-21 batt insulation or 2x8 with R-30 batt insulation. Modeling results include a full-height wood-framed wall and floor line. Standard framing allowance for 77% insulated cavity and 23% framing members such as studs, plates, and headers is used.
- **Masonry Ties:** Various tie types are considered at 16-inches by 16-inches on-center spacing. Tie types are shown in Fig. 3-11 and include:
 - Thermally optimized screw tie with stainless barrel and carbon steel fastener. Hooks are either hot-dipped galvanized steel or Type 304 stainless steel.
 - Double eye and pintle plate tie (14-gauge). Hooks are either hot-dipped galvanized steel or Type 304 stainless steel to match the tie plate.
- **Exterior Insulation:** This system is considered with and without exterior insulation and includes insulation materials with either a thermal resistance of R-4.2/inch or R-6/inch in thicknesses of 1-, 2-, and 3-inches. The R-values selected demonstrate the lower and upper thermal resistance of typical exterior insulation products.
- **Shelf Angle Supports:** Hot-dipped galvanized steel shelf angles. Either attached tight to the floor line structure (i.e., continuous shelf angle) as shown in Fig. 3-6 and Fig. 3-7 or offset to the depth of the exterior insulation and supported by intermittent hollow steel sections (HSS) at 4 feet on-center (i.e., standoff shelf angle) as shown similar in Fig. 3-8 and Fig. 3-9.

Thermal Modeling: Results

Modeling results are shown in Table 3-1, Fig. 3-12, and Fig. 3-13 (see page 3-12 and page 3-13) and demonstrate the system's effective R-value under various conditions; Fig. 3-12 and Fig. 3-13 graphically represent the results summarized in Table 3-1.

Below is a discussion of the results. Where reductions in the system's effective R-value are discussed, these values are as compared to the system's effective R-value "Without Penetrations" such as ties and shelf angles.

- As determined from Table 3-1 for ties only, the system's effective R-value is reduced by 2 and 12%. *Reducing the frequency of ties will increase the effective*

thermal performance of the system but will also need to be coordinated with structural requirements.

- As determined from Table 3-1 for ties only, stainless-steel plate ties and thermally optimized screw ties reduce the system's effective R-value 2 to 7%, whereas galvanized-steel plate ties reduce the effective R-value by 3 to 12%. Galvanized-steel plate ties provide a lesser effective R-value than both the stainless-steel or thermally optimized screw tie options as shown in Fig. 3-12. Both stainless-steel and thermally optimized screw ties provide similar effective R-value performance. *Whether galvanized-steel hooks or stainless-steel hooks are used for thermally optimized tie selection makes little difference; however, stainless-steel hooks provide better corrosion resistance. A standard all-stainless-steel tie may prove to be a cost-effective option when compared to a thermally improved proprietary tie, and it also provides a highly corrosion-resistant attachment.*
- A shelf angle further reduces the system's effective R-value after ties are considered as shown in Table 3-1 and Fig. 3-13. When considering ties, the system's effective R-value is reduced by 4 to 20% with a continuous shelf angle and 3 to 13% with a standoff shelf angle. As determined from Fig. 3-13, up to an additional half-inch of insulation may be required to achieve the same effective thermal performance for this system if a continuous angle is used in lieu of a standoff shelf angle. *Use of a standoff shelf angle in lieu of the continuous shelf angle improves the effective thermal performance of this system and may allow for thinner insulation thicknesses when meeting thermal performance targets.*

Sheathing Selection

The exterior sheathing of this system is typically a wood- or gypsum-based product and is designated by structural requirements. Where wood-based products are used, **plywood** is generally recommended for its moisture tolerance. Where gypsum board is used, a product resistant to organic growth and moisture is recommended. Fiberglass-faced gypsum board products are commonly used; avoid paper face products.

Drainage, Ventilation, and Water Deflection

The anchored masonry veneer is expected to shed most water it is exposed to; however, some moisture is expected to penetrate the cladding and enter the air cavity. This moisture is drained through the air cavity and exits the cladding system where cross-cavity flashings are provided.

Table 3-1 System 3 thermal modeling results

Wood-Framed Wall with Anchored Masonry Veneer, 23% Framing Factor 2x6 Framing, R-21 Batt Insulation, R-4.2/in - R-6/in Exterior Insulation						
Tie Type	Tie Penetration Area	Exterior Insulation Thickness	System Nominal Insulation R-value (Cavity + Exterior Insulation)	3D Thermal Modeling Effective R-Value of System (ft ² ·°F·hr/Btu)		
				Without Penetrations (Through Exterior Insulation)	With Masonry Tie Penetrations Considered @ 16" x 16" O.C.	
Thermally Optimized Screw Tie – Stainless-Steel Hook	0.05%	0"	21 + 0	18.3	18.2	–
		1"	21 + 4.2-6	22.6-24.4	22.2-23.8	22.0-23.6
		2"	21 + 8.4-12	26.9-30.6	26.0-29.1	25.7-28.7
Thermally Optimized Screw Tie – Galvanized-Steel Hook	0.05%	3"	21 + 12.6-18	31.1-36.5	29.6-34.0	29.1-33.2
		0"	21 + 0	18.3	18.2	–
		1"	21 + 4.2-6	22.6-24.4	22.1-23.7	22.0-23.5
Plate Tie (14 ga) – Stainless Steel	0.05%	2"	21 + 8.4-12	26.9-30.6	26.0-29.1	25.7-28.6
		3"	21 + 12.6-18	31.1-36.5	29.5-33.9	29.1-33.2
		0"	21 + 0	18.3	18.2	–
Plate Tie (14 ga) – Galvanized Steel	0.05%	1"	21 + 4.2-6	22.6-24.4	22.2-23.8	22.0-23.6
		2"	21 + 8.4-12	26.9-30.6	26.0-29.1	25.7-28.7
		3"	21 + 12.6-18	31.1-36.5	29.6-34.0	29.2-33.3
Plate Tie (14 ga) – Galvanized Steel	0.05%	0"	21 + 0	18.3	18.1	–
		1"	21 + 4.2-6	22.6-24.4	21.9-23.4	21.7-23.2
		2"	21 + 8.4-12	26.9-30.6	25.4-28.2	25.1-27.8
Plate Tie (14 ga) – Galvanized Steel	0.05%	3"	21 + 12.6-18	31.1-36.5	28.6-32.3	28.1-31.7
		2x8 Framing, R-30 Batts, No Exterior Insulation				
		Plate Tie (14 ga) – Galvanized Steel	–	0"	30	22.8

Table 3-2 System 3 prescriptive energy code compliance values excerpted from Table i-1 of the introductory chapter

OPAQUE ABOVE-GRADE WALL - THERMAL ENVELOPE REQUIREMENTS									
Guide Assembly #	Energy Code Climate Zone	2012 SEC		2012 WSEC		2014 OEESC		2012 IECC	
		5 and Marine 4		5, 6 and Marine 4		5 and Marine 4		5 and Marine 4	
3 Wood-Framed Wall with Anchored Masonry Veneer	Classification	All Other		Group R		All Other		Group R	
	Wood-Framed and Other	R-13 + R-7.5ci	R-21 Int	R-21 Int	R-13 + R-3.8ci OR R-21	R-13 + R-3.8ci OR R-21	R-13 + R-7.5ci OR R-20 + R-3.8ci	R-13 + R-7.5ci OR R-20 + R-3.8ci	Group R
		U-0.051 (R-19.6)	U-0.054 (R-18.5)	U-0.054 (R-18.5)	U-0.064 (R-15.6)	U-0.064 (R-15.6)	U-0.064 (R-15.6)	U-0.051 (R-19.6)	

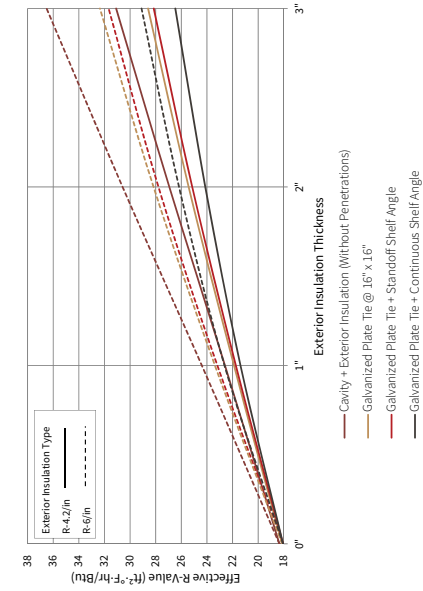


Fig. 3-13 System 3 effective R-value comparison of a galvanized steel plate tie and shelf angle options

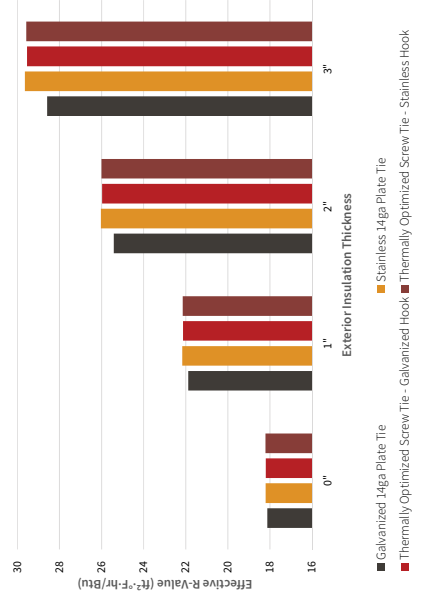


Fig. 3-12 System 3 effective R-value modeling results for various tie types and R-4.2/inch insulation

Drainage and Ventilation

In this system, the air cavity between the anchored masonry veneer and the exterior insulation provides drainage behind the cladding as well as ventilation when vent ports are provided at the top and bottom of the air cavity. The code-minimum air cavity depth is 1-inch, as required per TMS 402-16;⁶ however, the risk that mortar droppings will block the air cavity increases with smaller cavities. A 1-inch cavity may be considered when a strict quality control program is implemented to minimize the likelihood that mortar droppings will block the cavity; however, a 2-inch air cavity is best practice.

Where the air cavity is reduced, which commonly occurs at fenestration rough openings with return brick, a compressible free-draining filler is recommended such as semi-rigid mineral fiber insulation. Mortar should not be packed within these cavities.

The air cavity is ventilated through vents located at the top and bottom coursing of each wall section. Top vents typically occur just below parapet blocking and below intermittent bearing elements such as floor line shelf angles. Bottom vents, which also serve as weeps and may be referred to as weep/vents, also assist with draining moisture within the air cavity. These weep/vents are typically located just above bearing elements such as loose lintels, floor line shelf angles, or foundation walls. Example weep and weep/vent locations are shown in Fig. 3-14.

Vents and weep/vents are recommended to be spaced a maximum of 24-inches on-center (i.e., every two to three masonry units) and filled with a cellular or mesh product that fills the head joint of a standard brick unit. It is important that weep fillers extend into the bed joint of the course to facilitate drainage. Avoid weep tubes because they provide far less ventilation and are blocked easily with debris.

Use mortar collection nets at all veneer-bearing locations to prevent mortar from blocking the rainscreen cavity and weep/vents. Generally, a trapezoidal open-weave, moisture-tolerant net is used.

Sheet-Metal Components

Sheet-metal components used with this system are reflected throughout the details located at the end of this chapter. Cross-cavity sheet-metal components are typically located at all bearing elements such as the head of a penetration (e.g., window head), floor line shelf angles, and the foundation. These flashings assist with draining the rainscreen cavity and also serve to protect fluid-applied or flexible flashing membranes that may exist beneath them. Counterflashing sheet-metal components assist only with water shedding and are typically located at

window sill and parapet top conditions; they protect the cavity from water ingress while still allowing for cavity ventilation.

Refer to the Sheet-Metal Flashing Components discussion on page i-46 for general recommendations on sheet-metal flashing products, including design considerations and materials.

Movement Joints

For this system, anchored clay masonry will expand over time as a result of irreversible moisture gain, and mortar joints will shrink slightly overtime. In the support system, the wood-framed members will shrink due to moisture loss. To minimize the risk of veneer damage, breaks must be provided in the veneer to compensate for any differential movement between the cladding and the support wall. Expansion joints also must be provided to allow for overall expansion of the clay masonry veneer; control joints must be provided for shrinkage where concrete masonry veneer units are used.

Differential vertical movement between the structure and the veneer is accommodated with a horizontal gap between the veneer and elements that are directly attached to the wall structure, such as shelf angle supports, parapet



Fig. 3-14 Mesh weep/vents located within the head joints of a soldier course of lip brick. The base of each weep/vent is tight to an underlying cross-cavity sheet-metal flashing, which is concealed by the lip brick.

blocking, and windows. Either a backer rod and sealant joint or a cross-cavity sheet-metal flashing is placed at each horizontal gap. The sizing and location of joints will vary depending on the expected differential movement between the wall and the veneer.

Expansion joints (clay masonry veneer) or control joints (concrete masonry veneer) minimize stresses within the veneer and also between dissimilar materials such as at window jamb to veneer interfaces.

Expansion/shrinkage of the veneer or differential movement between the veneer, penetrations, and different cladding materials is accommodated with vertical joints in the veneer system as shown similar in Fig. 1-18 on page 1-16. Vertical gaps minimize stresses between the veneer and other components to provide crack control for the masonry veneer. Vertical gaps are typically sealed with a backer rod and sealant.

Typical locations of joints for the purposes of accommodating movement, drainage, and/or rainscreen cavity ventilation are identified with an asterisk (*) in chapter details. In general, a minimum gap dimension of $\frac{3}{8}$ -inch is recommended; however, it is the Designer of Record's responsibility to appropriately locate and size all movement joints.

Refer to the Movement Joints discussion on page i-48 for more information on locating veneer joints and sealant joint best practices.

Structural Considerations

The wood framing provides the primary structure of this wall system. It is the responsibility of the Designer of Record to ensure that all structural elements of the backup wall and veneer are designed to meet project-specific loads and local governing building codes. Generic placement of the reinforced elements and supports/ties is demonstrated within the details of this chapter and is provided for diagrammatic purposes only.

Masonry Ties

Masonry ties (i.e., masonry anchors) are used to connect the veneer to the wood-framed backup wall. They are designed to resist the out-of-plane loads applied to the wall, typically wind and seismic. At the same time, these ties must be flexible to allow the veneer to move in-plane relative to the wood-framed wall.

Building codes provide prescriptive requirements for masonry ties secured to concrete or masonry that includes spacing, size, placement, and tie type. These requirements are summarized in Table 3-3 and are based on TMS 402-16⁶

Table 3-3 Prescriptive spacing requirements for anchored masonry veneer ties based on TMS 402-16⁶ provisions

Prescriptive Spacing for Adjustable Two-Piece Masonry Veneer Ties			
Spacing Designation	Requirement Category (use more stringent spacing requirement where applies)		
	General	Seismic Design Categories D, E, and F ⁽¹⁾	High Wind ⁽²⁾
Maximum Wall Area per Anchor	2.67 ft ²	2.00 ft ² (75% of General Requirement Max.)	1.87 ft ² (70% of General Requirement Max.)
Maximum Horizontal Spacing	32 inches	32 inches	18 inches
Maximum Vertical Spacing	25 inches	25 inches	18 inches
Maximum Spacing at Opening ⁽³⁾	36 inches	36 inches	24 inches
Maximum Distance from Openings	12 inches	12 inches	12 inches

⁽¹⁾ Seismic design categories as determined by ASCE 7

⁽²⁾ High wind includes wind velocity pressures between 40 psf and 55 psf as determined by ASCE 7 and when the building's mean roof height is less than or equal to 60 feet

⁽³⁾ For openings larger than 16 inches in either dimension

provisions for adjustable ties (i.e., anchors). Use of these prescriptive requirements is limited to masonry veneer assemblies with a weight less than 40 psf, with a cavity depth no more than 6- $\frac{5}{8}$ -inches, and where the ASCE-7⁷ wind velocity pressure (q_z) is less than 55 psf (previously wind speed less than 130 mph). Wall assemblies that exceed these criteria require the design professional to evaluate the building loads and materials and rationally design the anchorage system accordingly. The majority of masonry tie manufacturers have empirical testing data available to support the use of their anchorage systems when the cavity depth or loads exceed these criteria.

Prescriptive spacing requirements for anchored masonry veneers are included in Table 3-3 for special requirements for Seismic Design Categories D, E, and F and high-wind zones with velocity pressures (q_z) between 40 and 55 psf. These higher seismicity and wind speed areas are common to some parts of the Northwest and are dependent on the geography and building occupancy category. Refer to local building code requirements to ensure seismicity and wind speed criteria are properly evaluated for the building occupancy and site conditions.

Common tie types for reference are shown in Fig. 3-15 on page 3-18. For wood-framed walls, the code does not restrict the use of any tie type.

- Based on local preference, double eye and pintle type ties (whether a plate or screw type) are commonly used. Double eye and pintle ties are available from a number of manufacturers in a variety of sizes to meet project requirements in the Northwest.
- Adjustable L-bracket triangular wire ties are acceptable but may not be preferred by installers because the vertical tie orientation can complicate exterior insulation installation by requiring vertical insulation boards.
- TMS 402-16⁶ does not allow non-adjustable ties, including corrugated and nonadjustable surface-mounted ties, for this system.

To prevent pull-out or push-through of the tie, TMS 402-16⁶ requires ties be embedded a minimum of 1-½-inches into the veneer, with at least ⅝-inch mortar or grout cover at the outside face. The mortar bed thickness is to be at least twice the thickness of the tie. To prevent excess movement between connecting parts of adjustable tie systems, the clearance between components is limited to a maximum ⅛-inch. The vertical offset of adjustable pintle-type ties may not exceed 1¼-inches.

TMS 402-16⁶ requires that masonry ties are fastened directly to the wood framing through the exterior sheathing. Masonry anchors are not to be fastened to the

sheathing alone. The code requires the use of 8d common nails or fasteners with equivalent or greater pull-out strength. However, in Seismic Design Categories D, E, and F, the code requires the use of 8d ring-shank nails or No. 10 corrosion-resistant screws with a minimum nominal shank diameter of 0.190-inches. *While the code may allow a horizontal anchor spacing up to 32-inches on-center, spacing anchors horizontally is recommended for alignment with the typical stud spacing, typically 16-inches on center.*

Vertical Supports

Anchored masonry veneers are supported vertically by the building's foundation or other structural components such as shelf angles and lintels; examples of vertical supports are shown in Fig. 3-16.

Vertical supports are designed to eliminate the possibility of cracking and deflection within the veneer; the support design considers the design loads, material type, moisture control, movement provisions, and constructibility. When vertical supports span horizontally, the deflection of these supports is limited to L/600 per TMS 402-16.⁶

For wood-framed backings, TMS 402-16 allows anchored masonry veneer supported vertically by noncombustible construction to be installed up to a height of 30 feet (or 38 feet at a gable). Wherever the masonry veneer is supported by wood construction, it must be supported every 12 feet. Best practice for commercial wood-framed construction is to support the lowest portion of the masonry cladding directly on the concrete foundation wall.

At moderately sized openings within the system (e.g., windows and doors), the masonry veneer is typically supported with loose lintels above the opening. Galvanized steel angles are commonly used; however, reinforced masonry or precast concrete lintels may be considered for appearance. Steel angle lintels



Fig. 3-15 Brick tie types. Top row, left to right: standard double eye and pintle plate tie, thermally optimized double eye and pintle screw tie. Bottom row, left to right: corrugated masonry tie, adjustable L-bracket, nonadjustable surface-mounted tie.



Fig. 3-16 This masonry veneer bears on continuous shelf angles (at right and above) and a concrete foundation element (at left).

span the opening and bear a minimum of 4-inches (per TMS 402-16⁶ or more where required by Designer of Record) onto the adjacent veneer at the jambs of the opening.

Corrosion Resistance

It is best practice to match the durability and longevity of metal components within this system to that expected of the masonry veneer. Metal components within this system include veneer ties, vertical support ledgers and lintels, sheet-metal flashings, and fasteners. This guide includes discussion for common corrosion-resistant materials; however, it is the Designer of Record's responsibility to appropriately select a level of corrosion resistance for project-specific application/exposure and the expected longevity of the masonry system.

It is common to provide hot-dipped galvanized carbon steel masonry veneer ties that comply with ASTM A 153⁸ Class B-2, AISI Type 304, or AISI Type 316 stainless steel per ASTM A580.⁹ Steel support angles such as shelf angle supports and loose lintels are at minimum hot-dipped galvanized and comply with ASTM A123.¹⁰

Best practice is to use sheet-metal flashing components of ASTM A666¹¹ Type 304 or 316 stainless steel, which is nonstaining and resistant to the alkaline content of mortar materials. Where stainless steel sheet-metal flashing components are not economically feasible or aesthetically desirable, prefinishing sheet-metal may be considered. Where used, this guide recommends the base sheet metal is a minimum G90 hot-dipped galvanized coating in conformance with ASTM A653¹² or minimum AZ50 galvalume coating in conformance with ASTM A792.¹³ Coating the exposed top finish of the sheet metal with an architectural-grade coating conforming to AAMA 621¹⁴ is recommended.

Fasteners used with metal components should be corrosion-resistant, either hot-dipped galvanized steel or stainless steel to match adjacent metal components. When used with preservative-treated wood, also consider fastener selection to prevent galvanic corrosion.

Masonry Veneer

There are several types of anchored masonry veneer products that may be used with this system. Those most typical within the Northwest include facing brick made of clay or shale. Concrete facing brick and concrete masonry units are also used.

For facing brick made from clay or shale, use anchored veneer units that comply with ASTM C216¹⁵ and are severe weather (SW) grade. When using concrete facing

brick, anchored veneer units are to comply with ASTM C1634.¹⁶ Hollow concrete masonry units used for veneer applications are typically 4-inches deep and comply with ASTM C90.¹⁷

Mortar designed for the anchored masonry veneer units is to conform to ASTM C270¹⁸ and be the appropriate type for the veneer application. Type N mortar is acceptable for most anchored masonry veneer applications. Select the lowest compressive strength (softest) mortar that satisfies the project requirements.

Appropriate product selection of masonry veneer unit and mortar materials is necessary to provide a durable and water-resistive cladding system. Install the masonry veneer units and mortar joints in conformance with industry standard best practices and manufacturer requirements. Have a qualified Designer of Record designed and review the specifics of architectural characteristics and structural properties of the masonry veneer units, mortar, and reinforcing.

Various industry resources are available to assist with veneer design and are listed in the Resources section at the back of this guide.

Clear Water Repellents

Application of a clear water repellent to the anchored masonry veneer of this system is common in the Northwest. Refer to the Surface-Applied Clear Water Repellents discussion on page i-59 for more information on selecting an appropriate clear water repellent and for best practice installation guidelines.

Pricing Summary

A pricing summary for this system is provided on Table 3-4 on page 3-24. Pricing demonstrates the relative price per square foot and is based on a 10,000-square-foot wall area with easy drive-up access. Pricing includes all components outboard of the exterior wall sheathing and provides no evaluation for interior finishes (including vapor retarder), framing/sheathing, or cavity insulation. Pricing is valid for 2018. Current pricing is also available at www.masonrysystemsguide.com.

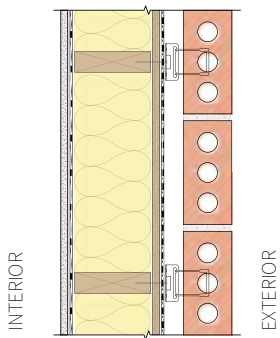
Online Availability

The content of this guide and additional resources may be accessed online at www.masonrysystemsguide.com. Also available online are downloadable versions of two- and three-dimensional system details and cutaway sections, sample project specifications, and ongoing updates to references and resources included within this guide.

Chapter References

1. International Code Council. *2015 International Building Code*. (Country Club Hills, IL: International Code Council, Inc., 2014).
2. National Fire Protection Association. *NFPA 285 - Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Non-Load-Bearing Wall Assemblies Containing Combustible Components*. (Quincy, MA: National Fire Protection Association, 2012).
3. American Society of Heating, Refrigerating, and Air-Conditioning Engineers. *ANSI/ASHRAE/IES Standard 90.1-2016 Energy Standard for Buildings Except Low-Rise Residential Buildings, IP ed.* (Atlanta: ASHRAE, 2016).
4. U.S. Department of Energy. COMcheck (version 4.0.7). Windows or Online. Washington, D.C.: U.S. Department of Energy, 2017, <https://www.energycodes.gov/comcheck>.
5. 2015 Washington State Energy Code, Commercial Provisions. Chapter 51-11C WAC (filed by Washington State Legislature, January 19, 2016).
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7. American Society of Civil Engineers. *Minimum Design Loads for Buildings and Other Structures*, ASCE/SEI 7-10. (Reston, VA: ASCE Press, 2013).
8. ASTM International. *ASTM A153/A153M-16a Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*. (West Conshohocken, PA: ASTM International, 2016).
9. ASTM International. *ASTM A580/580M-16 Standard Specification for Stainless-Steel Wire*. (West Conshohocken, PA: ASTM International, 2016).
10. ASTM International. *ASTM A123/A123M-15 Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products*. (West Conshohocken, PA: ASTM International, 2015).
11. ASTM International. *ASTM A666-15 Standard Specification for Annealed or Cold-Worked Austenitic Stainless-Steel Sheet, Strip, Plate, and Flat Bar*. (West Conshohocken, PA: ASTM International, 2015).
12. ASTM International. *ASTM A653/A653M-15e1 Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process*. (West Conshohocken, PA: ASTM International, 2015).
13. ASTM International. *ASTM A792-15 Standard Specification for Steel Sheet, 55% Aluminum-Zinc Allow-Coated by the Hot-Dip Process*. (West Conshohocken, PA: ASTM International, 2015).
14. American Architectural Manufacturers Association. *AAMA 621-02 Voluntary Specification for High-Performance Organic Coatings in Coil-Coated Architectural Hot-Dipped Galvanized (HDG) and Zinc-Aluminum Coated Steel Substrates*. (Schaumburg, IL: American Architectural Manufacturers Association, 2002).
15. ASTM International. *ASTM C216-17 Standard Specification for Facing Brick (Solid Masonry Units Made from Clay or Shale)*. (West Conshohocken, PA: ASTM International, 2017).
16. ASTM International. *ASTM C1634-16 Standard Specification for Concrete Facing Brick*. (West Conshohocken, PA: ASTM International, 2016).
17. ASTM International. *ASTM C90-16a Standard Specification for Loadbearing Concrete Masonry Units*. (West Conshohocken, PA: ASTM International, 2016).
18. ASTM International. *ASTM C270-14a Standard Specification for Mortar for Unit Masonry*. (West Conshohocken, PA: ASTM International, 2014).

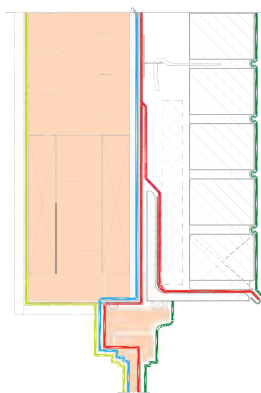
Table 3-4 System 3 wood-framed wall with anchored masonry veneer pricing summary

System 3: Wood Framed Wall with Anchored Masonry Veneer					
System Component		Baseline Product	Alternate (call for estimate)	Baseline Cost/ft ² (incl. labor)	
				Low	High
INTERIOR					
1	Interior gypsum board	No evaluation of these components provided.			
2	Vapor retarder				
3	Wood-framed wall with batt insulation				
4	Exterior sheathing				
5*	Air and water-resistive barrier (AB/WRB)	Fully adhered or mechanically attached sheet-applied membrane	Fluid-applied membrane system	\$1.50	\$3.75
6	Air cavity	Not applicable	Not applicable	-	-
7*	Anchored masonry veneer (without ties)	SW brick masonry modular unit (3-5/8" x 2-1/4" x 7-5/8") FBX, running bond; Type S or N mortar	No specified alternate	\$25.00	\$27.80
8*	Anchored masonry veneer ties	14-gauge hot-dipped galvanized or stainless-steel plate tie, including fasteners	Thermally optimized screw tie with stainless or hot-dipped galvanized hook	\$2.50	\$5.00
9*	Clear water repellent	Silane/siloxane blend	Antigraffiti clear water repellent	\$1.75	\$2.50
EXTERIOR					
Total cost to install 10,000 sq ft wall area w/easy drive-up access -->				\$30.75	\$39.05
Pricing Summary Discussion			System Plan View		
<ul style="list-style-type: none">- Low and high baseline costs are based on baseline products and installed labor costs. Call for an estimate for alternative product pricing.- Baseline costs provided will vary based on product specific conditions, as well as project location, and should be used as an estimate only.- Veneer unit prices are for typical units as noted. Pricing can vary based on size, color, and finish and should be confirmed with the unit manufacturer.- *See the Resources section of this guide for a list of resources related to this component.					

LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Vapor retarder
 - Wood-framed wall with batt insulation
 - Exterior sheathing
 - Sheet-applied air barrier and WRB field membrane
 - Air cavity
 - Anchored masonry veneer
 - Clear water repellent
2. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
3. Continuous mortar collection mesh
4. Continuous air barrier sealant
5. Hot-dipped galvanized-steel loose lintel (or continuous shelf angle support)
6. Sheet- or fluid-applied air barrier and WRB prestrip membrane
7. Weep/vent at maximum 24-inches on-center
8. Sheet-metal flashing with hemmed drip edge and end dams beyond
9. Sealant over backer rod
10. Air barrier sealant over backer rod, tie to continuous seal at window perimeter
11. Flanged window

Water-Shedding Surface and Control Layers

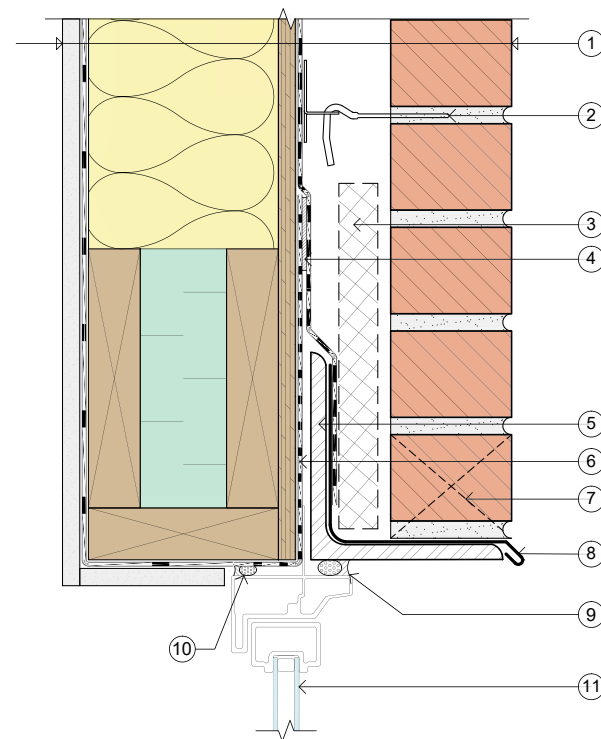


— Water-Shedding Surface

Control Layers:*

— Water
— Air
— Vapor
— Thermal

* Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing



Detail Discussion

- Air and water control layer continuity is provided by the sheet-applied air barrier and WRB field membrane, sheet-applied or fluid-applied air barrier and WRB prestrip membrane, continuous air barrier sealant, and air barrier sealant transition to the window.
- A flanged window is depicted. Consider using a non-flanged window unit to facilitate future window repair and replacement without the need to remove the anchored masonry veneer. Refer to window strap anchor detailing in Chapter 2 details when a non-flanged window is used.
- Refer Fig. i-41 on page i-53 of the introductory chapter of this guide for lip brick detailing options which can minimize the appearance of the sheet-metal flashing shown in this detail.
- Weep/vents located above the angle support provide rainscreen cavity drainage and assist with ventilation. The mortar collection mesh minimizes the risk that mortar dropping will block weep/vents.

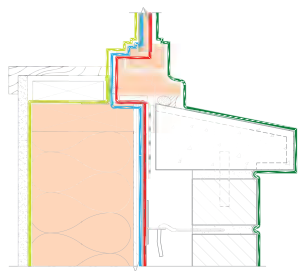
Typical Window Head

Detail 3-A

LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Vapor retarder
 - Wood-framed wall with batt insulation
 - Exterior sheathing
 - Sheet-applied air barrier and WRB field membrane
 - Air cavity
 - Anchored masonry veneer with
 - Clear water repellent
2. Flanged window
3. Sealant over backer rod
4. Minimum 1/4-inch-thick intermittent shims
5. Minimum 1/8-inch-thick intermittent shims behind sill flange for drainage
6. Sloped precast sill, sealant over backer rod (beyond), where applicable
7. Self-adhered or fluid-applied flashing membrane
8. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
9. Continuous air barrier sealant tied to continuous seal at window perimeter
10. Continuous back dam angle at rough opening sill, minimum 1-inch tall. Fasten window through back dam angle per window manufacturer recommendations.

Water-Shedding Surface and Control Layers



Water-Shedding Surface

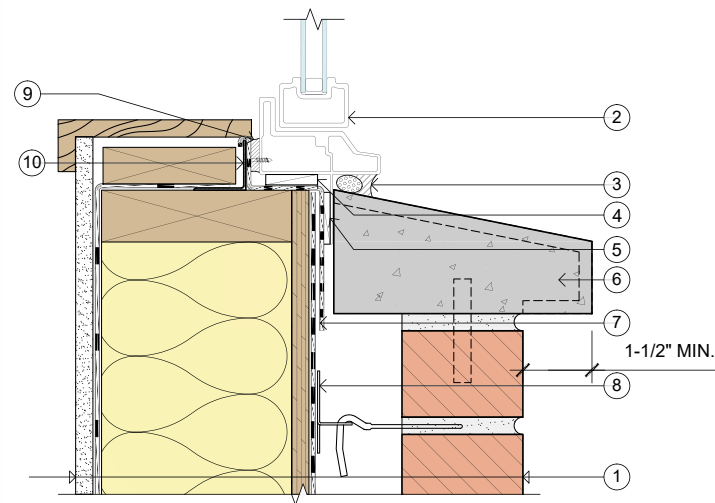
Control Layers:*

- Water
- Air
- Vapor
- Thermal

* Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing

Detail Discussion

- Air and water control layer continuity is provided by the sheet-applied air barrier and WRB field membrane, self-adhered or fluid-applied flashing membrane, and air barrier sealant transition to the window.
- A flanged window is depicted. Consider using a non-flanged window unit to facilitate future window repair and replacement without the need to remove the anchored masonry veneer. Refer to window strap anchor detailing in Chapter 2 details when a non-flanged window is used.
- This guide recommends that a sheet-metal flashing is **not** placed below the precast sill. It can prematurely degrade the mortar bed beneath the precast element.



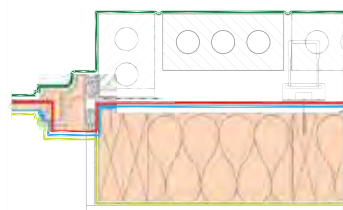
Typical Precast Windowsill

Detail 3-B

LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Vapor retarder
 - Wood-framed wall with batt insulation
 - Exterior sheathing
 - Sheet-applied air barrier and WRB field membrane
 - Air cavity
 - Anchored masonry veneer with
 - Clear water repellent
2. Flanged window
3. Sealant over backer rod
4. Minimum 1/2-inch drainage path, fill with free-draining compressible material
5. Sheet- or fluid-applied air barrier and WRB prestrip membrane
6. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations

Water-Shedding Surface and Control Layers

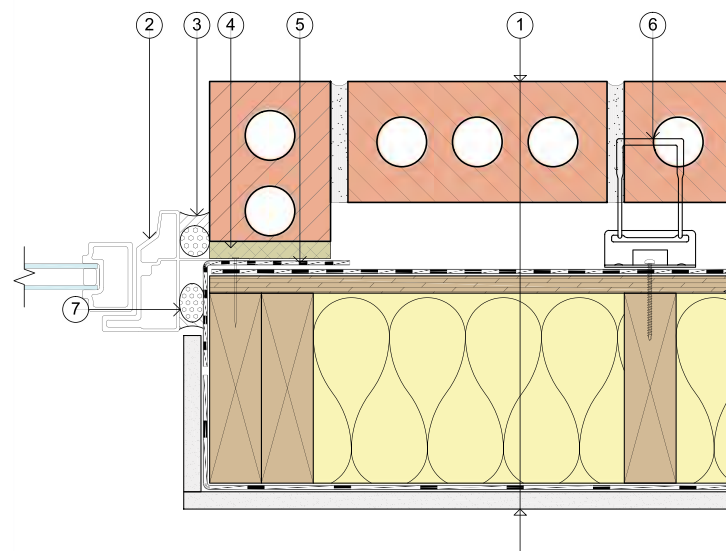


Water-Shedding Surface

Control Layers:*

Water
Air
Vapor
Thermal

* Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing



Detail Discussion

- Air and water control layer continuity is provided by the sheet-applied air barrier and WRB field membrane, sheet-applied or fluid-applied air barrier and WRB prestrip membrane, and air barrier sealant transition to the window.
- Maintain a clear drainage cavity between the brick return and the air barrier and WRB system by placing a free-draining material such as semi-rigid mineral fiberboard insulation between the masonry veneer and sheet-applied or fluid-applied air barrier and WRB prestrip membrane. Avoid filling this space with mortar.
- When exterior insulation is used with this wall system, consider the Chapter 2 rough opening details with sheet-metal jamb trim and sill flashing. Chapter 2 details are a thermally improved alternative to returning the masonry veneer at the jamb. This alternative allows for consistent exterior insulation thickness at the window perimeter.

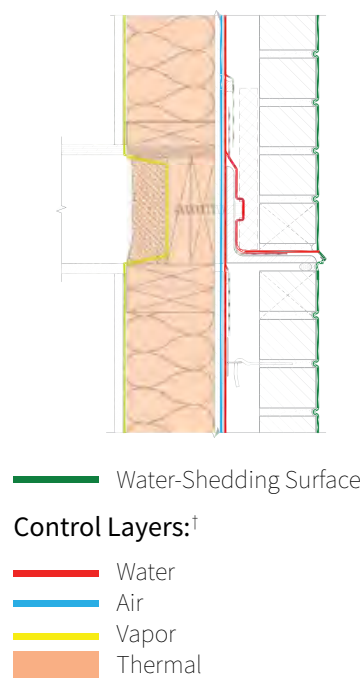
Typical Brick Return at Window Jamb

Detail 3-C

LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Vapor retarder
 - Wood-framed wall with batt insulation
 - Exterior sheathing
 - Sheet-applied air barrier and WRB field membrane
 - Air cavity
 - Anchored masonry veneer with
 - Clear water repellent
 2. Continuous air barrier sealant
 3. Self-adhered or fluid-applied flashing membrane
 4. Continuous mortar collection mesh
 5. Hot-dipped galvanized steel shelf angle support anchored to structure
 6. Closed cell spray foam insulation
 7. Weep/vent at maximum 24-inches on-center
 8. Sheet-metal flashing with hemmed drip edge
 9. Sealant over backer rod
 10. Vent at maximum 24-inches on-center
 11. Self-adhered or fluid-applied flashing membrane
 12. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
- * Size gap for project-specific movement, minimum 3/8-inch

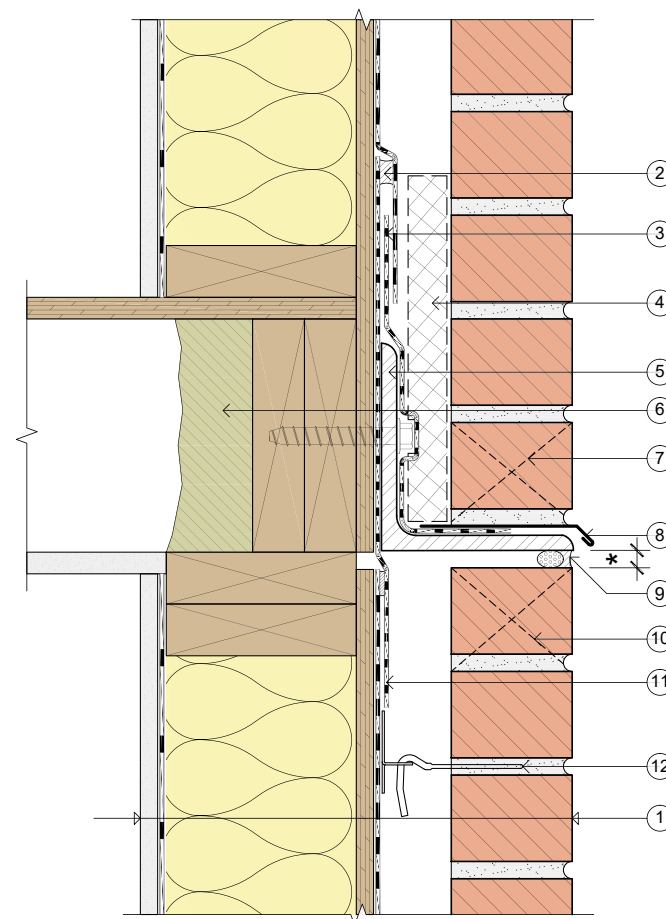
Water-Shedding Surface and Control Layers



† Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing

Detail Discussion

- Air and water control layer continuity is provided by the sheet-applied air barrier and WRB field membrane, self-adhered or fluid-applied flashing membranes, and continuous air barrier sealant.
- Mortar collection mesh and weep/vents and vents are provided to encourage drainage and ventilation of the rainscreen cavity.
- The floor line is insulated with a closed-cell spray foam, which provides both thermal control layer continuity and vapor control layer continuity (when the insulation is installed to a depth at which it performs as a vapor retarder)
- Refer Fig. i-41 on page i-53 of the introductory chapter of this guide for lip brick detailing options which can minimize the appearance of the sheet-metal flashing shown in this detail. Note that this joint is necessary for differential movement that may occur between the structure and anchored masonry veneer.



Typical Floor Line with Continuous Shelf Angle Support

Detail 3-D

LEGEND

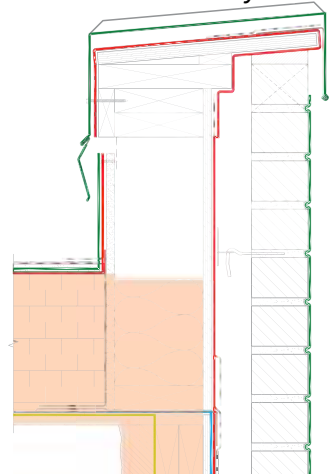
1. Parapet Assembly
 - Roof membrane
 - Exterior sheathing
 - Vented wood-framed parapet
 - Exterior sheathing
 - Sheet-applied air barrier and WRB field membrane
 - Air cavity
 - Anchored masonry veneer with
 - Clear water repellent
2. Conventional roof assembly
3. Sloped standing-seam sheet-metal coping with gasketed washer fasteners
4. High-temperature self-adhered membrane
5. Compressible filler
6. Vent at maximum 24-inches on-center
7. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per air barrier and WRB system manufacturer recommendations
8. Self-adhered or fluid-applied transition membrane
9. Roof assembly air/vapor barrier prestrip membrane
10. Sheet-applied air barrier and WRB field membrane
11. Batt insulation
12. Preservative-treated blocking
13. Insect screen

* Size gap for project-specific movement, minimum 3/8-inch

Detail Discussion

- In this detail, air control layer continuity is provided by the roof membrane air/vapor barrier prestrip membrane, the self-adhered or fluid-applied transition membrane, and the sheet-applied air barrier and WRB field membrane.
- Vents are located at the top masonry course to encourage ventilation of the rainscreen cavity. The sheet-metal parapet coping with hemmed drip edge is held off the anchored masonry veneer face to minimize blocking air flow through the vents. The sheet-metal coping also protects the vent opening from wind-driven rain.
- Refer to the next pages for a typical parapet detail with an alternative roof-to-wall air control layer transition.

Water-Shedding Surface and Control Layers

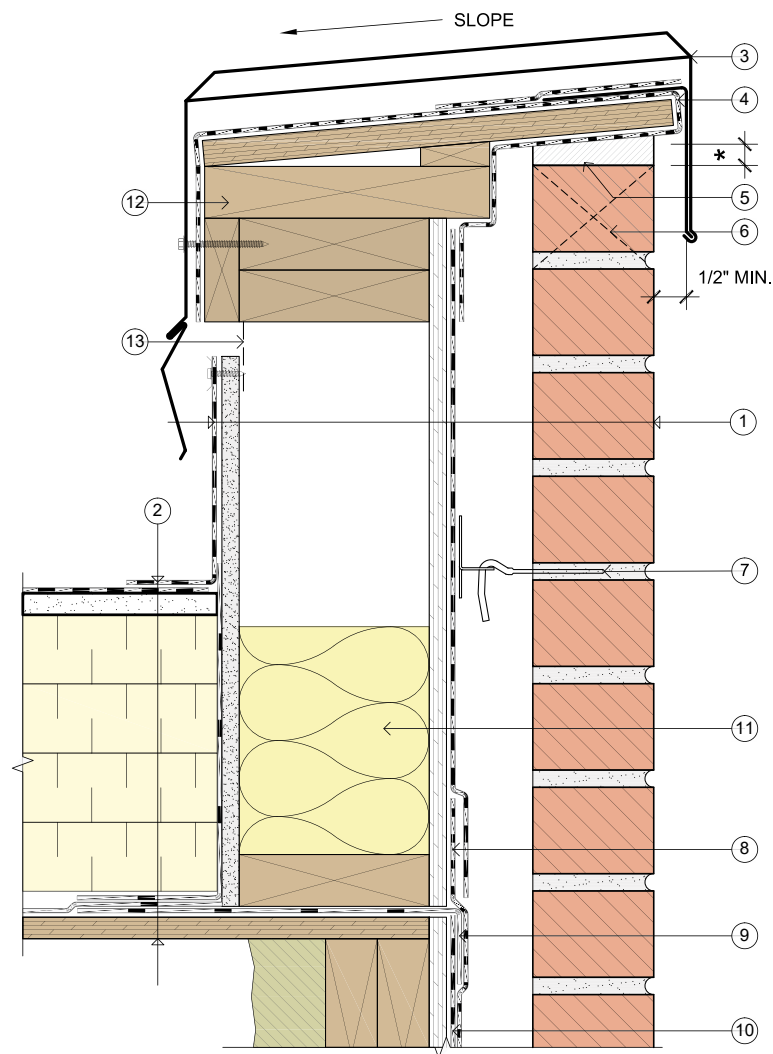


Water-Shedding Surface

Control Layers:†

Water
Air
Vapor
Thermal

† Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing



Parapet at Conventional Roof System with Air Barrier Prestrip

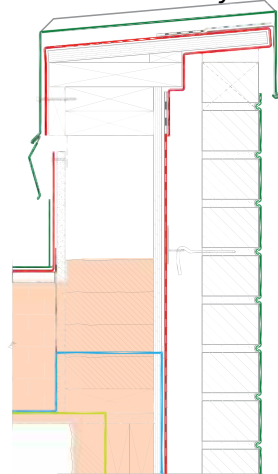
Detail 3-E

LEGEND

1. Parapet Assembly
 - Roof membrane
 - Exterior sheathing
 - Vented wood-framed parapet
 - Exterior sheathing
 - Sheet-applied air barrier and WRB field membrane
 - Air cavity
 - Anchored masonry veneer with
 - Clear water repellent
2. Conventional roof assembly
3. Sloped standing-seam sheet-metal coping with gasketed washer fasteners
4. High-temperature self-adhered membrane
5. Compressible filler
6. Vent at maximum 24-inches on-center
7. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per air barrier and WRB system manufacturer recommendations
8. Continuous air barrier sealant between sheathing and sheet air barrier and WRB field membrane
9. Insect screen
10. Preservative-treated blocking

* Size gap for project-specific movement, minimum 3/8-inch

Water-Shedding Surface and Control Layers



— Water-Shedding Surface

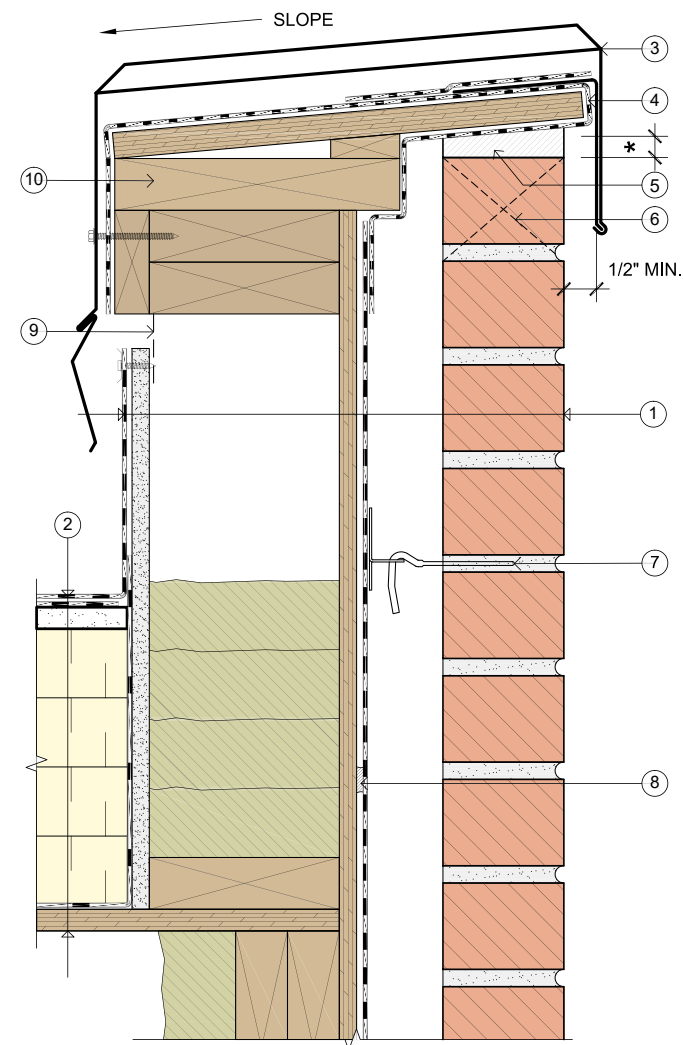
Control Layers:†

- Water
- Air
- Vapor
- Thermal

† Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing

Detail Discussion

- In this detail, air control layer continuity is provided by the roof assembly air/vapor barrier membrane, closed-cell spray foam insulation within the parapet cavity, the continuous air barrier sealant, and the sheet-applied air barrier and WRB field membrane.
- At minimum, parapet cavity and roof insulation R-values should be equivalent.
- The sheet-metal parapet cap is offset from the face of the masonry veneer to avoid blocking the ventilation path. A 1/2-inch gap is recommended.



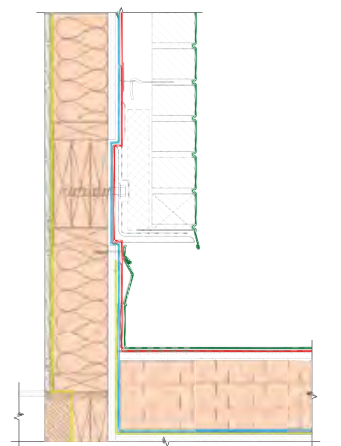
Parapet at Conventional Roof System with Spray Foam Plug

Detail 3-F

LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Vapor retarder
 - Wood-framed wall with batt insulation
 - Exterior sheathing
 - Sheet-applied air barrier and WRB field membrane
 - Air cavity
 - Anchored masonry veneer with
 - Clear water repellent
2. Typical conventional roof assembly
3. Continuous air barrier sealant
4. Self-adhered or fluid-applied flashing membrane
5. Self-adhered or fluid-applied flashing membrane
6. Continuous mortar collection mesh
7. Hot-dipped galvanized-steel continuous shelf angle support
8. Weep/vent at maximum 24-inches on-center
9. Sheet-metal flashing with hemmed drip edge
10. Two-piece sheet-metal counterflashing and termination bar at roof termination
11. Closed-cell spray foam insulation

Water-Shedding Surface and Control Layers



— Water-Shedding Surface

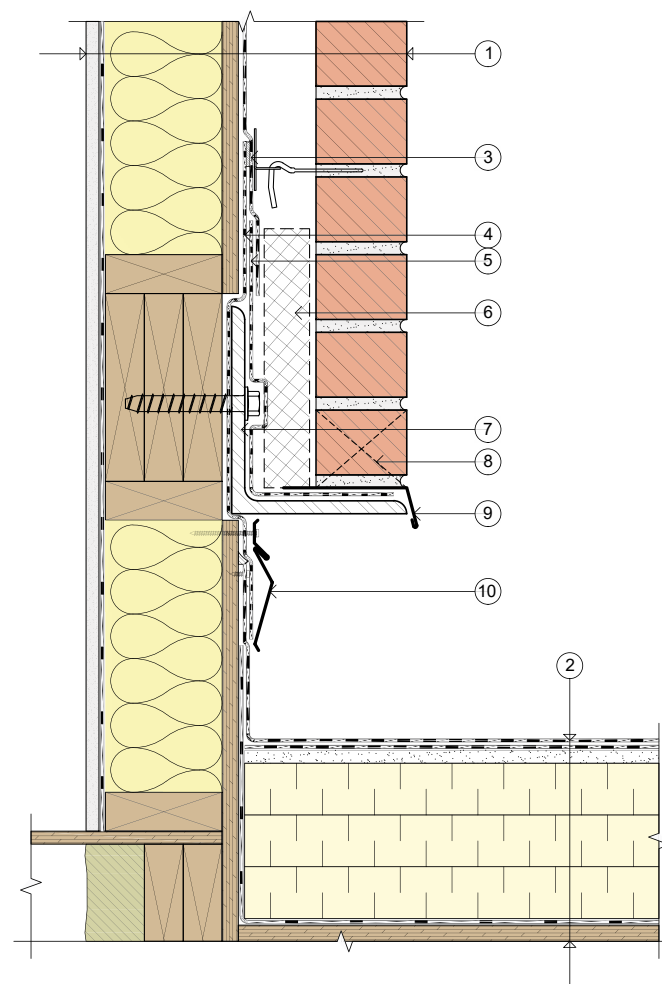
Control Layers:†

— Water
— Air
— Vapor
— Thermal

†Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing

Detail Discussion

- Masonry wall system installation often precedes roof membrane installation. As a result, the sequence of roof-to-wall transition detailing needs to be considered. As shown, the self-adhered flashing membrane behind the ledger may be left long, to hang below the ledger, to lap over the roof base flashing termination once installed. This membrane provides continuity of the air barrier system between the wall and roof assemblies.
- The roof termination bar and sheet-metal counterflashing conceal the self-adhered flashing from UV exposure.



Conventional Roof Assembly-to-Wall Interface

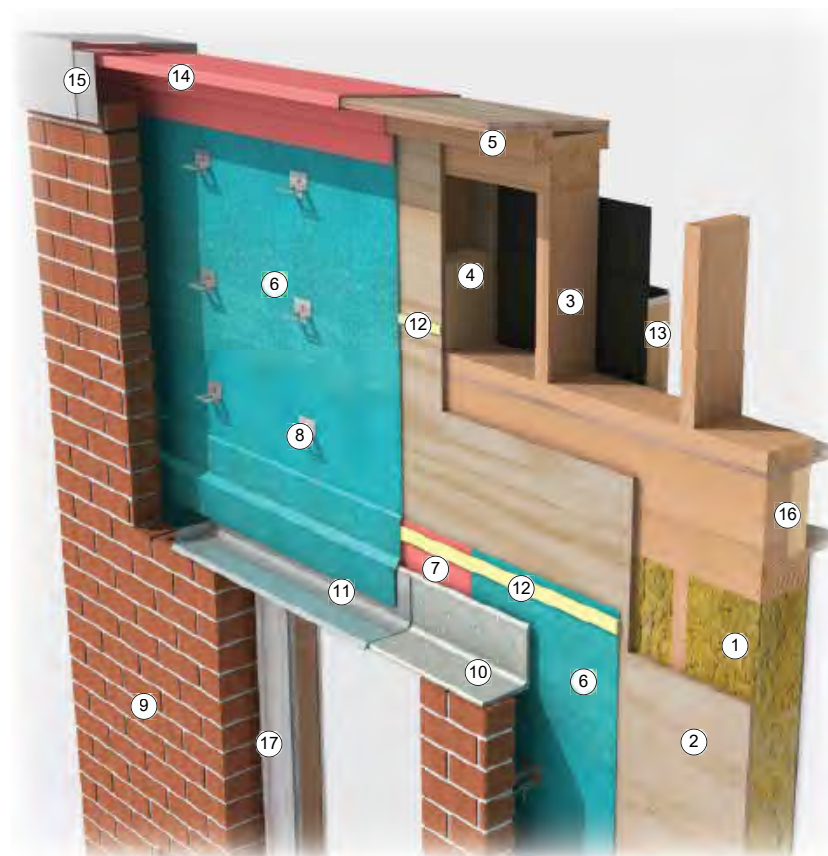
Detail 3-G

LEGEND

1. Wood-framed wall with batt insulation
2. Exterior sheathing
3. Vented wood-framed parapet
4. Closed-cell spray foam insulation
5. Sloped preservative-treated blocking
6. Sheet-applied air barrier and WRB field membrane
7. Sheet-applied or fluid-applied air barrier and WRB prestrip membrane
8. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
9. Anchored masonry veneer
10. Hot-dipped galvanized-steel loose lintel
11. Sheet-metal head flashing with hemmed drip edge and end dams beyond
12. Continuous air barrier sealant
13. Conventional roof assembly
14. High-temperature self-adhered membrane over
15. Sloped standing-seam sheet-metal coping with gasketed washer fasteners
16. Closed-cell spray foam insulation
17. Flanged window

3-D Detail Discussion (Details 3-H, 3-I, 3-J)

- Three-dimensional cutaway sections on the next three pages represent two-dimensional details of this system with the exception
- In all details, water control layer elements are shingle-lapped to encourage drainage within the rainscreen cavity.
- As shown in Detail 3-G, the lintel is placed above the window head and shingle-lapped into the air barrier and WRB field membrane. The continuous air barrier sealant above this location provides air barrier continuity between the sheet-applied or fluid-applied air barrier and WRB prestrip membrane field membrane.
- As shown in Detail 3-G, air control layer continuity at the roof-to-wall interface is maintained with the line of continuous air barrier sealant at the parapet and the closed-cell spray foam insulation within the parapet framing. These components transfer the air control layer from the roof assembly to wall system.
- Terminate the sheet-metal head flashing in Detail 3-G at a masonry veneer head joint. This allows for an end dam to be formed at the termination.
- Weep/vents at the floor line continuous shelf angle support shown in Detail 3-H provide both drainage and ventilation of the rainscreen cavity above. Mortar collection mesh helps keep the weeps and the base of the rainscreen cavity free of mortar droppings.
- Detail 3-I describes a typical rough opening with continuous sill back dam angle. The back dam angle creates a sill pan below the window; intermittent shims encourage drainage at the sill and into the rainscreen cavity.

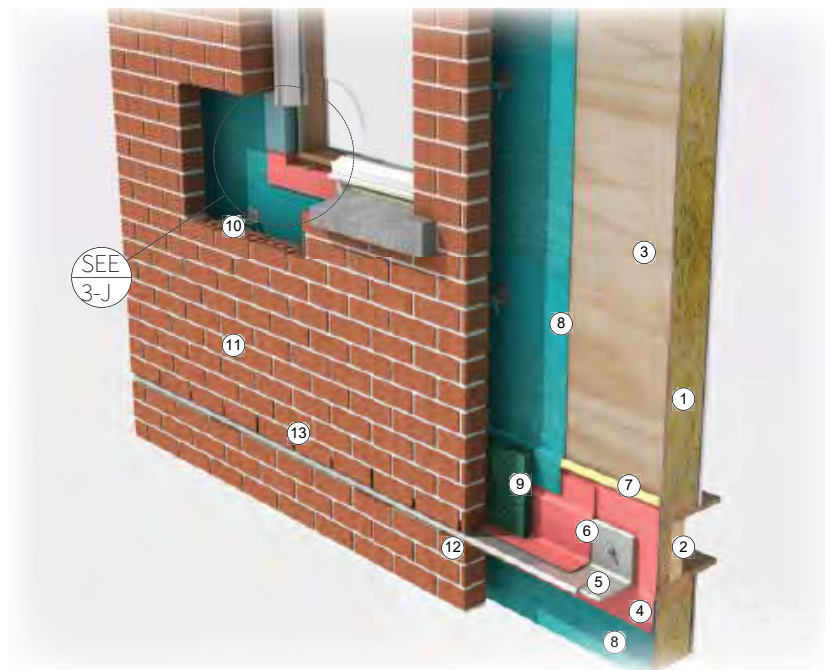


Parapet Assembly Cutaway Section

Detail 3-H

LEGEND

1. Wood-framed wall with batt insulation
2. Closed-cell spray foam insulation
3. Exterior sheathing
4. Self-adhered or fluid-applied flashing membrane
5. Sheet-metal flashing with hemmed drip edge over hot-dipped galvanized-steel continuous shelf angle support anchored to structure
6. Self-adhered or fluid-applied flashing membrane
7. Continuous air barrier sealant
8. Sheet-applied air barrier and WRB field membrane
9. Continuous mortar collection mesh
10. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
11. Anchored masonry veneer
12. Sealant over backer rod (movement joint)
13. Weep/vent at maximum 24-inches on-center

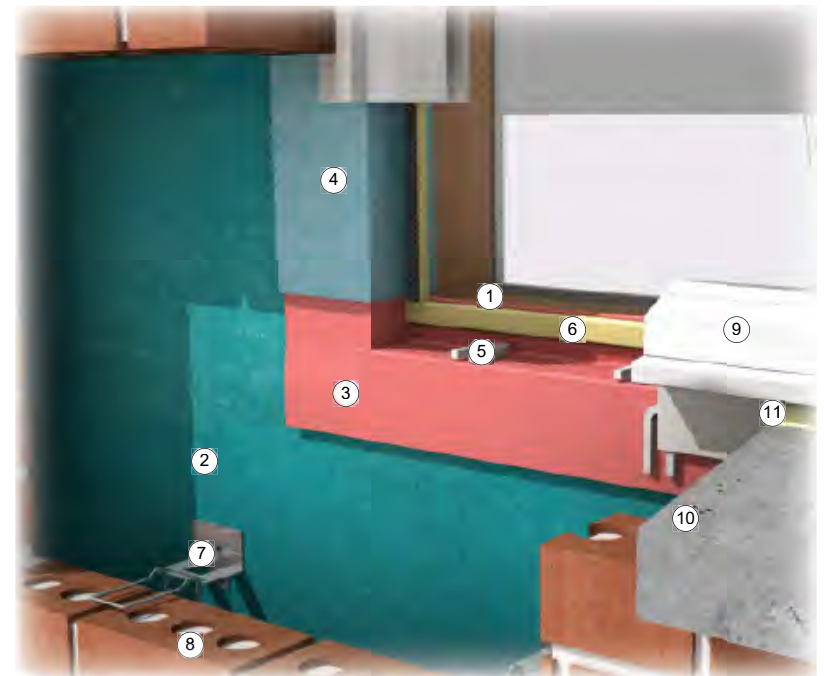


Floor Line Cutaway Section

Detail 3-I

LEGEND

1. Continuous back dam angle at rough opening sill, minimum 1-inch tall. Fasten window through back dam angle per window manufacturer recommendations.
2. Sheet-applied air barrier and WRB field membrane
3. Self-adhered or fluid-applied flashing membrane
4. Sheet-applied or fluid-applied air barrier and WRB prestrip membrane
5. Minimum 1/4-inch-thick intermittent shims
6. Continuous air barrier sealant, tie to continuous seal at window perimeter
7. Masonry veneer tie, fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per WRB system manufacturer recommendations
8. Anchored masonry veneer
9. Flanged window with minimum 1/8-inch-thick intermittent shims beneath sill flange
10. Sloped precast concrete sill
11. Sealant over backer rod between precast sill and window frame, continuous at window perimeter



Typical Windowsill and Jamb Cutaway Section

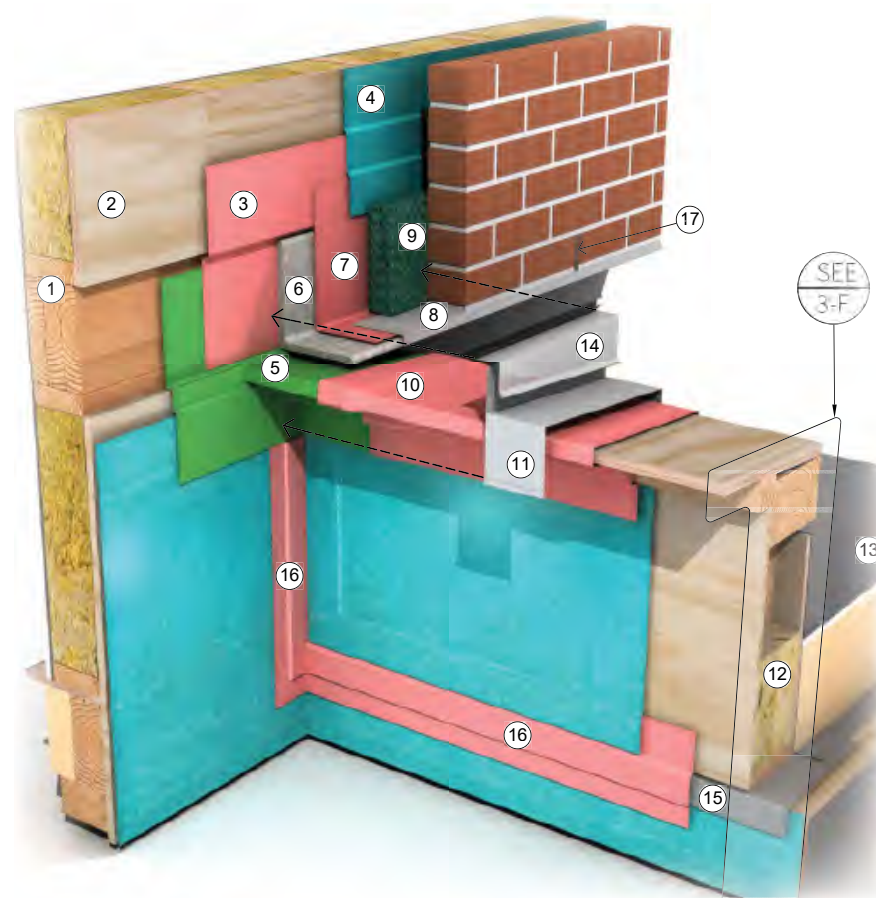
Detail 3-J

LEGEND

1. Wood-framed wall with batt insulation
2. Exterior sheathing
3. Self-adhered or fluid-applied flashing membrane
4. Sheet-applied air barrier and WRB field membrane
5. Parapet saddle flashing membrane, extend onto sloped parapet blocking beyond brick face and over wall beyond
6. Hot-dipped galvanized-steel continuous shelf angle support, bolted to structure
7. Self-adhered or fluid-applied flashing membrane
8. Sheet-metal flashing with hemmed drip edge
9. Continuous mortar collection mesh
10. High-temperature self-adhered membrane over sloped, preservative-treated blocking
11. Sloped standing-seam sheet-metal coping, end dam at anchored masonry veneer face beyond
12. Batt insulation
13. Conventional roof assembly with roof membrane
14. Sheet-metal counterflashing with spring-lock inserted into mortar bed beyond, seal with a sanded sealant over backer rod
15. Roof assembly air/vapor barrier prestrip membrane below parapet frame and roof structure and between parapet framing and wall structure
16. Self-adhered or fluid-applied transition membrane
17. Mortar weep/vent at maximum 24-inches on-center

3-D Detail Discussion (Detail 3-K)

- The saddle flashing in this detail is often a fluid-applied flashing. A self-adhered saddle flashing membrane may be difficult to form continuously at the parapet to wall interface. The saddle flashing membrane extends onto the wall structure/sheathing and shingle-laps the high-temperature self-adhered membrane at the parapet and the transition membrane at the wall.
- The continuous hot-dipped galvanized-steel shelf angle support is anchored directly back to the structure where exterior insulation is not used. Where exterior insulation is used, a stand-off shelf angle support is recommended. The ledger is located above the parapet blocking; the separation distance between the blocking and ledger is sized to accommodate any anticipated building movement during construction or occupancy.
- The sloped parapet below the ledger encourages drainage of water away from the parapet saddle transition.
- The standing-seam sheet-metal coping end dams at the anchored masonry veneer face and deflects water away from the parapet saddle transitions.
- The sheet-metal counterflashing with spring-lock is inserted into a mortar bed joint at the anchored masonry veneer and is sealed with a sanded sealant joint. Installation of the counterflashing can occur following installation of the anchored masonry veneer. The sanded sealant joint may be cut and counterflashing removed as needed for roof and parapet membrane repair and replacement.
- Refer to Detail 2-J in Chapter 2 for a similar cutaway section at the inside parapet face.



Saddle Flashing Cutaway Section

Detail 3-K

CHAPTER 4:

INTEGRALLY INSULATED CMU WALL

Masonry system 4 is a mass wall system with a single-wythe concrete masonry unit (CMU) wall structure, often comprised of split face block, and integral insulation. The components of this system, from interior to exterior, are described in Fig. 4-1. This system is appropriate for low-rise commercial applications; an example project application is shown in Fig. 4-2 on page 4-2.

Building Enclosure & Control layers

As noted in the Introduction, an above-grade wall system controls liquid water, air, heat, and possibly water vapor to function as an effective and durable environmental separator. Control of these elements, specific to this wall system, is provided by the following control layer systems and/or materials:

- Water control layer, primarily comprising the mass CMU wall
- Air control layer, comprising the air barrier system

INTERIOR

- Single-wythe CMU wall with water-repellent admixture
- Core insulation (or grout, where required)
- Clear water-repellent

EXTERIOR

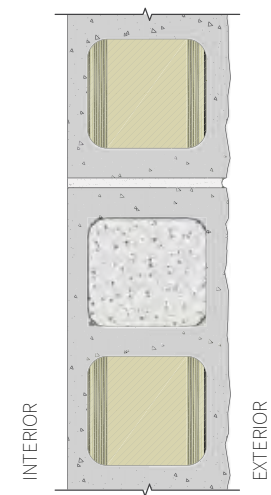


Fig. 4-1 Typical System 4 components from interior to exterior

- Thermal control layer, comprising thermal insulation and other low conductivity materials
- Vapor control layer, comprising vapor retarding materials

For a summary of the relationship between building enclosure loads, control layers, and associated systems and materials, Refer to Fig. i-13 on page i-21 of the introductory chapter.



Fig. 4-2 CMU wall with integral insulation example project application

Fig. 4-3 illustrates the water-shedding surface and control layer locations. The control layers for typical system details are also provided adjacent to each detail at the end of this chapter.

As shown in Fig. 4-3, the water-shedding surface occurs at the CMU wall face. The water control layer occurs at and within the CMU wall structure; the CMU wall structure is also the air control layer under certain provisions as discussed later in this chapter. The thermal control layer consists of the intermittent insulated core. This system has no defined vapor retarder control layer.

Water-Shedding Surface

The water-shedding surface is a system that serves to reduce the water load on the enclosure. A general discussion of the water-shedding surface is provided in the Water-Shedding Surface discussion on page i-19.

The CMU block and mortar provide the water-shedding surface of this system. Additional water-shedding surface components include sheet-metal flashings and drip edges, sealant joints, and fenestration systems as shown on the details included at the end of this chapter.

Water-repellent admixtures are added to the block and mortar of this system and a surface-applied clear water repellent is also recommended. These repellents serve to encourage water shed—along with other measures such as tooled “V” or concave shape (preferred) mortar joints, sufficient sheet-metal parapet cap design, and other general design recommendations as discussed in the Northwest Concrete Masonry Association (NWCMA) TEK Note on Rain-Resistant Architectural Concrete Masonry.¹

The water-shedding surface is most effective when free of gaps; therefore, movement joints and joints around fenestrations and penetrations should be continuously sealed with a backer rod and sealant.

Water Control Layer

The water control layer is a continuous control layer that is designed and installed to act as the innermost boundary against water intrusion. For this system, the CMU block, mortar, and grout (inclusive of any integral water repellents) provide the water control layer.

The water control layer is made continuous with the help of flashing membranes at parapet tops, fluid-applied flashings at fenestration rough openings, sealant joints, and fenestration systems as shown on the details included at the end of this chapter.

To increase the rain penetration resistance of this system, a Class IV vapor permeance fluid-applied WRB system may be applied to the inside face of the system, or an elastomeric coating applied to the exterior CMU wall face may also be considered. The WRB system may be a Class III vapor permeance fluid-applied membrane when carefully considered for the project-specific application. Refer to the Elastomeric Coatings discussion on page i-62 for additional information on elastomeric coatings.

Air Control Layer

The air barrier system provides the air control layer. In addition to controlling air, this layer also assists with controlling liquid water, heat, and water vapor. A general discussion of the air control layer and the air barrier system is provided in the Air Control Layer discussion on page i-26.

Water-Shedding Surface and Control Layers

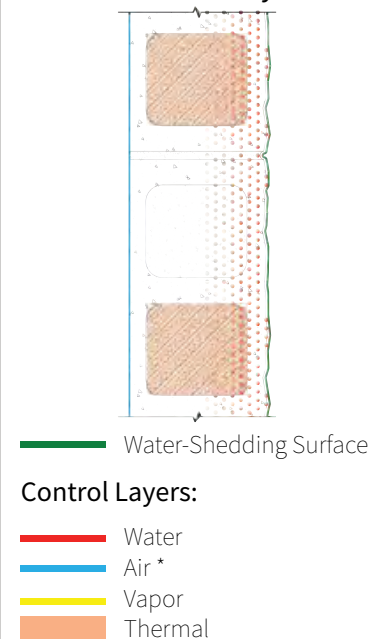


Fig. 4-3 System 4 water-shedding surface and control layer locations. *when an air barrier material is applied to the interior face of the CMU wall

The air barrier system for this wall system is typically satisfied through “deemed to comply” options within Section C402.4 of the 2012 International Energy Conservation Code² (IECC) and Section 502.4 of the 2014 Oregon Energy Efficiency Specialty Code³ (OEESC). These deemed to comply options include:

- “Concrete masonry walls coated with one application either of block filler or two applications of paint or sealer coating” as a deemed-to-comply air barrier system provided all joints are sealed.”
- “A Portland cement/sand parge, stucco, or plaster minimum ½-inch in thickness” as a deemed-to-comply air barrier system.”

The 2015 Washington State Energy Code⁴ (WSEC) and 2015 Seattle Energy Code⁵ (SEC) do not include deemed-to-comply air barrier materials or systems because the whole building is required to meet air leakage requirements per C402.5. The Code Airtightness Requirements discussion on page i-43 further addresses whole-building air leakage requirements.

Where a fluid-applied WRB system is used at the interior face of this wall system or where an exterior elastomeric coating is applied, these membranes—along with fenestration rough opening membranes—will typically form the air barrier system.

Vapor Control Layer

The vapor control layer retards or greatly reduces the flow of water vapor (e.g., vapor barrier) due to vapor pressure differences across enclosure assemblies. Unlike the other control layers presented in this guide, the vapor control layer is not always necessary or required to be continuous.

This system has no vapor retarder and utilizes the IBC Section 1405.3⁶ vapor retarder exception for “construction where moisture or its freezing will not damage the materials.” Note that the partially grouted cells do have some vapor-retarding properties but are not relied upon for control of vapor diffusion.

Thermal Control Layer

The thermal control layer controls heat flow and assists with controlling water vapor.

In this wall system, the core insulation is the primary material that forms the thermal control layer. At transition details, the thermal control layer includes insulation at the roof assembly, slab, and foundation elements. Windows and doors that penetrate this wall are also part of the thermal control layer.

The CMU wall of this system is also a thermal mass; thus, it may provide thermal mass benefits as addressed in the Mass Wall Considerations discussion on page i-42.

Insulation Selection

This wall system uses core insulation to meet thermal performance requirements of the energy code. Insulation may be loose fill such as perlite but is commonly a resinous, foam-in-place insulation product. Foam-in-place insulation is injected through ports in the CMU mortar joints following the construction of the CMU wall and grouting similar to that shown in Fig. 4-4.



Fig. 4-4 Installation of foam-in-place CMU core insulation

Thermal Performance and Energy Code Compliance

This wall system is typically classified as a mass above-grade opaque wall system for energy code compliance purposes. Prescriptive energy code compliance values for a mass wall are summarized in Table 4-2 on page 4-8 and describe:

- The minimum insulation R-values for a *prescriptive insulation R-value method* strategy.
- The maximum system U-factors for a *prescriptive assembly U-factor method* strategy. Note that the equivalent effective R-value of this U-factor has been calculated and is denoted in parenthesis ().
- The effective thermal performance of this system is dependent on the properties of the CMU (including density, size, and web configuration) and is also impacted by the grout schedule and core insulation type. System thermal performance values may be determined from the Thermal Catalog of Concrete Masonry Assemblies published by the National Concrete Masonry Association.⁷
- Footnote (2) for compliance by *exception* when insulation and project use requirements are met. The following exception applies to the 2014 OEESC³ provided the following conditions are met:

“1) At least 50 percent of cores must be filled with vermiculite or equivalent fill insulation; and

2) the structure encloses one of the following uses: gymnasium, auditorium, church chapel, arena, kennel, manufacturing plant, indoor swimming pool, pump station, water and wastewater treatment facility, storage facility, restroom/concessions, mechanical/electrical structures, storage area, warehouse (storage and retail), motor vehicle service facility).”

Similarly, under the 2015 WSEC4 provisions, the following exception applies, provided the following conditions are met:

“1) At least 50 percent of cores must be filled with vermiculite or equivalent fill insulation; and

2) The building thermal envelope encloses one or more of the following uses: Warehouse (storage and retail), gymnasium, auditorium, church chapel, arena, kennel, manufacturing plant, indoor swimming pool, pump station, water and waste water treatment facility, storage facility, storage area, motor vehicle service facility. Where additional uses not listed (such as office, retail, etc.) are contained within the building, the exterior walls that enclose these areas may not utilize this exception and must comply with the appropriate mass wall R-value from Table C402.1.3/U-factor from Table C402.1.4.”

A grouted area calculation chart is provided in Table 4-1 to assist with determining the area percentages of grouted cores versus ungrouted cores (e.g., cores available for insulation fill).

For all energy code compliance strategies except the *prescriptive insulation R-value method strategy*, this wall system’s U-factor will need to be calculated or determined from tables; however, it may or may not be required to be less than the prescriptive U-factors in Table 4-2 on page 4-8.

The Thermal Performance and Energy Code Compliance discussion on page i-33 and Fig. i-26 on page i-39 describe the typical process of navigating energy code compliance options.

Project-specific thermal performance values for an opaque above-grade wall should be used for energy code compliance and determined from a source that is approved by the authority having jurisdiction. Thermal performance sources may include the Appendices of the 2015 WSEC,⁴ ASHRAE 90.1,⁷ COMcheck,⁸ thermal modeling and calculation exercises, or other industry resources.

Table 4-1 Percent ungrouted / grouted area based on grouted cell spacing²¹

Percent UngROUTED Area/Percent Grouted Area				
Horizontal Grout Spacing (Inches)	Vertical Grout Spacing (Inches)			
	48	40	32	24
48	69/31	67/33	63/37	56/44
40	67/33	64/36	60/40	53/47
32	63/37	60/40	56/44	50/50
24	56/44	53/47	50/50	-

Movement Joints

CMU is a concrete-based product. It, along with the mortar, will shrink over time due to initial drying, temperature fluctuations, and carbonation. Not only will shrinkage movement need to be considered, but differential movement between the CMU structure and other structural elements due to deflection, settlement, and various design loads will need to be addressed.

Consider crack control within the CMU to increase the rain penetration resistance of this system. Material properties and reinforcing methods of the CMU structural wall should be implemented to reduce cracking; however, control joints within the CMU wall also need to be implemented to provide a plane of weakness to reduce shrinkage stresses and provide continuity of the water-shedding surface at these locations. Control joints in CMU can be constructed in a number of ways. Regardless of the method used, a continuous backer rod and sealant joint is installed at the joint as shown in Fig. 4-5 on page 4-8 to assist with water-shedding and to provide a continuous water control layer.

Refer to the Movement Joints discussion on page i-48 for more information on locating joints and sealant joint best practices.

Structural Considerations

The CMU block wall of this system provides the primary structure of this system. It is the responsibility of the Designer of Record to ensure that all structural elements of the wall are designed to meet project-specific loads and local governing building codes. Generic placement of the grout, reinforced elements, and supports/anchors are demonstrated within the details of this chapter and are provided for diagrammatic purposes only.

Table 4-2 System 4 prescriptive energy code compliance values excerpted from Table i-1 of the introductory chapter

OPAQUE ABOVE-GRADE WALL - THERMAL ENVELOPE REQUIREMENTS									
Energy Code		2012 SEC		2012 WSEC		2014 OEESC		2012 IECC	
Climate Zone		5 and Marine 4		5, 6 and Marine 4		5 and Marine 4		5 and Marine 4	
Guide Assembly #	Classification	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R
4	Integrally insulated CMU	Exterior: R-16cl ⁽¹⁾ U-0.057 (R-17.5)	Exterior: R-16cl ⁽¹⁾ U-0.057 (R-17.5)	R-9.5cl ⁽²⁾ U-0.104 ⁽²⁾ (R-9.6)	R-13.3cl ⁽²⁾ U-0.078 (R-12.8)	R-11.4cl U-0.078 (R-12.8)	R-13.3cl U-0.078 (R-12.8)	R-13.3cl U-0.078 (R-12.8)	R-15.2cl U-0.071 (R-14.1)

⁽¹⁾ When using interior insulation, R-13 + R-6 (for wood studs) or R-13 + R-10 (for metal studs), when using exterior insulation, R-16 cl

⁽²⁾ Exception: integrally insulated concrete block complying with ASTM C90 with all cores filled, with at least 50% of block core are filled with vermiculite (or equivalent fill insulation), and enclosing one of the following uses: gymnasium, auditorium, church chapel, arena, kernel, manufacturing plant, indoor swimming pool, pump station, water and wastewater treatment facility, warehouse (storage and retail), motor vehicle service facility, mechanical/electrical structures (OEESC only), and restroom/concessions (OEESC only). Under the WSEC, where additional uses not listed (such as office, retail, etc.) are contained within the building, the exterior walls that enclose these areas may not utilize this exception.



Fig. 4-5 Vertical CMU control joint

CMU Wall

The CMU in this system complies with ASTM C90.¹⁰ Mortar designed for the CMU conforms to ASTM C270¹¹ or ASTM C1714¹² when specifying preblended mortar. The mortar type selected should be appropriate for the CMU application; Type S is typically specified. Grout components should comply with ASTM C 476¹³ while aggregate within the grout should comply with ASTM C 404.¹⁴

Block and mortar are both specified with a water-repellent admixture as discussed in the Water Repellents discussion within this chapter. Additionally, refer to the Northwest Concrete Masonry Association (www.nwcma.org) for additional information on specifying block, mortar, and grout.

The CMU and mortar joints of this system should be installed in conformance with industry-standard best practices, manufacturer requirements, and guidelines outlined in the NWCMA Tek Note on Rain-Resistant Architectural Concrete Masonry;¹ appropriate product selection and installation of CMU and mortar materials is necessary to provide a durable and water-resistive cladding system.

The specifics of architectural characteristics and structural properties of the block, mortar, grout, and reinforcing should be designed and reviewed by a qualified Designer of Record. Various industry resources are available to assist with CMU wall design and are listed in the Resources section at the back of this guide.

Corrosion Resistance

For sheet-metal flashings that are integrated within this system (including through-wall flashings and sheet-metal drip flashings), it is best practice to provide components that are manufactured of ASTM A666¹⁵ Type 304 or 316 stainless steel, which are nonstaining and resistant to the alkaline content of mortar and grout materials. Where stainless steel sheet-metal flashing components are not economically feasible or aesthetically desirable, prefinishing sheet-metal may be considered. Where used, this guide recommends the base sheet metal is a minimum G90 hot-dipped galvanized coating in conformance with ASTM A653¹⁶ or minimum AZ50 galvalume coating in conformance with ASTM A792.¹⁷ Coating the exposed top finish of the sheet metal with an architectural-grade coating conforming to AAMA 621¹⁸ is recommended.

Water Repellents

Both integral water-repellent admixtures and a surface-applied clear water repellent are used in this system and assist with reducing the water absorption of the CMU wall and encourage water shedding. Water-repellent admixtures should be used in both the CMU and the mortar. Admixture within block units should comply with NCMA TEK 19-7,¹⁹ while mortar admixture should comply with ASTM C1384.²⁰ More discussion on surface-applied clear water repellents is provided in the Surface-Applied Clear Water Repellents discussion on page i-59.

Both the CMU and mortar admixtures as well as any surface-applied water repellent should have known compatibility performance.

Pricing Summary

A pricing summary for this system is provided on Table 4-3 on page 4-12. Pricing demonstrates the relative price per square foot and is based on a 10,000-square-foot wall area with easy drive-up access. Pricing is valid for 2018. Current pricing is also available at www.masonrysystemsguide.com.

Online Availability

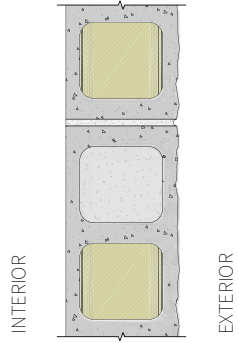
The content of this guide and additional resources may be accessed online at www.masonrysystemsguide.com. Also available online are downloadable versions of two- and three-dimensional system details and cutaway sections, sample project specifications, and ongoing updates to references and resources included within this guide.

Chapter References

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12. ASTM International. *ASTM C1714/C1714M-16 Standard Specification for Preblended Dry Mortar Mix for Unit Masonry*. (West Conshohocken, PA: ASTM International, 2016).
13. ASTM International. *ASTM C476-16 Standard Specification for Grout for Masonry*. (West Conshohocken, PA: ASTM International, 2016).

14. ASTM International. *ASTM C404-11 Standard Specification for Aggregates for Masonry Grout*. (West Conshohocken, PA: ASTM International, 2011).
15. ASTM International. *ASTM A666-15 Standard Specification for Annealed or Cold-Worked Austenitic Stainless-Steel Sheet, Strip, Plate, and Flat Bar*. (West Conshohocken, PA: ASTM International, 2015).
16. ASTM International. *ASTM A653/A653M-15e1 Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process*. (West Conshohocken, PA: ASTM International, 2015).
17. ASTM International. *ASTM A792/A792M-10(2015) Standard Specification for Steel Sheet, 55% Aluminum-Zinc Alloy-Coated by the Hot-Dip Process*. (West Conshohocken, PA: ASTM International, 2015).
18. American Architectural Manufacturers Association. *AAMA 621-02 Voluntary Specification for High-Performance Organic Coatings in Coil-Coated Architectural Hot-Dipped Galvanized (HDG) and Zinc-Aluminum Coated Steel Substrates*. (Schaumburg, IL: American Architectural Manufacturers Association, 2002).
19. National Concrete Masonry Association. *TEK 19-7 Characteristics of Concrete Masonry Units with Integral Water Repellent*. (Hendon, VA: National Concrete Masonry Association, 2008).
20. ASTM International. *ASTM C1384-12a Standard Specification for Admixtures for Masonry Mortars*. (West Conshohocken, PA: ASTM International, 2012).
21. National Concrete Masonry Association. *TEK 6-2C R-Values and U-Factors of Single Wythe Concrete Masonry Walls*. (Hendon, VA: National Concrete Masonry Association, 2013).

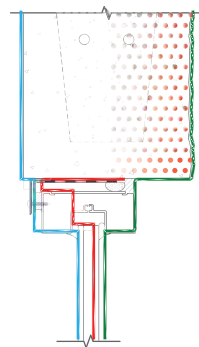
Table 4-3 System 4 integrally insulated CMU pricing summary

System 4: Integrally Insulated CMU					
System Component		Baseline Product	Alternate (call for estimate)	Baseline Cost/ft ² (incl. labor)	
				Low	High
INTERIOR					
1*	Structural CMU wall	8"x8"x16" standard split-face block with integral block and mortar water repellent; partially grouted	No specified alternate	\$20.00	\$27.50
2	Optional	Groundface block and colors alternates	No specified alternate	\$0.75	\$2.75
3	Rebar	Standard code reinforcement; minimum Category D requirement	Additional reinforcing	\$2.00	\$5.00
4	Core insulation	Resinous foam insulation at block cores	Perlite insulated cores	\$1.25	\$1.75
5*	Clear water repellent	Surface-applied clear water repellent	No specified alternate	\$1.75	\$2.50
EXTERIOR					
Total cost to install 10,000 sq ft wall area w/easy drive-up access -->				\$25.75	\$39.50
Pricing Summary Discussion			System Plan View		
<ul style="list-style-type: none">- Low and high baseline costs are based on baseline products and installed labor costs. Call for an estimate for alternative product pricing.- Baseline costs provided will vary based on product-specific conditions as well as project location and should be used as an estimate only.- Block prices are for typical units as noted. Pricing can vary based on size, color, and finish and should be confirmed with the unit manufacturer.- *See the Resources section of this guide for a list of resources related to this component.					

LEGEND

1. Typical Assembly:
 - Single-wythe CMU wall with water-repellent admixture at block and mortar
 - Core insulation or grout
 - Clear water repellent
2. Sealant over backer rod
3. Fluid-applied flashing membrane
4. Continuous air barrier sealant, tie to continuous seal at window perimeter
5. Continuous back dam angle at rough opening perimeter, minimum 1-inch tall, with window fastened through the back dam tie per window manufacturer recommendations
6. Storefront window

Water-Shedding Surface and Control Layers



Water-Shedding Surface

Control Layers:*

- Water
- Air
- Vapor
- Thermal

* when an air barrier material is applied to the interior face of the CMU wall

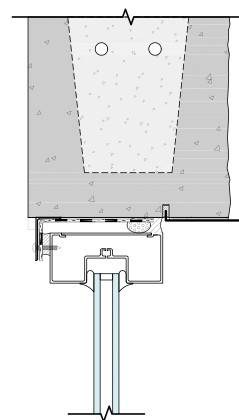
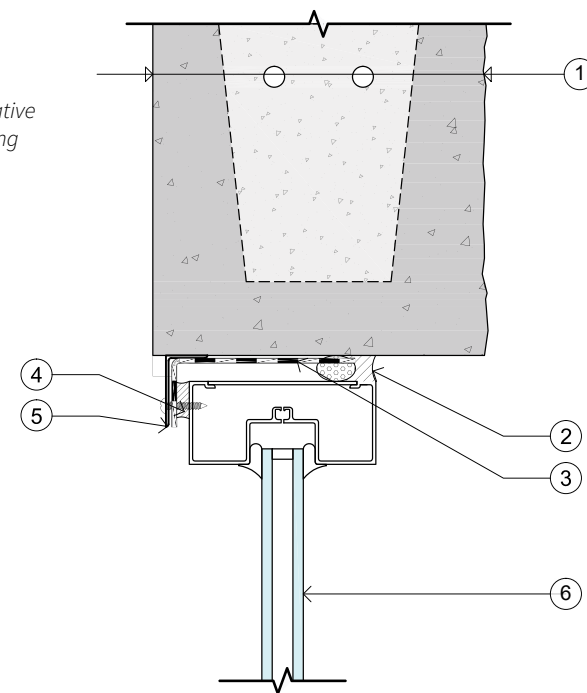


Fig. 4-6 System 4 alternative sheet-metal head flashing



Detail Discussion

- To promote watershed away from the window and wall below, consider a sheet-metal flashing with hemmed drip edge as shown in Fig. 4-6. This flashing is sealed into a kerf in the underside of the CMU rough opening head.
- Air control layer continuity is provided by the grouted and insulated CMU cores, the fluid-applied flashing membrane at the rough opening, and the air barrier sealant transition to the storefront window.
- The backer rod and sealant at the window perimeter provides continuity of the water-shedding surface between the CMU wall and storefront window face.

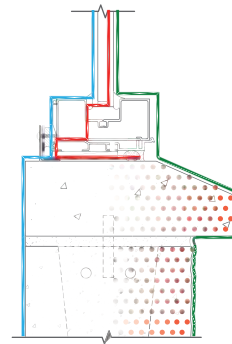
Storefront Window Head

Detail 4-A

LEGEND

1. Typical Assembly:
 - Single-wythe CMU wall with water-repellent admixture at block and mortar
 - Core insulation or grout
 - Clear water repellent
2. Storefront window
3. Minimum 1/4-inch intermittent shims
4. Fluid-applied flashing membrane
5. Wept sealant or backer rod
6. Sloped precast concrete sill
7. Continuous air barrier sealant tied to continuous seal at window perimeter
8. Continuous back dam angle at rough opening perimeter, minimum 1-inch tall, with window fastened through the back dam angle per window manufacturer recommendations

Water-Shedding Surface and Control Layers



Water-Shedding Surface

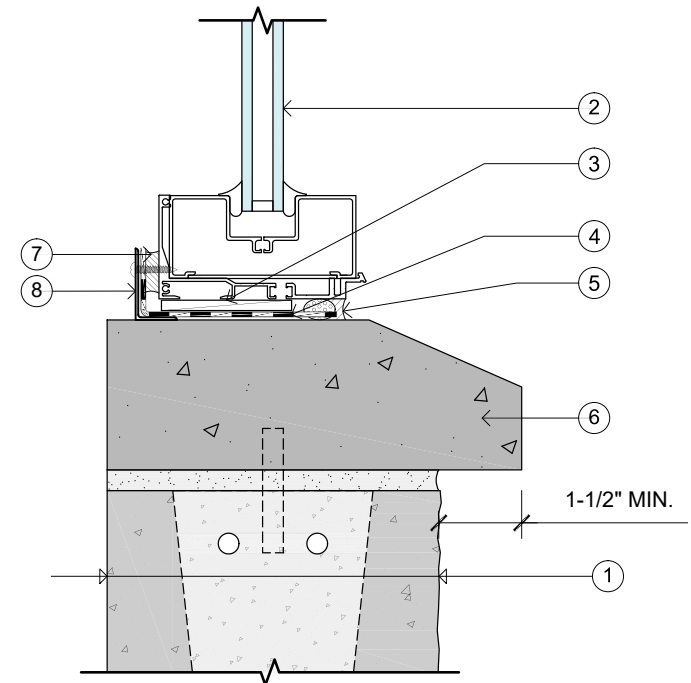
Control Layers:*

Water
 Air
 Vapor
 Thermal

* when an air barrier material is applied to the interior face of the CMU wall

Detail Discussion

- Intermittent shims support the window frame and allow the window rough opening to drain to the exterior. The exterior backer rod and sealant joint at the sill is wept at quarter points along the sill to drain the rough opening.
- When a sill can is used with the storefront system, a fluid-applied flashing membrane and wept sealant joint at the rough opening should still be used as shown in this detail.

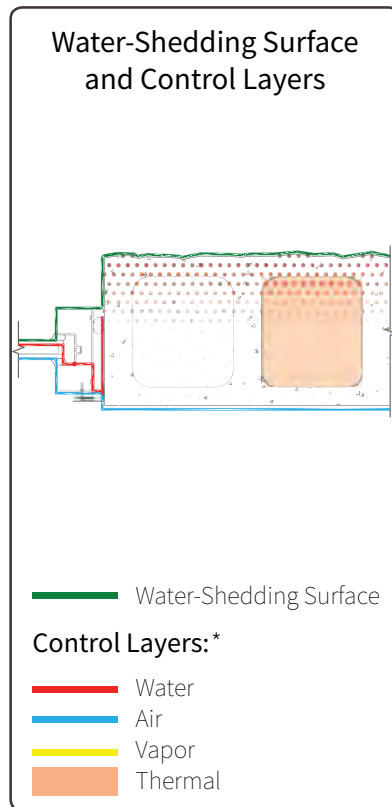


Precast Windowsill

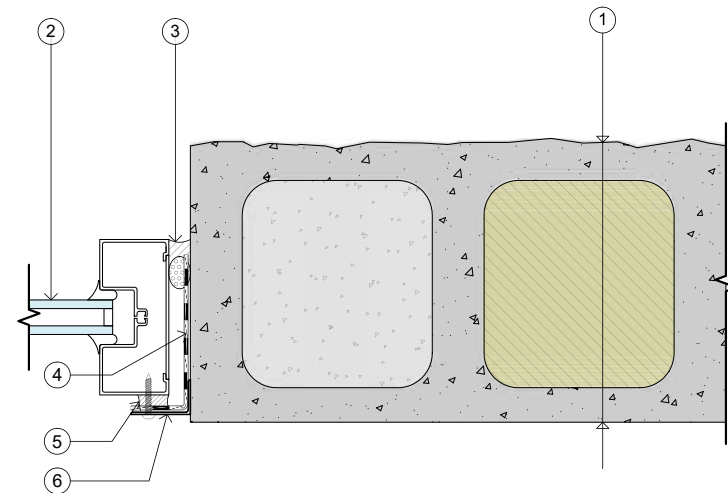
Detail 4-B

LEGEND

1. Typical Assembly:
 - Single-wythe CMU wall with water-repellent admixture at block and mortar
 - Core insulation or grout
 - Clear water repellent
2. Storefront window
3. Sealant over backer rod
4. Fluid-applied flashing membrane
5. Continuous air barrier sealant tied to continuous seal at window perimeter
6. Continuous back dam angle at rough opening perimeter, minimum 1-inch tall, with window fastened through the back dam angle per window manufacturer recommendations



* when an air barrier material is applied to the interior face of the CMU wall



Detail Discussion

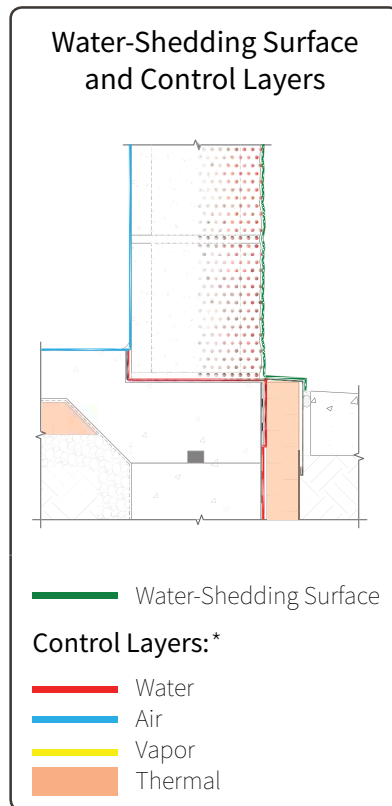
- A fluid-applied flashing membrane is recommended at the window rough opening due to its self-terminating properties.
- The continuous back dam angle shown allows for perimeter attachment of the storefront window without the need for F-clips or similar anchors, which often inhibit the air barrier sealant (and thus, the air control layer) at the window perimeter. Project-specific window attachment methods should be confirmed with the window manufacturer during the design phase of the project.

Storefront Window Jamb

Detail 4-C

LEGEND

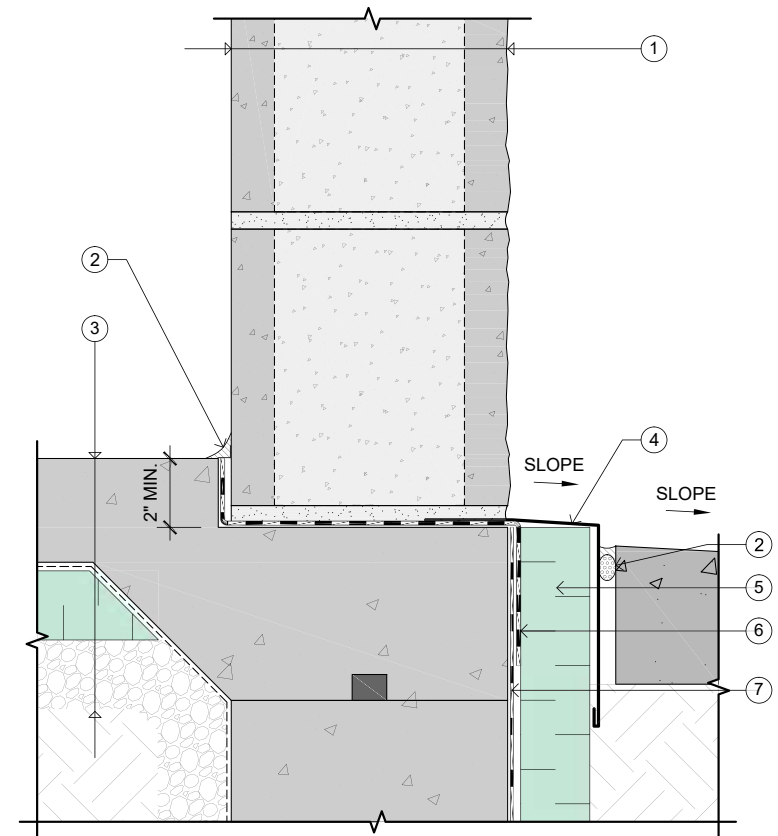
1. Typical Assembly:
 - Single-wythe CMU wall with water-repellent admixture at block and mortar
 - Core insulation or grout
 - Clear water repellent
2. Continuous air seal
3. Typical Assembly:
 - Thickened concrete floor slab
 - Vapor barrier
 - Rigid XPS insulation
 - Capillary break
4. Sheet-metal base-of-wall flashing with hemmed edge
5. Rigid XPS insulation
6. Fluid-applied or self-adhered flashing membrane
7. Damp proofing



* when an air barrier material is applied to the interior face of the CMU wall

Detail Discussion

- The base-of-wall sheet-metal flashing protects the rigid XPS foundation insulation from UV exposure and damage. The hemmed edge strengthens the sheet-metal flashing. Acceptability of this sheet-metal flashing placement should be confirmed with the project's structural engineer.
- A step at the thickened concrete floor slab perimeter encourages water that may exist at the wall base to collect below the finished floor elevation. This guide recommends a minimum 2-inch step.
- The continuous sealant joint at the interior floor line provides air control layer continuity from the CMU wall assembly to the concrete floor slab.
- See the next pages for an alternative floor slab detail.

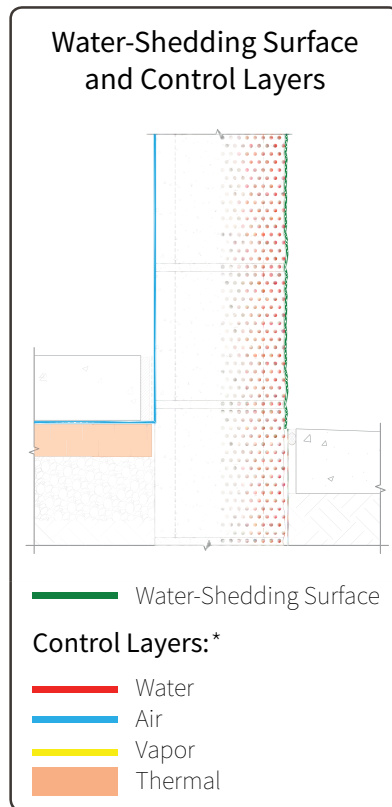


Thickened Concrete Slab/Foundation Detail

Detail 4-D

LEGEND

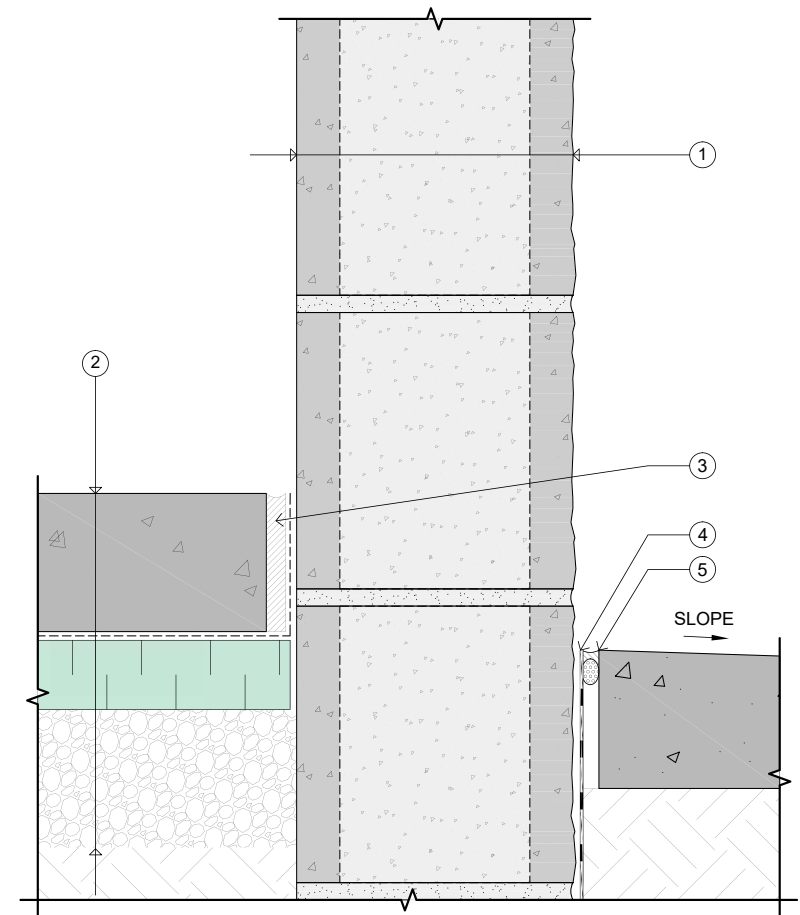
1. Typical Assembly:
 - Single-wythe CMU wall with water-repellent admixture at block and mortar
 - Core insulation or grout
 - Clear water repellent
2. Typical Assembly:
 - Concrete floor slab
 - Vapor barrier
 - Rigid XPS insulation
 - Capillary break
3. Slab isolation joint
4. Damp proofing (optional)
5. Hardscape sealant joint



* when an air barrier material is applied to the interior face of the CMU wall

Detail Discussion

- See Detail 4-D on the previous page for an alternative floor slab detail.
- The thermal performance of the concrete floor slab assembly may be improved by providing a thermal insulation break between the floor slab and CMU wall.

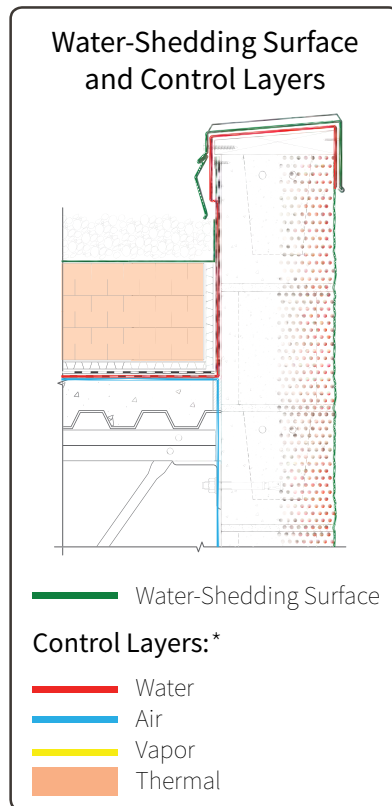


Concrete Slab/CMU Foundation Detail

Detail 4-E

LEGEND

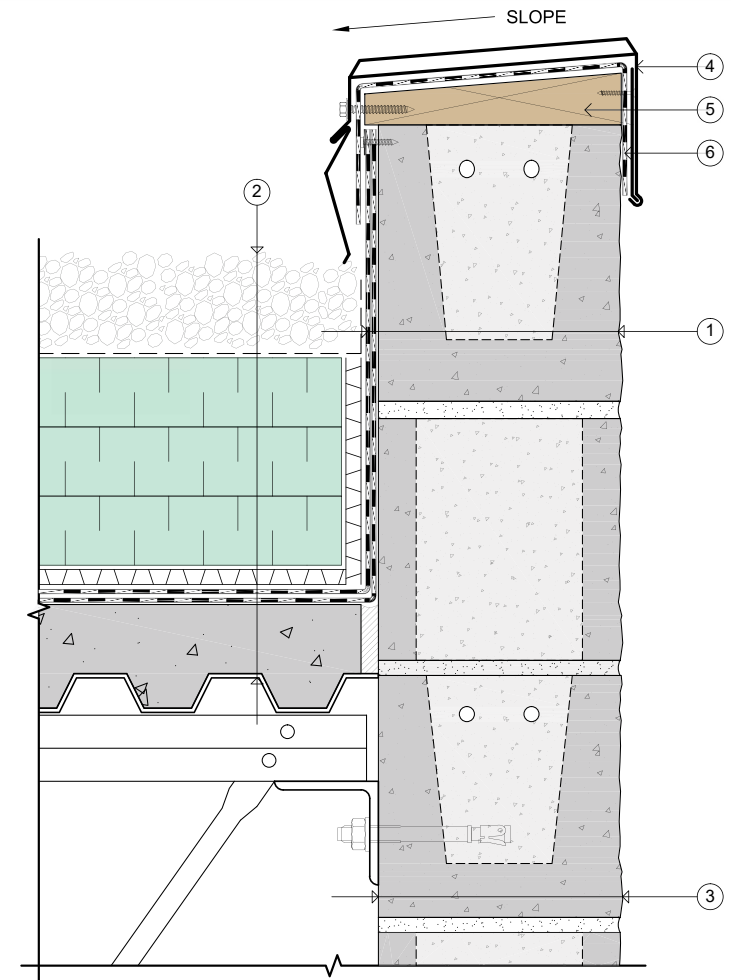
1. Typical Parapet Assembly:
 - Inverted roof membrane
 - Single-wythe CMU wall with water-repellent admixture at block and mortar
 - Core insulation or grout
 - Clear water repellent
2. Inverted roof membrane system
3. Typical Assembly:
 - Single-wythe CMU wall with water-repellent admixture at block and mortar
 - Core insulation or grout
 - Clear water repellent
4. Sloped standing-seam sheet-metal coping with gasketed washer fasteners
5. Preservative-treated blocking
6. High-temperature self-adhered membrane



* when an air barrier material is applied to the interior face of the CMU wall

Detail Discussion

- The sheet-metal coping with hemmed drip edge sheds water away from the wall top and CMU wall face below. It is recommended that the sheet-metal cap counterflash the top course of block by a minimum of 3-inches.
- When a fluid-applied membrane is applied to the interior face of the single-wythe CMU (to increase the rain penetration resistance and/or to assist with airtightness), as discussed in Water Control Layer on page 4-3, this membrane should extend onto the bottom of the roof structure and should be continuous around anchors.



Parapet at Inverted Roof Membrane System

Detail 4-F

LEGEND

1. Single-wythe CMU wall with water-repellent admixture within block and mortar
2. Partially grouted CMU wall
3. Sloped, preservative-treated wood blocking
4. High-temperature self-adhered membrane
5. Sloped standing-seam sheet-metal coping with gasketed washer fasteners
6. Inverted roof membrane assembly
7. Storefront window

3-D Detail Discussion

- Three-dimensional cutaway sections on the next three pages represent two-dimensional details of this system.
- This system is deemed to comply with some energy code exceptions when at least 50% of the CMU cores are insulated as discussed in Thermal Performance and Energy Code Compliance on page 4-5. Some cores may be grouted as shown in Detail 4-G and others insulated as shown in Detail 4-H.
- The high-temperature self-adhered membrane and standing-seam sheet-metal coping protect the top of the wall from water. The sheet-metal drip edge deflects water away from the wall face.
- Detail 4-I describes a typical rough opening with continuous back dam angle. The sill back dam angle creates a sill pan below the window; intermittent shims below the storefront window promote drainage at the sill and out through the sealant joint weeps.
- As shown in Detail 4-H, insulation below the thickened concrete floor slab and exterior of the foundation wall provides additional protection against heat loss at the wall-to-slab interface. The sheet-metal flashing protects the XPS insulation from UV and damage.

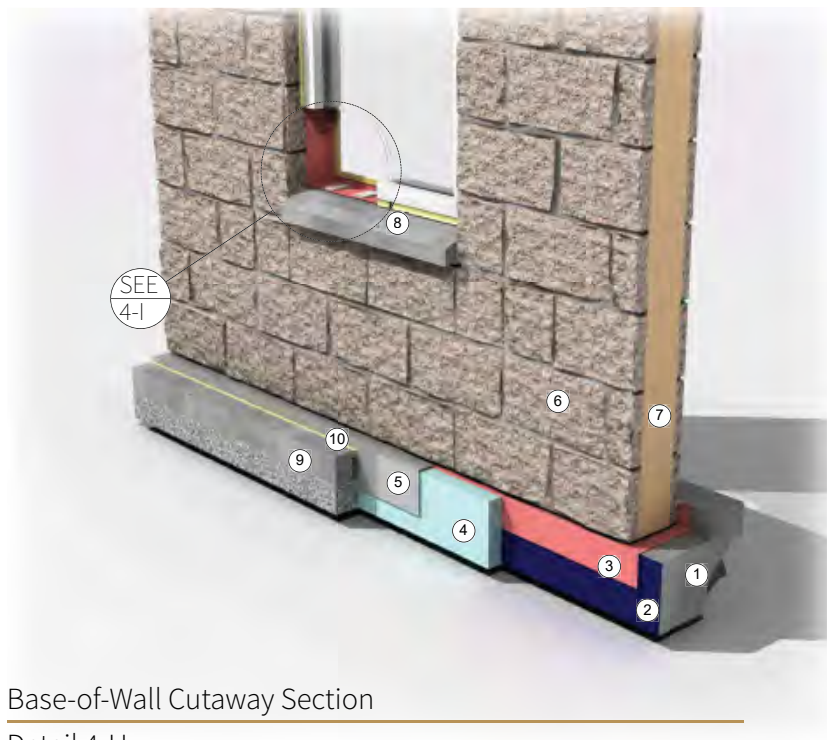


Parapet Section Cutaway

Detail 4-G

LEGEND

1. Thickened concrete floor slab and foundation element
2. Damp proofing
3. Fluid-applied or self-adhered flashing membrane
4. Rigid XPS foundation insulation
5. Base-of-wall sheet-metal flashing
6. Single-wythe CMU wall with water-repellent admixture within block and mortar
7. Core insulation
8. Sloped precast concrete sill
9. Concrete sidewalk or other hardscape, sloped away from structure
10. Continuous hardscape sealant joint
11. Continuous sealant joint at wall-to-slab interface

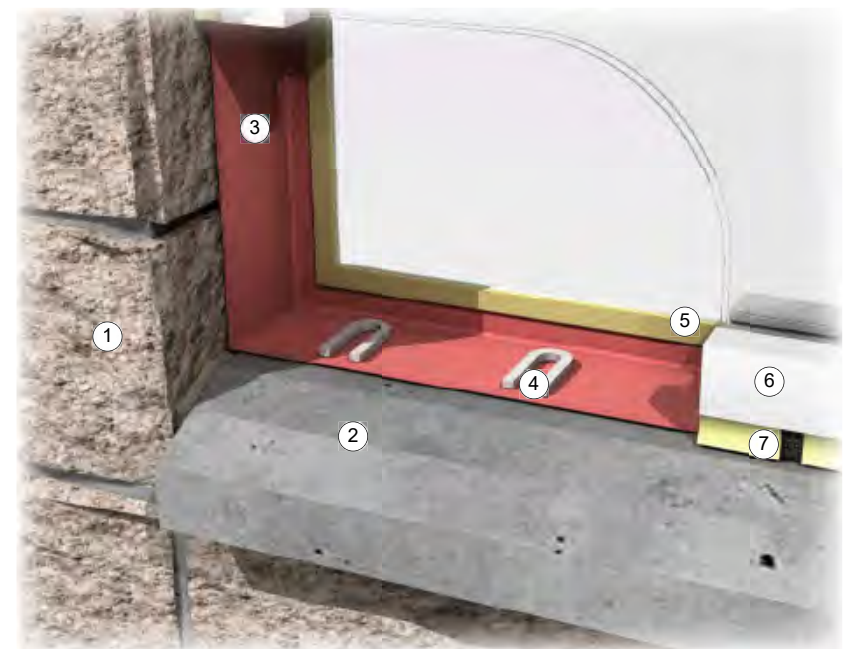


Base-of-Wall Cutaway Section

Detail 4-H

LEGEND

1. Single-wythe CMU wall with water-repellent admixture within block and mortar
2. Sloped precast concrete sill
3. Fluid-applied flashing membrane at rough opening and continuous perimeter back dam angle
4. Minimum 1/4-inch intermittent shims for drainage
5. Continuous air barrier sealant tied to continuous seal at window perimeter
6. Storefront window
7. Wept backer rod and sealant joint



Window Jamb and Sill Cutaway Section

Detail 4-I

CHAPTER 5:

INTERIOR-INSULATED CMU WALL

Masonry system 5 is a mass wall system with a concrete masonry unit (CMU) wall structure and interior insulation. The components of this system, from interior to exterior, are described in Fig. 5-1. This system is most appropriate for low- to mid-rise commercial applications but may be used for residential applications as well as some high-rise structures. An example application of this system is shown in Fig. 5-2 on page 5-2.

Building Enclosure Control layers

As noted in the introductory chapter, an above-grade wall system controls liquid water, air, heat, and possibly water vapor to function as an effective and durable environmental separator. This system controls these elements with the following control layer systems and/or materials:

- The water control layer, primarily comprising the mass CMU wall
- Air control layer, comprising the air barrier system

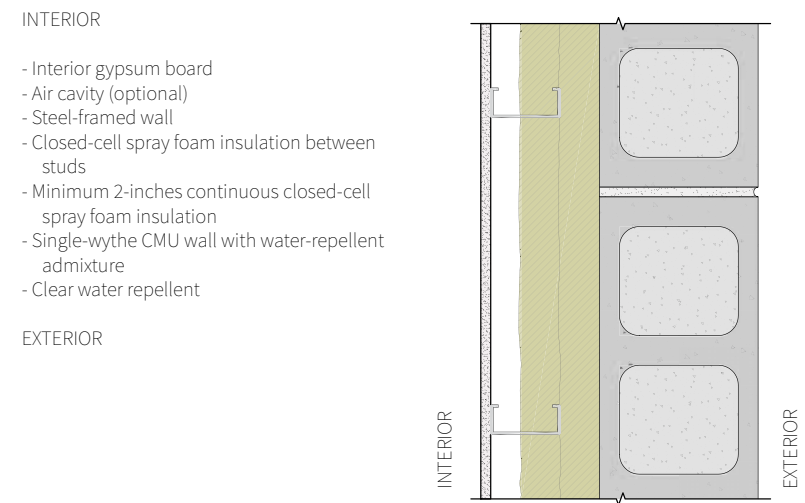


Fig. 5-1 Typical System 5 components from interior to exterior

- Thermal control layer, comprising thermal insulation and other low-conductivity materials
- Vapor control layer, comprising vapor retarding materials.

For a summary of the relationship between building enclosure loads, control layers, and associated systems and materials, refer to Fig. i-13 on page i-21 of the Introduction.

Fig. 5-3 illustrates the water-shedding surface and control layer locations. The control layers for typical system details are also provided adjacent to each detail at the end of this chapter.



Fig. 5-2 CMU wall with interior insulation example project application

As shown in Fig. 5-3, the water-shedding surface occurs at the CMU wall face. The water control layer exists within the CMU wall structure. Both the air control layer and the vapor control layer occur through the depth of the closed-cell spray foam insulation (CCSPF). The CCSPF, or other interior and cavity thermal insulation as discussed within this chapter, provides the thermal control layer.

Water-Shedding Surface

The water-shedding surface is a system that serves to reduce the water load on the enclosure. A general discussion of the water-shedding surface is provided in the Water-Shedding Surface discussion on page i-19.

The CMU block and mortar provide the water-shedding surface of this system. Additional water-shedding surface components include sheet-metal flashings and drip edges, sealant joints, and fenestration systems as shown on the details included at the end of this chapter.

Water-repellent admixtures are added to the block and mortar of this system and a surface-applied clear-water repellent is also recommended. These repellents serve to encourage water shed—along with other measures such as tooled “V” or concave shape (preferred) mortar joints, sufficient sheet-metal parapet cap design, and other general design recommendations as discussed in the Northwest Concrete Masonry Association (NWCMA) TEK Note on Rain-Resistant Architectural Concrete Masonry.¹

The water-shedding surface is most effective when free of gaps; therefore, movement joints and joints around fenestrations and penetrations should be continuously sealed with a backer rod and sealant.

Water Control Layer

The water control layer is a continuous control layer that is designed and installed to act as the innermost boundary against water intrusion. For this system, the CMU block, mortar, and grout (inclusive of any integral water repellents) assist to provide the water control layer.

The water control layer is made continuous with the help of flashing membranes at parapet tops, fluid-applied flashings at fenestration rough openings, sealant joints, and fenestration systems as shown on the details included at the end of this chapter.

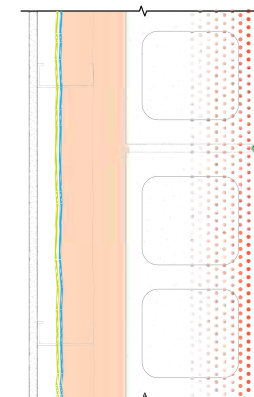
The CCSPF insulation at the interior face of the CMU structure may also provide additional rain penetration resistance.

The water control layer must be continuous across the wall face to serve as an effective control layer. Whereas this wall manages water at the CMU face and may manage some water at the CCSPF layer, window rough openings between these two planes must also have a water control system or material. Typically, this is a fluid-applied flashing membrane that is also part of the air control layer. It protects rough openings against water intrusion, minimizes air leakage, and is depicted in the details at the end of this chapter.

Air Control Layer

The air barrier system provides the air control layer. In addition to controlling air, this layer also assists with controlling liquid water, heat, and water vapor. A general

Water-Shedding Surface and Control Layers



Water-Shedding Surface

Control Layers:

- Water
- Air
- Vapor
- Thermal

Fig. 5-3 System 5 water-shedding surface and control layer location

discussion of the air control layer and the air barrier system is provided in the Air Control Layer discussion on page i-26.

The air barrier system in this system is typically the CCSPF interior of the CMU wall structure and has the air permeance properties described in the Design Checklist discussion on page i-44.

To serve as an effective air barrier system and to reduce the risk of air leakage condensation on the interior CMU face or steel-framing within this masonry system, CCSPF should be installed continuously up to rough openings, penetrations, and roof and floor structures.

When installing CCSPF, it is important to install the insulation in strict conformance with the manufacturer's installation instructions. Improper installation could lead to premature cracking and delamination from the substrate, which can allow air to move between the insulation and substrate and increase condensation risk. Improper installation can also lead to risk of fire during installation. It is recommended that only experienced applicators who are approved by the CCSPF product manufacturer are used.

Other considerations when using CCSPF insulation includes fire propagation and volatile organic compound (VOC) compliance. Make sure product selection, application, and use all comply with local jurisdiction requirements.

Vapor Control Layer

The vapor control layer retards or greatly reduces (e.g., vapor barrier) the flow of water vapor due to vapor pressure differences across the enclosure. Unlike the other control layers presented in this guide, the vapor control layer is not always necessary or required to be continuous.

In this wall system, the vapor control layer occurs throughout the depth of the CCSPF. CCSPF insulation has a minimum 2 lb/ft³ density (per ASTM C518⁴) and is typically applied at a minimum of 2-inches to be considered a Class II vapor retarder.

Because this system is insulated to the interior, it is important that the CCSPF (as the air, vapor, and thermal control layers) is continuous across the wall's interior face and up to rough openings and penetrations to minimize the risk of condensation on cooler surfaces.

Thermal Control Layer

The thermal control layer controls heat flow and assists with controlling water vapor.

In this wall system, the interior CCSPF insulation serves as the thermal control layer. At transition details, the thermal control layer includes interior insulation across bond beams and up to rough openings, windows and doors, and roof assembly insulation as well as slab and foundation insulation.

The thermal control layer should be as continuous as possible across the system to minimize heat loss, reduce condensation risk, and improve occupant thermal comfort. Continuity of interior insulation can be difficult to achieve at areas such as floor line slab edges and some wall-to-roof transitions. These transitions should be carefully considered for whole-building energy performance implications as well as for energy code compliance and other building code requirements.

The CMU wall of this wall system is also a thermal mass; thus, it may provide thermal mass benefits as discussed in the introductory chapter.

Additional thermal insulation discussion is provided in the Thermal Performance and Energy Code Compliance discussion on page i-33 of the Introduction and the Thermal Performance and Energy Code Compliance discussion on page 5-7 of this chapter.

Insulation Selection

An interior application of CCSPF is recommended for this system and typically has the following properties:

- Air Permeance: Meets the maximum air permeance properties described in the Design Checklist discussion on page i-44.
- Water Vapor Transmission: Less than 1 perm at 2-inch thickness when tested to ASTM E96.⁵
- Closed-Cell Content: Exceeds 95% when tested to ASTM D6226.⁶
- Density: Approximately 2 lb/ft³ when tested to ASTM C518.⁴

Use of alternative insulation types should be carefully considered along with a project's specific application and exposure.

- **Vapor- and Air-Permeable Insulation.** This includes fiberglass and mineral fiber batt or semi-rigid mineral fiber insulation. These products alone do not serve as air, water, and vapor control layers; thus they require additional materials or systems be implemented into the system. When additional materials are implemented to serve as these control layers, carefully consider the risk for condensation on the interior face of the CMU wall. Lack of a fully adhered water control layer membrane, such as a fluid-applied membrane, at the interior or exterior face of this wall system may also reduce the rain penetration resistance of the system when compared to the CCSPF insulation strategy.
- **Rigid Board Insulation.** This includes extruded polystyrene (XPS) or moisture-resistant foil-faced polyisocyanurate insulation products. These products provide an air and vapor control layers at the interior face of the product, which is fully taped and/or sealed at seams, edges, and penetrations and to perimeter elements such as floor slabs and roof structures. Rigid board insulation products require notching around wall projections such as roof joists and pipe penetrations; thus, additional insulating and air (and possibly vapor) sealing mechanisms at these locations can provide a continuous barrier. Rigid board insulation products do not provide continuous adhesion to the CMU wall structure like a CCSPF product does. As a result, if water is allowed to bypass the CMU wall structure, it is not contained within the wall but instead may reach horizontal elements. This risk can be minimized by stepping foundation elements to terminate the insulation at a lower elevation than the floor slab and by installing an elastomeric coating to the exterior wall face (see Elastomeric Coatings discussion on page i-62).

Install steel studs prior to installation of the continuous CCSPF layer as shown in Fig. 5-4. This eliminates the difficulty of installing studs against the irregular surface of the first lift and allows continuity of the CCSPF when multiple lifts are installed.

Although masonry is defined as a noncombustible cladding material, the use of a combustible air barrier and WRB system product or foam plastic insulation products within a wall cavity can trigger fire propagation considerations and requirements. Depending on the local jurisdiction, IBC Section 1403.5² regarding vertical and lateral flame propagation as it relates to a combustible air barrier and WRB system may require acceptance criteria for NFPA 285.³ The use of foam plastic insulation within a wall cavity should also be addressed for IBC Chapter 26² provisions.



Fig. 5-4 Closed-cell spray foam insulation installed between steel studs

Thermal Performance and Energy Code Compliance

This wall system is typically classified as a mass above-grade wall for energy code compliance purposes. Prescriptive energy code compliance values for this wall system are summarized in Table 5-1 on page 5-10 and describe:

- Minimum insulation R-values for a *prescriptive insulation R-value method* strategy.
- Maximum system U-factors for a *prescriptive assembly U-factor method* strategy. Note that the equivalent effective R-value of this U-factor has been calculated and is denoted in parenthesis () for easy comparison to thermal modeling results included within this chapter.
- Footnote (2) for compliance by *exception*. The ability to use this option depends on the jurisdiction, building's use, and availability of CMU cores to be filled with insulation. If this exception is to be used, refer to the Chapter 4 Thermal Performance and Energy Code Compliance discussion on page 4-5.

For all energy code compliance strategies except the *prescriptive insulation R-value method strategy*, this wall system's U-factor will need to be calculated or determined from tables; however, it may or may not be required to be less than the prescriptive U-factors in Table 5-1.

The Thermal Performance and Energy Code Compliance discussion on page i-33 and Fig. i-26 on page i-39 of the introductory chapter describes the typical process of navigating energy code compliance options. Additionally, the thermal modeling results demonstrated in this chapter may be used to assist with selecting wall system components (e.g., insulation R-value/inch and placement relative to steel studs, etc.) to achieve a target U-factor. Options for thermally optimizing this wall system, as determined through the modeling results, are also discussed.

Project-specific thermal performance values for an opaque above-grade wall should be used for energy code compliance and determined from a source that is approved by the authority having jurisdiction. Thermal performance sources may include the appendices of the 2015 WSEC,⁷ ASHRAE 90.1,⁸ COMcheck,⁹ thermal modeling and calculation exercises, or other industry resources.

System Effective Thermal Performance

The depth and location of the steel studs in this system will impact the system's effective thermal performance depending on their placement relative to the system's interior insulation. As shown in Fig. 5-5 and Fig. 5-6, various levels of thermal bridging can occur depending on the steel stud placement relative to the CMU and insulation. This thermal bridging reduces the system's effective thermal performance.

Three-dimensional thermal modeling demonstrates this system's effective thermal performance with various framing locations (relative to the insulation and CMU wall) and insulation thicknesses. A discussion on the modeling performed for this guide is included in the Appendix.

Thermal Modeling: Variables

The following are modeling variables specific to this system:

- Wall Structure: An 8-inch medium-weight block.
- Wall Framing: Galvanized steel studs at 16-inches on-center, including a top and bottom track. Various system options for locating framing relative to insulation are considered and depicted in Fig. 5-7 on page 5-11.
- Insulation: Cavity insulation is either R-15 batt insulation or R-6/inch insulation, such as CCSPF. Continuous insulation is either R-5 or R-6/inch; typical R-values for either rigid XPS or CCSPF insulation, respectively.

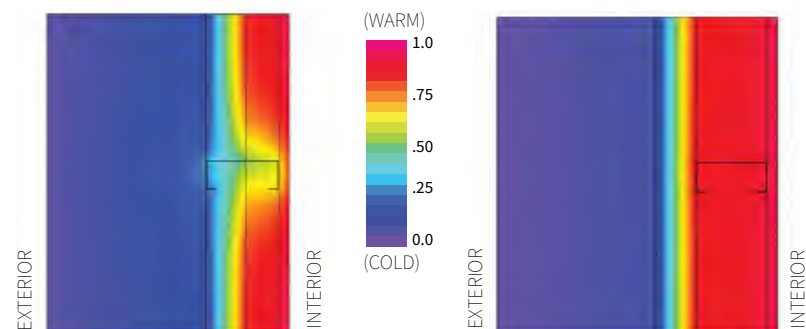


Fig. 5-5 Two-dimensional thermal model image of 2-inches of closed-cell spray foam insulation between studs tight to the CMU wall

Fig. 5-6 Two-dimensional thermal model image of 2-inch continuous closed-cell spray foam between studs and CMU wall

Thermal Modeling: Results

Modeling results are shown in Table 5-2 on page 5-11 and demonstrate the system's effective R-value under various conditions. Of the modeling results presented, many of the insulation strategies provide an effective R-value that satisfies the various prescriptive energy code requirements shown in Table 5-1. Key points for thermally optimizing this wall system are *italicized in boldface*.

- Options 2, 4, 5, 7, and 8 from Table 5-2 on page 5-11 provide an effective R-value in excess of R-20. In comparison to the remaining options, the greatest R-values achieved for this system are those that provide continuous insulation or continuous insulation with cavity insulation. *When thermally optimizing this wall system, it is more effective to provide unbridged continuous insulation or continuous insulation in addition to cavity insulation.*
- Cavity-only insulation produces an effective R-value of 7.2 for 2-inches of CCSPF (Option 1) and an effective R-value of 9.1 for 4-inches CCSPF (Option 6). These options reduce the thermal performance of the insulation by 53 to 67%. The steel studs and CCSPF may still provide a vapor control layer for this wall system; however, the insulation is de-bridged from the CMU at vertical framing and at head and sill tracks, creating discontinuities in the air control layer (and sometimes in the water control layer). *Cavity-only insulation for this system is a poor insulation strategy for thermal control and may be a poor strategy for air, water, and vapor control depending on the type of insulation and other materials used within the system.*

Table 5-1 System 5 prescriptive energy code compliance values

Guide Assembly #	Energy Code Climate Zone Classification	OPAQUE ABOVE-GRADE WALL - THERMAL ENVELOPE REQUIREMENTS							
		2012 SEC		2012 WSEC		2014 OEESC		2012 IECC	
		5 and Marine 4		5, 6 and Marine 4		5 and Marine 4		6	
5	Interior Insulated CMU	All Other	Interior: R-13 + R-6ci, or R-13 + R-10ci ⁽¹⁾ U-0.057 (R-17.5)	All Other	R-13.3ci ⁽²⁾ U-0.078 (R-12.8)	All Other	R-13.3ci U-0.078 (R-12.8)	All Other	R-13.3ci U-0.078 (R-12.8)
		Group R	Interior: R-13 + R-6ci, or R-13 + R-10ci ⁽¹⁾ U-0.057 (R-17.5)	Group R	R-11.4ci U-0.090 ⁽²⁾ (R-11.1)	Group R	R-11.4ci U-0.078 (R-12.8)	Group R	R-11.4ci U-0.078 (R-12.8)

⁽¹⁾ When using interior insulation: R-13 + R-6 ci for wood studs or R-13 + R-10 ci for metal studs; when using exterior insulation: R-13 ci. ⁽²⁾ Exception: integrally insulated concrete block complying with ASTM C90 with all cores filled, with at least 50% of block cores are filled with vermiculite (or equivalent fill insulation), and enclosing one of the following uses: gymnasium, auditorium, church chapel, arena, kennel, manufacturing plant, indoor swimming pool, pump station, water and wastewater treatment facility, storage facility, warehouse (storage and retail), motor vehicle service facility, mechanical/electrical structures (OEESC only), and restroom/concessions (OEESC only). Under the WSEC, where additional uses not listed (such as office, retail, etc.) are contained within the building, the exterior walls that enclose these areas may not utilize this exception.

Although the insulation strategies shown at right may meet the opaque wall prescriptive energy code requirements, additional considerations for how the various insulation strategies impact the remaining control layers is an important consideration.

Movement Joints

Because CMU is a concrete product, it will shrink over time (along with the mortar) due to initial drying, temperature fluctuations, and carbonation. Not only will shrinkage movement need to be considered, but differential movement between the CMU structure and other structural elements due to deflection, settlement, and various design loads will also need to be addressed.

Crack control within the CMU can increase the rain penetration resistance of this system. Material properties and reinforcing methods of the CMU structural wall should be implemented to reduce cracking; however, control joints within the CMU wall also need to be implemented to provide a plane of weakness to reduce shrinkage stresses and provide continuity of the water-shedding surface at these locations. Control joints in CMU can be constructed in a number of ways. Regardless of the method used, a continuous backer rod and sealant joint is installed at the joint to assist with water shedding and to provide a continuous water control layer.

Refer to the Movement Joints discussion on page i-48 for more information on locating joints and sealant joint best practices.

Table 5-2 System 5 effective R-value comparison chart. Insulation options are described in Fig. 5-7.

CMU Wall with Interior Insulation			
Insulation Option	Interior Insulation Thickness	Nominal Insulation R-Value*	3D Thermal Modeling Effective R-Value of System (ft ² ·°F·hr/Btu)
1	2"	12 cavity	7.2
2	4"	12 cavity + 12 ci	23.4
3	1"	5 ci	8.1
4	2"	12 ci	15.2
5	4"	24 ci	27.2
6	4"	24 cavity	9.1
7	2"	15 cavity + 10 ci	22.2
8	3"	15 cavity + 15 ci	27.3

*ci = continuous insulation

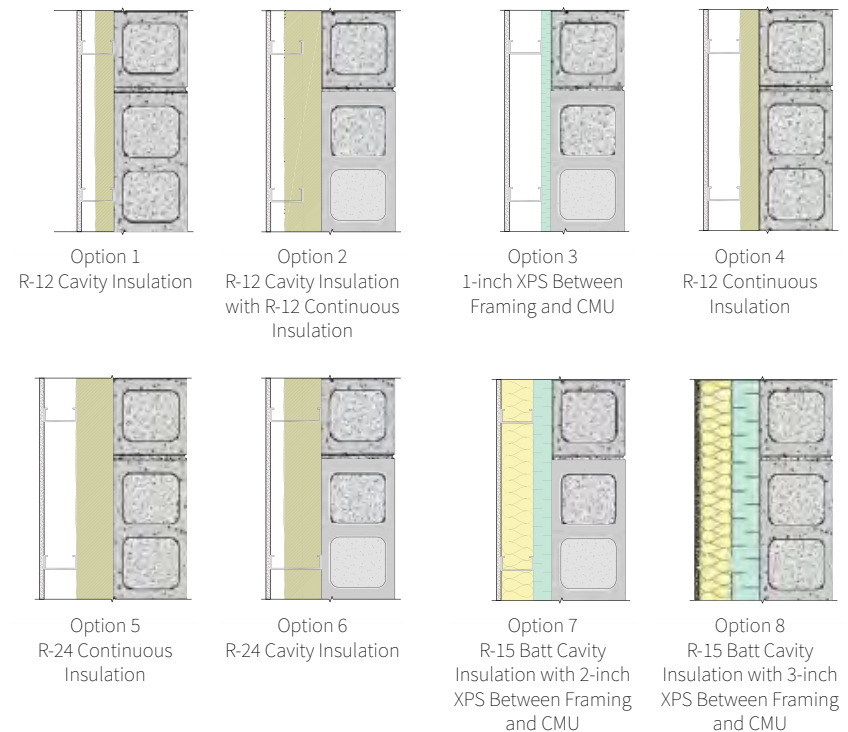


Fig. 5-7 System 5 insulation options reflected in the three-dimensional thermal modeling results shown in Table 5-2

Structural Considerations

The CMU block wall of this system provides the primary structure of this system. It is the responsibility of the Designer of Record to ensure that all structural elements of the wall are designed to meet project-specific loads and local governing building codes. Generic placement of the grout, reinforced elements, and supports/anchors is demonstrated within the details of this chapter and is provided for diagrammatic purposes only.

CMU Wall

The CMU in this system complies with ASTM C90,¹⁰ mortar designed for the CMU conforms to ASTM C270¹¹ or ASTM C1714¹² when specifying preblended mortar. The mortar type selected should be appropriate for the CMU application; Type S is typically specified. Grout components should comply with ASTM C 476¹³ while aggregate within the grout should comply with ASTM C 404.¹⁴

Block and mortar are both specified with a water-repellent admixture as discussed in the Water Repellents discussion within this chapter. Additionally, refer to the Northwest Concrete Masonry Association (www.nwcma.org) for additional information on specifying block, mortar, and grout.

Install the CMU and mortar joints of this system in conformance with industry-standard best practices, manufacturer requirements, and guidelines outlined in the NWCMA Tek Note on Rain-Resistant Architectural Concrete Masonry;¹ appropriate product selection and installation of CMU and mortar materials is necessary to provide a durable and water-resistive cladding system.

A qualified Designer of Record should design and review the specifics of the architectural characteristics and structural properties of the block, mortar, grout, and reinforcing. Various industry resources are available to assist with CMU wall design and are listed in the Resources section at the back of this guide.

Corrosion Resistance

For sheet-metal flashings that are integrated within this system (including flashings and sheet-metal drip flashings), it is best practice to provide components that are manufactured of ASTM A666¹⁵ Type 304 or 316 stainless steel, which are nonstaining and resistant to the alkaline content of mortar and grout materials. Consider prefinishing sheet-metal where stainless steel sheet-metal flashing components are not economically feasible or aesthetically desirable. Where used, this guide recommends the base sheet metal be a minimum G90 hot-dipped galvanized coating in conformance with ASTM A653¹⁶ or minimum AZ50 galvalume

coating in conformance with ASTM A792.¹⁷ Coating the exposed top finish of the sheet metal with an architectural-grade coating conforming to AAMA 621¹⁸ is recommended.

Water Repellents

Both integral water-repellent admixtures and a surface-applied clear water repellent are used in this system and assist with reducing the water absorption of the CMU wall and encourage water shedding. Use water-repellent admixtures both in the CMU and mortar. Admixture within block units should comply with NCMA TEK 19-7,¹⁹ while mortar admixture should comply with ASTM C1384.²⁰ More discussion on surface-applied clear water repellents is provided in the Surface-Applied Clear Water Repellents discussion on page i-59.

Make sure that both CMU and mortar admixtures as well as surface-applied water repellents have known compatibility performance.

Pricing Summary

A pricing summary for this system is provided on Table 5-3 on page 5-15. Pricing demonstrates the relative price per square foot and is based on a 10,000-square-foot wall area with easy drive-up access. Pricing provided does not include interior finishes or steel framing components. Pricing is valid for 2018. Current pricing is also available at www.masonrysystemsguide.com.

Online Availability

The content of this guide and additional resources may be accessed online at www.masonrysystemsguide.com. Also available online are downloadable versions of two- and three-dimensional system details and cutaway sections, sample project specifications, and ongoing updates to references and resources included within this guide.

Chapter References

1. Northwest Concrete Masonry Association. *Rain Resistant Architectural Concrete Masonry*. (Lynnwood, WA: Northwest Concrete Masonry Association, 2014).
2. International Code Council. *2015 International Building Code*. (Country Club Hills, IL: International Code Council, Inc., 2014).
3. National Fire Protection Association. *NFPA 285 - Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Non-Load-Bearing Wall Assemblies Containing Combustible Components*. (Quincy, MA: National Fire Protection Association, 2012).

4. ASTM International. *ASTM C518-15 Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus* (West Conshohocken, PA: ASTM International, 2015).

5. ASTM International. *ASTM E96/E96M-16 Standard Test Methods for Water Vapor Transmission of Materials*. (West Conshohocken, PA: ASTM International, 2016).

6. ASTM International. *ASTM D6226-15 Standard Test Methods for Open Cell Content of Rigid Cellular Plastics*. (West Conshohocken, PA: ASTM International, 2015).

7. 2015 Washington State Energy Code, Commercial Provisions . Chapter 51-11C WAC (filed by Washington State Legislature, January 19, 2016).

8. American Society of Heating, Refrigerating, and Air-Conditioning Engineers. *ANSI/ASHRAE/IES Standard 90.1-2016 Energy Standard for Buildings Except Low-Rise Residential Buildings*, IP ed. (Atlanta: ASHRAE, 2016).

9. U.S. Department of Energy. *COMcheck* (version 4.0.7). Windows or Online. Washington, D.C.: U.S. Department of Energy, 2017, <https://www.energycodes.gov/comcheck>.

10. ASTM International. *ASTM C90-16a Standard Specification for Loadbearing Concrete Masonry Units*. (West Conshohocken, PA: ASTM International, 2016).

11. ASTM International, *ASTM C270-14a Standard Specification for Mortar for Unit Masonry*. (West Conshohocken, PA: ASTM International, 2014).

12. ASTM International. *ASTM C1714/C1714M-16 Standard Specification for Preblended Dry Mortar Mix for Unit Masonry*. (West Conshohocken, PA: ASTM International, 2016).

13. ASTM International. *ASTM C476-16 Standard Specification for Grout for Masonry*. (West Conshohocken, PA: ASTM International, 2016).

14. ASTM International. *ASTM C404-11 Standard Specification for Aggregates for Masonry Grout*. (West Conshohocken, PA: ASTM International, 2011).

15. ASTM International. *ASTM A666-15 Standard Specification for Annealed or Cold-Worked Austenitic Stainless-Steel Sheet, Strip, Plate, and Flat Bar*. (West Conshohocken, PA: ASTM International, 2015).

16. ASTM International. *ASTM A653/A653M-15e1 Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process*. (West Conshohocken, PA: ASTM International, 2015).

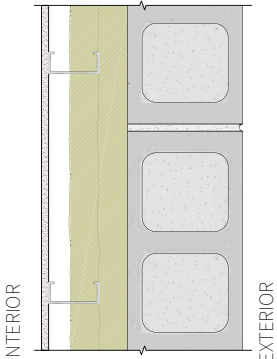
17. ASTM A792 ASTM International. *ASTM A792/A792M-10(2015) Standard Specification for Steel Sheet, 55 % Aluminum-Zinc Alloy-Coated by the Hot-Dip Process*. (West Conshohocken, PA: ASTM International, 2015).

18. American Architectural Manufacturers Association. *AAMA 621-02 Voluntary Specification for High-Performance Organic Coatings in Coil-Coated Architectural Hot-Dipped Galvanized (HDG) and Zinc-Aluminum Coated Steel Substrates*. (Schaumburg, IL: American Architectural Manufacturers Association, 2002).

19. National Concrete Masonry Association. *TEK 19-7 Characteristics of Concrete Masonry Units with Integral Water Repellent*. (Herndon, VA: National Concrete Masonry Association, 2008).

20. ASTM International. *ASTM C1384-12a Standard Specification for Admixtures for Masonry Mortars*. (West Conshohocken, PA: ASTM International, 2012).

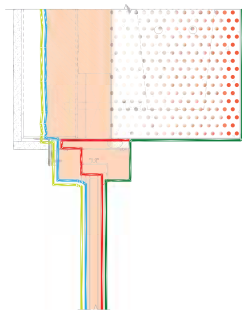
Table 5-3 System 5 CMU wall with interior insulation pricing summary

System 5: CMU Wall with Interior Insulation					
System Component	Baseline Product	Alternate (call for estimate)	Baseline Cost/ft ² (incl. labor)		
			Low	High	
INTERIOR					
1	Interior gypsum board	No evaluation of these components provided.			
2	Steel framing				
3*	Closed-cell spray foam insulation between studs	2-lb density closed-cell spray polyurethane foam, 2" thickness	No specified alternate	\$4.00	\$4.00
4*	Continuous closed-cell spray polyurethane foam insulation	2-lb density closed-cell spray polyurethane foam, 2" thickness	No specified alternate	\$4.00	\$4.00
5*	Single-wythe cmu wall	8"x8"x16" standard block, fully grouted with standard code-required rebar	No specified alternate	\$18.00	\$24.00
6*	Clear water repellent	Silane/siloxane blend	Antigraffiti clear water repellent	\$1.75	\$2.25
EXTERIOR					
Total cost to install 10,000 sq ft wall area w/easy drive-up access -->				\$27.75	\$34.25
Pricing Summary Discussion			System Plan View		
<ul style="list-style-type: none">- Low and high baseline costs are based on baseline products and installed labor costs. Call for an estimate for alternative product pricing.- Baseline costs provided will vary based on product-specific conditions as well as project location and should be used as an estimate only.- Block unit prices are for typical units as noted. Pricing can vary based on size, color, and finish and should be confirmed with the unit manufacturer.- *See the Resources section of this guide for a list of resources related to this component.					

LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Steel-framed wall
 - Closed-cell spray foam insulation between studs (CCSPF)
 - 2-inches CCSPF
 - Single-wythe CMU wall with water-repellent admixture
 - Clear water-repellent
2. Preservative-treated wood blocking and plywood
3. Sealant over backer rod
4. Fluid-applied flashing membrane
5. Continuous back dam angle at rough opening perimeter, minimum 1-inch tall, with window fastened through the back dam angle per window manufacturer recommendations
6. Continuous air barrier sealant, tie to continuous seal at window perimeter
7. Storefront window

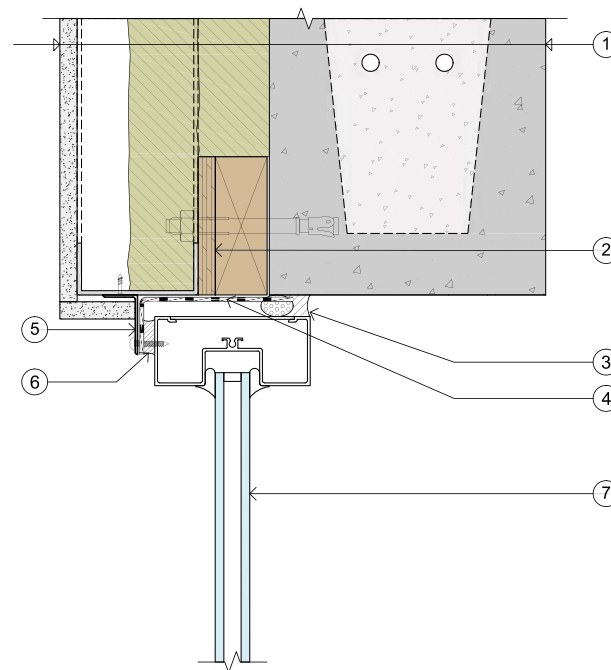
Water-Shedding Surface and Control Layers



Water-Shedding Surface

Control Layers:

Water
Air
Vapor
Thermal



Detail Discussion

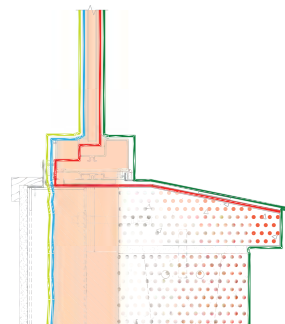
- A sheet-metal flashing as shown in Chapter 4 in Fig. 4-6 on page 4-15 may also be considered.
- Air control layer continuity is provided by the CCSPF fluid-applied flashing membrane at the rough opening and the air barrier sealant transition to the storefront window.
- Water control layer continuity is provided at the CMU wall, fluid-applied flashing membrane at the rough opening, and the air barrier sealant transition to the storefront window.
- Preservative-treated blocking and plywood provide a low-thermal conductivity structural support for the window perimeter and a suitable substrate for the fluid-applied flashing membrane application.

Typical Window Head
Detail 5-A

LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Steel-framed wall
 - Closed-cell spray foam insulation between studs (CCSPF)
 - 2-inches CCSPF
 - Single-wythe CMU wall with water-repellent admixture
 - Clear water-repellent
2. Storefront window on minimum 1/4-inch-thick intermittent shims
3. Sealant over bond breaker tape
4. Sloped sheet-metal sill flashing with hemmed drip edge
5. Drainage mesh or minimum 1/4-inch-thick intermittent shims
6. Fluid-applied flashing membrane
7. Preservative-treated wood blocking and plywood
8. Sloped precast concrete sill
9. Continuous air barrier sealant, tie to continuous seal at window perimeter
10. Continuous back dam angle at rough opening perimeter, minimum 1-inch tall, with window fastened through the back dam angle per window manufacturer recommendations

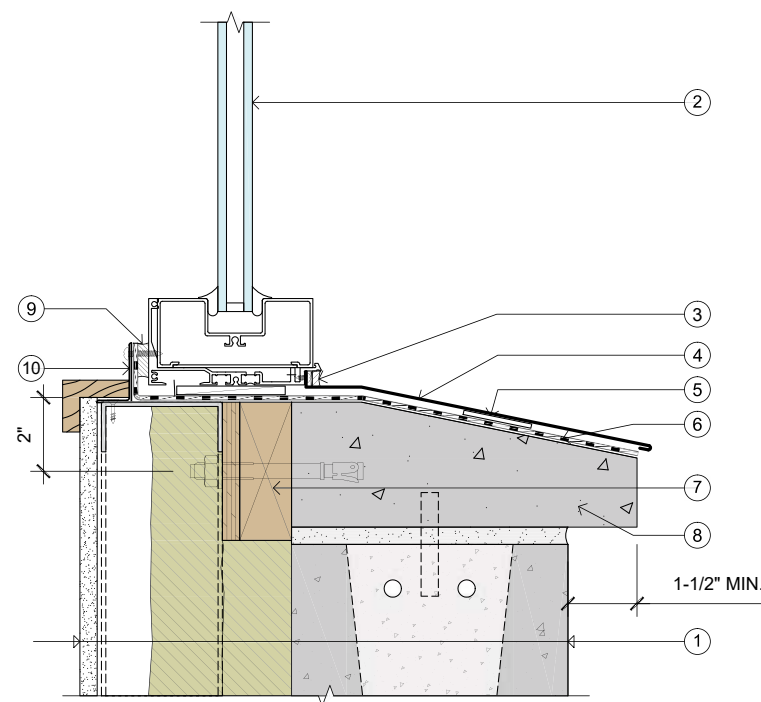
Water-Shedding Surface and Control Layers



Water-Shedding Surface

Control Layers:

- Water
- Air
- Vapor
- Thermal



Detail Discussion

- Air control layer continuity is provided by the CCSPF, the fluid-applied flashing membrane at the rough opening, and the air barrier sealant transition to the storefront window.
- Intermittent shims below the storefront window and sheet-metal sill flashing encourage drainage of the window rough opening to the exterior environment.
- The sheet-metal sill flashing promotes water shedding at the sill area and protects the fluid-applied air barrier/WRB flashing from UV exposure. The projected precast sill also promotes watershed away from the wall face.
- Anchor locations for rough opening preservative-treated blocking should be confirmed with the project's structural engineer.

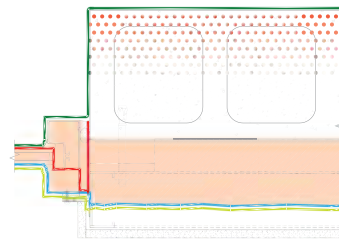
Precast Windowsill

Detail 5-B

LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Steel-framed wall
 - Closed-cell spray foam insulation between studs (CCSPF)
 - 2-inches CCSPF
 - Single-wythe CMU wall with water-repellent admixture
 - Clear water-repellent
2. Storefront window
3. Sealant over backer rod
4. Preservative-treated wood blocking and plywood
5. Fluid-applied flashing membrane
6. Continuous air barrier sealant, tie to continuous seal at window perimeter
7. Continuous back dam angle at rough opening perimeter, minimum 1-inch tall, with window fastened through the back dam angle per window manufacturer recommendations

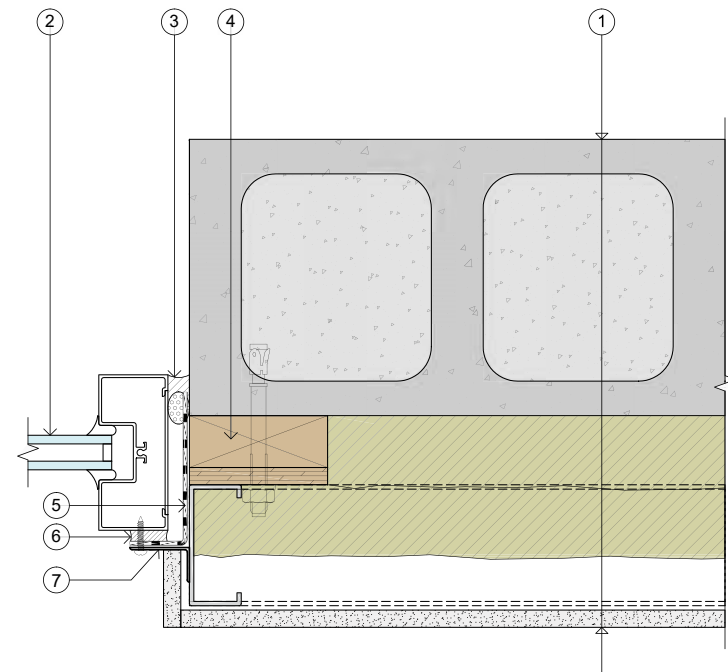
Water-Shedding Surface and Control Layers



Water-Shedding Surface

Control Layers:

- Water
- Air
- Vapor
- Thermal



Detail Discussion

- Air control layer continuity is provided by the CCSPF, fluid-applied flashing membrane at the rough opening, and the air barrier sealant transition to the storefront window.
- The sealant and backer rod joint between the storefront window and CMU wall provides water shedding surface continuity between the CMU wall and window face.
- The continuous back dam angle shown allows for perimeter attachment of the storefront window without the need for F-clips or similar anchors, which often inhibit the air barrier sealant (and thus, the air control layer) at the window perimeter. Project-specific window attachment methods should be confirmed with the window manufacturer during the design phase of the project.

Storefront Window Jamb

Detail 5-C

LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Steel-framed wall
 - Closed-cell spray foam insulation between studs (CCSPF)
 - 2-inches CCSPF
 - Single-wythe CMU wall with water-repellent admixture
 - Clear water repellent
2. Rigid XPS insulation
3. Underslab vapor barrier
4. Rigid XPS underslab insulation
5. Hardscape sealant joint at sidewalk
6. Damp proofing
7. Drainage composite or gravel backfill

Water-Shedding Surface and Control Layers



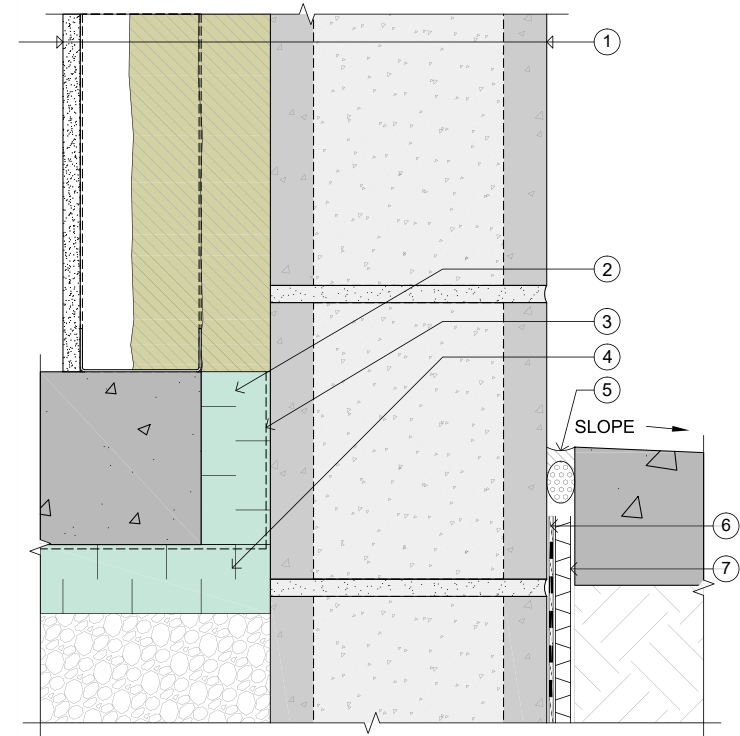
Water-Shedding Surface

Control Layers:

- Water
- Air
- Vapor
- Thermal

Detail Discussion

- The XPS insulation provides a thermal break between the slab and CMU wall and allows for a continuous thermal control layer at the slab-to-wall transition.



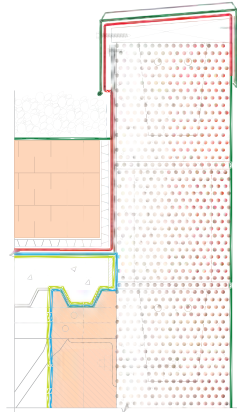
Slab and CMU Foundation

Detail 5-D

LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Steel-framed wall
 - Closed-cell spray foam insulation between studs (CCSPF)
 - 2-inches CCSPF
 - Single-wythe CMU wall with water-repellent admixture
 - Clear water repellent
2. Inverted roof membrane assembly
3. Typical Parapet Assembly:
 - Inverted roof membrane
 - Single-wythe CMU wall with water-repellent admixture
 - Clear water repellent
4. Sloped standing-seam sheet-metal coping with gasketed washer fasteners
5. Preservative-treated wood blocking
6. High-temperature self-adhered membrane

Water-Shedding Surface and Control Layers



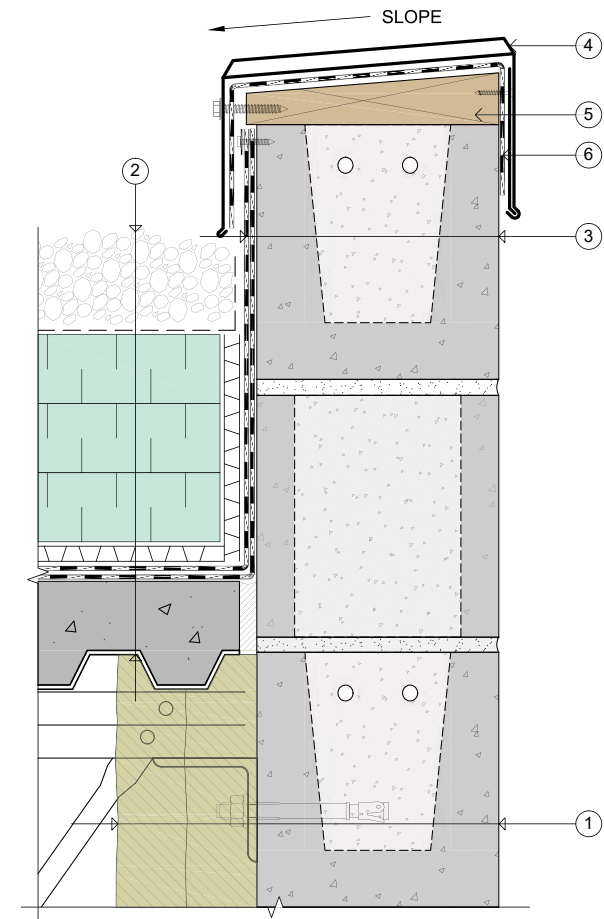
— Water-Shedding Surface

Control Layers:

— Water
— Air
— Vapor
— Thermal

Detail Discussion

- The sheet-metal coping with hemmed drip edge sheds water away from the wall top and CMU wall face below. It is recommended that the sheet-metal cap counterflash the top course of block by a minimum of 3-inches.
- The CCSPF extends tight up to the underside of the deck, around roof structure and anchor elements. This reduces the opportunity for warm, moisture-laden interior air to contact the deck and CMU wall where it's coldest. It also provides air control layer continuity from the wall insulation to the metal pan deck assembly.



Typical Parapet at Inverted Roof Membrane Assembly

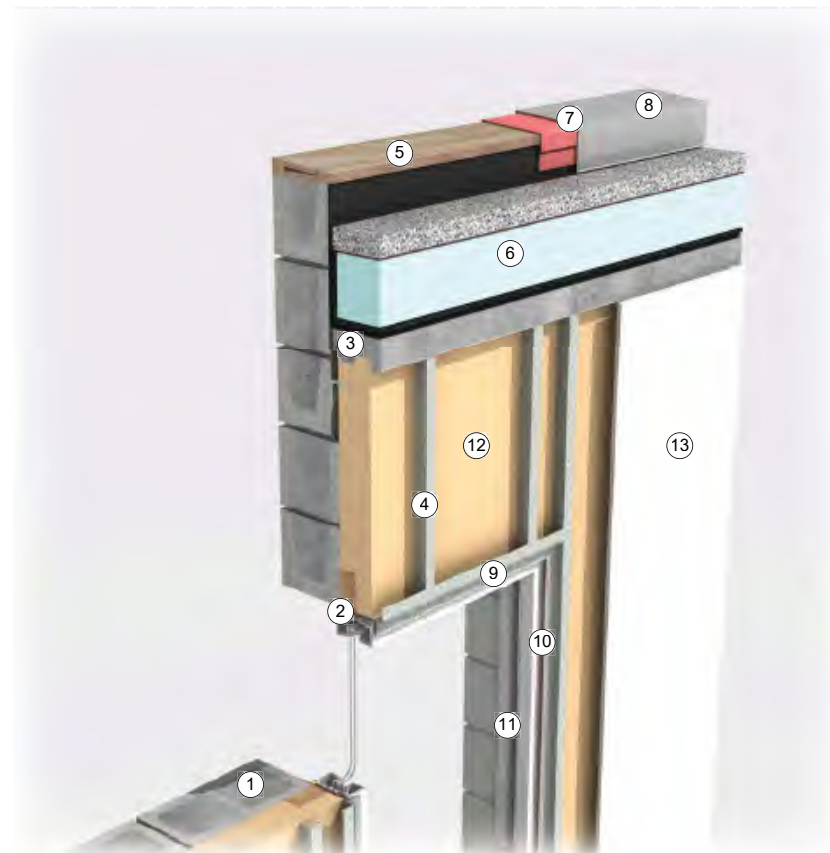
Detail 5-E

LEGEND

1. Single-wythe CMU wall with water-repellent admixture
2. Preservative-treated wood blocking and plywood anchored to CMU wall
3. Roof structure
4. Steel-framed wall
5. Sloped, preservative-treated wood blocking
6. Inverted roof membrane assembly
7. High-temperature self-adhered membrane
8. Sloped standing-seam sheet-metal coping with gasketed washer fasteners
9. Continuous back dam angle at rough opening perimeter, minimum 1-inch tall, with window fastened through the back dam angle per window manufacturer recommendations
10. Continuous air barrier sealant, tie to continuous seal at window perimeter.
11. Storefront window
12. CCSPF
13. Interior gypsum board

3-D Detail Discussion

- Three-dimensional cutaway sections on the next three pages represent two-dimensional details of this system.
- The preservative-treated blocking and plywood, as shown in Detail 5-F, at the window rough opening provide a low thermal conductivity structural support for the window perimeter and also provide a suitable substrate for the fluid-applied flashing membrane. The preservative-treated blocking and plywood is 2-inches deep to accommodate the minimum continuous CCSPF depth necessary to achieve a Class II permeance (vapor retarder).
- As shown in Detail 5-F, the steel studs bridge the interior 2-inches of CCSPF. The steel-stud framing may be moved inboard of the insulation entirely to eliminate thermal bridging and improve the system's thermal performance. See Fig. 5-7 on page 5-11 and the related text discussion for additional insulation options.
- As shown in Detail 5-G, The XPS insulation provides a thermal break between the slab and CMU wall and allows for a continuous thermal control layer at the slab-to-wall transition.
- Detail 5-H describes a typical rough opening with continuous back dam angle. The sill back dam angle creates a sill pan below the window; intermittent shims below the storefront window promote drainage at the sill and below the sheet-metal sill flashing.

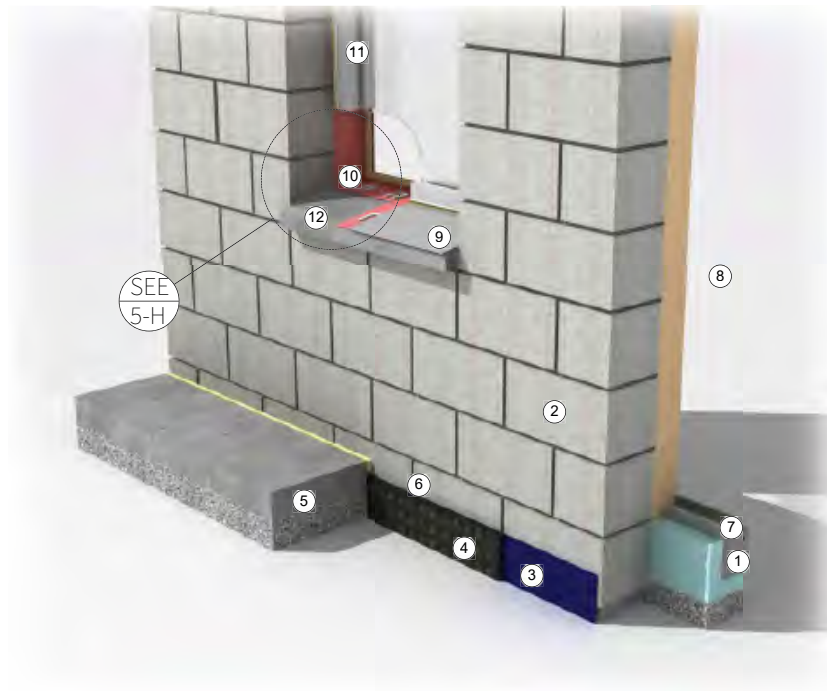


Parapet Assembly Section Cutaway (Interior)

Detail 5-F

LEGEND

1. Concrete floor slab over XPS insulation and vapor barrier
2. Single-wythe CMU wall with water-repellent admixture
3. Damp proofing
4. Drainage composite or gravel backfill
5. Hardscape, sloped away from structure
6. Hardscape sealant joint between hardscape and CMU wall
7. Steel-framed wall
8. CCSPF insulation per assembly
9. Sloped sheet-metal sill flashing
10. Fluid-applied flashing membrane
11. Storefront window
12. Sloped precast concrete sill

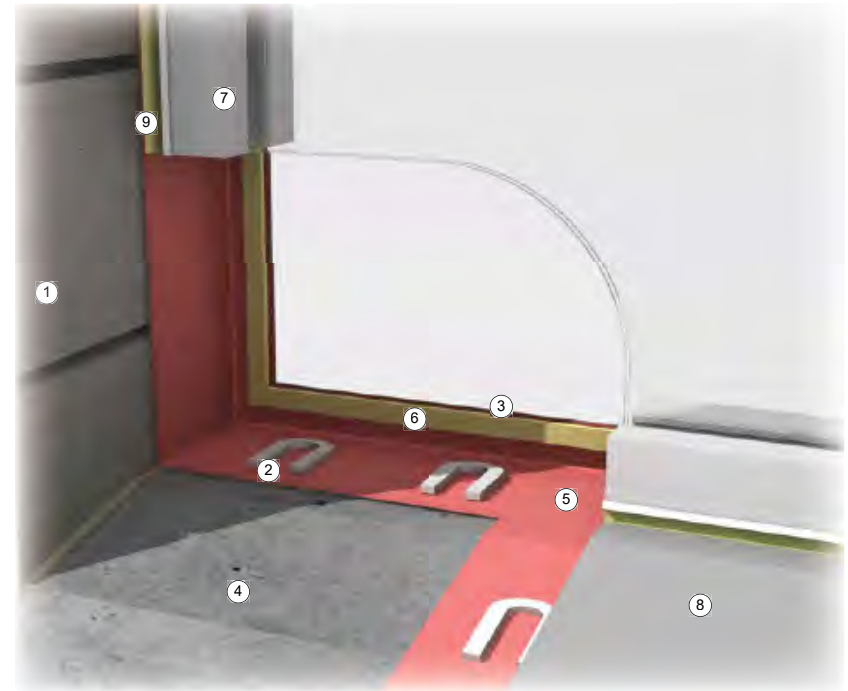


Base-of-Wall Cutaway Section

Detail 5-G

LEGEND

1. Single-wythe CMU wall with water-repellent admixture
2. Minimum 1/4-inch-thick intermittent shims
3. Continuous back dam angle at rough opening perimeter, minimum 1-inch tall, with window fastened through the back dam angle per window manufacturer recommendations
4. Sloped precast concrete sill
5. Fluid-applied flashing membrane
6. Continuous air sealant, tie to continuous seal at window perimeter.
7. Storefront window
8. Sloped sheet-metal sill flashing over drainage mesh or minimum 1/4-inch-thick intermittent shims
9. Sealant over backer rod, continuous at window perimeter



Window Jamb and Sill Cutaway Section

Detail 5-H

CHAPTER 6:**CMU WALL WITH ADHERED MASONRY VENEER**

Masonry system 6 is a rainscreen wall system with concrete masonry unit (CMU) structure and adhered veneer over a cement backer board substrate. The adhered masonry veneer may be thin brick, natural stone, or manufactured stone. The components of this system, from interior to exterior, are described in Fig. 6-1. This system is appropriate for many applications including low- or mid-rise residential or commercial buildings. An example application of this system is shown in Fig. 6-2 on page 6-2.

Building Enclosure and Control layers

As noted in the Introduction, an above-grade wall system controls liquid water, air, heat, and possibly water vapor to function as an effective and durable environmental separator. Control of these elements, specific to this wall system, is provided by the following control layer systems and/or materials:

- The water control layer, comprising the water-resistive barrier (WRB) system
- Air control layer, comprising the air barrier system

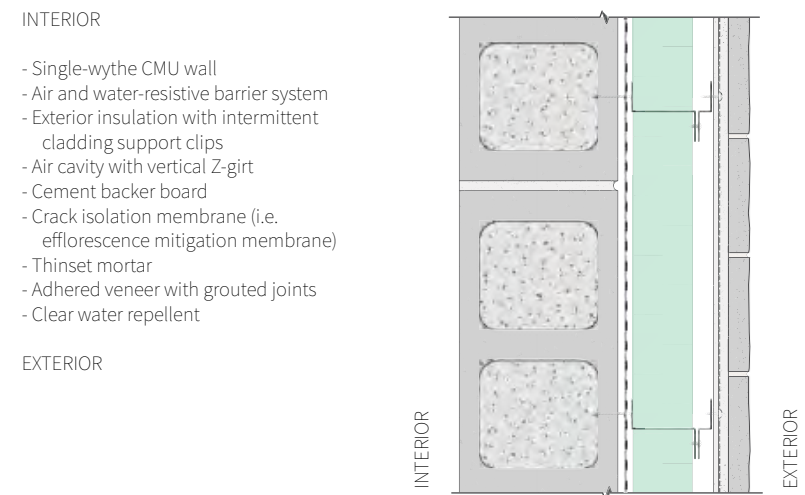


Fig. 6-1 Typical System 6 components from interior to exterior.

- Thermal control layer, comprising thermal insulation and other low-conductivity materials
- Vapor control layer, comprising vapor retarding materials

For a summary of the relationship between building enclosure loads, control layers, and associated systems and materials, refer to Fig. i-13 on page i-21 of the introductory chapter.

Fig. 6-3 illustrates the water-shedding surface and control layer locations for this system. The water-shedding surface and control layers are also shown on typical system details provided adjacent to each detail at the end of this chapter.



Fig. 6-2 Adhered CMU wall with adhered veneer example project application

As shown in Fig. 6-3, the water-shedding surface occurs at face of the adhered masonry veneer, with most water shedding occurring at the wall while some water may be stored within the masonry veneer to be released later. The water control layer, the air control layer, and the vapor control layer occur at the same location at the exterior face of the CMU wall structure. The thermal control layer within this system occurs at the exterior insulation.

Water-Shedding Surface

The water-shedding surface is a system that serves to reduce the water load on the enclosure. A general discussion of the water-shedding surface is provided in the Water-Shedding Surface discussion on page i-19.

The adhered veneer cladding—including both grout joints and veneer units—is the primary water-shedding surface of the wall system. Additional water-shedding surface components within the wall system include sheet-metal flashings and drip edges, sealant joints, and fenestration systems as shown on the details included at the end of this chapter.

To promote water shedding at the cladding, grout joints between veneer units should be installed with a tooled concave (preferred) or “V” shape.

The water-shedding surface is most effective when free of gaps other than those providing drainage and/or ventilation. Movement joints and joints around fenestrations and penetrations are recommended to be continuously sealed with backer rod and sealant or counterflashed with a sheet-metal flashing to deflect wind-driven rain and shed water away from the rainscreen cavity.

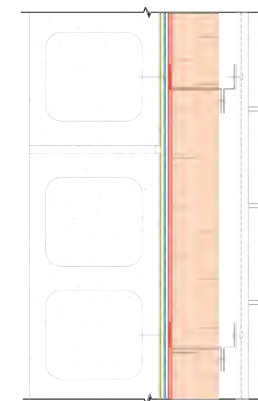
Water Control Layer

The water control layer is a continuous control layer that is designed and installed to act as the innermost boundary against water intrusion. In a rainscreen wall system, the water-resistive barrier (WRB) system is the last line of defense against water intrusion. A general discussion of the WRB system is provided in the Water Control Layer discussion on page i-24.

In this wall system, the WRB system is typically a self-adhered sheet or fluid-applied system that also functions as the air barrier system; thus, the WRB system is often referred to as the air barrier and WRB system. Either a self-adhered sheet or fluid-applied system is depicted in the details at the end of this chapter. An example of a fluid-applied air barrier and WRB membrane is shown in Fig. 6-4 on page 6-4. This membrane may have Class I, Class II, Class III, or Class IV vapor permeance properties because it is located interior of the system's thermal insulation. Physical properties of the WRB system products are discussed in detail in the Water Control Layer discussion on page i-24. Vapor permeability of materials is addressed in the Vapor Control Layer discussion on page i-28.

The WRB system must be continuous across the wall system to provide effective water control. In addition to the field membrane, the WRB system includes fluid-applied or self-adhered flashing membranes, sealants, sheet-metal flashings, and penetrations such as windows and doors as shown in the detail drawings that

Water-Shedding Surface and Control Layers



— Water-Shedding Surface

Control Layers:

— Water
— Air
— Vapor
— Thermal

Fig. 6-3 System 6 water shedding surface and control layer locations.



Fig. 6-4 Fluid-applied air barrier and WRB field membrane installed over CMU wall substrate

follow this chapter discussion. Where sheet-metal flashing components occur within the system, the back leg of the sheet-metal flashing is shingle-lapped into the WRB system to facilitate drainage at the face of the WRB system and to the exterior of the cladding.

Cladding support clip fasteners in this system penetrate the WRB system and should be sealed as required by the WRB system manufacturer's installation requirements. Fasteners may be required to be set in sealant, especially at uneven wall planes; however, requirements vary by manufacturer and should be confirmed.

Air Control Layer

The air barrier system serves to provide the air control layer. In addition to controlling air, this layer also assists with controlling liquid water, heat, and water vapor.

For this wall system, the air barrier system is the same field membrane and components that also serve as the WRB system. A general discussion of the air control layer and the air barrier system is provided in the Air Control Layer discussion on page i-26.

As discussed in the introductory chapter, the air barrier system must be continuous and fully sealed to resist air flow, whereas the WRB system is not required to be continuously sealed to be effective.

A mechanically attached air barrier and WRB system may be used for this wall system where recommended by the manufacturer for installation over a CMU wall substrate.

Vapor Control Layer

The vapor control layer retards or greatly reduces (e.g., vapor barrier) the flow of water vapor due to vapor pressure differences across enclosure assemblies. Unlike the other control layers presented in this guide, the vapor control layer is not always necessary or required to be continuous.

For this system, a vapor control layer is not necessary; the risk of condensation development or damage to the structure due to outward vapor drive and condensation is unlikely due to all of the system's thermal insulation being located exterior of the wall structure and the air barrier and WRB system.

Note that Fig. 6-3 on page 6-3 identifies the vapor control layer at the exterior face of the CMU wall. This represents the exterior-most plane of the CMU wall structure, which has some vapor resistance. It would also represent the location of a vapor control layer if a relatively low vapor permeance (Class I or II) air barrier and WRB system were used.

Thermal Control Layer

The thermal control layer controls heat flow and assists with controlling water vapor.

In this wall system, the exterior insulation is the primary material that forms the thermal control layer. At transition details, the thermal control layer extends to the exterior insulation across bond beams, peripheral floor lines, and insulation at the roof assembly, slab, and foundation elements. Windows and doors that penetrate this system are also part of the thermal control layer.

The location of the insulation in this wall system, exterior of the wall structure:

1. Allows for the exterior insulation to extend across floor lines (which are typically required to meet similar energy code compliance requirements as this wall system).
2. Keeps the structure warm, which reduces the risk of condensation developing inboard of the WRB system.
3. Protects the air barrier and WRB systems both from extreme temperature cycles and from damage during veneer installation.

Although masonry is defined as a noncombustible cladding material, the use of a combustible air barrier and WRB system or foam plastic insulation within a wall cavity can trigger fire propagation considerations and requirements. Depending on the local jurisdiction, IBC Section 1403.5¹ (regarding vertical and lateral flame propagation as it relates to a combustible WRB system) may require acceptance criteria for NFPA 285². The use of foam plastic insulation within a wall cavity should also be addressed for IBC Chapter 26 provisions.

The CMU in this system is also a thermal mass; thus, it may provide thermal mass benefits.

Additional thermal insulation information is provided in the Thermal Control Layer discussion on page i-30 of the introductory chapter.

Insulation Selection

In the Northwest region, the exterior insulation for this system is typically semi-rigid mineral fiber board insulation; moisture-tolerant rigid board insulation products (e.g., polyisocyanurate or XPS) may also be used. Refer to the Insulation Products discussion on page i-30 for information on various insulation types as well as additional considerations.

Thermal Performance and Energy Code Compliance

This wall system is typically classified as a mass above-grade wall for energy code compliance purposes. Prescriptive energy code compliance values for this system are summarized in Table 6-2 on page 6-11 and describe:

- Minimum insulation R-values for a *prescriptive insulation R-value method* strategy.
- Maximum system U-factors for a *prescriptive assembly U-factor method* strategy. Note that the equivalent effective R-value of this U-factor has been calculated and is denoted in parenthesis () for easy comparison to thermal modeling results included within this chapter.
- Footnote (2) for compliance by *exception*. The ability to use this option depends on the jurisdiction, the building's use, and the availability of CMU cores to be filled with insulation. If this exception is to be used, refer to the Thermal Performance and Energy Code Compliance discussion on page 4-5.

For all energy code compliance strategies except the *prescriptive insulation R-value method strategy*, this wall system's U-factor will need to be calculated or

determined from tables; however, it may or may not be required to be less than the prescriptive U-factors in Table 6-2.

The Thermal Performance and Energy Code Compliance discussion on page i-33 and Fig. i-26 on page i-39 of the introductory chapter describes the typical process of navigating energy code compliance options. Additionally, the thermal modeling results demonstrated in this chapter may be used to assist with selecting wall system components (e.g., cladding support clip type, insulation R-value/inch, etc.) to achieve a target U-factor. Also discussed are options for thermally optimizing this assembly, as determined through the modeling results.

Project-specific thermal performance values for an opaque above-grade wall should be used for energy code compliance and determined from a source that is approved by the authority having jurisdiction. Thermal performance sources may include the appendices of the 2015 WSEC,³ ASHRAE 90.1,⁴ COMcheck,⁵ thermal modeling and calculation exercises, or other industry resources.

System Effective Thermal Performance

Cladding support clips, such as intermittent Z-girt or fiberglass standoff clips as shown in Fig. 6-5, penetrate the exterior insulation in this system and create areas of thermal bridging (i.e., heat loss).

An example of the thermal bridging caused by an intermittent Z-girt is described by Fig. 6-6 and Fig. 6-7 on page 6-8. These figures demonstrate the geometry and the relative thermal gradient of this system when thermally modeled. The lighter blue thermal gradient color at the exterior face of the Z-girt describes a warmer temperature than the adjacent darker blue insulation face—an indicator of heat loss at the penetration through the thermal insulation. This thermal bridging reduces the system's effective thermal performance.

Three-dimensional thermal modeling demonstrates this system's effective thermal performance with various insulation thicknesses, insulation R-values, and cladding support clips/materials. A discussion on the modeling performed for this guide is included in the appendix.



Fig. 6-5 Cladding support clip options including intermittent Z-girt (top) and fiberglass standoff clip (bottom)

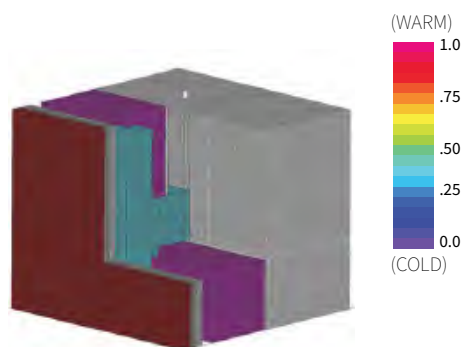


Fig. 6-6 Three-dimensional section of an intermittent Z-girt through exterior insulation

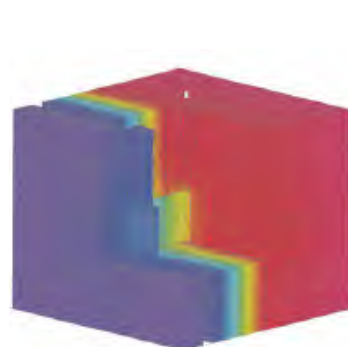


Fig. 6-7 Three-dimensional thermal image of the attachment depicted in Fig. 6-6

Thermal Modeling: Variables

The following are modeling variables specific to this system:

- **Wall Structure:** An 8-inch, medium-weight block
- **Cladding Supports Clips:** Two example cladding support clip types are considered and are shown in Fig. 6-5:
 - Intermittent Z-girts (16-gauge) made of either stainless steel or galvanized steel. Clips are 6-inches tall and spaced at 24-inches on-center vertically, 16-inches on-center horizontally.
 - Fiberglass standoff clips spaced at 24-inches on-center vertically and 16-inches on-center horizontally. Both stainless steel and galvanized steel fasteners are considered for the fiberglass standoff clip option.
- **Exterior Insulation:** R-4.2/inch or R-6/inch insulation product in thicknesses of 3-, 4-, and 5-inches. The R-values selected demonstrate the lower and upper thermal resistance of typical exterior insulation products.

Thermal Modeling: Results

Modeling results shown in Table 6-1, Fig. 6-8, and Fig. 6-9 (see page 6-10 and page 6-11) demonstrate the system's effective R-value under various conditions; Fig. 6-8, and Fig. 6-9 graphically represent the results summarized in Table 6-1.

Below is a discussion of the results. Where reductions in the system's effective R-value are discussed, these values are as compared to the system's effective R-value "Without Clips".

- As determined from Table 6-1, fiberglass standoff clips reduce the system's effective R-value by 11 to 32%, while intermittent Z-girts reduce the system's effective R-value by 21 to 53%. This system has a greater effective R-value when low-conductivity clip supports (such as fiberglass clips) are used in lieu of intermittent metal Z-girts. *Thermally improved cladding attachment options can achieve better effective thermal performance values; a number of systems are commercially available and new products continue to be developed. Most manufacturers of proprietary clip systems will have thermal modeling results available when determining the system's effective thermal performance value.*
- When considering fiberglass standoff clips, the results of Table 6-1, Fig. 6-8, and Fig. 6-9 demonstrate that the system's effective R-value is reduced by 11 to 19% for stainless-steel fasteners and by 20 to 32% for galvanized-steel fasteners. *Better system thermal performance can be achieved with fiberglass standoff clips when stainless-steel fasteners are used in lieu of galvanized fasteners.*
- As determined from Table 6-1, intermittent stainless-steel Z-girts reduce the system's effective R-value by 21 to 32%. Galvanized-steel intermittent Z-girts reduce the effective R-value by 35 to 53%. *Greater system effective R-values are achieved with stainless-steel intermittent Z-girts, as opposed to galvanized-steel Z-girts. Galvanized steel has a greater thermal conductivity than stainless steel.*
- The system's effective R-value is similar for both fiberglass standoff clips with galvanized-steel fasteners and stainless-steel intermittent Z-girts as shown in Table 6-1, Fig. 6-8, and Fig. 6-9. *Some performance targets can be met without proprietary cladding attachment systems. This consideration may prove to be a cost-effective solution.*

Drainage, Ventilation, and Water Deflection

Adhered masonry veneer with grouted joints typically sheds most water it is exposed to; however, some moisture is expected to penetrate the cladding and enter the rainscreen cavity. This moisture is drained through the air cavity (created by the continuous Z-girts that support the cladding) or through the drainable semi-rigid insulation (where used).

Drainage and Ventilation

The air cavity of this system is created by continuous Z-girts, often ¾-inch or 1-inch minimum depth, spaced at 16-inches on-center or as needed to accommodate movement joints. These continuous Z-girts are broken at horizontal joints where movement is expected to occur or at cross-cavity sheet-metal flashings.

In the Northwest region, the air cavity is typically open at the top and bottom to encourage ventilation. Where the air cavity is open, (e.g., base of walls, window head flashings, parapets, and cross-cavity flashings at floor lines), it is recommended that the cavity is screened to allow for ventilation to occur while still protecting the cavity from insects.

Sheet-Metal Components

Sheet-metal components for this system are reflected throughout the details located at the end of this chapter. Cross-cavity sheet-metal components are located at the head of wall penetrations (e.g., a window head) and at cross-cavity flashing locations similar to that shown in Fig. 6-10 on page 6-12. These flashings help drain the rainscreen cavity and protect any air barrier and WRB system components behind them. Counterflashing sheet-metal components assist with water shedding and are typically located at windowsill and parapet top conditions; they protect the cavity from water ingress while allowing ventilation of the air cavity.

Sheet-metal flashing components that penetrate the exterior insulation act as a thermal bridge and degrade the thermal

Table 6-1 System 6 thermal modeling results

8" CMU Wall with Adhered Masonry Veneer over Exterior Insulation, R-4.2/in - R-6/in Exterior Insulation					
3D Thermal Modeling Effective R-Value of System (ft ² ·°F·hr/Btu)					
Clip Type	Clip Penetration Area	Exterior Insulation Thickness	Nominal Exterior Insulation R-Value	Without Clips (Through Exterior Insulation)	Stainless Clip and/or Fasteners and/or Fasteners
Fiberglass Clips	0.80%	3"	12.6-18	15.8-21.2	14.0-17.9
		4"	16.8-24	20.1-27.4	17.6-22.6
		5"	21-30	24.2-33.3	20.9-26.9
Intermittent 6" Z-Girts	0.09%	3"	12.6-18	15.8-21.2	12.5-15.3
		4"	16.8-24	20.1-27.4	15.5-19.1
		5"	21-30	24.2-33.3	18.4-22.7

Table 6-2 System 6 prescriptive energy code compliance values excerpted from Table i-1 of the introductory chapter

OPAQUE ABOVE-GRADE WALL - THERMAL ENVELOPE REQUIREMENTS									
Energy Code		2012 SEC		2012 WSEC		2014 OEESC		2012 IECC	
Climate Zone		5 and Marine 4		5, 6 and Marine 4		5 and Marine 4		5 and Marine 4	
Classification		All Other		All Other		All Other		All Other	
Guide Assembly #		Group R		Group R		Group R		Group R	
6	CMU Wall with Adhered Masonry Veneer	Exterior: R-16 ⁽¹⁾	U-0.057 (R-17.5)	Exterior: R-16 ⁽¹⁾	U-0.057 (R-17.5)	Exterior: R-16 ⁽¹⁾	U-0.057 (R-17.5)	Exterior: R-16 ⁽¹⁾	U-0.057 (R-17.5)
		Exterior: R-16 ⁽¹⁾	U-0.057 (R-17.5)	Exterior: R-16 ⁽¹⁾	U-0.057 (R-17.5)	Exterior: R-16 ⁽¹⁾	U-0.057 (R-17.5)	Exterior: R-16 ⁽¹⁾	U-0.057 (R-17.5)
		Exterior: R-16 ⁽¹⁾	U-0.057 (R-17.5)	Exterior: R-16 ⁽¹⁾	U-0.057 (R-17.5)	Exterior: R-16 ⁽¹⁾	U-0.057 (R-17.5)	Exterior: R-16 ⁽¹⁾	U-0.057 (R-17.5)

⁽¹⁾ When using interior insulation: R-13 + R-6 cl for wood studs or R-13 + R-10 cl for metal stud; when using exterior insulation: R-16 cl

⁽²⁾ Exception: integrally insulated concrete block complying with ASTM C90 with all cores filled, with at least 50% of block cores are filled with vermiculite (or equivalent fill insulation), and enclosing one of the following uses: gymnasium, auditorium, church chapel, arena, kernel, manufacturing plant, indoor swimming pool, pump station, water and wastewater treatment facility, storage facility, motor vehicle service facility, mechanical/electrical structures (OEESC only), and restroom/concessions (OEESC only). Under the WSEC, where additional uses not listed (such as office, retail, etc.) are contained within the building. The exterior walls that enclose these areas may not utilize this exception.

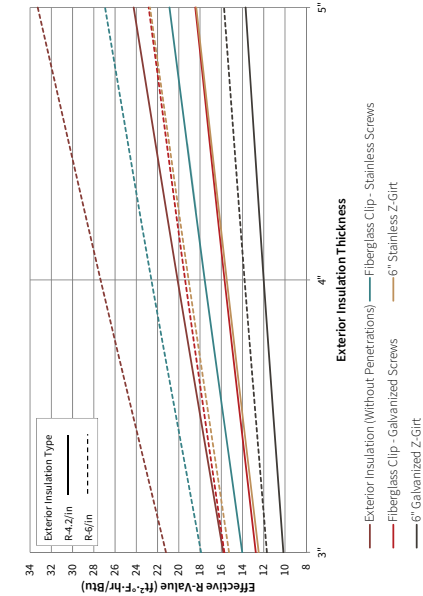


Fig. 6-8 System 6 effective R-value comparison of various cladding support clips and a range of insulation R-values per inch

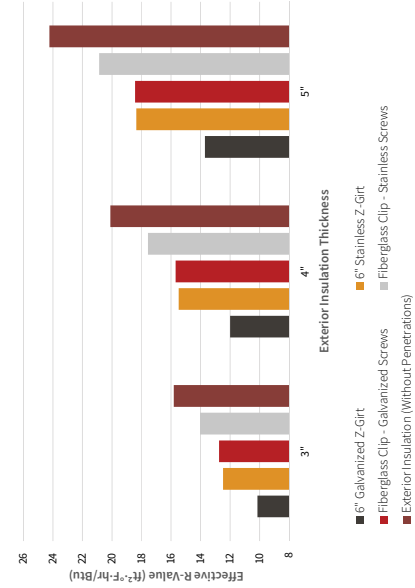


Fig. 6-9 System 6 effective R-value modeling results for R-4.2/inch insulation and various cladding support clips

performance of the system; however, they are a necessary element for rainscreen wall system performance.

Refer to the Sheet-Metal Flashing Components discussion on page i-46 for general recommendations on sheet-metal flashing products, including design considerations and materials.

Movement Joints

In this system, the masonry units are bonded to a crack isolation membrane over a cement backer board substrate. If using clay masonry units, they will expand over time, whereas concrete-based veneer products and grout joints between units will shrink. Minor movement is expected within the cement backer board and non-metal or intermittent metal cladding support clips; however, Z-furring may experience some movement due to temperature changes. The CMU backup wall structure of this system is expected to shrink over time due to initial drying, temperature fluctuations, and carbonation. As a result, both horizontal and vertical movement joints are needed to accommodate differential movement between the structure, cladding support system, and veneer components to prevent damage to the veneer or other wall components.

Horizontal gaps within the veneer and cladding support system typically occur at cross-cavity sheet-metal flashing locations that coincide with building floor lines, a common location for building movement. These gaps are typically provided at, and should be continuous across, all elevations of the building. Also recommended are gaps above and below through-wall penetrations (e.g., windows and those described in the Masonry Veneer Penetrations discussion on page i-54), below structure projections (such as parapet blocking), and where needed to minimize veneer panel sizes. At each horizontal gap, there is typically either a compressible backer rod and sealant joint or a cross-cavity sheet-metal flashing. The sizing and location of these joints will vary depending on the expected differential movement between the wall and veneer.

The location of vertical joints varies throughout the industry and should be confirmed with the veneer unit manufacturer



Fig. 6-10 Cross-cavity sheet-metal flashing shown below cement backer board

for the project-specific application. This guide recommends locating vertical movement joints throughout the veneer system and considering horizontal-to-vertical placement relationships.

Typical locations of joints for accommodating movement, drainage, and/or rainscreen cavity ventilation are identified with an asterisk (*) in chapter details. In general, a minimum gap dimension of $\frac{3}{8}$ -inch is recommended; however, it is the Designer of Record's responsibility to appropriately locate and size all movement joints.

Refer to the Movement Joints discussion on page i-48 for more information on locating both horizontal and vertical veneer joints and for sealant joint best practices.

Structural Considerations

Adhered veneers rely on adhesion to secure the masonry units and should be designed to comply with local building codes and TMS 402-16.⁶ The adhered veneer should be designed by the Designer of Record and—as described by TMS 402-16⁶ commentary—should consider the adhesion of the veneer units, the curvature of the veneer backing, freeze-thaw cycling, water penetration, and air and vapor transmission when necessary.

The code requires that adhered veneers be applied over concrete or masonry backings and, traditionally, adhered veneer was applied directly over these wall types. However, recent code cycles requiring exterior insulation have dictated that adhered veneers over a CMU wall include some insulation that may occur at the exterior face of the backup wall and WRB system plane.

Per TMS 402-16,⁶ adhesion between the adhered veneer units and the backer must have a minimum shear strength of 50 psi in accordance with ASTM C482;⁷ however, significantly higher bond strengths can be achieved with currently available products and may be appropriate for projects within the Northwest region. Adhered veneer units for this system are adhered in a thinset mortar to form a continuous bed that is free of voids. It is best practice to adhere the veneer units of this system with a polymer-modified mortar over a crack isolation membrane and water-resistive cement backer board.

When exterior insulation is required, the masonry veneer is supported by intermittent cladding support clips and continuous vertical Z-girts such as those shown in Fig. 6-11. The spacing of the clips and the sizing of the girts are designed by the Designer of Record to resist building loads and limit out-of-plane deflection of the wall to reduce the likelihood of flexural cracking. Minimizing the cladding

support clip spacing may be considered to limit out-of-plane deflection but can impact the effective thermal performance of the system. As shown in Fig. 6-12, smaller cladding support clip spacing is necessary to resist greater wind loads. As clip spacing is reduced, the effective thermal performance of the system is also reduced. Using lower-conductivity clips can reduce the impact that cladding support clips have on the thermal performance.

Corrosion Resistance

It is best practice to match the durability and longevity of metal components within this system to that expected of the masonry veneer. Metal components within this system include intermittent Z-girts (when constructed of metal), continuous Z-furring, sheet-metal flashings, and fasteners such as screws and anchors.

Where available, sheet-metal components supporting the veneer or acting as sheet-metal flashings should be AISI Type 304 or 316 stainless steel per ASTM A666,⁸ which is nonstaining, resistant to the alkaline content of mortar materials, and tolerant of the humidity conditions that can exist within the air cavity.

Where stainless-steel components may not be available or economically feasible, G90 or G185 hot-dipped galvanized-steel products per ASTM A653⁹ or minimum AZ50 or AZ55 galvalume-coated sheet steel in conformance with ASTM A792¹⁰ may be used but should be carefully considered based on the project's exposure and expected longevity. Coating the exposed top finish of any sheet metal with an architectural-grade coating conforming to AAMA 621¹¹ is recommended.

Fasteners used with metal components should be corrosion-resistant, either hot-dipped galvanized steel or stainless steel to match adjacent metal components.

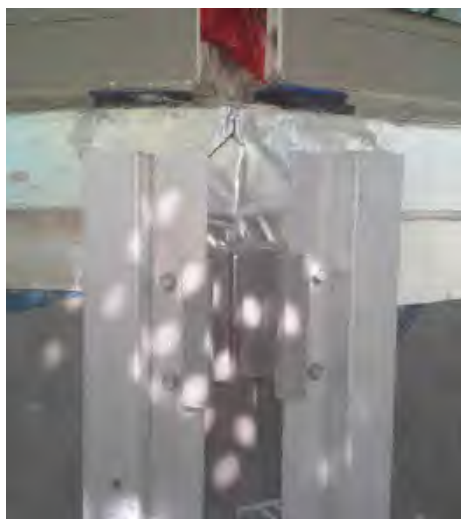


Fig. 6-11 Hot-dipped galvanized-steel Z-girts attached to fiberglass standoff clips

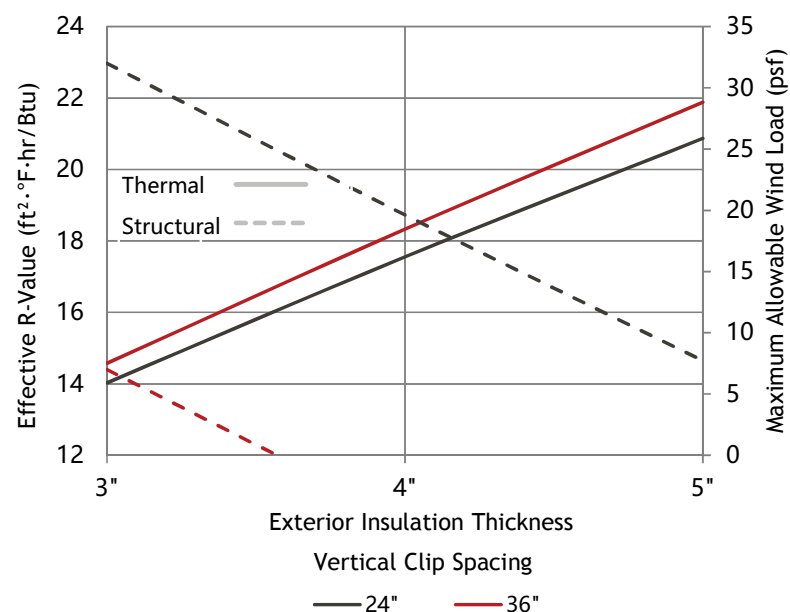


Fig. 6-12 System effective R-value as it compares to maximum-allowable wind loads for various fiberglass standoff clip spacings. These results assume fiberglass standoff clips with two stainless-steel screws spaced at 3-inches vertically and attached into a CMU wall substrate. The clips resist vertical gravity loads equally and receive horizontal loads based on their tributary areas. The design is generally limited by the pull-out resistance of the upper screw through the clip, which is under tension from the weight of the cladding and from horizontal wind suction pressures. The allowable screw loads are based on testing data and are specific to the type of screw modeled. The allowable wind pressure should always be compared to the specified wind pressure acting on the cladding, as determined by the local building code in the applicable jurisdiction. These structural values provide a schematic relationship between thermal and structural performance and are not intended to be used as structural design values. In the structural design graphs, the cladding weight was set at 20 psf. The horizontal clip spacing remained at 16-inches on-center. The clip vertical spacing options are 24- and 36-inches and the exterior insulation thickness ranges from 3- to 5-inches.

Cement Backer Board

Cement backer board used within this system is exterior-grade water-, mold-, and mildew-resistant, which meets ASTM C1325¹² Type A (exterior applications) or ANSI 118.9.¹³ The cement backer board is attached to the continuous vertical Z-girts as required by the backer board manufacturer and project-specific design loads. The attachment method used should be appropriate for the Z-furring and intermittent cladding support design.

Joints of the cement board are typically staggered and treated with a mesh tape bed in the thinset mortar. Cement backer board product should be installed in conformance with the manufacturer installation instructions. The cement backer board should not span joints within the veneer that are expected to accommodate movement similar to that shown in Detail 6-D.

Crack Isolation Membrane

A crack isolation membrane, like that shown in Fig. 6-13, is a flexible fluid-applied membrane used in adhered masonry veneer applications where the veneer is adhered to a cement backer board. The crack isolation membrane is applied following installation of the cement backer board and treatment of the board joints as required by the cement backer board manufacturer. This membrane assists with:

- Reducing risk of veneer cracking. The veneer adheres to the membrane, which allows the cement backer board to move relatively independent of the veneer. *It is important to remember that use of a crack isolation membrane does not reduce or replace the need for appropriately designed and installed movement joints.*
- Reducing fastener corrosion risk. The membrane protects cement board fasteners from moisture held within the veneer and thinset mortar.
- Reducing cement board exposure to moisture. The membrane reduces the moisture exchanged between the cement board and thinset mortar and can increase the longevity of the board.
- Reducing efflorescence. The membrane reduces the moisture exchanged between the cement board and thinset mortar and may result in reduced efflorescence; thus, it may also be referred to as an efflorescence mitigation membrane.

Traditionally, this membrane may have been installed to protect the primary

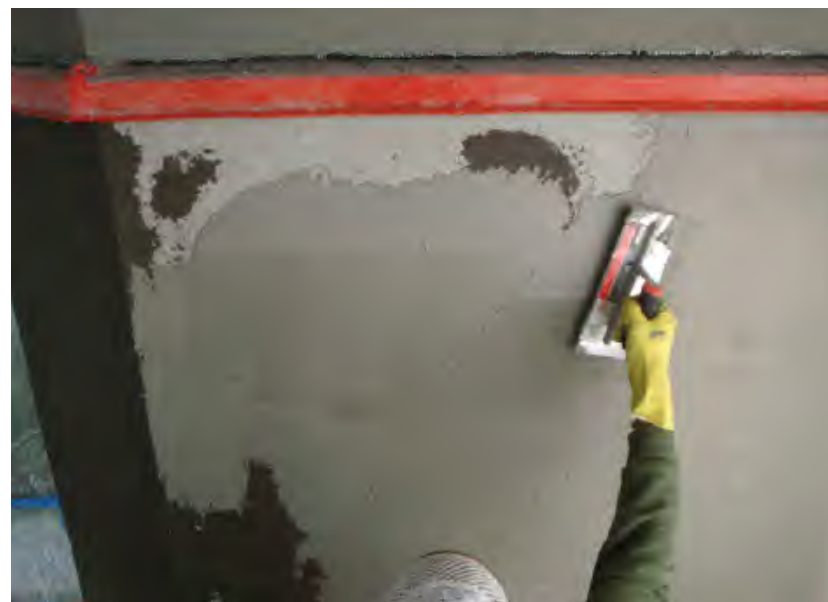


Fig. 6-13 Crack isolation membrane application over cement backer board. Cement board corners and fastener locations are treated prior to membrane application. A trowel-applied membrane is shown; membranes may also be fluid-applied.

structure from moisture exposure. However, in this rainscreen system, *the crack isolation membrane is not a replacement for the air and water control layers*, which are located on the exterior face of the CMU wall.

It is best practice to use a crack isolation membrane over cement backer board in adhered masonry veneer applications. Some manufacturers may require this membrane to achieve a warrantable cladding installation.

Masonry Veneer

There are several types of adhered veneer unit products that may be used with this system. Those most typical within the Northwest include thin brick made of clay or shale or manufactured stone.

Thin brick used for this system is exterior grade and complies with ASTM C1088.¹⁴ Manufactured stone masonry veneer units comply with ASTM C1670.¹⁵

For applications over cement board substrates, a polymer modified thinset mortar

is recommended. While the brick and manufactured stone veneer industries have not established standards for thinset mortar performance, this guide looks to the tile industry and the American National Standard Institute (ANSI) for the Installation of Ceramic Tile, particularly ANSI A118.15¹⁶ which provides standard specifications for improved performance of modified mortars. This guide recommends that the thinset mortars used in this system demonstrate conformance with the ANSI 118.15.¹⁶

Appropriate product selection of masonry veneer unit and thinset mortar materials is necessary to provide a durable and water-resistive cladding system. The veneer units, thinset mortar, and joints should also be installed in conformance with industry standard best practices and manufacturer requirements and should comply with ASTM C1780.¹⁷ The specifics of architectural characteristics and structural properties of the veneer system, including mortar and cladding support systems, should be designed and reviewed by a qualified Designer of Record.

Various industry resources are available to assist with veneer design and are listed in the Resources section.

Clear Water Repellents

Application of a clear water repellent to the adhered veneer of this system is common in the Northwest. Refer to the Surface-Applied Clear Water Repellents discussion on page i-59 for more information on selecting an appropriate clear water repellent and for best practice installation guidelines.

Pricing Summary

A pricing summary for this system is provided in Table 6-3 on page 6-21. Pricing demonstrates the relative price per square foot and is based on a 10,000-square-foot wall area with easy drive-up access. Pricing includes all components outboard of the CMU wall structure and provides no evaluation for interior finishes or CMU wall structure. Pricing is valid for the 2018 calendar year. Current pricing is also available at www.masonrysystemsguide.com.

Online Availability

The content of this guide and additional resources may be accessed online at www.masonrysystemsguide.com. Also available online are downloadable digital versions of two- and three-dimensional system details and cutaway sections as well as sample project specifications. Ongoing updates to references and resources included within this guide can also be accessed.

Chapter References

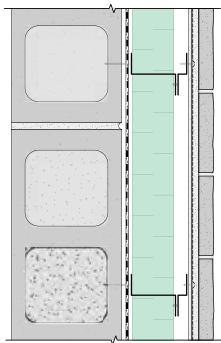
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Table 6-3 System 6 CMU wall with adhered veneer pricing summary

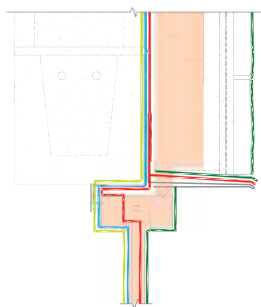
System 6: CMU Wall with Adhered Masonry Veneer					
System Component	Baseline Product	Alternate (call for estimate)	Baseline Cost/ft ² (incl. labor)		
			Low	High	
INTERIOR					
1	Structural concrete wall	No evaluation of these components provided.			
2*	Air and water-resistant barrier	Fully adhered sheet-applied membrane	Fluid-applied membrane system	\$1.50	\$3.00
3*	Exterior insulation	Rigid XPS board insulation; 2-inch thickness	No specified alternate	\$1.75	\$3.25
4*	Intermittent standoff clip with 1-inch Z-girt	6" tall clips at 24" o.c. vertical; clips and girts G185 hot-dipped galvanized; self-tapping fasteners	Stainless clips or thermally improved proprietary cladding support system	\$3.00	\$9.00
5*	Cement backer board	Moisture-resistant 5/8"-thick, taped & fastened	No specified alternate	\$2.50	\$4.75
6*	Adhered masonry or stone veneer with grouted joints, includes polymer modified thin-set	Modular (3/4" x 2-1/4" x 7-5/8") extruded TBX; running bond; 3/8" mortar joints	Alternate veneer products	\$39.00	\$42.10
7*	Clear water repellent	Silane/siloxane blend	Antigraffiti clear water repellent	\$1.75	\$2.50
EXTERIOR					
Total cost to install 10,000 sq ft wall area w/easy drive-up access -->				\$49.50	\$64.60
Pricing Summary Discussion			System Plan View		
<ul style="list-style-type: none">- Low and high baseline costs are based on baseline products and installed labor costs. Call for an estimate for alternative product pricing.- Baseline costs provided will vary based on product-specific conditions as well as project location and should be used as an estimate only.- Veneer unit prices are for typical units as noted. Pricing will vary based on size, color, and finish and should be confirmed with the unit manufacturer.- *See the Resources section of this guide for product recommendations.					

LEGEND

1. Typical System:
 - Single-wythe CMU wall
 - Self-adhered sheet or fluid-applied air barrier and WRB field membrane
 - Exterior insulation with intermittent cladding support clip
 - Air cavity with vertical Z-girt
 - Cement backer board
 - Crack isolation membrane
 - Thinset mortar
 - Adhered veneer with grouted joints
 - Clear water repellent
2. Self-adhered sheet or fluid-applied air barrier and WRB prestrip membrane
3. Sloped sheet-metal head flashing with hemmed drip edge and end dams (beyond)
4. Insect screen
5. Sealant over backer rod
6. Continuous back dam angle at rough opening perimeter, minimum 1-inch tall with window fastened through back dam angle per window manufacturer recommendations
7. Continuous air barrier sealant tied to continuous seal at window perimeter
8. Storefront window

* Size gap for drainage and ventilation, minimum 3/8-inch.

Water-Shedding Surface and Control Layers

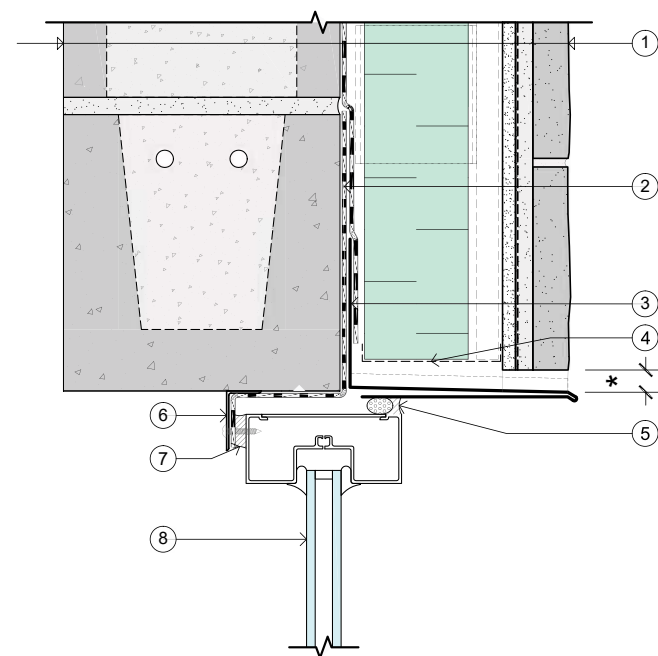


Water-Shedding Surface

Control Layers:[†]



[†] Where a Class I or II permeance (and sometimes Class III permeance) air barrier and WRB field and prestrip membrane exist



Detail Discussion

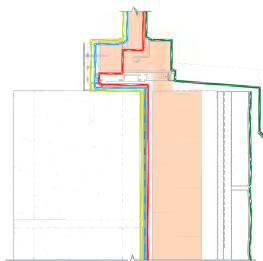
- Air and water control layer continuity is provided by the self-adhered sheet or fluid-applied air barrier and WRB field membrane, prestrip membrane, and air barrier sealant transition to the storefront window.
- The hemmed drip edge of the sheet-metal head flashing sheds water from the adhered masonry veneer above before it reaches the window and sill.
- The insect screen extends from the face of the air barrier and WRB membrane to the face of the vertical Z-girt to protect the cavity from insects and debris while still allowing for ventilation and drainage.

Typical Window Head
Detail 6-A

LEGEND

1. Typical System:
 - Single-wythe CMU wall
 - Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
 - Exterior insulation with intermittent cladding support clip
 - Air cavity with vertical Z-girt
 - Cement backer board
 - Crack isolation membrane
 - Thinset mortar
 - Adhered veneer with grouted joints
 - Clear water repellent
2. Storefront window on minimum ¼-inch-thick intermittent shims
3. Sealant over bond breaker
4. Insect screen
5. Sloped sheet-metal sill flashing with hemmed drip edge and end dams (beyond)
6. Fluid-applied or self-adhered flashing membrane
7. Continuous air barrier sealant tied to continuous seal at window perimeter
8. Continuous back dam angle at rough opening perimeter, minimum 1-inch tall, with window fastened through back dam angle per window manufacturer recommendations

Water-Shedding Surface and Control Layers



— Water-Shedding Surface

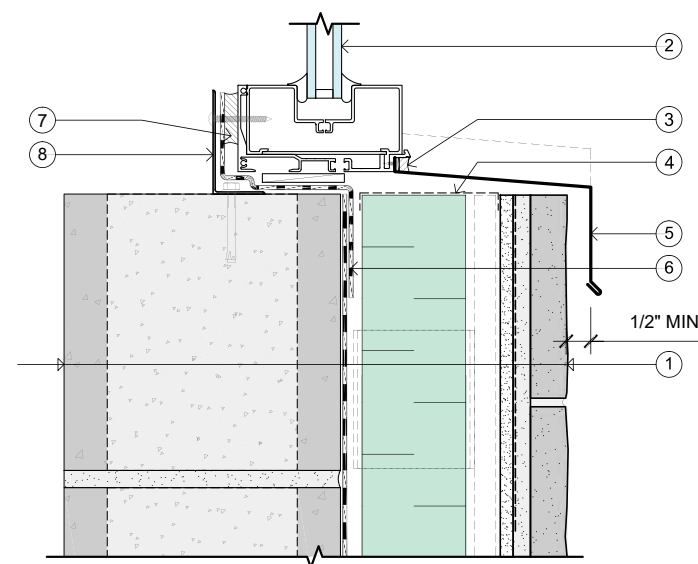
Control Layers:*

— Water
— Air
— Vapor
— Thermal

* Where a Class I or II permeance (and sometimes Class III permeance) air barrier and WRB field and prestrip membrane exist

Detail Discussion

- Air and water control layer continuity is provided by the self-adhered sheet- or fluid-applied air barrier and WRB field membrane, fluid-applied or self-adhered flashing membrane at the sill, and air barrier sealant transition to the storefront window.
- The sheet-metal sill flashing sheds water from the window above and protects the rainscreen cavity. The hemmed drip of the sheet-metal flashing projects away from the cladding to promote watershed away from the masonry veneer face. Terminate the sheet-metal sill flashing with end dams at each jamb and counterflash each end dam with the sheet-metal jamb trim to close off the rainscreen cavity and complete the water-shedding surface.



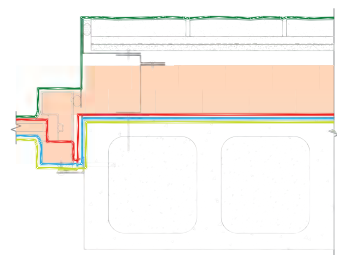
Typical Windowsill

Detail 6-B

LEGEND

1. Typical System:
 - Single-wythe CMU wall
 - Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
 - Exterior insulation with intermittent cladding support clip
 - Air cavity with vertical Z-girt
 - Cement backer board
 - Crack isolation membrane
 - Thinset mortar
 - Adhered veneer with grouted joints
 - Clear water repellent
2. Storefront window
3. Sealant over backer rod
4. Self-adhered or fluid-applied sheet air barrier and WRB prestrip membrane
5. Sheet-metal jamb trim counterflashed over sill flashing end dams below. Attach trim to nearest vertical Z-girt as shown.
6. Vertical Z-girt over intermittent cladding support clip, fasten clip through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per air barrier and WRB system manufacturer recommendations
7. Continuous back dam angle at rough opening perimeter, minimum 1-inch tall, with window fastened through back dam angle per window manufacturer recommendations.
8. Continuous air barrier sealant, tie to continuous seal at window perimeter

Water-Shedding Surface and Control Layers

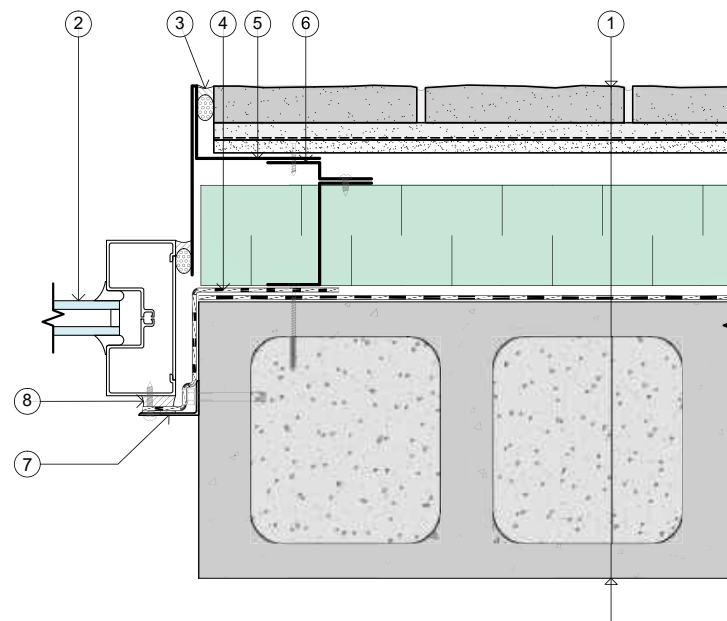


Water-Shedding Surface

Control Layers:*

Water
Air
Vapor
Thermal

* Where a Class I or II permeance (and sometimes Class III permeance) air barrier and WRB field and prestrip membrane exist



Detail Discussion

- Air and water control layer continuity is provided by the self-adhered sheet- or fluid-applied air barrier and WRB field membrane, prestrip membrane, and air barrier sealant transition to the storefront window.
- Where needed, the exterior insulation should be supported with intermittent fasteners such as mechanically attached impaling pins. Consult with the air barrier and WRB membrane manufacturer for requirements on detailing these pin attachments through the membrane.

Typical Window Jamb

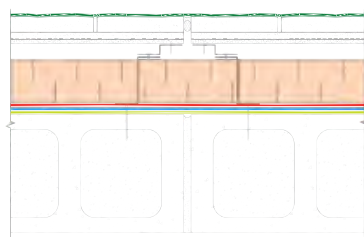
Detail 6-C

LEGEND

1. Typical System:
 - Single-wythe CMU wall
 - Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
 - Exterior insulation with intermittent cladding support clip
 - Air cavity with vertical Z-girt
 - Cement backer board
 - Crack isolation membrane
 - Thinset mortar
 - Adhered veneer with grouted joints
 - Clear water repellent
2. Continuous break in cement backer board
3. Sanded sealant joint over backer rod
4. Vertical Z-girt over intermittent cladding support clip, fasten clip through fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per air barrier and WRB system manufacturer recommendations

* Size joint for project-specific movement, minimum $\frac{3}{8}$ -inch

Water-Shedding Surface and Control Layers

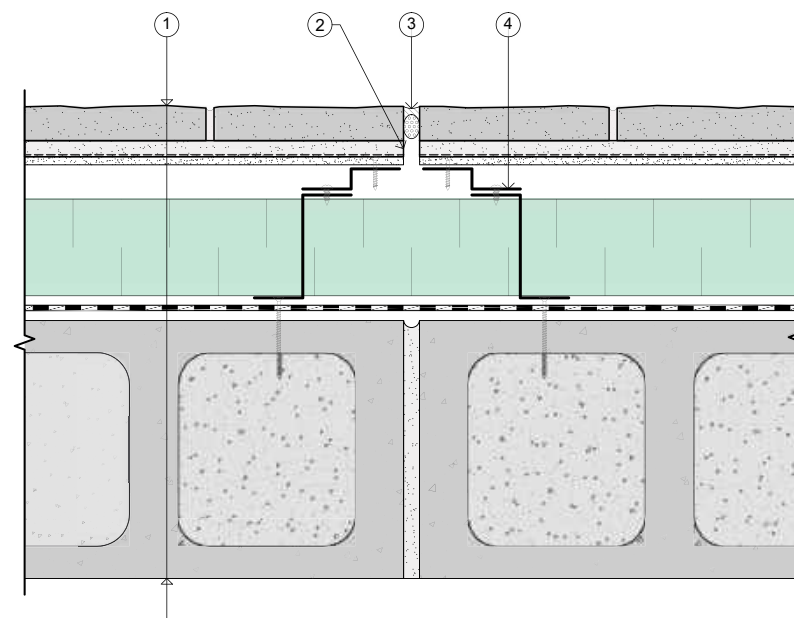


— Water-Shedding Surface

Control Layers:†

— Water
— Air
— Vapor
— Thermal

† Where a Class I or II permeance (and sometimes Class III permeance) air barrier and WRB field and prestrip membrane exist



Detail Discussion

- The cement backer board is supported by continuous vertical furring on both sides of the control joint. The gap within the veneer at this location is free of all materials with the exception of a compressible backer rod and sealant to allow for movement while maintaining a continuous water-shedding surface.

Refer to the Movement Joints discussion on page i-48 for more information on vertical control joint spacing.

- The location of control joints is determined by the project designer and clearly identified in the construction documents on elevations and in details.

Vertical Control Joint

Detail 6-D

LEGEND

1. Typical System:

- Single-wythe CMU wall
- Self-adhered sheet or fluid-applied air barrier and WRB field membrane
- Exterior insulation with intermittent cladding support clip
- Air cavity with vertical Z-girt
- Cement backer board
- Crack isolation membrane
- Thinset mortar
- Adhered veneer with grouted joints
- Clear water repellent

2. Inverted roof membrane assembly

3. Sloped standing-seam sheet-metal coping with gasketed washer fasteners

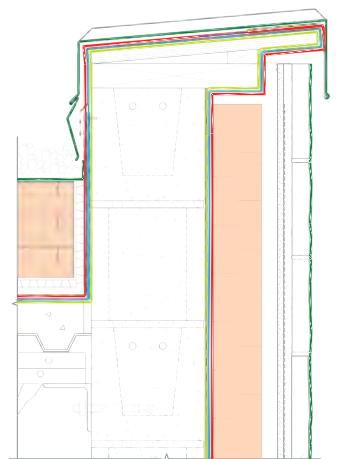
4. High-temperature self-adhered membrane

5. Preservative-treated blocking

6. Insect screen

* Size joint for ventilation, minimum 3/8-inch

Water-Shedding Surface and Control Layers



Water-Shedding Surface

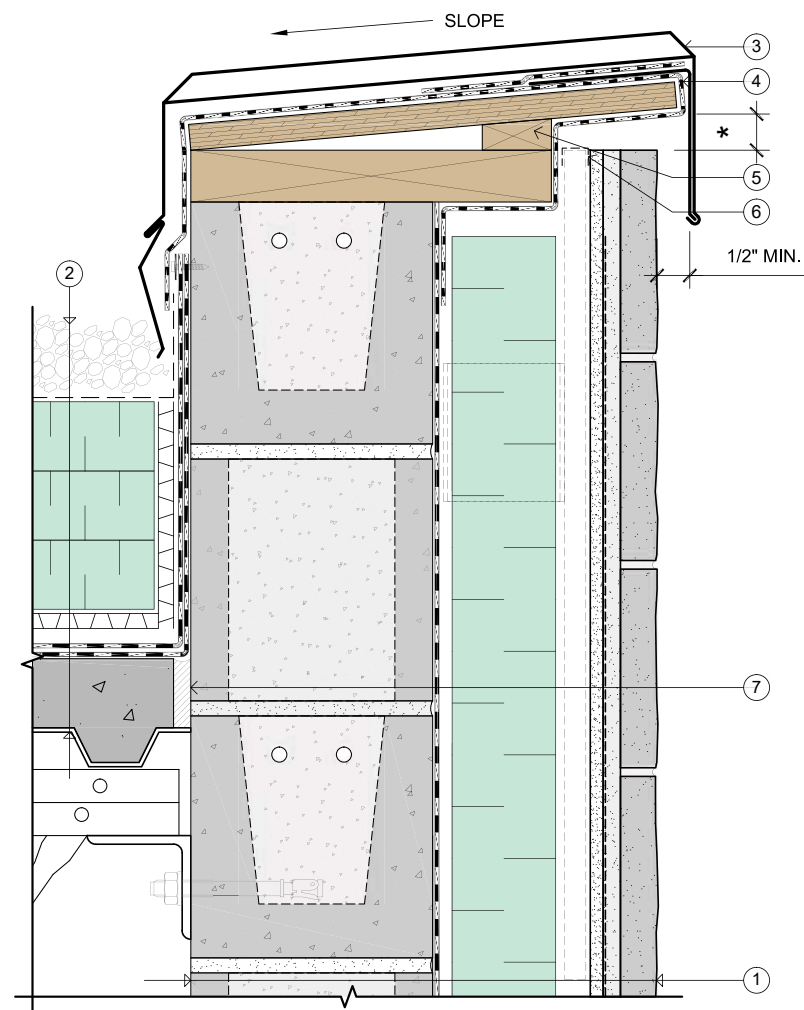
Control Layers:†

- Water
- Air
- Vapor
- Thermal

† Where a Class I or II permeance (and sometimes Class III permeance) air barrier and WRB field and prestrip membrane exist

Detail Discussion

- The sheet-metal parapet cap with hemmed drip edge is held off the adhered veneer face to minimize disruption of the air flow behind the veneer. A 1/2-inch gap is recommended.
- Insect screen around the insulation and vertical Z-girt cavity prevents insects and debris from entering the rainscreen cavity, while still allowing ventilation.
- The self-adhered sheet or fluid-applied air barrier and WRB field membrane, high temperature self-adhered membrane, and roof membrane provide the air and water control layers in this detail.



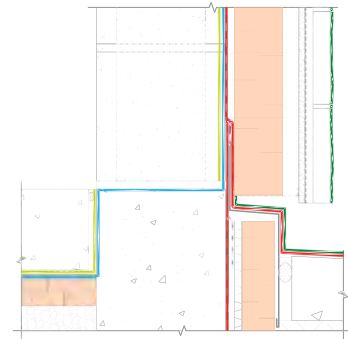
Typical Parapet at Inverted Roof System

Detail 6-E

LEGEND

1. Typical System:
 - Single-wythe CMU wall
 - Self-adhered sheet or fluid-applied air barrier and WRB field membrane
 - Exterior mineral fiber insulation with intermittent cladding support clip
 - Air cavity with vertical Z-girt
 - Cement backer board
 - Crack isolation membrane
 - Thinset mortar
 - Adhered veneer with grouted joints
 - Clear water repellent
2. Insect screen
3. Sloped sheet-metal flashing with hemmed edge
4. Fluid-applied or self-adhered flashing membrane
5. Drainage composite (optional)
6. Rigid XPS foundation insulation
7. Damp proofing (optional)
8. Typical Assembly:
 - Concrete floor slab
 - Vapor barrier
 - Rigid XPS insulation
 - Capillary break

Water-Shedding Surface and Control Layers

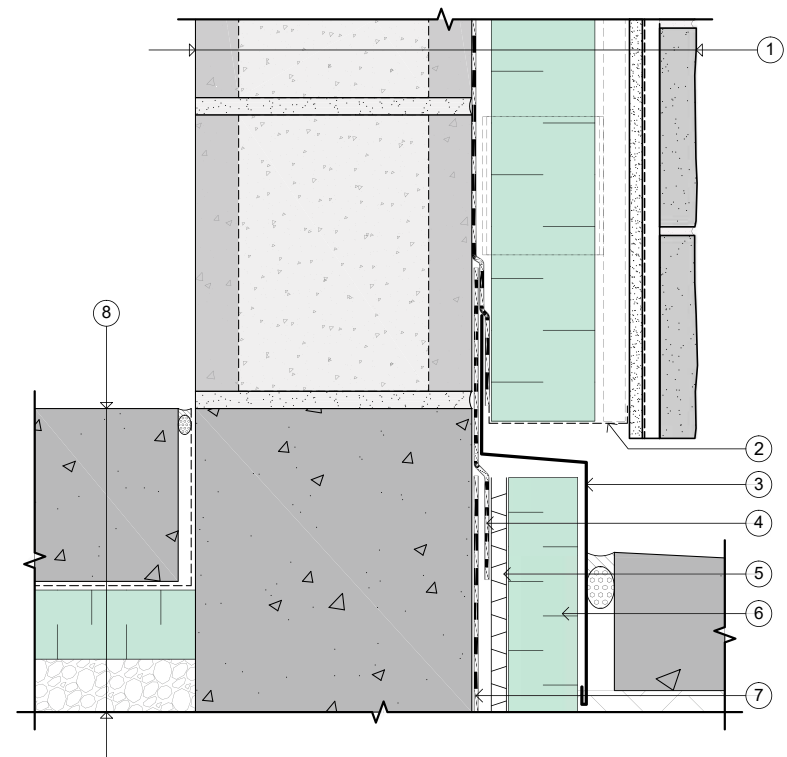


Water-Shedding Surface

Control Layers:*

- Water
- Air
- Vapor
- Thermal

* Where a Class I or II permeance (and sometimes Class III permeance) air barrier and WRB field and prestrip membrane exist



Detail Discussion

- The sheet-metal flashing protects the underlying components from UV exposure.
- Insulating below the slab and exterior of the foundation wall is an alternative approach to the thermal break shown in Chapter 1, Detail 1-D.

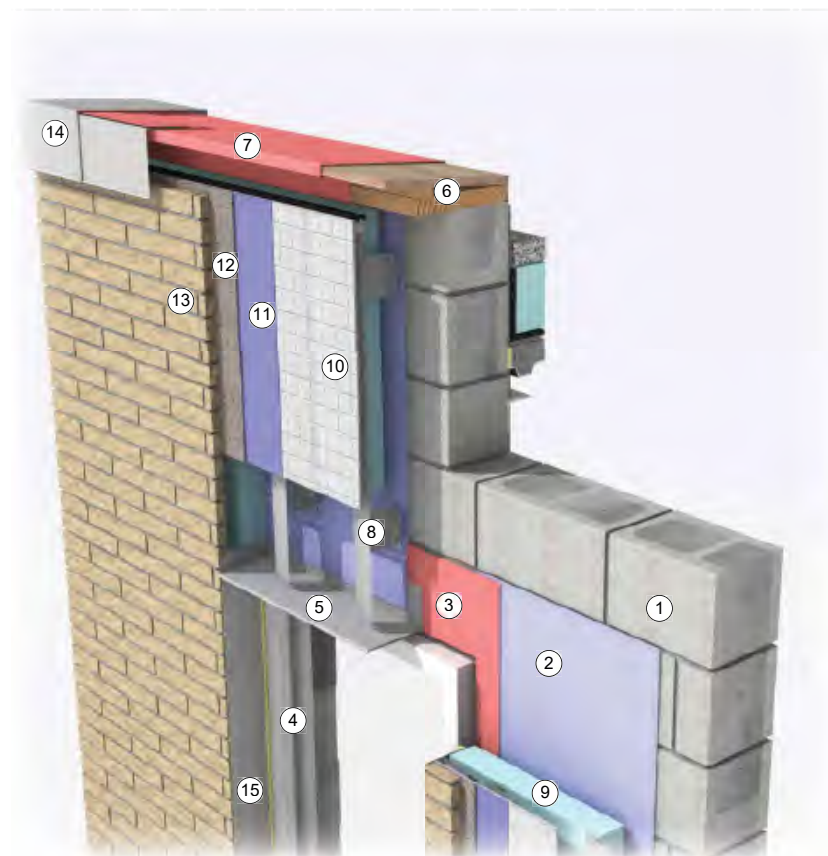
Typical Foundation
Detail 6-F

LEGEND

1. Single-wythe CMU wall
2. Self-adhered sheet or fluid-applied air barrier and WRB field membrane
3. Self-adhered sheet or fluid-applied air barrier and WRB prestrip membranes
4. Storefront window
5. Sloped sheet-metal head flashing with hemmed drip edge and end dams
6. Sloped preservative treated blocking
7. High-temperature self-adhered membrane
8. Vertical Z-girt over intermittent cladding support clip, fasten clip through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per air barrier and WRB system manufacturer recommendations
9. Exterior insulation
10. Cement backer board
11. Crack isolation membrane
12. Thinset mortar
13. Adhered veneer with grouted joints
14. Sloped standing-seam sheet-metal coping with gasketed washer fasteners
15. Sheet-metal jamb trim counterflashed over sill flashing end dams below. Attach trim to nearest vertical Z-girt as shown.

3-D Detail Discussion

- Three-dimensional cutaway sections on the next three pages represent two-dimensional details of this system.
- In all details, water control layer elements are shingle-lapped to encourage drainage of liquid water.
- As shown in Detail 6-F and Detail 6-G, exterior insulation fits between the intermittent cladding supports clips. When using rigid board insulation, the insulation may require notching around clips. Where needed, the exterior insulation should be supported with intermittent fasteners such as mechanically attached impaling pins. Impaling pins fasteners may need to be sealed where penetrating the air barrier and WRB membrane.
- End dams are formed at the ends of the sloped sheet-metal head flashing shown in Detail 6-F to direct water away from the rainscreen cavity and back to the exterior.

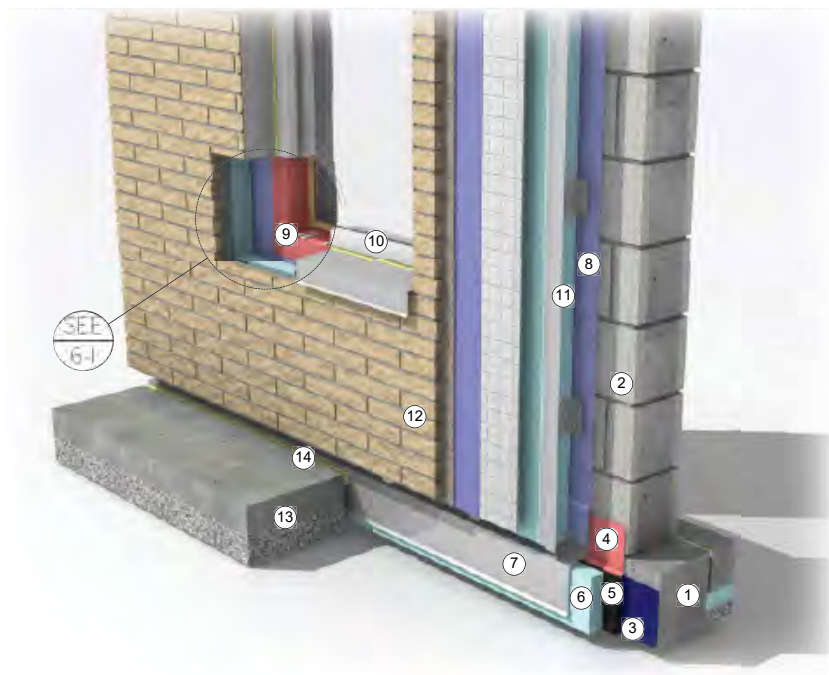


Parapet Cutaway Section

Detail 6-G

LEGEND

1. Concrete foundation element
2. Single-wythe CMU wall
3. Below-grade damp proofing (optional)
4. Fluid-applied or self-adhered flashing membrane
5. Drainage composite (optional)
6. Below-grade rigid XPS insulation
7. Sloped sheet-metal base flashing with hemmed edge for rigidity
8. Self-adhered sheet or fluid-applied air barrier and WRB field membrane
9. Self-adhered sheet or fluid-applied air barrier and WRB prestrip membranes
10. Storefront window
11. Exterior insulation
12. Adhered veneer with grouted joints over thinset mortar, crack isolation membrane, and cement backer board
13. Hardscape over gravel fill
14. Sealant over backer rod

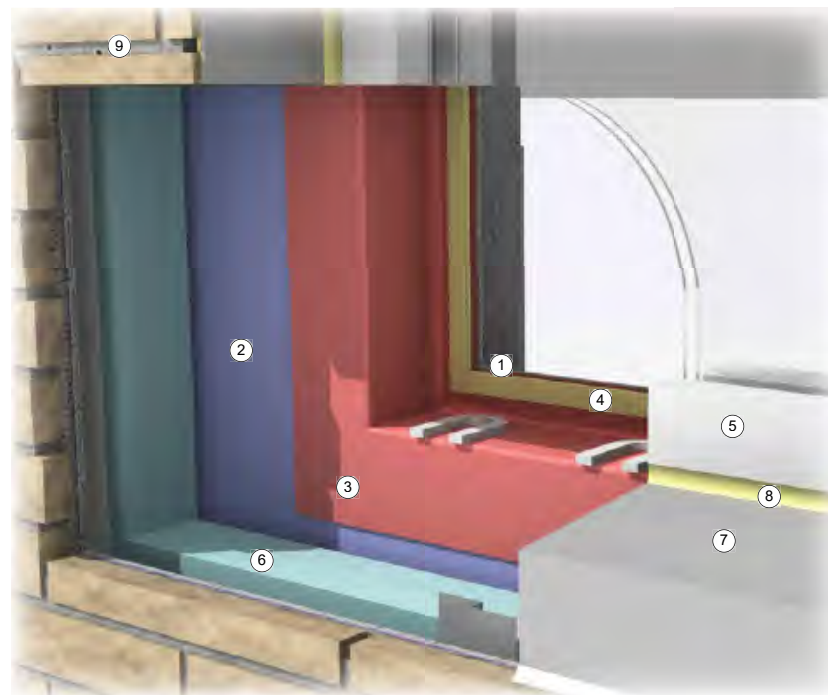


Base of Wall Cutaway Section

Detail 6-H

LEGEND

1. Continuous back dam angle at rough opening perimeter, minimum 1-inch tall, with window fastened through back dam angle per window manufacturer recommendations
2. Fluid-applied or self-adhered sheet air barrier/WRB field membrane
3. Self-adhered sheet or fluid applied air barrier and WRB flashing membranes at jamb and sill
4. Continuous air barrier sealant tied to continuous seal at window perimeter
5. Storefront window on minimum 1/4-thick intermittent shims
6. Exterior insulation
7. Sloped sheet-metal sill flashing with hemmed drip edge and end dams (beyond)
8. Sealant over backer rod
9. Adhered veneer with grouted joints over thinset mortar, crack isolation membrane, and cement backer board



Typical Window and Jamb Cutaway Section

Detail 6-I

CHAPTER 7:**STEEL-FRAMED WALL WITH ADHERED MASONRY VENEER**

Masonry system 7 is a rainscreen wall system with steel-framed wall structure and adhered veneer. The adhered masonry veneer may be thin brick, natural stone, or manufactured stone. The components of this system, from interior to exterior, are shown in Fig. 7-1. This system is appropriate for many applications including low- or mid-rise residential or commercial buildings. An example application of this system is shown in Fig. 7-2 on page 7-2.

Building Enclosure & Control layers

As noted in the Introduction, an above-grade wall system controls liquid water, air, heat, and possibly water vapor to function as an effective and durable environmental separator. Control of these elements, specific to this wall system, is provided by the following control layer systems and/or materials:

- Water control layer, comprising the water-resistive barrier (WRB) system
- Air control layer, comprising the air barrier system

INTERIOR

- Interior gypsum board
- Vapor retarder
- Steel-framed wall with batt insulation
- Exterior gypsum sheathing
- Air and water-resistive barrier membrane
- Semi-rigid exterior insulation with intermittent cladding support clips
- Air cavity with vertical Z-girt
- Cement backer board
- Crack isolation membrane (i.e., efflorescence mitigation membrane)
- Thinset mortar
- Adhered veneer with grouted joints
- Clear water repellent

EXTERIOR

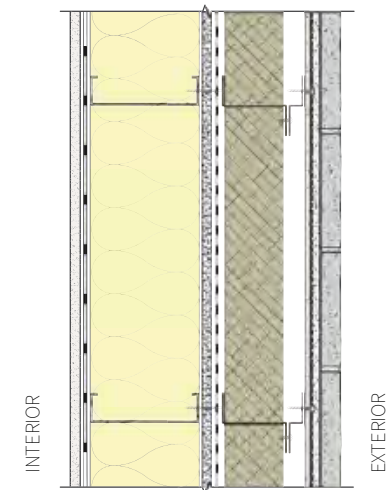


Fig. 7-1 Typical System 7 components from interior to exterior

- Thermal control layer, comprising thermal insulation and other low conductivity materials
- Vapor control layer, comprising vapor retarding materials

For a summary of the relationship between building enclosure loads, control layers, and associated systems and materials, Refer to Fig. i-13 on page i-21 of the introductory chapter.

Fig. 7-3 illustrates the water-shedding surface and control layer locations for this wall system. The water-shedding surface and control layers for typical system details are also provided adjacent to each detail at the end of this chapter.



Fig. 7-2 Steel-framed wall with adhered veneer example project application

As shown in Fig. 7-3, the water-shedding surface occurs at face of the adhered masonry veneer, with most water-shedding occurring at the wall while some water is stored within the masonry veneer to be released later. The water control layer and air control layer occur at the same location exterior of the wall sheathing. The thermal control layer occurs at the framed wall cavity insulation and exterior insulation. The vapor control layer is located at the interior (warm-in-winter side) of the steel-framed structure.

Water-Shedding Surface

The water-shedding surface is a system that serves to reduce the water load on the enclosure. A general overview of the water-shedding surface is provided in the Water-Shedding Surface discussion on page i-19.

The adhered veneer cladding—including both grout joints and veneer units—is the primary water-shedding surface of this wall system. Additional water-shedding surface components include sheet-metal flashings and drip edges, sealant joints, and fenestration systems as shown on the details included at the end of this chapter.

To promote water shedding at the masonry cladding, grout joints between veneer units should be installed with a tooled concave (preferred) or “V” shape.

The water-shedding surface is most effective when free of gaps other than for drainage and/or ventilation. Movement joints and joints around fenestrations and penetrations should be continuously sealed with backer rod and sealant or counterflashed with a sheet-metal flashing to deflect wind-driven rain and shed water away from the rainscreen cavity.

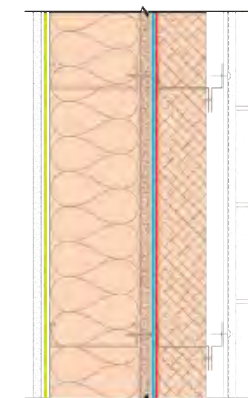
Water Control Layer

The water control layer is a continuous control layer that is designed and installed to act as the innermost boundary against water intrusion. In a rainscreen wall system, the water-resistive barrier (WRB) system is the last line of defense against water intrusion. A general discussion of the WRB system is provided in the Water Control Layer discussion on page i-24.

In this wall system, the WRB system is typically a self-adhered sheet or fluid-applied system that also functions as the air barrier system; thus, the WRB system is often referred to as the air barrier and WRB system. Either a self-adhered sheet or fluid-applied system is depicted in the details at the end of this chapter. An example of a fluid-applied air barrier and WRB system field membrane is shown in Fig. 7-4 on page 7-4. The air barrier and WRB system for this wall system may have:

- Class IV vapor permeance properties regardless of the insulation R-value placed within the wall cavity relative to the insulation placed exterior of the air barrier and WRB system.
- Class I and II vapor permeance properties when at least $\frac{1}{2}$ to $\frac{3}{4}$ the total nominal insulation R-value of the wall system is placed exterior of the air barrier and WRB system. For this case, the air barrier and WRB system will also function as the vapor control layer. As a result, a separate vapor retarder

Water-Shedding Surface and Control Layers



— Water-Shedding Surface

Control Layers:

— Water
— Air
— Vapor
— Thermal

Fig. 7-3 System 7 water-shedding surface and control layer locations

membrane (as shown typical on page 1 of this chapter at the interior side of the framing) may be omitted.

- Class III vapor permeance properties when carefully evaluated against other system material properties and the thermal control layer.

Physical properties of the WRB system products are discussed in detail in the Water Control Layer discussion on page i-24. Vapor permeability of materials is addressed in the Vapor Control Layer discussion on page i-28.

The air barrier and WRB system must be continuous across the wall system to provide effective water control. In addition to the field membrane, the WRB system includes fluid-applied or self-adhered flashing membranes, sealants, sheet-metal flashings, and penetrations such as windows and doors as shown in the detail drawings that follow this chapter discussion. Where sheet-metal flashing components occur within the system, the back leg of the sheet-metal flashing is shingle-lapped into the WRB system to facilitate drainage at the face of the WRB system and to the exterior of the cladding.

Cladding support clip fasteners in this system penetrate the WRB system and should be sealed as required by the WRB system manufacturer's installation



Fig. 7-4 Self-adhered sheet air barrier and WRB field membrane with fluid-applied flashings at rough openings and exterior semi-rigid mineral fiber insulation

requirements. Fasteners may be required to be set in sealant, especially at uneven wall planes; however, requirements vary by manufacturer and should be confirmed.

Air Control Layer

The air barrier system serves to provide the air control layer. In addition to controlling air, this layer also assists with controlling liquid water, heat, and water vapor. A general discussion of the air control layer and the air barrier system is provided in the Air Control Layer discussion on page i-26.

For this wall system, the air barrier system is the same field membrane and most of the components that serve as the WRB system. As discussed in the introductory chapter, the air barrier system must be continuous and fully sealed to resist air flow; whereas, the WRB system is not required to be continuously sealed to be effective, merely shingle-lapped.

Vapor Control Layer

The vapor control layer retards or greatly reduces (e.g., vapor barrier) the flow of water vapor due to vapor pressure differences across enclosure assemblies. Unlike the other control layers presented in this guide, the vapor control layer is not always necessary or required to be continuous.

When a Class IV permeance air barrier and WRB system is used within this wall system, typically a Class II vapor retarder is located at the face of or just behind the interior gypsum board. The vapor retarder for this system should comply with Section 1405.3 of the governing International Building Code (IBC).¹ In the Northwest, typical vapor retarder products include PVA vapor-retarding primer, asphalt-coated kraft paper, or a polyamide film retarder membrane. Refer to the Vapor Control Layer discussion on page i-28 for additional information.

When a Class I or II permeance air barrier and WRB system is used within this wall system, the WRB system becomes the vapor control layer and a separate vapor control layer (as shown in Fig. 7-1 on page 7-1) is not necessary. Note that in this case, the thermal insulation R-value within the framed wall cavity is recommended by this guide to be $\frac{1}{2}$ to $\frac{1}{3}$ the total nominal insulation R-value of the wall system.

Thermal Control Layer

The thermal control layer controls heat flow and assists with controlling water vapor.

In this wall system, the framed cavity and exterior insulation are the primary materials that form the thermal control layer. At transition details the thermal control layer also includes exterior insulation across floor lines; parapet cavity insulation; and insulation at the roof assembly, slab, and foundation elements. Windows and doors that penetrate this system are also part of the thermal control layer.

Additional thermal insulation information is provided in the Thermal Control Layer discussion on page i-30 of the introductory chapter.

Insulation Selection

The cavity insulation in this system is typically a fiberglass or mineral fiber batt insulation product.

The exterior insulation in this wall system is typically semi-rigid mineral fiber board insulation (R-4.2/inch)—which is hydrophobic, tolerates moisture, and has free-draining capabilities. Its vapor permeance makes it acceptable for use exterior of a high-permanence air barrier and WRB system without inhibiting drying. An example of this insulation is shown in Fig. 7-4. The semi-rigid properties of the insulation allow it to fit tightly around penetrations such as cladding support clips.

Exterior insulation such as XPS or moisture-resistant polyisocyanurate may be appropriate when a Class I or II permeance air barrier and WRB system is used. Refer to the Insulation Products discussion on page i-30 for a discussion on various insulation types and additional considerations.

Although masonry is defined as a noncombustible cladding material, the use of a combustible air barrier and WRB system or foam plastic insulation within a wall cavity can trigger fire propagation considerations and requirements. Depending on the local jurisdiction, IBC Section 1403.5¹ regarding vertical and lateral flame propagation as it relates to a combustible WRB system may require acceptance criteria for NFPA 285.² The use of foam plastic insulation within a wall cavity should also be addressed for IBC Chapter 26 provisions.

Thermal Performance and Energy Code Compliance

This wall system is typically classified as a metal-framed (or steel-framed) above-grade wall for energy code compliance purposes. Prescriptive energy code compliance values for this wall system are summarized in Table 7-2 on page 7-11 and describe:

- Minimum insulation R-values for a *prescriptive insulation R-value method* strategy.
- Maximum system U-factors for a *prescriptive assembly U-factor method* strategy. Note that the equivalent effective R-value of this U-factor has been calculated and is denoted in parenthesis () for easy comparison to the thermal modeling results included within this chapter.

For cavity insulation, steel stud walls are typically constructed with 16-inch on-center stud spacing and can accommodate up to an R-15 batt insulation for 3½-inch studs or R-21 batt insulation for 6-inch studs. Alternative insulation products may also be used to fill the cavity. Because of its high thermal conductivity, steel framing can reduce the nominal R-value of the stud cavity insulation by approximately 40 to 60%. For this reason, continuous insulation is typically needed to meet prescriptive energy code compliance strategies.

For all energy code compliance strategies except the *prescriptive insulation R-value method strategy*, this wall system's U-factor will need to be calculated or determined from tables; however, it may or may not be required to be less than the prescriptive U-factors in Table 7-2.

The Thermal Performance and Energy Code Compliance discussion on page i-33 and Fig. i-26 on page i-39 of the introductory chapter describes the typical process of navigating energy code compliance options. Additionally, the thermal modeling results demonstrated in this chapter may be used to assist with selecting wall system components (e.g. cladding support clip type, insulation R-value/inch, etc.) to achieve a target U-factor. Options for thermally optimizing this assembly, as determined through the modeling results, are also discussed.

Project-specific thermal performance values for an opaque above-grade wall should be used for energy code compliance and determined from a source that is approved by the authority having jurisdiction. Thermal performance sources may include the appendices of the 2015 WSEC,³ ASHRAE 90.1,⁴ COMcheck,⁵ thermal modeling and calculation exercises as well as other industry resources.

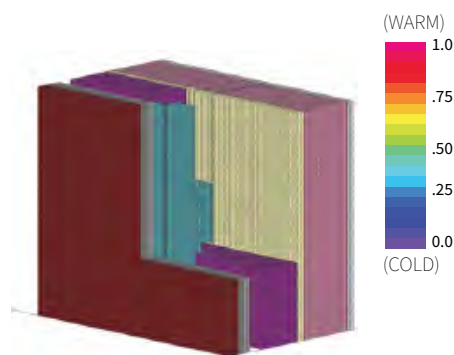


Fig. 7-5 Three-dimensional section of an intermittent Z-girt through exterior insulation

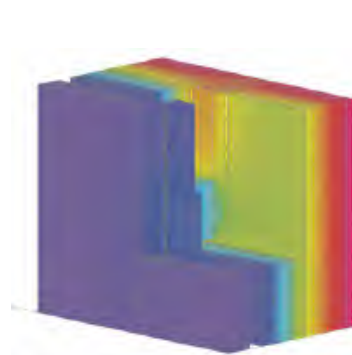


Fig. 7-6 Three-dimensional thermal image of the attachment depicted in Fig. 7-5

System Effective Thermal Performance

Claddings support clips—such as intermittent Z-girts or fiberglass standoff clips as shown in Fig. 7-7—penetrate the exterior insulation in this system and create areas of thermal bridging (i.e., heat loss).

An example of the thermal bridging caused by an intermittent Z-girt is described by Fig. 7-5 and Fig. 7-6, which show the relative thermal gradient of this system when thermally modeled. The lighter blue thermal gradient color at the exterior face of the Z-girt describes a warmer temperature than the adjacent, darker blue insulation face—an indicator of heat loss through the thermal insulation at the penetration. This thermal bridging reduces the system's effective thermal performance.

Three-dimensional thermal modeling demonstrates this system's effective thermal performance with various insulation thicknesses, insulation R-values, and cladding support clips/materials. A discussion on the modeling performed for this guide is included in the Appendix.

Thermal Modeling: Variables

The following are modeling variables specific to this system:

- **Framing and Cavity Insulation:** 3-5/8-inch steel stud wall with R-15 batt

insulation or 6-inch steel stud with R-21 batt insulation. A full-height steel stud wall including the top and bottom track adjacent to a concrete slab, but not including the wall area at the slab edge.

- **Cladding Support Clips:** where applicable: Two example cladding support clips are considered and are shown in Fig. 7-7:

- Intermittent Z-girts (16-gauge) made of either stainless steel or galvanized steel. Clips are 6-inches tall and spaced at 24-inches on-center vertically, 16-inches on-center horizontally.
- Fiberglass standoff clips spaced at 24-inches on-center vertically and 16-inches on-center horizontally. Both stainless steel and galvanized steel fasteners are considered for the fiberglass standoff clip option.



Fig. 7-7 Cladding support clip options including intermittent Z-girt (top) and fiberglass standoff clip (bottom)

- **Exterior Insulation:** R-4.2/inch or R-6/inch insulation product in thicknesses of 2-, 3-, and 4-inches. The R-values selected demonstrate the lower and upper thermal resistance of typical exterior insulation products.

Thermal Modeling: Results

Modeling results are shown in Table 7-1, Fig. 7-8, and Fig. 7-9 (see page 7-10 and page 7-11) for a 3-5/8-inch steel stud wall and Table 7-3 and Fig. 7-10 and Fig. 7-11 (on page 7-12 and page 7-13) for 6-inch steel stud wall.

Below is a discussion of the results. Where reductions in the system's effective R-value are discussed, these values are as compared to the system's effective R-value without clips considered.

- When comparing the same insulation thickness for the fiberglass standoff clips and intermittent Z-girts, Table 7-1 and Table 7-3 results demonstrate that fiberglass standoff clips reduce the system's effective R-value by 9 to 29%, while intermittent Z-girts will reduce the performance by 14 to 42%. *Thermally improved cladding attachment options can achieve better effective thermal performance values; a number of systems are commercially available and new*

products continue to be developed. Most manufacturers of proprietary clip systems will have thermal modeling results available for use when determining the system's effective thermal performance value.

- As determined from Table 7-1 and Table 7-3, when comparing the same insulation thickness for the fiberglass standoff clips, the system's effective R-value is reduced by 9 and 17% for stainless-steel fasteners and 17 and 29% for galvanized steel fasteners. *Stainless-steel cladding attachment options yield better system effective R-values than galvanized steel fasteners.*
- Greater effective R-values occur for intermittent Z-girts made of stainless steel than for galvanized steel when comparing the same insulation thickness in both Fig. 7-8 through Fig. 7-11. Overall, stainless-steel Z-girts reduce the effective R-value by 14 to 26%, while galvanized steel Z-girts reduce it by 24 to 42%. *In general, intermittent Z-girts made of stainless steel thermally perform better than those made of galvanized steel.*
- Fig. 7-9 and Fig. 7-10 can be used to demonstrate how effective thermal performance and exterior insulation depth can help determine the best combination of the insulation and cladding support clip type/material. For example, if an effective R-24 is desired from Fig. 7-9, the best insulation/cladding support combinations would be as described below. This exercise can help with determining the most

Table 7-1 System 7 (3%-inch steel stud) thermal modeling results

3-5/8" Steel Stud Wall with Adhered Masonry Veneer, R-15 Batt Insulation, R-4.2/in - R-6/in Exterior Insulation					
3D Thermal Modeling Effective R-Value of System (ft ² ·F·hr/Btu)					
Clip Type	Clip Penetration Area	Exterior Insulation Thickness	Nominal Insulation R-Value (Cavity + Exterior Insulation)	Cavity + Exterior Insulation (Without Clips Considered)	Stainless Steel Clip and/or Fasteners
Fiberglass Standoff Clips	0.80%	2"	15 + 8.4-12	19.1-22.9	17.2-20.0
		3"	15 + 12.6-18	23.3-28.9	20.6-24.4
		4"	15 + 16.8-24	27.7-35.1	24.1-29.1
Intermittent 6" Z-Girts	0.09%	2"	15 + 8.4-12	19.1-22.9	16.1-18.3
		3"	15 + 12.6-18	23.3-28.9	19.1-22.1
		4"	15 + 16.8-24	27.7-35.1	22.2-26.0
					14.2-15.7
					16.2-18.0
					18.2-20.3

Table 7-2 System 7 prescriptive energy code compliance values excerpted from Table i-1 of the introductory chapter

OPAQUE ABOVE-GRADE WALL - THERMAL ENVELOPE REQUIREMENTS									
Energy Code Climate Zone		2012 SEC 5 and Marine 4		2012 WSEC 5, 6 and Marine 4		2014 OEESC 5 and Marine 4		2012 IECC 5 and Marine 4	
Guide Assembly #	Classification	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R
7	Steel-Framed Wall with Adhered Masonry Veneer	R-13 + R-10ci U-0.055 (R-18.2)	R-19 + R-8.5ci U-0.055 (R-18.2)	R-13 + R-10ci U-0.055 (R-18.2)	R-19 + R-8.5ci U-0.055 (R-18.2)	R-13 + R-10ci U-0.064 (R-15.6)	R-13 + R-7.5ci U-0.064 (R-15.6)	R-13 + R-7.5ci U-0.064 (R-15.6)	R-13 + R-7.5ci U-0.057 (R-17.5)

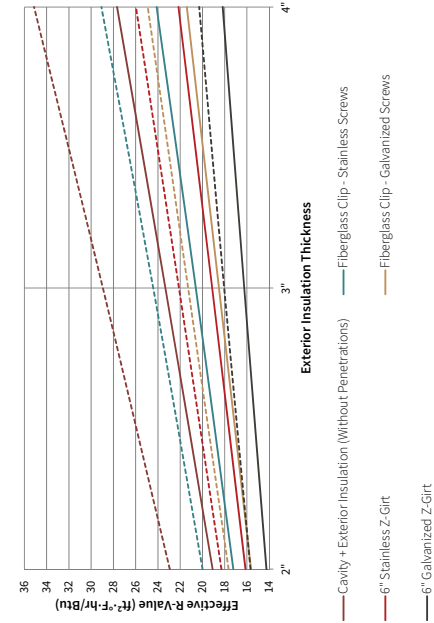


Fig. 7-9 System 7 (3%-inch steel stud) effective R-value comparison for a range of insulation thicknesses and various cladding support clip options. Figure generated from Table 7-1 values.

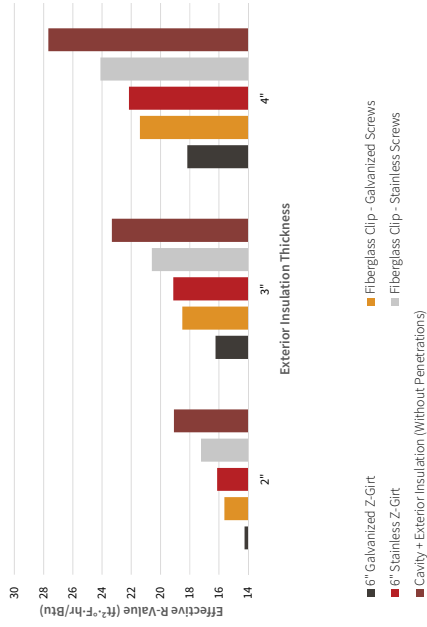


Fig. 7-8 System 7 (3%-inch steel stud) effective R-value modeling results for R-4.2/inch insulation and various cladding support clip options. Figure generated from Table 7-1 values.

cost-effective solution for reducing the wall thickness while meeting an energy performance target and can also help optimize effective thermal performance if a maximum exterior insulation thickness is known. *Consider the selection of insulation and cladding support as a combination, especially when wall thickness is important.*

- 3-inches (approx.) of R-6/inch insulation with fiberglass clips and stainless-steel screws
- 3.5-inches of R-6/inch insulation with intermittent stainless-steel Z-girts
- 4-inches (approx.) for R-6/inch insulation with fiberglass clips and galvanized steel fasteners or R-4.2/inch insulation with fiberglass clips and stainless-steel fasteners

Drainage, Ventilation, and Water Deflection

The adhered masonry veneer with grouted joints sheds most water it is exposed to; however, some moisture is expected to penetrate the cladding and enter the rainscreen cavity. This moisture is drained through the air cavity (created by the continuous Z-girts that support the cladding) or through the drainable, semi-rigid insulation.

Drainage and Ventilation

In the Northwest region, the air cavity is typically open at the top and bottom to encourage ventilation. When the air cavity

Table 7-3 System 7 (6-inch steel stud) thermal modeling results

6" Steel Stud Wall with Adhered Masonry Veneer, R-21 Batt Insulation, R-4.2/in - R-6/in Exterior Insulation						
3D Thermal Modeling Effective R-Value of System (ft²·°F·hr/Btu)						
Clip Type	Clip Penetration Area	Exterior Insulation Thickness	Nominal Insulation R-Value (Cavity + Exterior Insulation)	Cavity + Exterior Insulation (Without Clips Considered)	Stainless Steel Clip and/or Fasteners	Galvanized Clip and/or Fasteners
Fiberglass Standoff Clips	0.80%	2"	21 + 8.4 - 12	20.5 - 24.4	18.5 - 21.3	17.0 - 19.1
		3"	21 + 12.6 - 18	24.7 - 30.4	21.9 - 25.8	19.8 - 22.6
		4"	21 + 16.8 - 24	29.1 - 36.6	25.5 - 30.5	22.7 - 26.2
Intermittent 6" Z-Girts	0.09%	2"	21 + 8.4 - 12	20.5 - 24.4	17.5 - 19.7	15.5 - 17.0
		3"	21 + 12.6 - 18	24.7 - 30.4	20.4 - 23.4	17.5 - 19.2
		4"	21 + 16.8 - 24	29.1 - 36.6	23.5 - 27.3	19.4 - 21.5

Table 7-4 System 7 prescriptive energy code compliance values excerpted from Table 7-1 of the introductory chapter

OPAQUE ABOVE-GRADE WALL - THERMAL ENVELOPE REQUIREMENTS											
Energy Code		2012 SEC		2012 WSEC		2014 OEESC		2012 IECC			
Climate Zone		5 and Marine 4		5, 6 and Marine 4		5 and Marine 4		5 and Marine 4			
Guide Assembly #	Classification	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R
7	Steel-Framed Wall with Adhered Masonry Veneer	R-13 + R-10cl U-0.055 (R-18.2)	R-19 + R-8.5cl U-0.055 (R-18.2)	R-13 + R-10cl U-0.055 (R-18.2)	R-13 + R-10cl U-0.055 (R-18.2)	R-13 + R-10cl U-0.055 (R-18.2)	R-13 + R-10cl U-0.055 (R-18.2)	R-13 + R-10cl U-0.055 (R-18.2)	R-13 + R-10cl U-0.055 (R-18.2)	R-13 + R-10cl U-0.055 (R-18.2)	R-13 + R-10cl U-0.055 (R-18.2)
		R-13 + R-10cl U-0.055 (R-18.2)	R-19 + R-8.5cl U-0.055 (R-18.2)	R-13 + R-10cl U-0.055 (R-18.2)	R-13 + R-10cl U-0.055 (R-18.2)	R-13 + R-10cl U-0.055 (R-18.2)	R-13 + R-10cl U-0.055 (R-18.2)	R-13 + R-10cl U-0.055 (R-18.2)	R-13 + R-10cl U-0.055 (R-18.2)	R-13 + R-10cl U-0.055 (R-18.2)	R-13 + R-10cl U-0.055 (R-18.2)

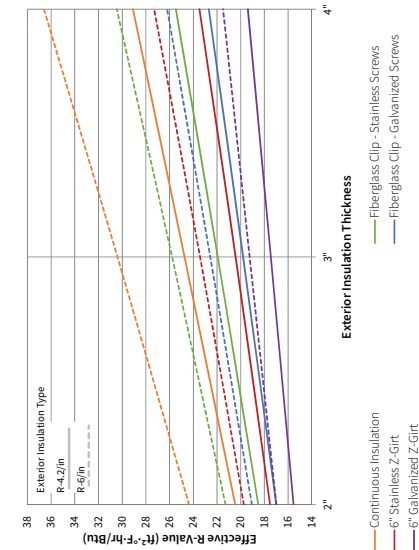


Fig. 7-10 Assembly 7 (6-inch steel stud) effective R-value comparison for a range of insulation thicknesses and various cladding support clip options. Figure generated from Table 7-3 values.

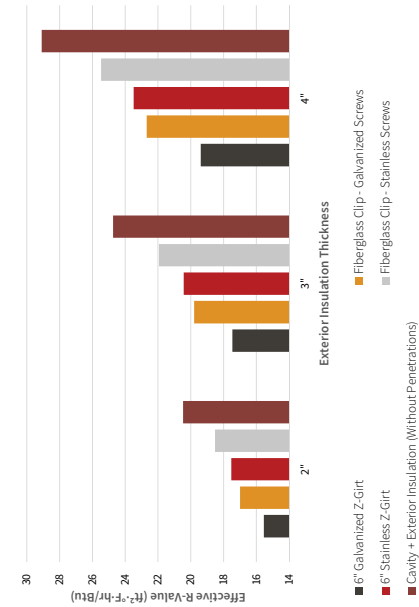


Fig. 7-11 System 7 (6-inch steel stud) effective R-value modeling results for R-4.2/inch insulation and various cladding support clip options. Figure generated from Table 7-3 values.

is open, (e.g., at the base of walls and at window head flashings, parapets, and cross-cavity flashings at floor lines), it is recommended that the cavity is covered with a screen to allow ventilation while still protecting the cavity from insects.

Sheet-Metal Components

Sheet-metal components for this system are reflected throughout the details located at the end of this chapter. Cross-cavity sheet-metal components are located at the head of wall penetrations (e.g., a window head) and at cross-cavity flashing locations similar to that shown in Fig. 7-12. These flashings assist with draining the rainscreen cavity and serve to protect any air barrier and WRB system components located behind them. Counterflashed sheet-metal components assist with water shedding and are typically located at windowsill and parapet top conditions; they protect the cavity from water ingress while allowing ventilation of the air cavity.

Sheet-metal flashing components that penetrate the exterior insulation act as a thermal bridge and degrade the thermal performance of the system; however, they are a necessary element for rainscreen wall system performance.

Refer to the Sheet-Metal Flashing Components discussion on page i-46 for general recommendations on sheet-metal flashing products, including design considerations and materials.

Movement Joints

In this system, the masonry units are bonded to a crack isolation membrane over a cement backer board substrate. Clay masonry units will expand over time, whereas concrete-based veneer products and grout joints between units will shrink. Minor movement is expected within the cement backer board and non-metal or intermittent metal-based cladding support clips; however, Z-furring may experience some movement due to temperature changes. The steel-framed backup wall will experience little volume change; however, some movement may occur where studs interface with floor and roof lines. As a result, both horizontal and vertical movement joints are needed to accommodate differential movement between the structure, cladding support system, and veneer components to prevent damage to the veneer or other wall components.

Horizontal gaps within the veneer and cladding support system typically occur at cross-cavity sheet-metal flashing locations that coincide with building floor lines, a common location for building movement. These gaps are typically provided at and should be continuous across all elevations of the building. Gaps are also

recommended above and below through-wall penetrations (e.g., windows and those described in the Masonry Veneer Penetrations discussion on page i-54), below structure projections (such as parapet blocking), and where needed to minimize veneer panel sizes. At each horizontal gap there is typically either a compressible backer rod and sealant joint or a cross-cavity sheet-metal flashing. The sizing and location of these joints will vary depending on the expected differential movement between the wall and the veneer.

The locations of vertical joints vary throughout the industry; confirm with the veneer unit manufacturer for the project-specific application. This guide recommends locating vertical movement joints throughout the veneer system and also considering horizontal-to-vertical placement relationships.

Typical joint locations to accommodate movement, drainage, and/or rainscreen cavity ventilation are identified with an asterisk (*) in chapter details. In general, a minimum gap dimension of $\frac{3}{8}$ -inch is recommended; however, it is the Designer of Record's responsibility to appropriately locate and size all movement joints.

Refer to the Movement Joints discussion on page i-48 for more information on locating veneer joints and sealant joint best practices.

Structural Considerations

Adhered veneers rely on adhesion to secure the masonry units and should be designed to comply with local building codes and TMS 402-16.⁶ The adhered veneer should be designed by the Designer of Record and as described by TMS 402-16⁶ commentary, should consider the adhesion of the veneer units, curvature of the veneer backing, freeze-thaw cycling, water penetration, and air and vapor transmission when necessary.

The code requires that adhered veneers be applied over concrete or masonry backings, and traditionally an adhered veneer was applied directly over these



Fig. 7-12 Fiberglass clip with continuous Z-girt, semi-rigid insulation, and prefinished cross-cavity sheet-metal flashing

wall types. However, recent code cycles requiring exterior insulation have dictated that adhered veneers over steel stud-framed walls include some insulation exterior of the wall sheathing and WRB system plane.

Per TMS 402-16,⁶ adhesion between the adhered veneer units and the backer must have a minimum shear strength of 50 psi in accordance with ASTM C482;⁷ however, significantly higher bond strengths can be achieved with currently available products and may be appropriate for projects within the Northwest region. Adhered veneer units for this system are adhered with a thinset mortar to form a continuous bed that is free of voids. It is best practice to adhere the veneer units of this system with a polymer-modified mortar over a crack isolation membrane and water-resistive cement backer board.

When exterior insulation is required, the masonry veneer is supported by intermittent cladding support clips and continuous vertical Z-girts such as those shown in Fig. 7-13. The spacing of the clips and the sizing of the girts are designed by the Designer of Record to resist building loads and limit out-of-plane deflection of the wall to reduce the likelihood of flexural cracking. Minimizing the cladding support clip spacing may be considered to limit out-of-plane deflection but can impact the effective thermal performance of the system. As shown in Fig. 7-15 on page 7-18, smaller cladding support clip spacing



Fig. 7-13 Intermittent Z-girt cladding support clips and continuous Z-girts. Mechanical impaling pins are attached between framing members for additional support of the exterior insulation. Note that a Class I (vapor permeance) air barrier and WRB system is depicted in this figure, which is typically acceptable where cavity insulation is minimized to 1/2 to 1/3 of the total nominal insulation R-value of this system and vapor control layer at the interior side of the framing is eliminated.



Fig. 7-14 Cement backer board installed over exterior insulation and cladding support system

is required to resist greater wind loads. As clip spacing is reduced, the effective thermal performance of the system is also reduced. Using lower-conductivity structural supports can reduce the impact cladding support clips have on the thermal performance.

Corrosion Resistance

It is best practice to match the durability and longevity of metal components within this system to that expected of the masonry veneer. Metal components within this system include intermittent Z-girts (when constructed of metal), continuous Z-furring, sheet-metal flashings, and fasteners.

Where available, sheet-metal components supporting the veneer or where acting as sheet-metal flashing components should be manufactured of AISI Type 304 or 316 stainless steel per ASTM A666,⁸ which are nonstaining, resistant to the alkaline content of mortar materials, and tolerant of the humidity conditions that can exist within the air cavity. Where stainless-steel components may not be available, G90 or G185 hot-dipped galvanized steel products per ASTM A653⁹ or minimum AZ50 or AZ55 galvalume-coated sheet steel in conformance with ASTM A792¹⁰ may be used but should be carefully considered based on the project's exposure and expected longevity.

Where the use of stainless steel sheet-metal flashing components is not always economically feasible or aesthetically desirable, prefinishing sheet metal may be considered. Where used, the base sheet metal should receive a minimum G90 hot-dipped galvanized coating in conformance with ASTM A653⁹ or minimum AZ50 galvalume coating in conformance with ASTM A792.¹⁰ Coating the exposed top finish of the sheet metal with an architectural-grade coating conforming to AAMA 621¹¹ is recommended.

Fasteners used with metal components should be corrosion-resistant, either hot-dipped galvanized steel or stainless-steel to match adjacent metal components.

Cement Backer Board

Cement backer board used within this system is exterior-grade water-, mold-, and mildew-resistant, which meets ASTM C1325¹² Type A (exterior applications) or ANSI 118.9.¹³ The cement backer board is attached to the continuous vertical Z-girts as required by the backer board manufacturer and project-specific design loads. The attachment method used should be appropriate for the Z-furring and intermittent cladding support design.

Joints of the cement board are typically staggered and treated with a mesh tape

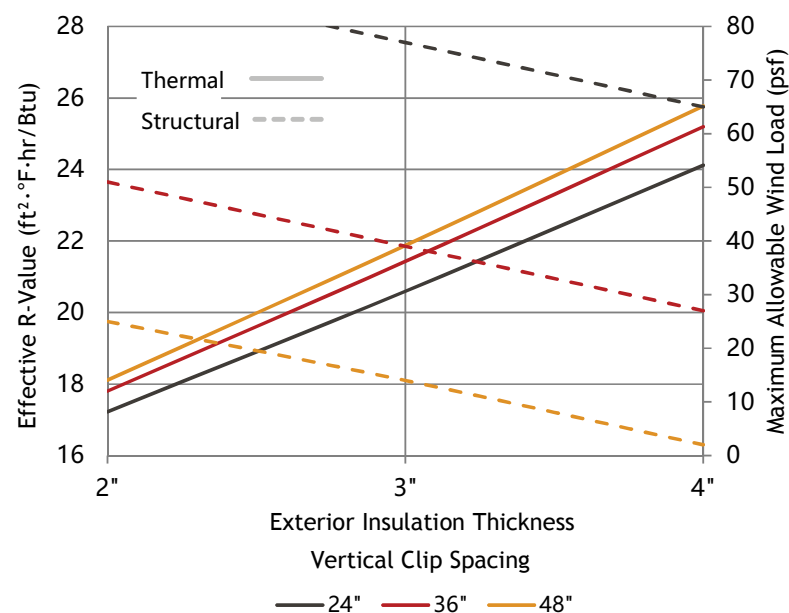


Fig. 7-15 System effective R-value as it compares to maximum-allowable wind loads for various fiberglass standoff clip spacings. These results assume fiberglass cladding support clips with two stainless-steel screws spaced at 3-inches vertically and attached into steel framing. The clips resist vertical gravity loads equally and receive horizontal loads based on their tributary areas. The design is generally limited by the pullout resistance of the upper screw through the clip, which is under tension from the weight of the cladding and from horizontal wind suction pressures. The allowable screw loads are based on testing data and are specific to the type of screw modeled. The allowable wind pressure should always be compared to the specified wind pressure acting on the cladding, as determined by the local building code in the applicable jurisdiction. These structural values provide a schematic relationship between thermal and structural performance and are not intended to be used as structural design values. In the structural design graphs, the cladding weight was set at 20 psf. The horizontal clip spacing remained at 16-inches on-center. The vertical spacing options are 24-, 36-, and 48-inches, and the exterior insulation thickness ranges from 2- to 4-inches.

that is bed into the thinset mortar. Cement backer board product should be installed in conformance with the manufacturer's installation instructions. The cement backer board should not span joints within the veneer that are expected to accommodate movement similar to that shown in Detail 7-E.

Crack Isolation Membrane

A crack isolation membrane is a flexible fluid-applied membrane used in thin masonry veneer applications where the veneer is adhered to a cement backer board. The crack isolation membrane is applied following installation of the cement backer board and treatment of the board joints as required by the cement backer board manufacturer. This membrane assists with:

- Reducing risk of veneer cracking. The veneer adheres to the membrane, which allows the cement backer board to move relatively independently of the veneer. *It is important to remember that use of a crack isolation membrane does not reduce or replace the need for appropriately designed and installed movement joints.*
- Reducing fastener corrosion risk. The membrane protects cement board fasteners from moisture held within the veneer and thinset mortar.
- Reducing cement board exposure to moisture. The membrane reduces the moisture exchanged between the cement board and thinset mortar and can increase the longevity of the board.
- Reducing efflorescence. The membrane reduces the moisture exchanged between the cement board and thinset mortar and may result in reduced efflorescence; thus, it may also be referred to as an efflorescence mitigation membrane.

Traditionally, this membrane may have been installed to protect the primary structure from moisture exposure. However, in this rainscreen system, *the crack isolation membrane is not a replacement for the air and water control layers*, which are located on the exterior face of the wall sheathing.

It is best practice to use a crack isolation membrane over cement backer board in adhered masonry veneer applications. Some manufacturers may require this membrane to achieve a warrantable cladding installation. A crack isolation membrane is visible in Fig. 7-16 on page 7-20.

Masonry Veneer

There are several types of adhered veneer unit products that may be used with this system. Those most typical within the Northwest include thin brick made of clay or shale or manufactured stone.

Thin brick used for this system is exterior-grade and complies with ASTM C1088.¹⁴ Manufactured stone masonry veneer units comply with ASTM C1670.¹⁵

For applications over cement board substrates, a polymer-modified thin set mortar is recommended. While the brick and manufactured stone veneer industries have not established standards for thinset mortar performance, this guide looks to the tile industry and the Tile Council of North America—particularly ANSI A118.15,¹⁶ which provides standard specifications for improved performance of modified mortars. This guide recommends that the thinset mortars used in this chapter's system demonstrate conformance with the ANSI 118.15.¹⁶

Appropriate product selection of masonry veneer unit and thinset mortar materials is necessary to provide a durable and water-resistive cladding system. The veneer units, thinset mortar, and joints should also be installed in conformance with industry-standard best practices and manufacturer requirements and should comply with ASTM C1780.¹⁷ The specifics of architectural characteristics and structural properties of the veneer system, including mortar and cladding support systems, should be designed and reviewed by a qualified Designer of Record.

Various industry resources are available to assist with veneer design and are listed in the Resources section.



Fig. 7-16 In-progress installation of masonry veneer over thinset mortar and crack isolation membrane

Clear Water Repellents

Application of a clear water repellent to the adhered masonry veneer of this system is common in the Northwest. Refer to the Surface-Applied Clear Water Repellents discussion on page i-59 for more information on selecting an appropriate clear water repellent and for best practice installation guidelines.

Pricing Summary

A pricing summary for this system is provided on Table 7-5 on page 7-23. Pricing demonstrates the relative price per square foot and is based on a 10,000-square-foot wall area with easy drive-up access. Pricing includes all components outboard of the exterior wall sheathing and provides no evaluation for interior finishes (including vapor retarder), framing/sheathing, or cavity insulation. Pricing is valid for the 2018 calendar year. Current pricing is also available at www.masonrystemsguide.com.

Online Availability

The content of this guide and additional resources may be accessed online at www.masonrystemsguide.com. Also available online are downloadable digital versions of two- and three-dimensional system details, cutaway sections, and sample project specifications as well as ongoing updates to references and resources included within this guide.

Chapter References

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2. National Fire Protection Association. *NFPA 285 - Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Non-Load-Bearing Wall Assemblies Containing Combustible Components*. (Quincy, MA: National Fire Protection Association, 2012).
3. 2015 Washington State Energy Code, Commercial Provisions. Chapter 51-11C WAC (filed by Washington State Legislature, January 19, 2016).
4. American Society of Heating, Refrigerating and Air-Conditioning Engineers. *ANSI/ASHRAE/IES Standard 90.1-2016 Energy Standard for Buildings Except Low-Rise Residential Buildings, SI ed.* (Atlanta: ASHRAE, 2016).
5. U.S. Department of Energy. *COMcheck* (version 4.0.7). Windows or Online. Washington, D.C.: U.S. Department of Energy, 2017, <https://www.energycodes.gov/comcheck>.

6. The Masonry Society. *TMS-402/602-16 Building Code Requirements and Specification for Masonry Structures*. (n.p.: The Masonry Society, 2016).

7. ASTM International. *ASTM C482-02(2014) Standard Test Method for Bond Strength of Ceramic Tile to Portland Cement Paste*. (West Conshohocken, PA: ASTM International, 2014).

8. ASTM International. *ASTM A666-15 Standard Specification for Annealed or Cold-Worked Austenitic Stainless-Steel Sheet, Strip, Plate, and Flat Bar*. (West Conshohocken, PA: ASTM International, 2015).

9. ASTM International. *ASTM A653/A653M-15e1 Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process*. (West Conshohocken, PA: ASTM International, 2015).

10. ASTM International. *ASTM A792/A792M-10(2015). Standard Specification for Steel Sheet, 55% Aluminum-Zinc Alloy-Coated by the Hot-Dip Process*. (West Conshohocken, PA: ASTM International, 2015).

11. American Architectural Manufacturers Association. *AAMA 621-02 Voluntary Specification for High Performance Organic Coatings in Coil Coated Architectural Hot Dipped Galvanized (HDG) and Zinc-Aluminum Coated Steel Substrates*. (Schaumburg, IL: American Architectural Manufacturers Association, 2002).

12. ASTM International. *ASTM C1325-17 Standard Specification for Non-Asbestos Fiber-Mat Reinforced Cementitious Backer Units*. (West Conshohocken, PA: ASTM International, 2017).

13. American National Standards Institute, "A118.9 American National Standard Specifications for Test Methods and Specifications for Cementitious Backer Units—1999 [Reaffirmed 2005 and 2010]," in *ANSI American National Standard Specifications for the Installment of Ceramic Tile*. (Anderson, SC: Tile Council of North America, Inc., 2014).

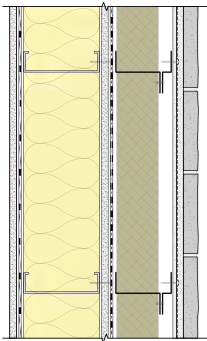
14. ASTM International. *ASTM C1088-14 Standard Specification for Thin Veneer Brick Units Made from Clay or Shale*. (West Conshohocken, PA: ASTM International, 2014).

15. ASTM International. *ASTM C1670/C1670M-16 Standard Specification for Adhered Manufactured Stone Masonry Veneer Units*. (West Conshohocken, PA: ASTM International, 2016).

16. American National Standards Institute, "A118.15 American National Standard Specifications for Improved Modified Dry-Set Cement Mortar –2012 [New]," in *ANSI American National Standard Specifications for the Installment of Ceramic Tile*. (Anderson, SC: Tile Council of North America, Inc., 2014).

17. ASTM International. *ASTM C1780-16a Standard Practice for Installation Methods for Adhered Manufactured Stone Masonry Veneer*. (West Conshohocken, PA: ASTM International, 2016).

Table 7-5 System 7 steel-framed wall with adhered veneer pricing summary

System 7: Steel Framed Wall with Adhered Masonry Veneer					
System Component	Baseline Product	Alternate (call for estimate)	Baseline Cost/ft ² (incl. labor)		
			Low	High	
INTERIOR					
1 Interior gypsum board	No evaluation of these components provided.				
2 Vapor retarder					
3 Steel-framed wall with batt insulation					
4 Exterior sheathing					
5* Air and water-resistive barrier	Fully adhered or mechanically attached sheet-applied membrane	Fluid-applied membrane system	\$1.50	\$3.75	
6* Semi-rigid insulation	Semi-rigid mineral fiber board; 2-inch thickness	No specified alternate	\$2.75	\$3.25	
4* Intermittent standoff clip with 1-inch Z-girt	6-inch-tall clips at 24" o.c. vertical; clips and girts G185 hot-dipped galvanized; self-tapping fasteners	Stainless clips or thermally improved proprietary cladding support system	\$3.75	\$9.50	
5* Cement backer board	Moisture-resistant 5/8"-thick, taped & fastened	No specified alternate	\$2.50	\$4.75	
6* Adhered masonry or stone veneer with grouted joints, includes polymer modified thin-set	Modular (3/4" x 2-1/4" x 7-5/8") extruded TBX; running bond; 3/8-inch mortar joints	Alternate veneer products	\$39.00	\$42.75	
7* Clear water repellent	Silane/siloxane blend	Antigraffiti clear water repellent	\$1.75	\$2.50	
EXTERIOR					
Total cost to install 10,000 sq ft wall area w/easy drive-up access -->			\$51.25	\$66.50	
Pricing Summary Discussion		System Plan View			
<ul style="list-style-type: none">- Low and high baseline costs are based on baseline products and installed labor costs. Call for an estimate for alternative product pricing.- Baseline costs provided will vary based on product specific conditions, as well as project location, and should be used as an estimate only.- Veneer unit prices are for typical units as noted. Pricing can vary based on size, color, and finish and should be confirmed with the unit manufacturer.- *See the Resources section of this guide for a list of resources related to this component.					

LEGEND

1. Typical Assembly:

- Interior gypsum board
- Vapor retarder
- Steel-framed wall with batt insulation
- Exterior gypsum sheathing
- Self-adhered sheet or fluid-applied air barrier and WRB field membrane
- Semi-rigid mineral fiber insulation with intermittent cladding support clip
- Air cavity with vertical Z-girt
- Cement backer board
- Crack isolation membrane
- Thinset mortar
- Adhered veneer with grouted joints
- Clear water repellent

- 2. Self-adhered sheet or fluid-applied air barrier and WRB prestrip membrane
- 3. Sloped sheet-metal head flashing with hemmed drip edge and end dams (beyond)

4. Insect screen

5. Sealant over backer rod

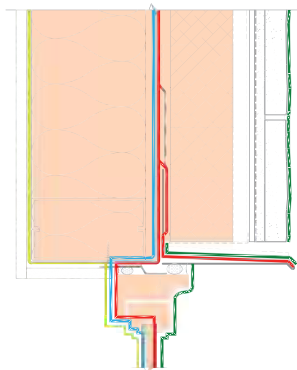
- 6. Window strap anchor, bed in air barrier sealant at continuous air barrier sealant joint plane

7. Non-flanged window

- 8. Continuous air barrier sealant tied to continuous seal at window perimeter

* Size joint for drainage and ventilation, minimum 3/8-inch

Water-Shedding Surface and Control Layers

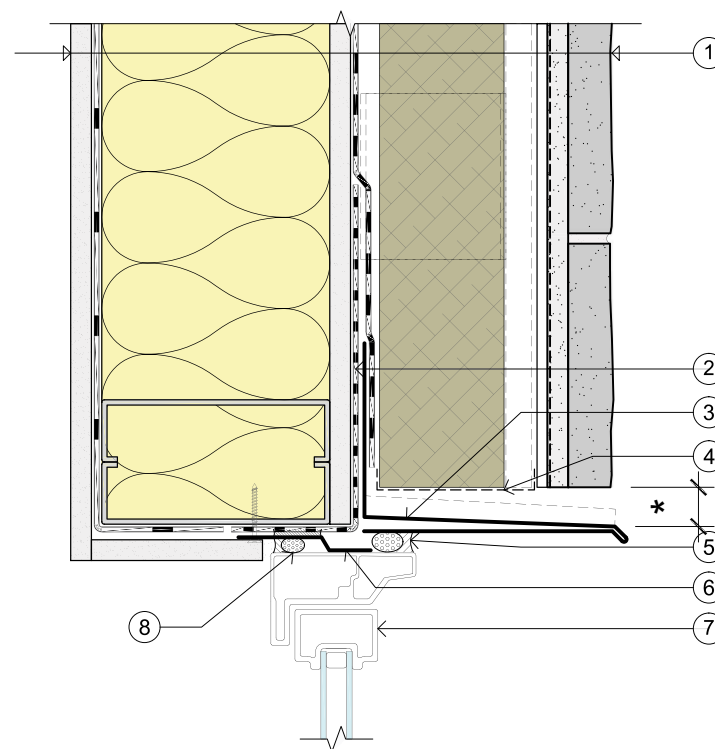


Water-Shedding Surface

Control Layers:†

- Water
- Air
- Vapor
- Thermal

† Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing



Detail Discussion

- Air and water control layer continuity is provided by the self-adhered sheet or fluid-applied air barrier and WRB field membrane, prestrip membrane, and air barrier sealant transition to the window. Window strap anchors are bed in sealant during fastening to eliminate an air barrier discontinuity behind the strap anchor that could otherwise lead to both air leakage and/or water intrusion.
- A non-flanged window is shown in Detail 2-A and facilitates future window repair and replacement without the need to remove the adhered masonry veneer.
- Intermittent cladding support clips (beyond) may need to be bed in air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per air barrier and WRB system manufacturer recommendations. This provides both airtightness and watertightness where the fasteners penetrate the air barrier and WRB membrane.

Typical Window Head

Detail 7-A

LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Vapor retarder
 - Steel-framed wall with batt insulation
 - Exterior gypsum sheathing
 - Self-adhered sheet or fluid-applied air barrier and WRB field membrane
 - Semi-rigid mineral fiber insulation with intermittent cladding support clip
 - Air cavity with vertical Z-girt
 - Cement backer board
 - Crack isolation membrane
 - Thinset mortar
 - Adhered veneer with grouted joints
 - Clear water repellent
2. Non-flanged window on minimum 1/4-inch thick intermittent shims
3. Sealant over bond breaker
4. Insect screen
5. Sloped sheet-metal sill flashing with hemmed edge and end dams (beyond), attached to intermittent L-angle at window per window manufacturer recommendations
6. Self-adhered sheet or fluid-applied air barrier and WRB prestrip membrane
7. Continuous air barrier sealant tied to continuous seal at window perimeter
8. Continuous back dam angle at rough opening sill, minimum 1-inch tall. Fasten window through back dam angle per window manufacturer recommendations.

* Size joint for ventilation, minimum 3/8-inch

Detail Discussion

- Air and water control layer continuity is provided by the self-adhered sheet or fluid-applied air barrier and WRB field membrane, self-adhered sheet or fluid-applied flashing membrane at the sill, and the air barrier sealant transition to the window.
- The sloped sheet-metal sill flashing conceals the rainscreen cavity; counterflash each end dam of the sill flashing with the sheet-metal jamb trim to close off the rainscreen cavity and complete the water shedding surface.
- Intermittent shims below the window allow drainage of the window rough opening into the rainscreen cavity.

Water-Shedding Surface and Control Layers

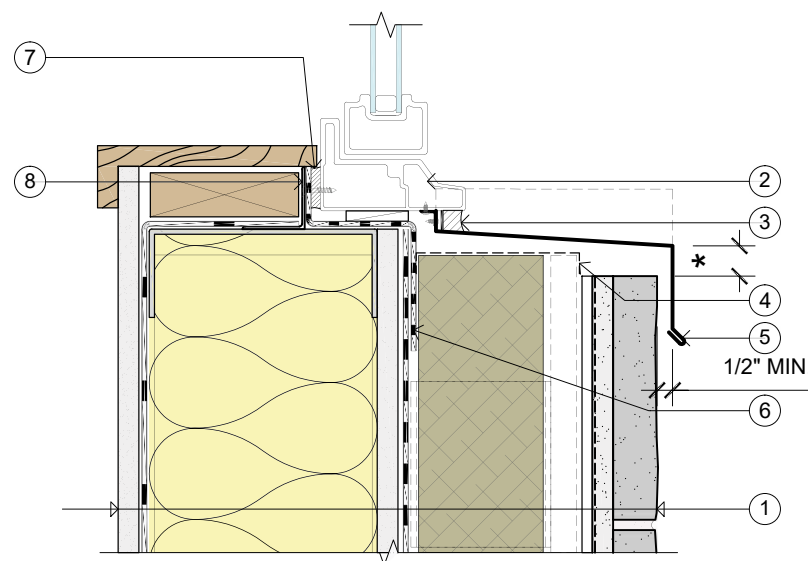


— Water-Shedding Surface

Control Layers:†

— Water
— Air
— Vapor
— Thermal

† where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing



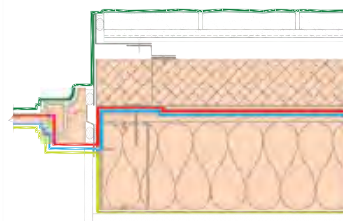
Typical Windowsill

Detail 7-B

LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Vapor retarder
 - Steel-framed wall with batt insulation
 - Exterior gypsum sheathing
 - Self-adhered sheet or fluid-applied air barrier and WRB field membrane
 - Semi-rigid mineral fiber insulation with intermittent cladding support clip
 - Air cavity with vertical Z-girt
 - Cement backer board
 - Crack isolation membrane
 - Thinset mortar
 - Adhered veneer with grouted joints
 - Clear water repellent
2. Non-flanged window
3. Sealant over backer rod
4. Self-adhered or fluid-applied sheet air barrier and WRB prestrip membrane
5. Sheet-metal jamb trim; counterflashed over sill flashing end dams beyond. Attach trim to nearest vertical Z-girt as shown.
6. Vertical Z-girt over intermittent cladding support clip, fasten clip through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per air barrier and WRB system manufacturer recommendations
7. Continuous air barrier sealant, tie to continuous seal at window perimeter
8. Window strap anchor, bed in air barrier sealant at continuous air barrier sealant joint plane

Water-Shedding Surface and Control Layers

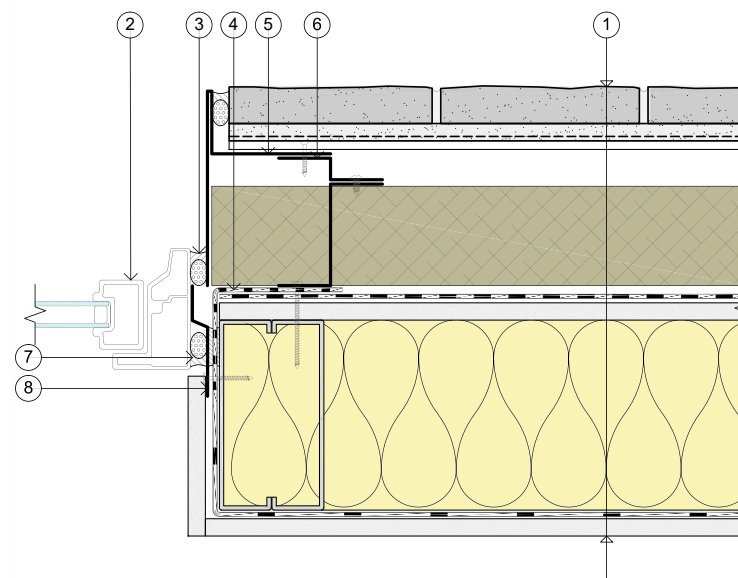


Water-Shedding Surface

Control Layers:*

Water
 Air
 Vapor
 Thermal

* Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing



Detail Discussion

- Air and water control layer continuity is provided by the self-adhered sheet or fluid-applied air barrier and WRB field membrane, prestrip membrane, and air barrier sealant transition to the window.
- Where needed, the exterior insulation should be supported with intermittent fasteners such as mechanically attached impaling pins. Consult with the air barrier and WRB membrane manufacturer for requirements on detailing these pin attachments through the membrane.

Typical Window Jamb

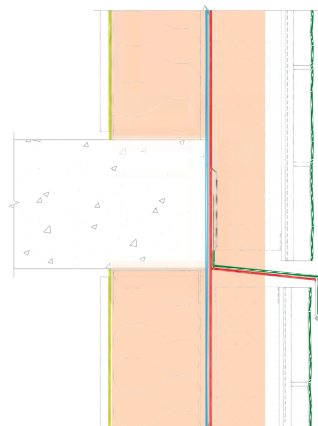
Detail 7-C

LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Vapor retarder
 - Steel-framed wall with batt insulation
 - Exterior gypsum sheathing
 - Self-adhered sheet or fluid-applied air barrier and WRB field membrane
 - Semi-rigid mineral fiber insulation with intermittent cladding support clip
 - Air cavity with vertical Z-girt
 - Cement backer board
 - Crack isolation membrane
 - Thinset mortar
 - Adhered veneer with grouted joints
 - Clear water repellent
2. Insect screen
3. Sloped sheet-metal flashing with hemmed drip edge and end dams beyond at intersecting elements

* Size gap for project-specific movement, drainage, and ventilation, minimum 3/8-inch

Water-Shedding Surface and Control Layers



Water-Shedding Surface

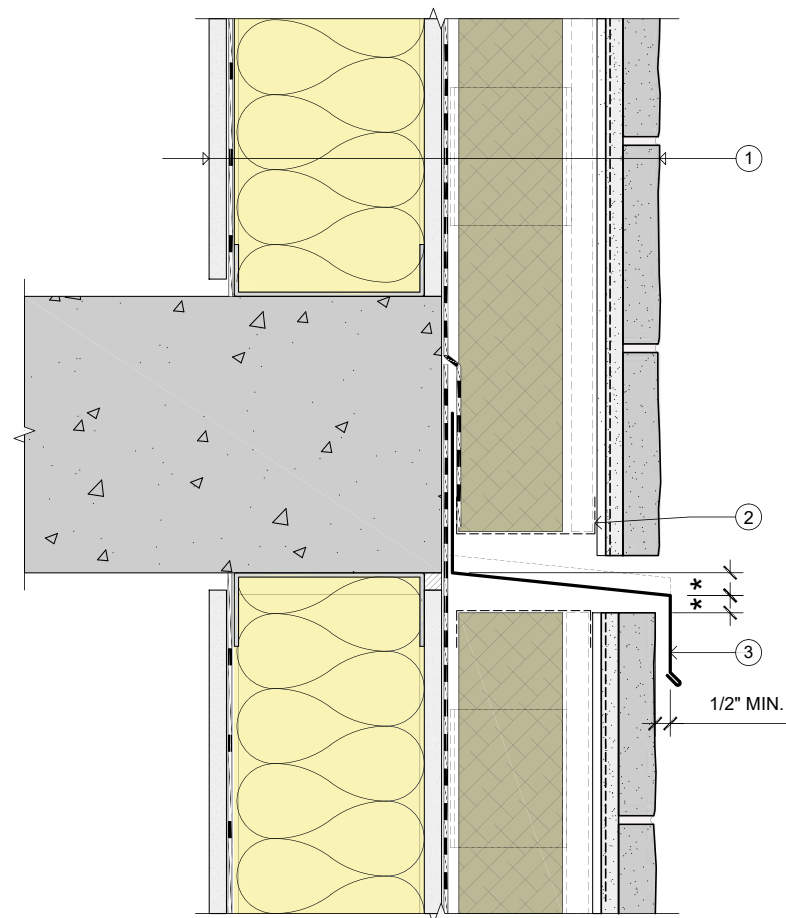
Control Layers:[†]

— Water
 — Air
 — Vapor
 — Thermal

[†] Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing

Detail Discussion

- The sloped cross cavity sheet-metal flashing conceals the rainscreen cavity from debris and wind-driven rain while still allowing ventilation.
- Space above and below the sloped cross cavity sheet-metal flashing is necessary to allow for differential movement between the structure and veneer.



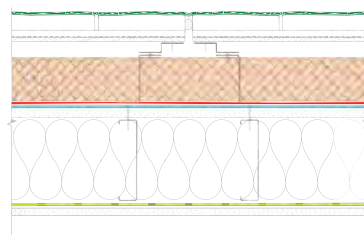
Typical Floor Line

Detail 7-D

LEGEND

1. Typical Assembly:
 - Interior gypsum board
 - Vapor retarder
 - Steel-framed wall with batt insulation
 - Exterior gypsum sheathing
 - Self-adhered sheet or fluid-applied air barrier and WRB field membrane
 - Semi-rigid mineral fiber insulation with intermittent cladding support clip
 - Air cavity with vertical Z-girt
 - Cement backer board
 - Crack isolation membrane
 - Thinset mortar
 - Adhered veneer with grouted joints
 - Clear water repellent
 2. Continuous break in cement backer board
 3. Sanded sealant joint over backer rod
 4. Vertical Z-girt over intermittent cladding support clip, fasten clip through fastened through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per air barrier and WRB system manufacturer recommendations
- * Size joint for project specific movement, minimum 3/8-inch

Water-Shedding Surface and Control Layers

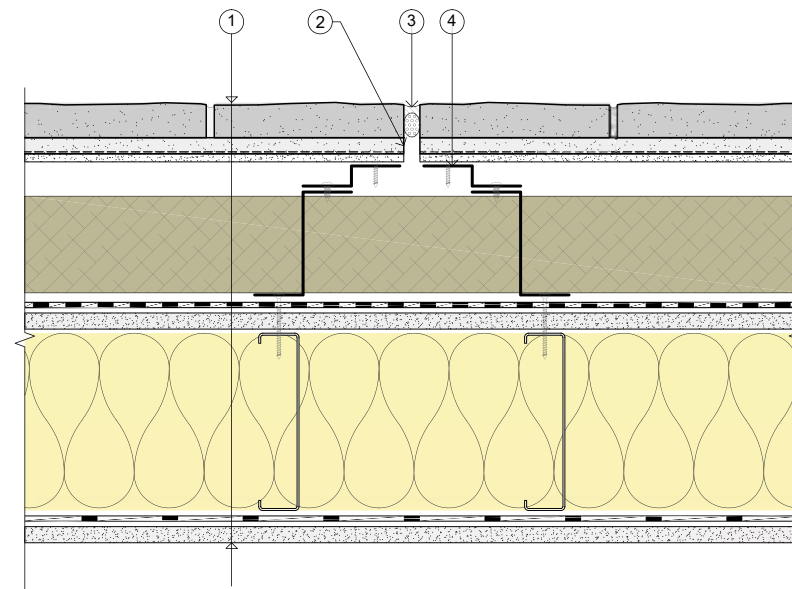


— Water-Shedding Surface

Control Layers:†

— Water
— Air
— Vapor
— Thermal

† Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing



Detail Discussion

- The cement backer board is supported by continuous vertical furring on both sides of the control joint. The gap within the veneer at this location is free of all materials with the exception of a compressible backer rod and sealant to allow for movement while maintaining a continuous water shedding surface.
- The location of control joints is determined by the project designer and clearly identified in the construction documents on elevations and in details.

Refer to the Movement Joints discussion on page i-48 for more information on vertical control joint spacing.

Vertical Control Joint

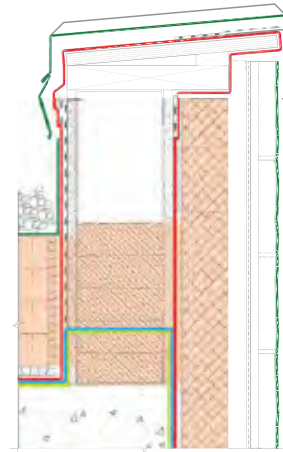
Detail 7-E

LEGEND

1. Parapet Assembly
 - Interior gypsum board
 - Vapor retarder
 - Steel-framed wall with batt insulation
 - Exterior gypsum sheathing
 - Self-adhered sheet or fluid-applied air barrier and WRB field membrane
 - Semi-rigid mineral fiber insulation with intermittent cladding support clip
 - Air cavity with vertical Z-girt
 - Cement backer board
 - Crack isolation membrane
 - Thinset mortar
 - Adhered veneer with grouted joints
 - Clear water repellent
2. Inverted roof membrane assembly
3. Sloped standing-seam sheet-metal coping with gasketed washer fasteners
4. Insect screen
5. Preservative-treated blocking
6. High-temperature self-adhered membrane
7. Closed-cell spray foam insulation plug (air barrier)

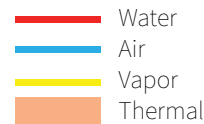
* Size gap for project-specific movement and ventilation, minimum 3/8-inch

Water-Shedding Surface and Control Layers



Water-Shedding Surface

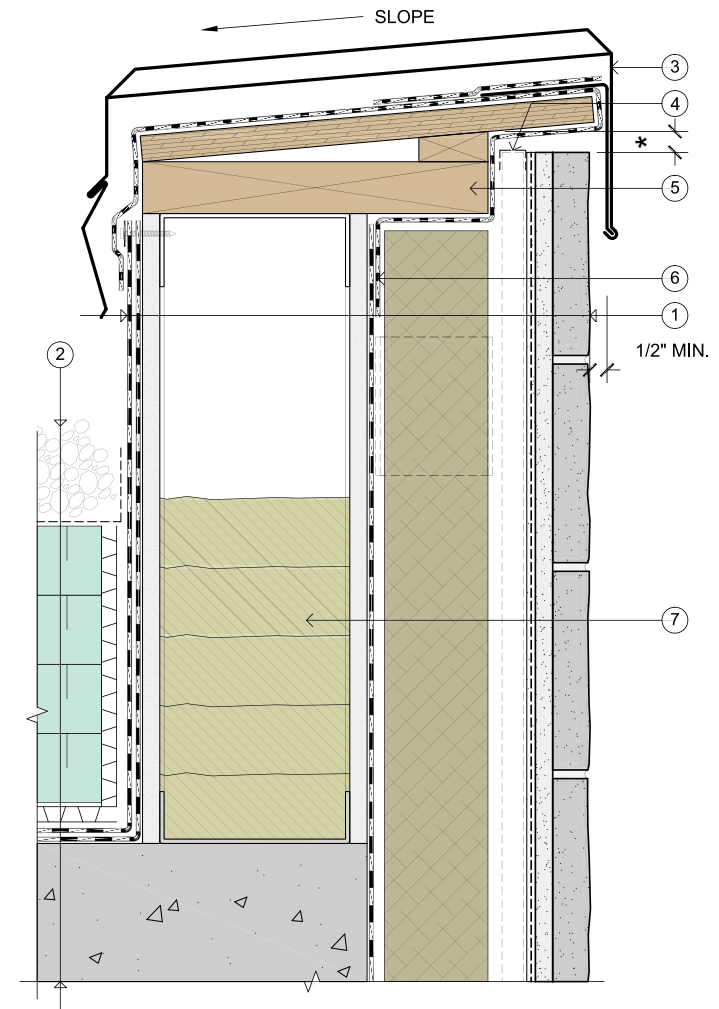
Control Layers:†



† Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing

Detail Discussion

- The sheet-metal parapet cap with hemmed drip edge is held off the adhered veneer face to minimize disruption of the air flow behind the veneer. A 1/2-inch gap is recommended.
- Insect screen around the insulation and vertical Z-girt cavity prevents insects and debris from entering the rainscreen cavity, while still allowing ventilation.
- The self-adhered sheet or fluid-applied air barrier and WRB field membrane, high temperature self-adhered membrane, and roof membrane provide the air and water control layers in this detail.



Typical Parapet at Inverted Roof Membrane System

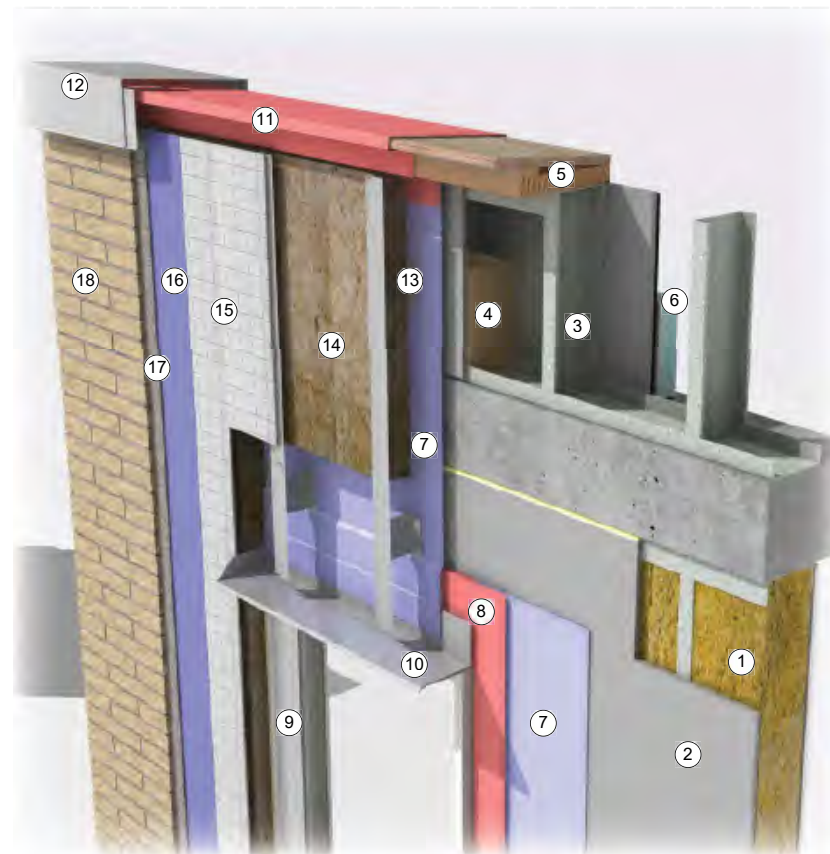
Detail 7-F

LEGEND

1. Steel-framed wall with batt insulation
2. Exterior gypsum sheathing
3. Steel-framed parapet framing
4. Closed-cell spray foam insulation plug (air barrier)
5. Sloped preservative-treated blocking
6. Inverted roof membrane assembly
7. Self-adhered sheet or fluid-applied air barrier and WRB field membrane
8. Self-adhered or fluid-applied sheet air barrier and WRB prestrip membrane
9. Non-flanged window
10. Sloped sheet-metal head flashing with hemmed drip edge and end dams
11. High-temperature self-adhered membrane
12. Sloped standing seam sheet-metal coping with gasketed washer fasteners
13. Vertical Z-girt over intermittent cladding support clip, fasten clip through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per air barrier and WRB system manufacturer recommendations
14. Semi-rigid mineral fiber insulation
15. Cement backer board
16. Crack isolation membrane
17. Thinset mortar
18. Adhered veneer with grouted joints

3-D Detail Discussion

- Three-dimensional cutaway sections on the next three pages represent two-dimensional details of this system.
- In all details, water control layer elements are shingle-lapped to encourage drainage of liquid water.
- As shown in Detail 7-F and Detail 7-G, exterior insulation fits between the intermittent cladding supports clips. When using rigid board insulation, the insulation may require notching around clips. Where needed, the exterior insulation should be supported with intermittent fasteners such as mechanically attached impaling pins. Impaling pins fasteners may need to be sealed where penetrating the air barrier and WRB membrane.
- End dams are formed at the ends of the sloped sheet-metal head flashing shown in Detail 7-F to direct water away from the rainscreen cavity and back to the exterior.

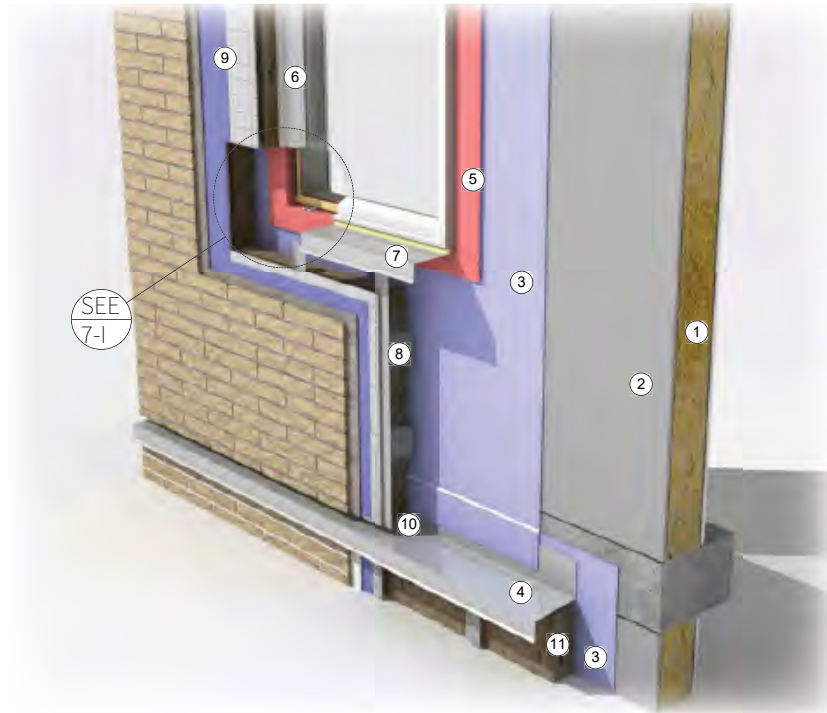


Parapet Assembly Cutaway Section

Detail 7-G

LEGEND

1. Steel-framed wall with batt insulation
2. Exterior gypsum sheathing
3. Self-adhered sheet or fluid-applied air barrier and WRB field membrane
4. Sloped sheet-metal cross cavity flashing with hemmed drip edge and end dams
5. Fluid-applied or self-adhered flashing membrane
6. Non-flanged window
7. Sloped sheet-metal sill flashing with hemmed drip edge and end dams
8. Vertical Z-girt over intermittent cladding support clip, fasten clip through air barrier sealant, fluid-applied flashing membrane, or self-adhered membrane patch per air barrier and WRB system manufacturer recommendations
9. Adhered veneer with grouted joints over thinset mortar, crack isolation membrane, and cement backer board
10. Insect screen
11. Semi-rigid mineral fiber insulation

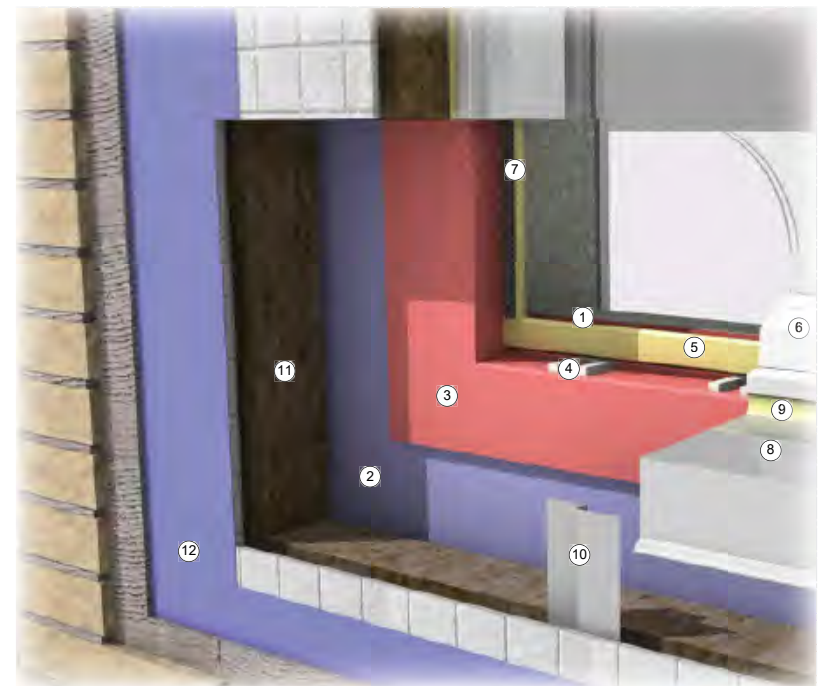


Floor Line Cutaway Section

Detail 7-H

LEGEND

1. Continuous back dam angle across sill, minimum 1-inch tall, with window fastened through back dam angle per window manufacturer recommendations
2. Self-adhered sheet or fluid-applied air barrier and WRB field membrane
3. Self-adhered sheet or fluid applied air barrier and WRB flashing membranes at jamb and sill
4. Minimum 1/4-inch thick intermittent shims
5. Continuous air barrier sealant tied to continuous seal at window perimeter
6. Non-flanged window
7. Continuous air barrier sealant over backer rod
8. Sloped sheet-metal sill flashing with hemmed drip edge and end dams
9. Sealant over bond breaker
10. Vertical Z-girt over intermittent cladding support clip
11. Semi-rigid mineral fiber insulation
12. Adhered veneer with grouted joints over thinset mortar, crack isolation membrane, and cement backer board



Window Jamb / Sill Cutaway Section

Detail 7-I

CHAPTER 8:**WOOD-FRAMED WALL WITH ADHERED MASONRY VENEER**

Masonry systems 8A and 8B are rainscreen wall systems with wood-framed wall structure and adhered veneer. The adhered veneer may be thin brick, natural stone, or manufactured stone. The components of this system, from interior to exterior, are described in Fig. 8-1 for two options: Option A and Option B. The veneer is applied with either a:

- Thick bed method using a scratch coat and bond coat of mortar, referred to as Option A.
- Thin bed method using a thinset mortar over cement backer board, referred to as Option B.

The thick bed method of application, identified as Option A, is most appropriate for low-rise structures. The thin bed method, identified as Option B, is most

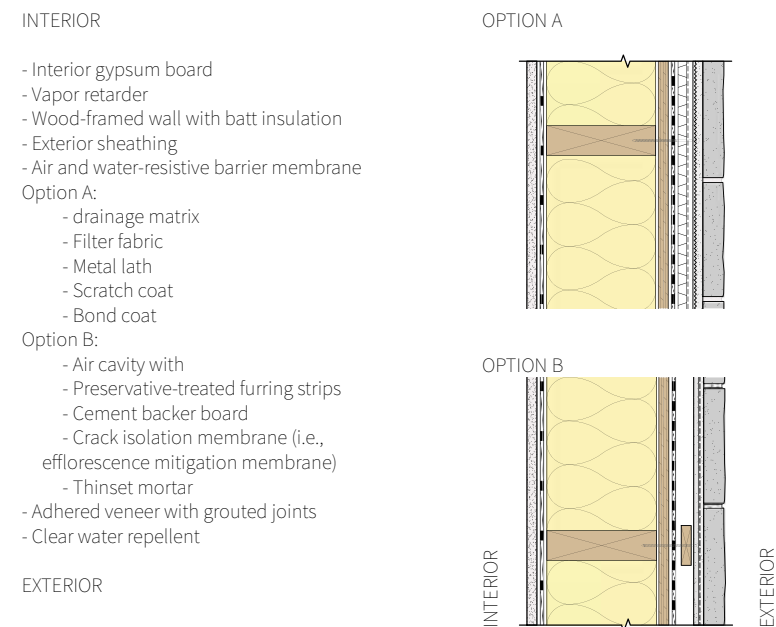


Fig. 8-1 Typical System 8, Option A and Option B, components from interior to exterior

appropriate for low- to mid-rise structures. Both systems are applicable for residential and commercial applications.

Building Enclosure & Control Layers

As noted in the Introduction, an above-grade wall system controls liquid water, air, heat, and possibly water vapor to function as an effective and durable environmental separator. Control of these elements, specific to this wall system, is provided by the following control layer systems and/or materials:

- Water control layer, comprising the water-resistive barrier (WRB) system
- Air control layer, comprising the air barrier system
- Thermal control layer, comprising thermal insulation and other low-conductivity materials
- Vapor control layer, comprising vapor retarding materials

For a summary of the relationship between building enclosure loads, control layers, and associated systems and materials, Refer to Fig. i-13 on page i-21 of the introductory chapter.

Fig. 8-3 illustrates the water-shedding surface and control layer locations for this system. The water-shedding surface and control layers for typical system details are also provided adjacent to each detail at the end of this chapter.

As shown in Fig. 8-3, the water-shedding surface occurs at the adhered masonry veneer, with most water-shedding occurring at the wall face while some water is stored within the masonry veneer to be released later. The water control layer and air control layer are located exterior of the wall sheathing. The thermal control layer occurs at the framed wall cavity insulation. The vapor control layer is located at the interior (warm-in-winter side) of the wood-framed structure.



Fig. 8-2 Wood-framed wall with adhered veneer example project application

Water-Shedding Surface

The water-shedding surface is a system that reduces the water load on the enclosure. A general discussion of the water-shedding surface is provided in the Water-Shedding Surface discussion on page i-19.

The adhered veneer cladding—including both grout joints and veneer units—is the primary water-shedding surface of the wall system. Additional water-shedding surface components include sheet-metal flashings and drip edges, sealant joints, and fenestration systems as shown on the details included at the end of this chapter.

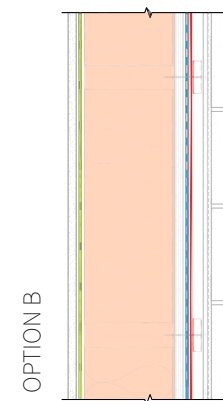
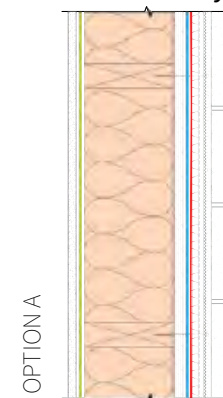
To promote water-shedding at the masonry cladding, grout joints between veneer units should be installed with a tooled concave (preferred) or “V” shape.

The water-shedding surface is most effective when free of gaps other than those providing drainage and/or ventilation. Movement joints and joints around fenestrations and penetrations should be continuously sealed with backer rod and sealant or counterflushed with a sheet-metal flashing to deflect wind-driven rain and shed water away from the rainscreen cavity.

Water Control Layer

The water control layer is a continuous control layer that is designed and installed to act as the innermost boundary against water intrusion. In a rainscreen wall system, the water-

Water-Shedding Surface and Control Layers



— Water-Shedding Surface

Control Layers:

- Water
- Air
- Vapor
- Thermal

Fig. 8-3 Water-shedding surface and control layer locations for Systems 8A and 8B

Low-permeance (Class I, Class II, and sometimes Class III vapor permeance) flashing membranes are commonly used in WRB systems that have vapor-permeable WRB system field membranes. These flashing membranes can be effective on horizontal or low-slope transitions such as window and door rough opening sills or to detail around penetrations and other transitions; however, it is recommended that the use of such membranes is minimized when a vapor-permeable WRB system field membrane is used. This may be achieved by reducing the installation of low-permeance membranes to less than 10 percent of the wall area and by avoiding concentrated areas of low-permeance membranes at wall areas that would otherwise benefit from drying to the exterior (such as in wood-framed systems).

resistive barrier (WRB) system is the last line of defense against water intrusion. A general discussion of the WRB system is provided in the Water Control Layer discussion on page i-24.

In this wall system, the WRB system typically has Class IV vapor permeance properties and may be a mechanically attached sheet membrane, a self-adhered sheet membrane, or a fluid-applied system that also functions as the air barrier system; thus, the WRB system is often referred to as the air barrier and WRB system. An air barrier and WRB system with a Class IV vapor permeance allows this wall system to dry to the exterior. Drying ability to the exterior is not only beneficial during the service life of the building but also helps relieve any construction-related moisture in the wood framing or wood-based sheathing products. A vapor-permeable air barrier and WRB system with mechanically attached field membrane is depicted in the details at the end of this chapter.

Physical properties of the WRB system products are discussed in detail in the Water Control Layer discussion on page i-24. Vapor permeability of materials is addressed in the Vapor Control Layer discussion on page i-28.

The WRB system must be continuous across the wall system to provide effective water control. In addition to the field membrane, the WRB system includes fluid-applied or self-adhered flashing membranes, sealants, sheet-



Fig. 8-4 Furring strips secure the sheet-applied air barrier and WRB system

metal flashings, and penetrations such as windows and doors as shown in the detail drawings that follow this chapter discussion. Where sheet-metal flashing components occur within the system, the back leg of the sheet-metal flashing is shingle-lapped into the WRB system to facilitate drainage at the face of the WRB system and to the exterior of the cladding.

Cladding support clip fasteners in this system penetrate the WRB system and should be sealed as required by the WRB system manufacturer's installation requirements. Fasteners may be required to be set in sealant, especially at uneven wall planes; however, requirements vary by manufacturer and should be confirmed.

Air Control Layer

The air barrier system provides the air control layer. In addition to controlling air, this layer assists with controlling liquid water, heat, and water vapor. A general discussion of the air control layer and the air barrier system is provided in the Air Control Layer discussion on page i-26.

For this wall system, the air barrier system is the same field membrane and many of the components that also serve as the WRB system. As discussed in the introductory chapter, the air barrier system must be continuous and fully sealed to resist air flow; whereas, the WRB system is not required to be continuously sealed to be effective.

Mechanically attached sheet-applied air barrier and WRB system materials should be attached per manufacturer recommendations to minimize the risk of membrane displacement and damage during wind events. For Option A of this wall system, manufacturer-recommended fasteners may be washer head nails or fasteners. The installation of drainage matrix and cladding components will also assist with securing the air barrier and WRB system in place. For Option B of this wall system, furring strips serve as the mechanical attachment as shown in Fig. 8-4. Note that furring strips should be installed immediately following membrane installation. Where furring strips are not immediately installed, manufacturer-recommended washer head fasteners should be installed.

Vapor Control Layer

The vapor control layer retards or greatly reduces (e.g., vapor barrier) the flow of water vapor due to vapor pressure differences across enclosure assemblies. Unlike the other control layers presented in this guide, the vapor control layer is not always necessary or required to be continuous.

Although masonry is defined as a noncombustible cladding material, the use of a combustible air barrier and WRB system or foam plastic insulation within a wall cavity can trigger fire propagation considerations and requirements. Depending on the local jurisdiction, IBC Section 1403.5¹ regarding vertical and lateral flame propagation as it relates to a combustible WRB system may require acceptance criteria for NFPA 285.² The use of foam plastic insulation within a wall cavity should also be addressed for IBC Chapter 26¹ provisions.

The vapor control layer of this system is located on the interior (warm-in-winter side) of the wall and is typically at the face of or just behind the interior gypsum board. The vapor retarder for this wall system should comply with Section 1405.3 of the governing International Building Code (IBC).¹ In the Northwest, typical vapor retarder products include PVA vapor-retarding primer, asphalt-coated kraft paper, or a polyamide film retarder membrane. Refer to the Vapor Control Layer discussion on page i-28 for additional discussion on vapor retarder products.

Thermal Control Layer

The thermal control layer controls heat flow and assists with controlling water vapor.

In this wall system, the low-conductivity wood framing and wall cavity insulation form the thermal control layer. At transition details, the thermal control layer also includes parapet cavity insulation and insulation at the roof assembly, slab, and foundation elements. Windows and doors that penetrate this wall system are also part of the thermal control layer. Exterior insulation may also be used with this system, as depicted in Fig. 8-5 on page 8-6, to improve thermal performance of Option B.

Additional thermal insulation information is provided in the Thermal Control Layer discussion on page i-30 of the introductory chapter.

Insulation Selection

The cavity insulation in this system is typically fiberglass or mineral fiber batt insulation product.

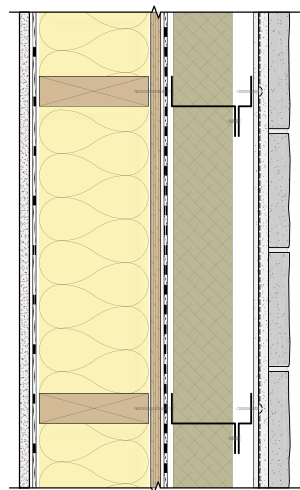


Fig. 8-5 System 8 Option B with exterior semi-rigid mineral fiber board insulation and intermittent cladding support clips

Exterior insulation is typically avoided with Option A due to the difficulty of fastening insulation, drainage matrix, and metal lath materials and the difficulty in supporting final veneer components of this wall system.

Where exterior insulation is desired, Option B of this wall system is more appropriate. The adhered veneer is supported with intermittent cladding support clips and vertical Z-girt furring as shown similarly in Fig. 8-5 and Fig. 8-6. Refer to Chapter 7 for additional discussion on insulation selection, cladding supports, and cladding discussion when exterior insulation is to be used.

Exterior insulation with relatively low vapor permeance properties (e.g., XPS or polyisocyanurate) may be avoided in this wall system because it can limit system drying to the exterior.

Refer to the Insulation Products discussion on page i-30 for information on various insulation types and additional considerations.

Thermal Performance and Energy Code Compliance

This chapter system is typically classified as a “wood-framed and other” above-grade wall for energy code compliance purposes. Prescriptive energy code compliance values for this system are summarized in Table 8-2 on page 8-13 and describe:

- Minimum insulation R-values for a *prescriptive insulation R-value method* strategy.
- Maximum system U-factors for a *prescriptive assembly U-factor method* strategy. Note that the equivalent effective R-value of this U-factor has been calculated and is denoted in parenthesis () for easy comparison to thermal modeling results included within this chapter.

Wood-framed walls are typically constructed with 16-inch on-center stud spacing for standard framing or 24-inches on-center stud spacing for advanced framing



Fig. 8-6 System 8 Option B on intermittent cladding support clips. Refer to Chapter 7 for exterior insulation selection and cladding attachment discussion.

methods. Nominal 2x6 framing accommodates up to an R-21 fiberglass or R-23 mineral fiber batt insulation and nominal 2x8 framing up to an R-30 mineral fiber batt insulation. When continuous insulation requirements are to be met, this system uses veneer Option B and will have insulation exterior of the wood frame structure, wall sheathing, and Class IV vapor permeance air barrier and WRB system as discussed in the Chapter 7 system.

For all energy code compliance strategies except the *prescriptive insulation R-value method strategy*, this wall system's U-factor will need to be calculated or determined from table values; however, it may or may not be required to be less than the prescriptive U-factors shown in Table 8-2.

The Thermal Performance and Energy Code Compliance discussion on page i-33 and Fig. i-26 on page i-39 of the introductory chapter describes the typical process of navigating energy code compliance options. Additionally, the thermal modeling results demonstrated in this chapter may be used to assist with selecting wall system components (e.g., cladding support clip type, insulation R-value/inch, etc.) to achieve a target U-factor. Options for thermally optimizing this assembly, as determined through the modeling results, are also discussed.

System Effective Thermal Performance

When exterior insulation is used with Option B of this wall system, cladding support clips such as intermittent Z-girts or fiberglass standoff clips (as shown in Fig. 8-7 and Fig. 8-9) penetrate the exterior insulation and create areas of thermal bridging (i.e., heat loss). An example of the thermal bridging that a hot-dipped galvanized intermittent Z-girt may have is described by Fig. 8-8, which shows the

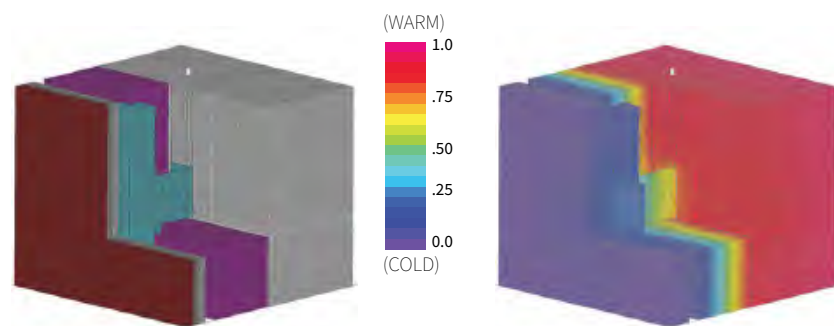


Fig. 8-7 Three-dimensional section of an intermittent galvanized steel Z-girt through exterior insulation

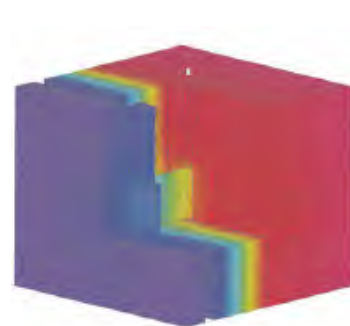


Fig. 8-8 Three-dimensional thermal image of the intermittent Z-girt shown in Fig. 8-7

relative thermal gradient of this system when thermally modeled.

The lighter blue thermal gradient at the clip represents a warmer temperature than the dark blue at the adjacent insulation face—an indicator of isolated heat loss at the penetration through the exterior insulation. This thermal bridging reduces the system's effective thermal performance.

Three-dimensional thermal modeling demonstrates the effective thermal performance of this wall system for Option A with various types of cavity insulation and for Option B with and without exterior insulation (e.g., Fig. 8-5). A discussion on the modeling performed for this guide is included in the Appendix.

Thermal Modeling: Variables

The following are system-specific modeling variables:

- **Framing and Cavity Insulation:** 2x6 with R-21 batt insulation or 2x8 with R-30 batt insulation. Modeling results include a full-height wood-framed wall with a floor line. Standard framing allowance for 77% insulated cavity and 23% framing members such as studs, plates, and headers is used.
- **Cladding Supports Clips:** For Option B, two example cladding support clip types are considered and are shown in Fig. 8-9:
 - Intermittent Z-girts (16-gauge) made of either stainless steel or galvanized steel. Clips are 6-inches tall and spaced at 24-inches on-center vertically, 16-inches on-center horizontally.
 - Fiberglass standoff clips spaced at 24-inches on-center vertically and 16-inches on-center horizontally. Both stainless steel and galvanized steel fasteners are considered for the fiberglass standoff clip option.
- **Exterior Insulation:** R-4.2/inch or R-6/inch insulation product in thicknesses of 1-, 2-, and 3-inches. The R-values selected demonstrate the lower and upper thermal resistance of typical exterior insulation products.



Fig. 8-9 Cladding support clip options including an intermittent Z-girt (top) and fiberglass standoff clip (bottom)

Project-specific thermal performance values for an opaque above-grade wall should be used for energy code compliance and determined from a source that is approved by the authority having jurisdiction. Thermal performance sources may include the appendices of the 2015 WSEC,³ ASHRAE 90.1,⁴ COMcheck,⁵ thermal modeling and calculation exercises as well as other industry resources.

Thermal Modeling: Results

Modeling results are shown in Table 8-1, Fig. 8-11, and Fig. 8-12 (see page 8-12 and page 8-13) and demonstrate the system's effective R-value under various conditions; Fig. 8-11, and Fig. 8-12 graphically represent Table 8-1 results.

Below is a discussion of the results. For Option B, where reductions in the system's effective R-value are discussed, these values are as compared to the system's effective R-value "Without Clips".

Option A

- Modeling results as shown in Table 8-1 demonstrate that the system's effective R-value is 17.7 with a 2x6 wall and R-21 batt. An effective R-value of 22.2 is achieved with a 2x8 wall and R-30 batt. When compared to the prescriptive energy code values in Table 8-2, modeling results demonstrate that *an R-30 cavity batt may be an alternative approach to using continuous insulation with this system.*

Option B

- Fiberglass standoff clips with galvanized fasteners and stainless steel intermittent Z-girts provide relatively similar system effective R-values as shown in Fig. 8-12 and Table 8-1. These clips reduce the system's effective R-value by 3 to 11% depending on the thickness of exterior insulation. The most optimal effective R-value is provided with a fiberglass clip and stainless steel fasteners. *These results demonstrate that some performance targets can be met without proprietary cladding attachment systems. This consideration may prove to be a cost-effective solution.*

Sheathing Selection

The exterior sheathing of this system is typically a wood- or gypsum-based product and is designated by structural requirements. Where wood-based products are used, plywood is generally recommended for its moisture tolerance. Where gypsum board is used, a product resistant to organic growth and moisture

Some wood preservative treatments may react with certain fastener products; care should be taken to select compatible fasteners and wood preservative treatment.

is recommended. Fiberglass-faced gypsum board products are commonly used; avoid paper face products.

Plywood sheathing may be preferred over gypsum sheathing in system Option A as it provides for a more durable attachment of temporary drainage mat fasteners between framing members.

Drainage, Ventilation, and Water Deflection

Adhered masonry veneer with grouted joints is expected to shed most water it is exposed to; however, some moisture is expected to penetrate the cladding and enter the drainage matrix of Option A or the air cavity of Option B. This moisture is either drained through the drainage matrix (see Fig. 8-10) or through the air cavity created by the furring strips of Option B (Fig. 8-13 on page 8-14) and is deflected back to the exterior of the cladding or evaporates by way of ventilation behind the cladding.

Drainage and Ventilation

For Option A, the drainage cavity is created by the drainage matrix. An example of an entangled-filament drainage matrix with filter fabric facer is shown in Fig. 8-10. A plastic-dimpled drainage matrix may be used as an alternative to the filament type of drainage matrix. This drainage material allows drainage of liquid water and some ventilation. In the Northwest region, a minimum drainage depth of $\frac{3}{4}$ -inch is often used; however, $\frac{1}{2}$ -inch is more common in non-marine areas. A moisture-tolerant filter fabric between the drainage matrix and the mortar bed protects the drainage cavity from mortar collection. This fabric is often factory-adhered to the drainage matrix and replaces the need for a separate installation of building paper prior to scratch coat application.



Fig. 8-10 Drainage matrix over a mechanically fastened air barrier and WRB system field membrane with sealed laps.

Table 8-1 System 8 thermal modeling results for Options A and B

System 8B: Wood Frame Wall with Adhered Masonry Veneer, 23% Framing Factor 2x6 Framing, R-21 Batt Insulation, R-4.2/in - R-6/in Exterior Insulation, Thin-Set Masonry					
3D Thermal Modeling Effective R-Value of System (ft ² ·F·hr/Btu)					
Clip Type	Clip Penetration Area	Exterior Insulation Thickness	Nominal Insulation R-Value (Cavity + Exterior Insulation)	Cavity + Exterior Insulation (Without Clips Considered)	Stainless-Steel Clip and/or Fasteners
Fiberglass Standoff Clips	0.80%	0"	21	18.2	-
		1"	21 + 4.2-6	22.5-24.3	21.9-23.5
		2"	21 + 8.4-12	26.8-30.5	25.8-28.8
		3"	21 + 12.6-18	31.0-36.4	29.4-33.8
Intermittent 6" Z-Girts	0.09%	0"	21	18.2	-
		1"	21 + 4.2-6	22.5-24.3	21.7-23.2
		2"	21 + 8.4-12	26.8-30.5	25.3-28.0
		3"	21 + 12.6-18	31.0-36.4	28.6-32.4

System 8A: Wood Frame Wall with Adhered Masonry Veneer, 23% Framing Factor No Exterior Insulation, Thick-Set Masonry over Drain Mat					
Framing					
2x6	-	-	21	17.7	-
2x8	-	-	30	22.2	-

Table 8-2 System 8 prescriptive energy code compliance values excerpted from Table i-1 of the introductory chapter

OPAQUE ABOVE-GRADE WALL - THERMAL ENVELOPE REQUIREMENTS									
Guide Assembly #	Energy Code Climate Zone	2012 SEC		2012 WSEC		2014 OEESC		2012 IECC	
		5 and Marine 4	Group R	5, 6 and Marine 4	Group R	5 and Marine 4	Group R	5 and Marine 4	Group R
8A 8B	Wood-Framed Wall with Adhered Masonry Veneer	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R
		R-13 + R-7.5ci	R-21 int	R-13 + R-3.8ci	R-13 + R-3.8ci	R-13 + R-3.8ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci
		U-0.051 (R-19.6)	U-0.054 (R-18.5)	U-0.054 (R-18.5)	U-0.064 (R-15.6)	U-0.064 (R-15.6)	U-0.064 (R-15.6)	U-0.051 (R-19.6)	U-0.051 (R-19.6)

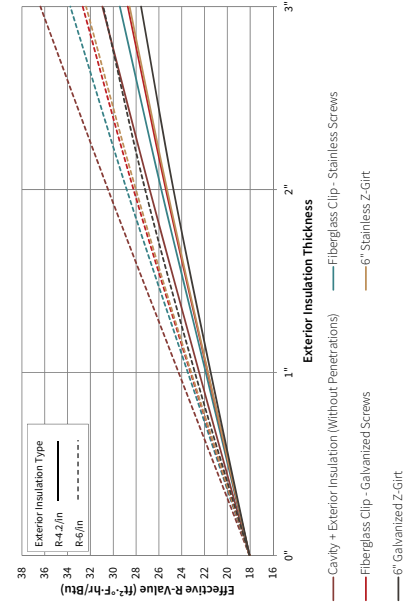


Fig. 8-11 System 8 Option B effective R-value modeling results for various cladding support clips and a range of insulation R-values/inch

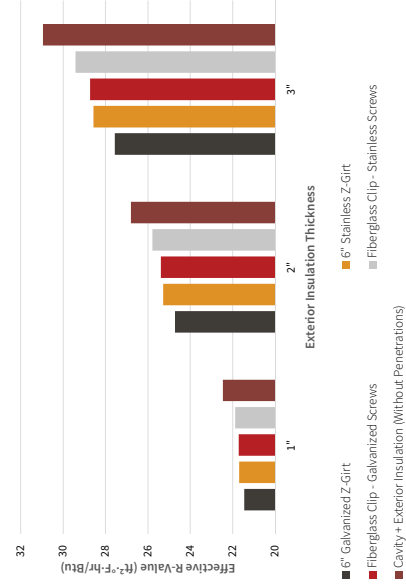


Fig. 8-12 System 8 Option B effective R-values for different cladding support clips and R-4.2/inch insulation

For Option B, the air cavity is typically created by 3/4-inch-thick preservative-treated furring strips that align with stud framing as shown in Fig. 8-13. Furring strips allow for more ventilation within the cavity than drainage matrix or mat products. Furring strips should be broken at floor lines and any other location where building movement may occur.



Fig. 8-13 Preservative-treated furring strips over a mechanically fastened air barrier and WRB system field membrane. Insect screen wraps around the top and bottom of the furring strips to close off the air cavity from insects while still allowing for drainage and ventilation.

In the Northwest region, the drainage matrix layer or furred air cavity is typically open at the top and bottom to encourage ventilation. When open, it is recommended that the cavity is protected from insects by wrapping the drainage matrix layer perimeter (Option A) or furring strip terminations (Option B) with insect screen. This approach would commonly be performed at cladding openings, base of walls, and sheet-metal transitions such as at head flashings and cross-cavity flashings.

Sheet-Metal Components

Sheet-metal components for this system are reflected throughout the details located at the end of this chapter. Cross-cavity sheet-metal components are located at the head of wall penetrations (e.g., a window head) and at cross-cavity flashing locations. These flashings help drain the rainscreen cavity and protect any air barrier and WRB system components behind them. Counterflashed sheet-metal components assist with water shedding and are typically located at windowsill and parapet top conditions; they protect the cavity from water ingress while allowing ventilation of the air cavity.

When Option B is used with exterior insulation, sheet-metal flashing components that penetrate the exterior insulation act as a thermal bridge and degrade the thermal performance of the system; however, they are a necessary element for rainscreen wall system performance.

Refer to the Sheet-Metal Flashing Components discussion on page i-46 for

general recommendations on sheet-metal flashing products, including design considerations and materials.

Movement Joints

For both options of this wall system, the wood-framed structure will undergo shrinkage. For Option A, the cement-based scratch and bond coat and mortar joints will shrink. Clay masonry veneer units will expand over time, whereas manufactured concrete veneer products and grout joints between units will shrink. While the reinforcing mesh of Option A will assist with crack control, movement within the veneer and between the veneer and backup wall structure still needs to be accommodated with horizontal and vertical movement joints. Similarly, with Option B, volumetric changes will occur between the veneer and wood-framed wall and must be accommodated. For additional discussion regarding movement of adhered veneers in cement backer board applications (Option B) refer to the Chapter 7 Movement Joints discussion on page 7-14.

For both Options A and B, horizontal gaps within the veneer and cladding and furring strips typically occur at cross-cavity sheet-metal flashing locations that coincide with building floor lines, a common location for building movement. These gaps are typically provided at, and should be continuous across, all elevations of the building. Gaps above and below penetrations (e.g., windows)

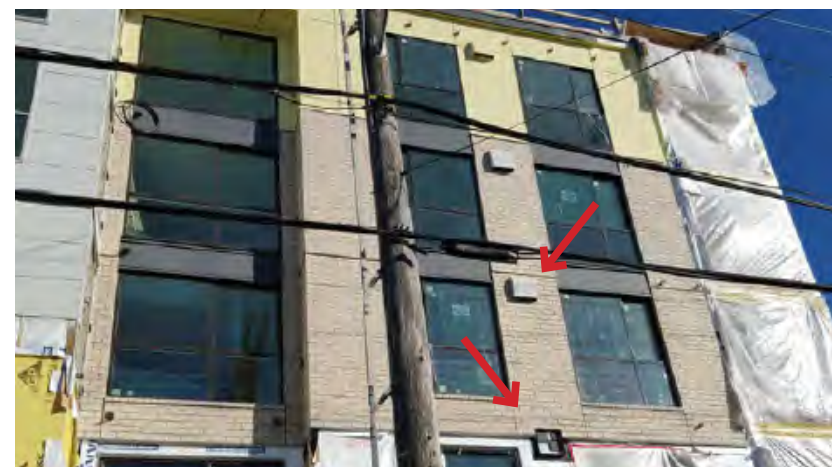


Fig. 8-14 Control joints align with window jambs in this adhered veneer application (lower arrow). Movement joints occur at cross-cavity sheet-metal flashings, which occur at each floor line (upper arrow).

and below structure projections (e.g., parapet blocking) are also recommended to minimize any stresses on the veneer system. Example locations for an adhered veneer application are shown in Fig. 8-14 on page 8-15.

The location of vertical joints varies throughout the industry and should be confirmed with the veneer unit manufacturer for the project-specific application. This guide recommends locating vertical movement joints throughout the veneer system and considering horizontal-to-vertical placement relationships.

Typical locations of joints for accommodating movement, drainage, and/or rainscreen cavity ventilation are identified with an asterisk (*) in chapter details. In general, a minimum gap dimension of $\frac{3}{8}$ -inch is recommended; however, it is the Designer of Record's responsibility to appropriately locate and size all movement joints.

Refer to the Movement Joints discussion on page i-48 for more information on locating veneer joints and sealant joint best practices.

Structural Considerations

For Option A, the masonry veneer is adhered with a bond coat to the mortar scratch and/or brown coats. Metal lath reinforces the mortar and is attached back to the wood-framed structure. The thin masonry veneer should be designed to comply with local building code and TMS 402-16⁶ requirements. The code requires that adhered veneers be applied over concrete or masonry backings and, as such, there are special requirements for installing adhered veneer over wood-framed walls.

In Option A, the metal lath reinforces the mortar scratch coat and minimizes the risk of cracking that may occur due to mortar shrinkage. Metal lath for this wall system is recommended to be a minimum 3.4 lbs/sq yd complying with ASTM C847,⁷ installed in conformance with ASTM C1780,⁸ and fastened with a minimum $\frac{3}{4}$ -inch embedment directly into the wood-framed structure as noted in ASTM 1063.⁹ Fastener spacing is typically no more than 6-inches on-center vertically. The wood-framed wall itself should be designed to limit the out-of-plane deflection of the wall framing. For thin brick veneer, the Brick Institute of America recommends a maximum deflection of L/360 with a maximum allowable variation of $\frac{1}{4}$ -inch per 10 feet from plane.¹⁰ Fig. 8-15 shows an example of the Option A veneer mock-up.

For the Option B Structural Considerations, refer to the related sections within Chapter 7. As discussed in Chapter 7, where exterior insulation is provided and cladding attachment clips are used, minimizing the cladding support spacing may be considered to limit out-of-plane deflection but should also be balanced with

the impact on the system's effective thermal performance of the wall system. As shown in Fig. 8-16 on page 8-18, smaller cladding support clip spacing is necessary to resist greater wind loads. As clip spacing is reduced, the effective thermal performance of the system is also reduced. Using lower-conductivity clips can reduce the impact that cladding support clips have on the thermal performance.

Corrosion Resistance

It is best practice to match the durability and longevity of metal components within this system to that expected of the masonry veneer. Metal components within this system include metal lath, sheet-metal flashings, and fasteners such as nails, screws, and staples. Where available, metal components should be manufactured of Type 304 or 316 stainless steel, which are nonstaining and resistant to the alkaline content of mortar materials. Consider minimum G185 hot-dipped galvanized where stainless-steel components may not be available.

Where available, sheet-metal components supporting the veneer or acting as sheet-metal flashings should be AISI Type 304 or 316 stainless steel per ASTM A666,¹¹ which are nonstaining, resistant to the alkaline content of mortar materials, and tolerant of the humidity conditions that can exist within the air cavity. Where stainless steel components may not be available or economically feasible, G90 or G185 hot-dipped galvanized steel products per ASTM A653¹² or minimum AZ50 or AZ55 galvalume-coated sheet steel in conformance with ASTM A792¹³ may be used but should be carefully considered based on the project's exposure and expected longevity. Coating the exposed top finish of any sheet metal with an architectural-grade coating conforming to AAMA 621¹⁴ is recommended.

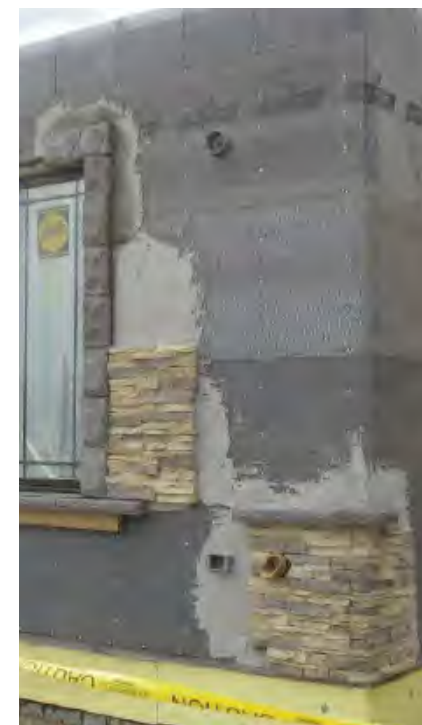


Fig. 8-15 Adhered manufactured stone mock-up. Metal lath is installed over top of a drainage matrix with filter fabric. A scratch coat is applied over top of the metal lath. The manufactured stone is set in a bond coat over top of the scratch coat.

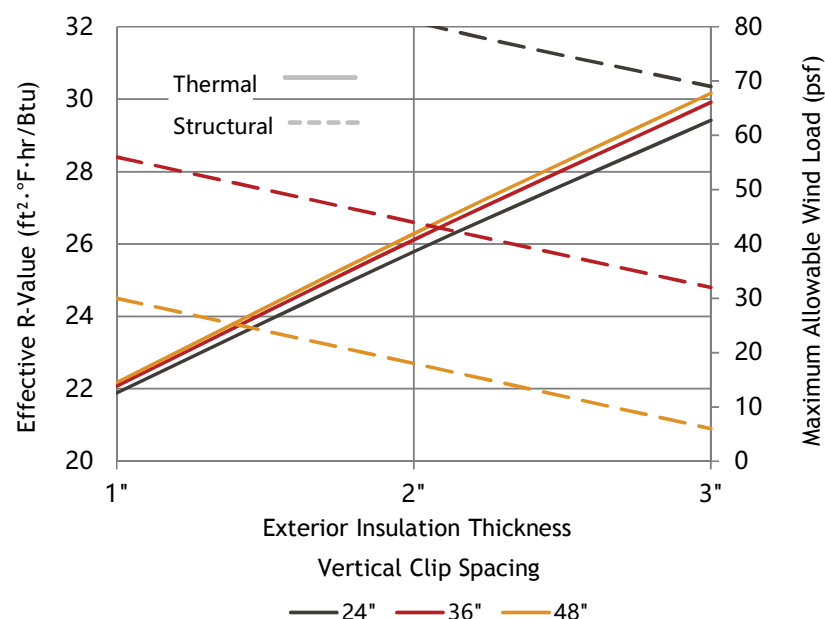


Fig. 8-16 System effective R-value as it compares to maximum-allowable wind loads for various fiberglass standoff clip spacing. These results assume fiberglass standoff clips with two stainless-steel screws spaced at 3-inches vertically and attached into wood framing. The clips resist vertical gravity loads equally and receive horizontal loads based on their tributary areas. The design is generally limited by the pull-out resistance of the upper screw through the clip, which is under tension from the weight of the cladding and from horizontal wind suction pressures. The allowable screw loads are based on testing data and are specific to the type of screw modeled. The allowable wind pressure should always be compared to the specified wind pressure acting on the cladding, as determined by the local building code in the applicable jurisdiction. These structural values provide a schematic relationship between thermal and structural performance and are not intended to be used as structural design values. In the structural design graphs, the cladding weight was set at 20 psf for all systems. The horizontal clip spacing remained at 16-inches on-center. The vertical spacing options are 24-, 36-, and 48-inches, and the exterior insulation thickness ranges from 1 to 3-inches.

Cement Backer Board

Cement backer board used within Option B of this system is exterior-grade water-, mold-, and mildew-resistant, which meets ASTM C1325¹⁵ Type A (exterior applications) or ANSI 118.9.¹⁶ The cement backer board is attached to the continuous vertical furring as required by the backer board manufacturer and project-specific design loads. The attachment method used should be appropriate for the furring and cladding support clip design.

Joints of the cement board are typically staggered and treated with a mesh tape bed in the thinset mortar. Cement backer board product should be installed in conformance with the manufacturer installation instructions. The cement backer board should not span joints within the veneer that are expected to accommodate movement, similar to that shown in Detail 7-E.

Crack Isolation Membrane

The crack isolation membrane in Option B is a flexible fluid-applied membrane used in adhered masonry veneer applications where the veneer is adhered to a cement backer board. The crack isolation membrane is applied following installation of the cement backer board and treatment of the board joints as required by the cement backer board manufacturer. This membrane assists with:

- Reducing risk of veneer cracking. The veneer adheres to the membrane, which allows the cement backer board to move relatively independent of the veneer. *It is important to remember that use of a crack isolation membrane does not reduce or replace the need for appropriately designed and installed movement joints.*
- Reducing fastener corrosion risk. The membrane protects cement board fasteners from moisture held within the veneer and thinset mortar.
- Reducing cement board exposure to moisture. The membrane reduces the moisture exchanged between the cement board and thinset mortar and can increase the longevity of the board.
- Reducing efflorescence. The membrane reduces the moisture exchanged between the cement board and thinset mortar and may result in reduced efflorescence; thus, it may also be referred to as an efflorescence mitigation membrane.

Traditionally, this membrane may have been installed to protect the primary structure from moisture exposure. However, in this rainscreen system, *the crack*

isolation membrane is not a replacement for the air and water control layers, which are located on the sheathing face of the wood-framed backup wall.

It is best practice to use a crack isolation membrane over cement backer board in adhered masonry veneer applications. Some manufacturers may require this membrane to achieve a warrantable cladding installation.

Masonry Veneer

There are several types of adhered veneer unit products that may be used with this system. Those most typical within the Northwest include thin brick made of clay or shale or manufactured stone.

Thin brick used for this system is exterior-grade and complies with ASTM C1088.¹⁷ Manufactured stone masonry veneer units comply with ASTM C1670.¹⁸ For thick bed applications (Option A), the scratch coat complies with ASTM C270¹⁹ for site mix applications or ASTM C1714²⁰ for preblended mortar and should be Type S or N. Setting bed mortar should also conform to these standards or may conform to ANSI 118.4.²¹

For applications over cement board substrates, a polymer-modified thinset mortar is recommended. While the brick and manufactured stone veneer industries have not established standards for thinset mortar performance, this guide looks to the tile industry and the American National Standard Institute (ANSI) for the Installation of Ceramic Tile—particularly ANSI A118.15,²² which provides standard specifications for improved performance of modified mortars. This guide recommends that the thinset mortars used in this system demonstrate conformance with the ANSI 118.15.²²

Appropriate product selection of masonry veneer unit and thinset mortar materials is necessary to provide a durable and water-resistive cladding system. The veneer units, thinset mortar, and joints should also be installed in conformance with industry standard best practices and manufacturer requirements and should comply with ASTM C1780.²³ The specifics of architectural characteristics and structural properties of the veneer system, including mortar and cladding support systems, should be designed and reviewed by a qualified Designer of Record.

Various industry resources are available to assist with veneer design and are listed in the Resources section.

Clear Water Repellents

Applied clear water repellents are recommended for either Option A or Option B applications of this system. Refer to the introductory chapter of this guide for more information on selecting an appropriate clear water repellent and best practice installation guidelines.

Pricing Summary

A pricing summary for this system is provided in Table 8-3 on page 8-24 (Option A) and Table 8-4 on page 8-25 (Option B). Pricing demonstrates the relative price per square foot and is based on a 10,000-square-foot wall area with easy drive-up access. Pricing includes all components outboard of the exterior wall sheathing and provides no evaluation for interior finishes (including vapor retarder), framing/sheathing, or cavity insulation. Where Option B may be used with exterior insulation and a cladding attachment support system, refer to the Chapter 7 system Pricing Summary Table 7-5 on page 7-23. Pricing is valid for the 2018 calendar year. Current pricing is also available at www.masonrysystemsguide.com.

Online Availability

The content of this guide and additional resources may be accessed online at www.masonrysystemsguide.com. Also available online are downloadable digital versions of two- and three-dimensional system details, cutaway sections, and sample project specifications as well as ongoing updates to references and resources included within this guide.

Chapter References

1. International Code Council. *2015 International Building Code*. (Country Club Hills, IL: International Code Council, Inc., 2014).
2. National Fire Protection Association. *NFPA 285 - Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Non-Load-Bearing Wall Assemblies Containing Combustible Components*. (Quincy, MA: National Fire Protection Association, 2012).
3. 2015 Washington State Energy Code, Commercial Provisions. Chapter 51-11C WAC (filed by Washington State Legislature, January 19, 2016).
4. American Society of Heating, Refrigerating, and Air-Conditioning Engineers. *ANSI/ASHRAE/IES Standard 90.1-2016 Energy Standard for Buildings Except Low-Rise Residential Buildings, SI ed.* (Atlanta: ASHRAE, 2016).
5. U.S. Department of Energy. *COMcheck* (version 4.0.7). Windows or Online. Washington, D.C.: U.S. Department of Energy, 2017, <https://www.energycodes.gov/comcheck>.

6. The Masonry Society. *TMS-402/602-16 Building Code Requirements and Specification for Masonry Structures*. (n.p.: The Masonry Society, 2016).

7. ASTM International. *ASTM C847-14a Standard Specification for Metal Lath*. (West Conshohocken, PA: ASTM International, 2014).

8. ASTM International. *ASTM C1780-16a Standard Practice for Installation Methods for Adhered Manufactured Stone Masonry Veneer*. (West Conshohocken, PA: ASTM International, 2016).

9. ASTM International. *ASTM C1063-17 Standard Specification for Installation of Lathing and Furring to Receive Interior and Exterior Portland Cement-Based Plaster*. (West Conshohocken, PA: ASTM International, 2017).

10. The Brick Industry Association. *Technical Notes 28C Thin Brick Veneer*. (Reston, VA: The Brick Industry Association, 2014).

11. ASTM International. *ASTM A666-15 Standard Specification for Annealed or Cold-Worked Austenitic Stainless-Steel Sheet, Strip, Plate, and Flat Bar*. (West Conshohocken, PA: ASTM International, 2015).

12. ASTM International. *ASTM A653/A653M-15e1 Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process*. (West Conshohocken, PA: ASTM International, 2015).

13. ASTM International. *ASTM A792/A792M-10(2015) Standard Specification for Steel Sheet, 55% Aluminum-Zinc Alloy-Coated by the Hot-Dip Process*. (West Conshohocken, PA: ASTM International, 2015).

14. American Architectural Manufacturers Association. *AAMA 621-02 Voluntary Specification for High-Performance Organic Coatings in Coil-Coated Architectural Hot-Dipped Galvanized (HDG) and Zinc-Aluminum Coated Steel Substrates*. (Schaumburg, IL: American Architectural Manufacturers Association, 2002).

15. ASTM International. *ASTM C1325-17 Standard Specification for Non-Asbestos Fiber-Mat Reinforced Cementitious Backer Units*. (West Conshohocken, PA: ASTM International, 2017).

16. American National Standards Institute, "A118.9 American National Standard Specifications for Test Methods and Specifications for Cementitious Backer Units—1999 [Reaffirmed 2005 and 2010]," in *ANSI American National Standard Specifications for the Installment of Ceramic Tile*. (Anderson, SC: Tile Council of North America, Inc., 2014).

17. ASTM International. *ASTM C1088-14 Standard Specification for Thin Veneer Brick Units Made from Clay or Shale*. (West Conshohocken, PA: ASTM International, 2014).

18. ASTM International. *ASTM C1670/C1670M-16 Standard Specification for Adhered Manufactured Stone Masonry Veneer Units*. (West Conshohocken, PA: ASTM International, 2016).

19. ASTM International. *ASTM C270-14a Standard Specification for Mortar for Unit Masonry*. (West Conshohocken, PA: ASTM International, 2014).

20. ASTM International. *ASTM C1714/C1714M-16 Standard Specification for Preblended Dry Mortar Mix for Unit Masonry*. (West Conshohocken, PA: ASTM International, 2016).

21. American National Standards Institute, "A118.4 American National Standard Specifications for Modified Dry-Set Cement Mortar – 2012 [Revised]," in *ANSI American National Standard Specifications for the Installment of Ceramic Tile*. (Anderson, SC: Tile Council of North America, Inc., 2014).

22. American National Standards Institute, "A118.15 American National Standard Specifications for Improved Modified Dry-Set Cement Mortar –2012 [New]," in *ANSI American National Standard Specifications for the Installment of Ceramic Tile*. (Anderson, SC: Tile Council of North America, Inc., 2014).

23. ASTM International. *ASTM C1780-16a Standard Practice for Installation Methods for Adhered Manufactured Stone Masonry Veneer*. (West Conshohocken, PA: ASTM International, 2016).

Table 8-3 System 8 Option A wood-framed wall with adhered veneer pricing summary

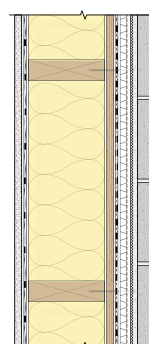
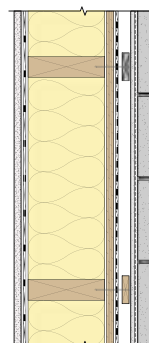
System 8(A): Wood Framed Wall with Adhered Masonry Veneer (Thick-Set)					
System Component	Baseline Product	Alternate (call for estimate)	Baseline Cost/ft ² (incl. labor)		
			Low	High	
INTERIOR					
1	Interior gypsum board	No evaluation of these components provided.			
2	Vapor retarder				
3	Wood-framed wall with batt insulation				
4	Exterior sheathing				
5*	Vapor-permeable air and water-resistive barrier	Fully adhered or mechanically attached sheet-applied membrane	Fluid-applied membrane system	\$1.50	\$3.75
6*	Minimum 1/2-inch drainage matrix with filter fabric	Entangled filament drainage matrix with moisture-resistive filter fabric	No specified alternate	\$1.50	\$2.75
7*	Metal lath	Expanded metal lath, 3.4 lb/sq yd, G90; hot-dipped galvanized fasteners	No specified alternate	\$5.50	\$7.25
8*	Mortar bed	Prepackaged/preblended polymer fortified	No specified alternate		
9*	Adhered masonry or stone veneer with grouted joints	Modular (3/4" x 2-1/4" x 7-5/8") extruded TBX; premixed mortar adhesive; running bond; 3/8" mortar joints	Alternate veneer products	\$30.00	\$41.00
10*	Clear water repellent	Silane/siloxane blend	Antigraffiti clear water repellent	\$1.00	\$1.50
EXTERIOR					
Total cost to install 10,000 sq ft wall area w/easy drive-up access -->				\$39.50	\$56.25
Pricing Summary Discussion			System Plan View		
<ul style="list-style-type: none">- Low and high baseline costs are based on baseline products and installed labor costs. Call for an estimate for alternative product pricing.- Baseline costs provided will vary based on product-specific conditions as well as project location and should be used as an estimate only.- Veneer unit prices are for typical units as noted. Pricing will vary based on size, color, and finish and should be confirmed with the unit manufacturer.- *See the Resources section of this guide for product recommendation.					

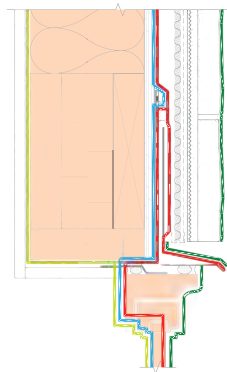
Table 8-4 System 8 Option B wood-framed wall with adhered veneer pricing summary

System 8(B): Wood Framed Wall with Adhered Masonry Veneer (Thin-Set)					
System Component	Baseline Product	Alternate (call for estimate)	Baseline Cost/ft ² (incl. labor)		
			Low	High	
INTERIOR					
1	Interior gypsum board	No evaluation of these components provided.			
2	Vapor retarder				
3	Wood-framed wall with batt insulation				
4	Exterior sheathing				
5*	Vapor-permeable air and water-resistive barrier	Fully adhered or mechanically attached sheet-applied membrane	Fluid-applied membrane system	\$1.50	\$3.75
6*	Furring strips	3/4"-thick preservative treated furring strips	No specified alternate	\$1.25	\$2.25
7*	Cement backer board	Moisture-resistant 5/8"-thick, taped & fastened	No specified alternate	\$2.50	\$4.00
8*	Adhered masonry or stone veneer with grouted joints, includes polymer-modified thin-set	Modular (3/4" x 2-1/4" x 7-5/8") extruded TBX; running bond; 3/8" mortar joints	Alternate veneer products	\$39.00	\$41.00
9*	Clear water repellent	Silane/siloxane blend	Antigraffiti clear water repellent	\$1.75	\$2.50
EXTERIOR					
Total cost to install 10,000 sq ft wall area w/easy drive-up access -->				\$46.00	\$53.50
Pricing Summary Discussion			System Plan View		
<ul style="list-style-type: none">- Low and high baseline costs are based on baseline products and installed labor costs. Call for an estimate for alternative product pricing.- Baseline costs provided will vary based on product-specific conditions as well as project location and should be used as an estimate only.- Veneer unit prices are for typical units as noted. Pricing will vary based on size, color, and finish and should be confirmed with the unit manufacturer.- *See the Resources section of this guide for product recommendation.					

LEGEND

1. Typical Assembly (Option A):
 - Interior gypsum board
 - Vapor retarder
 - Wood-framed wall with batt insulation
 - Exterior sheathing
 - Sheet-applied air barrier and WRB field membrane
 - Filter fabric over minimum drainage matrix
 - Metal lath
 - Scratch and bond coats
 - Adhered masonry veneer with grouted joints
 - Clear water repellent
 2. Continuous air barrier sealant at sheet-applied air barrier and WRB field membrane lap over prestrip
 3. Sheet- or fluid-applied air barrier and WRB prestrip membrane
 4. Sloped sheet-metal head flashing with hemmed drip edge and end dams beyond
 5. Insect screen
 6. Sealant over backer rod
 7. Window strap anchor, bed in air barrier sealant at continuous air barrier sealant joint plane
 8. Continuous air barrier sealant, tie to continuous seal at window perimeter
 9. Non-flanged window
- * Size gap for drainage and ventilation, minimum $\frac{3}{8}$ -inch

Water-Shedding Surface and Control Layers

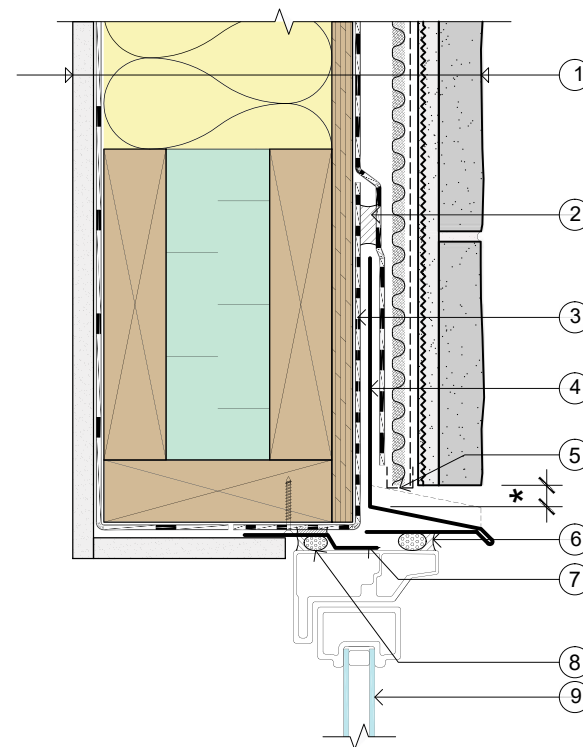


Water-Shedding Surface

Control Layers:†

Water
Air
Vapor
Thermal

†Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing



Detail Discussion

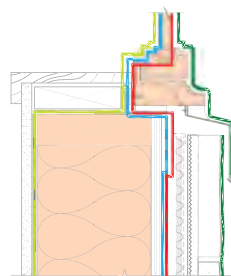
- Air and water control layer continuity is provided by the sheet-applied air barrier and WRB field membrane, sheet-applied or fluid applied air barrier and WRB prestrip membrane, continuous air barrier sealant, and air barrier sealant transition to the window.
- A non-flanged window is shown at right and facilitates future window repair and replacement without the need to remove the masonry veneer. The window strap anchors are bed in sealant prior to fastening to prevent the passage of air and water behind strap locations.
- See Chapter 7 detailing when a fluid-applied or self-adhered sheet field membrane will be used for this wall system.

Typical Window Head
Detail 8A-A

LEGEND

1. Typical Assembly (Option A):
 - Interior gypsum board
 - Vapor retarder
 - Wood-framed wall with batt insulation
 - Exterior sheathing
 - Sheet-applied air barrier and WRB field membrane
 - Filter fabric over minimum drainage matrix
 - Metal lath
 - Scratch and bond coats
 - Adhered masonry veneer with grouted joints
 - Clear water repellent
 2. Non-flanged window on minimum 1/4-inch-thick intermittent shims
 3. Sealant over backer rod
 4. Sloped sheet-metal sill flashing with hemmed edge and end dams beyond, attached to intermittent L-angle at window per window manufacturer recommendations
 5. Self-adhered sheet or fluid-applied flashing membrane
 6. Continuous air barrier sealant tied to continuous seal at window perimeter
 7. Continuous back dam angle at rough opening sill, minimum 1-inch tall. Fasten window through back dam angle per window manufacturer recommendations.
 8. Insect screen
- * Size gap for project-specific movement and ventilation, minimum 3/8-inch

Water-Shedding Surface and Control Layers

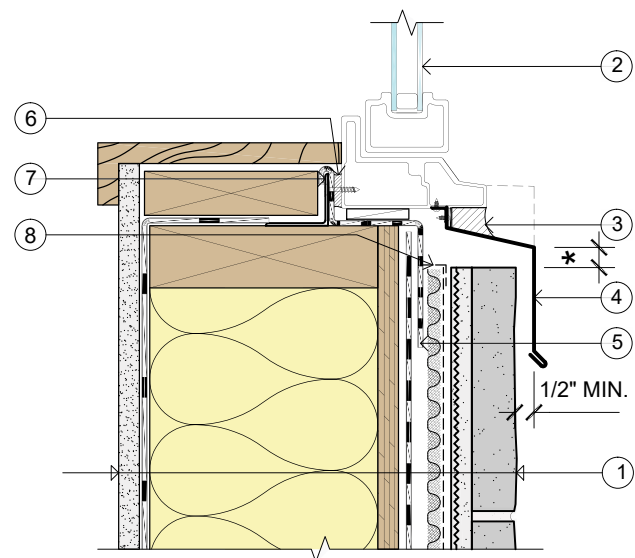


— Water-Shedding Surface

Control Layers:†

— Water
— Air
— Vapor
— Thermal

† Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing



Detail Discussion

- Air and water control layer continuity is provided by the sheet-applied air barrier and WRB field membrane, self-adhered or fluid-applied flashing membrane, and air barrier sealant transition to the window.
- The continuous back dam angle and self-adhered or fluid-applied flashing membrane form the windowsill pan. The window is set on intermittent shims over the sill pan to encourage drainage from the rough opening drainage into the rainscreen cavity, where it can exit the cladding system below.
- The sloped sheet-metal sill flashing with hemmed drip edge sheds water from the window and cladding above, directing it away from the rainscreen cavity and veneer face below.

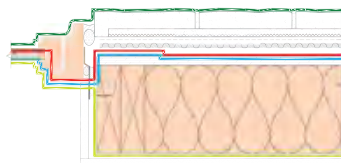
Typical Windowsill

Detail 8A-B

LEGEND

1. Typical Assembly (Option A):
 - Interior gypsum board
 - Vapor retarder
 - Wood-framed wall with batt insulation
 - Exterior sheathing
 - Sheet-applied air barrier and WRB field membrane
 - Filter fabric over minimum drainage matrix
 - Metal lath
 - Scratch and bond coats
 - Adhered masonry veneer with grouted joints
 - Clear water repellent
2. Non-flanged window
3. Sealant over backer rod
4. Sheet- or fluid-applied air barrier and WRB prestrip membrane
5. Continuous air barrier sealant, tie to continuous seal at window perimeter
6. Window strap anchor, bed in air barrier joint plane

Water-Shedding Surface and Control Layers

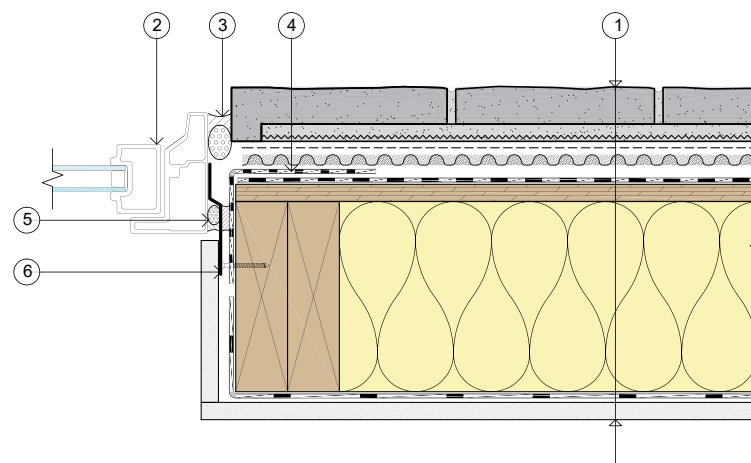


Water-Shedding Surface

Control Layers:*

- Water
- Air
- Vapor
- Thermal

* Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing



Detail Discussion

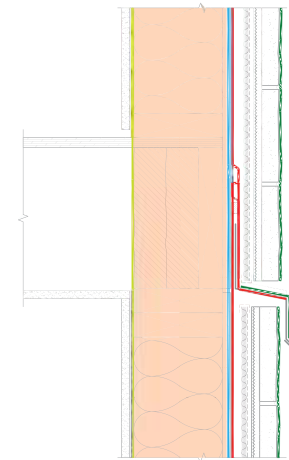
- Air and water control layer continuity is provided by the sheet- or fluid-applied air barrier and WRB field membrane, prestrip membrane, and air barrier sealant transition to the window.
- The window strap anchors are bed in sealant prior to fastening to prevent the passage of air and water behind strap locations.
- The backer rod and sealant between the window and adhered veneer provides a continuous water-shedding surface across the window-to- wall transition.
- In the Northwest region, vapor permeable sheet- or fluid-applied air barrier and WRB prestrip membranes are recommended at jamb and head conditions to allow underlying sheathing and framing components an opportunity to dry to the exterior.

Typical Window Jamb
Detail 8A-C

LEGEND

1. Typical Assembly (Option A):
 - Interior gypsum board
 - Vapor retarder
 - Wood-framed wall with batt insulation
 - Exterior sheathing
 - Sheet-applied air barrier and WRB field membrane
 - Filter fabric over minimum drainage matrix
 - Metal lath
 - Scratch and bond coats
 - Adhered masonry veneer with grouted joints
 - Clear water repellent
 2. Continuous air barrier sealant at air barrier and WRB field membrane lap
 3. Sloped sheet-metal cross-cavity flashing with hemmed drip edge and end dams beyond at intersecting elements
 4. Closed-cell spray foam insulation
 5. Expansion gap
 6. Insect screen
- * Size gap for project-specific movement, drainage, and ventilation, minimum 3/8-inch

Water-Shedding Surface and Control Layers

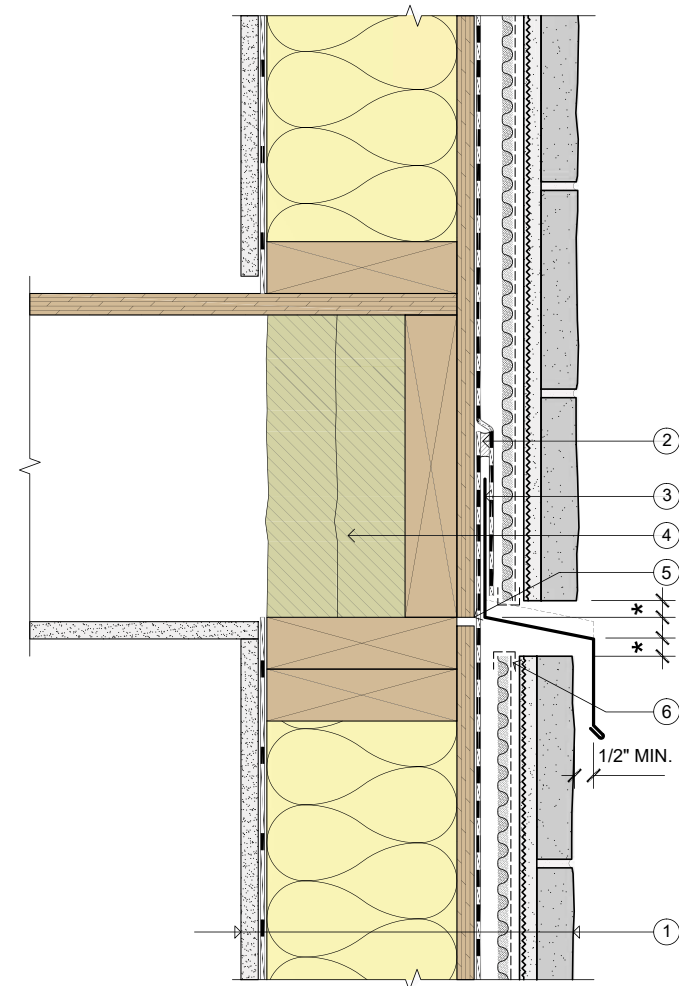


— Water-Shedding Surface

Control Layers:†

— Water
— Air
— Vapor
— Thermal

† Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing



Detail Discussion

- Floor line insulation is provided with closed-cell spray foam insulation to provide thermal control layer continuity and vapor control at the floor line. Refer to Chapter 3 for an alternative approach.
- Space above and below the sloped cross-cavity sheet-metal flashing is necessary to allow for differential movement between the structure and veneer.

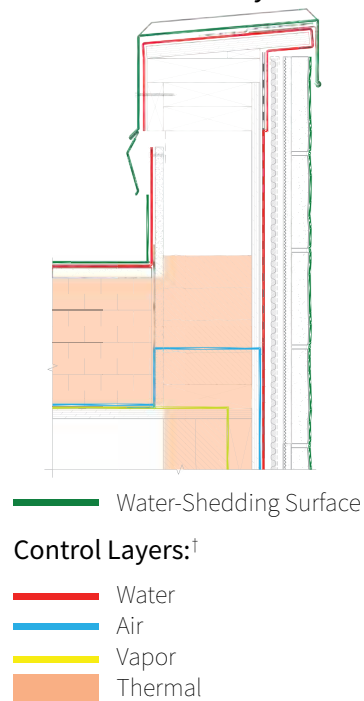
Typical Floor Line
Detail 8A-D

LEGEND

1. Parapet Assembly (Option A):
 - Roof membrane
 - Exterior sheathing
 - Vented wood-framed parapet
 - Exterior sheathing
 - Sheet-applied air barrier and WRB field membrane
 - Filter fabric over minimum drainage matrix
 - Metal lath
 - Scratch and bond coats
 - Adhered masonry veneer with grouted joints
 - Clear water repellent
2. Conventional roof assembly
3. Sloped standing-seam sheet-metal coping with gasketed washer fasteners
4. High-temperature self-adhered membrane
5. Insect screen
6. Closed-cell spray foam insulation plug
7. Continuous air barrier sealant between sheathing and sheet air barrier and WRB field membrane
8. Closed-cell spray foam insulation
9. Insect screen
10. Preservative-treated blocking

* Size gap for project-specific movement and ventilation, minimum $\frac{3}{8}$ -inch

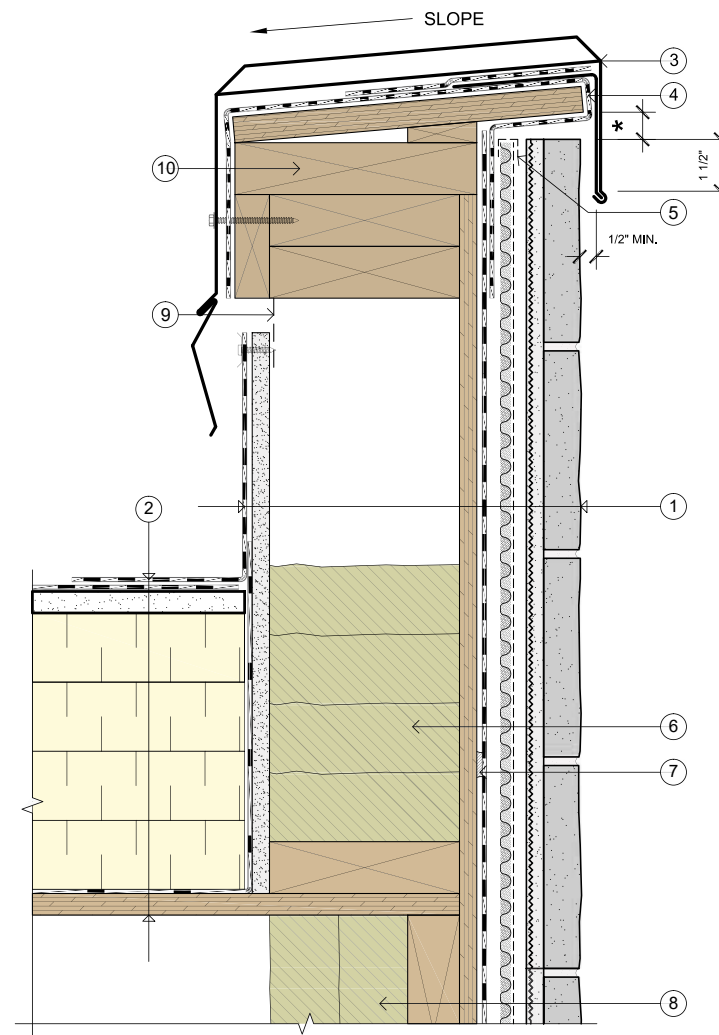
Water-Shedding Surface and Control Layers



[†] Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing

Detail Discussion

- In this detail, air control layer continuity is provided by the roof membrane's adhered air/vapor barrier membrane, closed-cell spray foam plug at the parapet cavity, and continuous bead of air barrier sealant between the sheathing and the air barrier and WRB field membrane.
- At minimum, parapet cavity and roof insulation R-values are recommended to be equivalent.
- The sheet-metal parapet cap is offset from the face of the masonry veneer to avoid blocking the ventilation path. A $\frac{1}{2}$ -inch gap is recommended.
- Refer to Detail 3-E in Chapter 3 for an alternative detail for providing a continuous air control layer at the parapet interface.



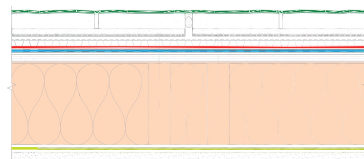
Typical Parapet at Conventional Roof System

Detail 8A-E

LEGEND

1. Typical Assembly (Option A):
 - Interior gypsum board
 - Vapor retarder
 - Wood-framed wall with batt insulation
 - Exterior sheathing
 - Sheet air barrier and WRB field membrane
 - Filter fabric over minimum drainage matrix
 - Metal lath
 - Scratch and bond coats
 - Adhered masonry veneer with grouted joints
 - Clear water repellent
 2. Continuous break in metal lath
 3. Sanded sealant joint over backer rod
- * Size joint for project-specific movement, minimum 3/8-inch

Water-Shedding Surface and Control Layers



— Water-Shedding Surface

Control Layers:†

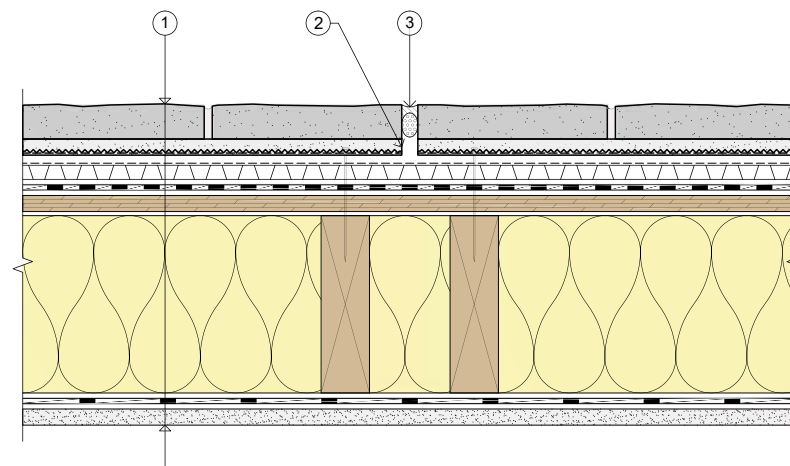
— Water
— Air
— Vapor
— Thermal

† Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing

Detail Discussion

- The metal lath at the control joint is broken to allow for movement within the veneer. The gap within the veneer is kept free of all materials except for a compressible backer rod and sealant, which allows for movement but maintains continuity of the water-shedding surface.
- The location of control joints is determined by the project designer and clearly identified in the construction documents on elevations and in details.

Refer to the Movement Joints discussion on page i-48 for more information on vertical control joint spacing.



Typical Vertical Control Joint

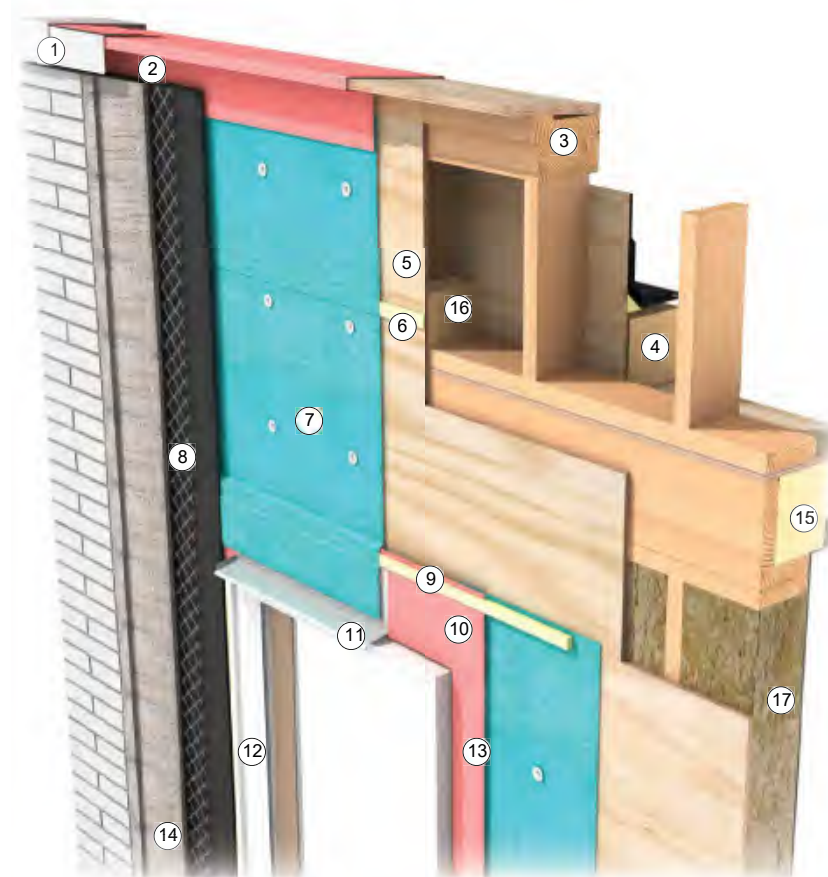
Detail 8A-F

LEGEND

1. Sloped standing-seam sheet-metal coping
2. High-temperature self-adhered membrane
3. Preservative-treated blocking
4. Conventional roof assembly
5. Exterior-grade sheathing
6. Continuous air barrier sealant between sheathing and sheet air barrier and WRB field membrane
7. Sheet air barrier and WRB field membrane, mechanically attached
8. Filter fabric over drainage matrix
9. Continuous air barrier sealant at sheet-applied air barrier and WRB field membrane lap over prestrip
10. Sheet or fluid-applied air barrier and WRB prestrip membrane, continuously tape/seal to sheet air barrier and WRB field membrane
11. Sloped sheet-metal head flashing with hemmed drip edge and end dams
12. Non-flanged window
13. Metal lath
14. Adhered veneer over scratch and bond coats
15. Closed-cell spray foam insulation within parapet cavity
16. Closed-cell spray foam insulation at floor line
17. Batt insulation

3-D Detail Discussion

- Three-dimensional cutaway sections on the next three pages represent two-dimensional details of this system.
- In all details, water control layer elements are shingle-lapped to encourage drainage of liquid water.
- Air control layer continuity is provided at the parapet in Detail 8A-G with the continuous air barrier sealant at the parapet and closed-cell spray foam insulation within the parapet cavity framing. These components assist with transferring the air control layer across the parapet sheathing layers to the air control layer at the roof assembly.
- Detail 8A-H describes a typical rough opening with sill back dam angle. The back dam angle and self-adhered or fluid-applied flashing membrane creates a sill pan below the window. Intermittent shims encourage drainage at the sill and into the rainscreen cavity.
- The filter fabric over drainage matrix shown in all three-dimensional cutaway sections protects the drainage layer from becoming clogged during installation of the scratch coat.
- Washer-head fasteners shown in Details 8A-I through 8A-I secure the sheet air barrier and WRB field membrane to the wall structure. Manufacturer-recommended attachment methods (for both temporary and long-term attachment) should be used and fully implemented to minimize the risk of damage to or displacement of the membrane prior to cladding installation and to provide long-term support of the membrane throughout the service life of the building.

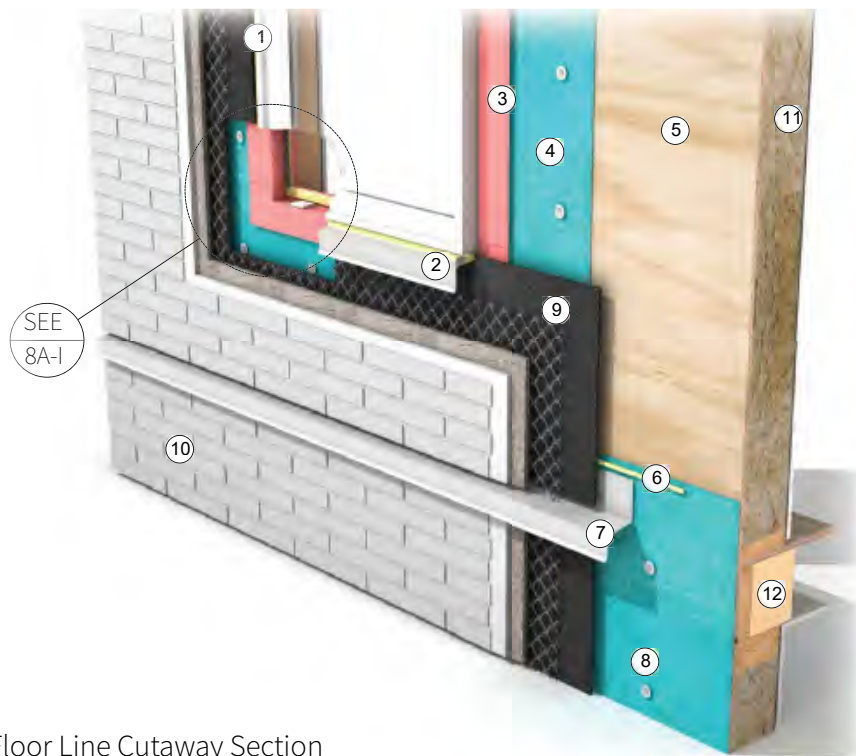


Parapet Assembly Cutaway Section

Detail 8A-G

LEGEND

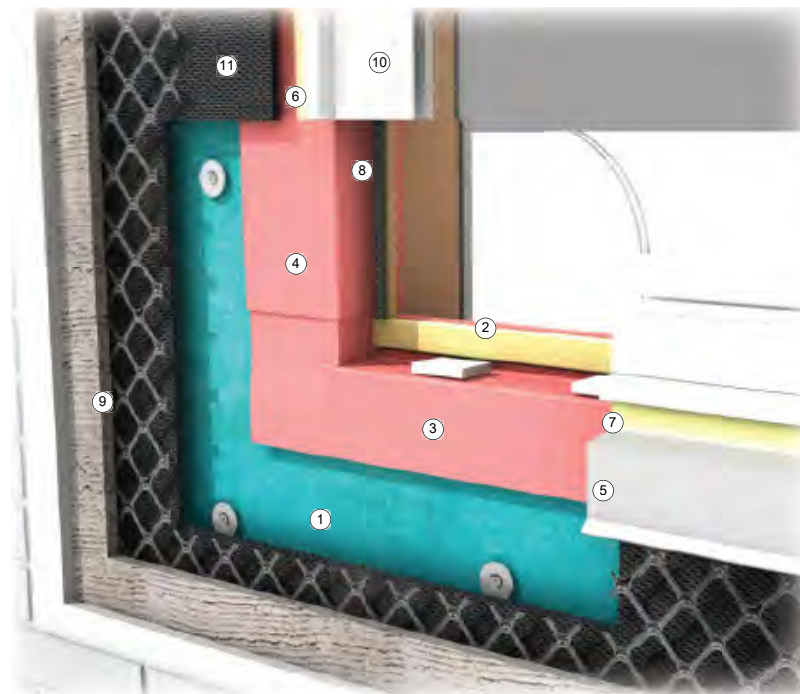
1. Non-flanged window
2. Sloped sheet-metal flashing with hemmed drip edge, end dam into grout joint at jamb veneer beyond
3. Sheet- or fluid-applied air barrier and WRB prestrip membrane, continuously taped/sealed to sheet air barrier and WRB field membrane
4. Sheet air barrier and WRB field membrane, mechanically attached
5. Exterior sheathing
6. Continuous air barrier sealant at air barrier and WRB field membrane lap
7. Sloped cross-cavity sheet-metal flashing with hemmed drip edge
8. Filter fabric over drainage matrix
9. Metal lath
10. Adhered veneer over scratch and bond coats
11. Batt Insulation
12. Closed-cell spray foam insulation and vapor control layer



Floor Line Cutaway Section
Detail 8A-H

LEGEND

1. Sheet air barrier and WRB field membrane, mechanically attached
2. Continuous back dam angle across sill, minimum 1-inch tall, with window fastened through back dam angle per window manufacturer recommendations
3. Self-adhered or fluid-applied flashing membrane at sill
4. Sheet- or fluid-applied air barrier and WRB prestrip membrane, continuously taped/sealed to sheet air barrier and WRB field membrane and flashing membrane at sill
5. Sloped sheet-metal sill flashing with hemmed drip edge
6. Sealant over backer rod at window perimeter
7. Minimum 1/4-inch thick intermittent shims
8. Continuous air barrier sealant, tie to continuous seal at window perimeter
9. Filter fabric over drainage matrix
10. Non-flanged window
11. Adhered veneer over scratch and bond coats over metal lath

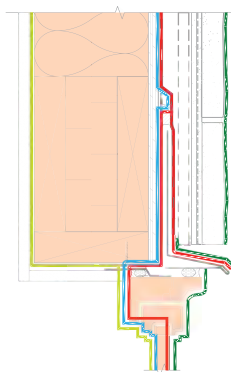


Typical Windowsill and Jamb Cutaway Section
Detail 8A-I

LEGEND

1. Typical Assembly (Option B):
 - Interior gypsum board
 - Vapor retarder
 - Wood-framed wall with batt insulation
 - Exterior sheathing
 - Sheet-applied air barrier and WRB field membrane
 - Air cavity with preservative-treated furring strips
 - Cement backer board
 - Crack isolation membrane
 - Thinset mortar
 - Adhered veneer with grouted joints
 - Clear water repellent
 2. Continuous air barrier sealant at sheet-applied air barrier and WRB field membrane lap over prestrip
 3. Sheet- or fluid-applied air barrier and WRB prestrip membrane
 4. Sloped sheet-metal head flashing with hemmed drip edge and end dams beyond
 5. Insect screen
 6. Sealant over backer rod
 7. Window strap anchor, bed in air barrier sealant at continuous air barrier sealant joint plane
 8. Continuous air barrier sealant, tie to continuous seal at window perimeter
 9. Non-flanged window
- * Size gap for drainage and ventilation, minimum 3/8-inch

Water-Shedding Surface and Control Layers

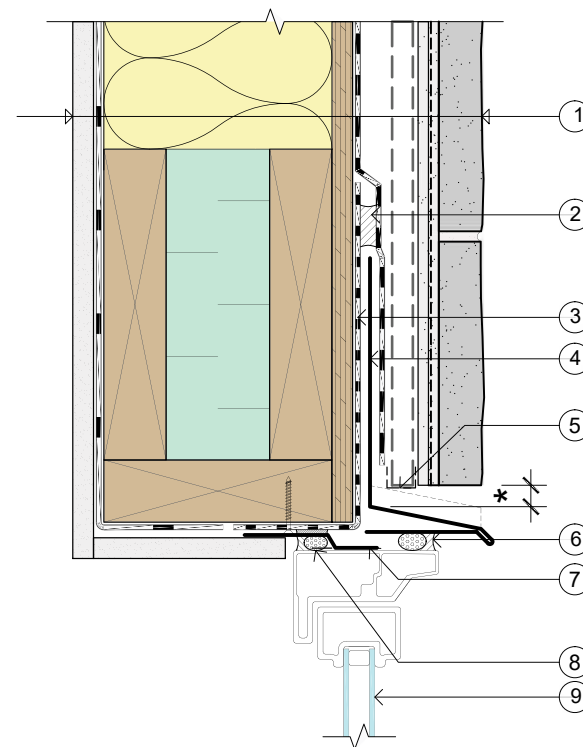


Water-Shedding Surface

Control Layers:[†]

- Water
- Air
- Vapor
- Thermal

[†] Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing



Detail Discussion

- Air and water control layer continuity is provided by the sheet-applied air barrier and WRB field membrane, sheet-applied or fluid-applied air barrier and WRB prestrip membrane, continuous air barrier sealant, and air barrier sealant transition to the window.
- A non-flanged window is shown at right and facilitates future window repair and replacement without the need to remove the masonry veneer. The window strap anchors are bed in sealant prior to fastening to prevent the passage of air and water behind strap locations.
- See Chapter 7 detailing where a fluid-applied or self-adhered sheet field membrane will be used for this system.

Typical Window Head
Detail 8B-A

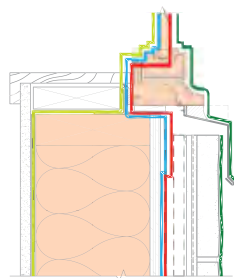
LEGEND

1. Typical Assembly (Option B):
 - Interior gypsum board
 - Vapor retarder
 - Wood-framed wall with batt insulation
 - Exterior sheathing
 - Sheet-applied air barrier and WRB field membrane
 - Air cavity with preservative-treated furring strips
 - Cement backer board
 - Crack isolation membrane
 - Thinset mortar
 - Adhered veneer with grouted joints
 - Clear water repellent
 2. Non-flanged window on minimum 1/4-inch thick intermittent shims
 3. Intermittent L-angle for sill flashing attachment, fastener to window per window manufacturer recommendations
 4. Sealant over backer rod
 5. Sloped sheet-metal flashing with hemmed drip edge, end dam into grout joint at jamb beyond
 6. Self-adhered sheet- or fluid-applied flashing membrane
 7. Continuous air barrier sealant tied to continuous seal at window perimeter
 8. Continuous back dam angle at rough opening sill, minimum 1-inch tall. Fasten window through back dam angle per window manufacturer recommendations.
 9. Insect screen
- * Size gap for project-specific movement and ventilation, minimum 3/8-inch

Detail Discussion

- Air and water control layer continuity is provided by the sheet-applied air barrier and WRB field membrane, self-adhered or fluid-applied flashing membrane, and air barrier sealant transition to the window.
- The continuous back dam angle and self-adhered or fluid-applied flashing membrane form the windowsill pan. The window is set on intermittent shims over the sill pan to encourage drainage from the rough opening drainage into the rainscreen cavity, where it can exit the cladding system below.
- The sloped sheet-metal sill flashing with hemmed drip edge sheds water from the window and cladding above, directing it away from the rainscreen cavity and veneer face below.

Water-Shedding Surface and Control Layers

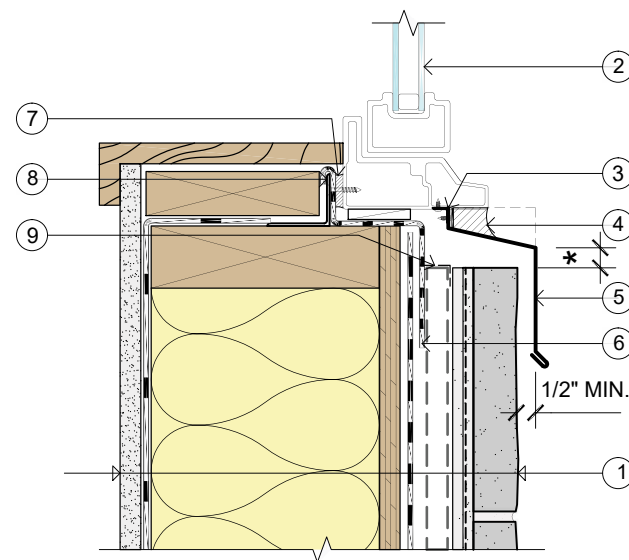


— Water-Shedding Surface

Control Layers:†

— Water
— Air
— Vapor
— Thermal

† Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing



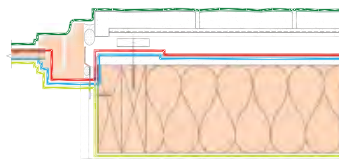
Typical Windowsill

Detail 8B-B

LEGEND

1. Typical Assembly (Option B):
 - Interior gypsum board
 - Vapor retarder
 - Wood-framed wall with batt insulation
 - Exterior sheathing
 - Sheet-applied air barrier and WRB field membrane
 - Air cavity with preservative-treated furring strips
 - Cement backer board
 - Crack isolation membrane
 - Thinset mortar
 - Adhered veneer with grouted joints
 - Clear water repellent
2. Non-flanged window
3. Sealant over backer rod
4. Sheet or fluid-applied air barrier and WRB prestrip membrane
5. Continuous air barrier sealant, tie to continuous seal at window perimeter
6. Window strap anchor, bed in air barrier sealant at continuous air barrier sealant joint plane

Water-Shedding Surface and Control Layers

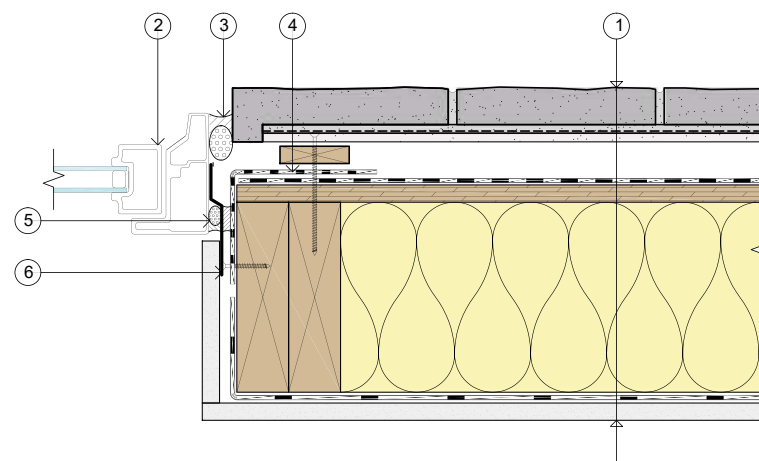


Water-Shedding Surface

Control Layers:*

Water
 Air
 Vapor
 Thermal

* Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing



Detail Discussion

- Air and water control layer continuity is provided by the sheet- or fluid-applied air barrier and WRB field membrane, prestrip membrane, and air barrier sealant transition to the window.
- The window strap anchors are bed in sealant prior to fastening to prevent the passage of air and water behind strap locations.
- The backer rod and sealant between the window and adhered veneer provides a continuous water-shedding surface across the window-to-wall transition.
- In the Northwest region, vapor-permeable sheet or fluid-applied air barrier and WRB prestrip membranes are recommended at jamb and head conditions to allow underlying sheathing and framing components an opportunity to dry to the exterior.

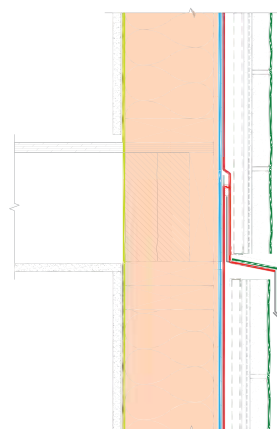
Typical Window Jamb

Detail 8B-C

LEGEND

1. Typical Assembly (Option B):
 - Interior gypsum board
 - Vapor retarder
 - Wood-framed wall with batt insulation
 - Exterior sheathing
 - Sheet-applied air barrier and WRB field membrane
 - Air cavity with preservative-treated furring strips
 - Cement backer board
 - Crack isolation membrane
 - Thinset mortar
 - Adhered veneer with grouted joints
 - Clear water repellent
 2. Continuous air barrier sealant at air barrier and WRB field membrane lap
 3. Sloped sheet-metal cross-cavity flashing with hemmed drip edge and end dams beyond at intersecting elements
 4. Closed-cell spray foam insulation
 5. Expansion gap
 6. Insect screen
- * Size gap for project-specific movement, drainage, and ventilation, minimum 3/8-inch

Water-Shedding Surface and Control Layers

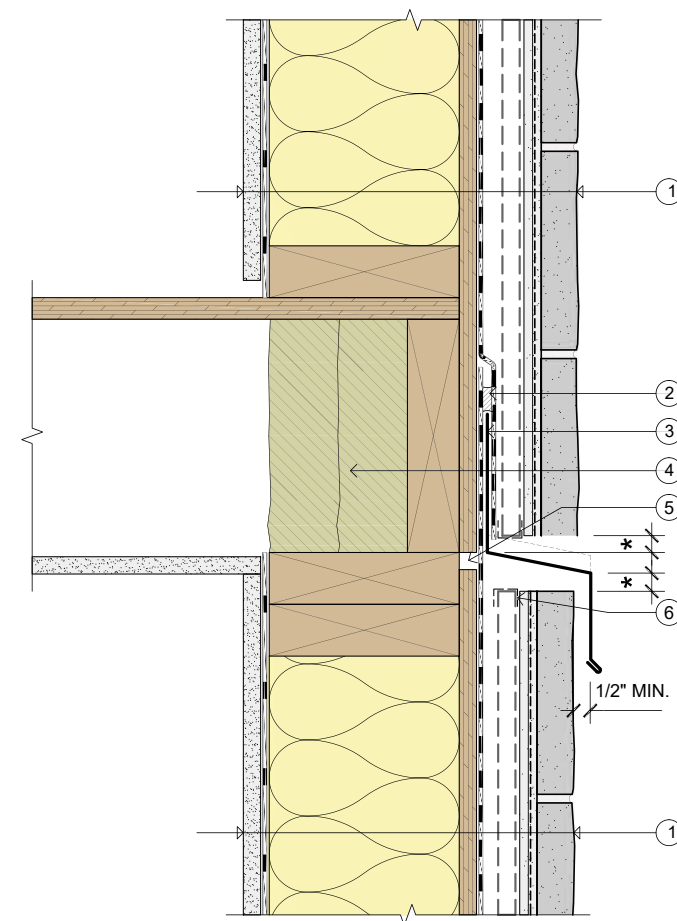


— Water-Shedding Surface

Control Layers:[†]

- Water
- Air
- Vapor
- Thermal

[†] Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing



Detail Discussion

- Floor line insulation is provided with closed-cell spray foam insulation to provide thermal control layer continuity and vapor control at the floor line. Refer to Chapter 3 for an alternative approach.
- Space above and below the sloped cross-cavity sheet-metal flashing is necessary to allow for differential movement between the structure and veneer.

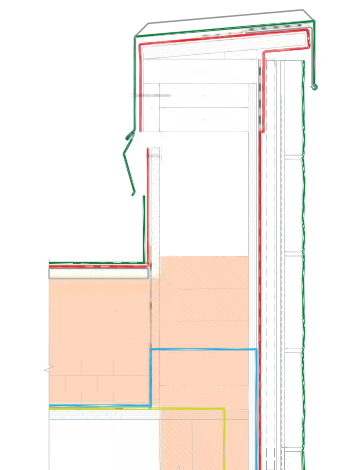
Typical Floor Line

Detail 8B-D

LEGEND

1. Parapet Assembly (Option B):
 - Roof membrane
 - Exterior sheathing
 - Vented wood-framed parapet
 - Exterior sheathing
 - Sheet-applied air barrier and WRB field membrane
 - Air cavity with preservative-treated furring strips
 - Cement backer board
 - Crack isolation membrane
 - Thinset mortar
 - Adhered veneer with grouted joints
 - Clear water repellent
 2. Conventional roof assembly
 3. Standing-seam sheet-metal coping with gasketed washer fasteners
 4. Insect screen
 5. Preservative-treated blocking
 6. High-temperature self-adhered membrane
 7. Closed-cell spray foam insulation plug
 8. Continuous air barrier sealant between sheathing and sheet air barrier and WRB field membrane
 9. Closed-cell spray foam insulation
 10. Insect Screen
- * Size gap for project-specific movement and ventilation, minimum 3/8-inch

Water-Shedding Surface and Control Layers



Water-Shedding Surface

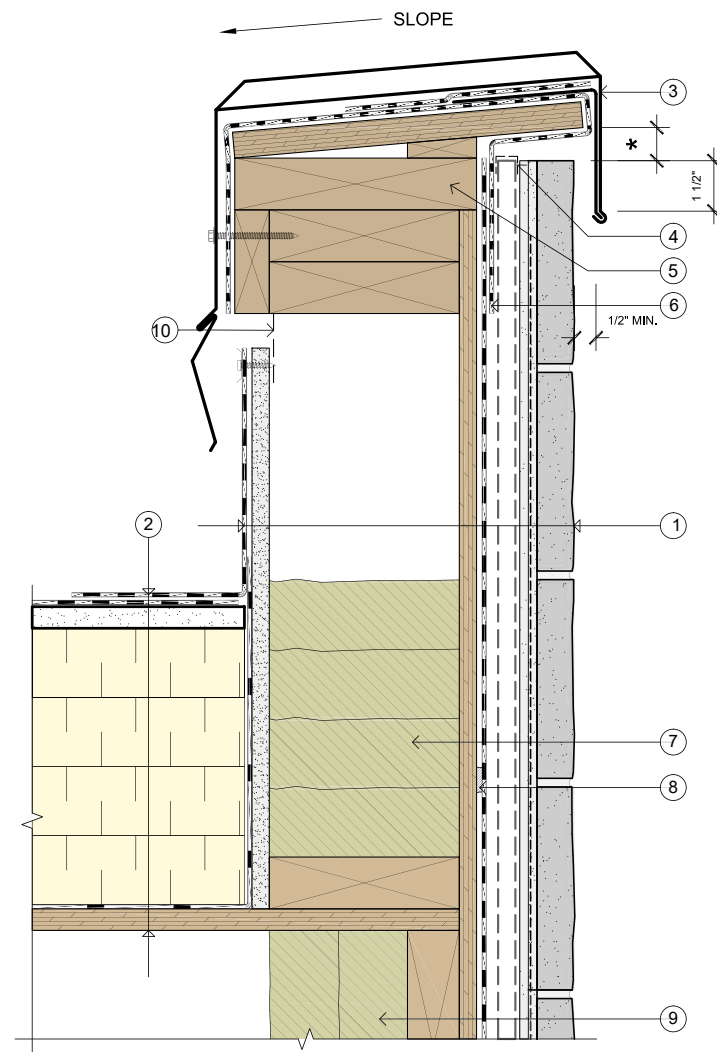
Control Layers:†

- Water
- Air
- Vapor
- Thermal

† Where a Class IV permeance (and sometimes Class III permeance) air barrier and WRB system exist and a vapor retarder is located inboard of wall framing

Detail Discussion

- In this detail, air control layer continuity is provided by the roof membrane's adhered air/vapor barrier membrane, closed-cell spray foam plug at the parapet cavity, and continuous bead of air barrier sealant between the sheathing and the air barrier and WRB field membrane.
- At minimum, parapet cavity and roof insulation R-values are recommended to be equivalent.
- The sheet-metal parapet cap is offset from the face of the masonry veneer to avoid blocking the ventilation path. A 1/2-inch gap is recommended.
- Refer to Detail 3-E in Chapter 3 for an alternative detail for providing a continuous air control layer at the parapet interface.



Typical Parapet at Conventional Roof System

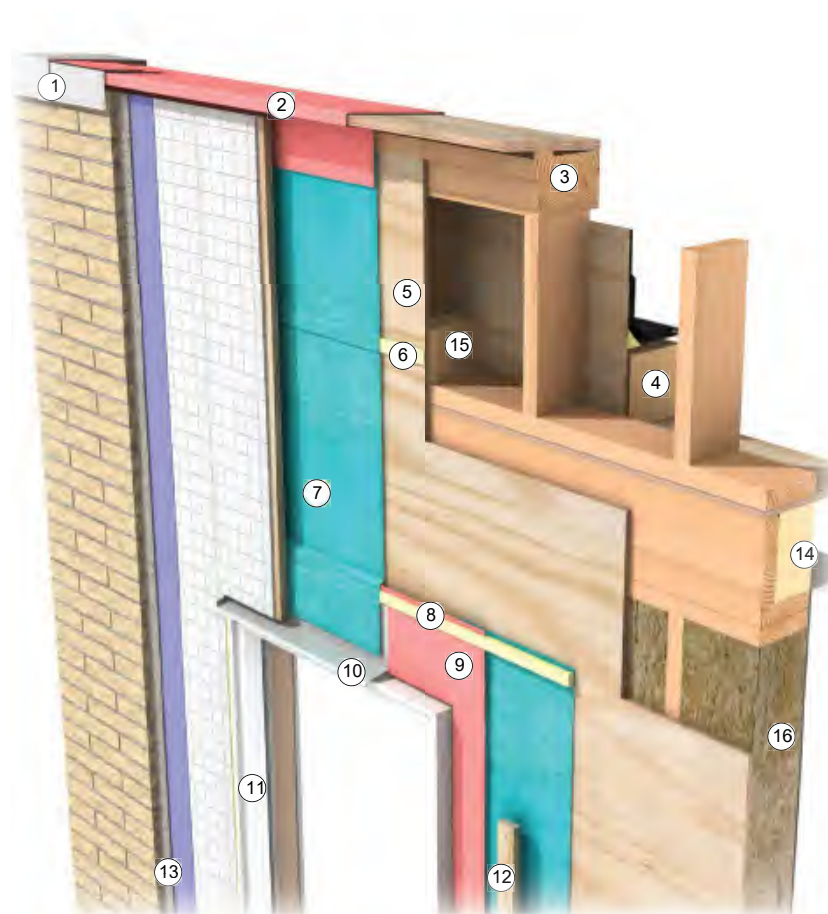
Detail 8B-E

LEGEND

1. Sloped standing-seam sheet-metal coping
2. High-temperature self-adhered membrane
3. Parapet framing
4. Conventional roofing system
5. Exterior sheathing
6. Continuous air barrier sealant between sheathing and sheet air barrier and WRB field membrane
7. Sheet air barrier and WRB field membrane, mechanically attached
8. Continuous air barrier sealant at sheet-applied air barrier and WRB field membrane lap over prestrip
9. Sheet or fluid-applied air barrier and WRB prestrip membrane, continuously tape/seal to sheet air barrier and WRB field membrane
10. Sloped sheet metal head flashing with hemmed drip edge and end dams
11. Non-flanged window
12. Preservative-treated furring
13. Adhered veneer over thinset mortar, crack isolation membrane, and cement backer board
14. Closed-cell spray foam insulation at floor line
15. Closed-cell spray foam insulation within parapet cavity
16. Batt insulation
17. Parapet vent strip with insect screen

3-D Detail Discussion

- Three-dimensional cutaway sections on the next three pages represent two-dimensional details of this system.
- In all details, water control layer elements are shingle-lapped to encourage drainage of liquid water.
- Air control layer continuity is provided at the parapet in Detail 8B-F with the continuous air barrier sealant at the parapet and closed-cell spray foam insulation within the parapet cavity framing. These components assist with transferring the air control layer across the parapet sheathing layers to the air control layer at the roof assembly.
- Detail 8B-H describes a typical rough opening with sill back dam angle. The back dam angle and self-adhered or fluid-applied flashing membrane creates a sill pan below the window. Intermittent shims encourage drainage at the sill and into the rainscreen cavity.
- Furring strips shown in Details 8b-F through 8b-H secure the sheet air barrier and WRB field membrane to the wall structure. Manufacturer recommended attachment methods (for both temporary and long-term attachment) should be used and fully implemented to minimize the risk of damage to or displacement of the membrane prior to cladding installation and to provide long-term support of the membrane throughout the service life of the building.

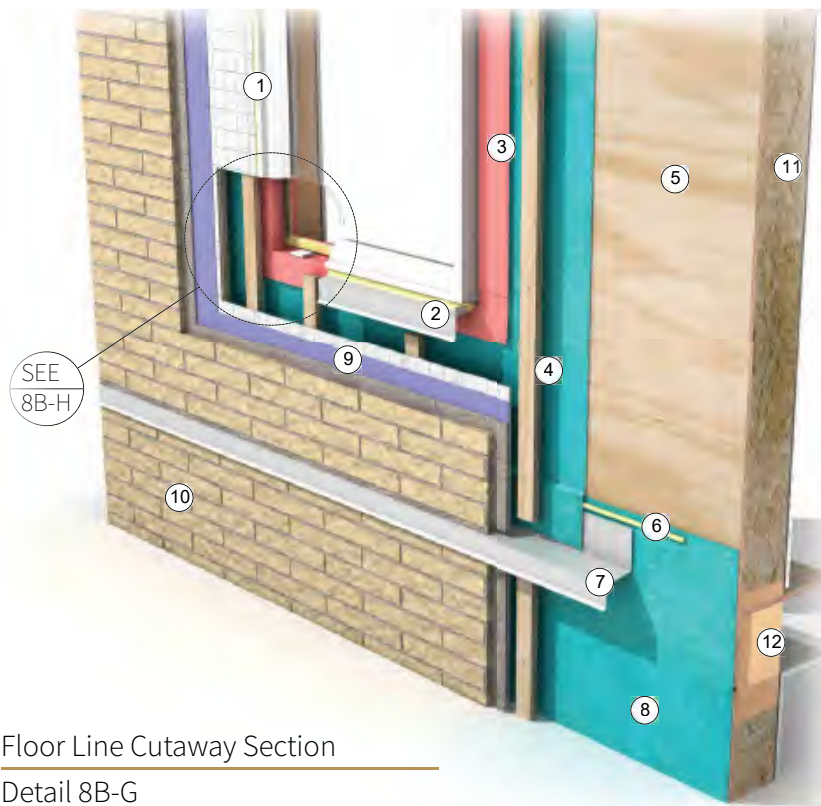


Parapet Assembly Cutaway Section

Detail 8B-F

LEGEND

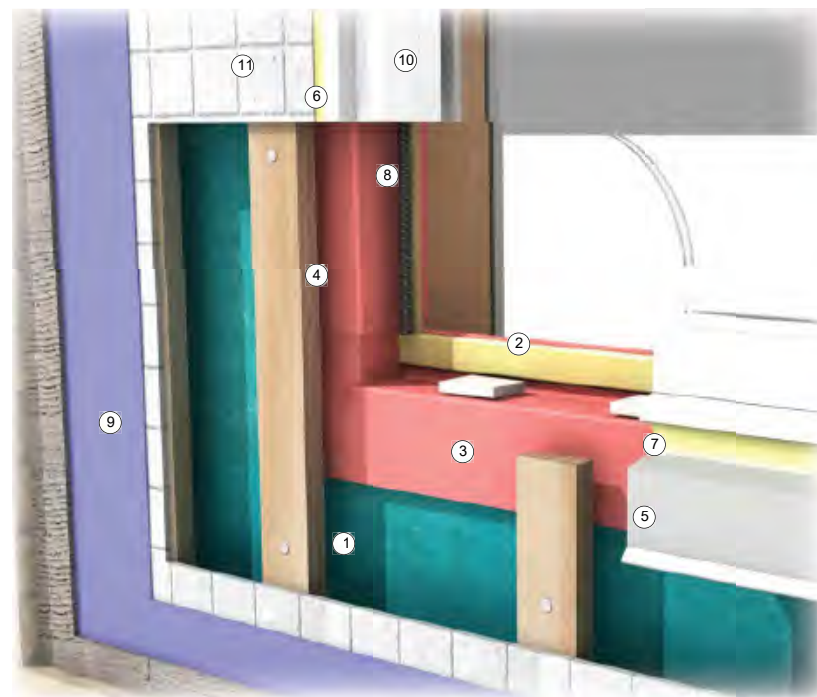
1. Sealant over backer rod at window perimeter
2. Sloped sheet-metal flashing with hemmed drip edge, end dam into grout joint at jamb veneer beyond
3. Sheet or fluid-applied air barrier and WRB prestrip membrane, continuously taped/sealed to sheet air barrier and WRB field membrane
4. Preservative-treated furring
5. Exterior sheathing
6. Continuous air barrier sealant at air barrier and WRB field membrane lap
7. Sloped sheet-metal cross-cavity flashing with hemmed drip edge
8. Bond coat over crack isolation membrane and cement backer board
9. Adhered veneer
10. Batt insulation
11. Closed-cell spray foam insulation and vapor control layer



Floor Line Cutaway Section
Detail 8B-G

LEGEND

1. Sheet air barrier and WRB field membrane, mechanically attached
2. Continuous back dam angle across sill, minimum 1-inch tall, with window fastened through back dam angle per window manufacturer recommendations
3. Self-adhered or fluid-applied flashing membrane at sill
4. Sheet or fluid-applied air barrier and WRB prestrip membrane, continuously taped/sealed to sheet air barrier and WRB field membrane and flashing membrane at sill
5. Sloped sheet-metal sill flashing with hemmed drip edge
6. Sealant over backer rod at window perimeter
7. Preservative-treated furring
8. Continuous air barrier sealant, tie to continuous seal at window perimeter
9. Crack isolation membrane over backer board
10. Non-flanged window
11. Minimum 1/4-inch thick intermittent shims



Typical Windowsill and Jamb Cutaway Section
Detail 8B-H

APPENDIX

Thermal modeling for this guide was undertaken using HEAT3.¹ HEAT3 is a three-dimensional finite-element thermal analysis software tool commonly used by the building industry to analyze building enclosure assemblies in three dimensions, which two-dimensional analysis tools (such as THERM) cannot accurately analyze. It allows for a more detailed analysis of building enclosure assemblies, including the impact of fasteners, masonry ties and discrete clips, and other construction realities. Modeling can determine effective R-values/U-factors from the heat flow measured through the building enclosure assembly.

The boundary conditions used for this guide's modeling are industry standard ASHRAE winter exterior and interior boundary conditions with temperatures of 0°F and 70°F and surface films 0.17 ft²·°F·hr/Btu and 0.68 ft²·°F·hr/Btu respectively. The material conductivities used for the modeling are provided in Table A-1.

Additional modeling parameters include the following:

- Material properties used are based on the following references:
 - ASHRAE Handbook - Fundamentals²
 - ASHRAE Standard 90.1³
 - Product testing data
 - NFRC 101⁴
- All thermal modeling and resulting R-values are for standard wall assemblies, including the floor line where applicable, but do not account for additional framing and resulting heat flow around penetrations (e.g., windows and doors) unless otherwise noted.
- Continuous Z-girts exterior of cladding support clips for the adhered veneer systems are modeled at 18-gauge thickness with 1-inch-deep air space for all cases.
- Modeling was completed for cladding support clips, masonry ties, and shelf angle support options based on common products available to the market but does not necessarily reflect the exact design and dimensions of these products.

Table A-1 Material conductivities used for the modeling

MATERIAL	THERMAL CONDUCTIVITY Btu·in/hr·ft ² ·°F (W/m·K)
Masonry veneer	5.5 (0.79)
Mortar	5.0 (0.72)
Cement Board	1.73 (0.25)
3/4" grout with metal lathe	32.6 (4.7)
Air cavities at varying thicknesses	Varies*
Polypropylene (in 1/2" drain mat)	1.53 (0.22)
High density polyethylene	3.5 (0.5)
EPDM	1.73 (0.25)
Galvanized sheet steel (studs, girts, ties)	430 (62)
Stainless steel (clips, ties, fasteners)	118 (17)
Mild steel (fasteners/angles)	314 (45.3)
Brass (masonry tie bolt sleeve)	832 (120)
Fiberglass frame (clip)	2.1 (0.3)
Exterior mineral wool insulation (R-4.2/in)	0.24 (0.0343)
Closed cell spray foam (R-6/in)	0.17 (0.0240)
1/2" Exterior gypsum	0.90 (0.13)
1/2" Plywood - Douglas Fir	0.65 (0.093)
Wood 2x SPF	0.83 (0.12)
Fiberglass batts 5.5" R-21	0.26 (0.0379)
Fiberglass batts 7.25" R-30	0.24 (0.0348)
Fiberglass batts 3.625" R-15	0.24 (0.0348)
Fiberglass batts 6" R-21	0.29 (0.0411)
1/2" Interior gypsum	1.1 (0.16)
Concrete (including reinforcing)	13.9 (2)
8" concrete masonry unit empty, including grout	8.0 (1.153)

* All air spaces assigned R-values based on values given for plane air spaces in the ASHRAE Handbook - Fundamentals.

- All air spaces, including vented air spaces behind masonry cladding, are assigned R-values based on values given for unventilated plain air spaces in the ASHRAE Handbook - Fundamentals.² This approach is consistent with numerous studies showing that air cavities, including vented air cavities, provide measurable resistance to heat flow. However, some energy codes may require air cavities to be treated differently or neglected entirely from the R-value determination of an assembly. Consult the local energy code and the authority having jurisdiction for additional requirements.

- All steel-stud back-up walls include fiberglass-reinforced exterior-grade gypsum sheathing and interior gypsum board.
- Steel studs are not modeled with conduit cutouts in the web of the stud.

Appendix References

1. Blocon USA. "HEAT3 - Heat transfer in three dimensions." <http://buildingphysics.com/index-filer/Page691.htm> (retrieved August 15, 2017).
2. American Society of Heating, Refrigerating and Air-Conditioning Engineers. *2017 ASHRAE Handbook – Fundamentals*. (Atlanta: ASHRAE, 2017).
3. American Society of Heating, Refrigerating and Air-Conditioning Engineers. *ANSI/ASHRAE/IES Standard 90.1-2016 Energy Standard for Buildings Except Low-Rise Residential Buildings, IP ed.* (Atlanta: ASHRAE, 2016).
4. National Fenestration Rating Council Incorporated. *NFRC 101-2017 Procedure for Determining Thermophysical Properties of Materials For Use in NFRC-Approved Software*. (Greenbelt: National Fenestration Rating Council Incorporated, 2016).

GLOSSARY OF TERMS

Adhesion	Property that describes a material's ability to bond to a surface physio-chemically or chemically.
Adhered Veneer	Veneer secured and supported through adhesion to bonding material applied over backing.
Anchored Veneer	Veneer secured to and supported by approved mechanical fasteners attached to backing.
Adhesive Failure	Loss of adhesion of a material to the surface to which it is applied. See also Adhesion.
Air Control Layer (or Air Barrier System)	<p>Air control layers are three-dimensional systems of materials designed and constructed and/or acting to control air flow across a building enclosure or between a conditioned space and an unconditioned space. The pressure boundary of the enclosure should, by definition, be coincident with the plane of a functional air control layer system.</p> <p>Air control layer systems are assembled from <i>materials</i> incorporated in <i>assemblies</i> (or <i>components</i> such as windows) that are interconnected to create "enclosures." Each of these three elements has measurable resistance to air flow. Common minimum recommended air permeances for the three components are:</p> <p>Material: 0.004 cfm/sf @ 0.3" WC</p> <p>Assembly/Component: 0.04 cfm/sf @ 0.3" WC</p> <p>Enclosure: 0.4 cfm/sf @ 0.3" WC</p> <p>Materials and assemblies that meet these performance requirements are said to be air control layer materials and air control layer assemblies. Air control layer materials that are incorporated into air control layer assemblies that in turn are interconnected to create enclosures are called air control layer systems.</p>
Air Leakage	Uncontrolled and/or unintended air flow through a building enclosure or between units of occupancy. Leakage from indoors to outdoors is known as <i>exfiltration</i> and leakage from outdoors to indoors is known as <i>infiltration</i> . Air leakage can cause insulation quality problems, condensation, excess energy use, comfort complaints, and smoke transport.
Backer Rod	A resilient foam material (typically closed-cell polyethylene) of circular cross-section installed under compression in a joint to provide a backing, control sealant joint depth, act as a bond breaker to prevent three-sided sealant adhesion, and provide an hour-glass contour of the finished sealant bead.
Bed Joint	The horizontal layer of mortar on which a masonry unit is laid.
Bond Breaker	A tape, sheet, wax, or liquid-applied treatment that prevents adhesion on a designated surface. Usually used with sealant to ensure a proper joint. See also Backer Rod.

Brick	A solid masonry unit of clay or shale, usually formed into a rectangular prism while plastic and burned or fired in a kiln.
Building Enclosure	The elements of a building that act as the environmental separator between the interior environment and the exterior environment. Walls, windows, roofs, slabs, basements, and joints are all part of the building enclosure.
Building Envelope	An outdated term for the building enclosure.
Cladding	A material or assembly that forms the exterior face of a wall such as brick/stone veneer.
Concrete Masonry Unit (CMU)	Precast hollow block or solid brick of concrete conforming to ASTM C-90.
Condensation	The change of state from vapor to liquid. A common factor in moisture damage. Occurs on surfaces when they are cooler than the air containing vapor next to it.
Control Joint	Formed, sawed, or tooled in a masonry structure to regulate the location and amount of cracking and separation resulting from the dimensional change of different parts of the structure, thereby avoiding the development of high stresses.
Control Layers	<p>Notional concepts used to describe which materials and/or assemblies provide the control functions in a building enclosure and as an aid to ensure continuity of the functions in design and construction. They comprise one or several materials and are formed into planes to create a three-dimensional boundary.</p> <p>See: Thermal Control Layer, Vapor Control Layer, Vapor Barrier, Air Control Layer (or Air Barrier System), Water Control Layer</p>
Cure	To develop the ultimate properties of a wet state material by a chemical process. Different than drying, which is not a chemical process—although drying is often a necessary part of a chemical process.
Drainage Plane	A water-repellent layer designed and constructed to allow the flow of water by gravity without allowing penetration of the layer. The materials that form the drainage plane often overlap each other shingle-fashion or are sealed so that water flow is downward and outward. They are part of the water control layer of drained enclosure systems and require interconnection (sealed or lapped) with flashings, with window and door openings, and with other penetrations of the building enclosure. See also Water-Resistant Barrier.
Drained	A building enclosure rain penetration control strategy that accepts that some water will penetrate the outer surface (the cladding, which "screens" rain) and removes this water back to the exterior by gravity drainage over a drainage plane and through a drainage gap and then exiting via flashing and weep holes. Many wall systems (including brick veneer) employ drained strategies. See also Rainscreen, Drainscreen.

Drainage Gap	A gap, highly permeable to gravity-driven water flow, that is located next to a water-resistant barrier to relieve hydrostatic pressure and provide a path for water to exit an assembly.
Drip Edge	A geometric feature provided in an exterior building surface to ensure that flowing water will drip free rather than be pulled back toward a vertical element due to surface tension or gravity. A drip groove is commonly employed in solid materials like concrete, whereas a drip edge is used for thinner sheet materials.
Durability	The capability of a building, assembly, component, product, or building to maintain serviceability (fitness for purpose) over a specified or expected period of time without replacement or unexpected repair and maintenance.
Efflorescence	The visible deposit (generally white) of dissolved salts transported within water (usually by capillary action) to the surface of a material such as concrete or brick after evaporation of the water. Often caused by free alkalies leached from mortar, grout, concrete, or clay.
End Dam	A vertical or near vertical upstand from the end of a flashing or windowsill that is used to prevent water from flowing horizontally off the end of the flashing or sill.
Expansion Joint	A structural separation between building elements that allows independent movement without damage to the assembly.
Fasteners	A general term describing a variety of screws, nails, rivets, etc., that are used for mechanically securing various components of a building.
Flashing	A waterproof material used to redirect or shed drained water or sometimes to act as a capillary break.
Framing Member	Studs, joists, plates (tracks), bridging, bracing, and related accessories manufactured or supplied for wood or light-gauge steel framing.
Grout	A mixture of cementitious material and aggregate to which sufficient water is added to produce placing consistency without segregation of the constituents.
Head Joint	The vertical mortar joint between ends of masonry units (also called a cross joint).
Insulation (i.e., thermal insulation)	Any material that significantly slows the flow or transfer of heat. Building insulation types are classified according to form (e.g., loose-fill, batt, flexible, rigid, reflective, foamed-in-place) or material (e.g., mineral fiber, organic fiber, foam plastic). All types of solid materials are rated according to their ability to resist heat flow (R-value). Some may apply the term to coatings, which slow only radiation heat transfer—that is, radiant barriers and low-e coatings.
Jamb	The vertical side or edge of a doorway, window, or other opening.

Joints	An interface between elements. Joints may be needed to allow for movement of different parts of a building or assembly or may be required to make construction sequences practical. In all cases, the functional requirements of the enclosure must be maintained. See Expansion Joint, Control Joint, Sealant Joint.
Maintenance	A regular process of inspection, cleaning, and conducting minor repairs of buildings elements and exterior systems. Cleaning is for normal activities for items as required on a regular basis. Minor repairs encompass small projects that reinstate failed elements such as areas of cracked sealant.
Masonry	That form of construction composed of stone, brick, concrete, gypsum, hollow clay tile, concrete block, tile, or other similar building units or materials or combination of these materials laid up unit by unit.
Mortar	A plastic mixture of cementitious materials, fine aggregate, and water.
On-Center (o.c.)	Used to define measurement spacing of repeating elements.
Occupiable Space (or occupied space)	Any enclosed space inside the pressure boundary and intended for human activities, including but not limited to all habitable spaces, toilets, closets, halls, storage and utility areas, and laundry areas.
Parapet Wall	A low wall around the perimeter of a roof that projects above the level of the adjoining roof level.
Penetration	A material passing through a building component such as a balcony through an insulation layer, a duct in a fire-rated partition, a pipe through an enclosure, a fastener of a WRB, etc. Windows may also be described as a penetration.
Perfect Barrier	One of the three available rain penetration control approaches (the other two are drained and mass/storage). This approach relies on the exterior face of the enclosure to act as the rain control layer and as a perfect barrier to rain penetration; neither drainage nor drying are required for successful performance.
Plywood	A wood product made of three or more layers of veneer joined with glue and usually laid with the grain of adjoining plies at right angles to one another.
Pressure Boundary	The primary air enclosure boundary separating conditioned air and unconditioned air or conditioned air and semi-conditioned air. The air control layer/air barrier system is by design intended to define the extent of the pressure boundary.

Rainscreen	A cladding system and/or rain control strategy that accepts that some water will penetrate the outer surface (the cladding, which “screens” rain) and removes this water back to the exterior by gravity drainage over a drainage plane and through a drainage gap and then exiting via flashing and weep holes. In this guide, this term applies to drained systems (see also Drained) and may include systems that are ventilated.
Relative Humidity	The ratio (expressed as a percentage) of the amount of moisture within the air to the maximum amount of moisture that the air could possibly contain at a specific temperature.
Repointing	Replacing mortar in masonry joints. Also known as tuckpointing.
R-Value	Quantitative measure of resistance to heat flow, the reciprocal of the U-factor. The units for R-value are ft ² °F hr/Btu (English).
Rigid Insulation	Rigid board material that provides thermal resistance. Foam plastic such as EPS, XPS, and polyisocyanurate are commonly used.
Rough Opening	The opening in a wall into which a door, window, or other enclosure component is to be installed.
Saddle	The transition of small horizontal surfaces, such as the top of a balcony guardrail or parapet wall, with a vertical surface, such as a wall.
Sealant	A flexible, polymer-based elastomeric material installed wet and used in the assembly of the building enclosure to seal gaps, seams, or joints and to provide a clean finish, or to waterproof or airtighten the joint.
Semi-Rigid Insulation	Formed board material that provides thermal resistance and comprises mineral fibers. Mineral fiber insulation is normally used for its noncombustible properties and is typically composed of glass or rock wool.
Sheathing	A board material used to provide stiffness to the wall and/or to provide sufficient strong and stiff backing for attaching cladding, membrane control layers. Typical materials are oriented strand board (OSB), plywood, timber, fiberboard, various forms of gypsum board, and some new high-density polymer hybrids.
Spall	A fragment of material, such as concrete or masonry, detached from a larger mass by a physical blow, freeze-thaw, high levels of compression, or subfluorescence.
Split Face	A rough concrete masonry face formed by splitting slabs in a split-face machine.

Stack Effect	Air movement driven by buoyancy—that is, the density difference between two columns of air at different temperatures. Often described as warmer air rising or cold air falling. Stack effect generates small but steady pressures over a height in direct relation to the temperature difference and the height of the column of air. The resulting pressure differences can lead to air leakage and can generate unplanned air flows within buildings, which can result in indoor air quality problems or which may be used to ensure a chimney evacuates smoke or drives natural ventilation.
Stud	One of a series of wood or light-steel vertical structural members placed as supporting elements in walls and partitions.
Termination Bar	Also called retention bar. A bar of rigid material (often metal) used to end a roofing, flashing or air control membrane in a secure and durable manner. Mechanical clamping is the primary function, but a gum lip is also usually provided to allow sealant as well. Site-built versions often use simple 1x2 wood strips, small galvanized angles, or flat-steel.
Thermal Bridge	A material with higher thermal conductivity transferring heat through an assembly with substantially lower thermal conductivity. For example, a steel stud in a wall will transfer more heat than the surrounding insulation, reducing the overall thermal control of the system.
Thermal Boundary	The layer in a building enclosure that controls the transfer of energy (heat) between the interior and the exterior. It is a component of the building enclosure and it may, but does not have to align with the pressure boundary.
Thermal Control Layer	The layer in a building enclosure (comprising one or several materials and formed into planes to create a three-dimensional boundary) that is designed, installed, and/or acts to form the primary control of heat flow in an enclosure assembly. It is often partially penetrated by thermal conductive elements, which, if large, are termed thermal bridges.
Through-Wall Flashing	Flashing that extends completely through a wall system and is designed and applied in combination with counter-flashings to prevent any water that enters the wall above from proceeding downward.
U-Factor	Quantitative measure of heat flow or conductivity; the reciprocal of R-value. While building scientists will use R-values for measures of the resistance to heat flow for individual building materials, U-factor is usually used as a summary metric for the ease of heat transfer through building assemblies.

Vapor Barrier	A layer (often comprising a single material) that has a water vapor permeance of 0.1 perm or less, and thus a Class I vapor control layer. A vapor barrier is a material that is essentially vapor-impermeable. The test procedure for classifying vapor barriers is typically ASTM E-96 Test Method A—the desiccant or dry cup method when the vapor barrier is located on the interior of the enclosure assembly. Examples include metal, glass, polyethylene, asphalt membranes, etc.
Vapor Control Layer	The element (or elements) that is (or are) designed and installed in an assembly to control the movement of water by vapor diffusion.
Vapor Permeance	A layer property that describes the ease with which water vapor molecules diffuse through it. It is defined as the quantity of vapor flow across a unit area that will flow through a unit thickness under a unit vapor pressure difference. The unit of measurement is typically the “perm” (gr/h-ft ² -in. Hg).
Vapor Retarder	A vapor retarder is a material that has a permeance of 1.0 perm or less and greater than 0.1 perm. A vapor retarder is a material that is vapor semi-impermeable. A vapor retarder is a Class II vapor control layer. The test procedure for classifying vapor retarders is ASTM E-96 Test Method A—the desiccant or dry cup method.
Water Resistive Barrier (WRB)	A water control layer product or system. See drainage plane.
Veneer	Nonstructural facing of brick, concrete, stone, tile, or other similar material attached to a backing for the purpose of ornamentation or protection.
Water Control Layer	The continuous layer (comprising one of several materials and formed into planes to form a three-dimensional boundary) in an enclosure assembly that is designed, installed, and/or acts to form the innermost boundary for rainwater. Penetration of any substantial amount of rainwater further into the enclosure is deemed or results in a performance failure.
Water-Shedding Surface	The outermost surface or material of a building enclosure exposed to rain. By definition it occurs in all building enclosures rain control strategies.
Weep Hole (i.e., weeps)	An opening placed in a wall or window assembly to permit the escape of liquid water from within the assembly. See also Weep-vent.
Weep-Vent	An opening placed in a wall to permit the escape of liquid water from within the assembly and to permit the flow of air.

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Organizations

Brick Industry Association

International Masonry Institute

Mason Contractors Association of America

Masonry Institute of Oregon

Masonry Institute of Washington

Masonry Promotion Group of Spokane

Northwest Concrete Masonry Association

The Tile Council of America

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