ROCKY MOUNTAIN MASONRY INSTITUTE

RMMI

2019 COLORADO MASONRY SYSTEMS DESIGN GUIDE

COLORADO / SOUTHERN WYOMING EDITION

BASALITE Concrete Products · General Shale · RDH Building Science · Rio Grande Co. Building Materials Since 1893 · Soderberg Masonry, Inc. · Solomon Colors, Inc · Spec Mix

COLORADO MASONRY SYSTEMS DESIGN GUIDE

COLORADO/ SOUTHERN WYOMING EDITION

Cover Design: KMG Design

THE ROCKY MOUNTAIN MASONRY INSTITUTE

686 Mariposa Street
Denver, CO 80204
303-893-3838

Printed in the U.S.A.

August 2019 | V3

ISBN: 13-978-0-692-07924-9

Guide Contributors

ROCKY MOUNTAIN MASONRY INSTITUTE

Bret Terry

RDH BUILDING SCIENCE

Bailey Brown | M.S., P.E.
Randy Van Straaten | PhD., P.Eng.
Graham Finch | Dipl.T, MASc, P.Eng
Michael Aoki-Kramer | LEED AP®

Atkinson-Noland & Associates

Michael Schuller | P.E.

Acknowledgments

In addition to the guide contributors and sponsors, we thank Taylor Newman of RDH Building Science Inc for his contributions to the details and renders included throughout this guide. We also thank Kara Moore for managing the manuscript and her graphic design support.

Notice to the Users of This Publication

1. DISCLAIMER OF WARRANTIES
a) The Rocky Mountain Masonry Institute (RMMI) and RDH Building Science Inc. (RDH) provide this Publication for informational purposes. b) This Publication contains "Data" which is believed by RMMI to be accurate and correct. But the data, including all information, ideas and expressions therein, is provided strictly "AS IS" with all faults. RMMI and RDH make no warranty either expressed or implied regarding the Data and RMMI AND RDH EXPRESSLY DISCLAIM ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR PARTICULAR PURPOSE. c) By using the data contained in this Publication, the user accepts the Data "AS IS" and assumes all risk of loss, harm or injury that may result from its use. User acknowledges that the Data is complex, subject to faults and requires verification by competent professionals, and that modification of parts of the Data by user may impact the results or other parts of the Data. d) IN NO EVENT SHALL RMMI OR RDH OR ANY SUPPORTING SPONSOR BE LIABLE TO USER, OR ANY OTHER PERSON, FOR ANY INDIRECT, SPECIAL OR CONSEQUENTIAL DAMAGES ARISING, DIRECTLY OR INDIRECTLY, OUT OF OR RELATED TO USER'S USE OF RMMI'S OR RDH'S PRODUCT OR MODIFICATION OF DATA THEREIN. This limitation of liability applies even if RMMI and/or RDH has been advised of the possibility of such damages. IN NO EVENT SHALL RMMI'S OR RDH'S LIABILITY EXCEED THE AMOUNT PAID BY USER FOR ACCESS TO RMMI'S AND RDH'S PRODUCT OR $1,000.00, WHICHEVER IS LESSER, REGARDLESS OF LEGAL THEORY. e) The User, by its use of this RMMI Publication, acknowledges and accepts the foregoing limitation of liability and disclaimer of warranty and agrees to indemnify and hold harmless RMMI and RDH from and against all injuries, claims, loss or damage arising, directly or indirectly, out of user's access to and use of this Publication or the Data contained therein.

2. ACCEPTANCE
This Publication is prepared for voluntary acceptance and use within the limitations of application defined herein, and otherwise as those adopting it or applying it deem appropriate. It is not a safety standard. Its application for a specific project is contingent on a designer or other authority defining a specific use. RMMI and RDH have no power or authority to police or enforce compliance with the contents of this document or publication and it has no role in any representations by other parties that specific components are, in fact, in compliance with it.

3. AMENDMENTS
RMMI and RDH may, from time to time issue formal interpretations or interim amendments, which can be of significance between successive editions.

4. PROPRIETARY PRODUCTS
RMMI and RDH encourage technological development in the interest of improving the industry for the public benefit. RMMI and RDH do not, however, endorse individual manufacturers or products.

5. FORMAL INTERPRETATION
a) A formal interpretation of the literal text herein or the intent of the technical committee or task force associated with this Publication is obtainable by a written petition, addressed to RMMI's Technical Director and sent to the RMMI's office in Denver, Colorado. If the petitioner has a substantive disagreement with the interpretation, an appeal may be filed with RMMI, which has technical oversight responsibility. The request must pertain to a specifically identified portion of the document that does not involve published text which provides the requested information. In considering such requests, RMMI will not review or judge compliance of products or components within the Publication. Oral and written interpretations otherwise obtained from anyone affiliated with RMMI are unofficial. This procedure does not prevent any RMMI Board or Committee member from expressing an opinion on a provision within the document, provided that such person clearly states that the opinion is personal and does not represent an official act of RMMI in any manner. b) RMMI disclaims any liability for any personal injury, property damage, or other damage of any nature whatsoever, whether special, indirect, consequential or compensatory, direct or indirectly resulting from the Publication. RMMI makes no guaranty or warranty as to the accuracy or completeness of any information published herein.

6. APPLICATION
a) Any standard contained in this Publication was developed using reliable engineering principles and research, plus consultation with, and information obtained from manufacturers, users, testing laboratories, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable. Construction and products which comply with these standards will not necessarily be acceptable if, when examined and tested, they are found to have other features which impair the result contemplated by these requirements. RMMI, RDH, and other contributors assume no responsibility and accept no liability for the application of the principles or techniques contained in this publication. Authorities considering adoption of any standards contained herein should review all federal, state, local, and contract regulations applicable to specific installations. b) In issuing and making this document available, RMMI and RDH are not undertaking to render professional or other services for or on behalf of any person or entity. RMMI and RDH are not undertaking to perform any duty owed to any person or entity to someone else. Any person or organization using this document should rely on his, her, or its own judgment. As appropriate, they should seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstance.

7. THE RMMI LOGO
The RMMI logo is registered as a membership identification mark and it prescribes acceptable use of the logo and expressly forbids the use of it to represent anything other than possession of membership. Possession of membership and use of the logo in no way constitutes or reflects RMMI approval of any product, method, or component. Furthermore, compliance of any such item with standards published or recognized by RMMI is not indicated by presence of the logo.

Thank You to Our Sponsors

Parapet Sponsors

Basalite Concrete Products

General Shale

RDH Building Science, Inc.

Rio Grande Co.

Soderberg Masonry, Inc.

Solomon Colors, Inc.

SpecMix

Cornerstone Sponsors

Continental Cast Stone

Gateway Sponsors

Ammex Masonry, Inc.

Colorado Best Block Company

Hohmann & Barnard, Inc.

US Mix

Pillar Sponsors

Atkinson-Noland & Associates, Inc.

Summit Brick Company

Wirebond

Foundation Sponsors

A.P. Eberlein Company, Inc.

Berich Masonry, Inc.

BrickStone, Inc.

Dow Building Solutions

EZG Manufacturing

GCC

Midwest Cast Stone

Mortar Net Solutions

St. Vrain Block Company

Threewit – Cooper Cement Company

York Manufacturing, Inc.

Foreword

This guide has been established by the Rocky Mountain Masonry Institute (RMMI) to provide masonry design details and construction practices acceptable in the state of Colorado and in southern Wyoming to owners, architects, and contractors. The RMMI guide is the first of its kind in the Rocky Mountain region, which fills a void in the masonry construction industry and will encourage the use of masonry in projects. The guide is meant to be a reference for masonry construction and design.

RMMI is THE resource for the masonry profession. This guide would not be the comprehensive resource it is without the expertise and practical knowhow of its members. All members of RMMI adhere to the highest professional standards as well as the exclusive RMMI Code of Ethics.

In addition to using this design guide as a resource, using an RMMI-certified contractor on your masonry project is key to successful construction. This can be done by requesting that bids are submitted by certified contractors. Masonry certification begins with a year-long continuing education program covering all aspects of masonry design, construction, and business management. Masonry professionals who successfully complete the courses and pass a comprehensive examination may earn the coveted title of Certified Masonry Contractor, Professional, or Specialist. As a condition of certification, all certified RMMI members pledge to adhere to the highest standards of craftsmanship and business practices. They agree to abide by the manufacturing, workmanship, and safety standards set forth by our industry's governing organizations—the National Concrete Masonry Association, Brick Industry Association, American Society for Testing & Materials (ASTM), and the Occupational Safety & Health Administration (OSHA). They also endure periodic inspections by our safety and technical advisors, and they are committed to ongoing training to improve their knowledge and skills. When you work with a certified RMMI-certified member, you work with the most knowledgeable, experienced, and committed professionals in our industry. Furthermore, RMMI's technical advisors will be there to help solve any technical problems or disagreements that may arise before, during, or after construction—at no cost to you. (http://www.rmmi.org/about_us.php).

As an additional service, RMMI's architectural and engineering experts are available to provide technical information and assistance at any stage of your project. For architectural help, contact RMMI at 303-893-3838. For engineering help, contact RMMI's expert advisors at Atkinson-Noland & Associates/ Consulting Engineers at 303-444-3620 or at info@ana-usa.com. For building enclosure consulting, contact RDH Building Science Inc. at 206-324-2272 or sea@rdh.com.

The Rocky Mountain Masonry Institute, 2018

COLORADO MASONRY SYSTEMS DESIGN GUIDE

Table of Contents

CHAPTER 5: QUALITY CONTROL AND ASSURANCE

CHAPTER 6: ANCHORED MASONRY VENEER SYSTEMS

CHAPTER 7: SINGLE-WYTHE CMU SYSTEMS

CHAPTER 8: THERMAL PERFORMANCE & ENERGY CODE COMPLIANCE

List of Details

RMMI

ROCKY MOUNTAIN MASONRY INSTITUTE

1

CHAPTER 1

Introduction

Fig. 1-1 Dairy Block in Denver, CO
Photo by Todd Winslow Pierce

For over a century, masonry has been used successfully as a primary structural system and as a cladding in building construction in Colorado and southern Wyoming. 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, load-bearing mass masonry wall systems were commonplace, primarily due to their superior fire resistance, durability, and weatherability. Over time, such systems have given way to alternative structural or framing materials with separate cladding and additional layers that provide a variety of functional purposes. Mass structures inherently address the many above-grade functions of walls, including control of water, air, heat, sound, and fire. Modern walls include increased complexity such as:

- 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, heat, sound, and pollutants that move with air—between the interior and exterior environments.
- Water vapor and liquid water barriers and drainage systems are necessary to ensure that moisture-sensitive structural and insulation components are protected.

Traditional decorative and durable cornice and cornerstone elements and built-in drip edges at strategic locations, such as those shown in Fig. 1-2, are typical of the mass masonry structures that have lasted the test of time. These elements deflect much of the water cascading down the face of these buildings away from the wall, including away from wall penetrations (e.g., windows, doors, and vents) that are most sensitive to water entry. Fig. 1-3 shows a typical modern brick veneer wall where rainwater-deflecting face elements have been eliminated or traded for a more modularized and economized veneer. Fortunately, most veneer wall assemblies can accommodate the added moisture ingress due to a concealed drainage plane and flashings. The result is a wall with similar fire-resistivity and weatherability that reflects a modern design.

Wall design has evolved to more complex overall systems, product selection, and code compliance than in previous years. The successful performance of masonry wall systems has demonstrated their durable, accommodating nature and suitability for the local climate conditions of Colorado and southern Wyoming.

Fig. 1-2 Common historic water-deflecting elements including cornice, belt course, and sill elements

Fig. 1-3 Contemporary masonry building
Photo by Joseph Deshler Photography

The focus of this guide is to provide comprehensive design and construction detailing information for clay or concrete masonry as anchored veneer or single-wythe concrete masonry unit (CMU) above-grade wall systems for Colorado, southern Wyoming, and similar geographic locations. The discussion and design guidance for each system is focused on managing moisture, air, and heat transfer between the interior and exterior environments, with an emphasis on constructability to promote long-term durability.

Each system within this guide is addressed specifically to Colorado and southern Wyoming and considers local climate, codes, and building preferences and practices. The systems in this guide have been developed for application to occupied multistory, multifamily residential or commercial structures with typical indoor environments. Although some of the systems discussed within this guide may be applicable to structures with special indoor environments (e.g., natatoriums, refrigerated and freezer warehouses, nonconditioned spaces, etc.), these applications are not the intended scope of this guide. The information in this guide is not meant to be exhaustive of all system variations, product performance properties, or detailing approaches but rather provides a selection of successful enclosure design and construction practices executed in Colorado and southern Wyoming.

This guide is not intended to replace professional advice. When information presented here is incorporated into the specifications of 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 bylaws.

How to Use This Guide

The masonry-based wall systems that are the focus of this guide are introduced in Chapter 2. The content of this chapter is provided to facilitate initial selection of a masonry wall system and provides a high-level comparison of each system relative to key performance attributes. Assembly examples of these wall systems are graphically depicted in Fig. 1-4 and Fig. 1-5.

General building enclosure design concepts and design concepts specific to masonry systems are presented in Chapter 3 and Chapter 4, respectively. These concepts provide the basis for discussion of specific designs in later chapters.

Quality control and quality assurance measures for both masonry and general building enclosure design and installation are presented in Chapter 5. This chapter includes discussion and recommendations for improving the aesthetic appearance as well as long-term durability of both anchored masonry veneer and CMU wall systems.

Anchored masonry veneer wall systems and mass wall systems are presented in Chapters 6 and 7, respectively. Within these chapters, building enclosure design principles, as they apply to specific wall systems and material selection, are discussed. These materials and principles may differ based on backup wall variations or insulation strategy for each type of masonry system. The chapters include two- and three-dimensional details and cutaway wall sections for illustration.

Chapter 8 provides thermal performance discussion, energy code compliance discussion, and thermal performance design tables that cover the masonry wall systems presented in Chapters 6 and 7. This chapter includes specific factors and

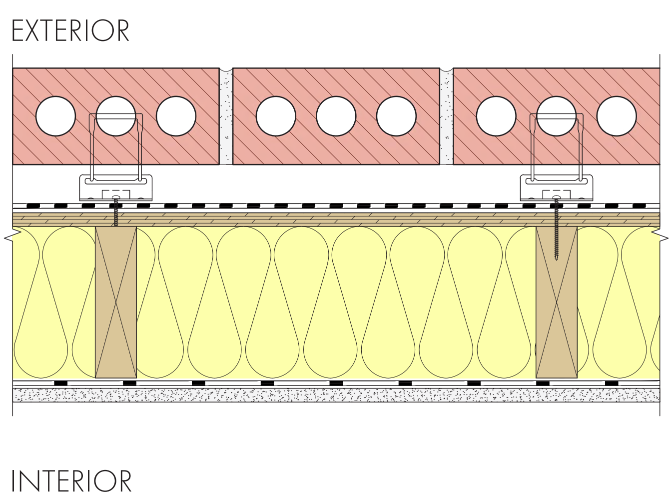


Fig. 1-4 Typical anchored masonry veneer wall assembly with wood-framed backup wall structure

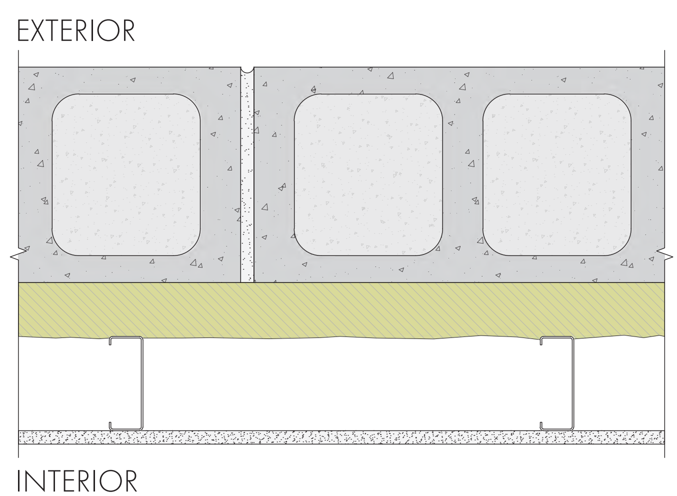


Fig. 1-5 Typical CMU wall assembly with interior insulation

assumptions made for the thermal modeling exercise for which the design tables are based. The thermal performance insights within Chapter 8 can be used to inform the selection of insulation material types, thicknesses, and location as well as veneer attachment options.

A glossary of commonly used terms is presented at the end of this document.

Online Availability

The content of this guide is available online at www.rmmi.org. Downloadable two- and three-dimensional system details and cutaway sections and additional resources are also available at this online location.

RMMI

ROCKY MOUNTAIN
MASONRY INSTITUTE

2

CHAPTER 2

Masonry Systems

Fig. 2-1 Elizabeth Hotel in Fort Collins, CO
(Mason Contractor: Ammex Masonry, General Contractor: Hensel Phelps, Architect: 4240 Architecture, Inc.) Photo by Bryn MaRae Photography

In this guide, a masonry system is defined as an above-grade exterior wall assembly that includes masonry as the primary cladding element. Masonry wall systems are 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 wall penetration and transition details.

The wall systems featured in this guide include anchored masonry veneer with concrete, CMU, steel stud-framed, or wood-framed backup wall structures as depicted in Fig. 2-2. These systems are discussed in Chapter 6 and allow for alternative veneer and insulation options from those shown.

Also featured in this guide is a single-wythe CMU wall system with insulation interior of the CMU. This system is depicted in Fig. 2-2 and is discussed in Chapter 7. Various interior insulation options are also described within this chapter.

Selecting a Masonry System

This chapter describes and compares anchored masonry veneer and single-wythe CMU wall systems according to several comparison categories. This comparison is provided in a System Comparison Matrix on page 12, which may be used to assist with the initial selection of an appropriate masonry system(s) for a particular project. The comparison categories are described in this section.

Maximum Building Height

The maximum building height recommended for each system is provided. These are determined by typical wind pressures, common building shape/form, and accessibility for material installation and long-term maintenance needs. Building height

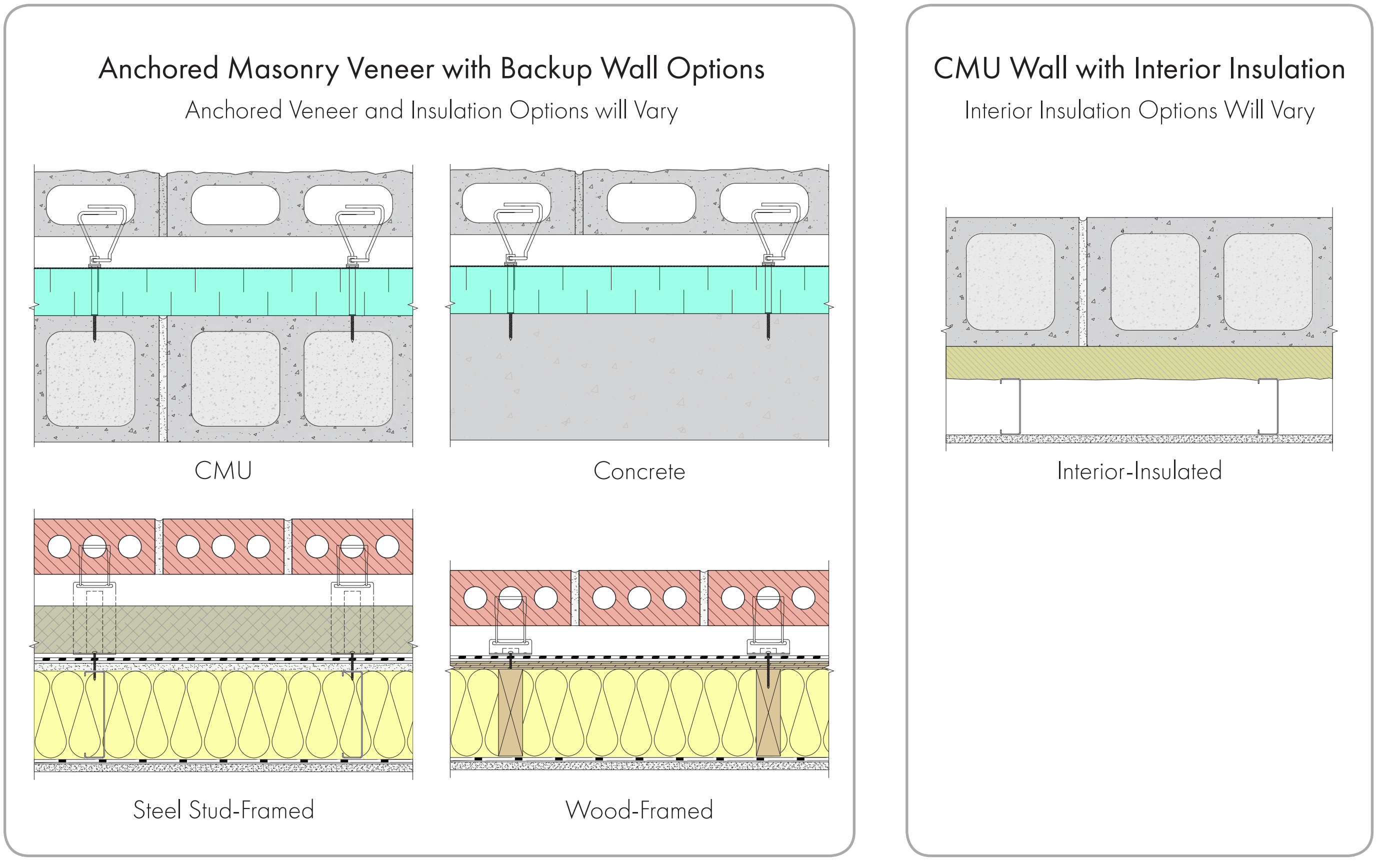


Fig. 2-2 Typical masonry system options discussed within this guide

definitions vary throughout the industry; however, in this guide, building height is classified by low-, mid-, and high-rise and is further described in the legend of the System Comparison Matrix. Some systems may be used for buildings of greater height than that identified within the matrix; however, these applications should be carefully evaluated by the project's design team.

Typical Assembly Thermal Performance

Defines the typical effective R-value for the field-of-wall area. The R-value range provided accounts for the thermal resistance of the wall layers (including equivalent interior and exterior air films) but also includes the three-dimensional effect of standard repetitive framing (e.g., steel studs and tracks), and cladding attachments such as masonry anchors. Within the system comparison matrix, the R-value provided assumes no major conductive penetrations such as balconies, shelf angles, or floor line transitions.

For veneer systems, it is assumed that framed wall cavities contain insulation and that exterior insulation is of a thickness that may be reasonably installed using typical construction practices of Colorado and southern Wyoming.

For single-wythe wall applications, typical R-values assume an 8-inch CMU wall and interior insulation types and thicknesses that may be reasonably installed using typical construction practices of Colorado and southern Wyoming.

Thermal performance of any system can vary with wall depth, insulation type and thickness, or cladding attachment methods. Refer to Chapter 8 for more discussion on the thermal performance of these systems and for effective R-value design tables.

Cladding Attachment (Lateral Loads)

Defines the attachment method used to laterally support the masonry veneer (where applicable).

Cladding Support (Gravity Loads)

Defines the method used to support the gravity loads of the masonry component of the system.

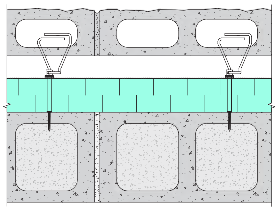
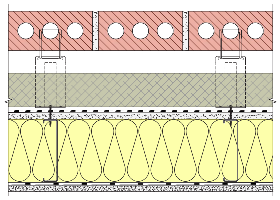
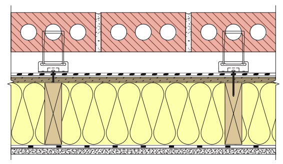
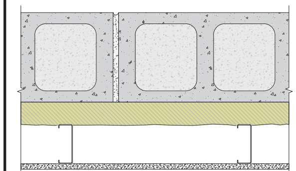
Fire-Resistance Rating

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. Single-wythe backup wall systems assume an 8-inch-wide CMU wall; thicker CMU walls may achieve a higher rating.

Chapter References

1. The Masonry Society. *TMS-402-16 Building Code Requirements for Masonry Structures.* (n.p.: The Masonry Society, 2016).

Table 2-1 System Comparison Matrix

Comparison Categories	Anchored Masonry Veneer Systems (See Chapter 6)			Single-Wythe CMU (See Chapter 7)
				
Backup Wall Structure	CMU or Concrete	Steel Stud-Framed	Wood-Framed	CMU
Maximum Building Height				
Insulation Strategy	Exterior of structure	In framed cavity and exterior of structure	In framed cavity; insulation exterior of structure optional	Interior of structure
Typical Assembly Thermal Performance	R-10 through R-20+ See page 138 for thermal performance information.	R-15 through R-20+ Exterior insulation typical to compensate for highly conductive steel framing. See page 141 for thermal performance information.	R-18 through R-20+ For a greater assembly effective R-value, exterior insulation may be added to this assembly. See page 147 for thermal performance information.	R-7 through R-20+ Interior continuous insulation unbridged by highly conductive steel framing provides the greatest effective R-value. See page 151 for thermal performance information.
Cladding Attachment (Lateral Loads)	Anchored Cavity depths are limited to 6 ⅝″ per TMS-402-16. [1] See page 71 for anchor options.	Anchored Cavity depths are limited to 6 ⅝″ per TMS 402-16. [1] See page 71 for anchor options.	Anchored Cavity depths are limited to 6 ⅝″ per TMS 402-16. [1] See page 71 for anchor options.	N/A Independent cladding design not applicable; wall structure provides cladding element.
Cladding Support (Gravity Loads)	Bearing Elements Requires TMS-402-16[1] required bearing elements such as footings, shelf angles, and floor slabs.	Bearing Elements Requires TMS-402-16 [1] required bearing elements such as footings, shelf angles, and floor slabs.	Bearing Elements Requires TMS-402-16 [1] 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 Rating				

Legend:

Maximum Building Height	**Low** ≤ 3 stories 	**Mid** 4–8 stories 	**High** ≥ 9 stories 	Fire Resistance Rating	 = 1 HOUR

RMMI

ROCKY MOUNTAIN

MASONRY INSTITUTE

3

CHAPTER 3

The Building Enclosure

Fig. 3-1 Northfield High School at Paul Sandoval Campus in Denver, CO
(Mason Contractor: Rocky Mountain Stonework, General Contractor: GE Johnson Construction Co., Architect: LOA Architects) Photo by Brad Nicol

The building enclosure (i.e., building envelope) is a system of materials, components, and assemblies physically separating 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) and much more. The building enclosure must also provide support against physical loads on the building (e.g., air pressures, gravity loads, impact, etc.). The building enclosure must also provide an acceptable interior and exterior finish and help distribute utilities through the building. An appropriately designed building enclosure benefits a building's serviceability, comfort, durability, and heating and cooling energy use. 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 interfaces and details in between. Many of these elements are visible in Fig. 3-1. The focus of this guide is above-grade masonry systems; where appropriate, roof, floor line, foundation, fenestration transition details, and typical wall penetration details are also discussed as they relate to the masonry wall systems.

Within building enclosure design, there is a relationship between the loads that act on the building enclosure and the various layers and materials that control these loads. This chapter describes each aspect of this relationship with respect to masonry wall systems.

Building Enclosure Loads

Over the life of a building, the building enclosure is subjected to a wide range of interior and exterior environmental loads.

Interior Environmental Loads

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

In general, these loads are relatively predictable and can be controlled through various heating, cooling, and ventilation strategies and regular building maintenance.

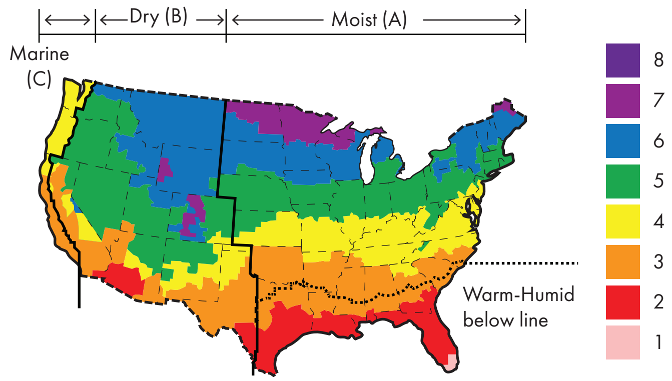


Fig. 3-2 Contiguous United States climate zone map, as referenced from Figure C301.1 of the 2018 International Energy Conservation Code[1]

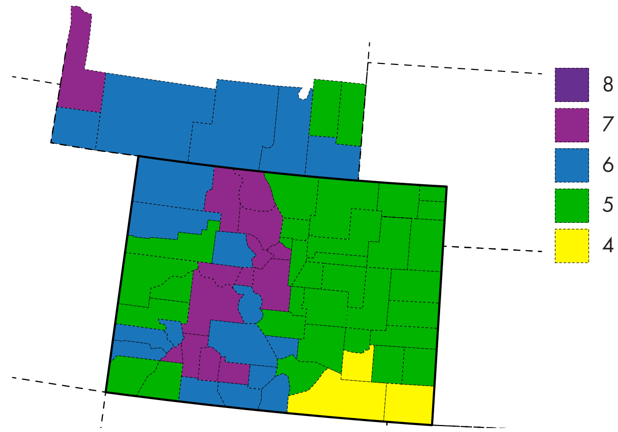


Fig. 3-3 Colorado and southern Wyoming climate zones as excerpted from Fig. 3-2

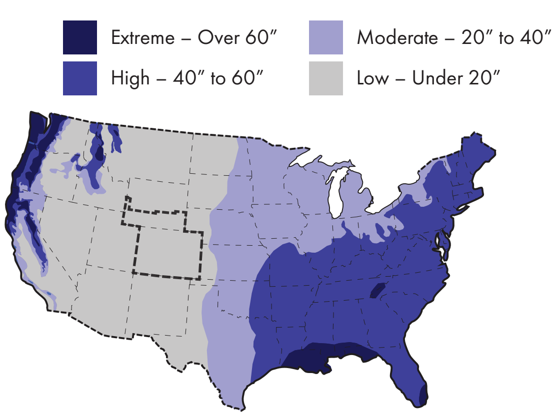


Fig. 3-4 Contiguous United States total annual rainfall levels[2]

Exterior Environmental Loads

Exterior environmental loads typically 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 addition to its site-specific features, dictates the magnitude and duration of these environmental loads. 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, a project in a regional high wind area adjacent to other buildings or a heavily wooded area of similar or greater height will reduce the wind and driving rain exposure of the building.

As depicted in Fig. 3-2 and Fig. 3-3, four climate zones exist in Colorado and southern Wyoming and include Zones 4, 5, 6, and 7. These climate zones impose a wide range of exterior temperatures; however, the masonry design guidance provided within this guide is generally applicable to all zones within Colorado and southern Wyoming. Colder temperatures of Zones 5, 6, and 7 may require special considerations for some masonry installations to minimize freeze-thaw cycle risk and is discussed in Chapter 4.

As shown in Fig. 3-4, Colorado is located within a relatively low rainfall area; however, the importance of providing good enclosure design for moisture management is still critical. The impact of snow melt or rain (i.e., liquid water) flowing over or falling on the exterior surface of the building and the masonry cladding creates the most critical loads acting on the enclosure with respect to long-term enclosure durability. As such, two factors further determine the loads that act on the enclosure: 1) the building's form and features, and 2) the enclosure's ability to shed water or provide a continuous water-shedding surface.

Fig. 3-5 On this façade, sunshades above window penetrations, canopy cover over a storefront window, and a parapet coping that projects beyond the wall face deflect or divert moisture and/or sun away from the enclosure. Photo by Bryn MaRae Photography

Fig. 3-6 Generous roof overhangs, gutter systems, and sloped sill and water table elements all serve to reduce the water load on the building enclosure. Photo by Bryn MaRae Photography

Fig. 3-7 Balcony elements on this façade are sloped away from the veneer to ensure runoff from rainfall and snowmelt is directed away from the wall system. Sloped sills are proud of the masonry veneer and form a drip to shed water before it has an opportunity to drain onto the masonry veneer below.

Building Form and Features

Region and site-specific climate determine the expected rain, snow, hail, solar, and wind loads. 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 the masonry cladding, fenestrations, cornice elements, counterflashings, and drip edges that all act as part of the water-shedding surface. Examples of building form and features on projects that used masonry wall systems are shown in Fig. 3-5, Fig. 3-6, and Fig. 3-7.

Specific to above-grade wall systems, exterior architectural elements such as balconies, canopies, or roof overhangs can deflect rainwater or snow accumulation away from fenestration systems, cladding elements, and building entrances. 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 onto masonry wall cladding could cause staining and efflorescence, cladding damage, or worse; water ingress into the building. In Colorado and southern Wyoming, it is especially critical in snowfall areas that a building's form and features are designed for snow accumulation and snow melt.

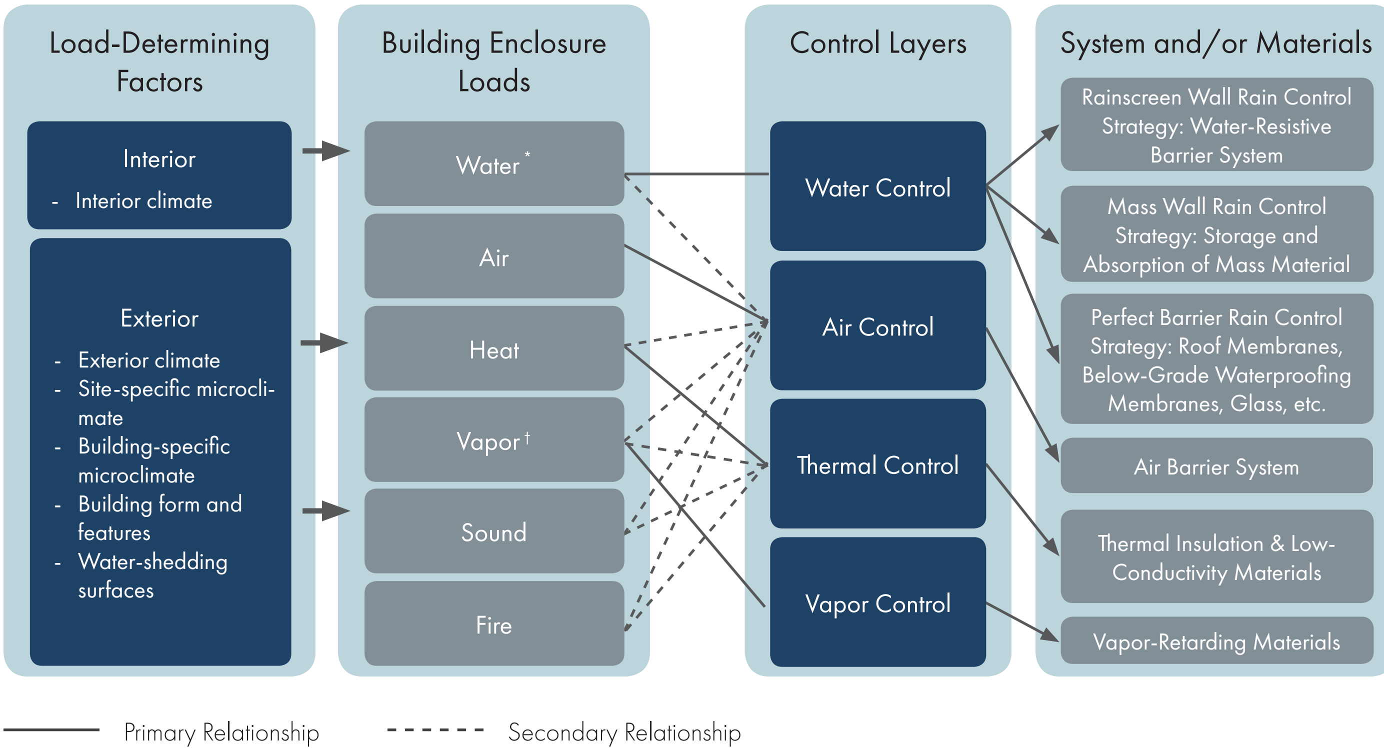
Water-Shedding Surface

The water-shedding surface is the outer surface of the building enclosure; particularly, the anchored veneer or CMU wall face at the field-of-wall area. This surface deflects and drains most 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 masonry system figures and details throughout this guide.

Control Layers

In this guide, water, air, thermal, and vapor control are described; the control of sound, fire, light, and contaminants are related to the concepts discussed within this guide but are not covered in detail.

Water, air, thermal, and vapor enclosure loads are controlled by specific layers called control layers. These layers comprise systems of materials or stand-alone materials that are intentionally selected and located within the enclosure as shown in Fig. 3-8.



* Water is defined here as precipitation (rain, snow, hail, etc.) and groundwater as well as condensate moisture.
† Vapor is separately defined here as the water vapor in air.

Fig. 3-8 Building enclosure load and control layer relationships

When control layers are intentionally designed to control a specific load, they are said to have a *primary relationship* with the building enclosure load. Some control layers also control other loads indirectly and form a *secondary relationship*. Primary and secondary relationships are depicted in Fig. 3-8 with a solid and dashed line, respectively. 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.

Using the control layer concept to evaluate assemblies and details follows industry best practices and can be useful to assess specific assemblies and details being considered for a project. Applying the control layer concept can help all parties better understand the role and importance or functions of the systems and materials associated with each layer and can help identify areas where control layers may be missing, discontinuous (if required to be continuous), or inappropriately redundant.

A general summary of the water, air, thermal, and vapor control layers is provided on page 21. Both Chapter 6 for anchored masonry veneer wall systems and Chapter 7 for single-wythe CMU wall systems discuss the control layers specific to each masonry wall system.

Additionally, throughout this guide, control layers are shown on system assembly figures and on detail figures as shown in Fig. 3-9.

System Rain Control Strategies

There are three categories of rain control strategies available for above-grade masonry walls:[3]

- Screened and drained (i.e., rainscreen)
- Mass (i.e., storage)
- Perfect barrier

Rainscreen and mass strategies are discussed further below. 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.

Rain Control: Rainscreen Strategy

The anchored masonry veneer wall systems described in this guide control rainwater with a rainscreen strategy. This rain control strategy assumes that some water makes its way through the cladding plane while the building is in service. In this guide, a rainscreen strategy assumes the characteristics discussed in Fig. 3-10.

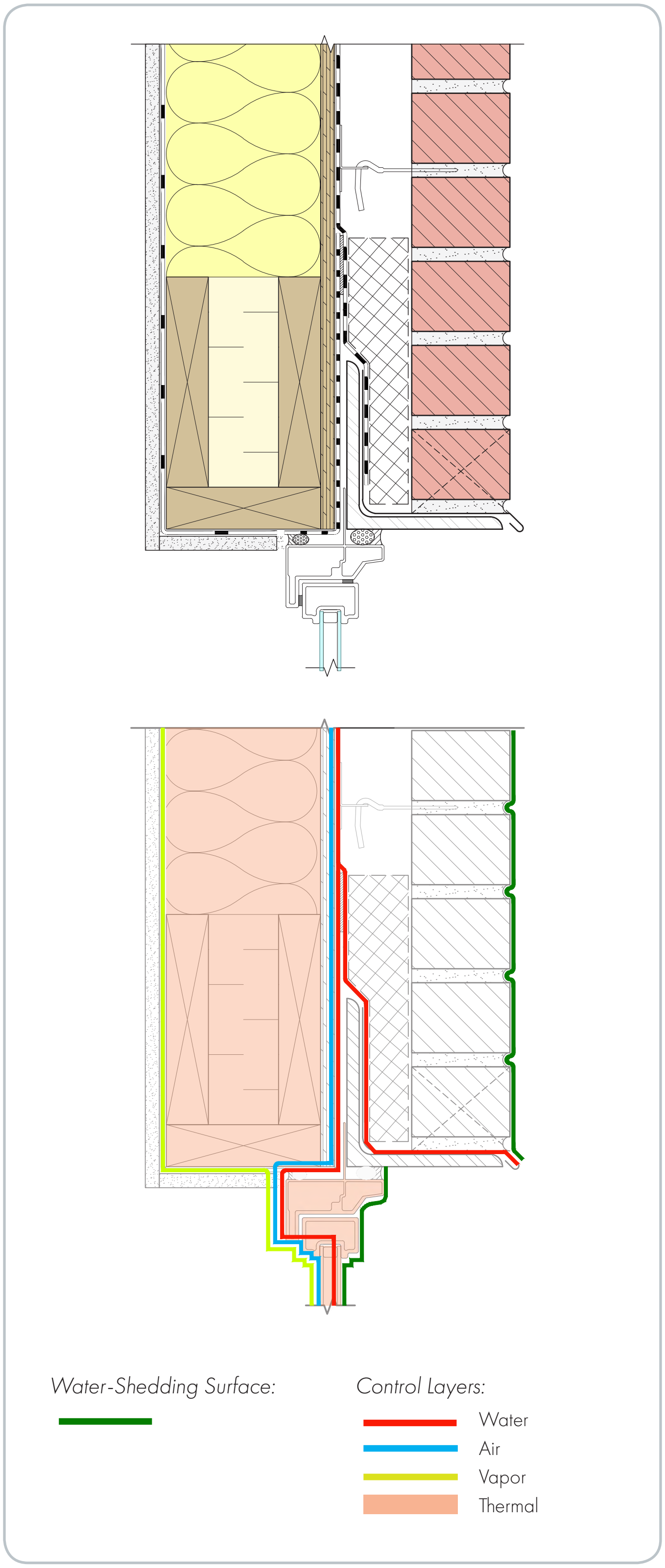
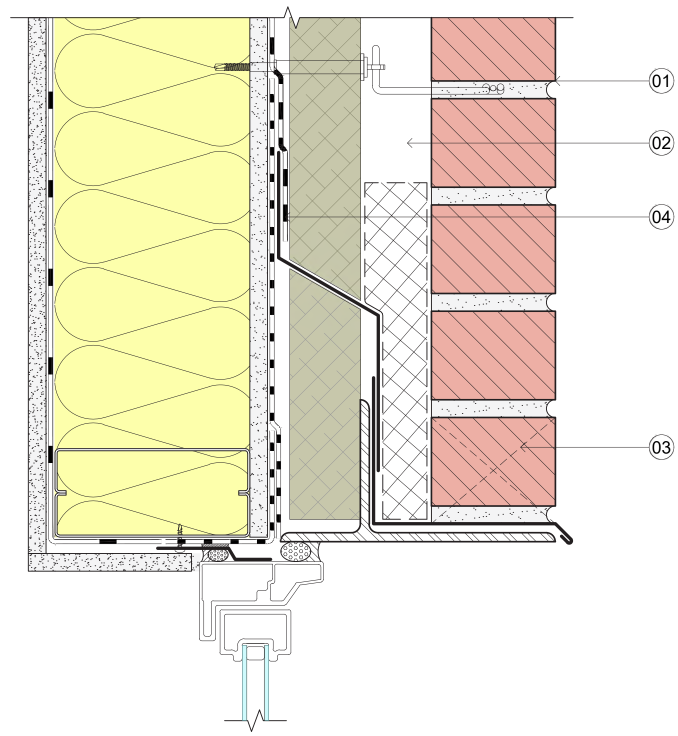


Fig. 3-9 *Window head detail with wood-framed backup wall and anchored masonry veneer (top). The accompanying water-shedding surface and control layers of the detail are also described (bottom).*



Legend:

1. *Cladding:* the anchored masonry veneer to shed water.
2. *Air Cavity:* behind the veneer to allow for drainage. This cavity may be vented or ventilated.
3. *Drain Holes or Gaps:* through the veneer system so drained water can leave the air cavity. Flashings are typically placed at drain hole or drainage gap locations (e.g., ledger supports, base-of-walls, doors, windows, etc.) to direct draining water to the exterior environment.
4. *Drainage Plane:* the face of a water-resistive barrier membrane (i.e., the water control layer). This membrane acts as a drainage plane within the air cavity behind the veneer. Flashings, whether flexible membranes or sheet metal, are also part of the drainage plane.

Fig. 3-10 *Window head detail depicting an anchored masonry veneer wall with steel stud-framed backup wall structure. Masonry wall systems, which control rain using a rainscreen strategy, include these characteristics.*

Control Layer Summary

Water Control Layer

The water control layer is a continuous control layer designed and installed to act as the innermost boundary against water intrusion.

The water control layer of an above-grade wall system will vary based on the wall system's rain control strategy (see "System Rain Control Strategies" on page 19) as described further in Chapter 6 for anchored masonry veneer wall systems and Chapter 7 for single-wythe CMU wall systems.

Air Control Layer

The air control layer controls the flow of air through the building enclosure, either inward or outward. Air flow is significant because it impacts heat flow (space conditioning), water vapor transport, and rain penetration control. The air control layer includes the air barrier system which is:

- Impermeable to air flow.
- Continuous across the building enclosure.
- Strong enough to transfer the forces that act upon on it (e.g., mechanical pressures, wind pressures, and stack effect) back to the structure.
- Stiff enough that it does not distort such that the performance properties of the system are changed.
- Durable over the life expectancy of the building enclosure.[6]

Specific to the scope of this guide and the International Energy Conservation Code (IECC),[1] an air barrier material has an air permeance less than 0.004 cfm/ft^2 at 1.57 psf (75 Pa) when tested to ASTM E2178.[4] An air barrier assembly has an air permeance of less than 0.04 cfm/ft^2 at 1.57 psf (75 Pa) when tested to ASTM E2357[5] and ASTM E283.[7]

The air barrier system extends to the masonry system's details and transitions including 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.

Thermal Control Layer

The thermal control layer controls 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 increase heat flow and be considered a thermal bridge, while others substantially minimize heat flow.

In the masonry wall system, materials that contribute to minimizing heat flow across the system include thermal insulation, low-conductivity framing elements, and thermally improved glazing systems. Materials that increase heat flow and may be considered thermal bridges include some anchored masonry ties and shelf angle supports. Careful consideration of thermal bridges or thermal discontinuities should be addressed by design.

Chapter 8 sections regarding thermal performance further discuss types of thermal insulation and wall components that create thermal bridges specific to the masonry wall systems addressed in this guide.

Vapor Control Layer

The vapor control layer retards or greatly reduces the flow of water vapor through the building enclosure. The ease with which water molecules diffuse through a layer is known as vapor permeance. The 2018 International Building Code[8] (IBC) 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,[8] a Class IV vapor permeance designation is often used for materials with a vapor permeance > 10 perms.

Section 1405.3 of the IBC[8] defines code requirements for vapor control in Colorado and southern Wyoming climate zones.

The location and need for a vapor control layer is dictated by the location and vapor permeance of the materials and systems that form the remaining control layers in the above-grade masonry wall system. A vapor control layer may not be necessary for some masonry wall systems. Specific recommendations for vapor control are provided in Chapters 6 and 7.

Rainscreen wall systems can exhibit good resistance to water penetration and are less sensitive to water ingress than the other two rain control strategies. However, good performance relies on implementing proper details and ensuring acceptable construction practices are followed. Improperly executed details are frequently sources of water ingress, critically affecting the moisture performance of the assembly and contributing to premature weathering or efflorescence of the masonry veneer system.

A continuous air control layer is not a requirement of the rainscreen strategy but is typically provided to control condensation, improve rain control, and to meet energy code requirements.

Rain Control: Mass Wall

The single-wythe CMU wall systems in this guide controls rain through a mass strategy.

Mass walls control rainwater by absorbing some water and shedding the rest. Enough hygric mass is present within the wall to store the water so it can be released later during times of drying. Because mass walls store water and do not use drainage, they do not require a drainage plane. The greater the mass within the wall, the greater the storage capacity, which is similar to the concept of thermal mass.

In modern times, mass walls such as CMU walls are thinner than historic mass wall systems. Thinner systems benefit a building's usable square footage and reduce material or labor costs; however, these walls have less mass and often have continuous mortar joints that may incur hairline cracks. Unless modified, these walls have less moisture storage capacity and would be more vulnerable to rainwater leaks than historic mass assemblies.

As a result, designs for new mass wall systems must compensate by either only using them in low rain load applications (dry climate, first story, etc.), reducing their exposure (overhangs, drips, etc.) and/or improving their water-shedding characteristics—either with hydrophobic admixtures, with penetrating surface-applied water repellents, or with surface-applied nonpenetrating vapor-permeable coatings. These changes minimize wetting, reduce absorption, and increase watershed while still allowing the wall to dry the small quantities of rain that may still be absorbed.

Perfect Barrier

Perfect barrier walls are not discussed within this guide; however, perfect barrier assemblies or materials (such as a conventional roof membrane assembly or window glass) are common. While further discussion of the perfect barrier category of rain control is beyond the scope of this guide, the glossary contains a definition of a perfect barrier system.

Chapter References

1. International Code Council. *2018 IECC International Energy Conservation Code.* (Country Club Hills, IL: International Code Council, Inc., 2018).

2. RDH Building Science Inc. *United States Total Annual Rainfall Levels.* Map. Seattle, WA: n.p., 2017. Data courtesy of National Oceanic and Atmospheric Administration (accessed August 3, 2017).

3. John Straube. "BSD-013: Rain Control in Buildings." *Building Science Corporation*, published August 23, 2011, https://buildingscience.com/documents/digests/bsd-013-rain-control-in-buildings.

4. ASTM International. *ASTM E2178-13 Standard Test Method for Air Permeance of Building Materials.* (West Conshohocken, PA: ASTM International, 2013).

5. ASTM International. *ASTM 2357-11 Standard Test Method for Determining Air Leakage of Air Barrier Assemblies.* (West Conshohocken, PA: ASTM International, 2011).

6. John Straube. "BSD-014: Air Flow Control in Buildings." *Building Science Corporation*, published October 15, 2007, https://buildingscience.com/documents/digests/bsd-014-air-flow-control-in-buildings.

7. ASTM International. ASTM E283-04. *Standard Test for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen.* (West Conshohacken, PA: ASTM International, 2012).

8. International Code Council. *2018 International Building Code.* (Country Club Hills, IL: International Code Council, Inc., 2017).

RMMI

ROCKY MOUNTAIN

MASONRY INSTITUTE

4

CHAPTER 4

Special Design Considerations

Fig. 4-1 Double Tree in Greeley, CO
(Mason Contractor: Ammex Masonry, General Contractor: Hensel Phelps, Architect: Johnson Nathan Strohe) Photo by Bryn MaRae Photography

This chapter focuses on masonry wall design elements and construction considerations. Specific design elements include masonry flashings, movement joints, penetration detailing, and surface-applied and integral water repellents. Good design and sound construction practices will minimize the risk of water ingress, freeze-thaw decay, and efflorescence, resulting in the long-term durability and performance of masonry cladding.

Masonry Flashings

Flashing components are used in both rainscreen and mass wall systems to divert or deflect liquid water away from the masonry wall system, to provide a capillary break between masonry and other materials, and/or to protect less-robust underlying materials such as flexible membranes. In masonry wall systems, flashings may be:

- Formed from flexible membranes with or without an adhesive backing.
- Formed from sheet metal.
- Integral to masonry or precast concrete elements.
- A combination of any of the above.

Common locations for masonry flashings are identified in Fig. 4-2.

Effective flashings are durable and waterproof materials that can be manipulated or formed to provide a continuous water-shedding surface or be integrated with the water-resistive barrier to provide water control and a continuous drainage plane.

Flexible membrane flashings are concealed by the masonry cladding or sheet-metal flashing elements and are typically found at floor line transitions, at parapet caps, within rough openings, and around wall penetrations. Where flexible flashing materials are used, it is important to consider the materials' ability to withstand ultraviolet (UV) exposure. Materials sensitive to UV exposure are typically concealed with additional flashing materials such as sheet-metal drip plates or counterflashings for protection. Fire propagation concerns may also need to be addressed for some asphalt-backed flexible flashing materials; refer to the local building code for requirements.

Sheet-metal flashings may be either exposed or concealed within the assembly. Often, sheet-metal flashings—particularly stainless-steel—are thermally less conductive than other metal types. 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

Fig. 4-2 Typical flashing locations occur:

1. *Above and below wall penetrations (e.g., head, jamb, and sill flashings at windows, doors, and service penetrations).*
2. *At perpendicular wall interfaces (e.g., parapet-to-wall or roof-to-wall saddle flashings).*
3. *At parapet tops and roof or balcony edges (e.g., parapet copings and edge flashings).*
4. *At floor lines (e.g., cross-cavity sheet-metal flashing at anchored masonry veneer wall ledger locations).*
5. *At vertical support elements (e.g., base-of-wall flashings).*

Cross-cavity flashings, such as those that occur at floor line transitions of anchored masonry veneer wall systems 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 air cavity of an anchored masonry veneer while a through-wall flashing extends through the entire depth of the wall, such as one might see at the base of a single-wythe CMU wall system.

in masonry veneer applications; however, they may have a shorter service life and require replacement before the masonry veneer. The Architectural Sheet Metal Manual[1] published by the Sheet Metal and Air Conditioning Contractors' National Association has additional discussion on the design and installation of sheet-metal components including for masonry systems.

Flashing components that are integral to the masonry include sloped masonry elements—such as a sloped precast concrete window sill or cornice projecting beyond the cladding plane—and form a drip to encourage water shed.

Consider the following design characteristics to improve the ability of the flashing to enhance the long-term performance of the building's façade:

- ✓ *Slope*. Slope flashings to drain away from the building or material transitions.
- ✓ *Drip edges*. Form drip edges to shed water away from the building face. Drip edges may include hemmed sheet-metal edges or drip kerfs in the underside of precast concrete components.
- ✓ *Continuity*. Require continuous flashing materials. Specify minimum lap dimensions as recommended by the flexible membrane manufacturer or industry-standard resources for sheet metal. Continuity can be achieved by fully adhering or sealing the laps of flexible membranes or sheet-metal flashings. Typically, sheet-metal flashings are sealed with high-quality silicone or butyl-based sealant, or they may be soldered. Continuity of precast concrete components typically includes an elastomeric sealant joint with an appropriate backer material.
- ✓ *End dams*. Provide end dams where flashing materials terminate, such as at the jambs of fenestration products to divert water away from the veneer wall air cavity or penetrations within the masonry wall system. End dams are typically shop- or field-formed from flexible and sheet-metal flashing products and are an integral element of precast concrete components such as window sills.
- ✓ *Back dams*. Provide back dams on flashing materials. This may include vertical back legs on flexible or sheet-metal flashing components (typically 4 inches or greater) or stepped profiles on precast concrete elements.
- ✓ *Movement accommodation*. Position flashing components such that anticipated building movement will not disrupt the flashing's long-term performance. Fig. 4-3 describes an example of building movement adversely affecting the sheet-metal flashing profile and function.

Fig. 4-3 Cross-cavity sheet-metal flashing displaced as a result of wood-framed wall shrinkage and anchored masonry veneer expansion

- ✓ *Integration into the water-resistive barrier*. Shingle-lap flashing components into the water-resistive barrier where the flashing is intended to drain the water control layer of a rainscreen wall system (e.g., anchored masonry veneer systems).
- ✓ *Counterflashing*. Counterflash wall components with a flashing material (typically an adhered flexible flashing membrane concealed by a sheet-metal flashing) to provide a continuous water-shedding surface such as at a parapet cap.
- ✓ *Thermal performance*. Stainless steel has a lower thermal conductivity than galvanized steel; thus, sheet-metal flashings formed of stainless steel are expected to contribute to less heat loss where the flashing bridges insulation layers. Self-adhered sheet flashings create even less of a thermal bridge where bridging insulation layers.

This guide recommends clearly depicting the above characteristics throughout construction drawings and describing them in project specifications.

Movement in Masonry Systems

Over time, volumetric changes will occur within any above-grade wall system and can result from temperature changes, moisture, elastic deformation, settlement, and creep. The amount of movement that occurs will depend on the building materials used within the wall system and on the intensity of the influencing mechanism (e.g., temperature change). In general, wood frame members, CMU, and stone will shrink, whereas clay masonry will expand. If steel stud framing 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. If not properly designed for, differential movement can cause unwanted cracking, spalling, buckling, settlement, or separation within the building structure or veneer. Differential movement can also cause damage to other enclosure components such as the water-shedding surface, as demonstrated by the example in Fig. 4-3.

In this guide, the discussion and design of movement joints is considered in relation to differential movement between the veneer and wall structure, including control and expansion joints within the masonry veneer. A discussion of where to locate and how to size building-specific expansion joints that occur within the wall structure is beyond the scope of this guide and must be appropriately designed for and integrated into the above-grade wall system where they occur. The discussion provided for locating movement joints within the masonry system is for general reference only; the Designer of Record is responsible for appropriately designing for all building movement.

Locating Movement Joints

General rules for locating movement (i.e., expansion or control) joints as they relate to the wall systems in this guide are:

- *For anchored clay masonry veneer*, provide expansion joints such that long wall sections do not exceed 25 feet at occupied space and 15 feet at parapet conditions. At wall sections that have openings, joint locations may be reduced to 20 feet apart. Additional guidance on brick veneer expansion joints may be referenced from BIA Technical Notes 18[2] and 18A.[3]

- *For anchored concrete masonry veneer*, provide control joints such that long wall sections do not exceed a length-to-height ratio of 1 ½. The maximum wall length between control joints is 20 feet. Additional guidance on concrete masonry veneer control joints may be referenced from NCMA Tek 10-4 *Crack Control for Concrete Brick and Other Concrete Masonry Veneers.*[4]

- *For CMU wall structures*, provide control joints such that long wall sections do not exceed a length-to-height ratio of 1 ½. The maximum wall length between control joints is 25 feet. Additional guidance on control joints may be referenced from the NCMA Tek 10-2C *Control Joints for Concrete Masonry Walls – Empirical Method.*[5]

There is no single set of recommendations for the placement and design of movement joints that will work for all projects. In some cases, joints may be added more frequently than needed 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. 4-4 demonstrates an example of these locations.

Joint Placement – Vertical

- Throughout long walls with no openings, as described in the previous section
- At wall offsets and setbacks
- 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 backup wall meets a framed backup wall)

Joint Placement – Horizontal

- 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

Horizontal joints are also recommended at various locations on a veneer wall system to allow for cavity drainage and building movement. This includes accommodating movement around penetrations affixed to or penetrating through the backup wall, in addition to the veneer.

The location of joints, to accommodate movement, drainage, and/or veneer air cavity ventilation, is further discussed and identified within Chapter 6 for anchored masonry veneer and Chapter 7 for single-wythe CMU; chapter details identify these locations with an asterisk (*).

Joint Design

Joints that accommodate movement in anchored masonry veneer and single-wythe CMU wall systems typically include a backer rod and sealant joint. Movement joints are typically designed and constructed to accommodate 3 to 4 times the anticipated movement and are no narrower than ⅜ of an inch. Movement joints should allow for unobstructed movement and also 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 these properties:

- ✓ *Movement Capabilities*: The sealant selected should allow for expansion or compression of the sealant joint without permanent deformation. The recommended sealant product is classified as a Class 100/50 sealant per ASTM C920.[6] This sealant has joint movement capabilities of a minimum 100% extension and 50% compression when tested to ASTM C719.[7]

- ✓ *Adhesion to Substrate:* The sealant selected should demonstrate 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 failure (rather than adhesive failure).

- ✓ *Durability:* Movement joints at cladding should be UV-stable as well as durable when exposed to moisture and temperature fluctuations.

- ✓ *Longevity:* The longevity of the sealant joint should be as great as possible to match the durability of the masonry. Masonry is a long-lasting cladding option and will likely outlive the sealant joint; however, to reduce the replacement frequency of the joint, this guide recommends a quality silicone sealant. When properly installed and maintained as needed, neutral cure silicone sealants can exhibit 20+ years of acceptable performance. Other sealant options such as hybrid or polyurethane sealants may perform acceptably for 10+ years before replacement is required.

Fig. 4-4 Typical control joint locations exist where indicated by arrows.
Photo by Bryn MaRae Photography, Illustration by RDH Building Science, Inc.

Best Practices

These joint design best practices will promote long-term performance of a movement joint:

- ✓ Select a quality sealant based on the criteria described in the Joint Design section of this guide.
- ✓ 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 Manual[8] as well as the joint dimensioning described in Fig. 4-5.
- ✓ Review and repair joints one year after installation and biannually thereafter. Areas of adhesive failure or damage should be repaired.

Architectural Considerations

Where there is a desire to minimize the visual appearance of movement joints, consider the following:

- ✓ Select a sealant color similar to the mortar color.
- ✓ Choose a sanded joint (a joint that has mason's sand bed into the sealant following tooling) such as that shown in Fig. 4-6.
- ✓ Consider details that minimize the visible area of the joint while still accommodating movement, such as the anchored masonry veneer floor line detail alternatives in Chapter 6 on page 63.
- ✓ Include a provision in the project specifications 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.

Cleaners, Repellents, and Coatings

In Colorado and southern Wyoming, surface-applied clear water repellents are not commonly applied to the masonry veneer wall systems in Chapter 6 of this guide. Surface-applied clear water repellents are commonly applied to the single-wythe CMU wall systems in Chapter 7 or an elastomeric coating may be used in targeted applications. An alternative to using surface treatments for CMU wall systems is integral water repellents, which are incorporated into the masonry block prior to construction and added to the mortar mix at the construction site. The success of a clear water repellent, integral water repellent, or elastomeric coating is reliant on appropriate product selection, cleaning procedures, and application methods. Although these products have several functions, as described below, their use does not compensate for poor masonry workmanship or detailing. This section covers cleaning methods and best practices for selection and application of clear water repellents, integral water repellents, and elastomeric coatings.

Cleaning Methods

Cleaning mortar or grout smears, construction dirt, staining, contaminants, and efflorescence from the wall during the construction phase is required prior to applying clear water-repellent coatings. When masonry surfaces will have an opaque coating, cleaning is only necessary to provide adequate adhesion between the coating and the masonry.

Several cleaning methods are available including hand, water, chemical, and abrasive. Cleaning procedures are selected 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 contaminates 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 lead to premature weathering. Using a lower-strength mortar type, where acceptable for structural considerations, can also minimize the intensity of cleaning required; for example, using a Type S mortar when a Type N mortar is sufficient for the project application may require additional cleaning effort.

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

ASTM D5703[9] and BIA Technical Note 20[10] are helpful resources for determining appropriate cleaning procedures for clay masonry units, whereas NCMA TEK 8-4A[11] provides helpful discussion on cleaning CMU block of various types and finishes. Also consult the masonry unit manufacturer and cleaning product manufacturer guidance documents (where applicable) prior to cleaning.

Surface-Applied Water Repellents

Surface-applied clear water repellents may be considered for unglazed anchored veneer or for exterior-exposed single-wythe CMU systems. Application of a clear water repellent can reduce water absorption of the veneer and CMU, as demonstrated in

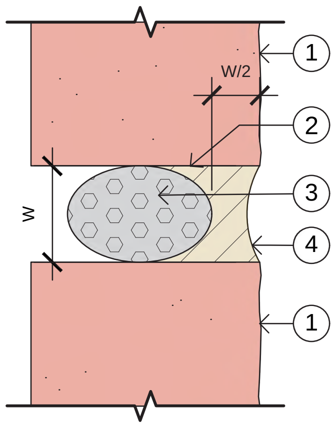


Fig. 4-5 Typical sealant joint design:

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. *Tooled sealant, sand joint surface where desired*

Fig. 4-6 Vertical sanded sealant joint example

Fig. 4-7, 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 freeze-thaw 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* penetrate 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—specifically silane/siloxane blend clear water repellents—are 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 or more 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 repellent products, limiting the effectiveness of the application.

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

- *Suitability for Substrate/Finish:* Products selected are suitable for vertical above-grade wall applications and project-specific masonry cladding types. Manufacturer-published literature should indicate 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 approximately 90% or more of the untreated masonry product vapor permeance is retained when tested to ASTM E96.[12]

- *Effective Water Penetration Resistance:* ASTM E514[13] results indicate a minimum 85% reduction in maximum leakage rate when compared to an untreated wall.

- *Block and Mortar Water-Repellent Admixture Compatibility:* Where a clear water repellent is applied over CMU and mortar containing a water-repellent admixture, use a clear water repellent that is compatible with the admixture. Incompatible repellents may be less durable.

Where antigraffiti repellent properties are desired, consider using a vapor-permeable silicone-based or fluorosiloxane-based water repellent with penetrating properties that is also marketed as an antigraffiti repellent. The antigraffiti repellent should provide similar water penetration resistance and vapor permeance to the characteristics/properties listed above. The effectiveness of antigraffiti properties is demonstrated through ASTM D7089[14] results, which may be used to compare the ease of graffiti removal.

Clear water repellents do not function as 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 resulting from water intrusion behind a masonry veneer and will require reapplication to be effective over the long-term service life of the building.

Best Practices

These general procedures and considerations are best practice for clear water repellent application:

✓ Complete the 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 to 21 days) prior to cleaning and application.

✓ Clean masonry substrates to remove debris and surface contaminants prior to water repellent application.

✓ Protect areas not to receive water repellent.

✓ Prevent contact between clear water repellents and non-masonry products such as asphalt-based products, glazing and glass products, 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 to review 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:

  – Beginning water repellent application on a dry substrate at lower surfaces, working upward as shown in Fig. 4-8. 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 for a minimum of 5 to15 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.

Integral Water Repellents

Integral water repellents are primarily used for weather-exposed single-wythe CMU systems and are incorporated in both CMU block and mortar. Repellents reduce the absorption and liquid water storage capacity of the masonry block and mortar and thus reduce

Fig. 4-7 Water beads on the surface of an anchored masonry veneer that has been treated with a clear surface-applied water repellent.

the risk of efflorescence or staining. However, this reduced storage capacity requires even more care to ensure a continuous water-shedding surface at the block wall face, transitions, and penetrations.

Integral water repellents alone do not singularly manage the water penetration resistance performance of a CMU wall system and have little impact on resisting water ingress at cracks or voids within the field of the wall. For these reasons, the integration of water-shedding measures such as flashing systems, weeps, vents, and control joints are critical to prevent moisture penetration in block walls. Proper design and quality workmanship are also critical to achieve a watertight system. This guide recommends that mortar joints be tooled with a concave or V-shaped profile to mitigate the risk of poor compaction and bond strength, especially when using integral water repellents in the mortar mix. Other joint profiles, such as raked, extruded, beaded, struck, or flush can create ledges to hold water and are not recommended.[15]

Integral water repellents can improve the long-term color retention of colored block, such as that commonly used for split-face block applications. Integral water repellents do not alter the finished appearance of the masonry walls (i.e., texture or color) and are a permanent part of the system; therefore, they do not require reapplication after a certain period to maintain the system's water repellency. Surface-applied products may be used with integral water repellents for added water penetration resistance at the surface; however, they will require reapplication for long-term performance.[16]

For CMU block, the water-repellent admixture is added into the concrete mix during the manufacturing process of the concrete masonry units and becomes evenly distributed throughout each block. For mortar, a compatible admixture product is incorporated into the mortar as it is mixed on-site. Integral water-repellent admixtures for preblended mortar products are typically powders added to the mortar mix during the manufacturing process.[17] Site-mixed water repellents are typically liquid admixtures.

It is critical that all CMU block and mortar, including other masonry components such as precast sills and lintels, contain the same or compatible integral water-repellent products and that those water-repellent products are compatible with other admixtures. The bond strength between mortar and CMU units may be compromised if incompatible products are used.[15] An adequate bond allows for continuity of the water control layer and water-shedding surface, especially at joint interfaces.

Clean CMU wall systems that include integral water repellents in accordance with the manufacturer's instructions. Avoid high-pressure water cleaning; it can reduce the effectiveness of the integral water repellent.[18]

Best Practices

These general application procedures and considerations are best practices for integral water repellent selection and application:

- ✓ Confirm the compatibility of the integral water repellent used both in the CMU blocks and in the mortar with the wall system grout or surface-applied repellents and coatings.
- ✓ If site-mixed integral water repellents are selected, incorporate the proper dosage of water-repellent admixture. Incorrect dosage can influence the workability of the mortar for masons and the performance of the repellent.
- ✓ Avoid the installation of integral water-repellent block and mortar in locations where the wall may be immersed in water over time, i.e., in below-grade applications.
- ✓ Specify concave or V-shaped mortar joint profiles to encourage water to run off the wall face.
- ✓ Clean the masonry wall in accordance with the integral water repellent manufacturer's instructions.

Elastomeric Coatings

Elastomeric coatings reduce the amount of water absorbed by masonry substrates and 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. Elastomeric coatings are most commonly used on CMU wall

Fig. 4-8 Application of a clear surface-applied water repellent. Materials and surfaces not intended to receive the application are protected. Repellent application begins at lower surfaces and continues upward.

systems. An example of an elastomeric-coated CMU wall is shown in Fig. 4-9. Elastomeric coatings may 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 and installed at the required thickness. It should be noted, however, that elastomeric coatings sacrifice the visible benefits of the masonry surface and can be prone to discoloration, abrasion, and other damages.

This guide recommends a vapor-permeable silicone or acrylic elastomeric coating with UV resistance and high elongation properties to achieve a good coating. A vapor-permeable coating allows the masonry substrate to dry and reduces the likelihood of salt buildup and bubbling or blistering of the coating.

When selecting an elastomeric coating, these 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 at the field of wall area when tested to ASTM D6904.[19]
- ✓ *Vapor Permeance:* A minimum vapor permeance of 8 perms when measured per ASTM E96[12] wet cup method at the manufacturer-recommended dry film thickness.
- ✓ *High Elongation Properties:* Elongation properties that exceed 300% when tested per ASTM D412.[20]
- ✓ *Crack-Bridging Ability:* No cracking when tested to ASTM C1305.[21]
- ✓ *Validation:* Products that include an "SWR Institute Validation Program" label on the product data sheet.[22] 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 from runoff below horizontal or sloped surfaces and penetrations including flashings, windows, and parapets. Staining can largely be reduced by reducing the amount of water that runs onto the wall from these dirt-collecting surfaces. This guide recommends using sheet-metal drip edges (such as at window and door sills) to deflect water away from the surface of the masonry coating to help reduce staining.

Best Practices

These general application procedures and considerations are 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 mortars and adjacent concrete surfaces prior to application.
- ✓ Seal all cracks and cladding joints as recommended by the coating manufacturer, with the exception of intentional drainage gaps and weeps. Use appropriate joint design and backing at movement joints. Typically, cracks or holes $1/16$-inch wide or greater require treatment.
- ✓ Use block filler on CMU walls 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.

Long-Term Cladding Performance

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.

Fig. 4-9 Elastomeric coating on an interior-insulated CMU wall

This section addresses how good design can extend the masonry cladding service life and minimize the risk of efflorescence and the risk posed by freeze-thaw cycles in masonry cladding.

Extending Cladding Service Life

The following can help achieve average or greater service life of the masonry systems discussed in this guide:

- 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 18). Ensure that water-shedding elements are constructed as continuous in the field.

- Design and construct continuous water and air control layers (see page 21). Use a moisture-tolerant and durable water-resistive barrier system, air barrier system, and insulation materials 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 Chapters 6 and 7 for discussion on Corrosion Resistance.

- Specify masonry units appropriate for the project application and location of installation. See Chapters 6 and 7 for discussion on unit selection.

- Implement a comprehensive maintenance program specific to the building. The following outline recommends frequencies for maintenance events:

  – *Immediately:* Correct water diversion mechanisms that may have disconnected or failed, such as scuppers, 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, organic growth, or sealant joint failures, and repair or clean as needed. Repair moisture sources that may be causing or contributing to efflorescence.

- *Every 5 to 10 years:* Review the condition of mortar in masonry veneer walls. Repoint mortar as necessary.
- *Every 5 to 10 years:* Perform a comprehensive condition assessment of cladding and cladding components including sheet-metal flashing and copings, sealant joints, weeps, etc.
- *Every 5 to 20 years:* Reapply masonry sealers based upon intervals recommended by the sealer manufacturer.

Freeze-Thaw Cycles

Freeze-thaw cycles can be described as repeated freezing and thawing of moisture within masonry pores due to temperature fluctuations. Masonry decays with freeze-thaw cycles only if the moisture conditions are above a material-specific critical level. Reducing the moisture source, encouraging drying, or avoiding freezing temperatures can reduce the risk of freeze-thaw damage. An example of decay resulting from freeze-thaw cycles is shown in Fig. 4-10.

The factors affecting 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 freezing temperatures have a greater risk of freeze-thaw occurrence. Freeze-thaw decay can occur anywhere in Colorado and southern Wyoming; however, it is more likely to occur in areas that experience colder freezing temperatures and greater precipitation, including snowfall and building areas subjected to splashback.

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

Material Properties

Porosity, pore structure/size, material strength, and saturation coefficient of the masonry material all affect the occurrence of and subsequent damage due to freeze-thaw cycles. While the direct relationships between these material properties and freeze-thaw occurrence are not described here, each chapter provides recommendations for specifying masonry components that are appropriate for exterior application and that limit the risk of freeze-thaw damage.

Most freeze-thaw damage seen on new buildings is seen on clay brick and natural stone façades. ASTM standards are available for various natural stone products, which require similar repeated freeze-thaw testing at moisture contents close the material's saturation level during extended rain exposure events. These standards may be conservative for some applications where the façade has limited rain exposure.

In most new building projects, manufactured clay brick must meet criteria established by ASTM International in the United States. ASTM Standard C62[23] and ASTM Standard C216[24] grade brick based on its resistance to frost damage as severe weathering (SW), moderate weathering (MW), or negligible weathering (NW). Clay bricks in Colorado construction are required to be of the severe weathering grade.

Fig. 4-10 Example of freeze-thaw damage at an anchored masonry veneer wall

Fig. 4-11 Example of efflorescence on an anchored masonry veneer wall system

The ASTM specifications prescribe only that a brick needs to either meet the maximum saturation coefficient or the cold water absorption criterion; it need not meet both. Alternatively, similar testing as that for natural stones can be performed to show compliance.

Note that the procedures used for clay brick in calculating the values of acceptance criteria are contained in a separate standard: ASTM Standard C67.[25] The acceptance criteria used by ASTM were selected under the assumption that adequate open-pore space should be provided to accommodate expansion of water as it freezes;[26] however, a significant fraction of bricks that pass the ASTM criteria subsequently fail in service, while other bricks that fail the standard have been proven durable in practice.[27] Hence, new clay bricks should be expected to have some vulnerability to freeze-thaw decay. Furthermore, Appendix X4 of ASTM C216-07a includes the disclaimer that "in severe exposures, even Grade SW brick may spall under certain conditions of moisture infiltration, chemical actions, or salt crystallization."[24] For building designers using clay brick, the moisture management approaches provided in this guide will help the façades avoid saturation above critical levels for most building applications. Cold climate façades with direct exposure to lake or sea spray or severe driving rain should consider criteria beyond these ASTM standards to ensure the durability of clay brick products for those specific applications.

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. These building-specific design concepts are important to consider, especially within higher-risk areas of Colorado and southern Wyoming:

- Building-specific form and features that reduce the cladding exposure to liquid water and snow accumulation. See Chapter 3 for more discussion.
- 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 systems in Chapter 6), which minimizes water buildup behind the masonry cladding; venting/ventilating behind the veneer, which encourages drying to remove 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 pressurization of humidified buildings should also be avoided. Excessive air leakage condensation on masonry materials can increase the moisture within the masonry and thus also increase the freeze-thaw risk.

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 concepts also 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, as shown in Fig. 4-11, 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 as discussed throughout this guide, sound construction practices, and regular long-term maintenance can help prevent efflorescence.

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 construction. 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.

Chapter References

1. Sheet Metal and Air Conditioning Contractors' National Association, Inc. *Architectural Sheet Metal Manual, 7th ed.* (Chantily, VA: SMACNA, 2012).

2. The Brick Industry Association. *Technical Note 18 Volume Changes – Analysis and Effects of Movement* (Reston, VA: The Brick Industry Association, 2006).

3. The Brick Industry Association. *Technical Note 18A Accommodating Expansion of Brickwork* (Reston, VA: The Brick Industry Association, 2008).

4. National Concrete Masonry Association. *TEK 10-4 Crack Control for Concrete Brick and Other Concrete Masonry Veneers* (Herndon, VA: National Concrete Masonry Association, 2001).

5. National Concrete Masonry Association. *TEK 10-2C Control Joints for Concrete Masonry Walls – Empirical Method* (Herndon, VA: National Concrete Masonry Association, 2010).

6. ASTM International. *ASTM C920-14a Standard Specification for Elastomeric Joint Sealants* (West Conshohocken, PA: ASTM International, 2014).

7. ASTM International. *ASTM C719-14 Standard Test Method for Adhesion and Cohesion of Elastomeric Joint Sealants Under Cyclic Movement (Hockman Cycle)* (West Conshohocken, PA: ASTM International, 2014).

8. Dow Corning. *Dow Corning Americas Technical Manual* (n.p.: The Dow Chemical Company, 2002-2017).

9. ASTM International. *ASTM D5703-95(2013) Standard Practice for Preparatory Surface Cleaning for Clay Brick Masonry* (West Conshohocken, PA: ASTM International, 2013).

10. The Brick Industry Association. *Technical Note 20 Cleaning Brickwork* (Reston, VA: The Brick Industry Association, 2006).

11. National Concrete Masonry Association. *TEK 8-4A Cleaning Concrete Masonry* (Herndon, VA: National Concrete Masonry Association, 2005).

12. ASTM International. *ASTM E96/E96M-16 Standard Test Methods for Water Vapor Transmission of Materials* (West Conshohocken, PA: ASTM International, 2016).

13. ASTM International. *ASTM E514/E514M-14a Standard Test Method for Water Penetration and Leakage Through Masonry* (West Conshohocken, PA: ASTM International, 2014).

14. ASTM International. *ASTM D7089-06(2014) Standard Practice for Determination of the Effectiveness of Anti-Graffiti Coating for Use on Concrete, Masonry and Natural Stone Surfaces by Pressure Washing* (West Conshohocken, PA: ASTM International, 2014).

15. National Concrete Masonry Association. *TEK 19-1 Water Repellents for Concrete Masonry Walls* (Herndon, VA: National Concrete Masonry Association, 2006).

16. National Concrete Masonry Association. *TEK 19-7 Characteristics of Concrete Masonry Units with Integral Water Repellent* (Herndon, VA: National Concrete Masonry Association, 2008).

17. National Concrete Masonry Association. *TEK 19-2A Design for Dry Single-Wythe Concrete Masonry Walls* (Herndon, VA: National Concrete Masonry Association, 2004).

18. Northwest Concrete Masonry Association. *Tek Note Rain-Resistant Architectural Concrete Masonry* (Mill Creek, WA: Northwest Concrete Masonry Association, 2014).

19. ASTM International. ASTM D6904-03(2013) *Standard Practice for Resistance to Wind-Driven Rain for Exterior Coatings Applied on Masonry* (West Conshohocken, PA: ASTM International, 2013).

20. ASTM International. *ASTM D412-16 Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension.* (West Conshohocken, PA: ASTM International, 2016).

21. ASTM International. *ASTM C1305 Standard Test Method for Crack Bridging Ability of Liquid Applied Waterproofing Membrane* (West Conshohocken, PA: ASTM International, 2016).

22. Sealant, Waterproofing & Restoration Institute. "SWR Institute Validation Program." SWR Institute. Accessed January 1, 2018. www.swrionline.org/Validation.

23. ASTM International. *ASTM Standard C62-17, Standard Specification for Building Brick* (Solid Masonry Units Made From Clay or Shale). (West Conshohocken, PA: ASTM International, 2017).

24. ASTM International. *ASTM Standard C216-07a, Standard Specification for Facing Brick* (Solid Masonry Units Made from Clay or Shale). (West Conshohocken, PA: ASTM International, 2017).

25. ASTM International. *ASTM Standard C67/C67M-18 Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile* (West Conshohocken, PA: ASTM International, 2018).

26. Crawford, C.B. 1984. "Frost durability of clay bricks—Evaluation criteria and quality control." *Proceedings of the CBAC/DBR Manufacturers' Symposium,* 1984. Ottawa, ON: NRCC.

27. John Straube, Christopher Schumacher, and Peter Mensinga. 2010. "Assessing the freeze-thaw resistance of clay brick for interior insulation retrofit projects." In *Proceedings of the Thermal Performance of the Exterior Envelopes of Whole Buildings XI Conference, Clearwater, FL, December 5-9, 2010, 1-8*. Clearwater, FL: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

RMMI
ROCKY MOUNTAIN
MASONRY INSTITUTE

5

CHAPTER 5

Quality Control & Assurance

Fig. 5-1 Douglas County Library in Lone Tree, CO
(Mason Contractor: Ammex Masonry, General Contractor: Fransen Pittman General Contractors, Architect: Anderson Mason Dale Architects)
Photo by Bryn MaRae Photography

In almost all construction projects, quality control is the responsibility of the general contractor, whereas quality assurance is the responsibility of the design professional, third-party reviewer, or other designated entities.

- *Quality Assurance*: The Designer of Record or third-party reviewer is responsible for quality assurance during both the design and construction processes. During the project's design phase, these entities develop standards and procedures to achieve a quality installation; these expectations are compiled into the construction documents. During the construction phase, the quality assurance role includes periodic review of construction to confirm that the installation complies with all aspects of the construction documents. The purpose of quality assurance review is to minimize installations that deviate from the project documents to deliver a high-quality final installation.

- *Quality Control*: The general contractor and subcontractors are responsible for performing quality control in the field. This entails a more comprehensive review of field work than that provided for by quality assurance. Quality control is the process of repeatedly executing every aspect of the construction in conformance with project documents and entails correcting deficiencies as they arise. The objective of quality control is to ensure all aspects of the final installation meets the project requirements.

Quality control and quality assurance items impact the specification, construction, and evaluation phases of the masonry and its related wall components. Whereas this guide focuses on building enclosure design guidance and product selection of masonry materials, this chapter specifically focuses on recommendations for improving the masonry installation quality through aesthetic design considerations, through sample panels and mock-ups, and through field review of masonry installations.

Aesthetic Design Considerations

Consider the following during a project's design phase to help develop a masonry wall system that meets the aesthetic expectations of the design and ownership team:

✓ How a building's interaction with sunlight will affect the aesthetic of the masonry product.

   – Example: One side of a building is always shaded (from adjacent buildings/trees) vs. one side is always in direct sunlight (south-facing elevation in the summer). See Fig. 5-2.

✓ The relationship between colors and textures of brick/block and the color(s) and texture(s) of mortar.

   – Example: A mortar color that contrasts with the masonry, such as light brick and dark mortar as shown in Fig. 5-3, accentuates the masonry, including any imperfections. Mortar that compliments the masonry is likely to distract as shown in Fig. 5-4.

✓ How profiles of flashings/drip edges affect aesthetics or reveals within the masonry coursing.

   – Example: Sheet-metal drip edges and reveals while affective for water shedding can also cast shadows. Sheet-metal flashing color and finish can also affect aesthetic. See Fig. 5-5.

✓ How brick material composition and firing techniques can affect aesthetics.

   – Example: If minimal brick or concrete masonry unit (CMU) block color variations are desired for a project, units can be fired and supplied in one continuous run. This usually means that the initial order of masonry should be as accurate as possible, because manufacturers cannot always guarantee an exact match from subsequent runs.

   – Example: For CMU, the timing of the mold or form-stripping during manufacturing impacts the color pigmentation and variation of color between units. Wider color variation is expected with smooth-faced units as opposed to split- or ground-faced units. [1]

✓ Acceptable criteria for unit color, texture, chips/cracks.

   – Example: Acceptable ASTM criteria may be used; however, the acceptable ASTM criteria may not be to a tolerance stringent enough for the architect and/or owner.

✓ How finish mortar joint profiles will affect weathering.

   – Example: Concave or V-shape mortar joint profiles promote water shedding at the surface of the masonry; however, other profiles (e.g. grapevine, beaded, raked, etc.) may collect water and encourage efflorescence or increase the risk of freeze-thaw cycle decay. See Fig. 5-6.

Fig. 5-2 Example of masonry texture during mid-afternoon; south elevation (left), east elevation (right)

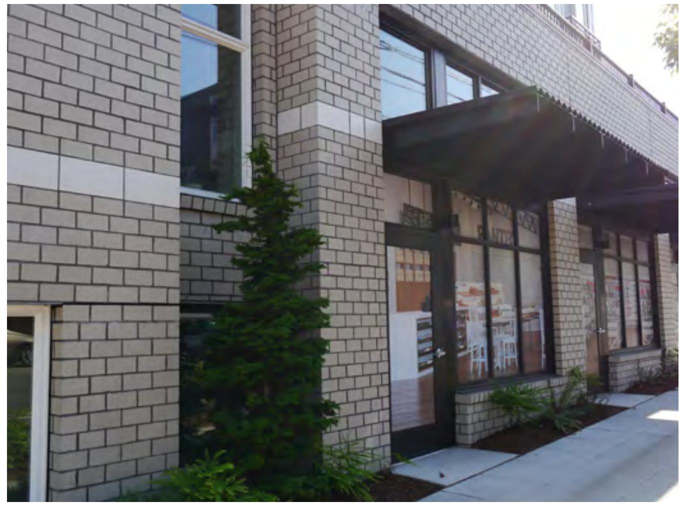


Fig. 5-3 Example of light-colored masonry with dark mortar

Fig. 5-4 Example of light-colored masonry with similar colored mortar

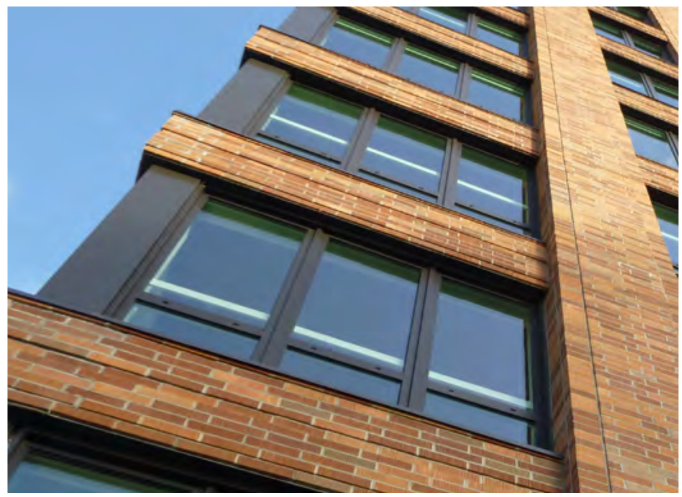


Fig. 5-5 Example of slight shadows cast by sheet-metal and masonry reveals

Fig. 5-6 Concave mortar joint profile

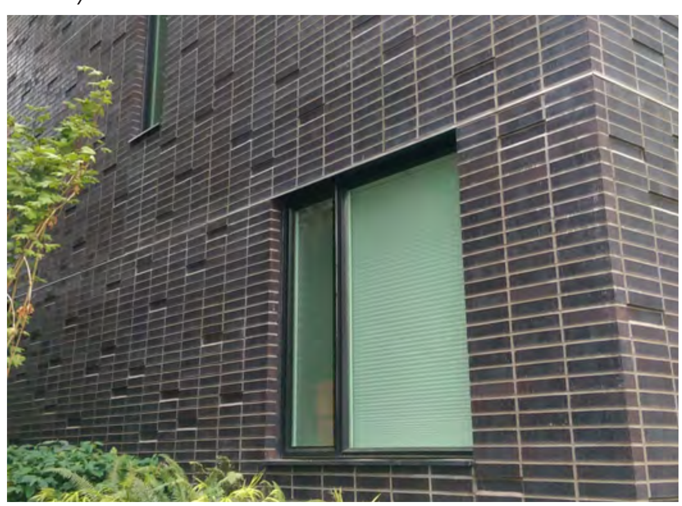


Fig. 5-7 Example of stack bond with recessed brick

- ✓ How patterns can affect weathering.
  - – Example: Stepping masonry (e.g., masonry not flush with adjacent units) can collect water and encourage efflorescence or increase the risk of freeze-thaw cycle decay. See Fig. 5-7.

Sample Panels and Mock-Ups

Once the design aesthetic and performance requirements of the above-grade masonry wall system are established, the next quality assurance and quality control item is to demonstrate the masonry installation using sample panels or mock-ups.

Sample panels and mock-ups are a visual representation of the project specification requirements. While not mandatory by code for all projects, this guide recommends sample panels for all masonry buildings as a critical component of quality assurance and quality control. Sample panels and mock-ups establish aesthetic and workmanship quality standards for reference throughout the project's construction phase, benefiting the project schedule and budget. Sample panels and mock-ups also help to resolve conflicts in work quality, multi-trade coordination, and enclosure performance.

The minimum code requirements for sample panels are described by TMS 602-16[2] and are dictated by ASCE 7.[3] Although code requirements for sample panels may vary per risk category, this guide recommends specifying and constructing a project-specific sample panel and/or a freestanding building enclosure mock-up to promote a quality masonry installation.

This guide outlines three options for specifying and constructing a sample panel and rates them in order of *Good*, *Better*, and *Best*. Table 5-1 summarizes the key attributes of each option. The *Good* option is based solely on the minimum code requirements of TMS 602-16,[2] while the *Better* option expands on these minimum requirements to include considerations for constructability and aesthetics. The *Best* option further identifies mock-up characteristics beneficial for aesthetics and building enclosure performance.

Although this guide identifies additional considerations and specifications beyond the minimum code requirements for sample panel specification and construction, it is the discretion of the project owner and/or architect to incorporate any additional aesthetic and/or performance requirements into the project specifications.

Good Option

A sample panel that remains as part of the final construction may be preferred by builders because it is more economical and typically accessible; however, should the project team find the work is unacceptable, removal of the sample work can damage the structure, enclosure components (e.g. flashing membranes), or other adjacent components. This damage may result in costly repairs or difficulty when reinstalling the sample panel.

The location of building sample panels should be carefully selected by the designer. The location of the sample panel on the building can hinder future accessibility for review or limit the designer's ability to understand the material aesthetic because it is limited to one location on the project site.

When specifying a sample panel, it is the Designer of Record's responsibility to reference the sample panel requirements outlined in Specification Section 1.6 D of TMS 602-16[2] as a baseline in developing sample panel specifications for their project. TMS 602-16 clarifies that the sample panel is to:

- Be constructed from preapproved materials and methods.
- Remain at the project site until the masonry work on the building has been accepted.
- Establish the acceptable standard of work for the masonry construction on the building.
- Be a minimum of 4 feet by 4 feet.
- Demonstrate minimum site tolerances for the construction of the sample panel, as listed in Article 3.3 F of TMS 602-16.[2]

At minimum, TMS 602-16 also requires that the project specifications identify which person(s) or parties have the authority to accept, reject, and request modifications to the sample panel construction This guide recommends that the project specifications identify the formal process required to approve the panel should panel characteristics deviate from the contract documents.

Submittal Phase Requirements

Due to the lead time on sample panel materials, it is important that project specifications include submittal phase requirements for the sample panel. These requirements can help ensure that sample panel submittal requirements are clear, leaving ample time for the designer to review items and return approval of the items to the contractor. Although not required by TMS 602-16,[2] this guide recommends that specifications require, at minimum:

Table 5-1 Summary of Good, Better, Best options for the job site sample panel

	Good	Better	Best
Description	Sample panel is part of the final installation	Stand-alone sample panel	Freestanding, wall system mock-up
Typical Components	Brick and mortar + repellents, coatings, and sealants + masonry accessories and enclosure components limited to the installation location	Brick and mortar + repellents, coatings, and sealants + most typical masonry accessories	Brick and mortar + repellents, coatings, and sealants + typical masonry accessories + window and/or door installation + architectural components (e.g. canopy, balcony, and signage attachments; lighting penetration; etc.)
Location Requirements	On building	Stand-alone, on project site	Freestanding, in a highly visible and protected location on the project site, available for reference and training as needed
Panel Size	4'x4'	4'x4'	Typically, larger than 4'x4'
Specified/ Constructed In Accordance With	TMS 602-16[2]	TMS 602-16[2] + project specifications for supplementary coordination and aesthetic requirements	TMS 602-16[2] + project specification for supplementary coordination and aesthetic requirements + project specification for building enclosure performance requirements
Performance Requirements	Article 3.3 F in TMS 602-16[2] for site tolerances	Article 3.3 F in TMS 602-16[2] for site tolerances	Article 3.3 F in TMS 602-16[2] for site tolerances + qualitative or quantitative air infiltration testing per standardized test methods + water penetration resistance testing per standardized test methods
Aesthetic Requirements	Minimum industry standards (ASTM, ANSI, ACI)	Minimum industry standards (ASTM, ANSI, ACI)	Minimum industry standards (ASTM, ANSI, ACI) + project-specified supplementary requirements
Example Image	 *Fig. 5-8 On-building sample panel example*	 *Fig. 5-9 Standalone sample panel example*	 *Fig. 5-10 Freestanding mock-up example*

- A specified number (e.g., 3 to 5) of full-size sample units be provided for each different type of masonry unit, representative of the approximate or full range of colors, textures, and dimensions expected in the completed construction.[4]

- More than one mortar and surface coating product be ordered for sample panel construction. The final selection for mortar color and surface coatings will be made once several cured samples are on the constructed sample panel.[5]

- Other accessory materials or products (e.g., reinforcement, anchors, sealants, and flashing membranes) are submitted for review and approved prior to constructing the sample panel. In general, all materials to be installed on the sample panel—except for mortar and surface coatings—must be approved before used in construction.[5]

Aesthetic Requirements

TMS 602-16[2] specification requirements are based on structural performance and do not explicitly address minimum requirements for the aesthetic quality of the masonry installation, though tolerances have some effect on the aesthetic. Thus, this guide recommends specifying minimum requirements for aesthetics prior to the bid phase to ensure project costs adequately represent the desired material aesthetic. Items include:

- The size, grade, and type of the masonry units (including cell arrangement, where applicable).[4]

- Product-specific specification for visible masonry accessories such as weeps, including desired color. If a substituted product may be considered, the specifications should contain a clause to address this process.

- Industry standards for the appearance of masonry units. Example standards for brick include ASTM C216[6] for facing brick, ASTM C652[7] for hollow brick, ASTM C1088[8] for thin veneer brick, and ASTM C1405[9] for glazed brick. Example standards for CMU units include ASTM C55[10] for concrete building brick, ASTM C90[11] for loadbearing CMU, ASTM C129[12] for nonloadbearing CMU, and ASTM C1634[13] for concrete facing brick. Use of industry standards establish the minimum acceptance criteria related to the appearance or aesthetic quality of the masonry upon shipment, including: chippage size and frequency, out-of-square, and warpage/distortion.[14]

- Mortar joint profiles and tooling methods. This guide recommends concave or V-joint profiles to facilitate water shedding to increase long-term system performance.[1]

- The minimum-expected level of work. For example, the specifier can require that the mock-up be built by a mason who has a minimum number of years' experience and who will also be the mason doing the installation work on the larger project.

Material Performance Requirements

Minimum material performance requirements for the type or grade of masonry units, mortar, and other accessories used on a project are based on appropriate industry standards (e.g., ASTM, ANSI, and/or ACI standards). This ensures the products conform to the minimum and latest industry performance standards. Chapters 6 and 7 of this document further describe material performance requirements and reference standards.

Better Option

This approach provides the benefit of minimum disruption to the building structure if sample panel construction revisions are required. It allows the sample panel to be installed in an easily accessed location for continued reference and subcontractor training throughout the construction phase. The architect may also prefer the sample panel to be located where it is possible to view the panel in various sun exposure or adjacency conditions.

In addition to the minimum submittal and material performance requirements and recommendations listed in the *Good* option above, additional aesthetic requirements may be incorporated into the project specifications.

Best Option

The *Good* and *Better* options described above are typically limited to 4x4 singular planes of installation; however, the best option recommended by this guide expands the sample panel installation into a larger construction of the full masonry system that requires multi-trade coordination. A full-system mock-up can include the components of all the enclosure elements and adjacent or penetrating components, including, but not limited to:

- Windows and/or doors, including rough opening detailing.

- Canopy attachments.

- Embedded flashing and trim elements.

- Expansion, control, and sealant joints.

- Typical penetrations, such as electrical and lighting.

- Balcony and signage attachments.
- Transitions (e.g., roof-to-wall, inside/outside corners, etc.).
- Decorative or special architectural features.

The full-system mock-up incorporates the benefits of sample panel construction while considering adjacency of other building components in addition to the ability to perform building enclosure testing to confirm the performance of the enclosure elements for items such as water penetration resistance and air infiltration/exfiltration.

If a full-system mock-up is chosen, the project specifications need to be comprehensive and include all requirements of the mock-up system and the performance criteria. This guide recommends that the requirements of the mock-up are clear and fully documented prior to the bid phase and that the designer provide dimensioned drawings of the mock-up as part of the contract documents in addition to specifications. These supplementary provisions provide the trades with the adequate information to include an accurate scope of work in their bid documents, including labor and material estimates and the ability to plan for the time and cost of erecting the mock-up. [15]

Although additional aesthetic requirements, beyond those included with the *Better* option, are not necessarily included within this option, a mock-up will provide additional aesthetic confirmation for aspects such as masonry transitions at inside and outside corners, shelf angle supports, and transitions to other cladding types or components such as sheet-metal trim and wall penetrations.

Building Enclosure Performance Requirements

When using the *Best* option, this guide recommends outlining building enclosure-specific performance requirements in the project specifications. Often, the performance level of these requirements is determined with the assistance of the project's building enclosure consultant.

For a freestanding full-system mock-up, there are numerous qualitative and quantitative tests used to evaluate the air infiltration/exfiltration and water penetration resistance of the building enclosure. Identification of potential leak paths during the mock-up allows for time to review project details or nonconforming work for revision or repair to reduce the risk for water penetration during the actual building service life.

Water penetration resistance testing, as shown in Fig. 5-11, is typically performed using the ASTM E1105 [16] standard at an air pressure differential appropriate for the exposure and wind load on the building enclosure. This test method can identify leakage

Fig. 5-11 Freestanding mock-up undergoing water penetration resistance testing prior to cladding installation

pathways such as at window rough openings or other penetrations within the primary water control layer of the enclosure.

The designer can also specify air infiltration/exfiltration testing of the building enclosure mock-up and its components including windows and doors. This test is becoming increasingly important where energy code requirements for airtightness are more stringent or energy performance goals are a high priority. An ASTM E783 [17] test is performed using specialized fan equipment and pressure gauges to determine the rate of air leakage through the mock-up. Using smoke tracers in conformance with ASTM E1186 [18] may also help identify specific air leakage pathways that require rework.

This guide recommends specifying building enclosure performance testing to occur prior to the installation of any masonry veneer but following the installation of all penetrations and air, water, and thermal control layer materials. Although a more stringent test, this approach allows areas of air or water leakage to be readily identified during testing and to still be accessible should repair and/or reinstallation be required.

Field Review of Masonry Installations

The following evaluation items may be performed to ensure aesthetic quality of the masonry components or to ensure that system-specific building enclosure components conform to the project documents. These evaluation items may be performed on the sample panel or mock-up or through the course of construction. The aesthetic review for quality control items listed below apply to all systems in this guide, while building enclosure performance quality control items are provided individually, specific to anchored masonry and single-wythe CMU wall systems.

Partner with Continental Cast Stone on your next project

The Arrabelle at Vail Village

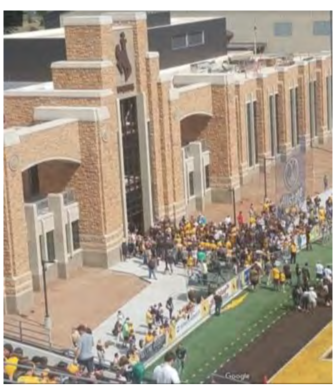
Mason Contractor: Gallegos Corp

One of Continental Cast Stone's largest projects to date, The Arrabelle is a great representation of the flexibility, durability and sophistication of cast stone.

Medical Center of Aurora

Mason Contractor: AP Eberlein Company Inc.

Utilizing Continental Cast Stone modular "Select Stone" offered the project a substantial cost savings.



UW High Altitude Performance Center

Mason Contractor: Soderberg Masonry

Continental Cast Stone decorative elements were used along with sandstone to stay true to the campuses architectural tradition.

1927
CAST STONE INSTITUTE

New Ownership

Shelby Story & Bryan Hinkle

"New Faces With a New Direction"

CONTINENTAL CAST stone MANUFACTURING INC.

Continental Cast Stone – 22001 West 83rd Street – Shawnee, KS 66227
913-422-7575

The items provided do not encompass structural review considerations, because these items extend beyond the scope of this guide; however, these items are equally as important for the long-term durability and safety of the masonry wall system installation.

Aesthetic Review – All Systems

Review and evaluate the sample panel, mock-up, or wall:

- ✓ When the panel/wall is clean and has been coated with required repellents or coatings and any surface-applied treatments are dry or fully cured.
- ✓ Under diffused lighting. Non-diffuse lighting creates undesirable shadows and highlights flaws on the wall, giving a distorted visual appearance of the workmanship or materials. [14]
- ✓ After colored mortar has had sufficient time to dry. [5]

Confirm the following when reviewing the sample panel, mock-up, or field installation of anchored masonry veneer or single-wythe CMU wall systems:

- ✓ The masonry materials and colors are represented in the sample panel and conform to the submitted and returned project submittals.
- ✓ The sample panel includes intermixed or same-run brick or block representative; and a similar installation is performed on the building installation.
- ✓ Modular coordination/pattern or cell arrangement complies with the architectural details.
- ✓ Any variations within the field of the wall are acceptable to the designer.
- ✓ Mortar joint thicknesses are uniform and alignment of units are plumb and level.
- ✓ The color, texture, and blending of masonry units; the relationship of mortar and sealant colors to masonry unit colors; the tooling of joints; the aesthetic qualities of workmanship; and other material and construction qualities meet the project specifications and designer/owner expectations.

- ✓ Mortar joints are consistently tooled to the profile defined by the project requirements (e.g., concave or V-shape); and horizontal mortar joints (i.e., bed joints) are tooled before vertical joints (e.g., head joints) and are tooled when thumbprint-hard.
- ✓ Control joints are spaced and located as defined by the project documents. Joints are free of debris and mortar and are of a thickness defined by the project documents.
- ✓ Sheet-metal components are of the correct metal type, gauge, profile, and color/finish.

General Building Enclosure Review – Anchored Masonry Wall System

The following evaluation items are system-specific to evaluating anchored masonry veneer.

Review and evaluate the sample panel, mock-up, or wall area:

- ✓ At a distance of 15 feet and under diffused lighting for FBX/HBX/TBX brick and at 20 feet for FBS/HBS/TBS and FBA/HBA/TBA brick per ASTM C216,[6] ASTM C652,[7] and ASTM C1088.[8]
- ✓ At a distance of not less than 20 feet and under diffused lighting for CMU veneer per ASTM C1634.[13]

Confirm the following when reviewing the sample panel, mock-up, or any field installation of anchored masonry veneer.

- ✓ The air cavity depth meets or exceeds the required depth.
- ✓ The air cavity behind masonry veneer is kept free of mortar droppings and debris.
- ✓ A mortar net is installed per the manufacturer requirements/recommendations at the base of the veneer wall.
- ✓ Flashing components are of the correct dimension, profile, slope, and material and are detailed at laps and transitions as required.
- ✓ End dams are provided at sheet-metal terminations.
- ✓ Flashing components within the wall are shingle-lapped into the water-resistive barrier (WRB) system and exit the veneer (to provide drainage).
- ✓ Any sealing requirements at or above flexible membrane or sheet-metal flashing components, as required for air barrier system continuity, are provided.
- ✓ Anchors and fasteners are the specified product and material finish (e.g. stainless steel or hot-dipped galvanized).
- ✓ Anchor attachment penetrations through the air barrier and/or WRB system are detailed as required by the project documents and manufacturer requirements.
- ✓ Mortar joints are of the specified profile type, well compacted, and free of voids at the surface.
- ✓ Weep vents are located at the bottom course of veneer that bears on a bearing element. Weep vents are spaced as required and located tight to the bearing element (through the bed course). See page 68 for more information.
- ✓ Vents (where required) exist in the top course of veneer and are spaced as required. Vents are staggered from weep vent locations directly above.
- ✓ Exterior insulation of the correct thickness and type is installed continuously across the wall face and up tight to penetrations.
- ✓ Exterior sealant joints at expansion joints and around penetrations are continuous, properly backed, appropriately dimensioned, and demonstrate an acceptable bond to the anchored masonry veneer and other substrates.
- ✓ Exterior-applied clear water repellents are applied in conformance with the manufacturer installation instructions.

General Building Enclosure Review – Single-Wythe CMU Wall System

The following evaluation items are system-specific to evaluating single-wythe CMU systems.

Review and evaluate the sample panel, mock-up, or wall:

- ✓ At a distance of not less than 20 feet, under diffused lighting, for load and nonloadbearing CMU per ASTM C90[11] and ASTM 129.[12]
- ✓ When all or a portion of the panel/wall is clean and has been coated with required clear water repellents or coatings and any surface-applied treatments are dry or fully cured.[5]

Confirm the following when reviewing the sample panel, mock-up, or any field installation of single-wythe CMU:

- ✓ Mortar joints are of the specified profile type, well compacted, and free of voids at the surface.
- ✓ Exterior sealant joints at expansion joints and around penetrations are continuous, properly backed, appropriately dimensioned, and demonstrate an acceptable bond to the CMU and other substrates.
- ✓ Flashing components are of the correct dimension, profile, slope, and material and are detailed at laps and transitions as required.
- ✓ End dams are provided at sheet-metal terminations.
- ✓ Interior insulation is a continuous depth across the wall face and up tight to penetrations. Rigid board insulation products are fully taped and/or sealed for airtightness at all penetrations, terminations, and joints.
- ✓ Installation of any fluid-applied air barrier and WRB system membranes at the interior wall face are continuous and installed in conformance with the manufacturer's installation instructions.
- ✓ Exterior-applied coatings demonstrate acceptable adhesion to the wall substrate and are applied at the manufacturer-required thickness following appropriate substrate preparation.
- ✓ Exterior-applied clear water repellents are applied in conformance with the manufacturer installation instructions.

Chapter References

1. National Concrete Masonry Association. *TEK 5-16 Aesthetic Design with Concrete Masonry* (Herndon, VA: National Concrete Masonry Association, 2011).

2. The Masonry Society. *TMS-402/602-16 Building Code Requirements and Specification for Masonry Structures* (n.p.: The Masonry Society, 2016).

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

4. The Brick Industry Association. *Technical Notes 11 Guide Specifications for Brick Masonry, Part 1* (Reston, VA: The Brick Industry Association, 2001).

5. Concrete Products Group. "Using Sample Panels to Assure Project Quality." Last accessed September 19, 2017. Video, 4:30, http://www.concreteproductsgroup.com/index.php/videos.

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

7. ASTM International. *ASTM C652-17 Standard Specification for Hollow Brick* (Hollow Masonry Units Made From Clay or Shale). (West Conshohocken, PA: ASTM International, 2017).

8. ASTM International. *ASTM C1088-17 Standard Specification for Thin Veneer Brick Units Made From Clay or Shale* (West Conshohocken, PA; ASTM International, 2017).

9. ASTM International. *ASTM C1405-16 Standard Specification for Glazed Brick* (Single Fired, Brick Units). (West Conshohocken, PA; ASTM International, 2016).

10. ASTM International. *ASTM C55-17 Standard Specification for Concrete Building Brick* (West Conshohocken, PA; ASTM International, 2017).

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

12. ASTM International. *ASTM C129-17 Standard Specification for Nonloadbearing Concrete Masonry Units* (West Conshohocken, PA; ASTM International, 2017).

13. ASTM International. *ASTM C1634-17 Standard Specification for Concrete Facing Brick* (West Conshohocken, PA; ASTM International, 2017).

14. Bronzella Cleveland. "Tech Talk: How To Look At A Brick Wall," *Masonry Magazine*, published June 1, 2017, https://www.masonrymagazine.com/blog/2017/06/01/tech-talk-how-to-look-at-a-brick-wall/.

15. Alan Esche and Charles W. Ostrander, "Job Site Mock-Up Panel Qualifies the Bidders," originally published in MasonryEdge/the StoryPole, n.d., Volume 4, Number 4. Republished by Masonry Advisory Council, last accessed September 19, 2017, http://masonryadvisorycouncil.org/wp-content/uploads/2016/06/Job-Site-Mock-ups-for-Bidders.pdf.

16. ASTM International. *ASTM E1105-15 Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference* (West Conshohocken, PA: ASTM International, 2015).

17. ASTM International. *ASTM E783-02 (2010), Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors* (West Conshohocken, PA: ASTM International, 2010).

18. ASTM International. *ASTM E1186-17, Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems* (West Conshohocken, PA: ASTM International, 2017).

RMMI

ROCKY MOUNTAIN

MASONRY INSTITUTE

6

CHAPTER 6

Anchored Masonry Veneer Systems

Fig. 6-1 Isabella Bird Community School in Denver, CO
(Mason Contractor: Dels Masonry, General Contractor: Golden Triangle Construction Inc., Architect: Humphries Poli Architects) Photo by Paul Brockering

The anchored masonry veneer wall systems in this guide consist of an anchored masonry veneer with concrete masonry unit (CMU), concrete, light-gauge steel stud framing, or wood framing backup wall structures. While many wall system variations and products may apply to these backup wall types and/or veneer options, this chapter focuses on preferred anchored masonry veneer systems and alternative products that have demonstrated success within Colorado and southern Wyoming. The typical components of these systems are described in Table 6-1.

All systems described in this chapter are appropriate for low- and mid-rise residential or commercial buildings. Additionally, the CMU, concrete, and light-gauge steel framing backup wall systems are appropriate for high-rise residential or commercial buildings.

Typical wall system details that illustrate the design concepts for CMU, steel stud-framed, and wood-framed backup wall structures are included at the end of this chapter. A concrete backup wall structure is not included within these details; however, it would be similar to those shown for a CMU backup wall.

Building Enclosure Control Layers

As noted in Chapter 3, an above-grade wall system provides control of liquid water, air, heat, and water vapor to serve as an effective and durable environmental separator. Control of these elements, specific to the general design of masonry wall systems, is provided by the following surface and control layer systems and/or materials:

- The water-shedding surface, comprising the cladding, flashing, and enclosure penetration components
- The water control layer, comprising the water-resistive barrier (WRB) system
- The air control layer, comprising the air barrier system
- 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 Chapter 3.

Table 6-1 illustrates the water-shedding surface and control layer locations for anchored masonry veneer with various backup wall structures. The control layers shown are specific to the types of air barrier system, WRB system, thermal insulation, and vapor control materials selected for representation and discussion within this chapter. 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.

Water-Shedding Surface

The water-shedding surface reduces the water load on the enclosure.

As shown in Table 6-1 the anchored masonry veneer cladding, including both mortar joints and masonry veneer units, is the primary water-shedding surface of the wall system. Additional wall system components include flashings and drip edges, sealant joints, and fenestration systems.

To promote water shedding at the masonry veneer face, mortar joints are 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 air cavity.

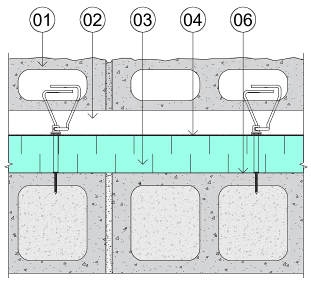
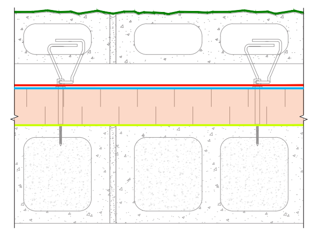
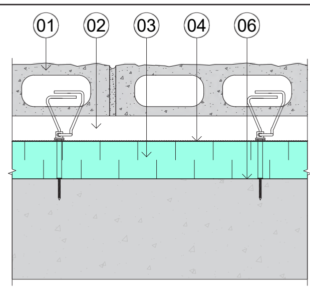
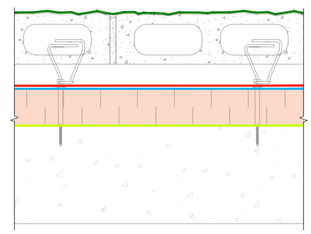
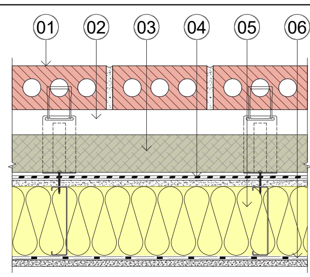
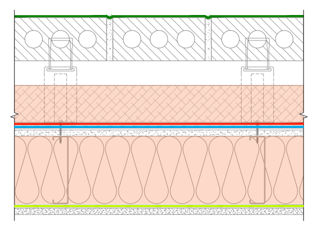
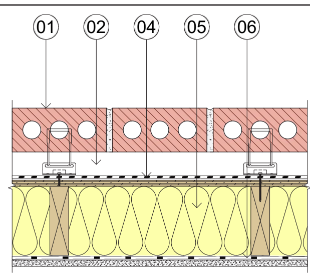
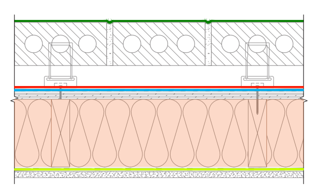
Water Control Layer

The water control layer is a continuous control layer designed and installed to act as the innermost boundary for water intrusion. In the anchored veneer wall system, the water-resistive barrier (WRB) system provides the function of water control along with flashings and wall penetrations (e.g., windows and doors).

At the field-of-wall area of the anchored masonry veneer, the 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 must be continuous and shingle-lapped to promote a continuous drainage plane and water-shedding ability. Where flashing components exist within the system, such as at floor line and base-of-wall conditions, the back leg of the sheet-metal flashing is shingle-lapped into the WRB field membrane to drain water at the face of the WRB system and to the exterior of the masonry veneer.

Where the WRB system is also part of the air barrier system, it will be sealed for airtightness using tapes, sealants, gaskets, and other components.

Table 6-1 Anchored masonry veneer wall assembly components and water-shedding surface and control layer summary

Backup Wall Structure	Masonry Veneer Assembly	Water Shedding-Surface and Control Layers
CMU		EXTERIOR  INTERIOR
Concrete		EXTERIOR  INTERIOR
Steel Stud-Framed		EXTERIOR  INTERIOR
Wood-Framed		EXTERIOR  INTERIOR
LEGEND	1. Anchored masonry veneer (fired clay brick or CMU) 2. Air cavity 3. Exterior insulation 4. Air barrier and water-resistive barrier 5. Batt insulation 6. Vapor control membrane	Water-Shedding Surface Control Layers: Water Air Vapor Thermal

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
- Vapor permeable (i.e., transmits water vapor) – Such that the WRB system does not contribute to the development of condensation within the system that could damage enclosure layers or other elements
- Airtight – The air barrier is sealed for airtightness using tapes, sealants, gaskets and other components where the WRB system also performs as the air barrier system (i.e., the air barrier and WRB system)

WRB system components may also be required to comply with combustibility requirements set forth by the authority having jurisdiction.

For the anchored masonry veneer wall systems discussed in this chapter, the WRB system is either:

1. The exterior facer of rigid board insulation and self-adhered or fluid-applied flashing materials, as depicted on the CMU wall and concrete backup wall in Table 6-1. This WRB system type is also applicable to a steel stud-framed backup wall.
2. A self-adhered sheet- or fluid-applied membrane installed over the wall sheathing and self-adhered or fluid-applied flashing materials, as depicted on a steel stud-framed backup wall in Table 6-1. This WRB system is also applicable to a CMU, concrete, or wood-frame back up wall.
3. A mechanically attached membrane and self-adhered or fluid-applied flashing materials, as depicted on a wood-framed backup wall in Table 6-1. This WRB system is typically not used on concrete or CMU backup walls due to the difficulty of temporarily attaching the membrane to the substrate. This WRB system may be used for low-rise steel stud-framed backup wall systems. This system is often avoided for a steel stud-framed backup wall system on higher rise applications due to the likelihood for construction-phase damage from high wind exposures.

The WRB system may also be a 2-part spray-applied closed-cell polyurethane foam insulation product with self-adhered flashing membranes. This approach is most common on concrete, CMU, or steel stud-framed backup walls.

Table 6-2 summarizes common air barrier and WRB systems used with anchored masonry veneer systems.

Masonry veneer anchors penetrate the WRB system and should be sealed as required by the WRB system manufacturer's installation requirements. Typically, plate anchors are bed in a compatible sealant or fluid-applied flashing product or are attached through a self-adhered membrane patch, whereas screw anchors with gasketing washers are typically not required to be sealed. Where a ladder eye-wire masonry veneer attachment method is used, this guide recommends a fluid-applied WRB system; seal each wire penetration through the membrane with sealant, with a fluid-applied flashing material, or with a liberal application of fluid-applied field membrane as recommended by the membrane manufacturer.

In many instances, the WRB system will also function as the air barrier system. In this case, the WRB system is required to have the performance properties of an air barrier system and to be continuously taped and/or sealed to control air flow.

Vapor Permeance

The vapor permeance of the WRB system (or air barrier and WRB system) is important to consider when selecting a system for water control. The vapor permeance of the WRB system must be considered relative to the vapor permeance of the other field-of-wall components (e.g., exterior wall sheathing, insulation type, insulation locations in wall, etc.).

Vapor permeance classes and their corresponding vapor transmission rates are described in Chapter 3 on page 21. General guidance for Colorado- and southern Wyoming-based systems described in this guide are as follows:

CMU/Concrete

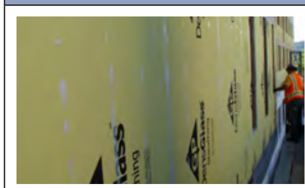
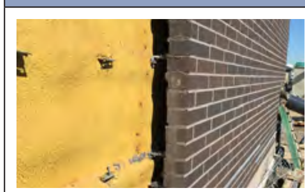
CMU and concrete wall backup systems are almost always insulated to the exterior of the wall; thus, the vapor permeance class of the WRB system may be of any class.

Steel Stud-Framed and Wood-Framed

For steel stud-framed and wood-framed backup wall systems the WRB system may have a:

- Class IV vapor permeance properties regardless of the placement of insulation relative to the WRB system. Where used without exterior insulation or with a vapor permeable

Table 6-2 Air barrier and/or water-resistive barrier systems common in Colorado and southern Wyoming

Air Barrier & WRB System	Description	Typical Accessories at Transitions/Penetrations Common Typical Backup Wall Structures	Typical Primary Control Layer Function**			
			Vapor	Thermal	Air	Water
MECHANICALLY ATTACHED SHEET						
	Loose-laid sheet mechanically attached to the exterior sheathing and/or framing with washer head fasteners, staples, cladding supports/masonry anchors, etc.	Self-adhered or fluid-applied flashing membranes WOOD-FRAMED	✓*		✓	✓
SELF-ADHERED MEMBRANE						
	Sheet membrane with adhesive backing, continuously bonded to the backup wall sheathing or structure	Self-adhered or fluid-applied flashing membranes CMU, CONCRETE, STEEL STUD-FRAMED, WOOD-FRAMED	✓*		✓	✓
FLUID-APPLIED MEMBRANE						
	Fluid-applied membrane, continuously bonded to the backup wall structure following membrane cure	Self-adhered or fluid-applied flashing membranes CMU, CONCRETE, STEEL STUD-FRAMED, WOOD-FRAMED	✓*		✓	✓
INSULATED SHEATHING						
	Exterior rigid board insulation (i.e., XPS or faced EPS/polyisocyanurate) with board seams sealed and/or taped	Self-adhered or fluid-applied flashing membranes CMU, CONCRETE, STEEL STUD-FRAMED, WOOD-FRAMED	✓	✓	✓	✓
SEALED SHEATHING						
	Exterior gypsum board or plywood sheathing with sealed seams (either joint sealant, fluid-applied membrane, or tape)	Self-adhered or fluid-applied flashing membranes CMU, CONCRETE, STEEL STUD-FRAMED, WOOD-FRAMED			✓	
CLOSED-CELL SPRAY POLYURETHANE FOAM (CCSPF)						
	Spray foam insulation is spray-applied and bonds to the backup wall sheathing or structure	Self-adhered or fluid-applied flashing membranes CMU, CONCRETE, STEEL STUD-FRAMED, WOOD-FRAMED	✓	✓	✓	✓

*Sheathing membrane products (i.e., loose-laid sheets, self-adhered membrane, and fluid-applied membrane) are available in a range of permeance classes. In Colorado and southern Wyoming, typically these air and water control layers function as the vapor control layer when the membrane is a Class 1 or Class 2 vapor permeance. In this instance, these membranes should typically only be used when ½ of the wall's total R-value of insulation is located outboard of this membrane.

**Refer to page 21 for the properties of each control layer. Systems listed can only perform as the control layer indicated when these properties are met.

exterior insulation material (e.g., semi-rigid mineral fiber), this class provides the greatest opportunity for the wall system to dry to the exterior. This drying can be beneficial during the service life of the building and also helps relieve construction-related moisture that may be present.

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

- Class I or II vapor permeance properties when at least half the wall system's total nominal insulation R-value is exterior of the WRB system. For this case, the WRB system will also function as the vapor control layer and a separate vapor retarder membrane at the interior of the wall system may be omitted; however, should be confirmed with local jurisdictional requirements. The recommendation to provide half the wall system's total nominal insulation R-value exterior of the WRB system is generally applicable to most projects occurring within Colorado and southern Wyoming. This value may need to be increased to ⅔ of the wall system's total nominal R-value for some projects, particularly those located at higher elevations with colder temperatures (Climate Zone 7) or those expected to have greater than usual interior relative humidity conditions.

Air Control Layer

The air control layer comprises of 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 because it impacts heat flow (space conditioning), water vapor transport, and condensation on cold surfaces. Refer to Chapter 3 for a discussion regarding the air control layer and properties of the air barrier system.

For the anchored masonry veneer systems shown in this guide, the air barrier system is the same as the WRB system (i.e., the air barrier and WRB system). The air barrier system must be continuous and fully taped and/or sealed to resist air flow; whereas the WRB system is not required to be continuously sealed to be effective, merely shingle-lapped.

For anchored masonry wall systems, there are many types of air barrier systems available on the market today. Different types of air barrier system options are included in Table 6-2.

Vapor Control Layer

The vapor control layer retards or greatly reduces the flow of water vapor across the enclosure. Unlike the other control layers presented in this guide, the vapor control layer is not always necessary, nor is it always required to be continuous; the location and/or the physical properties of other materials within the assembly, including the wall sheathing, insulation, and air barrier and WRB system can also affect the need for or necessary properties of the vapor control layer.

CMU/Concrete

For CMU and concrete backup wall systems the insulated sheathing option shown in this chapter's details provides a foil-faced backer (Class 1 permeance) on the interior face of the insulated sheathing and serves as the vapor control layer.

Where a self-adhered sheet or fluid-applied WRB system is applied directly to the exterior face of the CMU or concrete (similar to the steel stud-framed wall system details shown in this chapter), 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 because the system's thermal insulation is located exterior of the wall structure and the air barrier and WRB system.

Steel Stud-Framed/Wood-Framed

For steel stud-framed and wood-framed backup walls, refer to Section 1405.3 of the governing International Building Code.[1] Typical vapor retarder products include PVA vapor-retarding primer, asphalt-coated kraft paper, polyethylene sheet, or a polyamide film membrane.

Shelf Angle Flashing Options

In the shelf angle flashing options on this page the brick coursing changes when it meets the shelf angle. A sheet-metal flashing with hemmed drip edge and a compressible backer rod and sealant joint remain visible for the final installation. Weeps and/or vents are located within the head joint of the first courses above and below the shelf angle. The projected hem of the drip edge diverts water from the wall cavity and from the veneer above to minimize runoff onto the wall areas below, minimizing staining and increasing the long-term durability of the cladding. The sheet-metal flashing or drip plate used within these options can compensate for construction tolerances within the wall framing, floor slab, and shelf angle. These options may be used with either a continuous shelf angle or standoff shelf angle design.

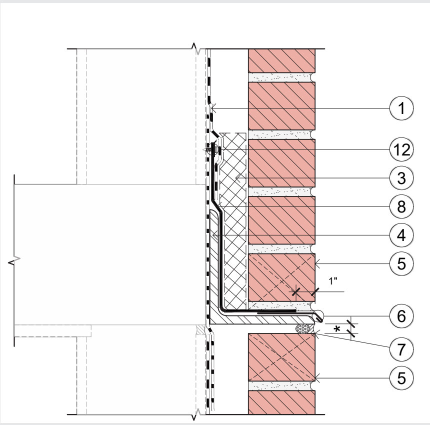


Fig. 6-2 Flexible membrane

Option 1: Flexible Flashing Membrane

A flexible nonadhered flashing membrane is used to drain the wall cavity to the face of the veneer. The membrane is terminated with a termination bar at the top and shingle-lapped into the WRB field membrane. The nonadhered flashing membrane is held back approximately 1 inch from the face of the masonry to ensure it is not visible. The flashing membrane is sealed at the top of the termination bar to the prestrip membrane behind the shelf angle, at laps, and at its termination on the veneer. The nonadhered flashing membrane shown in this option is a cost-effective flashing option.

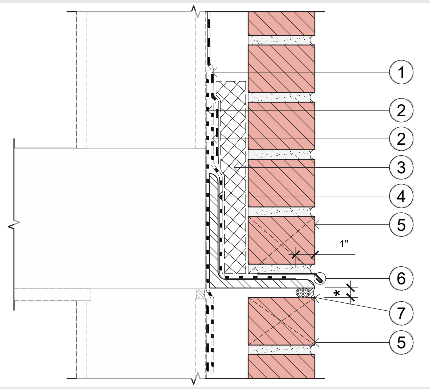


Fig. 6-3 Self-adhered membrane

Option 2: Self-Adhered Flashing Membrane

A flexible self-adhered flashing membrane is used to drain the wall cavity to the face of the veneer. The membrane is adhered to the prestrip membrane behind the shelf angle and is shingle-lapped into the WRB field membrane. The self-adhered flashing membrane is terminated under the sheet-metal drip plate and approximately 1 inch from the face of the shelf angle. Typically, a high-temperature self-adhered membrane product is used to minimize the risk of "bleed-out" should the membrane be installed on top of the drip plate (see Fig. 6-7). The self-adhered flashing membrane in this option is adhered to the substrate and does not typically require further sealing at laps or terminations.

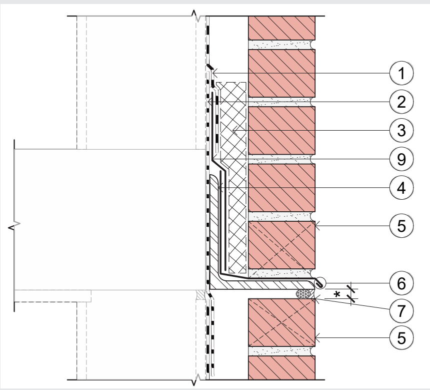


Fig. 6-4 Two-piece sheet-metal flashing

Option 3: Two-Piece Sheet-Metal Flashing

A two-piece sheet-metal flashing (typically formed from stainless steel) is used to drain the wall cavity to the face of the veneer. The sheet-metal flashing is shingle-lapped into the WRB field membrane. The sheet-metal flashing laps are sealed or soldered. This option eliminates the need for a separate flexible flashing membrane and provides a robust flashing material. The use of the two-piece profile allows the sheet-metal flashing below the course to float in or out as needed to compensate for construction tolerances without requiring significant modifications to the profile throughout the length of the wall.

In the shelf angle flashing options on this page, the brick coursing does not change when it meets the shelf angle; a lipped brick overhangs the face of the shelf angle. In the options depicted, either a sanded sealant joint or sheet-metal drip edge remain visible for the final installation. Weeps and/or vents are located within the head joint of the first courses above the flashing membrane and below the shelf angle. The use of a lipped brick is more sensitive to construction tolerances within the wall framing, floor slab, and shelf angle. If the shelf angle projects too far forward, it may be difficult to install the lipped brick without disruption to the plane of the veneer. These options may be used with either a continuous shelf angle or standoff shelf angle design.

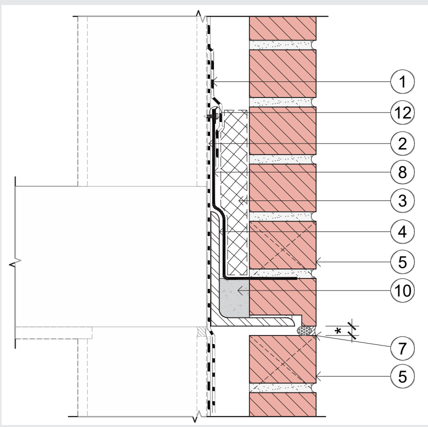


Fig. 6-5 Flexible membrane with lipped brick

Option 4: Flexible Flashing Membrane – Lipped Brick

A flexible nonadhered flashing membrane is used to drain the wall cavity to the face of the veneer. The membrane is terminated with a termination bar at the top and shingle-lapped into the WRB field membrane. The nonadhered flashing membrane laps onto the top of the first course of masonry and is held back approximately 1 inch from the face of the veneer to ensure it is not visible. The flashing membrane is sealed at the top of the termination bar to the prestrip membrane behind the shelf angle, at laps, and at its termination on the veneer. The cavity behind the first course of masonry on the shelf angle is grouted solid. This option does not provide a means to deflect water away from the veneer face and may encourage staining or efflorescence to develop.

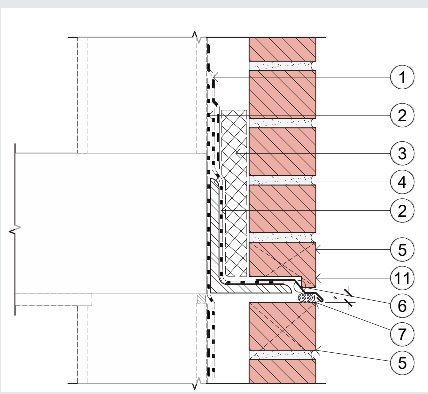


Fig. 6-6 Self-adhered membrane with lipped brick

Option 5: Self-Adhered Flashing Membrane – Lipped Brick

A flexible self-adhered flashing membrane is used to drain the wall cavity to the face of the veneer. The membrane is adhered to the prestrip membrane behind the shelf angle and is shingle-lapped into the WRB field membrane. The self-adhered flashing membrane is terminated under the sheet-metal drip plate. Typically, a high-temperature self-adhered membrane product is used to minimize the risk of "bleed-out" should the membrane be installed on top of the drip plate (see Fig. 6-7). The self-adhered flashing membrane in this option is adhered to the substrate and does not require further sealing at laps or terminations. The projected hem of the drip edge diverts water from the wall cavity and from the veneer above to minimize runoff onto the wall areas below, minimizing staining and increasing the long-term durability of the cladding; however, it can be difficult to form at inside and outside wall corner transitions.

Fig. 6-7 Example of self-adhered membrane "bleed-out" from a self-adhered flashing membrane at a shelf angle detail

Legend

1. Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
2. Self-adhered sheet- or fluid-applied air barrier and WRB prestrip flashing or membrane
3. Mortar collection mesh
4. Hot-dipped galvanized steel shelf angle support
5. Vent/weep at maximum 24 inches on-center
6. Sheet-metal flashing with hemmed drip edge
7. Sealant over backer rod
8. Flexible non-adhered masonry flashing fastened to substrate with termination bar
9. Transitional sheet-metal flashing over sheet-metal drip flashing
10. Non-shrink grout
11. Lipped brick, see Fig. 6-8
12. Termination bar and sealant

* Size joint for project specific movement

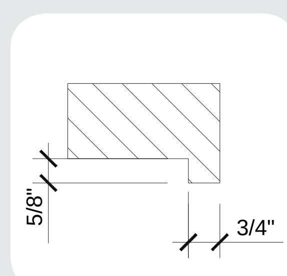


Fig. 6-8 Typical lipped brick dimensions

Anchored Masonry Veneer Penetrations

As with most exterior cladding materials, penetrations through masonry systems are common. Service penetrations, temporary scaffold tie-back supports, or structural penetrations, such as knife plate connections as shown in Fig. 6-9, are a common method of supporting balcony structures, building signage, and canopies. These penetrations are typically anchored to the building structure and penetrate the air and water control layers as shown in Fig. 6-10; 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.

Water, Air, and Thermal Control Layer 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. Two common practices for detailing around penetrations are shown in the flashing sequences in Fig. 6-11 and Fig. 6-12: 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. 6-12.

Although Fig. 6-11 and Fig. 6-12 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., continuous steel channel supports, unit exhaust vents, 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 extending through thermal insulation layers should also be evaluated on a case-by-case basis for thermal bridging effects and condensation potential. These risks can be minimized by using lower-conductivity penetration materials (e.g., PVC in lieu of steel for sleeves or pipes).

Differential Movement

When designing and detailing penetrations that project through an anchored masonry veneer, 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 introduce movement; thus, sealant joints between the masonry and penetration are designed for both compression and tension.

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. 6-9 Typical knife plate penetrations through an anchored masonry veneer. Exterior sealants joint around the knife plate penetration and across the floor line transition, along with final cleaning, have not yet been performed.

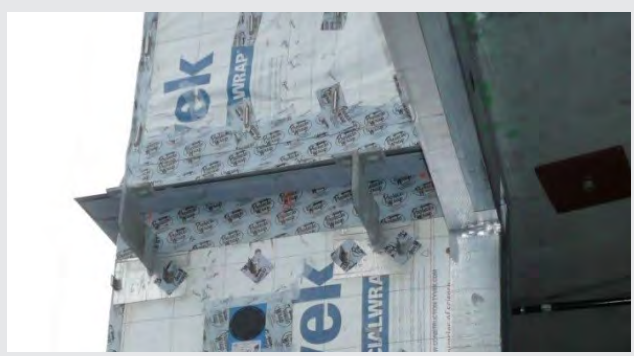


Fig. 6-10 Typical structural knife plate penetrations flashed with a foil-faced self-adhered flashing membrane similar to the sequence in Fig. 6-11. Also visible is a preformed penetration boot for a pipe penetration.

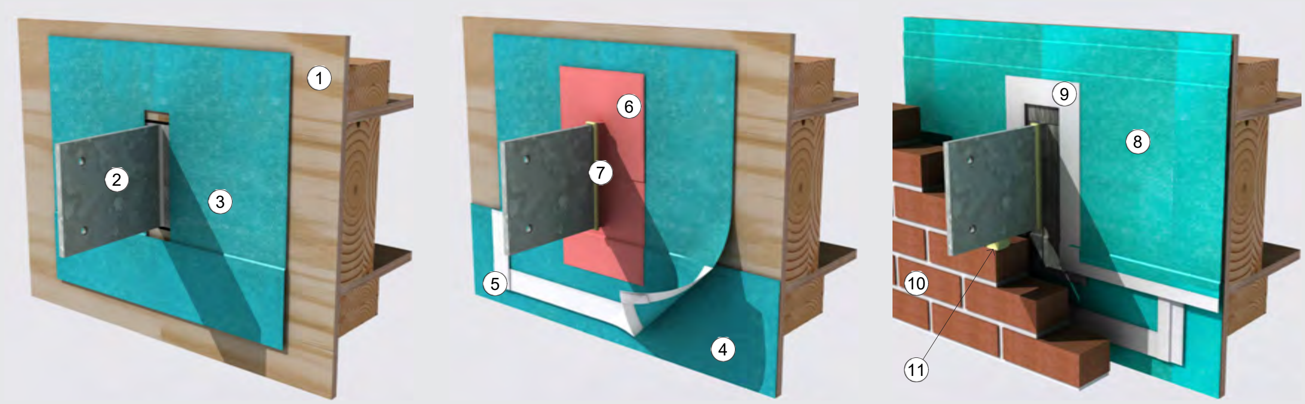


Fig. 6-11 Sheet-applied membrane flashing sequence

Sheet-Applied Air Barrier and WRB System – Flashing Sequence

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 tape (typically not required with self-adhered air barrier and WRB systems)
6. Self-adhered flashing membrane, fit tightly onto penetration
7. Continuous sealant at flashing membrane leading edges around penetration
8. Air barrier and WRB field membrane
9. Continuous air barrier and WRB 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 movement

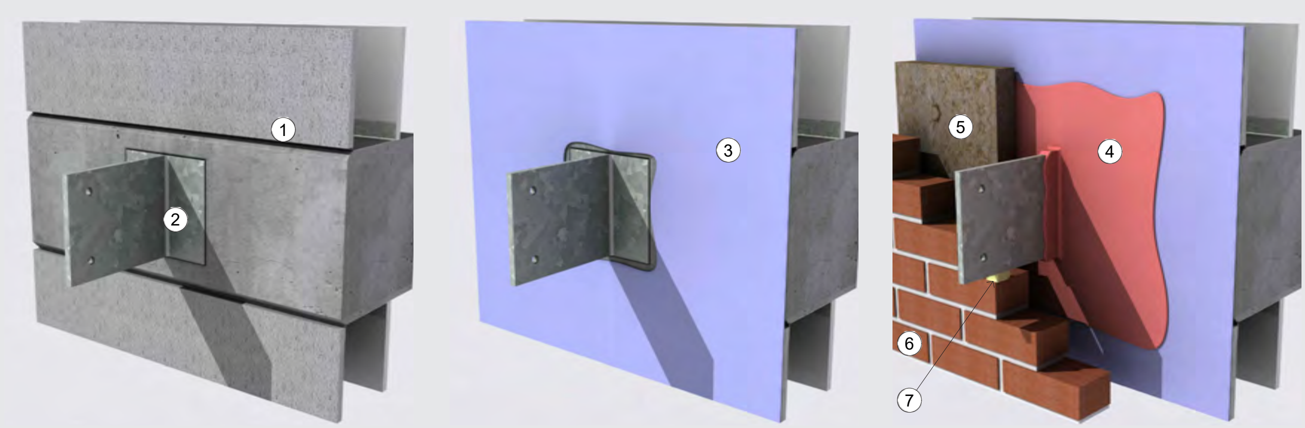


Fig. 6-12 Fluid-applied membrane flashing sequence

Fluid-Applied Air Barrier and WRB System – Flashing Sequence

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 movement

Thermal Control Layer

The thermal control layer controls heat flow and assists with controlling water vapor (e.g., condensation risk). The insulation in this chapter's system is either exterior of the backup wall structure or within stud-framed cavities. At transition details, the thermal control layer also includes insulation at framed parapet cavities, roof assembly, underslab, and foundation elements. Windows and doors that penetrate the above-grade wall are also part of the thermal control layer.

Where insulation is located exterior of the wall structure, this placement provides the following benefits:

1. Allows for the exterior insulation to extend across floor lines, which can be a large source of heat loss—especially for mass floor line conditions.

2. Keeps the structure warm and reduces the risk that condensation may develop inboard of the air barrier and WRB system.

3. Protects the air barrier and WRB system from both extreme temperature cycles and damage during veneer installation.

For additional discussion on the thermal control layer, refer to Chapter 3. Chapter 8 can be referred to for additional discussion on wall system thermal performance and insulation types as well as energy code compliance strategies.

CMU/Concrete

For CMU and concrete backup wall systems the exterior insulation is the primary material that forms the thermal control layer. Interior insulation is acceptable but should be carefully selected and detailed to ensure that condensation risk (due to either vapor drive or air leakage condensation) is not increased. Refer to Chapter 7 for additional discussion on insulating interior of the CMU wall structure.

Fig. 6-13 Fluid-applied air barrier and WRB system. The field membrane is depicted over a concrete backup wall face. Exterior semi-rigid mineral fiber insulation, double-eye and pintle plate ties, and a CMU veneer are also shown.

In Colorado and southern Wyoming, the exterior insulation may be moisture-tolerant rigid board insulation (e.g., polyisocyanurate or XPS), closed-cell spray foam insulation, expanded polystyrene (EPS) or semi-rigid mineral fiber board insulation as shown in Fig. 6-13.

Steel Stud-Framed

For steel stud-framed backup wall systems, the framed cavity insulation and exterior insulation are the primary materials that form the thermal control layer for steel stud-framed walls.

Cavity insulation is typically fiberglass or mineral fiber batt insulation product, or it may be spray foam insulation in some cases. Steel stud framing bridges cavity insulation and can significantly reduce the actual thermal performance (i.e., effective R-value) of the insulation. The high conductivity of steel can reduce cavity insulation R-values by 40 to 60%. Thus, exterior insulation is common in steel stud-framed backup wall systems.

Where insulated sheathing is used as shown in Fig. 6-14, the exterior insulation may be moisture-tolerant rigid board insulation (e.g., polyisocyanurate or XPS). Closed-cell spray foam insulation rated for exterior wall cavity applications may also be appropriate.

Wood-Framed

The wall cavity insulation and the lower-conductivity wood framing that bridge this insulation form the thermal control layer in the wood-framed backup wall system. Exterior insulation may also be used with this system to improve thermal performance.

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 1403.5[1] (regarding vertical and lateral flame propagation as it relates to a combustible WRB system) may require acceptance criteria for NFPA 285.[2] Also address IBC Chapter 26 provisions when using foam plastic insulation within a wall cavity.

Exterior Sheathing

Exterior sheathing is often used outboard of the framed backup wall systems for anchored masonry veneer wall systems.

CMU/Concrete

For CMU and concrete backup wall systems, the use of sheathing is not typical and air barrier and WRB systems or insulation products are applied directly to the CMU or concrete face.

Steel Stud-Framed

For steel stud-framed backup wall systems, a faced gypsum-based sheathing that is resistant to organic growth and moisture is most common.

Some rigid board insulation systems that also serve as the air barrier and WRB system are attached directly over the face of steel stud-framed walls and may not require exterior sheathing.

Wood-Framed

For wood-framed backup wall systems, the exterior sheathing is typically a wood or faced gypsum product and is designated by structural requirements. Where wood products are used, plywood is generally recommended for its moisture tolerance. Where gypsum board is used, a glass mat reinforced facer in lieu of a paper-faced product is recommended for resistance to organic growth as well as its moisture resistance.

Water Deflection and Drainage

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 behind the veneer. This moisture is drained through the air cavity and exits the cladding system where cross-cavity flashings and weeps are provided. A typical anchored masonry veneer wall cavity, at the base of the wall, is shown in Fig. 6-15.

Flashings

Flashings are used throughout anchored masonry veneer wall systems and are most commonly found above and below penetrations, at parapet copings, at base-of-wall transitions, and at floor line transitions. Typical flashings used within anchored masonry veneer wall systems are depicted throughout the details located at the end of this chapter. A general discussion regarding masonry flashings is provided in chapter 4, while a discussion specific to floor line flashing detailing is provided on pages 63–64.

Drainage and Ventilation

Although the minimum air cavity depth per TMS 402-16[3] is 1 inch, this guide recommends a 2-inch air cavity depth between the anchored masonry veneer and exterior insulation (or sheathing) to provide sufficient drainage and ventilation behind the cladding. This larger air cavity depth minimizes the risk that mortar droppings will block the cavity and provides a construction tolerance for framing and veneer components. A 1-inch cavity may be considered where a strict quality control program is implemented to ensure mortar droppings are not allowed to collect within the cavity and where backup wall structure and veneer alignment does not encroach on the 1-inch dimension. Where the air cavity is reduced, which commonly occurs at fenestration rough openings with return brick (refer to Detail 6-10 at the end of this chapter), this guide recommends a compressible free-draining filler. Semi-rigid mineral fiber insulation may be appropriate where additional thermal insulation may benefit the enclosure detailing; mortar collection net material may be

Fig. 6-14 Insulated sheathing with water-resistive facer and fluid-applied flashing membrane over a steel stud-framed backup wall structure.

Fig. 6-15 Typical anchored masonry veneer with steel stud-framed backup wall structure. Exterior insulation and the air cavity are visible behind the veneer. A mortar collection net exists at the base of the wall.

considered when thermal insulation exterior of the sheathing is not needed. Mortar should not be packed within these cavities.

The air cavity is <u>either</u> *vented* with vents located at the bottom course of the wall section at veneer bearing locations or the cavity may also be *ventilated* by locating vents at the top and bottom coursing of each wall section. Both vented and ventilated anchored masonry veneer systems are used in Colorado and southern Wyoming. Ventilated systems provide more air flow behind the anchored masonry veneer and benefit assembly drying, which can increase long-term durability of the masonry veneer, of the wall sheathing, and of the components within the air cavity.

As a best practice, weeps are located within the head joints at the bottom course of the anchored masonry veneer at veneer-bearing locations. In an anchored masonry veneer wall system, weeps drain moisture that may enter the air cavity behind the veneer. Where open cellular- or mesh-type weeps are used, weeps may also serve as vents (i.e., weep vents).

This guide recommends that weeps and vents are spaced at a maximum of 24 inches on-center (e.g., every two to three masonry units) and are filled with a cellular product that fills the head joint of a standard brick unit. Masons within Colorado and southern Wyoming generally do not prefer mesh filler products for weeps or vents. Additionally, this guide recommends avoiding weep tubes at vent locations because they provide far less ventilation and are easily blocked with mortar, insects, and other debris. Where top vents provide a ventilated veneer, this guide recommends that weeps are staggered from any vents located in courses below. During installation, it is important that weeps extend into the bed joint of the masonry veneer to facilitate drainage as shown in Fig. 6-16.

Fig. 6-16 Cellular weep vents at an anchored masonry veneer. Weep vents extend into the mortar bed joint to allow water within the air cavity to drain to the exterior.

This guide recommends mortar collection nets at all veneer-bearing locations to prevent mortar from blocking the air cavity and weeps. Generally, a trapezoidal open-weave moisture-tolerant net is used.

Structural Considerations

In the anchored masonry veneer wall systems in this guide, the CMU, concrete, steel stud-framed, and wood-framed backup walls provide the primary structure of the 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. Details at the end of this chapter demonstrate generic placement of the reinforced elements and supports/anchors for diagrammatic purposes only.

Masonry Anchors

Masonry anchors (i.e., masonry ties) are used to connect the veneer to the backup wall structure. They are designed to resist the out-of-plane loads applied to the wall, typically wind and seismic. At the same time, anchors must be flexible to allow the veneer to move in-plane relative to the backup wall. Table 6-4 describes common anchor types and their applications.

Building codes provide prescriptive requirements for masonry anchors secured to concrete or masonry that include spacing, size, placement, and anchor type. These requirements are summarized in Table 6-3 and are based on TMS 402-16[3] provisions for adjustable anchors. Use of these prescriptive requirements is limited to anchored masonry veneer systems with a weight less than 40 psf, with a cavity depth no more than 6⅝ inches, and where the ASCE-7[4] wind velocity pressure (qz) is less than 55 psf. Wall systems that exceed these criteria require the design professional to evaluate the building loads and materials and rationally design the anchorage system accordingly. Most masonry anchor manufacturers have empirical test data available to support the use of their anchorage systems when the cavity depth or load exceeds these criteria.

Table 6-3 also includes prescriptive spacing requirements for anchored masonry veneers for special requirements for Seismic Design Categories D, E, and F and high-wind zones with velocity pressures (qz) between 40 and 55 psf. These higher seismicity and wind speed areas are common to some parts of Colorado and southern Wyoming 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.

To prevent pull-out or push-through of the anchor, TMS 402-16[3] 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 anchor. To prevent excess movement between connecting parts of adjustable anchor systems, the clearance between components is limited to a maximum 1⁄16 of an inch. The vertical offset of adjustable pintle-type ties may not exceed 1 ¼ inches.

For steel stud-framed wall systems, TMS 402-16[3] requires that masonry anchors 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.

For wood-framed wall systems, TMS 402-16[3] requires fastening masonry ties directly to the wood framing through the exterior sheathing. Masonry anchors are not to be fastened to the sheathing alone. The code requires 8d common nails or fasteners with equivalent or greater pull-out strength.

For framed backup wall systems, 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 of 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 as shown in Fig. 6-17. 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.

This guide recommends that intermediate supports for masonry be 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.[3] As noted in the Movement Joints sections in this chapter and in Chapter 4, this guide recommends a joint filled with a compressible material beneath the angle.

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. Where steel angle lintels span the opening, TMS 402-16[3] requires that the lintel bear a minimum of 4 inches onto the adjacent masonry at the jambs of the opening.

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

CMU/Concrete

TMS 402-16[3] does not place any height restrictions or requirements for intermediate support of masonry with concrete or masonry backings except in Seismic Design Categories D,

Table 6-3 Summary of TMS 402-16[3] provisions for adjustable anchors

Prescriptive Spacing for Adjustable Two-Piece Masonry Veneer Ties			
Spacing Designation	Requirement Category (use more stringent spacing requirements where applies)		
	General	Seismic Design Categories D, E, and F*	High Wind†
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‡	36-inches	36-inches	24-inches
Maximum Distance from Openings	12-inches	12-inches	12-inches

* Seismic design categories as determined by ASCE 7

† 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 ft

‡ For openings larger than 16-inches in either dimension

Table 6-4 Summary of TMS 402-16[3] provisions for adjustable and non adjustable masonry anchors. Photos courtesy of Hohmann & Barnard, Inc.

	Common Anchor Types					
	ADJUSTABLE ANCHOR TYPE				NON ADJUSTABLE ANCHOR TYPE	
						
	Plate Anchor	Embedded Joint Reinforcement Anchor	Screw Anchor	L-Bracket Anchor	Surface-Mounted Anchor	Corrugated Metal Anchor
CMU Backup	🟢	🟢 Offers less adjustability due to fixed placement of reinforcing in block bed joints.	🟢	🟡 See general notes below.	🔴 TMS 402-16[3] requires an adjustable tie.	🔴 TMS 402-16[3] requires an adjustable anchor.
Concrete Backup	🟢	Anchor not constructible with backup wall structure.	🟢	🟡 See general notes below.	🔴 TMS 402-16[3] requires an adjustable anchor. Anchor may be paired with a dove tail slot to provide adjustability; however, the slot is difficult to waterproof and is typically avoided.	🔴 TMS 402-16[3] requires an adjustable anchor.
Steel Stud-Framed Backup	🟢	Anchor not constructible with backup wall structure.	🟢	🟡 See general notes below.	🔴	
Wood-Framed Backup	🟢	Anchor not constructible with backup wall structure.	🟢	🟡 See general notes below.	🟡 Adjustable anchors are preferred when possible.	🟡 Anchor has poor corrosion resistance and is typically avoided.
General Notes		Consider air barrier and WRB system detailing requirements around wires.	Thermally improved anchor option; see Chapter 8 for more discussion.	May not be preferred by some installers as it requires vertical installation of some insulation boards.		

🟢 Permitted by TMS 402-16[3]

🟡 Permitted by TMS 402-16;[3] however, see additional table discussion/notes

🔴 Not permitted by TMS 402-16[3]

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.

Steel Stud-Framed

For steel stud-framed backup wall systems, TMS 402-16[3] 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.

Wood-Framed

For wood-framed backings, TMS 402-16[3] 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.

For all backup wall types it is also important to consider vertical supports from a building enclosure thermal performance aspect, particularly at floor lines. Supports can create thermal bridges through exterior insulation and can significantly reduce the effectiveness of this insulation layer. This thermal bridging can be minimized by using intermediate standoff supports as further discussed in Chapter 8.

Corrosion Resistance

It is best practice to match the durability and longevity of metal components to that expected of the masonry veneer. Metal components include veneer anchors, 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 anchors that comply with ASTM A153[5] Class B-2 or AISI Type 304 or Type 316 stainless steel per ASTM A580.[6] Steel support angles such as shelf angle supports and loose lintels are at minimum hot-dipped galvanized and comply with ASTM A123.[7] Best practice is to use sheet-metal flashing components of ASTM A666[8] 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, prefinished sheet metal may be appropriate. Where used, this guide recommends the base sheet metal is a minimum G90 hot-dipped galvanized coating in conformance with ASTM A653[9] or minimum AZ50 galvalume coating in conformance with ASTM A792.[10] This guide also recommends coating the exposed top finish of the sheet metal with an architectural-grade coating conforming to AAMA 621.[11]

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.

Fig. 6-17 Stand off shelf angle floor line support

Accommodating Movement

In an anchored masonry veneer system, clay masonry will expand, concrete masonry veneer units will shrink, and mortar joints will shrink. Clay masonry veneer systems require expansion joints located throughout the veneer and concrete masonry veneer systems require control joints. These joints minimize stresses within the veneer and between dissimilar materials such as at window jamb-to-veneer interfaces.

To avoid damage to the veneer or other wall components, it is crucial to consider differential movement between the wall structure and veneer. Differential movement between the backup wall and veneer will also vary dependent on the backup wall type as described below.

CMU/Concrete

In CMU and concrete wall structures, shrinkage will occur over time due to initial drying and carbonation.

Steel Stud-Framed

In the support system, the steel stud-framed backup wall will experience little volume change; however, some movement may occur where studs interface with floor and roof lines.

Wood-Framed

In the support system, the wood stud-framed members will shrink due to moisture loss. Shrinkage is most concentrated at floor lines.

Differential movement (between the structure and the veneer) in the vertical direction 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 top blocking, and windows. A backer rod and sealant or compressible filler placed within these gaps prevents insects and debris from entering the air cavity.

Differential movement in the horizontal direction, often between the veneer and penetrations or different cladding materials is accommodated with a vertical joint through the anchored masonry veneer. 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.

Both horizontal and vertical joints are designed based on the amount of differential movement expected and the compression or expansion limitations of any sealant joint or filler within the gap. For additional discussion on locating movement joints and for best practice sealant joint guidelines, refer to Chapter 4.

Typical locations of joints for the purposes of accommodating movement, drainage, and/or air cavity ventilation are identified with an asterisk (*) in the details located in this chapter. In general, a minimum gap dimension of ⅜ of an inch is recommended; however, it is the Designer of Record's responsibility to appropriately locate and size all movement joints.

Veneer Products and Properties

There are several types of anchored masonry veneer products that may be used with this system. Those most typical within Colorado and southern Wyoming 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 C216 [12] and are severe weather (SW) grade. When using concrete facing brick, anchored veneer units are to comply with ASTM C1634. [13] Hollow concrete masonry units used for veneer applications are typically 4 inches deep and comply with ASTM C90. [14]

Mortar designed for the anchored masonry veneer units is to conform to ASTM C270 [15] 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 to minimize stress on the anchored masonry veneer units, improve durability, and reduce initial cleaning efforts.

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 design and review the specifics of architectural characteristics and structural properties of the masonry veneer units, mortar, and reinforcing.

Clear Water Repellents

Application of a clear water repellent to the anchored masonry veneer of this system is not common in Colorado and southern Wyoming. Where a clear water repellent is used, refer to the Surface-Applied Clear Water Repellents discussion in Chapter 4 for more information on selecting an appropriate clear water repellent and for best practice installation guidelines.

Quality Assurance and Control

High-quality masonry wall system installations are the result of quality control and quality assurance measures that occur throughout the design and construction phases. The general design guidance provided throughout this guide provides the information necessary for understanding and designing the anchored masonry wall system. More specifically, Chapter 5 provides a more in-depth discussion on the topic of quality assurance and quality control.

Chapter References

1. International Code Council. *2018 International Building Code* (Country Club Hills, IL: International Code Council, Inc., 2017).

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. The Masonry Society. *TMS-402/602-16 Building Code Requirements and Specification for Masonry Structures* (n.p.: The Masonry Society, 2016).

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

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

6. ASTM International. *ASTM A580/A580M-16 Standard Specification for Stainless Steel Wire* (West Conshohocken, PA: ASTM International, 2016).

7. 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).

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).

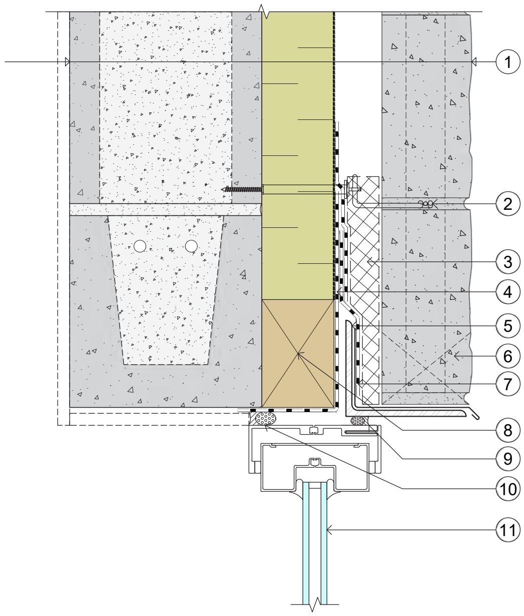
12. ASTM International. *ASTM C216-17 Standard Specification for Facing Brick (Solid Masonry Units Made from Clay or Shale)*. (West Conshohocken, PA: ASTM International, 2017).

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

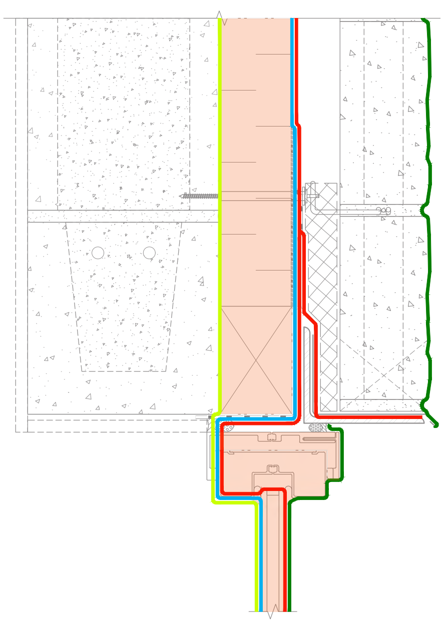
14. ASTM International. *ASTM C90-16a Standard Specification for Loadbearing Concrete Masonry Units* (West Conshohocken, PA: ASTM International, 2016).

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

CMU BACKUP WALL: Window Head Detail



Detail 6-1 CMU Backup Wall: Window Head Detail



Water-Shedding Surface and Control Layers of Detail 6-1

Legend

1. Typical Assembly:
    - Single-wythe CMU wall
    - Faced rigid board insulation
    - Air cavity
    - Anchored masonry veneer
2. Masonry veneer anchor
3. Mortar collection mesh
4. Fluid-applied air barrier and WRB flashing membrane
5. Hot-dipped galvanized-steel loose lintel
6. Vent/weep at maximum 24 inches on-center
7. Self-adhered flashing lapping on a sheet metal flashing with end dams (beyond)
8. Continuous blocking anchored to structure for window support and attachment
9. Sealant over backer rod
10. Continuous air barrier sealant tied to continuous seal at window perimeter
11. Storefront window, align thermal break with rigid board insulation

Detail Discussion

The window in this series of details is aligned with the adjacent insulation to minimizing thermal bridging around the rough opening at the window-to-wall interface.

A self-adhered flashing membrane transitions from the face of the insulation to the sheet-metal flashing. This allows water at the face of the insulation (the water control layer) to drain to the exterior through the vent/weep. A self-adhered flashing is used in lieu of a sheet-metal flashing; a sheet-metal flashing would require additional blocking, and less insulation, at the rough opening head for attachment.

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

Water

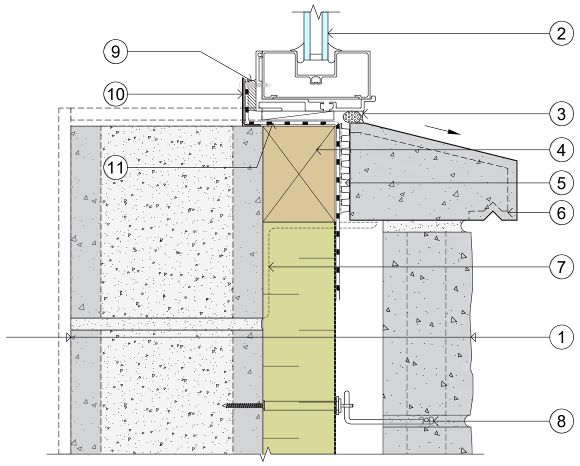
Air

Vapor

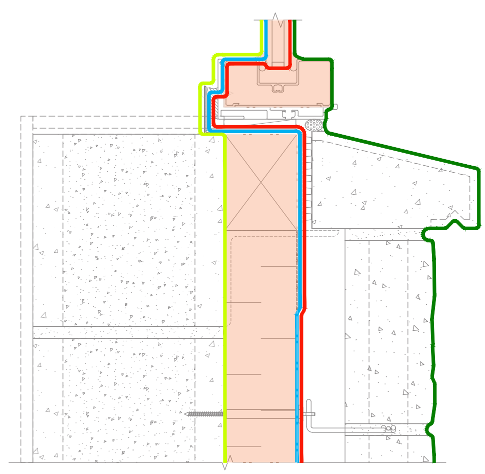
Thermal

Note: Control layers are shown for a Class I or II faced rigid insulation board product.

CMU BACKUP WALL: Window Sill Detail



Detail 6-2 CMU Backup Wall: Window Sill Detail



Water-Shedding Surface and Control Layers of Detail 6-2

Legend

1. Typical Assembly:
   - Single-wythe CMU wall
   - Faced rigid board insulation
   - Air cavity
   - Anchored masonry veneer
2. Storefront window, align thermal break with rigid board insulation
3. Sealant over backer rod
4. Continuous blocking anchored to structure for window support and attachment
5. Drainage matrix
6. Sloped precast sill with chamfered drip edge and sealant over backer rod at precast joints
7. Intermittent structural support for precast sill (beyond)
8. Masonry veneer anchor
9. Continuous air barrier sealant tied to continuous seal at window perimeter
10. Back dam angle at sill, minimum 1 inch tall, fasten window through back dam angle
11. Fluid-applied air barrier and WRB flashing membrane

Detail Discussion

Intermittent attachments back to the structure may be required to support the precast sill element. These attachments require detailing with a fluid-applied or self-adhered flashing membrane where they project through the insulation and facer. Intermittent attachments disrupt the insulation (thermal control layer) less than continuous attachments and are preferred.

The drainage matrix behind the precast sill element allows for a continuous pathway for water to drain from the window rough opening into the air cavity below where it can be redirected exterior of the masonry veneer. This allows for a backer rod and sealant joint at the window perimeter to maintain a continuous water-shedding surface.

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

Water

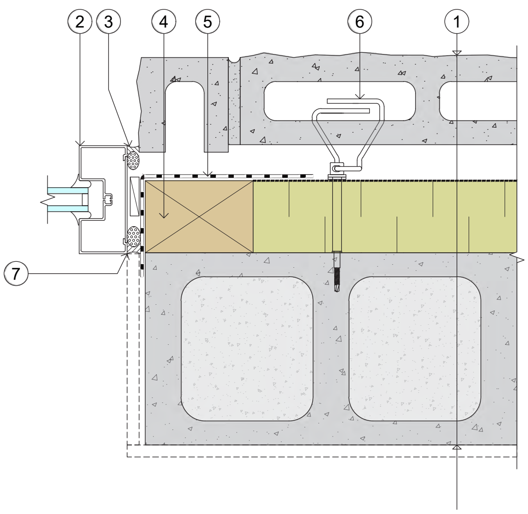
Air

Vapor

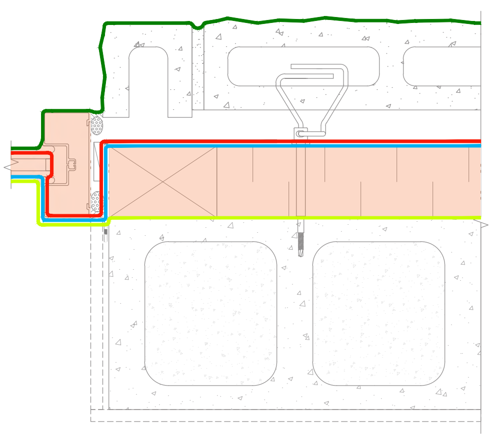
Thermal

Note: Control layers are shown for a Class I or II faced rigid insulation board product.

CMU BACKUP WALL: Window Jamb Detail



Detail 6-3 CMU Backup Wall: Window Jamb Detail



Water-Shedding Surface and Control Layers of Detail 6-3

Legend

1. Typical Assembly:
    - Single-wythe CMU wall
    - Faced rigid board insulation
    - Air cavity
    - Anchored masonry veneer
2. Storefront window, align thermal break with rigid board insulation
3. Sealant over backer rod
4. Continuous blocking anchored to structure for window support and attachment
5. Fluid-applied air barrier and WRB flashing membrane
6. Masonry veneer anchor
7. Continuous air barrier sealant tied to continuous seal at window perimeter

Detail Discussion

Wood blocking shown at the jamb serves as a nailer to attach the window. Air and water control layer continuity between the window and wall is provided by a continuous seal and the fluid applied flashing membrane at the window rough opening perimeter. A veneer return at the jamb may be needed to allow for the exterior backer rod and sealant to be installed. An air gap is to remain between the return brick and flashing membrane. It should not be packed with mortar.

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

Water

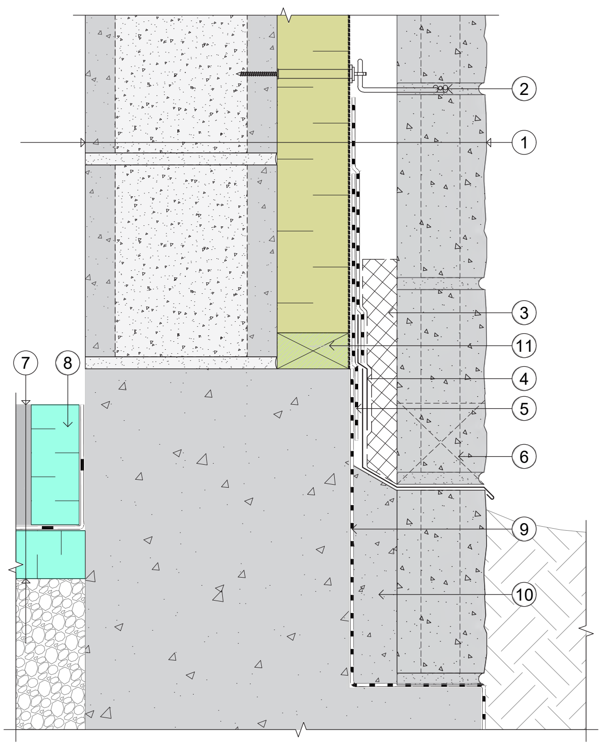
Air

Vapor

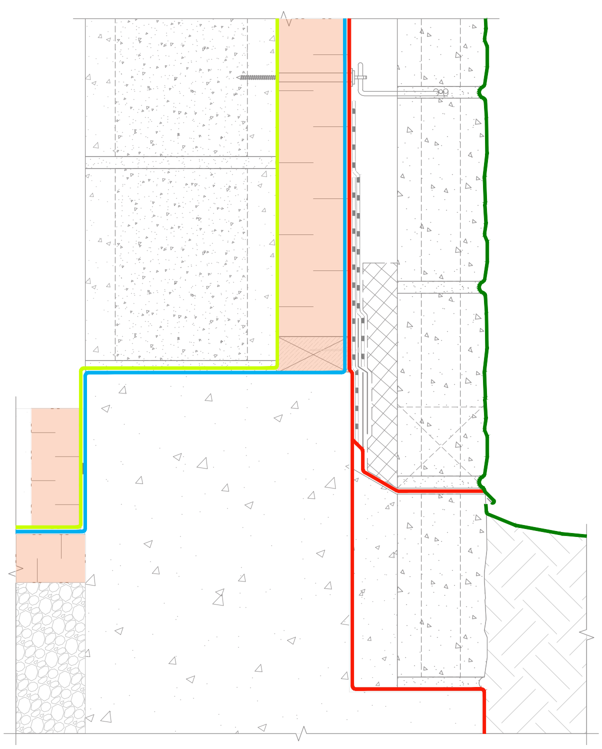
Thermal

Note: Control layers are shown for a Class I or II faced rigid insulation board product.

CMU BACKUP WALL: Base-of-Wall Detail



Detail 6-4 CMU Backup Wall: Base-of-Wall Detail



Water-Shedding Surface and Control Layers of Detail 6-4

Legend

1. Typical Assembly:
   - Single-wythe CMU wall
   - Faced rigid board insulation
   - Air cavity
   - Anchored masonry veneer
2. Masonry veneer anchor
3. Mortar collection mesh
4. Two-piece sheet-metal flashing with hemmed drip edge and end dams beyond, attached through the wood blocking
5. Fluid-applied air barrier and WRB flashing membrane
6. Vent/weep at maximum 24 inches on-center
7. Typical Assembly at Floor:
   - Concrete floor slab
   - Vapor barrier
   - Rigid XPS insulation
   - Capillary break
8. Rigid XPS insulation thermal break
9. Below-grade waterproofing or dampproofing with protection course where required
10. Continuous grout, sloped at top
11. Preservative treated wood blocking

Detail Discussion

In this detail, a thermal break is provided between the concrete floor slab and foundation element to minimize heat loss at the floor-to-wall interface.

The bottom courses of masonry are at or below-grade; continuous grout exists behind the veneer for support. The sheet-metal flashing shown drains the wall cavity above to the exterior and stops the transfer of any moisture between the above- and below-grade masonry.

Wood blocking shown serves as a nailer to attach the two-piece sheet-metal flashing.

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

Water

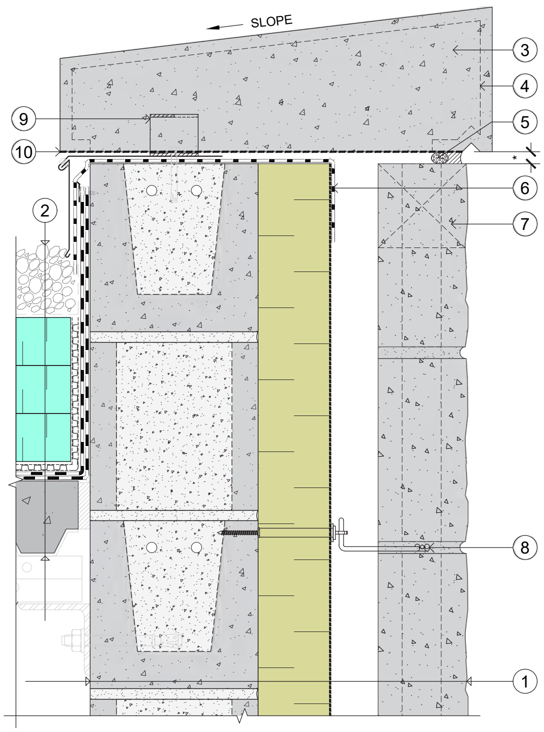
Air

Vapor

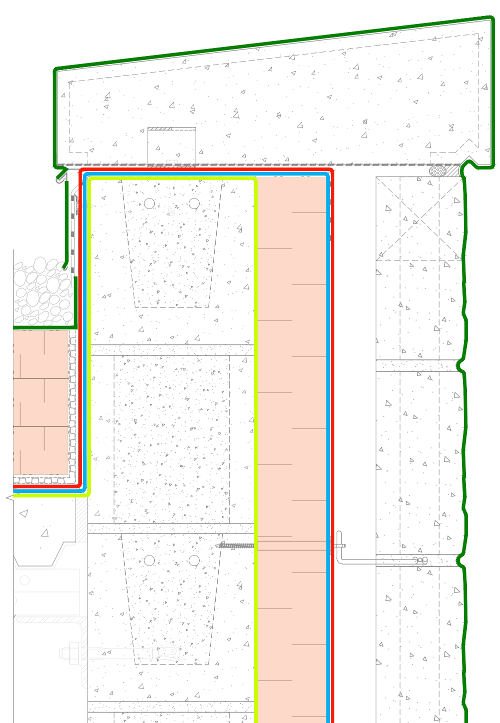
Thermal

Note: Control layers are shown for a Class I or II faced rigid insulation board product.

CMU BACKUP WALL: Roof Parapet Detail



Detail 6-5 CMU Backup Wall: Roof Parapet Detail



Water-Shedding Surface and Control Layers of Detail 6-5

Legend

1. Typical Assembly:
   - Single-wythe CMU wall
   - Faced rigid board insulation
   - Air cavity
   - Anchored masonry veneer
2. Inverted roof membrane assembly
3. Precast cornice with chamfered drip edge
4. Sealant over backer rod at precast joints beyond
5. Sealant over backer rod
6. Fully-reinforced fluid-applied roof flashing membrane
7. Vents at maximum 24 inches on-center (optional)
8. Masonry veneer anchor
9. Split-tail anchor
10. Cementitious-based waterproof coating

*Minimum ⅜-inch to allow for movement. Confirm dimension with Engineer of Record.

Detail Discussion

An application of cementitious-based waterproof coating is applied on the underside of the architectural precast concrete, cast stone, or limestone cap to minimize the migration of moisture below the cap area. This application can mitigate efflorescence in the wall below.

The drip edge at the underside of the parapet cap encourages water to shed away from the enclosure before it can run down the face of the masonry cladding. This application can minimize staining and efflorescence.

The thermal performance of this detail may be improved by framing and insulating the parapet as shown in Detail 6-13. The best approach for minimizing heat loss at the parapet is by insulating up and over the parapet structure.

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

Water

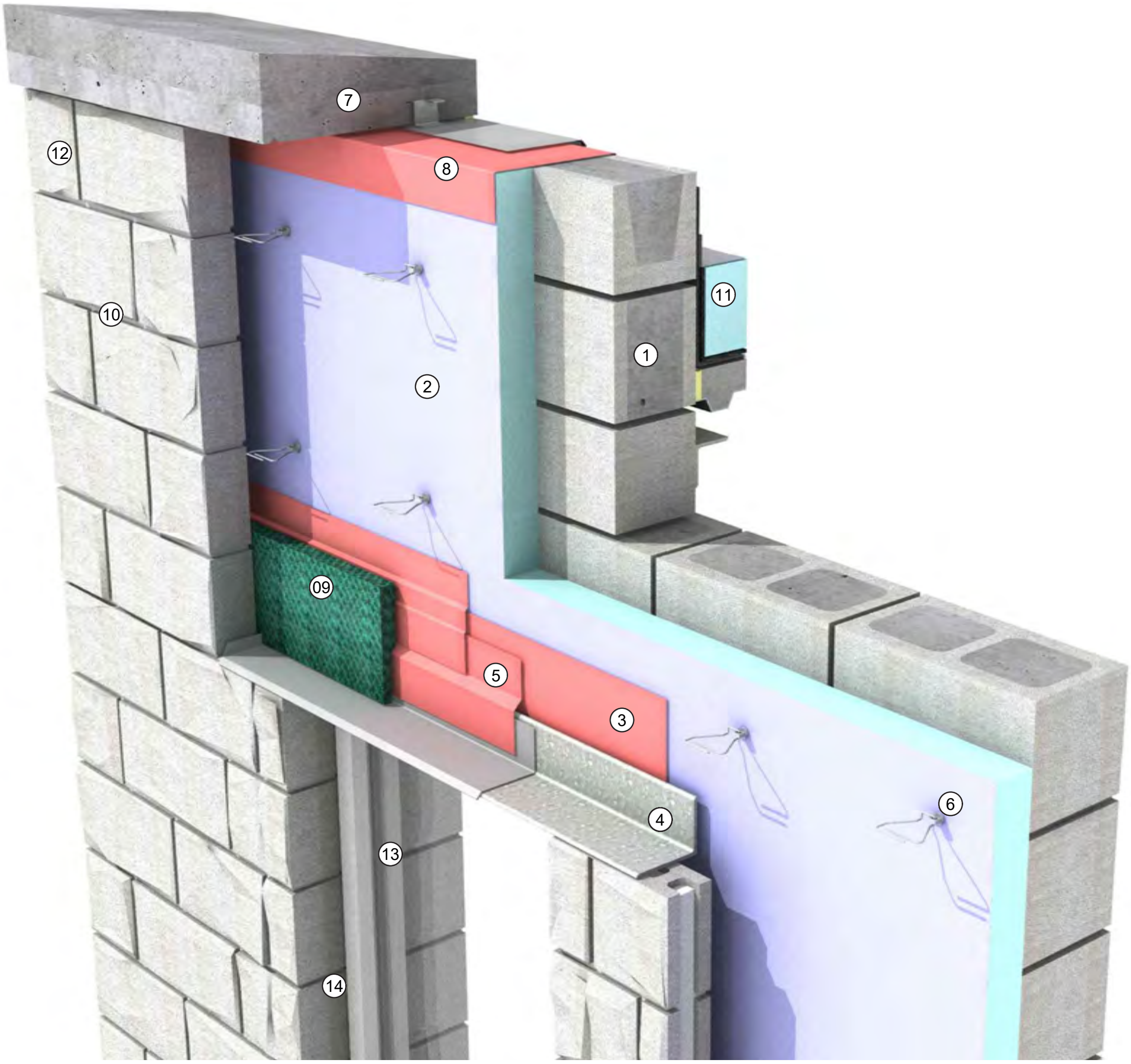
Air

Vapor

Thermal

Note: Control layers are shown for a Class I or II faced rigid insulation board product.

CMU BACKUP WALL: Roof Parapet 3D Detail



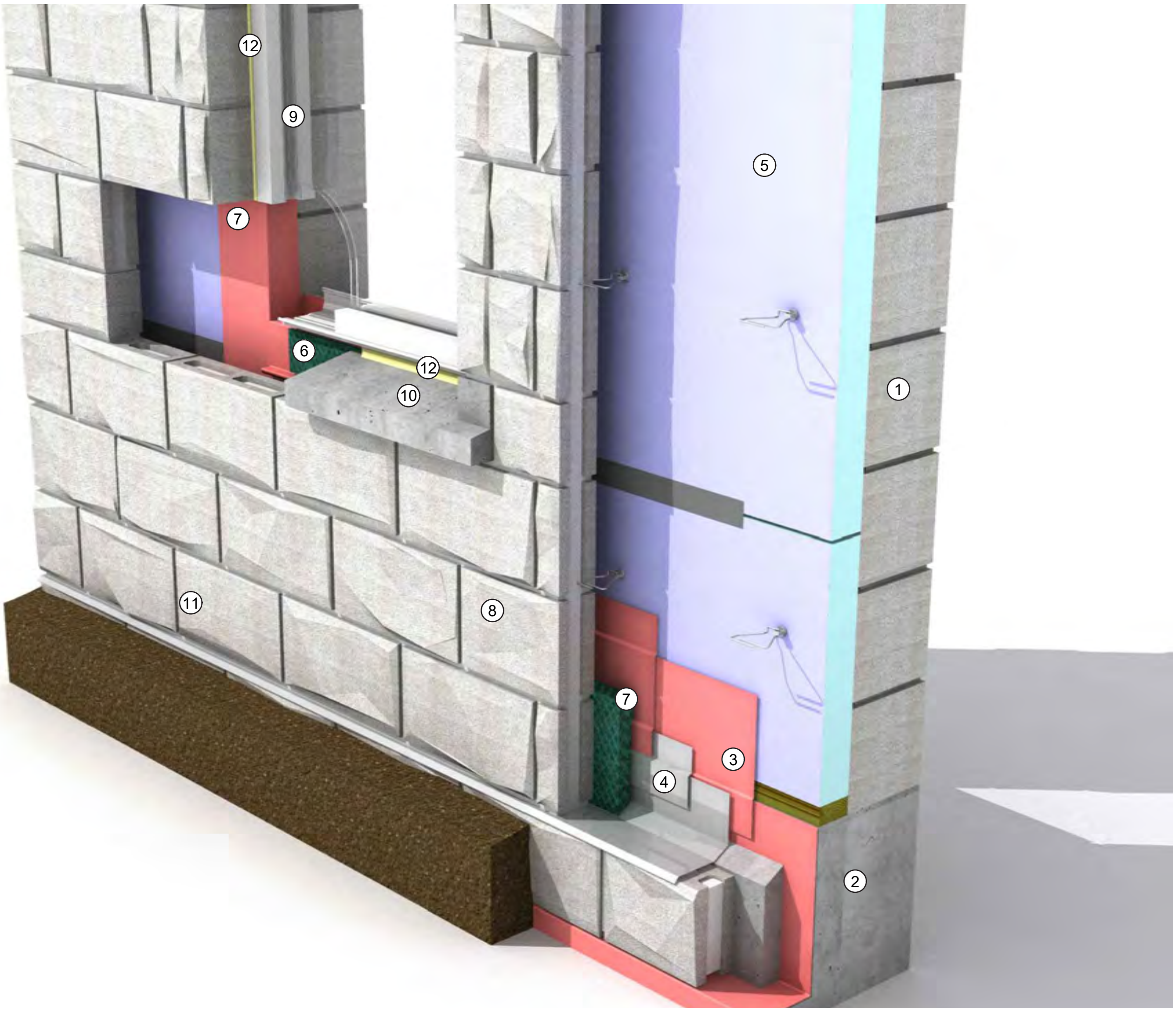
Detail 6-6 CMU Backup Wall: Roof Parapet 3D Detail

Legend

1. Single-wythe CMU wall
2. Faced rigid board insulation
3. Fluid-applied air barrier and WRB flashing membranes
4. Hot-dipped galvanized-steel loose lintel
5. Self-adhered flashing lapping on a sheet metal flashing with end dams (beyond)
6. Masonry veneer tie
7. Precast cornice with chamfered drip edge
8. High-temperature self-adhered membrane
9. Mortar collection mesh
10. Anchored masonry veneer
11. Inverted roof membrane assembly and roof structure
12. Vents at maximum 24-inches on-center (optional)
13. Storefront window
14. Sealant over backer rod

Refer to Detail 6-1, Detail 6-3, and Detail 6-5 for more information.

CMU BACKUP WALL: Base-of-Wall 3D Detail



Detail 6-7 CMU Backup Wall: Base-of-Wall 3D Detail

Legend

1. Single-wythe CMU wall
2. Concrete foundation element
3. Fluid-applied or self-adhered flashing membrane
4. Two-piece sheet-metal flashing with hemmed drip edge and end dams beyond, attached through the wood blocking
5. Faced rigid board insulation
6. Mortar collection mesh
7. Fluid-applied air barrier and WRB flashing membrane
8. Anchored masonry veneer
9. Storefront window
10. Sloped precast sill with chamfered drip edge and sealant over backer rod at precast joints
11. Vent/weep at maximum 24-inches on-center
12. Continuous sealant and backer rod

Refer to Detail 6-2, Detail 6-3, and Detail 6-4 for more information.

SOLOMON COLORS, INC.

Enhance the beauty and value of masonry with Solomon Colors

A, H, & X SERIES MORTAR COLOR

Mortar joints make up to 20% of a masonry wall's surface area. Coloring the mortar will beautifully enhance a building's appearance.

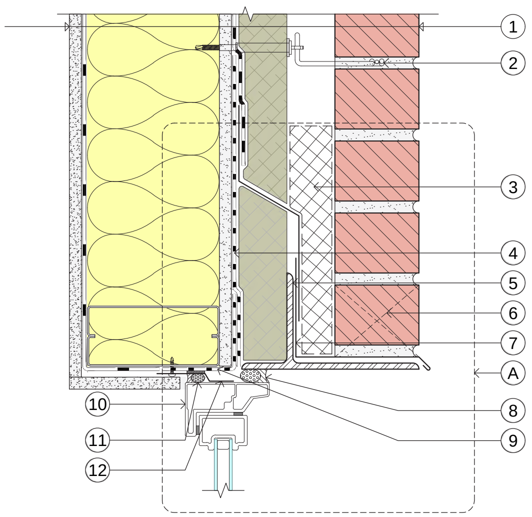
SOLOMON COLORS sets the standard with the most consistent and most frequently specified mortar colors in the industry. Each package of Solomon Colors mortar color is pre-weighed and available in 60 standard colors. Color matching and custom blending are available, making your project exciting and bringing your design to life.

Whether you are building a new home or a new home field, Solomon Colors is the most trusted name in mortar color.

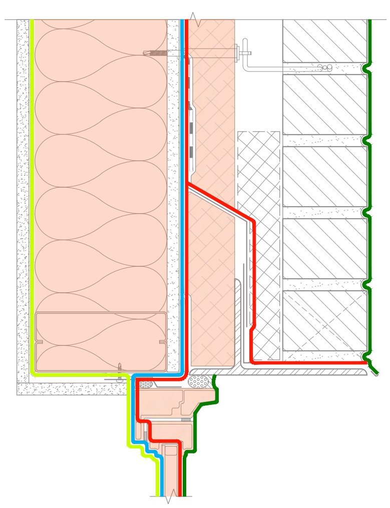
SOLOMON COLORS, INC. • *An Employee Owned Company* • **4050 Color Plant Rd., Springfield, IL 62702 • (800) 624-0261**

WESTERN FACILITY: 1371 Laurel Ave., Rialto, CA 92376 • (800) 483-9628

STEEL STUD-FRAMED BACKUP WALL: Window Head Detail



Detail 6-8 Steel Stud-Framed Backup Wall: Window Head Detail



Water-Shedding Surface and Control Layers of Detail 6-8

Legend

1. Typical Assembly:
   - Interior gypsum board
   - Vapor retarder
   - Steel stud-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
2. Masonry veneer anchor
3. Mortar collection mesh
4. Self-adhered sheet- or fluid-applied air barrier and WRB field 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. Sealant over backer rod
9. Self-adhered sheet- or fluid-applied air barrier and WRB flashing membrane
10. Non-flanged window
11. Continuous air barrier sealant tied to continuous seal at window perimeter
12. Window strap anchor, bed in air barrier sealant at continuous air barrier sealant joint plane

A. See alternate shelf angle support detailing options on page 63

Detail Discussion

A non-flanged window is shown in the detail and facilitates future window replacement without the need to remove the anchored masonry veneer or window flanges.

The intermittent strap anchors used to attach the window to the structure are bed in sealant at the plane of the continuous air barrier sealant at the window perimeter. This allows the air and water control layer to be continuous between the window and rough opening flashing membrane behind strap anchors.

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

Water

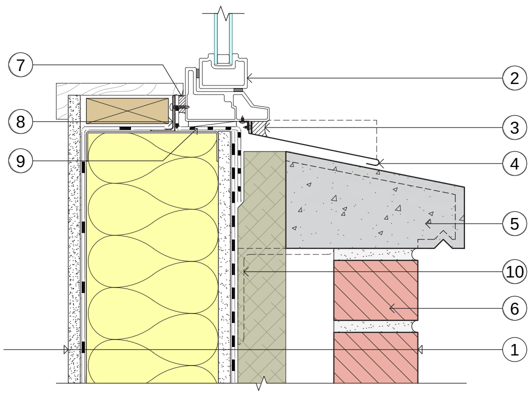
Air

Vapor

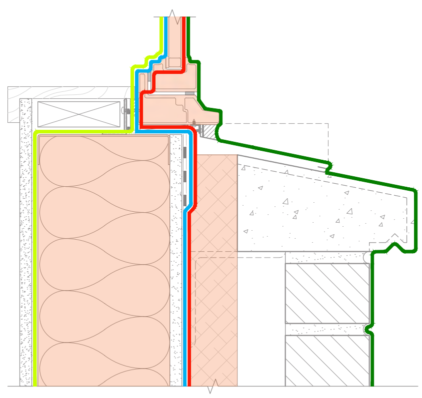
Thermal

Note: Control layers are shown for a Class IV permeance (and sometimes Class III permeance) air barrier and WRB field membrane and where a vapor retarder is located at the interior face of the framing.

STEEL STUD-FRAMED BACKUP WALL: Window Sill Detail



Detail 6-9 Steel Stud-Framed Backup Wall: Window Sill Detail



Water-Shedding Surface and Control Layers of Detail 6-9

Legend

1. Typical Assembly:
   - Interior gypsum board
   - Vapor retarder
   - Steel stud-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
2. Non-flanged window on minimum ¼-inch thick intermittent plastic 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 with chamfered drip edge and sealant over backer rod at precast joints
6. Anchored masonry veneer
7. Continuous air barrier sealant tied to continuous seal at window perimeter
8. Back dam angle at sill, minimum 1 inch tall, fasten window through back dam angle
9. Self-adhered sheet- or fluid-applied air barrier and WRB flashing membrane
10. Intermittent structural support for precast sill (beyond)

Detail Discussion

The sheet-metal sill flashing conceals the rainscreen cavity. End dams exist on the sheet-metal sill flashing and terminate within a bed joint of the brick return beyond. This provides continuity of the water-shedding surface at the jamb to sill interface, minimizing the opportunity for water to enter the air cavity behind the brick.

This guide recommends against placing a sheet-metal flashing below the precast sill. It can prematurely degrade the mortar bed beneath the precast sill.

A chamfer is shown in the underside of the precast sill to form a drip. This encourages water to shed from the sill before reaching the masonry veneer below.

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

Water

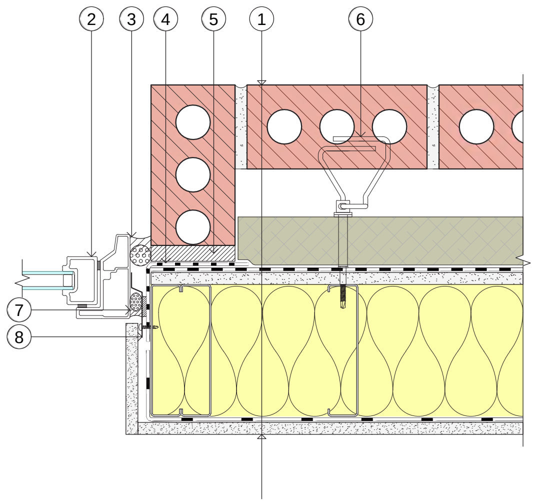
Air

Vapor

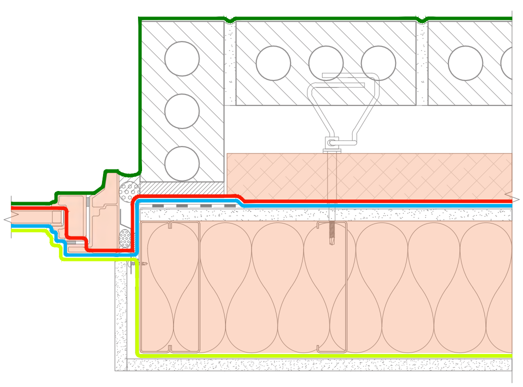
Thermal

Note: Control layers are shown for a Class IV permeance (and sometimes Class III permeance) air barrier and WRB field membrane and where a vapor retarder is located at the interior face of the framing.

STEEL STUD-FRAMED BACKUP WALL: Window Jamb Detail



Detail 6-10 Steel Stud-Framed Backup Wall: Window Jamb Detail



Water-Shedding Surface and Control Layers of Detail 6-10

Legend

1. Typical Assembly:
   - Interior gypsum board
   - Vapor retarder
   - Steel stud-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
2. Non-flanged window
3. Sealant over backer rod
4. Self-adhered sheet- or fluid-applied air barrier and WRB flashing membrane
5. Minimum ½-inch drainage path, fill with free draining compressible filler
6. Masonry veneer anchor
7. Continuous air barrier sealant tied to continuous seal at window perimeter
8. Window strap anchor, bed in air barrier sealant at continuous air barrier sealant joint plane

Detail Discussion

The backer rod and sealant joint at the interior side of the window provides air and water control layer continuity from the window to the air barrier and WRB flashing membrane at the rough opening. Strap anchors, which interrupt this sealant joint, are bed in sealant to maintain continuity of the air and water control layer.

In this detail the brick return at the jamb prevents the exterior insulation from extending up to the window. To improve the thermal performance of this interface, the exterior insulation can extend up to the window rough opening and a shallower brick return may be used. A sheet-metal jamb flashing (typically attached to the window with small clips) can be used to conceal the air cavity and insulation and provide continuity of the water-shedding surface.

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

Water

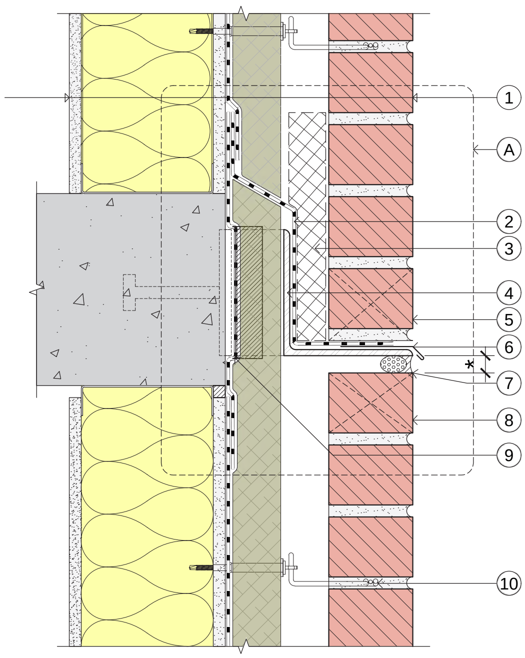
Air

Vapor

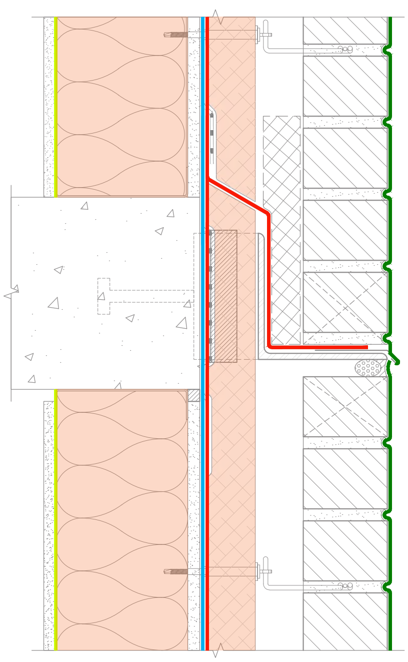
Thermal

Note: Control layers are shown for a Class IV permeance (and sometimes Class III permeance) air barrier and WRB field membrane and where a vapor retarder is located at the interior face of the framing.

STEEL STUD-FRAMED BACKUP WALL: Floor Line Detail



Detail 6-11 Steel Stud-Framed Backup Wall: Floor-Line Detail



Water-Shedding Surface and Control Layers of Detail 6-11

Legend

1. Typical Assembly:
   - Interior gypsum board
   - Vapor retarder
   - Steel stud-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
2. Self-adhered flashing membrane
3. Mortar collection mesh
4. Hot-dipped galvanized-steel standoff shelf angle support anchored on intermittent structural support
5. Vent/weep 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 (optional)
9. Self-adhered sheet- or fluid-applied air barrier and WRB flashing membrane, extend onto intermittent structural support
10. Masonry veneer anchor

A. See alternate shelf angle support detailing options on page 63

*Minimum 3/8-inch to allow for movement. Confirm dimension with Engineer of Record.

Detail Discussion

See Shelf Angle Flashing Options on page 63 and page 64 for alternative flashing solutions that may be used at the floor line.

The use of a standoff shelf angle to support the anchored masonry veneer allows insulation to run continuously across the floor line and minimize thermal bridging. This minimizes heat loss at the floor line and can improve thermal comfort; it is more thermally efficient than a continuous shelf angle support as discussed in Chapter 8.

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

Water

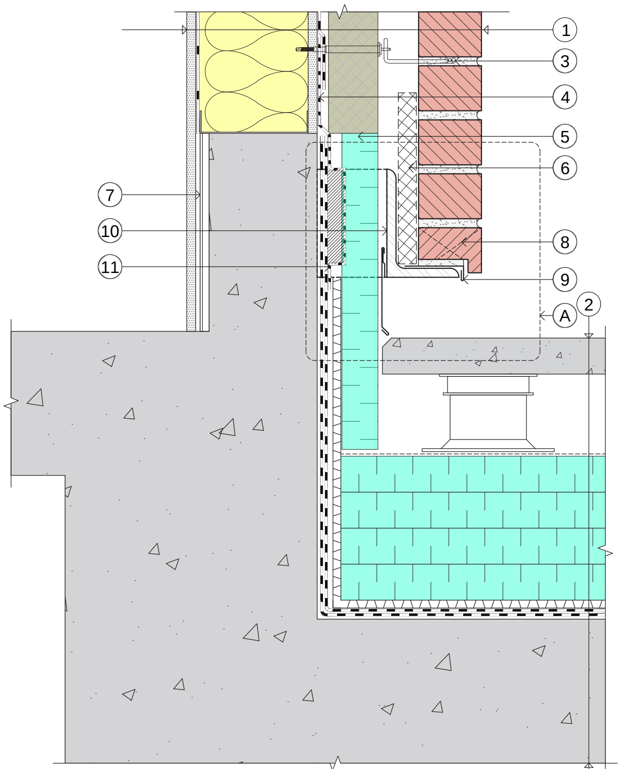
Air

Vapor

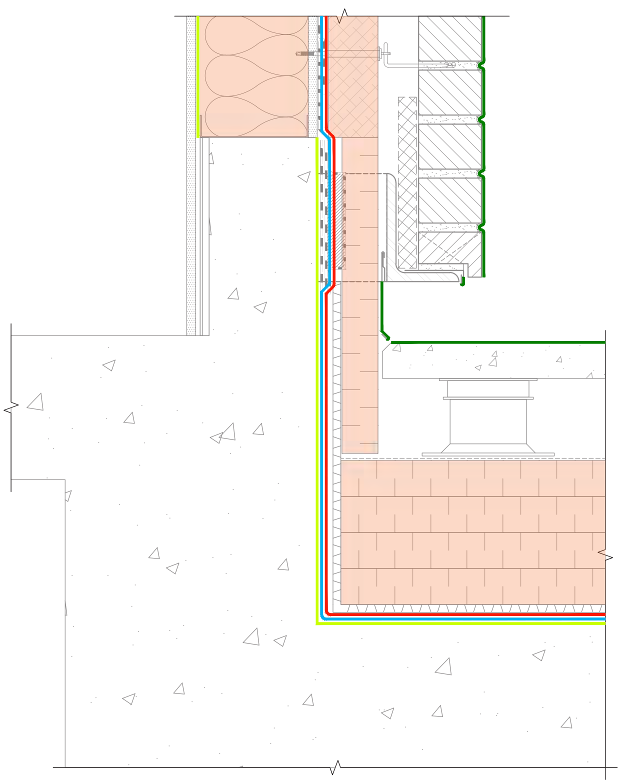
Thermal

Note: Control layers are shown for a Class IV permeance (and sometimes Class III permeance) air barrier and WRB field membrane and where a vapor retarder is located at the interior face of the framing.

STEEL STUD-FRAMED BACKUP WALL: Roof-to-Wall Detail



Detail 6-12 Steel Stud-Framed Backup Wall: Roof-to-Wall Detail



Water-Shedding Surface and Control Layers of Detail 6-12

Legend

1. Typical Assembly:
   - Interior gypsum board
   - Vapor retarder
   - Steel stud-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
2. Inverted roof assembly
3. Masonry veneer anchor
4. Self-adhered sheet- or fluid-applied air barrier and WRB flashing membrane, lapped over roof membrane termination and roof penetration flashing membrane
5. Continuous rigid or semi-rigid exterior insulation over drainage composite
6. Mortar collection mesh
7. Interior furring for finish attachment
8. Vent/weep at maximum 24 inches on-center
9. Sheet-metal flashing with hemmed drip edge
10. Hot-dipped galvanized-steel standoff shelf angle support anchored on intermittent structural support
11. Roof penetration flashing membrane (per roof membrane manufacturer), extend onto structural support

A. See alternate shelf angle support detailing options on page 63

Detail Discussion

The standoff shelf angle support at this transition allows for continuous thermal insulation across the roof and wall assemblies.

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. 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. The roof membrane manufacturer can provide recommended prestrip detailing.

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

Water

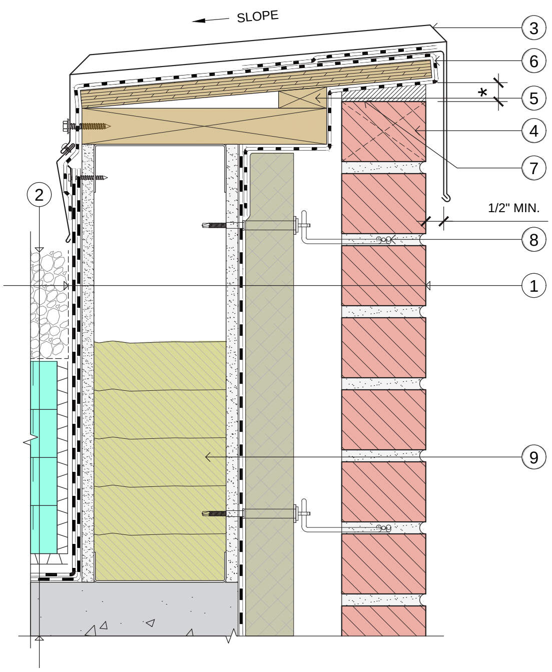
Air

Vapor

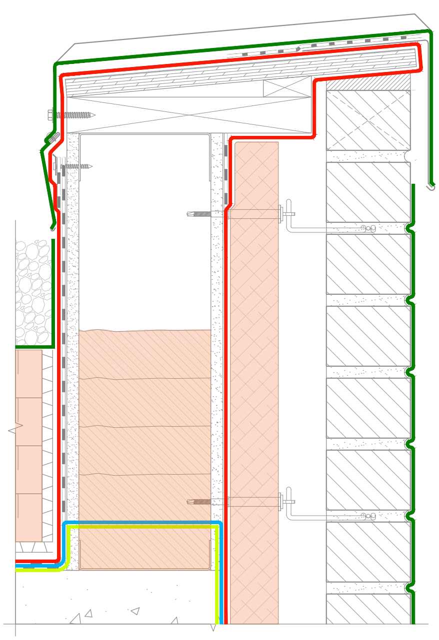
Thermal

Note: Control layers are shown for a Class IV permeance (and sometimes Class III permeance) air barrier and WRB field membrane and where a vapor retarder is located at the interior face of the framing.

STEEL STUD-FRAMED BACKUP WALL: Roof Parapet Detail



Detail 6-13 Steel Stud-Framed Backup Wall: Roof Parapet Detail



Water-Shedding Surface and Control Layers of Detail 6-13

Legend

1. Parapet Assembly:
   - Roof membrane
   - Exterior sheathing
   - Vented steel stud-framed wall
   - Exterior sheathing
   - Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
   - Air cavity
   - Anchored masonry veneer
2. Inverted roof membrane assembly
3. Standing-seam sheet-metal coping with gasketed washer fasteners
4. Vent at maximum 24 inches on-center (optional)
5. Preservative-treated wood blocking
6. High-temperature self-adhered membrane
7. Compressible filler
8. Masonry veneer anchor
9. Closed-cell spray foam insulation

*Minimum 3/8-inch to allow for movement. Confirm dimension with Engineer of Record.

Detail Discussion

The vents shown in the top course of the anchored masonry veneer are optional and may be used to increase ventilation of air behind the brick cavity. As shown in this detail, the sheet-metal coping is held away from the face of the masonry so as not to block the vent.

A compressible filler is used between the masonry veneer and parapet blocking to allow for a separation between the blocking and anchor masonry veneer while preventing insects and debris from entering the cavity behind the masonry veneer.

Parapet cavity insulation provides continuity of the thermal control layer at the roof-to-wall transition.

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

Water

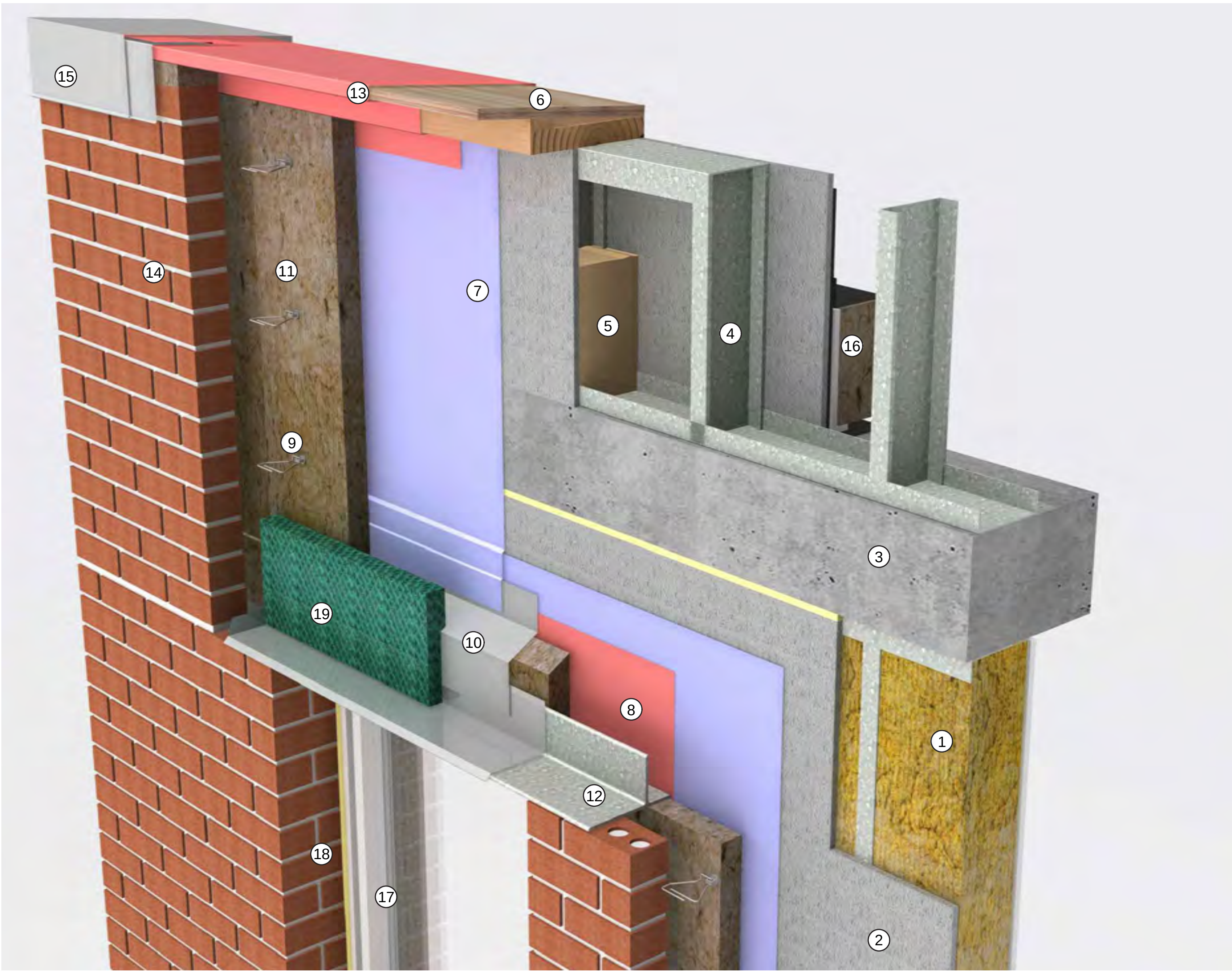
Air

Vapor

Thermal

Note: Control layers are shown for a Class IV permeance (and sometimes Class III permeance) air barrier and WRB field membrane and where a vapor retarder is located at the interior face of the framing.

STEEL STUD-FRAMED BACKUP WALL: Parapet 3D Detail



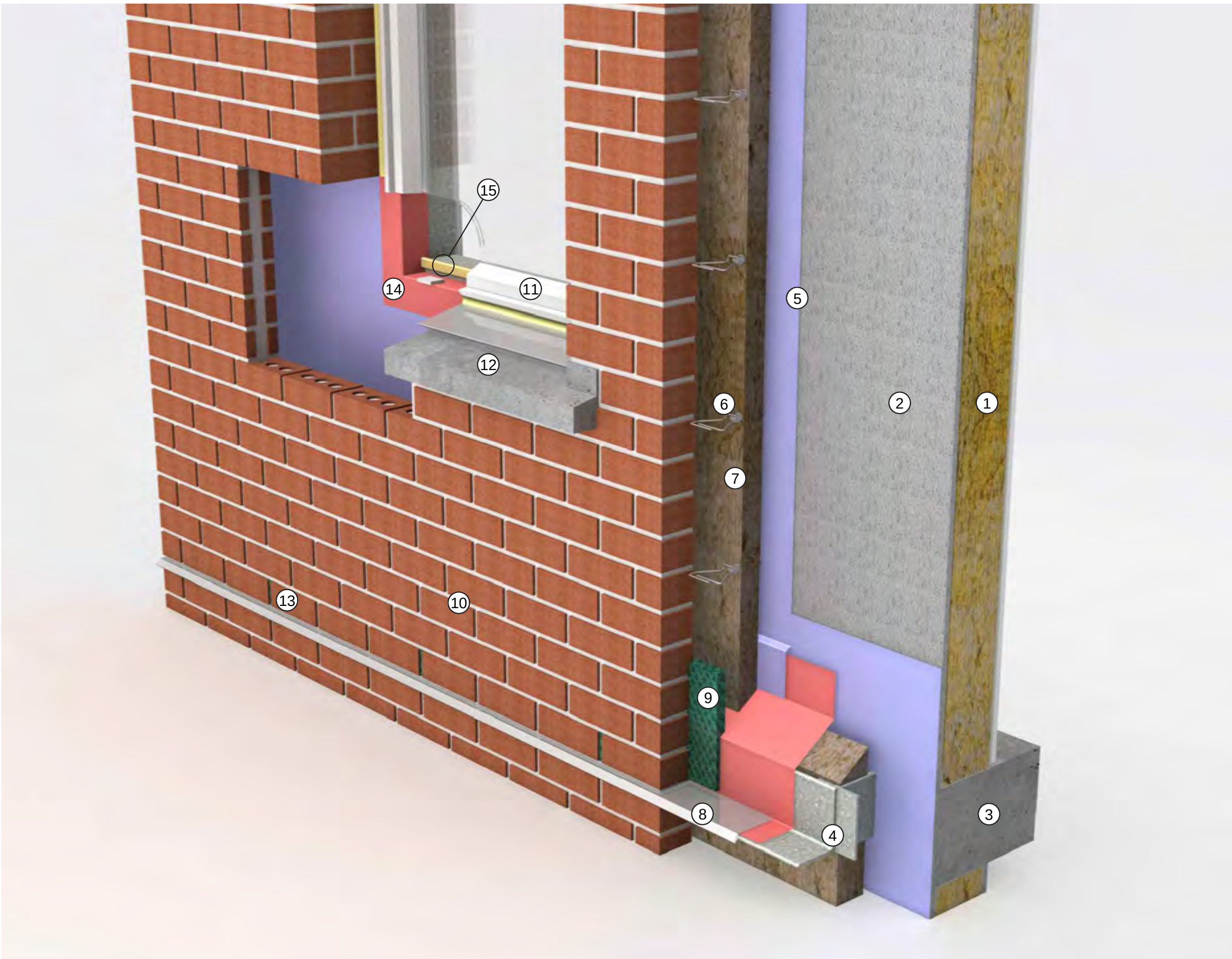
Detail 6-14 Steel Stud-Framed Backup Wall: Parapet 3D Detail

Legend

1. Steel stud-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 flashing membranes
9. Masonry veneer anchor, 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. Anchored masonry veneer
19. Mortar collection mesh

Refer to Detail 6-8, Detail 6-10, and Detail 6-13 for more information.

STEEL STUD-FRAMED BACKUP WALL: Base-of-Wall 3D Detail



Detail 6-15 Steel Stud-Framed Backup Wall: Base-of-Wall 3D Detail

Legend

1. Steel stud-framed wall with batt insulation
2. Exterior sheathing
3. Concrete floor slab
4. Hot-dipped galvanized-steel standoff shelf angle support anchored on intermittent structural support
5. Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
6. Masonry veneer anchor, 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. Mortar collection mesh
10. Anchored masonry veneer
11. Non-flanged window
12. Sloped precast concrete sill with sloped sheet-metal sill flashing
13. Vent/weep at maximum 24-inches on-center
14. Self-adhered sheet- or fluid-applied air barrier and WRB flashing membrane
15. Continuous air barrier sealant tied to continuous seal at window perimeter

Refer to Detail 6-9, Detail 6-10, and Detail 6-11 for more information.

STEEL STUD-FRAMED BACKUP WALL: Saddle Flashing 3D Detail

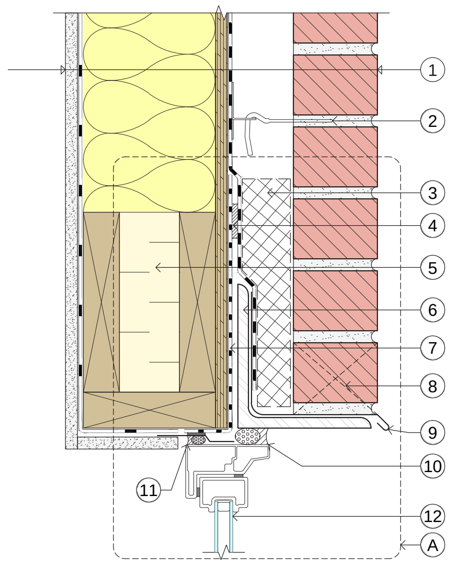
Detail 6-16 Steel Stud-Framed Backup Wall: Saddle Flashing 3D Detail

Legend

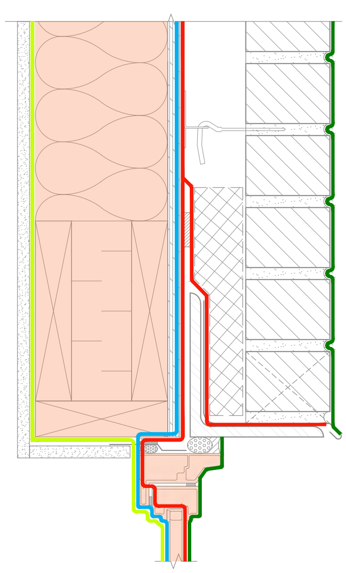
1. Inverted roof membrane assembly over concrete roof structure
2. Inverted roof membrane
3. Self-adhered or fluid-applied flashing membrane, lap over roof membrane termination, roof penetration flashing membrane, and parapet saddle flashing membrane
4. Self-adhered sheet- or fluid-applied air barrier and WRB field membrane
5. Parapet saddle flashing membrane, extend onto sloped parapet blocking beyond anchored masonry veneer wall face (above)
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 roof penetration flashing membrane (per roof membrane manufacturer)
9. 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

Refer to Detail 6-12 and Detail 6-13 for more information.

WOOD-FRAMED BACKUP WALL: Window Head Detail



Detail 6-17 Wood-Framed Backup Wall: Window Head Detail



Water-Shedding Surface and Control Layers of Detail 6-17

Legend

1. Typical Assembly:
   - Interior gypsum board
   - Vapor retarder
   - Wood-framed wall with batt insulation
   - Exterior sheathing
   - Mechanically attached air barrier and WRB field membrane
   - Air cavity
   - Anchored masonry veneer
2. Masonry veneer anchor
3. Mortar collection mesh
4. Continuous air barrier sealant
5. Insulated window header
6. Hot-dipped galvanized-steel loose lintel
7. Self-adhered sheet- or fluid-applied air barrier and WRB flashing membrane
8. Vent/weep at maximum 24 inches on-center
9. Sheet-metal head flashing with hemmed drip edge and end dams (beyond)
10. Sealant over backer rod
11. Continuous air barrier sealant tied to continuous seal at window perimeter
12. Non-flanged window

A. See alternate shelf angle support detailing options on page 63

Detail Discussion

A loose lintel is depicted in this detail; however, the structure support for the anchored masonry above the window could also be a shelf angle support attached back to the wood-framed structure. In this case, the shelf angle would be detailed similar to Detail 6-20.

A continuous bead of air barrier sealant exists between the rough opening flashing and the mechanically attached air barrier and WRB field membrane to maintain air control layer continuity.

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

Water

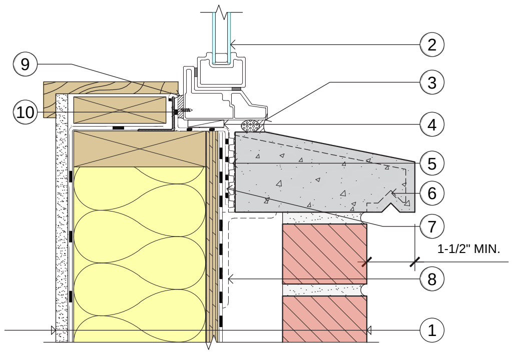
Air

Vapor

Thermal

Note: Control layers are shown for a Class IV permeance (and sometimes Class III permeance) air barrier and WRB field membrane and where a vapor retarder is located at the interior face of the framing.

WOOD-FRAMED BACKUP WALL: Window Sill Detail



Detail 6-18 Wood-Framed Backup Wall: Window Sill Detail

Legend

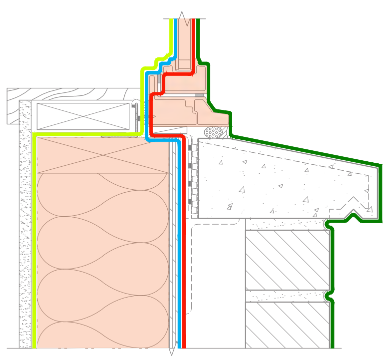
1. Typical Assembly:
   - Interior gypsum board
   - Vapor retarder
   - Wood-framed wall with batt insulation
   - Exterior sheathing
   - Mechanically attached air barrier and WRB field membrane
   - Air cavity
   - Anchored masonry veneer
2. Non-flanged window on minimum ¼-inch thick intermittent plastic shims
3. Sealant over backer rod
4. Minimum ⅛-inch thick intermittent shims behind sill flange for drainage
5. Drainage matrix behind precast sill for drainage
6. Sloped precast sill with chamfered drip edge and sealant over backer rod at precast joints
7. Self-adhered sheet- or fluid-applied air barrier and WRB flashing membrane
8. Intermittent structural support for precast sill (beyond), detail anchor through air barrier and WRB membrane per membrane manufacturer requirements
9. Continuous air barrier sealant tied to continuous seal at window perimeter
10. Back dam angle at sill, minimum 1 inch tall, fasten window through back dam angle

Detail Discussion

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 sill.

Air and water control layer continuity in this detail is achieved by sealing the window frame against the flashing membrane at the sill back dam. The flashing membrane is adhered to the field membrane.

Intermittent structural supports may be needed to support the sloped precast sill. Air and water control layer continuity should be considered at these supports; additional sealant and/or flashing membranes may be required.



Water-Shedding Surface and Control Layers of Detail 6-18

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

Water

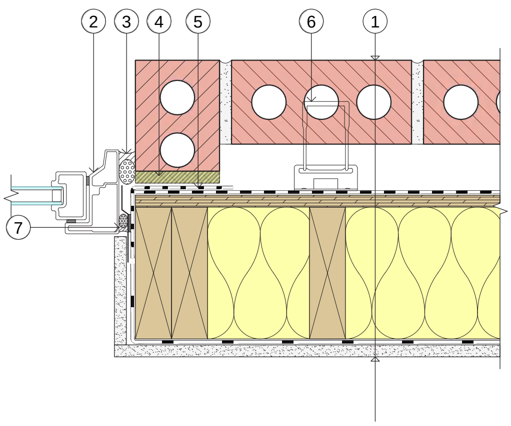
Air

Vapor

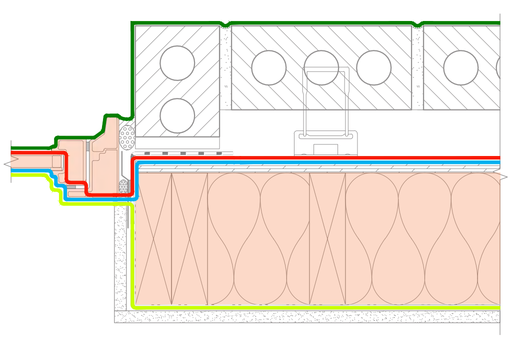
Thermal

Note: Control layers are shown for a Class IV permeance (and sometimes Class III permeance) air barrier and WRB field membrane and where a vapor retarder is located at the interior face of the framing.

WOOD-FRAMED BACKUP WALL: Window Jamb Detail



Detail 6-19 Wood-Framed Backup Wall: Window Jamb Detail



Water-Shedding Surface and Control Layers of Detail 6-19

Legend

1. Typical Assembly:
    - Interior gypsum board
    - Vapor retarder
    - Wood-framed wall with batt insulation
    - Exterior sheathing
    - Mechanically attached air barrier and WRB field membrane
    - Air cavity
    - Anchored masonry veneer
2. Non-flanged window
3. Sealant over backer rod
4. Minimum ½-inch drainage path, fill with free-draining compressible filler
5. Self-adhered sheet- or fluid-applied air barrier and WRB flashing membrane
6. Masonry veneer anchor
7. Continuous air barrier sealant tied to continuous seal at window perimeter

Detail Discussion

A drainage pathway is maintained between the brick return and the flashing membrane at the rough opening. This pathway may be filled with a free-draining material such as semi-rigid mineral fiber insulation or drainage matrix. Avoid packing this cavity with mortar, which can transfer moisture from the masonry veneer to the flashing membrane and possibly the sheathing beneath.

A non-flanged window is depicted in this set of details. Flanged windows may be used with masonry veneer but non-flanged window are often considered for the ease of future window removal and replacement.

Where exterior insulation is used with a wood-framed backup wall condition, refer to the steel stud-framed details for similar detailing.

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

Water

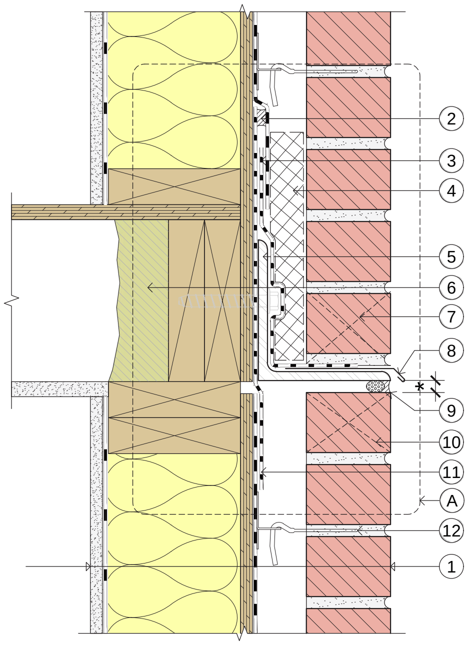
Air

Vapor

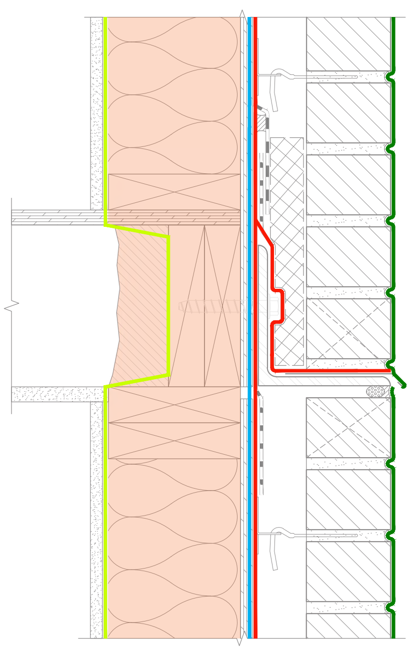
Thermal

Note: Control layers are shown for a Class IV permeance (and sometimes Class III permeance) air barrier and WRB field membrane and where a vapor retarder is located at the interior face of the framing.

WOOD-FRAMED BACKUP WALL: Floor Line Detail



Detail 6-20 Wood-Framed Backup Wall: Floor Line Detail



Water-Shedding Surface and Control Layers of Detail 6-20

Legend

1. Typical Assembly:
   - Interior gypsum board
   - Vapor retarder
   - Wood-framed wall with batt insulation
   - Exterior sheathing
   - Mechanically attached air barrier and WRB field membrane
   - Air cavity
   - Anchored masonry veneer
2. Continuous air barrier sealant
3. Self-adhered sheet- or fluid-applied air barrier and WRB flashing membrane
4. Mortar collection mesh
5. Hot-dipped galvanized-steel standoff shelf angle
6. Closed-cell spray foam insulation
7. Vent/weep at maximum 24 inches on-center
8. Sheet-metal flashing with hemmed drip edge
9. Sealant over backer rod
10. Vent/weep at maximum 24 inches on-center (optional)
11. Self-adhered sheet- or fluid-applied air barrier and WRB flashing membrane
12. Masonry veneer anchor

A. See alternate shelf angle support detailing options on page 63

*Minimum ⅜-inch to allow for movement. Confirm dimension with Engineer of Record.

Detail Discussion

See Shelf Angle Flashing Options on page 63 for alternative flashing that may be used at the window head condition.

A continuous bead of air barrier sealant exists between the flashing membrane and the mechanically attached air barrier and WRB field membrane to maintain air control layer continuity.

Water-Shedding Surface & Control Layers

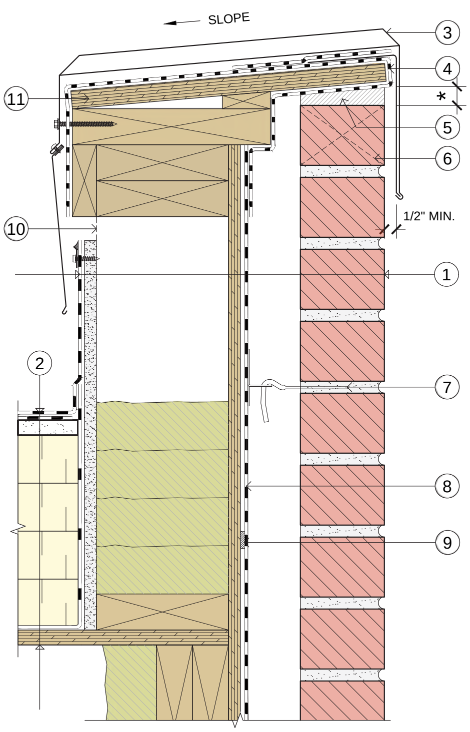
Water-Shedding Surface

Control Layers:

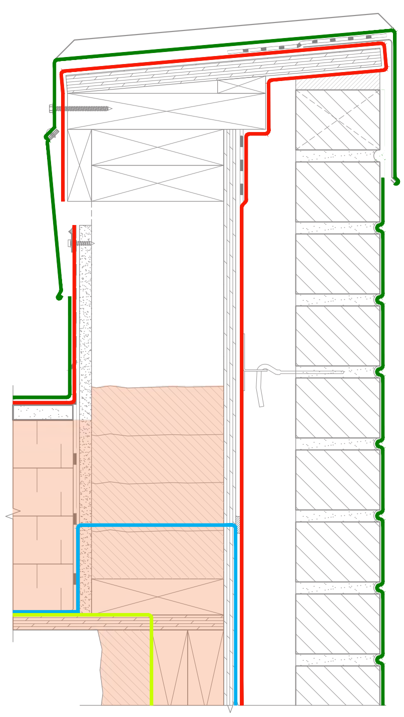
Water
Air
Vapor
Thermal

Note: Control layers are shown for a Class IV permeance (and sometimes Class III permeance) air barrier and WRB field membrane and where a vapor retarder is located at the interior face of the framing.

WOOD-FRAMED BACKUP WALL: Parapet Detail



Detail 6-21 Wood-Framed Backup Wall: Parapet Detail



Water-Shedding Surface and Control Layers of Detail 6-21

Legend

1. Parapet Assembly:
   - Roof membrane
   - Exterior sheathing
   - Vented wood-framed parapet
   - Exterior sheathing
   - Mechanically attached air barrier and WRB field membrane
   - Air cavity
   - Anchored masonry veneer
2. Conventional roof assembly
3. Standing-seam sheet-metal coping with gasketed washer fasteners
4. High-temperature self-adhered membrane
5. Compressible filler
6. Vents at maximum 24 inches on-center (optional)
7. Masonry veneer anchor
8. Closed-cell spray foam insulation
9. Continuous air-barrier sealant between sheathing and mechanically attached air barrier and WRB field membrane
10. Insect screen
11. Preservative-treated wood blocking

*Minimum ⅜-inch to allow for movement. Confirm dimension with Engineer of Record.

Detail Discussion

At the roof parapet transition, the closed-cell spray foam insulation and the continuous bead of air barrier sealant provide continuity of the air control layer. Additionally, the closed-cell spray foam assists with vapor control at this transition. An alternative to the use of closed-cell spray foam insulation within the parapet is to provide a prestrip membrane below the parapet framing to transition the air control layer from the wall to the roof assembly. This requires the exterior sheathing to be broken at the parapet and the membrane installation to be coordinated with framing.

A compressible filler is used between the masonry veneer and parapet blocking to allow for differential movement between the backup wall and masonry veneer while preventing insects and debris from entering the cavity behind the masonry veneer.

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

Water

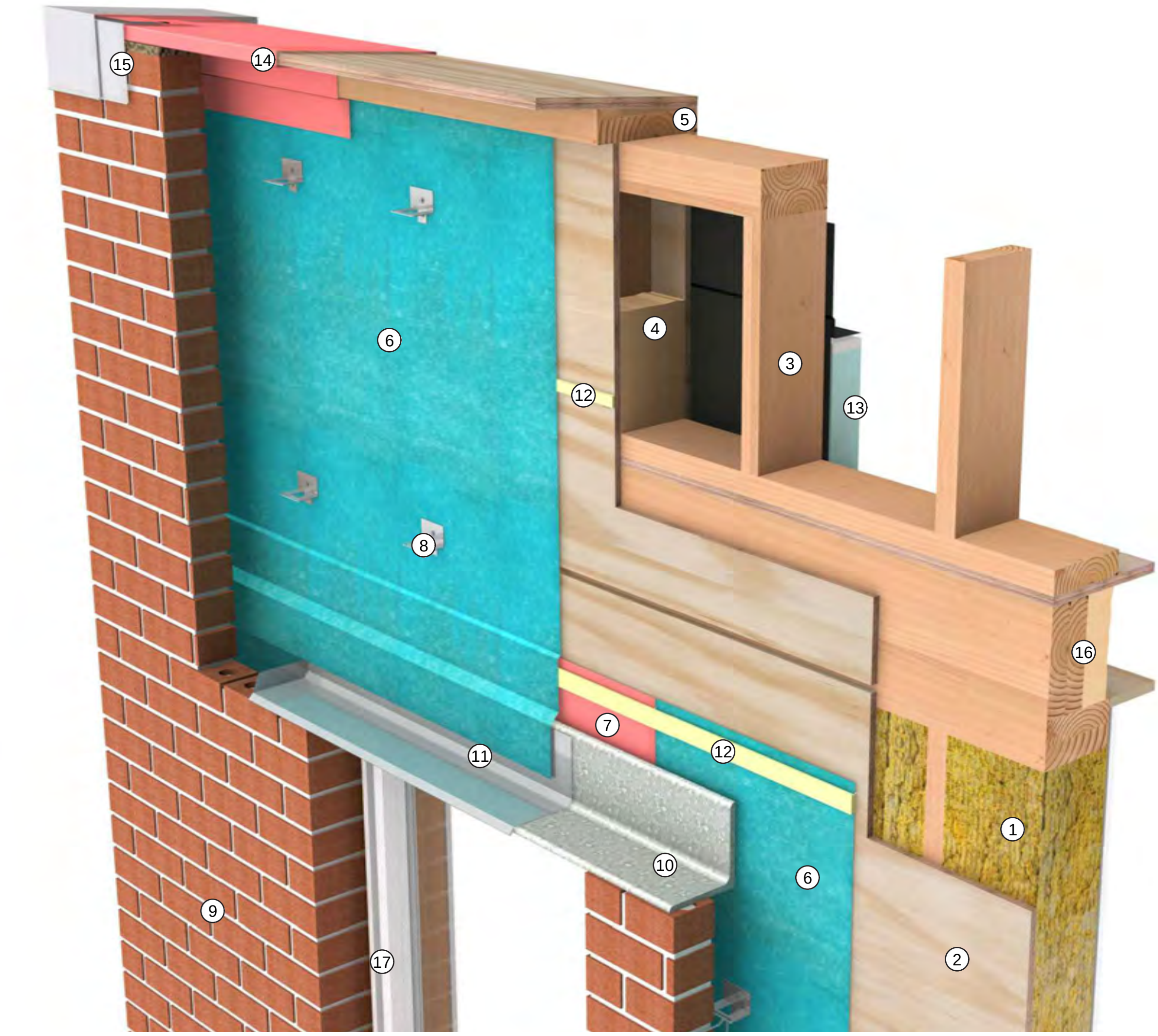
Air

Vapor

Thermal

Note: Control layers are shown for a Class IV permeance (and sometimes Class III permeance) air barrier and WRB field membrane and where a vapor retarder is located at the interior face of the framing.

WOOD-FRAMED BACKUP WALL: Parapet 3D Detail



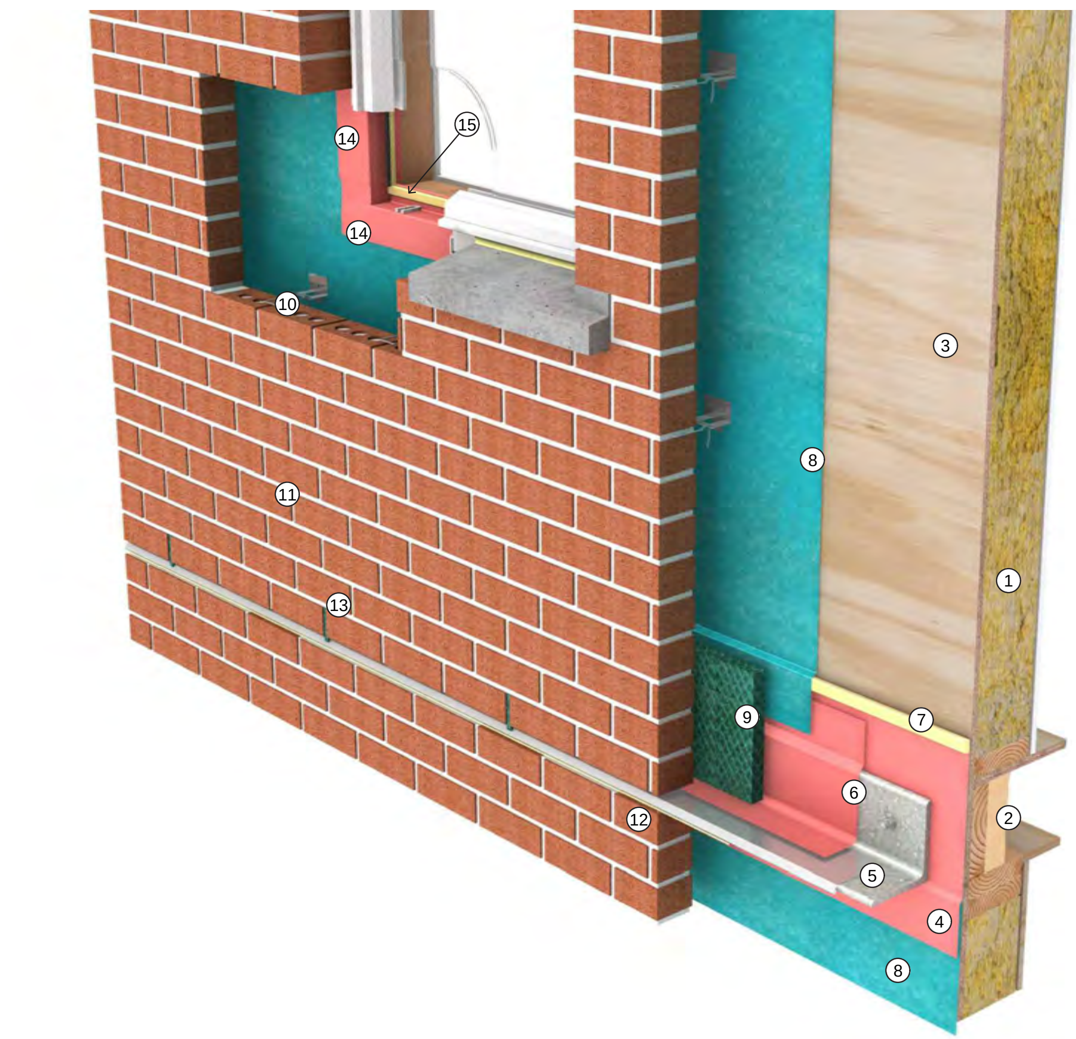
Detail 6-22 Wood-Framed Backup Wall: Parapet 3D Detail

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. Mechanically attached air barrier and WRB field membrane
7. Sheet-applied or fluid-applied air barrier and WRB flashing membrane
8. Masonry veneer anchor, 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
15. Sloped standing-seam sheet-metal coping with gasketed washer fasteners
16. Closed-cell spray foam insulation
17. Flanged window

Refer to Detail 6-17, Detail 6-19, and Detail 6-21 for more information.

WOOD-FRAMED BACKUP WALL: Base-of-Wall 3D Detail



Detail 6-23 Wood-Framed Backup Wall: Base-of-Wall 3D Detail

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 angle
6. Self-adhered or fluid-applied flashing membrane
7. Continuous air barrier sealant
8. Mechanically attached air barrier and WRB field membrane
9. Mortar collection mesh
10. Masonry veneer anchor, 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
13. Weep/vent at maximum 24-inches on-center
14. Self-adhered sheet- or fluid-applied air barrier and WRB flashing membrane
15. Continuous air barrier sealant tied to continuous seal at window perimeter

RDH

Making Buildings Better™

MAKING BUILDINGS BETTER

As industry leaders, we are called upon to consult on a variety of buildings across North America. Whether it's bringing new construction projects to life, providing existing building owners peace of mind, or testing innovative and sustainable building solutions, we are passionate about helping clients make informed decisions that lead to durable and high-performance buildings.

Vancouver . Seattle . Toronto . Portland . Victoria . Oakland . Waterloo . Courtenay . Boston

RMMI

ROCKY MOUNTAIN

MASONRY INSTITUTE

7

CHAPTER 7

Single-Wythe CMU Systems

Fig. 7-1 South Adams Fire District Station No. 4 in Commerce City, CO
(Mason Contractor: Ammex Masonry, General Contractor: Dohn Construction, Inc., Architect: Allred & Associates) Photo by Bryn MaRae Photography

The Chapter 7 wall systems consist of a single-wythe concrete masonry unit (CMU) wall structure, often composed of split-face block. While many wall system variations may apply to single-wythe CMU wall systems, this chapter focuses on an interior-insulated CMU wall system that has demonstrated successful building enclosure performance within Colorado and southern Wyoming. This masonry wall system with interior insulation is most appropriate for low- to mid-rise commercial applications but may be used for residential applications in addition to some high-rise structures, where carefully considered.

Building Enclosure Control Layers

As noted in Chapter 3, an above-grade wall system provides control of liquid water, air, heat, and water vapor to serve as an effective and durable environmental separator. Control of these elements, specific to these systems, 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
- 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 Chapter 3.

Table 7-1 illustrates the water-shedding surface and control layer locations for each system. The water-shedding surface and control layers are also shown on typical system details provided at the end of this chapter.

Water-Shedding Surface

The water-shedding surface reduces the water load on the enclosure.

The single-wythe CMU wall structure, including mortar joints, is the primary water-shedding surface of the wall system. Additional components include sheet-metal flashings and drip edges, sealant joints, and fenestration systems as shown on the details at the end of this chapter.

Water-repellent admixtures within the block and mortar and a surface-applied clear water repellent are recommended for single-wythe CMU wall systems. These repellents reduce moisture absorption and encourage water to shed off the face of the wall system. Additional measures encourage water shed, such as tooled "V" or concave shape (preferred) mortar joints and sufficient sheet-metal parapet cap design.

Joints around fenestrations and penetrations through the single-wythe CMU also serve as a water-shedding surface, thus they should be continuously sealed with a backer rod and sealant, except where drainage is necessary such as below a window rough opening.

Water Control Layer

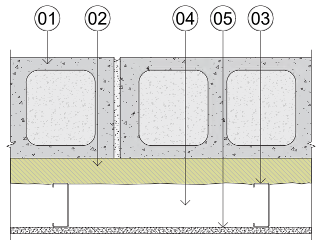
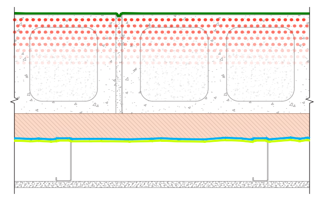
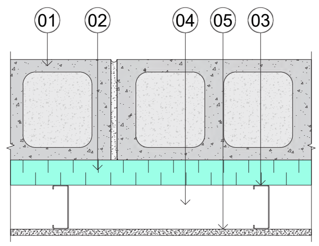
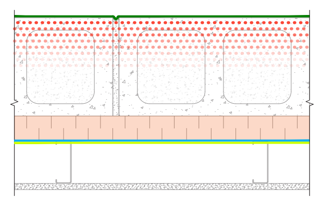
The water control layer is a continuous layer designed and installed to act as the innermost boundary for water intrusion. The water control layer needs to be continuous across the wall face to serve as an effective control layer. The CMU block, mortar, and grout—inclusive of any integral water repellents and surface-applied water repellents—provide the water control layer in these systems. Additional water control layer materials include flashing membranes at parapet tops.

Penetrations within the wall also require continuity of the water control layer, thus penetrations such as fenestrations (e.g., windows and doors) and service penetrations are part of the water control layer. At fenestration rough openings, a flashing membrane (typically a fluid-applied flashing membrane) provides the function of a water control layer; it protects rough openings against water intrusion and can also minimize air leakage. This membrane is depicted in the details at the end of this chapter.

Additional measures can also improve this wall system's water control:

- The installation of continuous closed-cell spray foam (CCSPF) insulation inboard of the CMU structure. This insulation provides additional thermal, air, and vapor control as discussed throughout this chapter.
- The installation of a fluid-applied WRB membrane on the inboard face of the CMU structure. This option is often used with interior continuous rigid board insulation products and can improve wall system airtightness.
- The installation of a vapor-permeable elastomeric coating on the exterior face of the CMU wall. This coating bridges hairline cracks and increases the water-shedding potential of the CMU. This option is most often used with smooth-face block and may be used with either of the insulation

Table 7-1 Single-wythe CMU wall assembly components and water-shedding surface and control layer summary

Insulation Option	Single-Wythe CMU Wall	Water Shedding-Surface and Control Layers
Closed-Cell Spray Foam Insulation		EXTERIOR  INTERIOR
Vapor-Impermeable Board Insulation*		EXTERIOR  INTERIOR
LEGEND	1. Single-wythe CMU wall with water-repellent admixture and surface-applied clear water repellent 2. Continuous insulation 3. Steel stud-framed wall 4. Air cavity w/services (optional) 5. Interior gypsum board * With fully tapered/sealed joints, terminations, and penetrations	Water-Shedding Surface Control Layers: Water Air Vapor Thermal

options listed in Table 7-1. Elastomeric coatings are further discussed in Chapter 4.

Air Control Layer

The air control layer comprises 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 because it impacts heat flow (space conditioning), water vapor transport, and rain penetration control. Refer to Chapter 3 for a discussion regarding the air control layer and properties of the air barrier system.

For the single-wythe wall system shown in Table 7-1, the air barrier system is either:

- The CCSPF interior of the CMU wall structure.
- XPS insulation when fully taped and/or sealed at all joints, terminations, and penetrations.
- The foil facer of board insulation products when the facer is fully taped and/or sealed at all joints, terminations, and penetrations.

Additional measures that can improve the wall systems air control include:

- A fluid-applied air barrier and WRB membrane where used on the interior face of the CMU wall structure.
- An elastomeric coating where used on the exterior face of the CMU wall structure.

These options assume the materials listed are installed at a thickness that provides a lesser air leakage rate than the allowable threshold discussed in Chapter 3.

To serve as an effective air barrier system, air control layer material(s) should be installed continuously across the wall face (behind all framing) and up to rough openings, penetrations, and roof and floor structures.

Although the fluid-applied air barrier and WRB membrane and elastomeric coating options listed function as the air control layer, additional sealing of board insulation products inboard of the wall system (where applicable) still require air sealing at joints, penetrations, and terminations. This air sealing minimizes the opportunity for warm, moisture-laden interior air to interface with the interior face of the CMU, where condensation or dampness could form in cooler seasons. Two planes of airtightness (one at the membrane/coating plane and one at the insulation face) may seem redundant; however, this redundancy may occur inherently if the membrane/coatings are also used to assist with water control purposes.

Trade activities including the installation of wall framing and services can sometimes damage the air control layer material, especially the foil facer of board insulation products; thus, this guide recommends additional quality control measures to ensure that any damage to joint, penetration, and termination sealing or damage to the insulation facer is repaired prior to closing up the wall.

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 increased risk of fire during installation. This guide recommends using only experienced applicators who are approved by the CCSPF product manufacturer.

Other considerations when using CCSPF insulation or other foam plastic insulation products include fire propagation with respect to code compliance. Make sure product selection, application, and use comply with local jurisdiction requirements. Volatile organic compounds may also need to be considered based on project material property requirements.

Vapor Control Layer

The vapor control layer retards or greatly reduces the flow of water vapor due to vapor pressure differences across enclosure systems. Unlike the other control layers presented in this guide, the vapor control layer is not always required to be continuous; the location of insulation and vapor permeance of the air barrier and WRB system can also impact the need for or necessary properties of the vapor control layer.

In this system the vapor control layer is:

- Continuous closed-cell spray foam insulation at the interior face of the CMU along with any additional CCSPF that may be installed within the framed wall cavity. The vapor control layer exists throughout the depth of the CCSPF; a minimum 2 lb/ft^3 density installed in a minimum of 2-inch lift is typically considered a Class II vapor retarder.

- The face of the XPS or facer of board insulation products.

Thermal Control Layer

The thermal control layer controls heat flow and assists with controlling water vapor. For single-wythe CMU wall systems, the thermal control layer is either closed-cell spray foam insulation or board insulation.

At transition details, the thermal control layer includes insulation at the roof assembly, under-slab, and foundation elements.

Fig. 7-2 Closed-cell spray foam insulation on the inboard side of a single-wythe CMU wall. The closed-cell spray foam insulation is installed continuously behind steel stud framing such that no gaps within the insulation are created.

Windows and doors that penetrate the above-grade wall are also part of the thermal control layer.

The thermal envelope should be as continuous as possible across all assemblies and transitions 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 lines, slab edges, and some wall-to-roof transitions.

The insulation products most commonly used with this wall system are shown in Table 7-1, and additional discussion for each type of insulation is provided in Fig. 8-3 of Chapter 8. For this wall system, closed-cell spray foam insulation is often preferred for the following reasons:

- To minimize the need to notch and fill gaps around penetrations, which is required with board insulation products.
- To provide a fully adhered insulation layer, which reduces the risk that warm, moisture-laden interior air may contact the cooler CMU wall surface and condense. This risk can also be minimized with board insulation products by ensuring that all joints, penetrations, and terminations of the board insulation are fully taped and sealed for airtight installation.
- To provide a supplemental water control layer function as discussed in previous sections of this chapter.

Vapor- and air-permeable insulation layers such as fiberglass and mineral fiber batt or unfaced semi-rigid mineral fiber insulation are typically avoided in this system. These products alone do not serve as air, water, and vapor control layers, and thus require additional materials or systems be installed to perform these control functions. When additional materials are implemented to serve as these control layers, the risk for condensation on the interior face of the CMU wall or any vapor-impermeable insulation layer should be carefully considered. Lack of a fully adhered membrane or insulation product at the interior or exterior face of this assembly may also reduce the water-resistivity of the assembly when compared to the CCSPF insulation strategy.

Alternative insulation products that are integral to the CMU block are also available, such as those shown in Fig. 7-3. These insulation options are often bridged by the web element of the CMU. Gaps may also exist between the insulation layers once installed. As a result, these options provide a lesser degree of thermal resistance than the continuous insulation options described in Table 7-1. Where these insulation options are used, additional air, water, and vapor control layers need to be considered.

a)

b)

Fig. 7-3 Alternative insulation products integral to the CMU block include, a) molded foam slotted inserts and b) injectable resinous foam. Images courtesy of Masonry Magazine and Concrete Products Group, respectively.

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 1403.5[1] regarding vertical and lateral flame propagation as it relates to a combustible air and 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[1] provisions.

Structural Considerations

The CMU block wall of these wall systems provides the primary structure. It is the responsibility of the Designer of Record to ensure that all structural elements of the wall system are designed to meet project-specific loads and local governing building codes. Generic placement of the grout and reinforced elements shown within the details of this chapter are provided for diagrammatic purposes only.

Corrosion Resistance

For sheet-metal flashings 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 A666[3] Type 304 or 316 stainless steel and are non-staining 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, consider using prefinished sheet metal. Where used, this guide recommends the base sheet metal is a minimum G90 hot-dipped galvanized coating in conformance with ASTM A653[4] or minimum AZ50 galvalume coating in conformance with ASTM A792.[5] This guide recommends coating the exposed top finish of the sheet metal with an architectural-grade coating conforming to AAMA 621.[6]

Accommodating Movement

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.

To increase or maintain the water-resistivity of the single-wythe wall systems, crack control needs to be considered. Appropriate design of the material properties and reinforcing methods of the CMU wall will reduce cracking; however, implementing control joints within the CMU wall provides a plane of weakness to reduce shrinkage stresses and improve the long-term continuity of the water shedding surface.

Control joints in CMU can be constructed in several ways. Regardless of the method used, a continuous backer rod and sealant joint is installed at the joint as shown in Fig. 7-4 to assist with water shedding and to maintain a continuous water control layer. Refer to Chapter 4 for more discussion on locating and spacing movement joints and sealant joint best practices.

Concrete Masonry Unit (CMU)

The CMU in this system complies with ASTM C90.[7] Mortar designed for the CMU conforms to ASTM C270[8] or to ASTM C1714[9] 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 476,[10] while aggregate within the grout should comply with ASTM C 404.[11]

Block and mortar are both specified with a water-repellent admixture as discussed in the Water Repellents section of Chapter 4. Additionally, refer to the National Concrete Masonry Association for additional resources on specifying block, mortar, and grout.[12]

The CMU and mortar joints of this system should be installed in conformance with industry-standard best practices and manufacturer requirements. 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.

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,[13] while mortar admixture should comply with ASTM C1384.[14] Both the CMU and mortar admixtures, as well as any surface-applied water repellent, should be compatible.

Fig. 7-4 Typical CMU wall system expansion joint location

More discussion on surface-applied clear water repellents is provided in Chapter 4.

Quality Assurance and Control

High quality masonry wall system installations are the result of quality control and quality assurance measures that occur throughout the design and construction phases. The general design guidance provided throughout this guide provides the information necessary for understanding and designing the masonry wall system. More specifically, Chapter 5 provides a more in-depth discussion on the topic of quality assurance and quality control.

Chapter References

1. International Code Council. *2018 International Building Code* (Country Club Hills, IL: International Code Council, Inc., 2017).

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. 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).

4. 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).

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

6. 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).

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

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

9. ASTM International. *ASTM C1714/C1714M-16 Standard Specification for Preblended Dry Mortar Mix for Unit Masonry* (West Conshohocken, PA: ASTM International, 2016).

10. ASTM International. *ASTM C476-16 Standard Specification for Grout for Masonry* (West Conshohocken, PA: ASTM International, 2016).

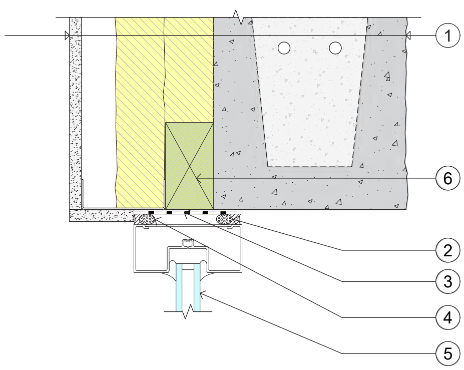
11. ASTM International. *ASTM C404-11 Standard Specification for Aggregates for Masonry Grout* (West Conshohocken, PA: ASTM International, 2011).

12. National Contract Management Association. "NCMA Home." *National Contract Management Association.* Accessed March 27, 2018. https://www.ncmahq.org/.

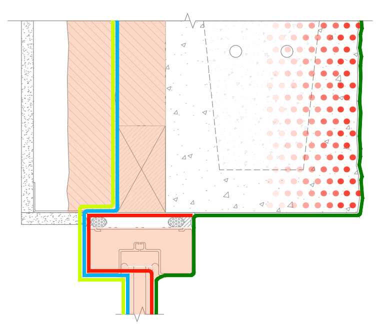
13. National Concrete Masonry Association. *TEK 19-7 Characteristics of Concrete Masonry Units with Integral Water Repellent* (Herndon, VA: National Concrete Masonry Association, 2008).

14. ASTM International. *ASTM C1384 Standard Specification for Admixtures for Masonry Mortars* (West Conshohocken, PA: ASTM International, 2012).

SINGLE-WYTHE CMU WALL: Window Head Detail



Detail 7-1 Single-Wythe CMU Wall: Window Head Detail



Water-Shedding Surface and Control Layers of Detail 7-1

Legend

1. Typical Assembly:
   - Interior gypsum board
   - Steel stud-framed wall
   - Closed-cell spray foam (CCSPF) insulation between studs (optional) and min. 2 inches continuous CCSPF
   - Single-wythe CMU wall with water-repellent admixture at block and mortar
   - Clear water-repellent
2. Sealant over backer rod
3. Fluid-applied air barrier and WRB flashing membrane
4. Continuous air barrier sealant tied to continuous seal at window perimeter
5. Storefront window
6. Preservative treated wood blocking

Detail Discussion

The flashing membrane extends from the interior framing to the CMU rough opening. The flashing membrane and the continuous air barrier sealant joint provide air and water control layer continuity from the window to the CMU wall.

Blocking at the window perimeter provides a low-conductivity solution for mechanically attaching the window as required by the window manufacturer.

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

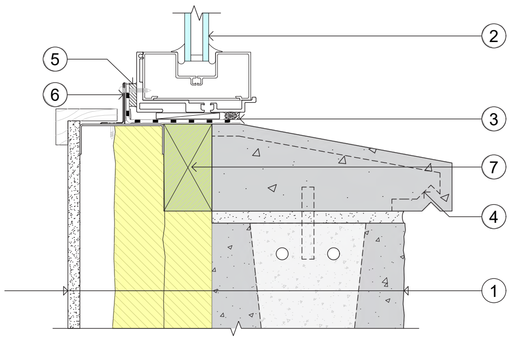
Water

Air

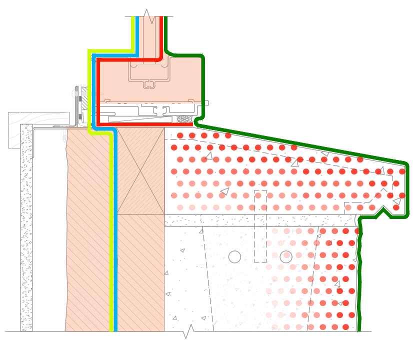
Vapor

Thermal

SINGLE-WYTHE CMU WALL: Window Sill Detail



Detail 7-2 Single-Wythe CMU Wall: Window Sill Detail



Water-Shedding Surface and Control Layers of Detail 7-2

Legend

1. Typical Assembly:
   - Interior gypsum board
   - Steel stud-framed wall
   - Closed-cell spray foam (CCSPF) insulation between studs (optional) and min. 2 inches continuous CCSPF
   - Single-wythe CMU wall with water-repellent admixture at block and mortar
   - Clear water-repellent
2. Storefront window on minimum ¼-inch thick intermittent shims
3. Sealant joint over backer rod (weep at quarter points)
4. Sloped precast sill with chamfered drip edge, with sealant over backer rod at precast joints
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
7. Preservative treated wood blocking

Detail Discussion

The slope at the precast sill encourages water to drain away from the window rough opening. A chamfer is shown in the underside of the precast sill to form a drip. This encourages water to shed from the sill before reaching the masonry veneer below.

Attachment of the window is shown through a structural back dam angle in lieu of down through the sill membrane. This minimizes the risk for water intrusion into the wall cavity below should water exist within the window rough opening. Intermittent shims below the window encourage drainage of the rough opening. Water that may exist within the rough opening can exit through weeps in the exterior sealant joint.

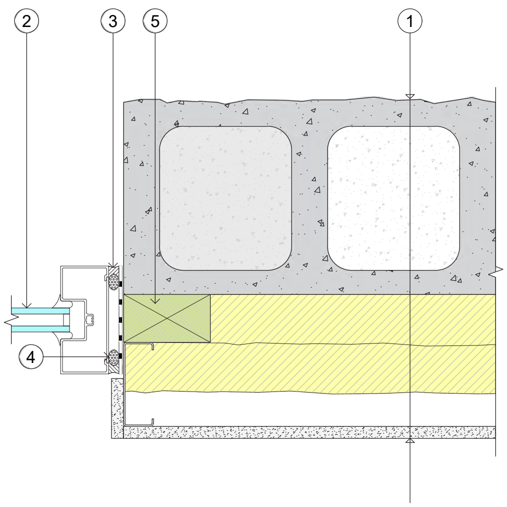
Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

- Water
- Air
- Vapor
- Thermal

SINGLE-WYTHE CMU WALL: Window Jamb Detail



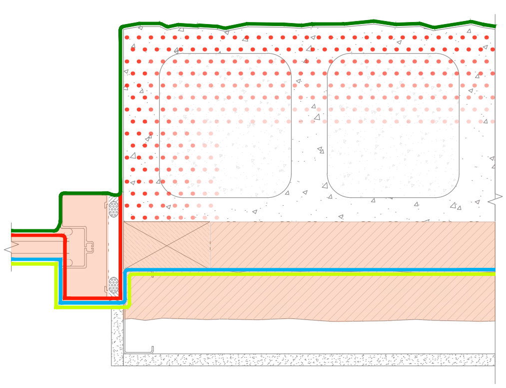
Detail 7-3 Single-Wythe CMU Wall: Window Jamb Detail

Legend

1. Typical Assembly:
   - Interior gypsum board
   - Steel stud-framed wall
   - Closed-cell spray foam (CCSPF) insulation between studs (optional) and min. 2 inches continuous CCSPF
   - Single-wythe CMU wall with water-repellent admixture at block and mortar
   - Clear water-repellent
2. Storefront window
3. Sealant joint over backer rod
4. Continuous air barrier sealant tied to continuous seal at window perimeter
5. Preservative treated wood blocking

Detail Discussion

The window is aligned with the rough opening blocking and insulation, rather than with the CMU wall, to provide better continuity of the thermal control layer. The continuous air barrier sealant joint, along with the flashing membrane, provide continuity of the air and water control layer.



Water-Shedding Surface and Control Layers of Detail 7-3

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

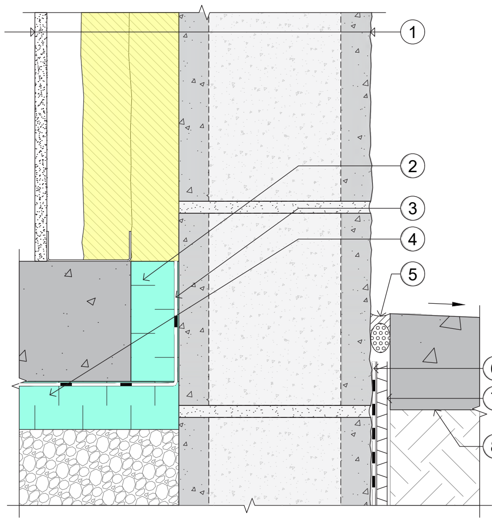
Water

Air

Vapor

Thermal

SINGLE-WYTHE CMU WALL: Base-of-Wall Detail



Detail 7-4 Single-Wythe CMU Wall: Base-of-Wall Detail

Water-Shedding Surface and Control Layers of Detail 7-4

Legend

1. Typical Assembly:
   - Interior gypsum board
   - Steel stud-framed wall
   - Closed-cell spray foam (CCSPF) insulation between studs (optional) and min. 2 inches continuous CCSPF
   - Single-wythe CMU wall with water-repellent admixture at block and mortar
   - Clear water-repellent
2. Rigid XPS insulation
3. Underslab vapor barrier
4. Rigid XPS underslab insulation
5. Hardscape sealant joint
6. Damp-proofing (optional)
7. Drainage composite or gravel backfill
8. Hardscape

Detail Discussion

The XPS insulation provides a thermal break between the concrete floor slab and the single-wythe CMU wall. This allows for thermal continuity between the underslab insulation and wall insulation.

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

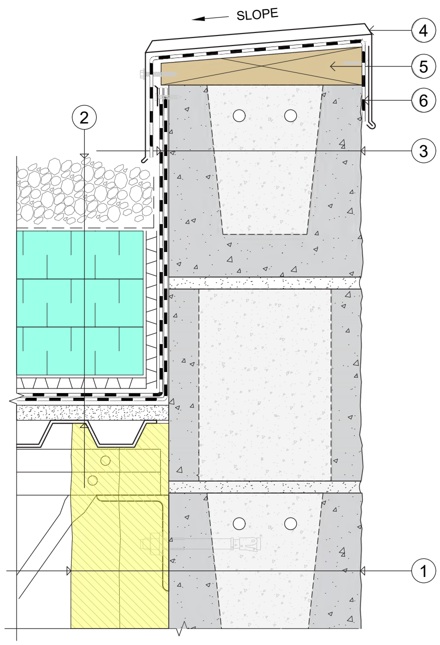
Water

Air

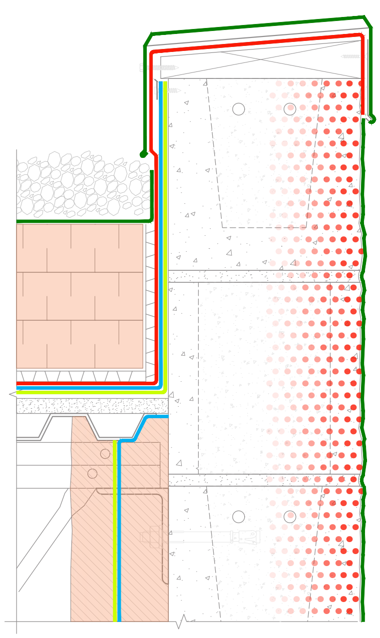
Vapor

Thermal

SINGLE-WYTHE CMU WALL: Roof Parapet Detail



Detail 7-5 Single-Wythe CMU Wall: Roof Parapet Detail



Water-Shedding Surface and Control Layers of Detail 7-5

Legend

1. Typical Assembly:
   - Interior gypsum board
   - Steel-framed wall
   - Closed-cell spray foam (CCSPF) insulation between studs, min. 2 inches continuous CCSPF
   - Single-wythe CMU wall with water-repellent admixture at block and mortar
   - Clear water-repellent
2. Inverted roof membrane assembly
3. Typical Parapet Assembly:
   - Inverted roof membrane
   - Single-wythe CMU wall with water-repellent admixture at block and mortar
   - Clear water repellent
4. Standing-seam sheet-metal coping with gasketed washer fasteners
5. Preservative-treated wood blocking
6. High-temperature self-adhered membrane

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 coping counterflash the top course of block by a minimum of 3 inches.

The CCSPF extends tight up to the underside of the deck and 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.

Water-Shedding Surface & Control Layers

Water-Shedding Surface

Control Layers:

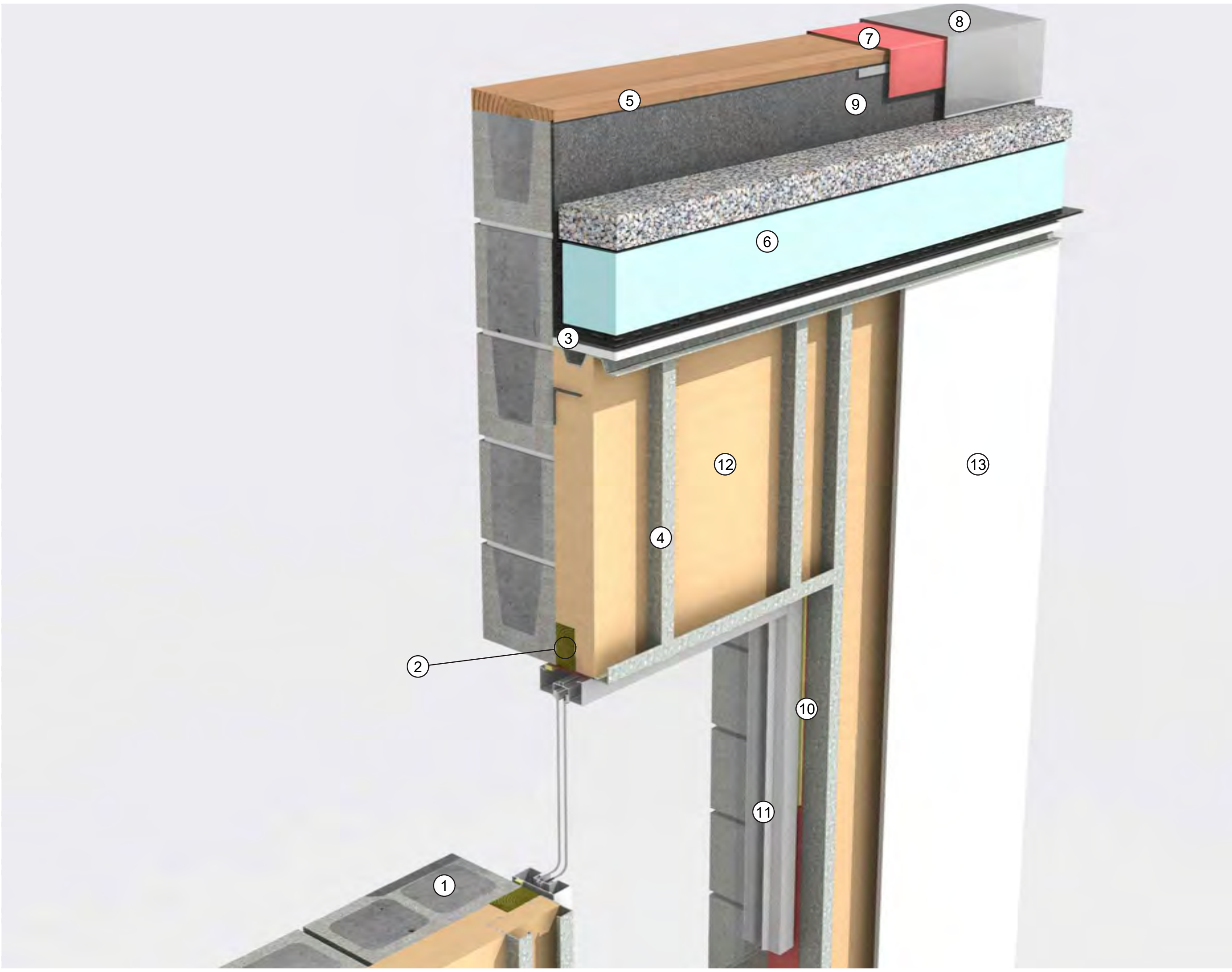
Water

Air

Vapor

Thermal

SINGLE-WYTHE CMU WALL: Roof Parapet 3D Detail

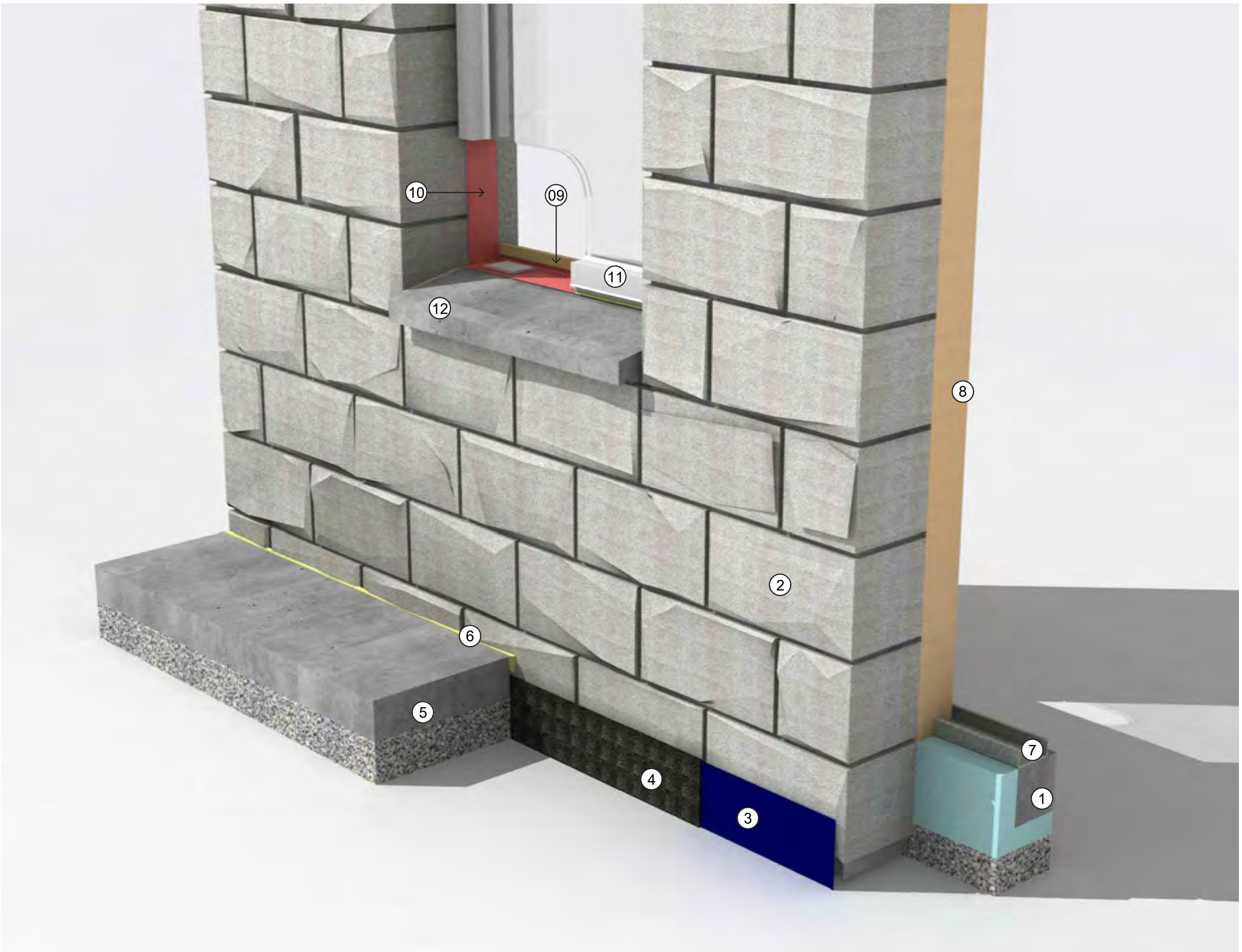


Detail 7-6 Single-Wythe CMU Wall: Roof Parapet 3D Detail

Legend

1. Single-wythe CMU wall with water-repellent admixture
2. Preservative-treated wood blocking
3. Roof structure
4. Steel stud-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. Roof membrane termination
10. Continuous air barrier sealant, tied to continuous seal at window perimeter.
11. Storefront window
12. Closed-cell spray foam (CCSPF) insulation between studs
13. Interior gypsum board

SINGLE-WYTHE CMU WALL: Base-of-Wall 3D Detail



Detail 7-7 Single-Wythe CMU Wall: Base-of-Wall 3D Detail

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 stud-framed wall
8. Closed-cell spray foam (CCSPF) insulation between studs
9. Continuous air barrier sealant tied to continuous seal at window perimeter
10. Fluid-applied flashing membrane
11. Storefront window
12. Sloped precast concrete sill

BASALITE®
Concrete Products

Basalite-your resource for architectural masonry

www.basalite.com

800-289-2562

Denver | Colorado Springs | Cheyenne

RMMI

ROCKY MOUNTAIN
MASONRY INSTITUTE

8

CHAPTER 8

Thermal Performance & Energy Code Compliance

Fig. 8-1 Thermal image of a multi-story residential building with anchored masonry veneer.

Air and thermal control layers manage heat flow across the building enclosure, influencing the amount of energy and fuel required to heat and cool a building and affecting occupant thermal comfort and condensation risk. Chapter 3 discusses the basic function of the air and thermal control layers.

In Colorado and southern Wyoming, air control layer performance requirements and the thermal performance of opaque above-grade wall assemblies (e.g., masonry wall systems) is governed by locally adopted energy codes. Thus, this chapter discusses basic the air and thermal control layer in the context of energy code compliance requirements for whole-building air leakage and thermal performance, specifically conductive heat flow, of masonry wall systems. At the end of this chapter are design tables that may be used to estimate the thermal performance of typical masonry systems and their components.

Governing Energy Codes

In Colorado and southern Wyoming, building codes are adopted and enforced at the local level. While there is no statewide energy code, legislation passed in Colorado in 2007[1] set the 2003 International Energy Conservation Code (IECC)[2] as the minimum-required energy code for all jurisdictions in the state that have adopted building codes. In jurisdictions where no building codes have been adopted, the state requires that hotels, motels, and multifamily buildings[3] conform to the 2015 IECC.[4] In addition, factory-built structures[5] are required to conform to the minimum requirements of the 2009 IECC[6] where the locally adopted code is less stringent than the 2012 IECC.[7] Public buildings are required to conform to the 2015 IECC[4] statewide.

Most larger jurisdictions within Colorado have adopted the 2009,[6] 2012,[7] or 2015 IECC,[4] and several of these jurisdictions have enacted local amendments to the governing version of the IECC. This guide addresses some of these amendments; however, the Designer of Record is responsible to refer to code amendments of the authority having jurisdiction on a project-specific basis. Additionally, this guide references general 2018 IECC requirements, which have not yet been enacted by any jurisdiction at the time of publication.

Table 8-1 summarizes the governing energy codes for various jurisdictions within Colorado and southern Wyoming at the time of publication. Refer to the Colorado Department of Local Affairs website for the current IECC adoptions by county.[9] In general, these energy codes address the *minimum* requirements for both the air and thermal control layers of the opaque above-grade wall systems.

Table 8-1 Summary of governing energy codes for jurisdictions in Colorado and southern Wyoming

Jurisdiction	Governing Energy Code
City and County of Denver	2016 Denver Building and Fire Code based on the 2015 IECC with amendments[10]
City of Fort Collins	2015 IECC with amendments[11]
County of Boulder	2015 Boulder County Building Code Amendments based on the 2015 IECC with amendments[12]
City of Boulder	2017 City of Boulder Energy Conservation Code (COBECC), based on 2012 IECC with amendments[13]
County of Arapahoe	Energy Conservation Code of Arapahoe based on 2009 IECC with amendments[14]
City of Arvada	Code of the City of Arvada, Colorado based on 2015 IECC with amendments[15]
City of Aurora	City Code of Aurora, Colorado based on 2015 IECC with amendments[16]
County of Jefferson	The 2015 Jefferson County Building Code Supplement based on 2015 IECC without amendments[17]
City of Lakewood	Lakewood Building Code based on 2015 IECC with amendments[18]
County of Larimer	County of Larimer, Colorado Amendments to the 2015 IECC with amendments[19]
City of Cheyenne	2009 IECC[6]
City of Laramie	2012 IECC[7]

Air Control

It is a building enclosure best practice and energy code requirement to provide an air control layer. The previous chapters in this guide discuss the air control layer (see Control Layer Summary on page 21) and specific air barrier systems (see Table 6-2) commonly used with masonry wall systems. As demonstrated in Fig. 3-8 on page 19, the air control layer has relationships with all of the building enclosure loads listed, including heat flow, making it a critical component of the building enclosure. Unintentional air flow across the enclosure can be defined as *air leakage* and is specifically addressed by the governing energy codes in the state of Colorado and southern Wyoming. Maximum air leakage targets are typically prescribed in local energy codes as maximum allowable flow rates at a specified pressure differential across the building enclosure.

Code Air Leakage Requirements

The governing energy codes within the state of Colorado and southern Wyoming require a continuous air barrier system throughout the building's thermal envelope that is continuously sealed and supported by the structure (e.g., fastened or adhered). The 2015 IECC 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

Table 8-2 Summary of IECC Air Leakage Requirements for Above-Grade Walls

<table>
<tr><th>Energy Code</th><th>Seals required at openings, penetrations, and joints?</th><th>Maximum air leakage rate requirement for fenestration assemblies?</th><th>Maximum air permeability requirement for materials?</th><th>Maximum air leakage requirement for assemblies?</th><th>Maximum whole-building air leakage requirement?*</th></tr>
<tr><td>2003/2009 IECC[2, 6]</td><td>Yes</td><td>Yes</td><td>No</td><td>No</td><td>No</td></tr>
<tr><td>2012 IECC[7]</td><td>Yes</td><td>Yes</td><td colspan="3">A continuous air barrier must comply with one of the following options:
1. The air permeability of materials shall not exceed 0.004 cfm/ft^2 under a pressure differential of 0.3 inch water gauge when tested in accordance with ASTM E 2178.[25]
2. The average air leakage of assemblies of materials and components shall not exceed 0.04 cfm/ft^2 under a pressure differential of 0.3 inch water gauge when tested in accordance with ASTM E 2357,[26] ASTM E 1677,[27] or ASTM E 283.[28]
3. The air leakage rate of the completed building shall not exceed 0.4 cfm/ft^2 under a pressure differential of 0.3 inch water gauge when tested in compliance with ASTM E 779[20] (or an equivalent method approved by the code official).</td></tr>
<tr><td>2015/2018 IECC[4, 8]</td><td>Yes, if not pursuing the whole-building air leakage test compliance option.</td><td>Yes, if not pursuing the whole-building air leakage test compliance option.</td><td colspan="2">The air barrier must comply with one of the following options if not pursuing the whole-building air leakage test compliance option:
1. The air permeability of materials shall not exceed 0.004 cfm/ft^2 under a pressure differential of 0.3 inch water gauge when tested in accordance with ASTM E 2178.[25]
2. The average air leakage of assemblies of materials and components shall not exceed 0.04 cfm/ft^2 under a pressure differential of 0.3 inch water gauge when tested in accordance with ASTM E 2357,[26] ASTM E 1677,[27] or ASTM E 283.[28]</td><td>Compliance may be demonstrated by performing a whole-building air leakage test in compliance with ASTM E 779[20] (or an equivalent method approved by the code official) with a final result that does not exceed 0.40 cfm/ft^2 at 0.3 inch water gauge in lieu of the prescriptive requirements for seals, materials, and assemblies.*</td></tr>
</table>

*Local amendments in the cities of Fort Collins and Boulder include mandatory whole-building air leakage testing.

spaces."[4] Note that the thermal envelope may not always occur at the building enclosure.

Prescriptive air leakage requirements vary by the governing version of the IECC as well as local code amendments. IECC air leakage requirements for above-grade wall assemblies are summarized in Table 8-2. This table is not inclusive of all IECC air leakage provisions or local amendments. This guide recommends that all members of the design and construction team be familiar with the specific air leakage requirements of the governing jurisdiction as well as project-specific performance targets.

Both the 2012 and 2015 IECC provide a whole-building air leakage testing compliance option as an alternative to certain prescriptive requirements for the air permeance of materials and/or air leakage of assemblies as well as specific installation requirements. If pursuing this compliance option, the rate of air leakage for the whole-building may not exceed 0.40 cfm/ft^2 under a pressure differential of 0.3-inch water gauge when tested in compliance with ASTM E 779[20] or an equivalent method approved by the code official. Whole-building air leakage testing is typically completed by pressurizing and depressurizing the building with multiple blower door setups as shown in Fig. 8-2.

The cities of Fort Collins and Boulder have both introduced amendments to the IECC that include provisions for mandatory whole-building air leakage testing. These requirements are summarized below:

- City of Fort Collins *(2015 IECC with amendments)*:[11] The maximum-allowable whole-building air leakage rate is 0.25 cfm/ft^2 at 0.3 in-H_2O (75 Pa) when tested in accordance with the *City of Fort Collins Building Air Leakage Test Protocol* for commercial buildings[21] or the *City of Fort Collins Building Code Protocol for New Multifamily Building Airtightness Testing.*[22] Failure to comply with the maximum-allowable leakage rate requires a diagnostic evaluation in accordance with ASTM E1186-03 (2009),[23] followed by repair and retesting of the air barrier system.

- City of Boulder (2017 COBECC, based on the 2012 IECC):[13] The maximum-allowable whole-building air leakage rate is 0.40 cfm/ft^2 at a pressure differential of 0.3 in-H_2O (75 Pa) when tested in accordance with ASTM E779.[20] In addition, a sampling of dwelling units must be tested using a blower door in multi-unit residential buildings to demonstrate that the maximum air leakage rate in any one dwelling does not exceed 0.25 cfm/ft^2 at a pressure differential of 0.2 in-H_2O (50 Pa). The sampling must include at least 20% of the units in each building, at least one of each unit type, and approximately an equal number of units on each floor level. Any unit that fails the above-noted testing requirement must be diagnosed, the air barrier system corrected, and the unit retested. A minimum of two additional dwelling units must be tested for each failed test.

Checklists for Successful Air Barrier Design and Construction

Regardless of the governing air leakage requirements and path to compliance, the air barrier is an essential control layer. The construction and design checklist items provided on page 125 and page 126 can be used to increase the likelihood of a successful design and installation for a continuous air barrier system in any jurisdiction. These checklists were adapted from the *National Masonry Systems Guide: Northwest Edition.*[24]

Fig. 8-2 Blower door setup during whole-building air leakage testing of a building with an anchored masonry veneer wall system

Design Checklist

- ✓ Select appropriate air barrier system materials and assemblies. Refer to Table 8-2 for air barrier system materials and assembly properties. The Air Barrier Association of American (ABAA) also lists several commercially available compliant air barrier membrane products and systems at www.airbarrier.org.[29]

- ✓ Ensure that a continuous line representing the plane of airtightness can be drawn across all wall assemblies, details, and transitions between assemblies. This includes in both plan and section perspectives. Details included within this guide demonstrate this practice; an example is shown in Fig. 8-3.

- ✓ Clearly delineate the air barrier system 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. 8-4. This delineation is required by the City of Fort Collins energy code (local amendments to the 2015 IECC) for compliance,[11] in addition to the calculation of the air barrier pressure boundary surface area.

- ✓ 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 the ABAA's website and may be modified to meet local code and project-specific requirements.

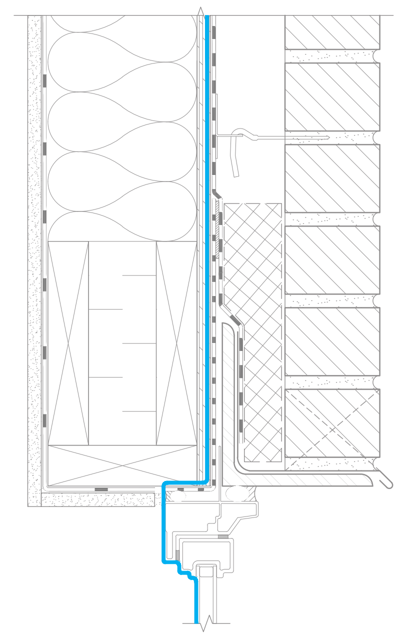


Fig. 8-3 Typical window head detail and wood stud–framed backup wall. The plane of airtightness (i.e., the air control layer) is denoted in blue.

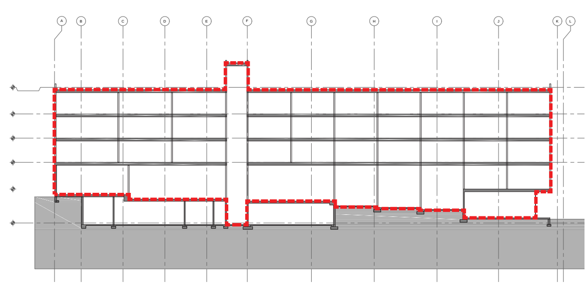


Fig. 8-4 Whole-building section with the continuous air barrier system pressure boundary denoted in red.

Adapted from the National Masonry Systems Guide: Northwest Edition

Construction/Installation Checklist

- ✓ Prior to the installation of air barrier system components, coordinate an air barrier system preconstruction meeting with the general contractor, designer(s), and the trade/subcontractor responsible for the installation of the air barrier system as well as all additional trades whose work may interface or penetrate the air barrier system (e.g., window installers, framers, siders, mechanical, etc.). Clarify the responsibilities of all parties involved with the air barrier system installation and review installation requirements and limitations of the system as well as any details/installations that will require significant coordination efforts to implement.

- ✓ Use installers who are experienced with the specific air barrier system installation to perform the installation of air barrier components. For example, if the primary air barrier strategy is a sealed sheathing approach, using an installer with experience installing sealed sheathing can increase the likelihood for quality air barrier installation.

- ✓ Designate an air barrier system/building enclosure supervisor or superintendent from the construction team to oversee all trades involved in installation related to the air barrier system.

- ✓ Build freestanding mock-ups of all project-specific typical and unique air barrier system 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 E1186[23] for air leakage site detection practices.

- ✓ Implement a quality control program. Develop a checklist of items that need to be reviewed before the air barrier system is covered 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 ensure airtight transitions, especially at roof-to-wall and wall-to-foundation transitions and at the floor line and window perimeter details.

- ✓ 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.

Adapted from the National Masonry Systems Guide: Northwest Edition

Thermal Control

In a masonry wall system, the thermal control layer of the field of wall area is provided by one or more layers of thermal insulation. All insulation products share the same underlying physical property: the material has a relatively low conductivity such that it resists heat flow better than other system components. Regardless of the cladding type, the thermal control layer will almost always be interrupted by materials with greater conductivities due to the need to transfer structural loads. For example, insulation located within a framed wall cavity is commonly interrupted by framing members as shown in Fig. 8-5, and exterior insulation is often interrupted by masonry anchors as shown in Fig. 8-6. When insulation is interrupted by elements of a higher conductivity, more heat flow occurs through the more highly conductive materials as the path of least resistance, degrading the overall thermal performance of the insulation layer. This phenomenon is commonly known as *thermal bridging*. The conductive thermal performance of a masonry system is thus determined by the insulation's ability to resist heat flow, the quality of its installation, and the degree to which the insulation is interrupted or bridged.

Minimizing thermal bridges within the building enclosure is a best practice and is often an energy code requirement. The basic principles of thermal control are discussed in the Control Layer Summary on page 21. The following section addresses specific insulation types and thermal control considerations.

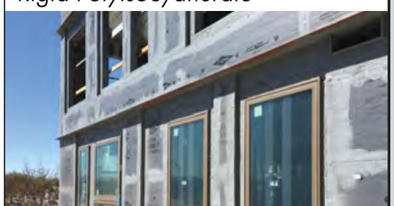
Insulation Types

A variety of insulation products exist for use in exterior walls; common insulation products used within masonry wall systems are described on the following page. Additional insulation products are available but are not as common for masonry wall systems in Colorado and southern Wyoming. Where split insulation occurs within the wall assembly (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.

Fig. 8-5 Insulation located within a framed wall cavity interrupted by framing members

Fig. 8-6 Exterior semi-rigid mineral fiber insulation bridged by thermally optimized screw anchors

Table 8-3 Typical insulation types used in masonry wall systems

Insulation Product	Typical R-Value / Use in Wall Assembly	Air Permeance / Vapor Permeance	Moisture Tolerance	Installation Notes
Semi-Rigid Mineral Fiber 	approx. R-4.2 per inch / Cavity (Wood Stud–Framed) & Exterior	Air-Permeable / Class IV	Hydrophobic, tolerates moisture, and has free-draining capabilities.	The semi-rigid properties of this insulation facilitate a snug fit at board joints and around penetrations such as masonry anchors without requiring notching.
Rigid Extruded Polystyrene (XPS) 	R-5 per inch / Interior & Exterior	Air-Impermeable* / Class II	Moisture-resistant and suitable for wet environments.	Rigid board insulation may require notching around masonry anchors or other supports to create a snug fit. When multiple board layers are used, stagger board joints.
Rigid Polyisocyanurate 	R-5 to R-5.6 per inch / Interior, Exterior, or Cavity	Air-Impermeable* / Class I-Class III depending on the facer	Typically includes a foil or moisture-resistant facer. Uses a compatible tape at faced board joints to protect the insulation core from incidental moisture.	Rigid board insulation may require notching around masonry anchors or other supports to create a snug fit. When multiple board layers are used, stagger board joints.
Closed Cell Spray Foam 	R-5.5 to R-6.5 per inch / Interior, Exterior, or Cavity	Air-Impermeable / Class II at 2-inch thickness	Spray foam product should be rated for exterior use where used within the anchored masonry veneer air cavity.	Spray in place after framing, wall penetrations, and masonry anchors are in place.
Fiberglass Batt 	R-3.3 to R-3.7 per inch / Cavity	Air-Permeable / Class IV	Not moisture-tolerant; use in dry cavities only.	Size batt to fit snug in framing cavities and around penetration and building services. Do not compress batt.

* With all rigid board joints and edges taped/sealed

Exterior Insulation Considerations with Masonry Veneers

Exterior insulation outboard of the backup wall structure and behind the veneer is a common insulation strategy for improving the thermal performance of an anchored masonry veneer wall system. The type of exterior insulation is dependent on several factors and is further discussed in Chapter 5.

As mentioned in Chapter 5, building codes and standards provide prescriptive attachment requirements for cladding. Where the masonry veneer weighs less than 40psf and where the ASCE-7 wind velocity pressure is less than 55psf, a maximum air cavity depth of 6 ⅝ inches is allowed behind the masonry veneer. If the veneer weight and project-specific wind loads do not exceed these values, prescriptive attachment requirements can accommodate up to 4 ⅝ inches of exterior insulation within the cavity, allowing for the recommended 2-inch air gap behind the masonry veneer.

The exterior insulation behind an anchored masonry veneer will be bridged to some degree by the anchorage system. Thermal bridging from the anchorage system degrades the insulation's thermal performance. Whether the exterior insulation can be considered continuous for code-compliance purposes is dependent on the specific anchoring system used and code interpretations by the authority having jurisdiction and is discussed in the Continuous Insulation section of this chapter. This guide recommends clarifying with the authority having jurisdiction on a project-specific basis whether exterior insulation is considered continuous for code-compliance purposes.

Fig. 8-7 Masonry anchor types. Top row, left to right: double eye and pintle plate anchor, thermally optimized double eye and pintle screw anchor, adjustable L-bracket. Bottom row, left to right: embedded double eye and pintle wire anchor, corrugated masonry anchor.
Photos courtesy of Hohmann & Bernard, Inc.

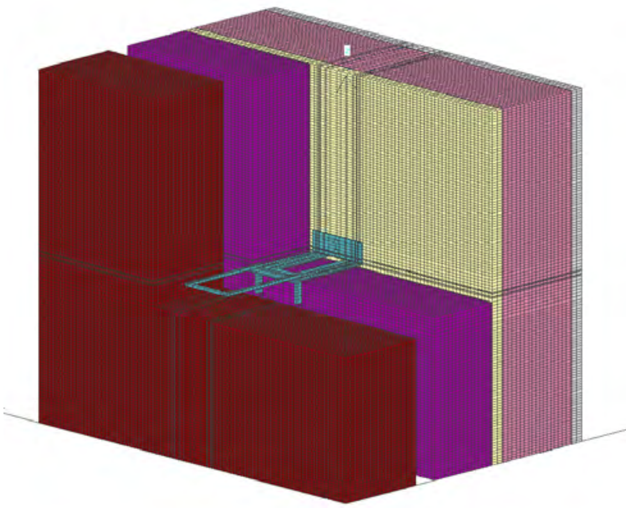
Masonry Anchors

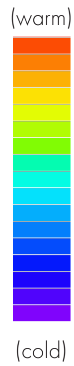
Masonry anchors, such as those shown in Fig. 8-7, act as thermal bridges when installed through exterior insulation; however, the degree to which the anchoring system degrades the thermal performance of the exterior insulation depends on several factors, primarily the following:

- Masonry Anchor Geometry: The greater the penetration area of the anchor that bridges the insulation, the greater the conductive heat loss through each anchor. An example of the thermal bridging created by a galvanized-steel masonry anchor is shown in Fig. 8-8.
- Anchor Material: The greater the conductivity of the anchor materials, the greater the conductive heat loss and the more severe the thermal bridging. For example, stainless-steel anchors are more thermally efficient than mild-steel anchors because the conductivity of stainless steel is approximately ⅓ that of the mild steel. In addition, some proprietary anchors have been thermally optimized and incorporate low-conductivity components to minimize thermal bridging.
- Anchor Spacing: The greater the spacing between anchors, the more thermally efficient the anchorage system; however, spacing needs to be coordinated with structural requirements.

From the thermal modeling results presented in the Masonry System Thermal Performance Design Tables, the masonry anchor systems considered can be ordered from *most thermally efficient* to *least thermally efficient* as follows for typical anchor spacing:

1. Stainless-steel embedded wire anchor (only applicable for CMU backup wall structures)
2. Stainless-steel plate anchor
3. Thermally optimized screw anchor with galvanized- or stainless-steel hook
4. Galvanized-steel embedded wire anchor (only applicable for CMU backup wall structures)
5. Galvanized-steel plate anchor





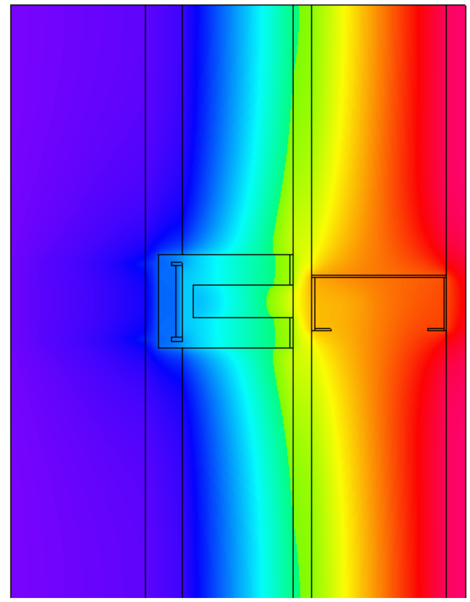


Fig. 8-8 *Three-dimensional cutaway model image of a galvanized-steel masonry anchor through exterior insulation (left) and a two-dimensional image of a galvanized-steel masonry anchor through exterior insulation (right)*

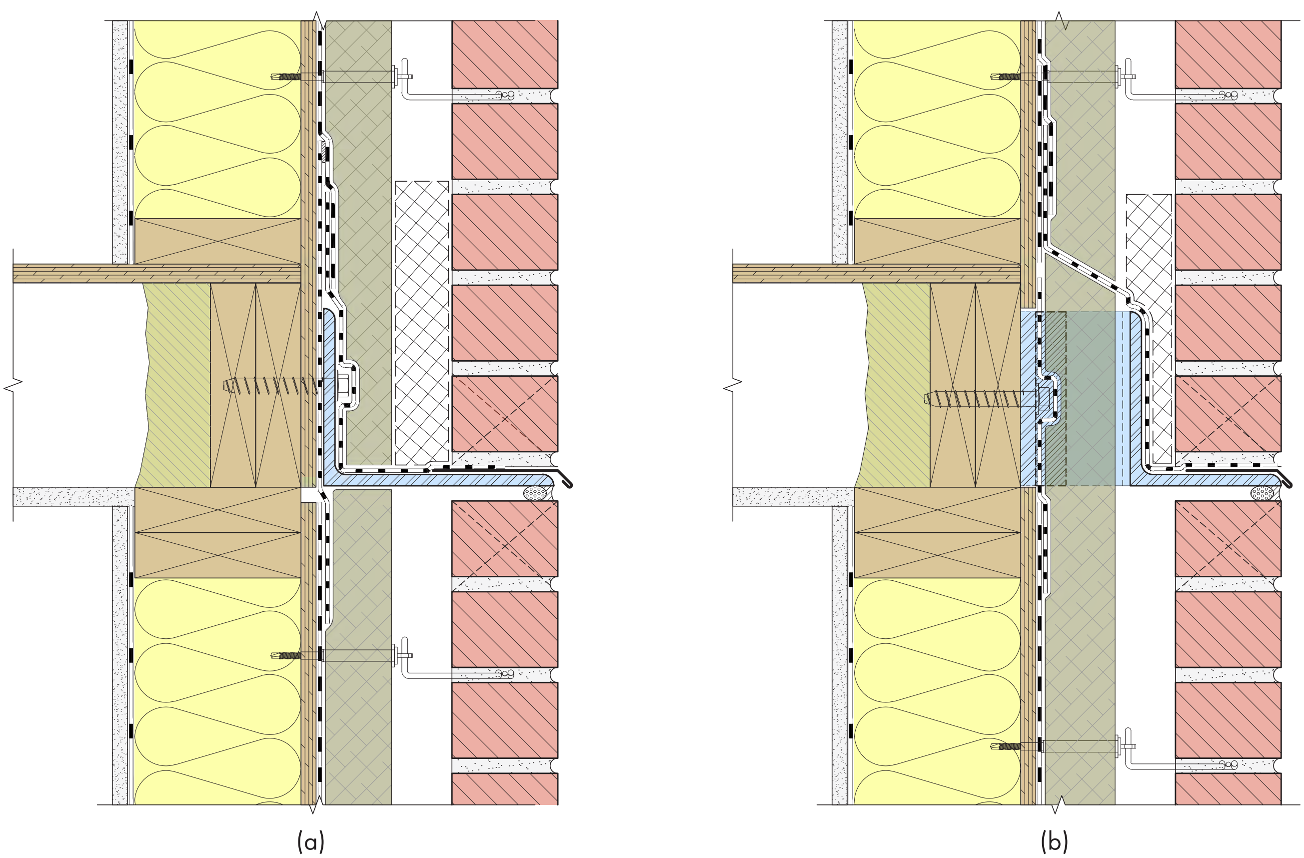


Fig. 8-9 *A continuous shelf angle support at a wood-framed floor line (a) and standoff shelf angle support at a wood-framed floor line (b).*

Masonry Shelf Angle Supports

Intermediate bearing support of anchored veneer systems is commonly provided by lintels or shelf angle supports at floor lines or above fenestration rough openings. These supporting elements bridge exterior insulation that may exist within the masonry veneer air cavity.

Shelf angles attached tight to the structure (e.g., a *continuous* shelf angle), as shown similarly in Fig. 8-9a, continuously bridge exterior insulation, resulting in a significant thermal bridging effect. To reduce the insulation area bridged by the shelf angle and improve thermal performance, the shelf angle can be off-set from the structure to the depth of the exterior insulation (e.g., a *standoff* shelf angle) using intermittent supports as shown similar in Fig. 8-9b. The intermittent supports may use hollow steel sections (HSS), knife plates, or proprietary standoff anchor systems.

Standoff shelf angle supports with exterior insulation, such as that shown in Fig. 8-10, are increasing in popularity. Due to the lesser degree of thermal bridging, a thinner exterior insulation thicknesses can be used to meet similar thermal performance requirements than if a continuous shelf angle support was used. For example, as determined from the thermal modeling results discussed later in this chapter, a continuous shelf angle support may require up to an additional half-inch of insulation to provide a comparable effective thermal performance value as a standoff shelf angle support for wood stud–framed systems. For steel stud and concrete masonry unit (CMU) backup wall structures, an additional 2 inches of exterior insulation or more may be needed to off-set the thermal losses created with using a continuous shelf angle as opposed to a stand-off shelf angle. The thermal bridging at both continuous and standoff shelf angles can be visualized from the three-dimensional thermal modeling images shown in Fig. 8-11.

Fig. 8-10 Hot-dipped galvanized-steel standoff shelf angle support

Mass Wall Considerations

A mass wall can store thermal energy (i.e., heat) that can be released later, reducing peak heating and cooling loads and improving occupant thermal comfort. The benefit of thermal mass varies with climate zone and is generally more beneficial in warmer climates, particularly in areas with large daily temperature swings; however, thermal mass can still provide some benefit in cooler climates, especially in spaces with high passive solar heating. The IECC has less-stringent prescriptive thermal performance requirements for mass walls when compared to framed wall types. When complying with the energy code through a whole-building modeling approach, any dynamic heat transfer and storage effects of thermal mass are directly considered within the building model.

The 2009,[6] 2012,[7] 2015,[4] and 2018[8] versions of the IECC in general define a 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 less than 120 pcf.[4, 6, 7, 8] Furthermore, the 2015 and 2018 IECC clarify that mass walls may also include walls having a heat capacity that exceeds 7 Btu/ft^2 degree F or walls having a heat capacity greater than 5 Btu/ft^2 degree F when the material weight is not more than 120 pcf.[4, 8]

The mass wall classification is typically determined by the backup wall structure and does not consider the mass from masonry veneers; however, this guide recommends confirming the treatment of veneer mass with the authority having jurisdiction. Masonry wall systems that include a CMU wall structure typically qualify as mass walls.

Integrally Insulated Mass Walls

In partially grouted CMU structures, the ungrouted cores can be insulated to form an integrally insulated mass wall. Integral insulation may be loose fill, such as perlite, but it is more commonly a resinous, foam-in-place insulation product that is post-applied through ports in the CMU mortar.

With conventional integrally insulated CMU walls, thermal bridging will occur through CMU webs and grouted cores, and it is typically not possible to comply with prescriptive thermal performance targets using the core insulation alone. Improved thermal performance can be achieved using proprietary composite CMU block products. These products typically incorporate rigid foam board inserts and optimize CMU web and core design to minimize thermal bridging and are discussed in Chapter 7. These products may be able to meet prescriptive energy code compliance mass wall code requirements without the need for additional interior or exterior insulation. For effective R-value capabilities of proprietary insulated CMU products, consult the manufacturer.

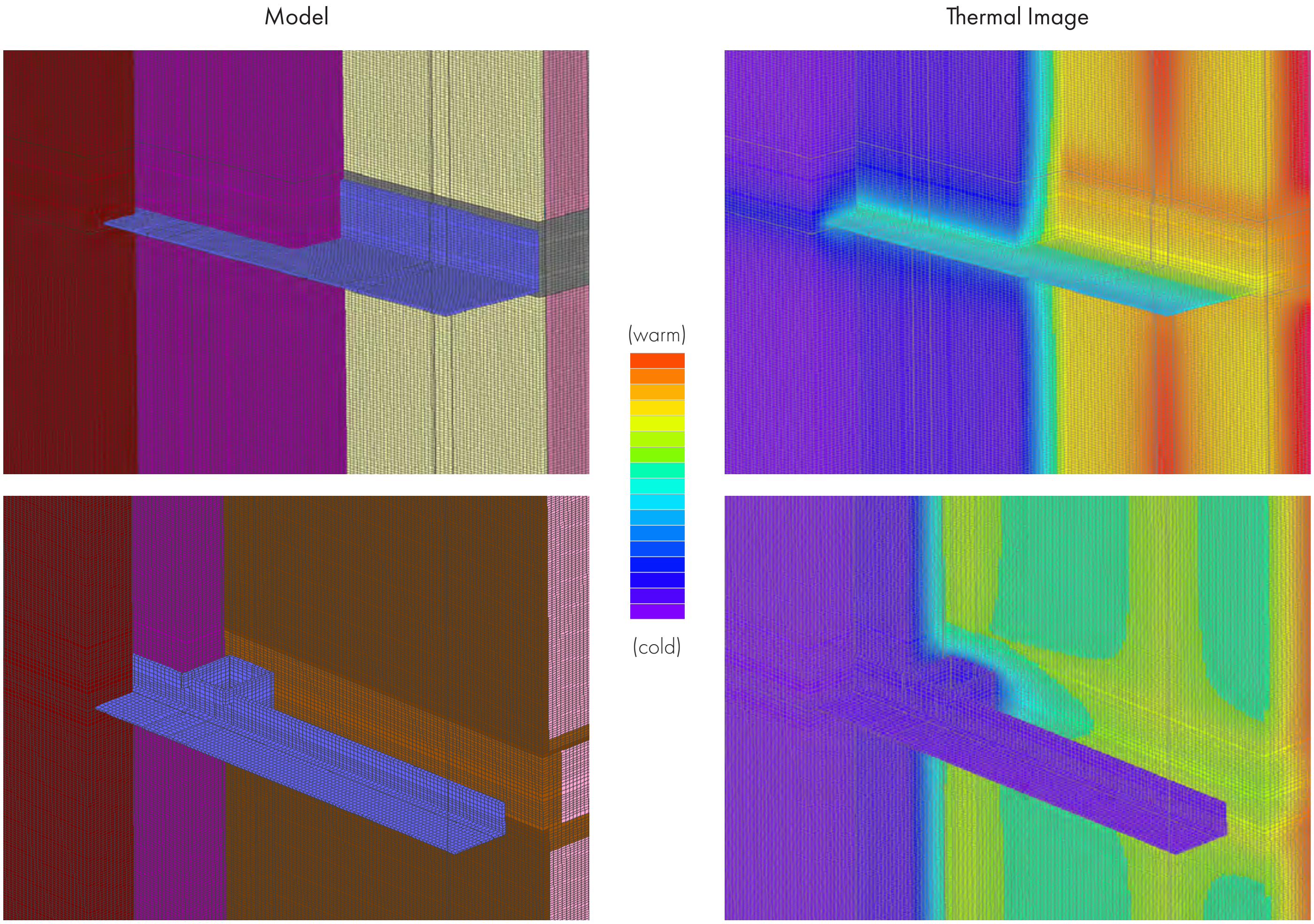


Fig. 8-11 Three-dimensional model and thermal images of a continuous (top) and standoff (bottom) shelf angle support arrangement at a concrete floor line and steel-stud framed backup wall.

Thermal Control: Energy Conservation Code Requirements

This guide addresses energy code compliance specific to opaque above-grade wall systems under the 2009, 2012, 2015, and 2018 IECC code commercial provisions; residential provisions are not addressed. Definitions of residential and commercial buildings may be found within the Definitions chapters of each code.

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

- Climate zone, as shown in Fig. 8-12: Zone 4B, Zone 5B, Zone 6B, or Zone 7B
- Occupancy: All Other or Group R, if operating under the 2012 IECC or later
- Wall classification: mass, metal-framed (i.e. steel stud-framed), wood-framed (i.e. wood stud–framed), or other

Fig. 8-13 describes the typical process for navigating the opaque above-grade wall system thermal enclosure energy code compliance options and strategies. It also describes how this process relates to the system-specific thermal performance results and discussions provided in the design tables through this chapter. Refer to Table 8-3 on page 128 for a summary of common insulation products.

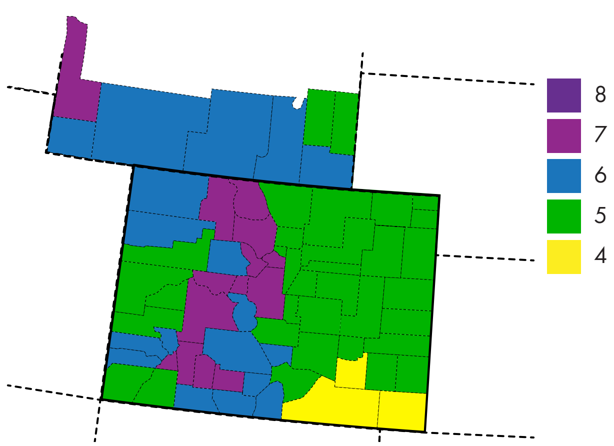


Fig. 8-12 Colorado and southern Wyoming climate zones including Zone 4B, Zone 5B, Zone 6B, and Zone 7B as referenced from Figure C301.1 of the 2018 IECC.

Prescriptive Energy Code Compliance

Refer to Fig. 8-13 for the *prescriptive compliance options* for energy code compliance. Where a project seeks this compliance option, the above-grade wall system must demonstrate compliance with one of the following strategies:

- *Insulation R-Value Method:* The assembly thermal insulation R-value must meet or exceed the minimum nominal insulation R-value(s) listed in Table 8-4. For example, under the 2015 IECC,[4] a Group R project in Climate Zone 5B with a wood-framed backup wall requires at least a nominal R-13 wall cavity insulation with R-7.5 continuous insulation or, alternatively, R-20 cavity insulation with R-3.8 continuous insulation to meet this compliance strategy.[15] Where continuous insulation (ci) is denoted, defer to the interpretation of the authority having jurisdiction.
- *Assembly U-Factor Method:* The assembly U-factor must be less than or equal to that listed in Table 8-4. For this strategy, the project-specific assembly U-factor will need to be determined either through calculations or table values. A U-factor defines the maximum thermal transmittance of the system when insulation and other bridging elements are considered (e.g., 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 in Table 8-4 is also provided as an equivalent effective R-value, shown in parentheses. For simplicity, the R-value is the inverse of the U-factor.
- *Component Performance Alternative:* The assembly U-factor may exceed that listed in Table 8-4; however, the summation of the area-weighted U-factors for all assemblies at the thermal enclosure may not exceed that required by the code, as described by Equation 8-1:

Eq. 8-1 $$\sum \text{Proposed } UA \leq \text{Target } UA$$

Nonprescriptive Energy Compliance

Fig. 8-13 identifies the *nonprescriptive compliance* option (e.g., whole-building modeling strategies). When a project seeks this compliance option, the thermal performance of an above-grade wall assembly is determined as a U-factor; however, it may or may not be required to meet the prescriptive values shown in Table 8-4. This option allows the designer to trade-off the performance of the thermal enclosure with mechanical (i.e., HVAC) and lighting systems.

Step 1: *Determine*	Determine Governing Energy Code IECC version and local amendments →		Determine Project Climate Zone Zone 4B, Zone 5B, Zone 6B, or Zone 7B. →	Determine Project Occupancy Group R or All Other
Step 2: *Select an Option*	Prescriptive Compliance Options: Use when a whole-building energy model will not be performed to demonstrate energy code compliance. Typically, whole-building energy modeling methods are required when assembly R-values 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.			Non-prescriptive Compliance Option: Use when prescriptive compliance options cannot be used to demonstrate energy code compliance.
Step 3: *Select a Strategy*	R-Value–Based Method Provide opaque above-grade wall insulation with an R-value equivalent to or greater than that described in Table 8-4. This is the least flexible strategy.	U-Factor–Based Method/U-Factor Provide an opaque above-grade wall assembly with an assembly U-factor less than or equal to that described in Table 8-4. U-factors should consider all instances of thermal bridging required by the governing jurisdiction.	Component Performance Alternative/U-Factor–Based Method/Building Envelope Trade-Off Option Provide an area-weighted calculation of assembly and component U-factors for comparison with the prescriptive target. Use when overpreforming assemblies can offset underpreforming assemblies and components. This strategy is typically not successful when a project exceeds maximum glazing area percentages set by the energy code.	Total Building Performance/ Energy Cost Budget Method Perform a whole-building energy model using approved software. Use when enclosure components, lighting, and HVAC performance will 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.
Step 4: *Determine System*	Provide insulation that meets or exceeds the R-values listed in Table 8-4.	Provide assembly U-Factors from calculations, modeling, ASHRAE 90.1 [31] Appendix A tables, or other approved sources. Refer to modeling results presented at the end of this chapter to assist with determining appropriate insulation thickness.		

Fig. 8-13 Energy code compliance chart. Use this chart to navigate selection of an energy code compliance strategy and application of the modeling results within this guide.

Table 8-4 Colorado and southern Wyoming – prescriptive energy code compliance values for opaque above-grade wall systems within this guide

Opaque Above-Grade Wall – Thermal Envelope Requirements														
		Energy Code	2012 IECC										2015 IECC	
		Climate Zone	4B		5B		6B		7B		8B		4B	
Guide Assembly Type		Classification	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R
Anchored Masonry Veneer	CMU (or Concrete) Wall	Mass	R-9.5ci	R-11.4ci	R-11.4ci	R-13.3ci	R-13.3ci	R-15.2ci	R-15.2ci	R-15.2ci	R-25ci	R-25ci	R-9.5ci	R-11.4ci
			U-0.104 (R-9.6)	U-0.090 (R-11.1)	U-0.078 (R-12.8)	U-0.078 (R-12.8)	U-0.078 (R-12.8)	U-0.071 (R-14.1)	U-0.061 (R-16.4)	U-0.061 (R-16.4)	U-0.061 (R-16.4)	U-0.061 (R-16.4)	U-0.104 (R-9.6)	U-0.090 (R-11.1)
	Steel Stud-Framed Wall	Metal-Framed	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-15.6ci	R-13 + R-7.5ci	R-13 + R-17.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci
			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-0.064 (R-15.6)	U-0.057 (R-17.5)	U-0.064 (R-15.6)	U-0.052 (R-19.2)	U-0.045 (R-22.2)	U-0.045 (R-22.2)	U-0.064 (R-15.6)	U-0.064 (R-15.6)
	Wood-Framed Wall	Wood-Framed & Other	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-15.6ci or R-20 + R-10ci	R-13 + R-15.6ci or R-20 + R-10ci	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20
			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-0.051 (R-19.6)	U-0.051 (R-19.6)	U-0.051 (R-19.6)	U-0.051 (R-19.6)	U-0.036 (R-27.8)	U-0.036 (R-27.8)	U-0.064 (R-15.6)	U-0.064 (R-15.6)
Single-Wythe CMU	Interior-Insulated	Mass	R-9.5ci	R-11.4ci	R-11.4ci	R-13.3ci	R-13.3ci	R-15.2ci	R-15.2ci	R-15.2ci	R-25ci	R-25ci	R-9.5ci	R-11.4ci
			U-0.104 (R-9.6)	U-0.090 (R-11.1)	U-0.078 (R-12.8)	U-0.078 (R-12.8)	U-0.078 (R-12.8)	U-0.071 (R-14.1)	U-0.061 (R-16.4)	U-0.061 (R-16.4)	U-0.061 (R-16.4)	U-0.061 (R-16.4)	U-0.104 (R-9.6)	U-0.090 (R-11.1)

ci= continuous insulation

Continuous Insulation

Energy code requirements reference continuous insulation; however, the definition of continuous insulation and its interpretation needs to be carefully considered as it can vary by code and the authority having jurisdiction:

- *2009 and 2012 IECC:* No definition provided. This guide recommends confirming local requirements with the authority having jurisdiction.[6,7]
- *2015 and 2018 IECC:* "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."[4]

In general, continuous insulation is typically interpreted as follows:

- Continuous insulation can be interior, exterior, or integral to the building envelope.
- Insulation bridged by continuous structural members (such as steel studs in a framed wall) is not considered continuous. Insulation bridged by external structural members, whether continuous or intermittent (such as cladding attachment systems and masonry shelf angle supports) may or may not be considered continuous.
- Fasteners have no impact on whether insulation is classified as continuous. However, when fasteners—especially metal fasteners, which are highly conductive—penetrate the insulation, the effective R-value is reduced. Various versions of the IECC do not provide a definition for a fastener; whether cladding attachment systems such as masonry veneer anchors are considered fasteners depends on the definition interpretation.
- Service openings (e.g., doors, ducts, etc.) have no impact on whether insulation is classified as continuous or not.

This guide recommends clarifying continuous insulation requirements with the authority having jurisdiction on a project-specific basis.

Opaque Above-Grade Wall – Thermal Envelope Requirements *(continued)*																	
2015 IECC *(continued)*								2018 IECC									
5B		6B		7B		8B		4B		5B		6B		7B		8B	
All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R
R-11.4ci	R-13.3ci	R-13.3ci	R-15.2ci	R-15.2ci	R-15.2ci	R-25ci	R-25ci	R-9.5ci	R-11.4ci	R-11.4ci	R-13.3ci	R-13.3ci	R-15.2ci	R-15.2ci	R-15.2ci	R-25ci	R-25ci
U-0.090 (R-11.1)	U-0.080 (R-12.5)	U-0.080 (R-12.5)	U-0.071 (R-14.1)	U-0.071 (R-14.1)	U-0.061 (R-16.4)	U-0.061 (R-16.4)	U-0.061 (R-16.4)	U-0.104 (R-9.6)	U-0.090 (R-11.1)	U-0.090 (R-11.1)	U-0.080 (R-12.5)	U-0.080 (R-12.5)	U-0.071 (R-14.1)	U-0.071 (R-14.1)	U-0.071 (R-14.1)	U-0.061 (R-16.4)	U-0.061 (R-16.4)
R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-15.6ci	R-13 + R-7.5ci	R-13 + R-17.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-15.6ci	R-13 + R-7.5ci	R-13 + R-17.5ci
U-0.064 (R-15.6)	U-0.064 (R-15.6)	U-0.064 (R-15.6)	U-0.057 (R-17.5)	U-0.064 (R-15.6)	U-0.052 (R-19.2)	U-0.045 (R-22.2)	U-0.045 (R-22.2)	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-0.064 (R-15.6)	U-0.064 (R-15.6)	U-0.064 (R-15.6)	U-0.052 (R-19.2)	U-0.064 (R-15.6)	U-0.045 (R-22.2)
R-13 + R-3.8ci or R-20	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-15.6ci or R-20 + R-10ci	R-13 + R-15.6ci or R-20 + R-10ci	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-15.6ci or R-20 + R-10ci	R-13 + R-15.6ci or R-20 + R-10ci
U-0.064 (R-15.6)	U-0.064 (R-15.6)	U-0.051 (R-19.6)	U-0.051 (R-19.6)	U-0.051 (R-19.6)	U-0.051 (R-19.6)	U-0.036 (R-27.8)	U-0.036 (R-27.8)	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-0.051 (R-19.6)	U-0.051 (R-19.6)	U-0.051 (R-19.6)	U-0.051 (R-19.6)	U-0.036 (R-27.8)	U-0.036 (R-27.8)
R-11.4ci	R-13.3ci	R-13.3ci	R-15.2ci	R-15.2ci	R-15.2ci	R-25ci	R-25ci	R-9.5ci	R-11.4ci	R-11.4ci	R-13.3ci	R-13.3ci	R-15.2ci	R-15.2ci	R-15.2ci	R-25ci	R-25ci
U-0.090 (R-11.1)	U-0.080 (R-12.5)	U-0.080 (R-12.5)	U-0.071 (R-14.1)	U-0.071 (R-14.1)	U-0.061 (R-16.4)	U-0.061 (R-16.4)	U-0.061 (R-16.4)	U-0.104 (R-9.6)	U-0.090 (R-11.1)	U-0.090 (R-11.1)	U-0.080 (R-12.5)	U-0.080 (R-12.5)	U-0.071 (R-14.1)	U-0.071 (R-14.1)	U-0.071 (R-14.1)	U-0.061 (R-16.4)	U-0.061 (R-16.4)

Determining Wall Assembly U-Factors

The most convenient method for determining the thermal performance or U-factor for a wall assembly is to use an industry-accepted default value. Appendix A of ASHRAE 90.1 [31] is a commonly used and industry-accepted resource to obtain tabulated U-factors for various wall assembly and insulation configurations. Where accepted, tabulated values are not always representative of the proposed wall assembly. Various methods are available for calculating the thermal performance of the wall and are listed below. Confirm appropriate calculation methods with the local jurisdiction, because not all methods may be accepted:

- *Parallel Path and Isothermal Planes* (refer to the ASHRAE Handbook of Fundamentals):[32] The parallel path method is typically used for wall assemblies with relatively nonconductive thermal bridges such as wood studs or plastic materials. The isothermal planes method is more appropriate when the thermal bridge material is moderately conductive, such as with the concrete web between insulated CMU cores in an integrally insulated CMU wall. These methods are not reliable for assemblies with highly conductive materials (e.g., steel studs) or intermittent components such as fasteners or anchors through exterior insulation.

- *Zone Method and Modified Zone Method* (refer to the ASHRAE Handbook of Fundamentals):[32] Typically used for assemblies with highly conductive elements that bridge the insulation, such as steel studs. These methods are not recommended for determining the performance of assemblies with intermittent fasteners or anchors through exterior insulation.

- *Two-Dimensional Computer Modeling:* Programs such as Lawrence Berkley National Laboratory's THERM calculate two-dimensional heat transfer.[33] This method may be used for most above-grade wall assemblies; however, it is not appropriate for assemblies where intermittent fasteners, anchors, or cladding supports bridge exterior insulation. An example of a two-dimensional thermal image produced from this modeling approach is shown in Fig. 8-8.

- *Three-Dimensional Computer Modeling*: Programs such as HEAT3 calculate three-dimensional heat transfer.[34] 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 produced from this modeling approach is shown in Fig. 8-11.

- *Heat Transmittance Coefficients*: Linear heat transmittance coefficients (ψ-values) factor in the heat flow through a wall attributed to a linear thermal bridge (e.g., a continuous shelf angle). Point heat transmittance coefficients (χ-values) similarly factor the attributed heat flow from intermittent or point thermal bridges (e.g., a fastener). These factors can then can be superimposed onto the clear wall assembly U-factor to obtain the effective wall U-factor. The clear wall assembly U-factor is defined as the U-factor for the enclosure area containing only insulation and necessary framing materials for a clear section with no fenestration, corners, penetrations, or connections between other enclosure elements such as roofs, foundations, and other walls. Tabulated linear and point heat transmittance coefficients can be found in ISO 14683:2017 *Thermal Bridges in Building Construction*,[35] in the *Building Envelope Thermal Bridging Guide*,[36] and from manufacturers of proprietary structural systems.

Within the following section, three-dimensional computer modeling was employed to demonstrate how typical thermal bridges in masonry assemblies—like masonry anchors, shelf angles, and wall framing—contribute to the effective thermal performance of wall systems for design and analysis purposes.

Masonry System Thermal Performance Design Tables

While there are various methods available for calculating the effective U-factor of a masonry wall system, accurately assessing the thermal performance of systems with highly conductive thermal bridges such as anchors can be complex and time-intensive, particularly when intermittent steel clips, anchors, or fasteners interrupt an insulation layer. The simplest method for determining thermal performance is to use tabulated values from industry-accepted sources, such as ASHRAE 90.1 Appendix A.[31] These values, however, may not be appropriate where the U-factors for masonry veneer wall systems with specific types of anchors and shelf angle options are being considered or must be known.

This section presents effective R-values for exterior-insulated anchored masonry veneer wall systems and interior-insulated CMU wall systems determined through three-dimensional thermal modeling. There is no industry-standard definition for the term effective R-value. This guide uses this term to refer to the assembly R-value inclusive of all wall layers, air films, and thermal bridging.

Using the Design Tables and Figures

Modeling results presented within this guide can be used to estimate project-specific thermal performance requirements for anchored masonry veneer wall systems and interior insulated single-wythe CMU wall systems.

Anchored masonry veneer wall system results are organized by four backup wall structures:

1. 8-inch CMU wall
2. 3 ⅝-inch steel stud-framed wall with R-15 batt insulation
3. 6-inch steel stud-framed wall with R-21 batt insulation
4. 5 ½ inch wood-framed wall with R-21 batt insulation

For each backup wall structure, effective R-values are presented for different combinations of masonry anchor systems, shelf angle configurations (continuous or standoff), and exterior insulation thickness.

Single-wythe CMU wall system results are organized by interior insulation approach:

- R-12 cavity insulation
- R-12 cavity insulation with R-12 continuous insulation
- 1-inch XPS insulation between framing and CMU
- R-12 continuous insulation
- R-24 continuous insulation
- R-24 cavity insulation
- R-15 batt cavity insulation with 2-inch XPS between framing and CMU
- R-15 batt cavity insulation with 3-inch XPS insulation between framing and CMU

For all wall systems, the effective R-values in the table results are presented as a range, with the lower value representing an insulation with a resistance value of R-4.2 per inch and the upper value representing insulation with a resistance value of R-6 per inch. To estimate the thermal performance for exterior values between R-4.2/inch and R-6/inch, the lower and upper range values can be linearly interpolated within an accuracy of 1%. Refer to the Linear Interpolation sidebar of page 138 for the linear interpolation equation and an example calculation.

Anchored masonry veneer wall system results are also graphically presented by backup wall type for ease of interpolation and to visualize the relative thermal degradation of different anchor systems.

Modeling specifics and additional information used to complete the modeling within this guide are provided in the Appendix.

Thermal Modeling Results: CMU Backup Wall With Anchored Masonry Veneer

The modeled system includes the components depicted graphically in Fig. 8-14:

1. 8-inch medium weight single-wythe CMU wall
2. 3, 4, and 5 inches of R-4.2/inch or R-6 per inch exterior insulation
3. Air cavity
4. Anchored masonry veneer

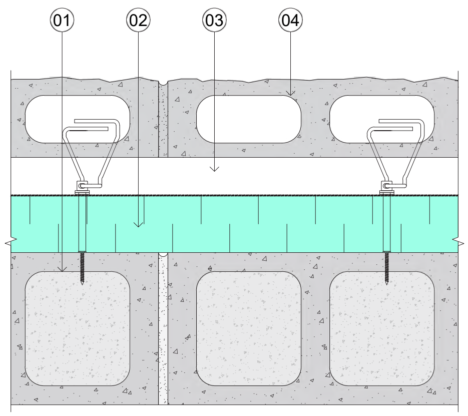


Fig. 8-14 Modeled CMU backup wall with anchored masonry veneer.

Anchor types are considered at 16 inches by 16 inches spacing for results where exterior insulation is not assumed to be continuous. Modeled anchor types include:

- Ladder eye-wire anchor (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 anchor 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 anchor (14-gauge). Hooks are either hot-dipped galvanized steel or Type 304 stainless steel to match the anchor plate.

Modeling results consider a concrete slab bypass condition with and without hot-dipped galvanized-steel shelf angles. Shelf angles are either attached tight to the floor line structure (continuous shelf angle) or offset to the depth of the exterior insulation and supported by intermittent hollow steel sections (HSS) at 4 feet on-center (standoff shelf angle).

Linear Interpolation

Effective R-values in this guide can be interpolated for assemblies with exterior insulation with thermal resistances between R-4.2/inch and R-6/inch from tabulated results using the equation below:

$$\text{R-EFF} = \frac{R_6\text{-NOM} - R_{4.2}\text{-NOM}}{\text{R-NOM} - R_{4.2}\text{-NOM}} \left(R_6\text{-EFF} - R_{4.2}\text{-EFF}\right) + R_{4.2}\text{-EFF}$$

Eq. 8-2

Where:

R-EFF = Effective R-value for specific assembly in question by interpolation

R-NOM = Nominal R-value of the specific assembly in question

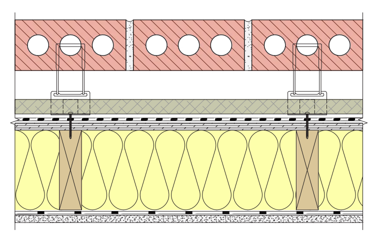
$R_{4.2}$-NOM = Nominal R-value from lower range in design tables (i.e., R-4.2/inch exterior insulation)

R_6-NOM = Nominal R-value from upper range of design tables (i.e., R-6/inch exterior insulation)

$R_{4.2}$-EFF = Effective R-value from lower range in design tables (i.e., R-4.2/in exterior insulation)

R_6-EFF = Effective R-value from upper range in design tables (i.e., R-6/in exterior insulation)

Example:



2x6 wood frame with R-21 batts and 1-inch R-5/in exterior insulation, thermally optimized screw tie with stainless hook, no shelf angle:

R-NOM = R-21 + R-5 = R-26

$R_{4.2}$-NOM = R-21 + R-4.2 = R-25.2

R_6-NOM = R-21 + R-6 = R-27

$R_{4.2}$-EFF = R-22.2

R_6-EFF = R-23.8

$$\text{R-EFF} = \frac{\text{R-26} - \text{R-25.2}}{\text{R-27} - \text{R-25.2}} (\text{R-23.8} - \text{R-22.2}) + \text{R-22.2}$$

R-EFF = **R-22.9**

Table 8-5 CMU backup wall with anchored masonry veneer: tabulated thermal modeling results

8" CMU Wall with Anchored Masonry Veneer, R-4.2/in - R-6/in Exterior Insulation						
Tie Type	Exterior Insulation Thickness	Nominal Insulation R-value	3D Thermal Modeling Effective R-Value of System (ft²·°F·hr/Btu)			
			Without Penetrations (Through Exterior Insulation)	With Masonry Anchor Penetrations @ 16" x 16" o.c.		
				Ties Only	Anchors + Standoff Shelf Angle	Anchors + Continuous Shelf Angle
Embedded Wire Tie (e.g., ladder style) – Stainless Steel	3"	12.6–18.0	15.9–21.3	14.9–19.3	13.1–16.2	9.5–10.9
	4"	16.8–24 .0	20.2–27.5	18.7–24.6	16.0–19.9	11.0–12.5
	5"	21.0–30.0	24.4–33.4	22.4–29.7	18.8–23.4	12.3–13.9
Embedded Wire Tie (e.g., ladder style) – Galvanized Steel	3"	12.6–18.0	15.9–21.3	13.2–16.4	11.8–14.1	8.8–9.9
	4"	16.8–24.0	20.2–27.5	16.3–20.4	14.2–17.1	10.1–11.3
	5"	21.0–30.0	24.4–33.4	19.3–24.2	16.5–19.8	11.3–12.6
Thermally Optimized Screw Tie – Stainless-Steel Hook	3"	12.6–18.0	15.9–21.3	14.1–17.9	12.4–15.2	9.2–10.4
	4"	16.8–24.0	20.2–27.5	17.4–22.2	15.1–18.4	10.5–11.9
	5"	21.0–30.0	24.4–33.4	20.6–26.3	17.4–21.2	11.7–13.1
Thermally Optimized Screw Tie – Galvanized Steel Hook	3"	12.6–18.0	15.9–21.3	14.0–17.8	12.4–15.1	9.2–10.4
	4"	16.8–24.0	20.2–27.5	17.4–22.1	15.0–18.3	10.5–11.9
	5"	21.0–30.0	24.4–33.4	20.5–26.2	17.4–21.2	11.7–13.1
Plate Tie (14 ga) – Stainless Steel	3"	12.6–18.0	15.9–21.3	14.1–18.0	12.5–15.3	9.2–10.5
	4"	16.8–24 .0	20.2–27.5	17.7–22.8	15.3–18.7	10.7–12.0
	5"	21.0–30.0	24.4–33.4	21.1–27.2	17.8–21.8	11.9–13.3
Plate Tie (14 ga) – Galvanized Steel	3"	12.6–18.0	15.9–21.3	12.2–14.8	11.0–12.9	8.4–9.3
	4"	16.8–24.0	20.2–27.5	14.8–17.9	13.0–15.3	9.5–10.5
	5"	21.0–30.0	24.4–33.4	17.1–20.7	14.9–17.4	10.5–11.6

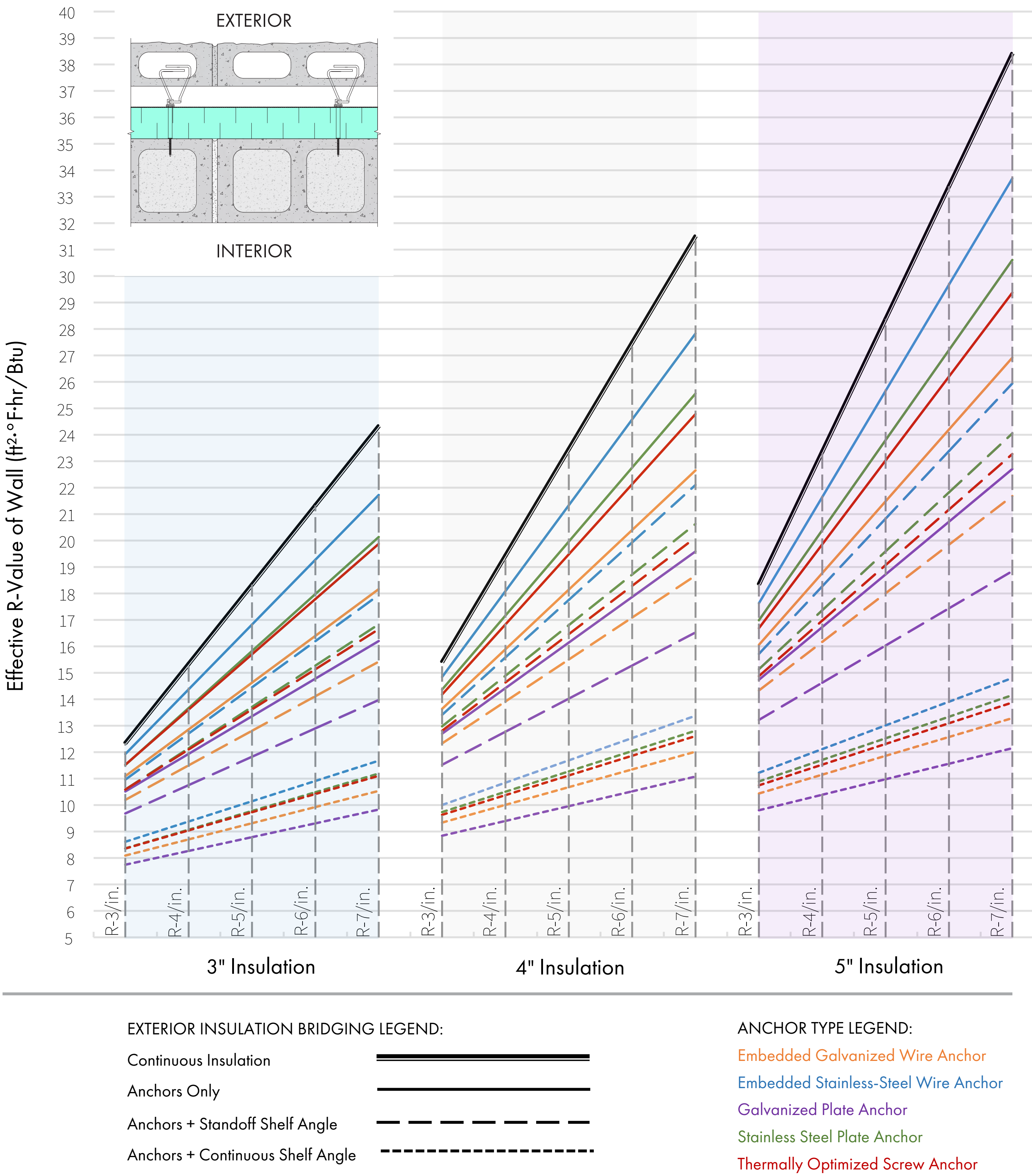


Fig. 8-15 CMU backup wall with anchored masonry veneer: thermal modeling results

Thermal Modeling Results: Steel Stud-Framed Wall

The modeled system includes the components depicted graphically in Fig. 8-17:

1. Interior gypsum board
2. 3 ⅝-inch steel studs at 16 inches on-center (including the top and bottom track of a full-height wall) or 6-inch steel studs at 16 inches on-center (including the top and bottom track of a full-height wall)
3. R-15 (with 3 ⅝-inch steel studs) or R-21 (with 6-inch steel studs) batt insulation
4. Exterior gypsum sheathing
5. 2, 3, and 4 inches of R-4.2 or R-6/inch exterior insulation
6. Air cavity
7. Anchored masonry veneer

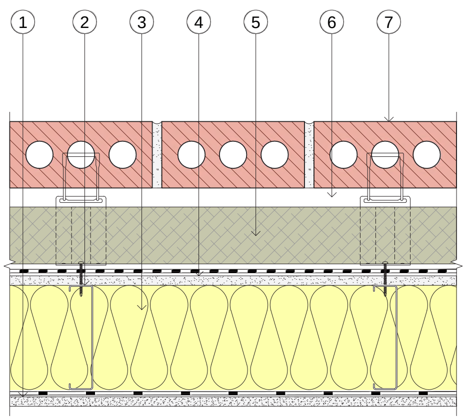


Fig. 8-17 Modeled steel stud-framed wall assembly

Anchor types are considered at 16 inches by 16 inches spacing where exterior insulation is not continuous. Modeled anchor types include:

- Thermally optimized screw anchor 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 anchor (14-gauge). Hooks are either hot-dipped galvanized steel or Type 304 stainless steel to match the anchor plate.

For this wall system, shelf angle supports will typically occur at the periphery of concrete slab edges, such as that shown in Fig. 8-16 a and b. The slab-edge would be classified as an above-grade mass wall and can be considered as a separate assembly from the steel stud-framed wall for energy code compliance purposes. For this reason, the concrete floor line shelf angle assembly was modeled separately from the steel stud-framed wall. In the concrete floor line shelf angle assembly presented in Table 8-7, hot-dipped galvanized-steel shelf angles are either attached tight to the concrete floor line structure (continuous shelf angle) or off-set to the depth of the exterior insulation and supported by intermittent hollow steel sections (HSS) at 4 feet on-center (standoff shelf angle). Floor line modeling results consider the effects of the steel stud-framed system above and below.

(a)

(b)

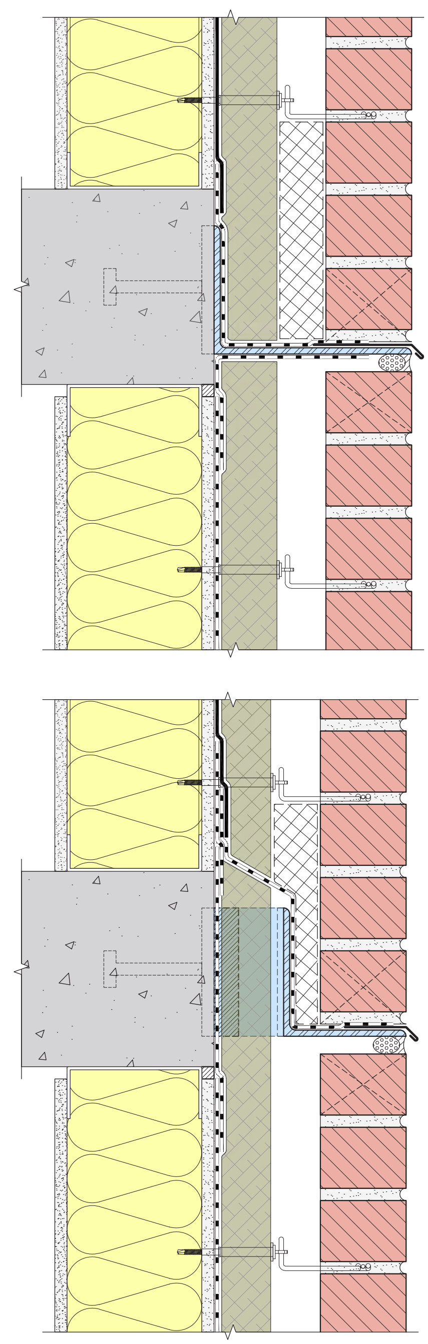


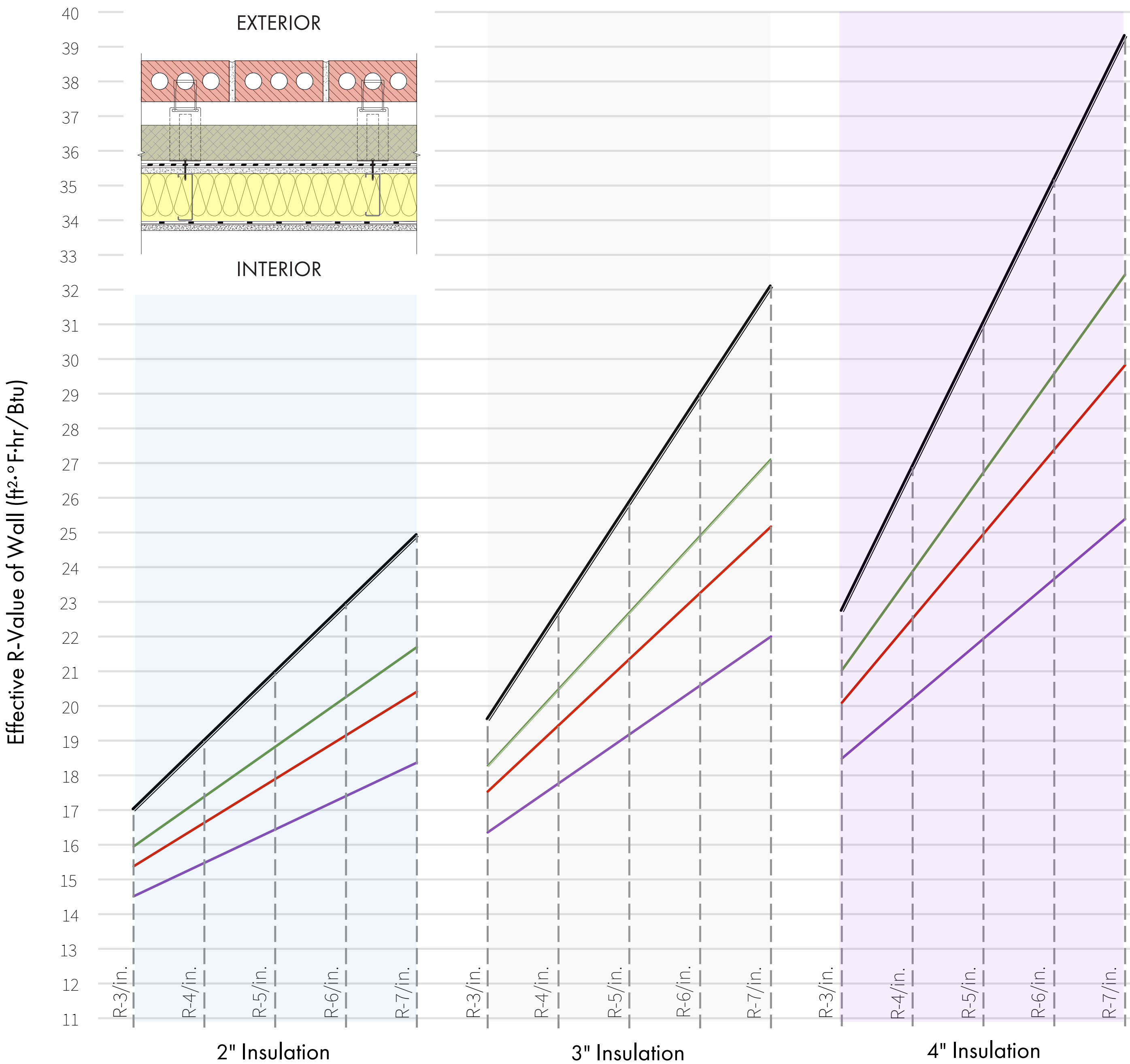
Fig. 8-16 a & b Modeled floor line condition (a) continuous shelf angle support, (b) standoff shelf angle support

Table 8-6 3⅝-inch steel stud-framed wall thermal modeling results

3⅝″ Steel Stud-Framed Wall with Anchored Masonry Veneer, R-15 Batt Insulation, R-4.2/in - R-6/in Exterior Insulation					
Tie Type	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)	2″	15.0 + 8.4–12.0	19.4–22.9	17.7–20.3	15.7–17.4
	3″	15.0 + 12.6–18.0	23.4–29.0	20.9–24.9	18.0–20.6
	4″	15.0 + 16.8–24.0	27.7–35.2	24.4–29.6	20.6–23.7
Thermally Optimized Screw Tie	2″	15.0 + 8.4–12.0	19.4–22.9	17.0–19.3	16.9–19.2
	3″	15.0 + 12.6–18.0	23.4–29.0	19.9–23.4	19.8–23.3
	4″	15.0 + 16.8–24.0	27.7–35.2	23.1–27.5	23.0–27.4

Table 8-7 Concrete floor line thermal modeling results with 3⅝-inch steel stud-framed wall above and below

Concrete Slab Edge with Anchored Masonry				
Exterior Insulation Thickness	Nominal Exterior Insulation R-Value	3D Thermal Modeling Effective R-Value of System (ft²·°F·hr/Btu)		
		Exterior Insulation (Without Penetrations)	Standoff Shelf Angle	Continuous Shelf Angle
2"	8.4 – 12.0	12.4–16.2	6.6–6.8	2.8
3"	12.6–18.0	16.8–22.3	7.2–7.3	2.9
4"	16.8–24.0	21.3–28.7	7.6–8.2	3.1



EXTERIOR INSULATION BRIDGING LEGEND:

Continuous Insulation

Anchors Only

ANCHOR TYPE LEGEND:

Galvanized Plate Anchor

Stainless-Steel Plate Anchor

Thermally Optimized Screw Anchor

Fig. 8-18 3 5⁄8-inch steel stud-framed wall with anchored masonry veneer: thermal modeling results

Table 8-8 6-inch steel stud-framed wall thermal modeling results

6″ Steel Stud-Framed Wall with Anchored Masonry Veneer, R-21 Batt Insulation, R-4.2/in - R-6/in Exterior Insulation					
Tie Type	Exterior Insulation Thickness	System 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)	2″	21.0 + 8.4–12	20.4–24.4	18.7–21.6	16.7–18.7
	3″	21.0 + 12.6–18	24.7–30.4	22.3–26.3	19.3–21.8
	4″	21.0 + 16.8–24	29.1–36.6	25.8–31.0	21.8–24.9
Thermally Optimized Screw Tie	2″	21.0 + 8.4–12.0	20.4–24.4	18.0–20.6	17.9–20.5
	3″	21.0 + 12.6–18.0	24.7–30.4	21.2–24.7	21.1–24.6
	4″	21.0 + 16.8–24.0	29.1–36.6	24.4–28.9	24.3–28.7

Table 8-9 Concrete floor line thermal modeling results with 6-inch steel stud-framed wall above and below

Concrete Slab Edge with Anchored Masonry				
Exterior Insulation Depth	System Nominal Exterior Insulation R-Value	3D Thermal Modeling Effective R-Value of System (ft²·°F·hr/Btu)		
		Cavity + Exterior Insulation (Without Penetrations)	Standoff Shelf Angle	Continuous Shelf Angle
2"	8.4 – 12.0	12.8–16.6	5.9–6.4	3.9–4.1
3"	12.6–18.0	17.2–22.7	6.8–7.3	4.0–4.3
4"	16.8–24.0	21.7–29.1	7.6–8.2	4.2–4.5

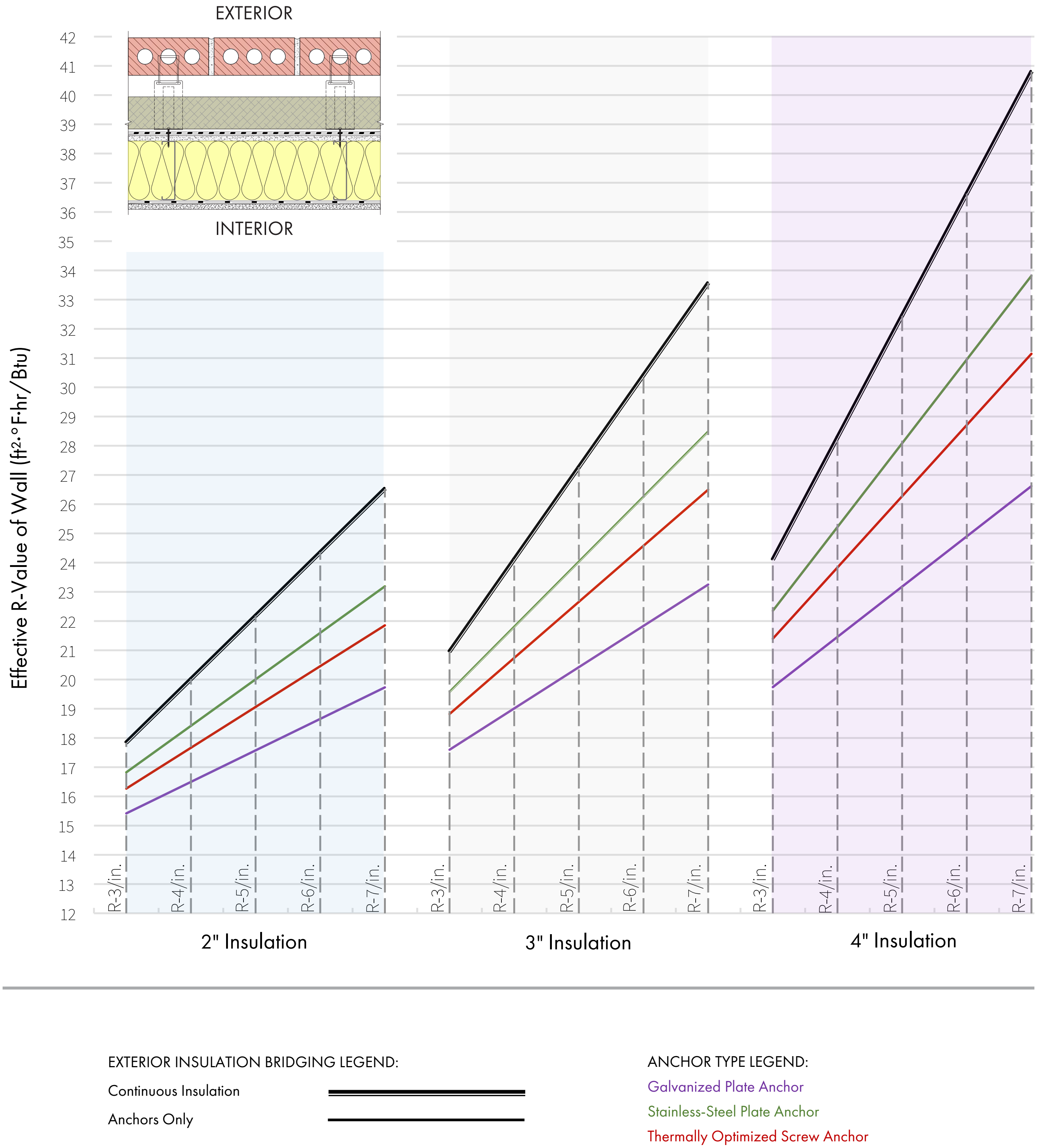


Fig. 8-19 6-inch steel stud-framed wall with anchored masonry veneer: thermal modeling results

Thermal Modeling Results: Wood-Framed Wall

The modeled system includes the components depicted graphically in Fig. 8-20:

1. Interior gypsum board
2. 2x6 wood studs including the top and bottom plates of a full-height wall (23% framing factor) with R-21 batt insulation
3. Exterior plywood sheathing
4. 1, 2, and 3 inches of R-4.2 or R-6/inch exterior insulation 1-inch air cavity
5. Air cavity
6. Anchored masonry veneer

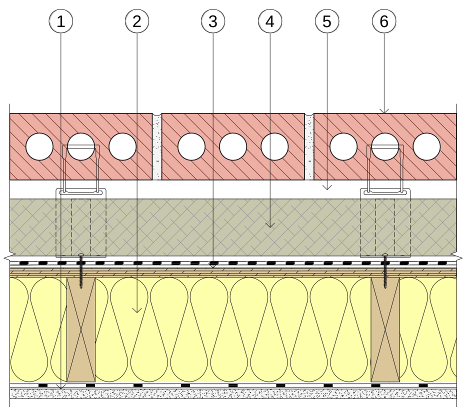


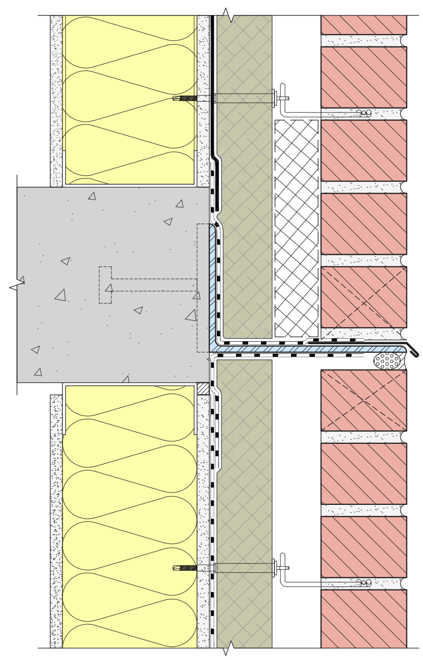
Fig. 8-20 Modeled wood-framed wall assembly

Anchor types are considered at 16 inches by 16 inches spacing where exterior insulation is not continuous. Modeled anchor types include:

- Thermally optimized screw anchor 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 anchor (14-gauge). Hooks are either hot-dipped galvanized steel or Type 304 stainless steel to match the anchor plate.

Modeling results consider a full-height wall with a wood-framed floor line condition. Hot-dipped galvanized-steel shelf angles are either attached tight to the floor line structure (continuous shelf angle) or offset to the depth of the exterior insulation and supported by intermittent hollow steel sections (HSS) at 4 feet on-center (standoff shelf angle).

(a)



(b)

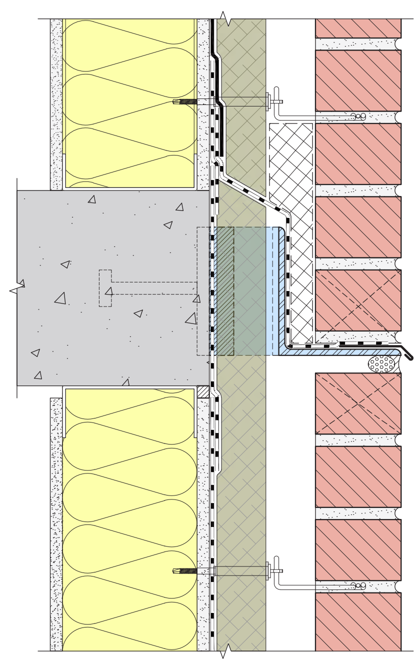


Fig. 8-21 a & b Modeled floor line condition (a) continuous shelf angle support, (b) standoff shelf angle support

YOU CHOOSE...WE DELIVER!

SPEC MIX® provides 3 easy ways to lock-in colored mortar consistency. Building owners, designers and contractors can choose any Custom Color we'll match, or a Standard Color from our Channel Color Kit, or go with the Color Canister Systems "pick & mix" plan that turns SPEC MIX gray mortar into the color of your choice.

CUSTOM COLORS
Blended to Perfection

Pick a color, any color under the sun! We'll accurately design, blend and bag your color of choice.

STANDARD COLORS
Preblended Colors

The SPEC MIX Standard Colored Mortar selection and Channel Color Kit is available throughout North America. You choose a color and we preblend your colored mortar mix in 80 or 3,000 pound bags.

CANISTER COLORS
1 Can + 1 Bag = Consistent Color

The SPEC MIX Color Canister System is perfect for any size project and it's simple! Just pick a color from the Channel Kit, then using your jobsite mixer add 1 Color Canister of pigment with 1 SPEC MIX 80 pound bag of gray mortar. Simply follow the "1 Can to 1 Bag Plan" for perfect colored mortar every batch!

Contact: Aaron Gray (720) 256-1308
SPEC MIX - COLORADO

SPEC MIX®

WWW.SPECMIX.COM

Table 8-10 Wood-framed backup wall with anchored masonry veneer: tabulated 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	Exterior Insulation Thickness	System 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 Considered @ 16″ x 16″ o.c.		
				Ties Only	Ties + Standoff Shelf Angle	Ties + Continuous Shelf Angle
Thermally Optimized Screw Tie – Stainless-Steel Hook	0″	21.0 + 0.0	18.3	18.2	–	18.1
	1″	21.0 + 4.2–6	22.6–24.4	22.2–23.8	22.0–23.6	21.6–23.0
	2″	21.0 + 8.4–12.0	26.9–30.6	26.0–29.1	25.7–28.7	24.6–27.0
	3″	21.0 +12.6–18.0	31.1–36.5	29.6–34.0	29.1–33.2	27.3–30.4
Thermally Optimized Screw Tie – Galvanized-Steel Hook	0″	21.0 + 0.0	18.3	18.2	–	18.1
	1″	21.0 + 4.2–6.0	22.6–24.4	22.1–23.7	22.0–23.5	21.6–23.0
	2″	21.0 + 8.4–12.0	26.9–30.6	26.0–29.1	25.7–28.6	24.6–26.9
	3″	21.0 + 12.6–18.0	31.1–36.5	29.5–33.9	29.1–33.2	27.3–30.4
Plate Tie (14 ga) – Stainless Steel	0″	21.0 + 0.0	18.3	18.2	–	18.1
	1″	21.0 + 4.2–6.0	22.6–24.4	22.2–23.8	22.0–23.6	21.6–23.0
	2″	21.0 + 8.4–12.0	26.9–30.6	26.0–29.1	25.7–28.7	24.7–27.0
	3″	21.0 +12.6–18.0	31.1–36.5	29.6–34.0	29.2–33.3	27.4–30.4
Plate Tie (14 ga) – Galvanized Steel	0″	21.0 + 0.0	18.3	18.1	–	18.1
	1″	21.0 + 4.2–6.0	22.6–24.4	21.9–23.4	21.7–23.2	21.4–22.6
	2″	21.0 + 8.4–12.0	26.9–30.6	25.4–28.2	25.1–27.8	24.1–26.2
	3″	21.0 +12.6–18.0	31.1–36.5	28.6–32.3	28.1–31.7	26.5–29.1
2x8 Framing, R-30 Batts, No Exterior Insulation						
Plate Tie (14 ga) – Galvanized Steel	0″	30	22.8	22.6	–	22.5

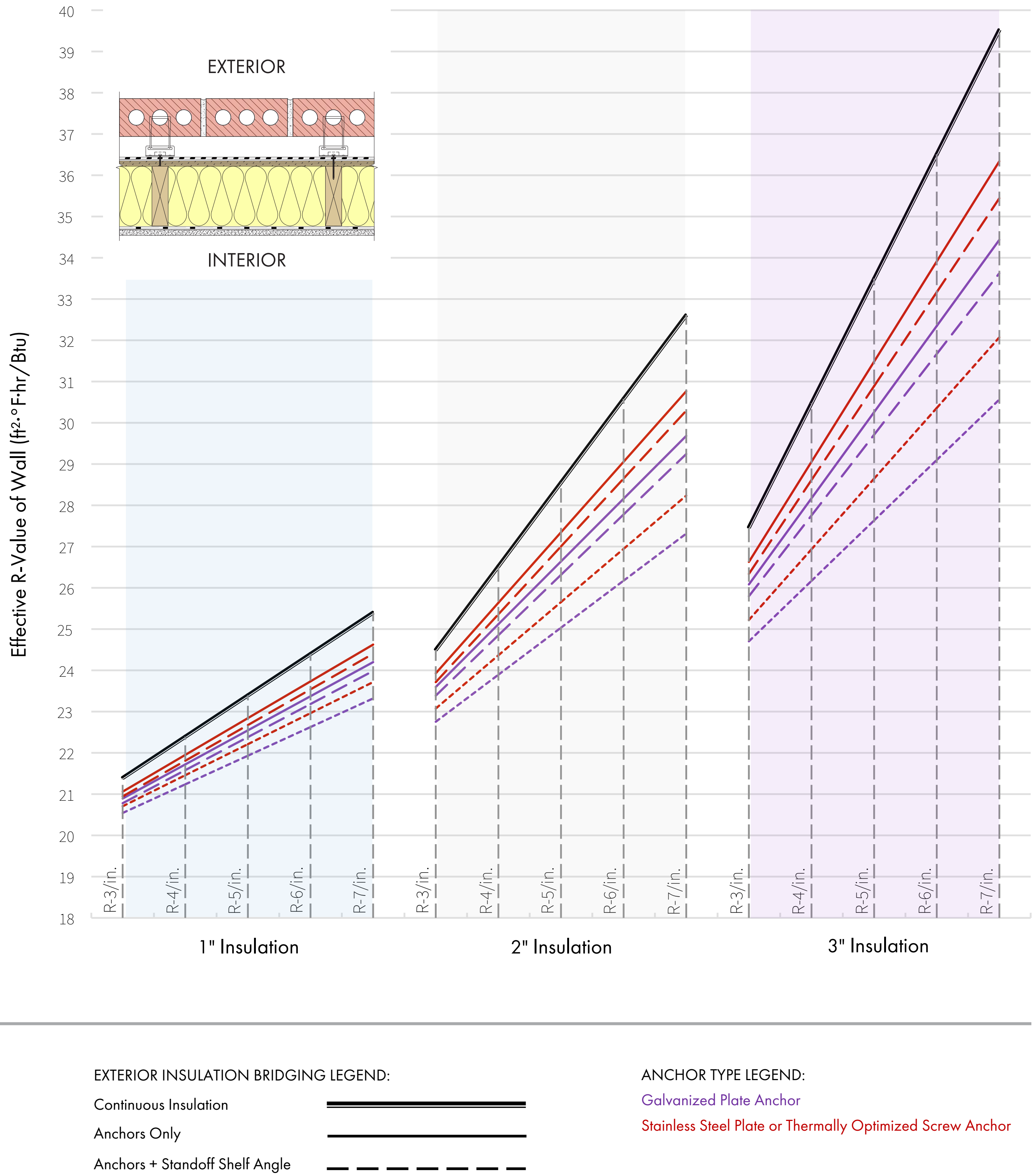


Fig. 8-22 Wood-framed wall with anchored masonry veneer: thermal modeling results

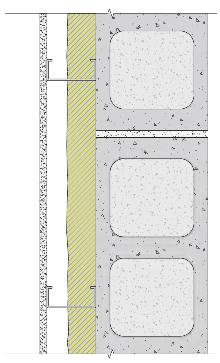
Thermal Modeling Results: Interior-Insulated Single-Wythe CMU

The modeled system includes an 8-inch medium-weight CMU block and eight configurations of interior insulation as depicted graphically in Fig. 8-23. Interior wall framing is provided by galvanized steel studs at 16-inches on-center, including a top and bottom track. Options 1, 3, and 4 were modeled with the wall framing offset from the CMU wall structure to allow clearance for a continuous insulation layer. The remaining options were modeled with wall framing tight to the CMU wall structure. 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.

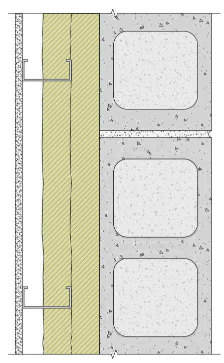
Table 8-11 Interior-insulated single-wythe CMU wall thermal modeling results

CMU Wall with Interior Insulation			
Insulation Option	Interior Insulation Thickness	Nominal Insulation R-Value*	3D Thermal Modeling Effective R-Value of System ($ft^2 \cdot °F \cdot hr/Btu$)
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

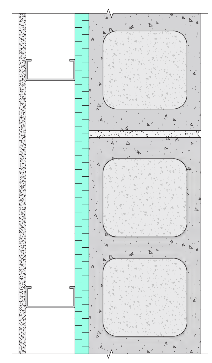
**ci = continuous insulation*



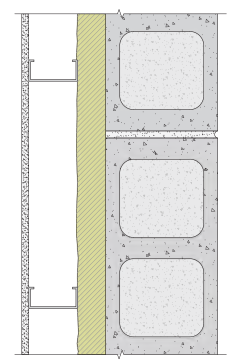
Option 1
R-12 Cavity Insulation



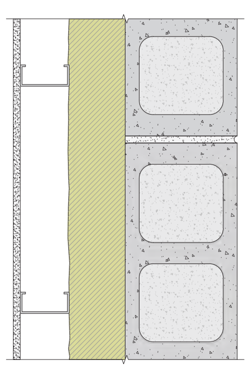
Option 2
R-12 Cavity Insulation with
R-12 Continuous Insulation



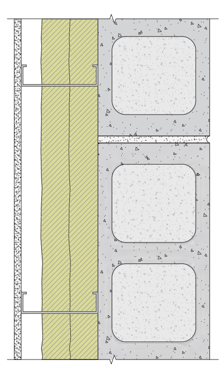
Option 3
R-5 Continuous Insulation



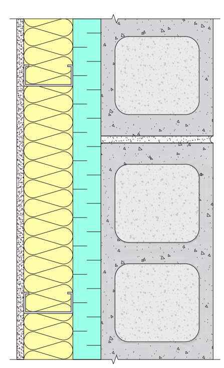
Option 4
R-12 Continuous Insulation



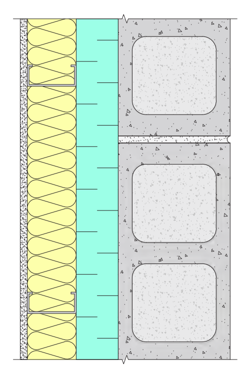
Option 5
R-24 Continuous Insulation



Option 6
R-24 Cavity Insulation



Option 7
R-15 Cavity Insulation
R-10 Continuous Insulation



Option 8
R-15 Cavity Insulation
R-15 Continuous Insulation

Fig. 8-23 Modeled insulation options for the interior insulated single-wythe CMU

Chapter References

1. Laws of 2007, ch. 189, Sixth-sixth General Assembly of the State of Colorado. (2007).

2. International Code Council. *2003 IECC International Energy Conservation Code, Sixth Printing* (Country Club Hills, IL: International Code Council, Inc., 2005).

3. *Resolution #36 On-Site Construction and Safety Codes for Motels, Hotels and Multi-Family Dwellings in Those Areas of the State Where No Such Standards Exist*, 8 CCR 1302-8, Department of Local Affairs, Division of Housing, State Housing Board of the State of Colorado (2018).

4. International Code Council. *2015 IECC International Energy Conservation Code* (Country Club Hills, IL: International Code Council, Inc., 2015).

5. *Resolution #35 Factory-Built Nonresidential Structures*, 8 CCR 1302-11, Department of Local Affairs, Division of Housing, State Housing Board of the State of Colorado (2018).

6. International Code Council. *2009 IECC International Energy Conservation Code, 10th Printing* (Country Club Hills, IL: International Code Council, Inc., 2013).

7. International Code Council. *2012 IECC International Energy Conservation Code* (Country Club Hills, IL: International Code Council, Inc., 2012).

8. International Code Council. *2018 IECC International Energy Conservation Code* (Country Club Hills, IL: International Code Council, Inc., 2012).

9. Colorado Department of Local Affairs. *Colorado Energy Codes*. https://www.colorado.gov/pacific/dola/colorado-energy-codes-0

10. *Amendments to the Building and Fire Code for the City and County of Denver* (adopted by the City and County of Denver, CO, March 7, 2016).

11. *2015 International Energy Conservation Code with Local Amendments* (adopted by City of Fort Collins, CO City Council, July 17, 2017).

12. *Resolutions 2015-104 & 2016-96: Amendments to Boulder County Building Code* (updated by Boulder County, October 10, 2017).

13. *2017 City of Boulder Energy Conservation Code* (adopted by City of Boulder, March 7, 2017).

14. *Energy Conservation Code of Arapahoe* (adopted by Arapahoe County, n.d.).

15. *Code of the City of Arvada, Colorado*. Chapter 18 article VI (adopted by Order of the [Arvada] City Council, August 26, 2017).

16. *City Code of the City of Aurora, Colorado*. Article VI § 26 (adopted by City of Aurora, Colorado, n.d.).

17. *The 2015 Jefferson County Building Code Supplement* (adopted by Jefferson County, January 1, 2016).

18. *Lakewood Building Code*, Title 14 of Municipal Code (adopted by City of Lakewood, 2018).

19. *County of Larimer, Colorado Amendments to the 2015 International Energy Conservation Code* (adopted by Board of Commissioners of Larimer County Colorado, March 7, 2016).

20. ASTM International. *ASTM E779-10 Standard Test Method for Determining Air Leakage Rate by Fan Pressurization* (West Conshohocken, PA: ASTM International, 2010).

21. City of Fort Collins. *Building Air Leakage Test Protocol* (Fort Collins, CO: City of Fort Collins, 2011).

22. City of Fort Collins. *Building Code Protocol for New Multifamily Building Airtightness Testing* (Fort Collins, CO: City of Fort Collins, 2017).

23. ASTM International. *ASTM E1186-03(2009) Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems* (West Conshohocken, PA: ASTM International, 2009).

24. The Northwest Masonry Institute and Masonry Institute of Washington. *National Masonry Systems Guide: Northwest Edition* (Seattle, WA: MIW, 2018).

25. ASTM International. *ASTM E2178-13 Standard Test Method for Air Permeance of Building Materials* (West Conshohocken, PA: ASTM International, 2013).

26. ASTM International. *ASTM E2357-11 Standard Test Method for Determining Air Leakage of Air Barrier Assemblies* (West Conshohocken, PA: ASTM International, 2011).

27. ASTM International. *ASTM E1677-11 Standard Specification for Air Barrier (AB) Material or System for Low-Rise Framed Building Walls* (West Conshohocken, PA: ASTM International, 2011).

28. ASTM International. *ASTM E283-04(2012) Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Difference Across the Specimen* (West Conshohocken, PA: ASTM International, 2011).

29. The Air Barrier Association of America (website), accessed May 25, 2018, www.airbarrier.org.

30. The Masonry Society. *TMS-402/602-16 Building Code Requirements and Specification for Masonry Structures* (n.p.: The Masonry Society, 2016).

31. 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).

32. American Society of Heating, Refrigerating and Air-Conditioning Engineers. *2017 ASHRAE Handbook Fundamentals* (Atlanta: ASHRAE, 2017).

33. Lawrence Berkeley National Laboratory. *THERM* (version 7.5.13). Windows, Berkeley, CA: Lawrence Berkeley National Laboratory, 2017, https://windows.lbl.gov/software/therm/therm.html.

34. BLOCON SWEDEN. *HEAT3-Heat transfer in three dimensions* (version 8.02 2017. Windows. Lund, Sweden: BLOCON SWEDEN, 2017, http://www.buildingphysics.com/index-filer/Page691.htm.

35. International Organization for Standardization. ISO 14683:2017 Thermal Bridges in Building Construction (ISO, 2017).

36. Morrison Hershfield Limited. *Building Envelope Thermal Bridging Guide v1.1* (Vancouver, BC: BC Hydro Power Smart, 2016).

Appendix: Thermal Modeling

Thermal modeling for this guide was undertaken using HEAT3.1.[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.

Table A-1 Material conductivities used for thermal modeling

Material	Thermal Conductivity Btu·in/hr·ft·°F (W/m·K)
Masonry veneer	5.5 (0.79)
Mortar	5.0 (0.72)
Cement Board	1.73 (0.25)
¾-inch grout with metal lathe	32.6 (4.7)
Air cavities at varying thicknesses	Varies*
Polypropylene (in ½-inch 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)
½-inch Exterior gypsum	0.90 (0.13)
½-inch Plywood – Douglas Fir	0.65 (0.093)
Wood 2x SPF	0.83 (0.12)
Fiberglass batts 5.5-inch R-21	0.26 (0.0379)
Fiberglass batts 7.2-inch R-30	0.24 (0.0348)
Fiberglass batts 3.625-inch R-15	0.24 (0.0348)
Fiberglass batts 6-inch R-21	0.29 (0.0411)
½-inch Interior gypsum	1.1 (0.16)
Concrete (including reinforcing)	13.9 (2)
8-inch 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.

Additional modeling parameters include the following:

- Material properties used are based on the following references:
  - ASHRAE Handbook - Fundamentals [2]
  - ASHRAE Standard 90.1 [3]
  - Product testing data
  - NFRC 101 [4]
- 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.
- Modeling was completed for 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.
- 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.

References

1. Blocon USA. "HEAT3 - Heat transfer in three dimensions." https://buildingphysics.com/heat3-3/ (retrieved June 14, 2018).
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.
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)	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. Air control layer systems are assembled from *materials* incorporated in *assemblies* (or *components* 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: Material: 0.004 cfm/sf @ 0.3" WC Assembly/Component: 0.04 cfm/sf @ 0.3" WC Enclosure: 0.4 cfm/sf @ 0.3" WC 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.
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 *exfiltration* and leakage from outdoors to indoors is known as *infiltration*. 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, to control sealant joint depth, to act as a bond breaker to prevent three-sided sealant adhesion, and to provide an hourglass 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	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. See: Thermal Control Layer, Vapor Control Layer, Vapor Barrier, Air Control Layer (or Air Barrier System), Water Control Layer
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-Resistive 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.
Drainage Gap	A gap, highly permeable to gravity-driven water flow, that is located next to a water-resistive 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 counterflashings 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 is 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" ($gr/h{\cdot}ft^2{\cdot}in.\ Hg$).
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 and installed to act as 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 enclosure 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.

ISBN 978-0-692-07924-9

9 780692 079249

$100 USA $131.50 CAN