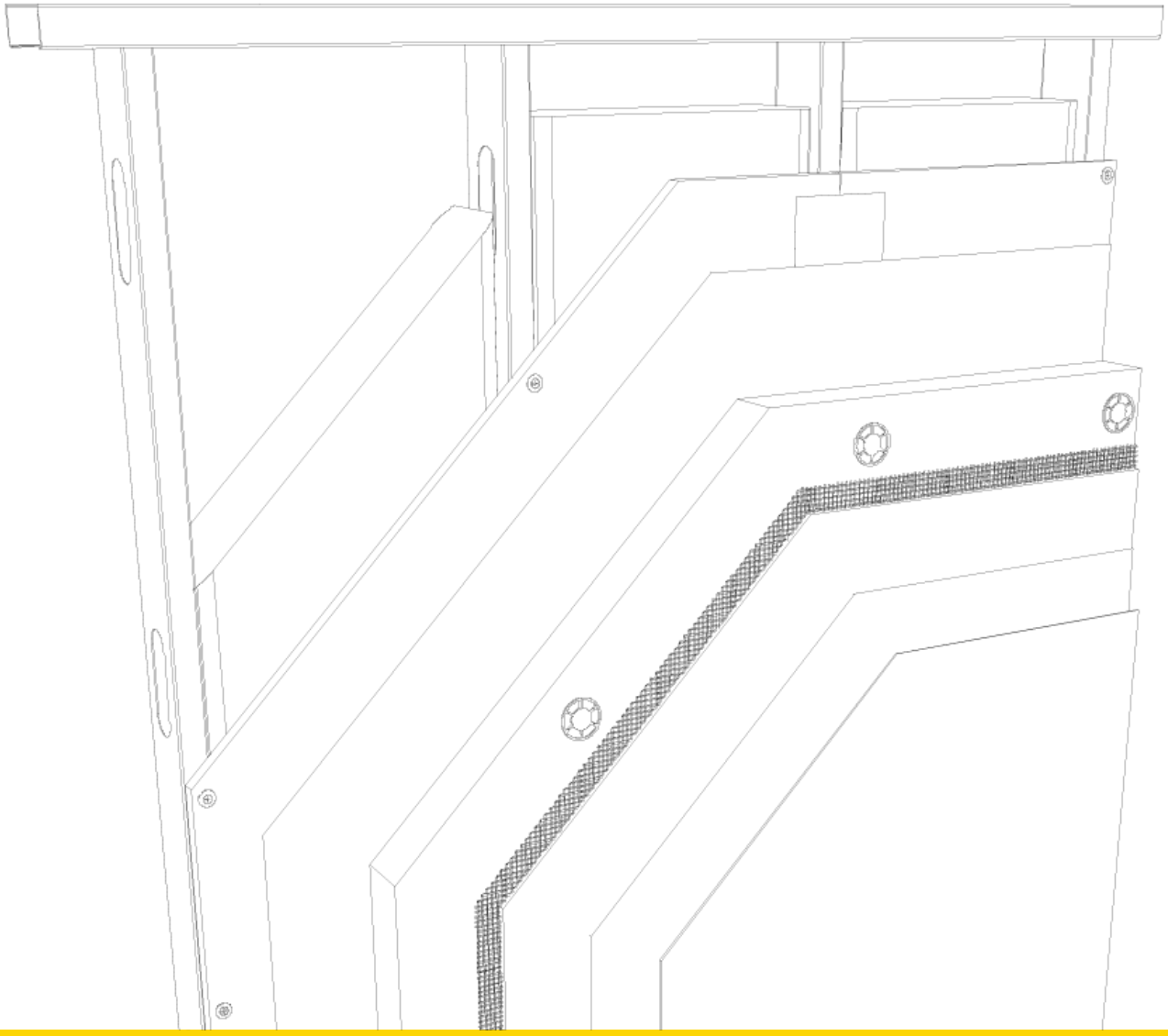
Building with conscience.

Design Guide

StoTherm® ci Mineral

October 2018



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1. INTRODUCTION

The StoTherm® ci Mineral System is a decorative and protective exterior wall system that combines superior air and weather tightness with excellent thermal performance and fire resistance. It incorporates noncombustible continuous exterior insulation and a continuous air and moisture barrier with Sto's high performance finishes to produce an advanced high performance wall cladding assembly.

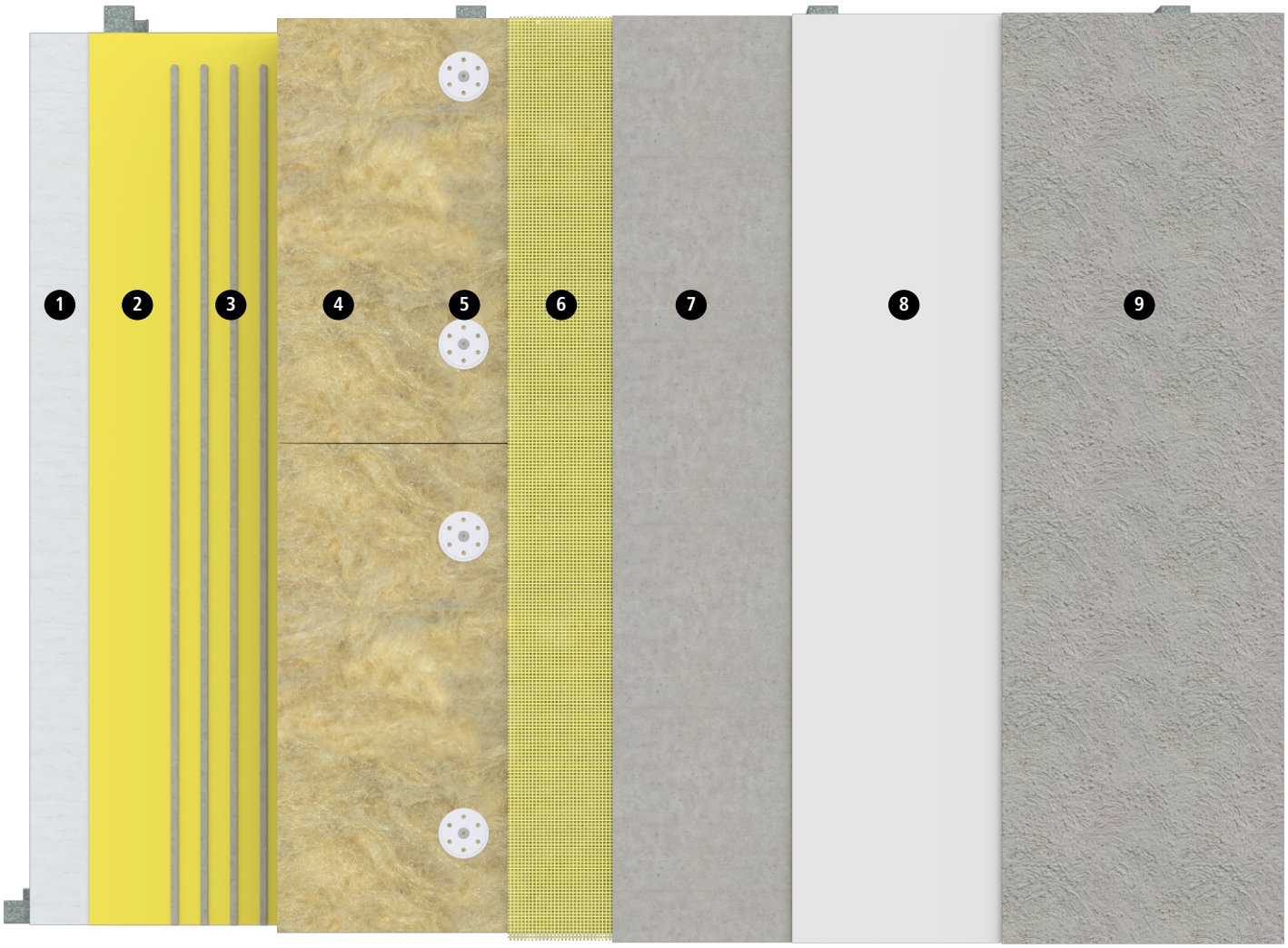
This technical design guide is intended for architects, specifiers, engineers, and contractors as an aid to understanding the system, its features and performance. For standards and other documents referenced in this publication, see References listed on p.25-27.

Features and Benefits

- Specially designed thermal dowel attachment system - limits thermal conductivity to the exterior
- Fully integrated high density mineral wool core - continuous exterior thermal control layer that resists fire and temperatures in excess of 2000°F (1093°C)
- Fully integrated seamless air and moisture barrier - fully compatible air, water, and vapor control layer from a single source
- Virtually unlimited finish color selection in multiple textures - color and texture design freedom

2. System Components

1. Substrate (by others)
2. StoGuard® Air and Moisture Barrier
3. Sto BTS Plus Adhesive
4. Owens Corning Thermafiber® CI-C SC18 Mineral Wool Insulation Board
5. Sto Thermo Dowel
6. Sto Mesh (embedded in Sto Base Coat)
7. Sto BTS Plus Base Coat
8. StoPrime Sand (optional)
9. Sto Textured Finish



3. Fire Safety

The StoTherm ci Mineral System has several features that enhance fire protection of the building and its occupants:

- The insulation:
  - » is noncombustible (NFPA 220) and continuous
  - » is a Class A building material with 0 flame spread and smoke development (ASTM E84)
  - » can withstand temperatures above 2000°F (1093°C) while still resisting fire
  - » maintains the hourly rating of concrete, concrete masonry, and non-load-bearing steel frame wall assemblies
- Other components of StoTherm ci Mineral are Class A building materials with low flame spread and smoke development.
- StoTherm ci Mineral has a narrow cavity and stays in place during a fire, thus minimizing any chimney effect.
- The air barrier component of StoTherm ci Mineral is bound between two noncombustible materials - gypsum sheathing and mineral wool - and is therefore unexposed in the event of a fire.

These design features exempt the mineral wool based system from NFPA 285 and NFPA 268 testing that is typically required for similar foam plastic-based insulated wall assemblies, and permit its use on Types I, II, III and IV (noncombustible) construction without height or setback limitations.

The few external combustible materials used in StoTherm ci Mineral, (PVC accessories), comprise a very limited amount of combustible material that is encased in the cementious base coat when installed. In this context they are considered not to pose a risk of excess flaming or fire spread.

4. Thermal Control

Continuous exterior insulation is an effective and practical way to insulate a wall. Stud cavity insulation is only partially effective in insulating a wall since the studs are thermal bridges that conduct heat energy towards the exterior (or interior if in a cooling climate) and as much as 50% of R-value can be lost through steel studs (See 2018 IECC Table C402.1.4.1, Effective R-Values for Steel Stud Wall Assemblies, p. C-32).

Building codes today prescribe minimum continuous insulation (ci) R-values for wall assemblies (Tables 2 and 3, Climate Zone Map p.11). These values are readily achieved with the insulating component of StoTherm ci Mineral , with a ci R-value of 4.0 per inch.

Table 2. 2018 IECC ci R-value requirements for above grade frame walls[1] and mass walls[2], non-residential occupancies

CLIMATE ZONE	1	2	3	4	5	6	7	8
METAL FRAME	R-13 + R-5 ci	R-13 + R-5 ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5 ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci
WOOD FRAME	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-3.8ci or R-20	R-13 + R-3.8ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5 ci or R-20 + R-3.8ci	R-13 + R-15.6 ci or R-20 + R-10 ci
MASS[1]	R-5.7ci	R-5.7ci	R-7.6ci	R-9.5ci	R-11.4ci	R-13.3ci	R-15.2ci	R-25ci

1. Does not include Group R occupancies. See Table 3.
2. For R-5.7ci some allowances provided for low thermal conductivity fill in un-grouted CMU cores.

Table 3. 2018 IECC ci R-value requirements for above grade frame walls and mass walls[1], residential buildings

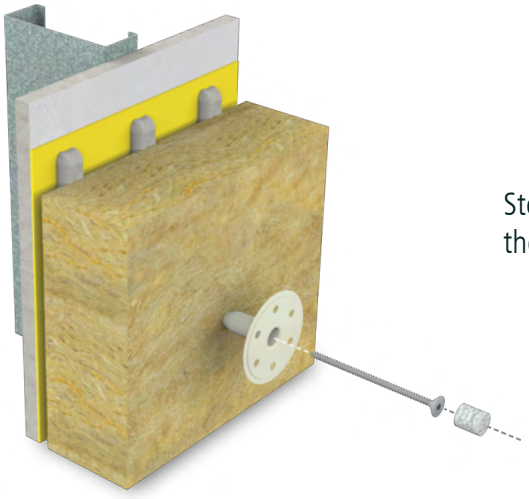
CLIMATE ZONE	1	2	3	4	5	6	7	8
METAL FRAME	Multiple options based on cold-formed steel frame equivalent R-values to wood frame walls. Refer to 2018 IECC Table R402.2.6, page R-31							
WOOD FRAME	R-13	R-13	R-20 or R-13 + R-5ci	R-20 or R-13 + R-5ci	R-20 or R-13 + R-5ci	R-20 + R-5ci or R-13 + R-10ci	R-20 + R-5ci or R-13 + R-10ci	R-20 + R-5ci or R-13 + R-10ci
MASS[1]	R-3/4	R-4/6	R-8/13	R-8/13[2]	R-13/17[3]	R-15/20	R-19/21	R-19/21

1. Mass walls do not require ci. Second R-value applies when more than half of the insulation is on the inside of the wall.
2. Except Marine 4
3. Includes Marine 4

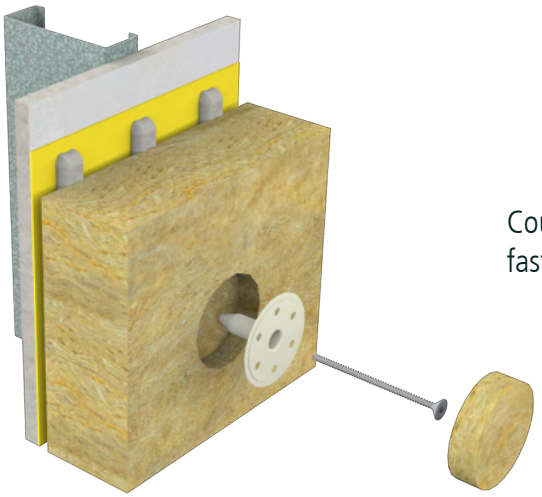
Other important aspects of the insulation system are:

- The mineral wool insulation component in StoTherm ci Mineral is an ASTM C612 compliant board. Its tensile and compressive strength, dimensional stability and dimensional tolerances are optimized for the direct application of Sto base coat, reinforcing mesh and finish coats. For complete information refer to the Product Bulletin at www.stocorp.com.
- The Sto Thermo Dowels used to attach the mineral wool insulation board are designed to minimize or eliminate thermal bridging. The dowels are made of low thermal conductivity material and employ a thermal plug or cap as a thermal break between fasteners and the finished exterior wall surface.
- For 2"(51mm) insulation thickness, the dowels are surface mounted and the fastener receives a thermal plug.
- For insulation thickness of 3 or 4 inches (76 or 102mm) the dowel is countersunk and covered with a Sto Thermo Cap Wool.

By insulating on the exterior and diminishing the thermal bridging effect of fasteners, StoTherm ci Mineral maximizes thermal efficiency and occupant comfort with reduced energy consumption and lower energy costs as compared to between-the-stud insulation.



Sto Thermo Dowel with thermal plug isolates the metal fastener from the exterior minimizing thermal bridging effects.



Countersunk Sto Thermo Dowel with thermal cap isolates the metal fastener and dowel, virtually eliminating thermal bridging effects.

5. Impact Resistance

Impact resistance is measured in accordance with ASTM E2486, a test method that uses a standard weight dropped at increasing heights to determine levels of impact resistance that can be achieved. Impact resistance is classified with four levels as outlined in Table 4.

Table 4: Impact resistance levels of StoTherm ci Mineral

IMPACT RESISTANCE LEVEL (in accordance with ASTM E2486)	Reinforcing Mesh needed to achieve Impact Resistance levels
Standard: 25-49 in-lb (2.8-5.6 J)	Pass with one layer Sto Mesh (4.5 oz/yd^2)
Medium: 50-89 in-lb (5.7-10.1 J)	Pass with one layer Sto Mesh (4.5 oz/yd^2)
High: 90-150 in-lb (10.2-17.0 J)	Pass with one layer Sto Mesh (6 oz/yd^2)
Ultra-High: Over 150 in-lb (>17.0 J)	Pass with one layer Sto Intermediate Mesh (11 oz/yd^2)

Note that impact resistance of StoTherm ci Mineral exceeds the levels achieved with a typical foam plastic-based system. For example, the standard grade of reinforcing mesh (4.5 oz) achieves medium impact resistance in the StoTherm ci Mineral system, and the ultra-high impact resistance level recommended for ground floors is achieved with one layer of intermediate mesh as opposed to the two mesh layers typically required for a foam plastic-based system. Areas other than standard or medium impact resistance should be delineated on elevation drawings to signal these special requirements to the contractor.

In general, an ultra-high level of impact resistance is recommended for ground floors to a minimum height of 6 feet (1.8m) and at other areas that may be exposed to abnormal stress or impact. In some cases, for example, urban areas with heavy pedestrian traffic, industrial areas with forklift traffic, or a hotel porte cochere with frequent vehicular traffic and luggage carts, an alternative material such as portland cement stucco, cement board stucco, stone, or tile, may be a more suitable finish as a wainscot or up to full first floor height.

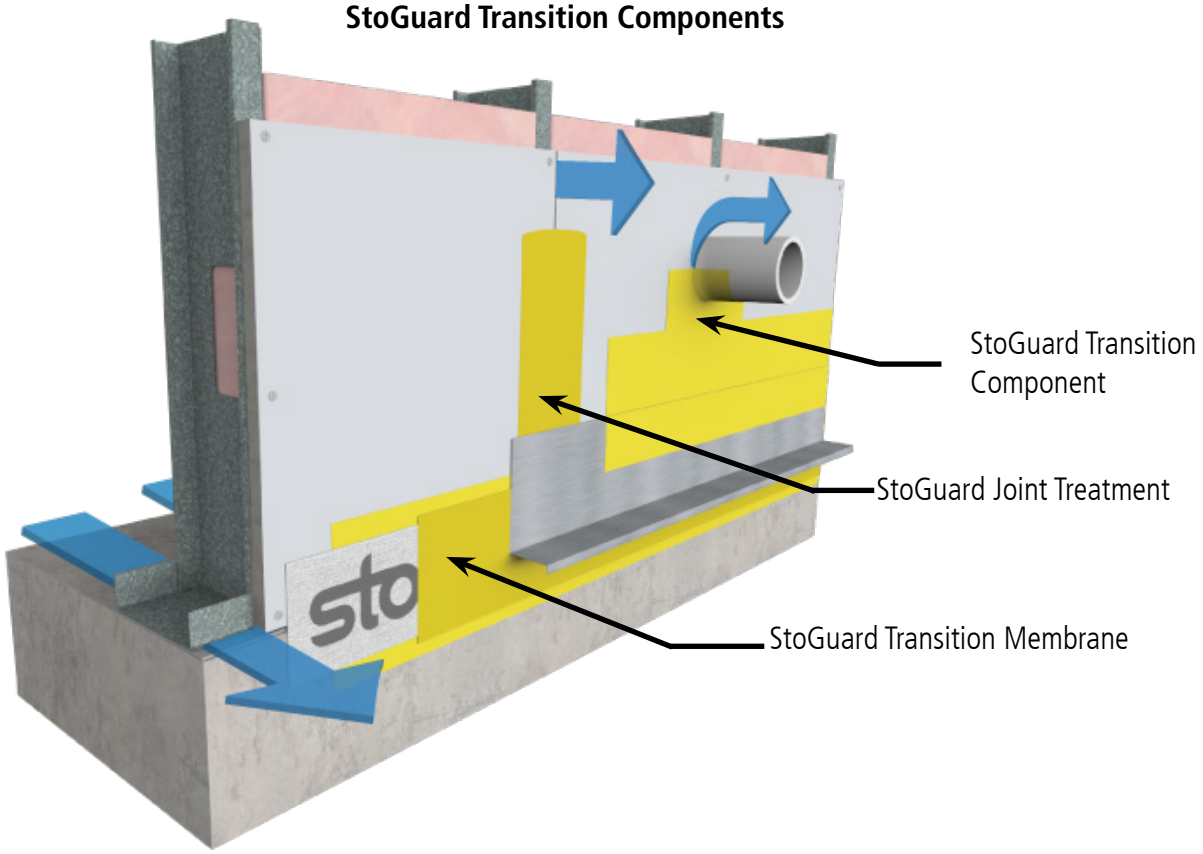
StoTherm ci Mineral , like other wall claddings, should be terminated above finished grade. This not only protects the system from ground water and staining or soiling, but it is also important for protection against weed trimmers and other landscaping tools that can damage the system at grade.

6. Air Leakage Control

Air leakage through the building envelope can be a source of condensation and water accumulation in walls. It is also a source of heat loss in cold months and a carrier of pollen and other airborne contaminants that can infiltrate and affect indoor air quality. Most building codes today require an air barrier in wall construction, which can enhance building durability, reduce energy consumption, and improve occupant comfort (see Effects from the Reduction of Air Leakage on Energy and Durability report: https://archive.airbarrier.org/library/ORNL_TM-2013_507.pdf).

For an air barrier to be effective it must be continuous. Connections with other air barrier components (e.g., roof material, foundation waterproofing) must be verified for compatibility along with connections to penetrations through the wall assembly – fenestration, scuppers, and dryer vents, for example. StoTherm ci Mineral includes compatible air barrier components for detailing at joints, seams, and rough openings, and for transitioning to other materials in wall construction. The primary air barrier material is a coating that can be applied by spray, roller, or brush (or trowel for some coatings). Both vapor permeable and vapor impermeable (vapor barrier) air barrier coatings are available. Refer to individual Product Bulletins and the StoTherm ci Mineral detail booklet for information on Sto Guard coatings, and StoGuard detailing and transition components, and where they are applied in wall construction.

Air Leakage Paths Detailed with StoGuard Transition Components



7. Condensation Control - Water Vapor Diffusion

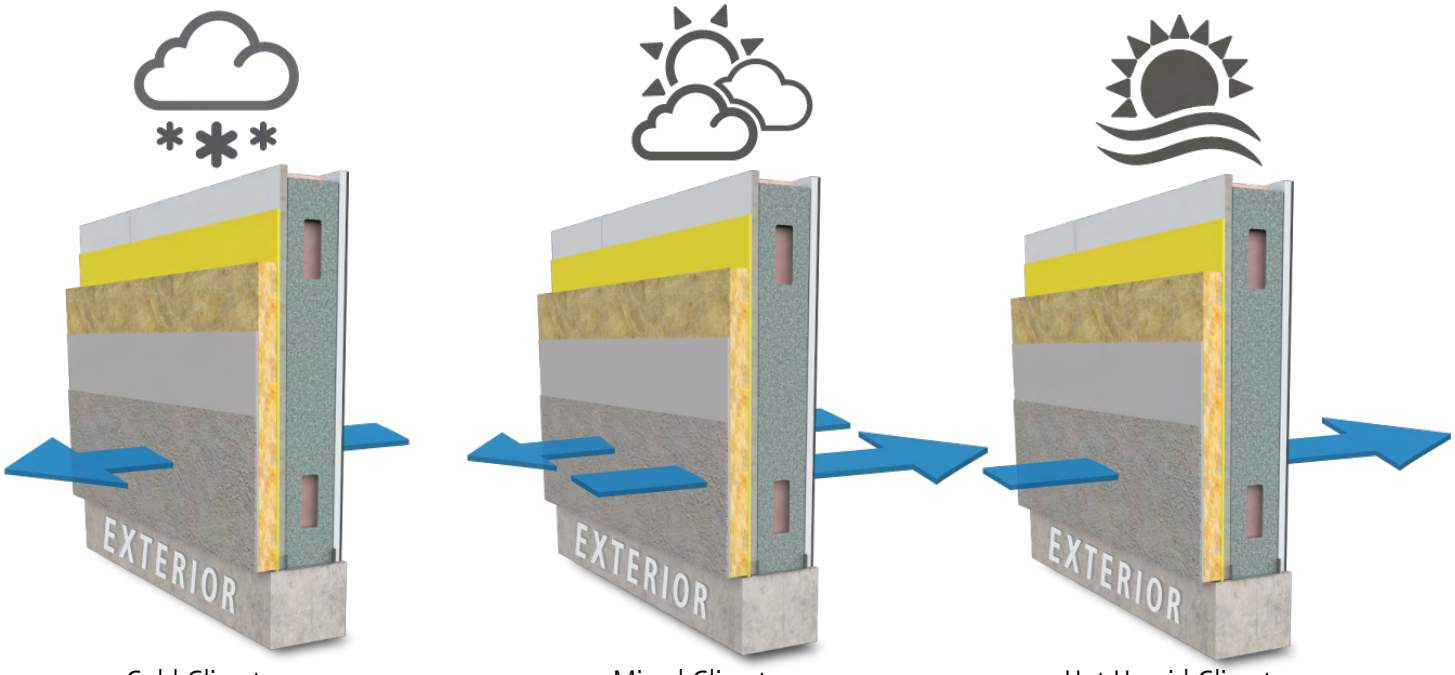
Condensation can occur in wall assemblies, not only along air leakage paths, but also as water vapor diffuses inward or outward through the assembly and reaches a cold surface that is at or below the dew point. The set of components that make up the wall assembly and their material properties (primarily thermal resistance and water vapor diffusion resistance) and the range of temperature and humidity conditions inside and outside determine whether condensation will occur in a wall. By placing sufficient insulation on the exterior in cold climate zones the potential for diffusion condensation (as opposed to air leakage condensation) can be eliminated in cold months by keeping wall components above the dew point.

Diffusion condensation can also be prevented by placing a vapor barrier in the correct location in the wall assembly to restrict movement of water vapor so it cannot move through the wall to a cold surface. In cold climates water vapor drive is primarily from inside to outside over the course of a year. Traditionally a vapor barrier has been placed on the warm-in-winter (interior) side of the wall in cold climates to restrict water vapor movement from the interior to the exterior. At times this practice has been extended to hot humid climates with the unintended consequence of causing condensation in wall cavities, because vapor drive in hot humid climates is primarily from outside to inside, and the dew point in a frame wall cavity is near the relatively cold conditioned interior environment.

Building codes today strive to diminish the risk of diffusion condensation with prescriptive requirements that permit more "vapor open" wall assemblies and that recognize the influence of exterior insulation on dew point and of low perm exterior insulation on drying potential of the wall assembly. "Vapor open" assemblies aid in seasonal drying of residual moisture in construction materials and in drying of incidental moisture in walls.

Building codes classify vapor barriers (and rename them vapor retarders) into three classes and prescribe their use (or non-use) over frame walls by Climate Zone (Table 5) and by whether or not low perm insulated sheathing is used to the exterior of the frame.

Climate and Primary Water Vapor Diffusion Direction

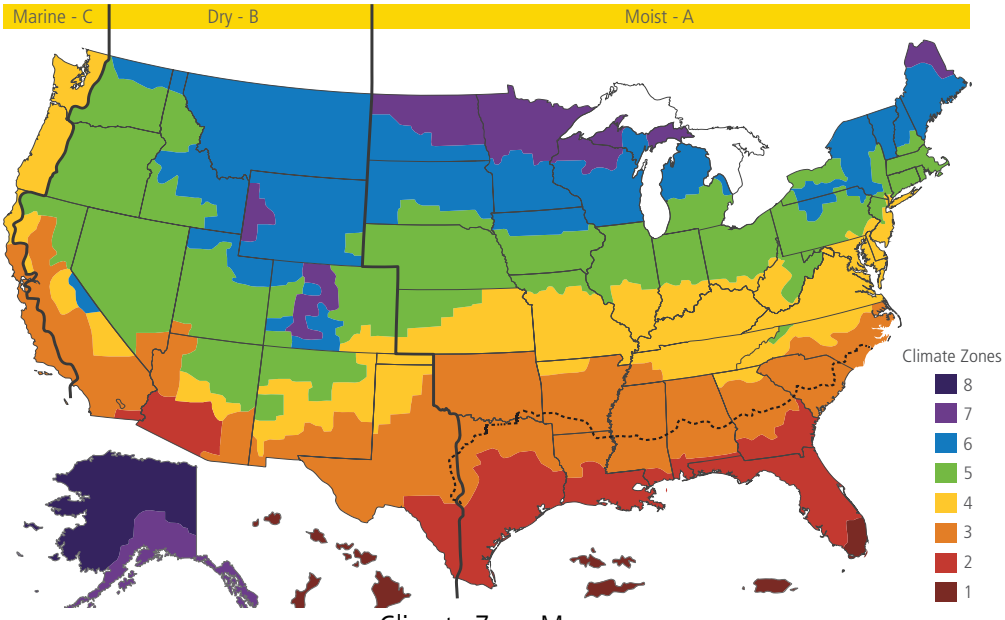


Cold Climate | Mixed Climate | Hot Humid Climate

Table 5: Prescriptive use of vapor retarders as defined by 2018 IBC for above grade walls[1]

VAPOR RETARDER CLASS	2018 IBC AND IRC DEFINITION	PRESCRIBED USE (OR NON-USE)
Class I	water vapor permeability less than or equal to 0.1 perms (e.g., sheet polyethylene)	Use on the interior side of frame walls in Zones 5, 6, 7, 8 and Marine 4 Not for use on the interior side of frame walls in Zones 1 and 2 Not for use on the interior side of frame walls in Zones 3 and 4 (except Marine 4)
Class II	water vapor permeability greater than 0.1 perms and less than or equal to 1 perm (e.g., kraft paper)	Use on the interior side of frame walls in Zones 5, 6, 7, 8 and Marine 4 Not for use on the interior side of frame walls in Zones 1 and 2
Class III	water vapor permeability greater than 1 perm and less than or equal to 10.0 perms	Use on the interior side of frame walls where foam plastic insulating sheathing with a perm rating of less than 1 is applied to exterior side of frame wall: Marine 4: ci R-value ≥ 2.5 over 2x 4 wall ci R-value ≥ 3.75 over 2x6 wall Zone 5: ci R-value ≥ 5 over 2x 4 wall ci R-value ≥ 7.5 over 2x6 wall Zone 6: ci R-value ≥ 7.5 over 2x 4 wall ci R-value ≥ 11.25 over 2x6 wall Zones 7 and 8: ci R-value ≥ 10 over 2x 4 wall ci R-value ≥ 15 over 2x6 wall

1. Note, allowance is also made for use of a Class III vapor retarder with vented cladding assemblies in Marine 4, Zone 5, and Zone 6. Basement walls and construction where moisture or its freezing will not damage the materials are also treated as Exceptions. Refer to 2018 IBC Table 1404.3.2



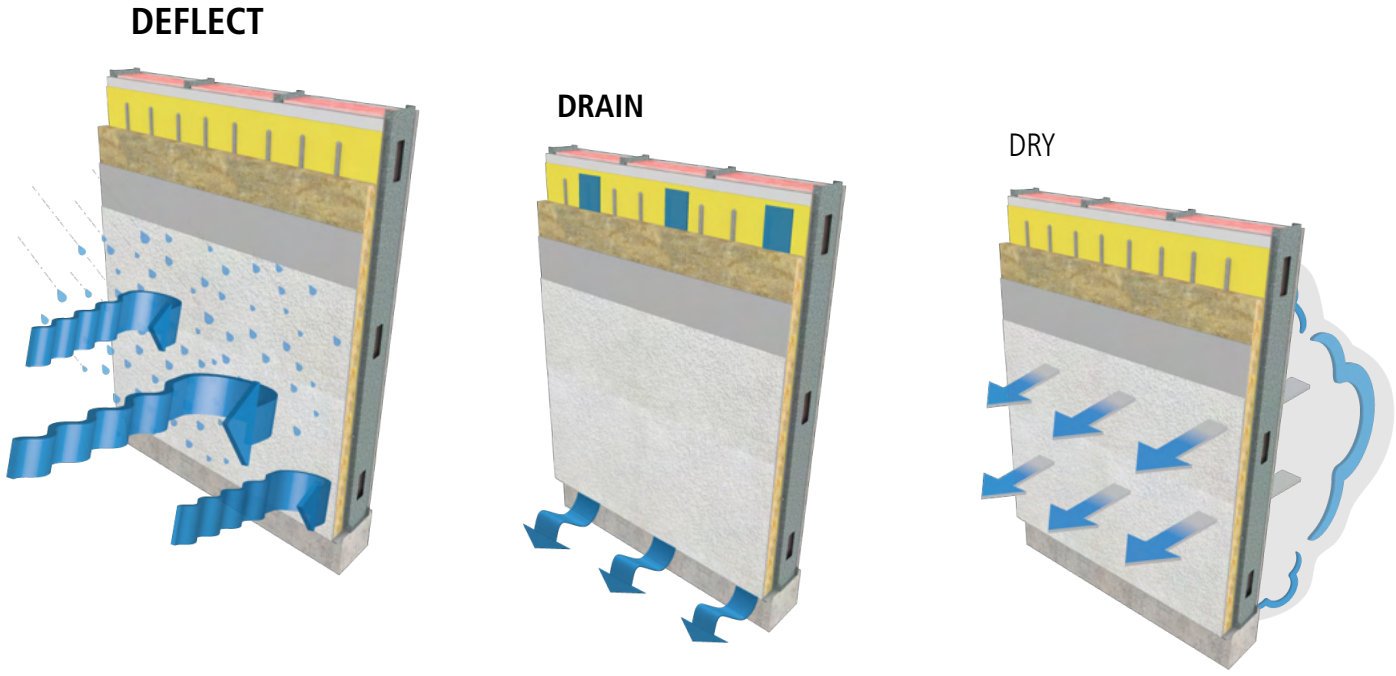
Climate Zone Map

Note that options often exist for which type of vapor retarder to use. Certain conditions like consistent elevated interior relative humidity in a cold climate may favor the lower perm Class I vapor retarder as opposed to a Class II. A final determination of which vapor retarder is best or whether one is needed at all can be made with hygrothermal modeling programs such as WUFI (Wärme Und Feuchtetransport Instationär -heat and moisture transport) that take into account initial moisture loads from residual moisture in construction materials, seasonal weather changes, interior temperature and relative humidity conditions, material properties of the components that make up the wall assembly, and other variables to predict condensation potential and relative humidity within wall section components.

The insulation in StoTherm ci Mineral is vapor permeable with a perm rating of 55 for 2 inch (51mm) thick insulation board and 28 for 4 inch (102mm) thick board. The lamina components are also vapor permeable.

Because StoTherm ci Mineral uses "vapor open" continuous insulation and lamina, it not only reduces the risk of diffusion condensation by keeping the temperature of back-up wall components above the dew point in cold months, but it also provides enhanced drying to the exterior in comparison to low perm foam plastic exterior insulation.

8. Water Management



The most effective way to "manage" water is to prevent it from getting through or into wall assemblies - DEFLECTION. This is accomplished not only through fundamentally sound design details (refer to Appendix: Sto Tech Hotline Nos. 0403-BSc and 0603 BSc) that direct water away from walls, but with non-porous facing materials that effectively resist rain water penetration. The outer "skin", or lamina, of StoTherm ci Mineral is an effective barrier against water penetration, unlike other more porous claddings such as uncoated stucco or masonry. The water barrier performance of StoTherm ci Mineral has been tested in accordance with ASTM E331 with no water penetration through the lamina (see p.20-22 for test summaries). In addition StoTherm ci Mineral has very few joints that disrupt the continuity of the barrier, thus minimizing reliance on caulks and sealants to maintain waterproofing integrity at the outer face of the wall. In tandem with proper flashing and design details the lamina prevents water from entering the wall to keep it dry and avoid troubles – corrosion, rot, and mold – that water intrusion into walls can cause.

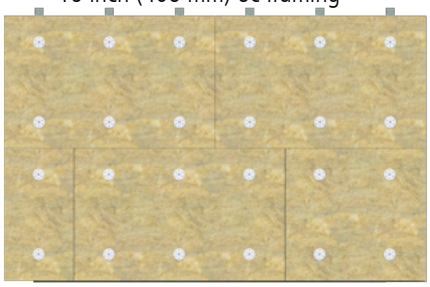
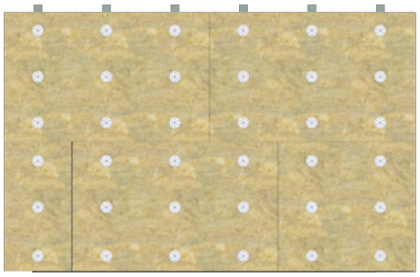
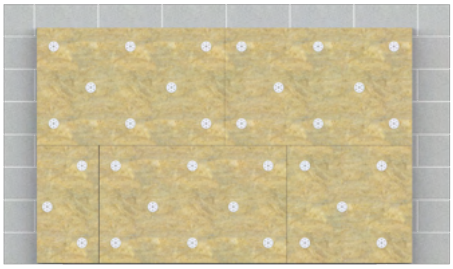
Other water management controls built into StoTherm ci Mineral are:

- The air barrier component is also a code compliant water-resistive barrier (WRB). It does double duty by minimizing air leakage and any associated condensation in the wall assembly, and it is a second barrier against water infiltration, should water ever get past the outer "skin" (lamina).
- A DRAINAGE plane is built into the system, formed by the vertical ribbons of adhesive used for initial attachment of the insulation board to the substrate. The drainage channels direct incidental water to flashing located at floor lines, window heads, and other horizontal terminations. Drainage efficiency in excess of 90% is achieved based on testing in accordance with ASTM E2273 (see p.20-22 for test summaries).
- The "vapor open" characteristics described previously for StoTherm ci Mineral aid in DRYING to the exterior in the event incidental water gets into the wall assembly through a breach in the StoTherm ci Mineral wall covering.

9. Wind Load Resistance

Wind load resistance of StoTherm ci Mineral Wool is achieved with dowels, not adhesive, as the means of attachment to the structure (the adhesive supports the insulation board by resisting gravity loads). In most cases, one of three dowel patterns will be used, with a minimum of 6, and a maximum of 9 fasteners per insulation board (Table 6). While other fastening patterns are possible, testing or analysis should always be done by a qualified engineer to verify adequacy of the proposed fastening pattern relative to design wind pressures. Frequency and spacing of dowels is the most important consideration in resisting wind loads, as the typical failure mode is "pulling" of the insulation over the dowels under negative wind pressure. This assumes supporting construction – typically wood or steel frame with sheathing, or masonry wall construction – is capable of resisting loads. The supporting construction must be designed with an allowable deflection limit of L/240. The maximum stud spacing for StoTherm ci Mineral is 16 inches (406mm) on center for frame wall construction.

Table 6. Wind load resistance of StoTherm ci Mineral

StoTherm ci Mineral AVG Negative Wind Load Test Results (ASTM E330)				
FASTENING PATTERN	**MINERAL WOOL THICKNESS: 2 and 3 in (52 and 76 mm)**		**MINERAL WOOL THICKNESS: 4 in (102mm)**	
16 inch (406 mm) oc framing 	6 Fasteners per Board- Surface Mount or Countersunk (3 in [76mm] only)	-54.1 lb/ft^2 (-2.59 kPa)	6 Fasteners per Board- Countersunk	-95.8 lb/ft^2 (-4.58 kPa)
16 inch (406 mm) oc framing 	9 Fasteners per Board- Surface Mount or Countersunk (3 in [76mm] only)	-77.8 lb/ft^2 (-3.73 kPa)	9 Fasteners per Board- Countersunk	-126 lb/ft^2 (-6.03 kPa)
Solid substrate - CMU or Wood 	8 Fasteners per Board- Surface Mount or Countersunk (3 in [76mm] only)	-54.1 lb/ft^2 (-2.59 kPa)	8 Fasteners per Board- Countersunk	-95.8 lb/ft^2 (-4.58 kPa)

NOTE: Average positive load: 253 lb/ft^2 (12.1 kPa). All test results based on 18 Gage Framing at 16" (406mm) in center with 6" (152mm) deep steel studs.

Wind Load Resistance cnt'd...

Table 7. Fasteners for StoTherm ci Mineral

Insulation Board Thickness	Surface Mount or Countersunk	Metal Framing	Wood Framing	Concrete
2" (51 mm)	Surface mount	2" Thermo Dowel S	2" Thermo Dowel W	not available
3" (76 mm)	Countersunk	3" Thermo Dowel S	3" Thermo Dowel W	3" Thermo Dowel C
4" (102mm)	Countersunk	4" Thermo Dowel S	4" Thermo Dowel W	4" Thermo Dowel C

10. Acoustic Control

Mineral wool insulation is commonly used between the studs in frame wall assemblies to reduce sound transmission from one room to another (or from the outside to the interior). The StoTherm ci Mineral System provides further reductions in sound transmission through exterior wall assemblies with its dense, continuous layer of mineral wool insulation.

A common measurement for sound attenuation through wall assemblies is sound transmission loss (ASTM E90), which measures the ability of the wall assembly to block sound at a given frequency. Based on measurements at different frequencies, aimed at blocking sounds from speech, a composite rating, Sound Transmission Class (STC), is calculated in accordance with ASTM E413. Similarly, a rating for attenuation of lower frequency sounds, aimed at blocking sounds from outdoors (e.g., airplanes, cars, trains), Outdoor-Indoor Transmission Class (OITC), is calculated in accordance with ASTM E1332.

A StoTherm ci Mineral wall assembly was tested to determine its OITC rating. Test results show effectiveness of the mineral wool-based system in blocking outdoor-indoor sound transmission with a rating of 45 as compared to the base wall assembly rating of 43.

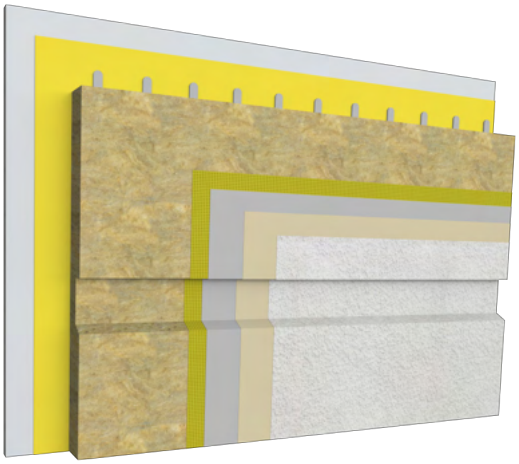
Table 8: OITC ratings of wall assemblies

WALL ASSEMBLY DESCRIPTION	OITC
Base wall assembly: 6 inch (152mm) metal studs with R-19 unfaced batt insulation, 5/8 (16mm) gypsum wallboard interior, 5/8 inch (16mm) glass mat gypsum sheathing exterior	43
Base wall assembly plus StoTherm ci Mineral with 4 in (102mm) insulation	45

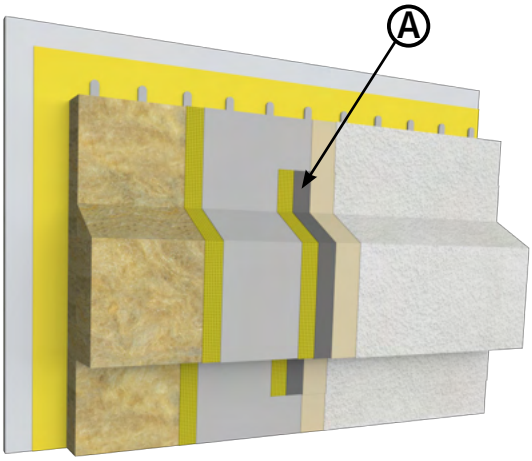
11. Aesthetic Design Elements

StoTherm ci Mineral offers virtually unlimited finish color selection and multiple finish textures. While similar foam plastic-based systems limit the use of dark colors because of service temperature limits (typically 165°F [73.8°C]) of foam plastic insulating materials, the StoTherm ci Mineral System does not have these dark color restrictions, since the insulation is unaffected by high temperature exposure.

Other aesthetic options such as reveals are accomplished with tools by scoring into the mineral wool making sure to leave a minimum 1-1/2 inch (38 mm) thickness at the base of the reveal. The location of reveal lines must be carefully planned relative to the location of "dowel lines" with a minimum distance of 3 inches (76mm) from any edge of the reveal to the edge of a dowel. Architectural features such as trim around windows and doors, pilasters, or other decorative features can be added to the assembly using mineral wool insulation build-outs, or by varying the thickness of the insulation. Horizontal trim, feature bands (and reveals) must have a minimum 6:12 slope to shed water along their top surface (or bottom surface of reveals) and are limited to a maximum 2 inch (51mm) build-out dimension unless protected with waterproofing or flashing.

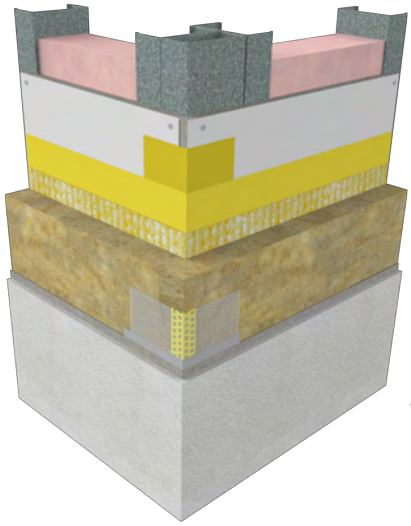


Typical Aesthetic Reveal

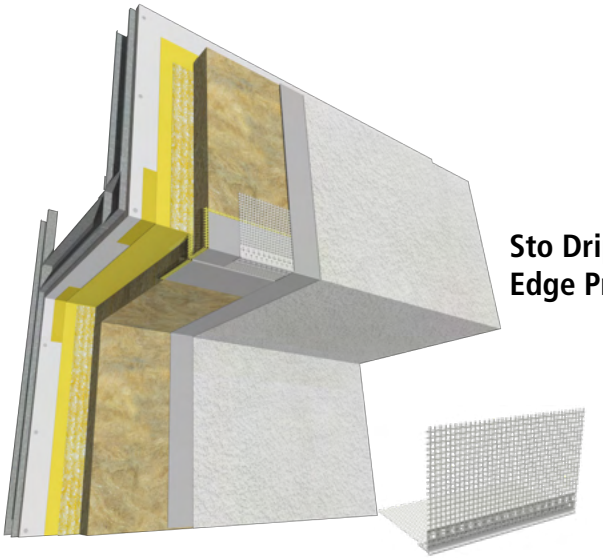


Thick Build Out with Added Waterproofing Component (A)

For additional reinforcement and crisp straight lines at corners and terminations, several accessories are used to enhance aesthetics as shown below.



Sto-Mesh Corner Bead Standard



Sto Drip Edge Profile

Two important aesthetic considerations of StoTherm ci Mineral are:

1. Surface mount thermal dowels with fasteners can potentially "read" through the finished wall surface, particularly on facades that experience frequent rain events or condensing cycles. The rate of drying over the dowel differs from the immediate surrounding area. Eventually, as more and more cycles of wetting and drying occur each year, the aged appearance of the textured finish may differ over the dowels.

2. Mineral wool insulation boards have a slightly wavy surface, an inherent byproduct of the manufacturing process, which can show through the finished wall surface, particularly during periods of critical light, if careful attention is not given during application of the system.

Steps have been taken in the design and installation of the system to account for these limitations. The thermal dowels are designed with a thermal plug to minimize thermal bridging or can be countersunk (with 3 or 4 inch [76 or 102mm] insulation) to virtually eliminate thermal bridging to the exterior and any effects of frequent rain or condensing cycles.

Before commencing any plastering work the surface is inspected for dips, depressions, unevenness between insulation boards, and any other surface irregularities that could affect the aesthetics of the finished wall surface. The surface is "shaved" to correct offsets between boards and other surface irregularities, by using a trowel edge or scoring knife. Rasping, commonly used to correct surface imperfections in similar foam plastic-based systems, is not recommended, other than in very limited areas to correct small imperfections. Dips and depressions are pre-filled with base coat, and dowel heads (if surface mount) are spotted with base coat. An initial base coat layer with reinforcing mesh is then used to reinforce the entire surface and, when the first base coat layer is dry, a final layer of base coat is applied to "true up" the wall surface and eliminate or minimize any wavy appearance or other surface irregularities. The use of smooth or fine finish textures is discouraged. Minimum 1.5mm (medium) or heavier textures are preferred to minimize visibility of minor surface imperfections.

12. Joints

Typical working joints in StoTherm ci Mineral at floorline deflection joint and at dissimilar construction

Aesthetic joints (reveals) installed in the system serve two purposes: they are aesthetic shadow lines that become part of the overall aesthetic of the façade, and they serve as starting and stopping points for plaster application to eliminate cold joints on large unbroken walls. Functional joints are necessary in the system as follows:

- At expansion, deflection, control, or cold joints in supporting construction
- At changes in building height
- At dissimilar construction or materials
- At floor lines in multi-level wood frame construction

Functional joints are sized to correspond with anticipated movement. Joints are formed by terminating the system so it coincides with the edges of the joint in the supporting construction. Where the system abuts dissimilar materials a minimum ½"(13mm) gap is maintained between the terminating edge of the mineral wool and the abutting element (e.g., window or door frame or fixture penetration). Terminating edges of the mineral wool insulation are typically backwrapped and joints are filled with properly sized backer rod and compatible low modulus sealant to form an effective weatherseal. As with all claddings, joints must be periodically inspected and maintained to prevent water infiltration.

13. Sustainability

StoTherm ci Mineral features enhanced fire safety, energy efficiency, and built-in water management. The system offers fire protection, by blanketing the exterior in noncombustible ci and eliminating a cavity with chimney effect in the outer wall. At the same time, exterior ci reduces heating and cooling energy consumption and greenhouse gas emissions over the life of the building.

The company that stands behind the system, Sto Corp., and the manufacturer of the mineral wool insulation board, Thermafiber Inc., are committed to safety in manufacturing and in the built environment. Sto Corp. maintains ISO certified Quality Management and Environmental Management Systems that focus on safely producing quality products and the reduction of environmental impacts by reducing energy and greenhouse gas emissions, fine particulate matter and toxic air emissions, water consumption, and waste to landfill reductions. Sto worldwide has over 4,305,564,166 ft^2 (400,000,000 m^2) of insulated façade installed since 1965, with resulting reduction in carbon dioxide emissions of over 272,270,893 tons (247,000,000 metric tons).

For more information go to:

- http://www.stocorp.com/sustainability-us/
- https://www.owenscorning.com/corporate/sustainability

The durability and longevity of the StoTherm ci Mineral Wool System is another aspect of its sustainability. Sto mineral wool-based continuous exterior insulation systems have been installed in the US and Canada for over 25 years, and worldwide, for more than 50 years. Protection against water infiltration has always been one of their primary functions. Water is one of the most common sources of building envelope problems and deterioration of building materials. Yesterday's systems were designed with prevention of water infiltration at the outer face of the wall as the primary and only WRB. While today's systems retain that function, they are designed with a secondary moisture protection plane that also serves as an air barrier. The dual function of this air and moisture barrier component prevents condensation caused by air leakage, protects the substrate from water damage, and prevents ingress of moisture to the interior. The system is also equipped with a drainage plane, which, in conjunction with properly incorporated flashing details, is designed to evacuate incidental water, should it ever get through the outer lamina. These and other important functions of the system, such as resistance to salts, freeze-thaw cycles, and UV degradation, are validated by independent third party testing in accordance with accepted industry standards (see p.20-22 for test summaries).

14. Testing

Air and Moisture Barrier: Water Resistance Testing (ASTM E2570)

TEST	METHOD	REQUIREMENT	RESULT
Tensile Bond	ASTM C297	Average tensile bond strength greater than 15 psi (105 kPa)	Greater than 15 psi (105 kPa)
Freeze Thaw	ASTM E2485	No delamination or surface changes such as cracking or crazing when viewed by minimum 5X magnification	Pass
Water Resistance	ASTM D2247	No deleterious effects such as cracking or crazing	Pass
Water Vapor Transmission	ASTM E96	Shall be reported	Multiple grades available Vapor retarder grades: Class I: ≤ 0.1 perm Class II: > 0.1 and ≤ 1.0 perm Class III: > 1.0 perm and ≤ 10.0 perms Vapor permeable grade: > 10 perms
Water Penetration	ASTM E331	No visible water penetration at sheathing joints when viewed from the back of the panel	Pass
Durability		No cracking of the WRB as determined by visual examination within the field of the panel, at substrate joints, and at interface of the flashing. No visible water penetration at sheathing joints as viewed from the back of the panel.	Pass
Transverse Load	ASTM E1233		
Racking	ASTM E72		
Environmental Conditioning	ASTM E2570, par 8.5.3		
Water Penetration	ASTM E331		
Weathering		No cracking of the coating or bond failure between the WRB and substrate. No water penetration on the plane of the exterior facing side of the substrate.	Pass
Ultraviolet Light Exposure	ASTM D2898		
Accelerated Aging	ASTM E2570, par 8.6.2		
Hydrostatic Pressure	AATCC 127 (modified)		

Air and Moisture Barrier: Air Leakage Testing

TEST	METHOD	REQUIREMENT	RESULT
Air Leakage Resistance	ASTM E2178	< 0.004 cfm/ft² at 0.3 in ΔP (0.02 L/s/m²) at 75 Pa ΔP	Pass
Assembly Air Leakage Resistance[1]	ASTM E2357	< 0.04 cfm/ft² at 0.3 in ΔP (0.2 L/s/m²) at 75 Pa ΔP	Pass

1. Based on testing of joint treatment and detail components (no air barrier top coating)

StoTherm ci Mineral System Testing (ASTM E2568)

SYSTEM PERFORMANCE TESTS			
TEST	**METHOD**	**REQUIREMENT**	**RESULT**
Accelerated Weathering	ASTM G155	2000 hours	No deleterious effects when viewed under 5X magnification
Freeze-Thaw Resistance	ASTM E2485	10 cycles	No deleterious effects when viewed under 5X magnification
Salt Spray	ASTM B117	300 hour exposure	No deleterious effects
Tensile Bond Adhesion	ASTM C 297	Not applicable (see Note 1)	
Water Penetration Resistance	ASTM E331	No water penetration after 2 hours water spray at 6.24 psf (299 Pa) pressure differential	No water penetration
Water Resistance	ASTM D2247	14 day exposure	No deleterious effects
Impact Resistance	ASTM E2486	Standard: 25-49 in-lb (2.83-5.54J) Achieve with Sto Mesh 4.5 oz/yd2 (153 g/m2)	Standard impact resistance achieved with Sto Mesh 4.5 oz
		Medium: 50-89 in-lb (5.65-10.1J) Achieve with Sto Mesh 6 oz/yd2 (203 g/m2)	Medium impact resistance achieved with Sto Mesh 4.5 oz
		High: 90-150 in-lbs (10.2-17J) Achieve with Sto Intermediate Mesh 11.2 oz/yd2 (380 g/m2)	High impact resistance achieved with Sto Mesh 6 oz
		Ultra-High: > 150 in-lbs (17 J) Achieve with one layer Sto Armor Mat 15 oz/yd2 (509 g/m2) + one layer Sto Mesh	Ultra-high impact resistance (greater than 150 in-lbs [17 J]) achieved with Sto Intermediate Mesh 11 oz.
DRAINAGE EFFICIENCY TEST			
Drainage Efficiency	ASTM E2273	Greater than 90%	92%

Testing cnt'd..

StoTherm ci Mineral System Testing (continued)

COMPONENT PERFORMANCE TESTS			
TEST	**METHOD**	**REQUIREMENT**	**RESULT**
Physical Properties and Requirements of EPS	ASTM C578	Not applicable (see Note 2)	
Physical Properties and Requirements of Polyisocy-anurate	ASTM C1289	Not applicable (see Note 2)	
Alkali Resistance of Reinforcing Mesh	ASTM E2098	120 pli (21 N/mm)retained tensile strength	Pass

SYSTEM FIRE PERFORMANCE TESTS			
TEST	**METHOD**	**REQUIREMENT**	**RESULT**
Fire Endurance	ASTM E119	Maintain resistance of known, rated wall assembly	Maintains hourly fire resistance rating of concrete, concrete masonry, and non-load-bearing steel frame wall assemblies
Full-Scale Multi-Story Fire Test	NFPA 285	Not applicable (see Note 3)	
Ignition Resistance	NFPA 268	Not applicable (see Note 3)	

COMPONENT FIRE PERFORMANCE TESTS			
TEST	**METHOD**	**REQUIREMENT**	**RESULT**
Surface Burning	ASTM E84	Flame spread 25 or less Smoke developed 450 or less	<table><tr><td></td><td>Insulation</td><td>Lamina</td></tr><tr><td>Flame Spread:</td><td>0</td><td>5</td></tr><tr><td>Smoke Developed:</td><td>0</td><td>5</td></tr></table>

STRUCTURAL PERFORMANCE TESTS			
TEST	**METHOD**	**REQUIREMENT**	**RESULT**
Wind Load Resistance	ASTM E330	Report negative and positive wind load values	+253 lb/ft^2 (12.1 kPa) all dowel patterns
			- 54.1 lb/ft^2 (2.59 kPa) 6 dowels/bd (2 inch [52mm] thick)
			- 77.8 lb/ft^2 (3.72 kPa) 9 dowels/bd (2 inch [52mm] thick)
			- 95.8 lb/ft^2 (-4.58 kPa) 6 dowels/bd (4 inch [102mm] thick)
			-126 lb/ft^2 (-6.03 kPa) 9 dowels/bd (4 inch [102mm] thick)

1. Tensile bond adhesion testing may be used as a basis for extending results of full scale wind load tests conducted over gypsum sheathing to other substrates (see AC 235, Acceptance Criteria for EIFS Clad Drainage Wall Assemblies, published by ICC Evaluation Service, www.icc-es.org) when tensile bond test results average a minimum of 15 psi (103 kPa). This practice is typically applied to foam plastic-based assemblies. Because mineral wool insulation board has tensile strength normal to the face of the board of less than 15 psi (103 kPa) results of full scale tests (ASTM E330) must be used to determine ultimate wind load capacity of mineral-wool based assemblies.

2. ASTM C578 and ASTM C1289 are applicable to foam plastic insulating materials. ASTM C612 is the applicable standard for mineral wool board insulation.

3. Based on successful testing of similar foam plastic-based assemblies StoTherm ci Mineral with its non-combustible mineral wool insulation board is considered to be an acceptable substitute for foam plastic in the tested assemblies (see References - Jensen Hughes engineering judgements).

15. Building Code Compliance

IECC

StoTherm ci Mineral complies with the prescriptive ci R-value requirements for above-grade walls of Section C402.2 of the 2018 IECC. It also contributes to assembly U-value for above-grade walls when figuring compliance on the basis of U-factor.

The air barrier in StoTherm ci Mineral complies with Section C402.5 as an air barrier material based on testing in accordance with ASTM E2178 and as an air barrier assembly based on testing in accordance with ASTM E2357. It also meets the general requirements of Table R402.4.1.1 as "a continuous air barrier for the exterior thermal envelope…." Refer to ICC-ES ESR 1233 for certification of the air barrier material based on independent third party testing.

IBC and IRC

StoTherm ci Mineral complies with the requirements of Section 1407 of the 2018 IBC and Section R703.9.2 of the 2018 IRC. These Sections of the codes require that the wall system:

- Has a water-resistive barrier (WRB) that meets the performance requirements of ASTM E2570.
- Meets the performance requirements of ASTM E2568.
- Is designed with drainage and has an average minimum drainage efficiency of 90% when tested in accordance with ASTM E2273

Independent third party testing and evaluation confirms compliance with the above referenced code requirements. Refer to Pei Evaluation Service Report No. AER -18117 and ICC-ESR 1233

In addition StoTherm ci Mineral complies with Section 1402.5 of the 2018 IBC for use on buildings of Types I, II, III, or IV construction, without height limitation (other than height restrictions governed by design wind pressure limits of the system). Analysis by an independent third party fire protection engineering firm, Jensen Hughes, confirms that, "…mineral wool insulation can be used in lieu of the EPS or XPS insulation used in the previously tested NFPA 285 and NFPA 268 complying assemblies".

16. Precautions and Limitations

- Standard insulation board thickness: 2, 3 or 4 inches (51, 76, or 102mm).
- Keep insulation board dry during construction and while in service. R-value, adhesion and other properties can be compromised if insulation stays wet. Protect with tenting, base coat, or other protection to maintain insulation board integrity and properties.
- Wind load resistance: structural back-up wall assembly must be designed for maximum allowable deflection of L/240, normal to the plane of the wall. Stud spacing: 16 inches (406mm) on center maximum. Ultimate wind load resistance: positive 253 lb/ft^2 (12.1 lb/ft^2), negative 126 lb/ft^2 (-6.03kPa). Refer to Sto Design Guide for fastening details to achieve ultimate loads.
- Impact resistance: heavy reinforcing mesh layer (11 oz/yd2[373 g/m2]) or other design adjustments recommended for ground floors and other areas at risk of impacts or abuse.
- Not for use on horizontal or low slope surfaces, below grade, roofs or roof-like surfaces, or in areas of water immersion, pooling or ponding water. For use on vertical above grade walls only.
- Aesthetics: slight surface irregularities may be apparent in the finished wall surface for brief periods during the day in critical light. Smooth or fine texture finishes are discouraged. Minimum 1.5 mm (Medium) or heavier textures are preferred to hide surface imperfections. On some occasions, surface mount dowels may "read" through the finished wall surface as the building ages. This can be remedied by recoating (or prevented by using countersunk dowels).
- Air Barrier, insulation board, and base coat materials are not intended for permanent weather exposure. Refer to specific component product bulletins and packaging for other limitations that may apply involving use, handling and storage of component materials.

17. Appendix

A. Sto Tech Hotline No. 0403 BSc

B. Sto Tech Hotline No. 0603 BSc

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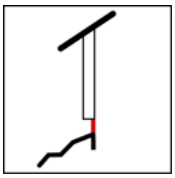
Appendix A
Tech Hotline

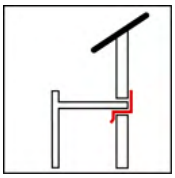
No. 0403-BSc

Critical Detail Checklist for Wall Assemblies

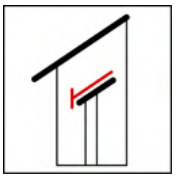
Water intrusion into wall assemblies has become a growing concern in the construction industry, yet water intrusion can be prevented simply by following sound construction practices that are required by model building codes. The list of details below illustrates some of the key areas of construction to pay attention to when designing, detailing or constructing walls.



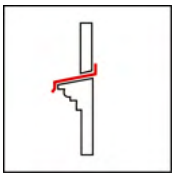
☐ 1. Terminate grade 8" (203 mm) below cladding



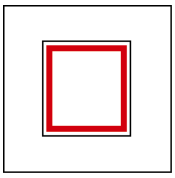
☐ 2. Provide flashing at decks



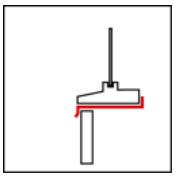
☐ 3. Provide diverter flashing at roof/sidewall terminations



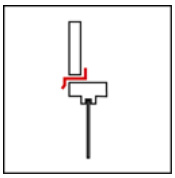
☐ 4. Provide flashing over build-outs



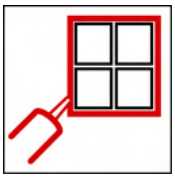
☐ 5. Protect rough openings



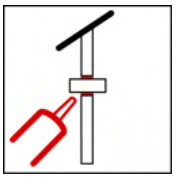
☐ 6. Provide sill flashing beneath windows and doors



☐ 7. Provide head flashing above windows and doors

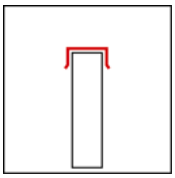


☐ 8. Seal around window and door penetrations

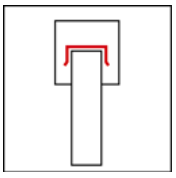


☐ 9. Seal around wall penetrations

☐ 10. Provide joints at required locations and seal



☐ 11. Provide coping over parapets



☐ 12. Provide saddle flashing at lower/higher walls

It has been said that, "As much as 90 percent of all water intrusion problems occur within 1 percent of the total building exterior surface area. The 1 percent of the structure's façade contains the terminations and transition detailing that all too frequently lead to envelope failures." [1] By paying close attention to construction details at cladding terminations, water intrusion can be prevented and building durability enhanced.

1. *Waterproofing the Building Envelope,* Kubal, Michael, T. (New York, 1993), p. 4.

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Appendix B
Tech Hotline

No. 0603-BSc
Revised: July, 2005

Moisture Control Principles for Design and Construction of Wall Assemblies

Moisture control is one of the basic requirements of a properly designed and constructed wall assembly. Without moisture control, problems such as degradation of moisture sensitive construction materials, mold growth, and poor indoor air quality can result. Listed below are basic principles that must be employed in design and construction of wall assemblies to control moisture.

Rain Water Penetration Control

- □ Develop and construct details that prevent rain water entry into walls.
- □ Protect against rain water penetration from potential leak sources such as windows and doors at their source with flashings that divert water to the exterior. Do not drain leaky construction components into the wall. Terminate flashings in daylight so water is deposited beyond the cladding.
- □ Minimize moisture load on walls from wind driven rain by designing with wide eaves, trim, recesses, drip edges, and other features that keep water off of walls.
- □ Protect non-vertical surfaces with flashing, coping, and/or waterproof materials.
- □ Recognize that complex roof lines funnel water to critical junctions in construction. Construct roof line details to accommodate increased water flow.
- □ Seal the perimeter of all penetrations through the wall with quality sealant materials. Inspect and maintain sealant through the life of the structure.
- □ Protect water-sensitive sheathing materials with Sto Guard fluid applied air/moisture barrier to prevent degradation from precipitation during construction and incidental moisture intrusion after construction.
- □ Whenever possible test complex details where multiple materials come together to verify performance and understand sequencing of work.

Condensation Control

- □ Provide a continuous air barrier *system* of interconnected air barrier *materials* around the building envelope to control air leakage and minimize the risk of condensation.
- □ Install vapor barriers in cold climates on the warm-in-winter side of the wall.
- □ Do not install interior vapor retarders in hot humid climates (to protect against warm moist air condensing behind the vapor retarder).
- □ Insulate metal frame construction on the exterior to avoid thermal bridging effects.
- □ Adjust rigid exterior insulation type and/or thickness in cold climates to move the dew point to the rigid insulation.
- □ Do a water vapor transmission analysis to determine whether or not there is any problem with condensation in the assembly and make appropriate adjustments to minimize condensation.
- □ Provide special analysis for buildings with very high or very low interior relative humidity conditions for all climates.
- □ Vent or remove excess humidity caused by the use of temporary heaters during construction. Vent or remove excess humidity during occupancy.

Mechanical Controls

- □ Pressurize interior space in hot humid climates with conditioned (dehumidified) air so that warm humid outside air is not drawn to the interior.
- □ De-pressurize the building slightly in cold climates to prevent exfiltration of warm/humid air into cold walls.
- □ Maintain interior relative humidity at all times within ASHRAE recommended guidelines to control microbial growth, to minimize condensation potential, and to provide occupant comfort. Follow ASHRAE recommendations when designing an air tight building envelope.

Last but not least, pay attention to construction details. For a list of critical details see Sto Tech Hotline No. 0403-BSc.

18. References

2018 IECC - International Energy Conservation Code, November 2017, https://basc.pnnl.gov/resources/2018-iecc-international-energy-conservation-code

AATCC, 2013, Water Resistance: Hydrostatic Pressure Test.

ASTM B117-18, Standard Practice for Operating Salt Spray (Fog) Apparatus, ASTM International, West Conshohocken, PA, 2018, www.astm.org

ASTM C612-14, Standard Specification for Mineral Fiber Block and Board Thermal Insulation, ASTM International, West Conshohocken, PA, 2014, www.astm.org

ASTM C297 / C297M-16, Standard Test Method for Flatwise Tensile Strength of Sandwich Constructions, ASTM International, West Conshohocken, PA, 2016, www.astm.org

ASTM C578-18, Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation, ASTM International, West Conshohocken, PA, 2018, www.astm.org

ASTM C1289-18, Standard Specification for Faced Rigid Cellular Polyisocyanurate Thermal Insulation Board, ASTM International, West Conshohocken, PA, 2018, www.astm.org

ASTM D2247-15, Standard Practice for Testing Water Resistance of Coatings in 100 % Relative Humidity, ASTM International, West Conshohocken, PA, 2015, www.astm.org

ASTM D2898-10(2017), Standard Practice for Accelerated Weathering of Fire-Retardant-Treated Wood for Fire Testing, ASTM International, West Conshohocken, PA, 2017, www.astm.org

ASTM E84-18, Standard Test Method for Surface Burning Characteristics of Building Materials, ASTM International, West Conshohocken, PA, 2018, www.astm.org

ASTM E90-09(2016), Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements, ASTM International, West Conshohocken, PA, 2016, www.astm.org

ASTM E413-16, Classification for Rating Sound Insulation, ASTM International, West Conshohocken, PA, 2016, www.astm.org

ASTM E1332-16, Standard Classification for Rating Outdoor-Indoor Sound Attenuation, ASTM International, West Conshohocken, PA, 2016, www.astm.org

ASTM E2486 / E2486M-13, Standard Test Method for Impact Resistance of Class PB and PI Exterior Insulation and Finish Systems (EIFS), ASTM International, West Conshohocken, PA, 2013, www.astm.org

ASTM E330 / E330M-14, Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference, ASTM International, West Conshohocken, PA, 2014, www.astm.org

ASTM E331-00(2016), Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference, ASTM International, West Conshohocken, PA, 2016, www.astm.org

ASTM E2273-03(2011), Standard Test Method for Determining the Drainage Efficiency of Exterior Insulation and Finish Systems (EIFS) Clad Wall Assemblies, ASTM International, West Conshohocken, PA, 2011, www.astm.org

ASTM E2178-13, Standard Test Method for Air Permeance of Building Materials, ASTM International, West Conshohocken, PA, 2013, www.astm.org

ASTM E2357-17, Standard Test Method for Determining Air Leakage of Air Barrier Assemblies, ASTM International, West Conshohocken, PA, 2017, www.astm.org

References cnt'd..

ASTM E2570 / E2570M-07(2014)e1, Standard Test Methods for Evaluating Water-Resistive Barrier (WRB) Coatings Used under Exterior Insulation and Finish Systems (EIFS) or EIFS with Drainage, ASTM International, West Conshohocken, PA, 2014, www.astm.org

ASTM E2568-17a, Standard Specification for PB Exterior Insulation and Finish Systems, ASTM International, West Conshohocken, PA, 2017, www.astm.org

ASTM E2485 / E2485M-13(2018), Standard Test Method for Freeze/Thaw Resistance of Exterior Insulation and Finish Systems (EIFS) and Water Resistive Barrier Coatings, ASTM International, West Conshohocken, PA, 2018, www.astm.org

ASTM E96 / E96M-16, Standard Test Methods for Water Vapor Transmission of Materials, ASTM International, West Conshohocken, PA, 2016, www.astm.org

ASTM E1233 / E1233M-14, Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights, and Curtain Walls by Cyclic Air Pressure Differential, ASTM International, West Conshohocken, PA, 2014, www.astm.org

ASTM E72-15, Standard Test Methods of Conducting Strength Tests of Panels for Building Construction, ASTM International, West Conshohocken, PA, 2015, www.astm.org

ASTM E2098 / E2098M-13(2018), Standard Test Method for Determining Tensile Breaking Strength of Glass Fiber Reinforcing Mesh for Use in Class PB Exterior Insulation and Finish Systems (EIFS), after Exposure to a Sodium Hydroxide Solution, ASTM International, West Conshohocken, PA, 2018, www.astm.org

ASTM E119-18b, Standard Test Methods for Fire Tests of Building Construction and Materials, ASTM International, West Conshohocken, PA, 2018, www.astm.org

ASTM G155-13, Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials, ASTM International, West Conshohocken, PA, 2013, www.astm.org

BSI-091: Flow-Through Assemblies." Building Science Corporation, 13 Jan. 2016, buildingscience.com/documents/building-science-insights-newsletters/bsi-091-flow-through-assemblies.

CP-1101: The Influence of Low-Permeance Vapor Barriers on Roof and Wall Performance." Building Science Corporation, John Straube, 25 Mar. 2011, buildingscience.com/documents/confpapers/cp-1101-influence-low-permeance-vapor-barriers-roof-wall-performance/view.

IBC. "2018 International Building Code." CHAPTER 14 EXTERIOR WALLS | 2018 International Building Code | ICC PremiumACCESS, Aug. 2017, codes.iccsafe.org/content/IBC2018/chapter-14-exterior-walls.

IRC. "2018 International Residential Code for One- and Two-Family Dwellings." CHAPTER 7 WALL COVERING | 2018 International Residential Code for One- and Two-Family Dwellings | ICC PremiumACCESS, Aug. 2017, codes.iccsafe.org/content/IRC2018/chapter-7-wall-covering.

ICC-ES Evaluation Report." ICC Evaluation Service, LLC (ICC-ES), Feb. 2018, www.icc-es.org/. ESR-1233

NFPA 220, Standard on Types of Building Construction Scope, 2018, www.nfpa.org

NFPA 268, Standard Test Method for Determining Ignitability of Exterior Wall Assemblies Using a Radiant Heat Energy Source, 2017, www.nfpa.org

NFPA 285, Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Non-Load-Bearing Wall Assemblies Containing Combustible Components, August 2012, www.nfpa.org

References cnt'd..

Effects from the Reduction of Air Leakage on Energy and Durability, October 2013, https://archive.airbarrier.org/library/ORNL_TM-2013_507.pdf

Jensen Hughes Engineering Judgement -SUBSTITUTION OF MINERAL WOOL FOR FOAM PLASTIC INSULATION–NFPA 268, Sept. 2018

Jensen Hughes Engineering Judgement -SUBSTITUTION OF MINERAL WOOL FOR FOAM PLASTIC INSULATION–NFPA 285, Aug. 2018

Lstiburek, Joseph. "BSI-026: They All Laughed...." Building Science Corporation, 15 Jan. 2017, buildingscience.com/documents/building-science-insights-newsletters/bsi-026-they-all-laughed.

Pei Evaluation Service Report AER -18117, Oct. 2018, www.p-e-i.com

Shah, N., and V. Kochkin. "Moisture Performance of High-R Wall Systems." (United States), ASTM International, Materials Park, OH, 1 July 2018, www.osti.gov/biblio/1459497-moisture-performance-high-wall-systems.