

Vapor Diffusion

Vapor Diffusion and Condensation Control
for Commercial Wall Assemblies





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Contents

Vapor Diffusion and Condensation Control for Commercial Wall Assemblies	1
Understanding Vapor Diffusion	1
Understanding Vapor Barriers & Retarders.....	2
Understanding Air Leakage in Walls.....	3
Wrong Side and Double Vapor Retarders	4
Vapor Diffusion and Wall Assembly Design.....	5
Stud Cavity Insulated Walls	5
Exterior Insulated Walls	7
Split Insulated Walls	9
Exposed Concrete Interior Insulated Walls	11
Moisture Storing Claddings & Inward Vapor Drive.....	12
Summary.....	13

Vapor Diffusion and Condensation Control for Commercial Wall Assemblies

Ever more stringent energy code requirements have necessitated increased insulation levels for non-combustible (i.e. steel stud, CMU, concrete) walls, and in many cases this includes adding exterior insulation. Additional insulation thickness and changes to the insulation location require reconsideration with regards to vapor diffusion and condensation control.

Varying vapor permeability of different insulation products, membranes and other building materials introduces significant complexity to wall assembly design. Some insulation materials, like mineral wool and fiberglass, are vapor permeable, while others, like XPS, EPS, polyisocyanurate and closed-cell spray foam, are relatively impermeable.

Energy codes are silent on the issue and building codes can be confusing as it relates to exterior insulation selection and vapor diffusion control for walls.

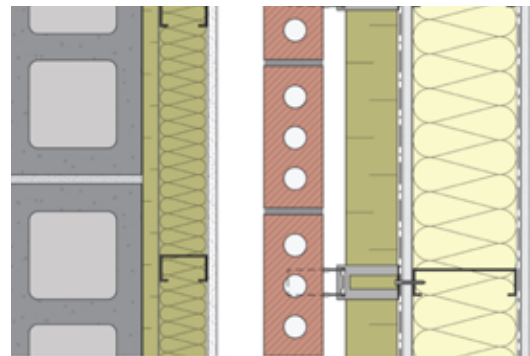
This bulletin clarifies and provides guidance on vapor diffusion and condensation control in these new wall assemblies.

An exterior wall physically separates the outdoor and indoor environments. The differences in temperature, moisture, and air pressure between the outdoors and indoors result in loads that the wall must control or accommodate. Insulation is used to control heat flow, an air barrier is installed to control air flow, and claddings, flashings and sheathing membranes are used to control water penetration. Selection of a particular arrangement of material layers, and the vapor permeance of those layers, will control vapor diffusion.

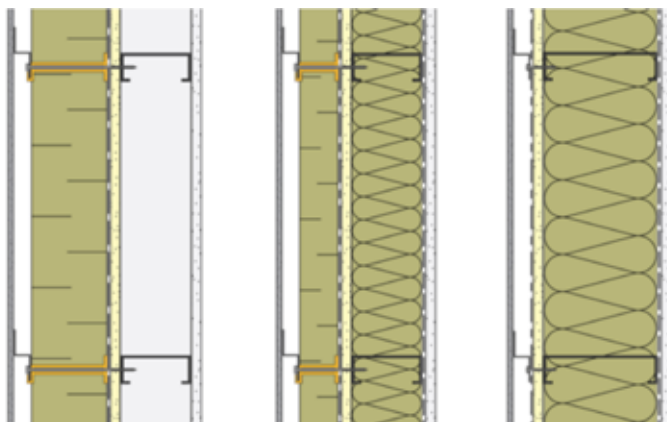
Understanding Vapor Diffusion

Vapor diffusion is the movement of water vapor molecules through porous materials (e.g. wood, insulation, drywall, concrete, etc.) as a result of vapor pressure differences. Vapor pressure differences occur as the result of temperature and water vapor content differences in the air. These vapor pressures can be looked up on a psychometric chart or calculated.

Vapor diffusion flow always occurs through an assembly from the high to low vapor pressure side, which is often from the warm side to the cold side because warm air can hold more water than can cold air. In cold climates, this means that vapor diffuses primarily from the heated interior to the colder outdoors, whereas in hot climates, the vapor drive is reversed and instead is primarily from the warm humid exterior to the air conditioned interior. The direction of vapor diffusion can also be reversed when the sun heats up damp, absorptive wall claddings like masonry and drives water vapor inward.

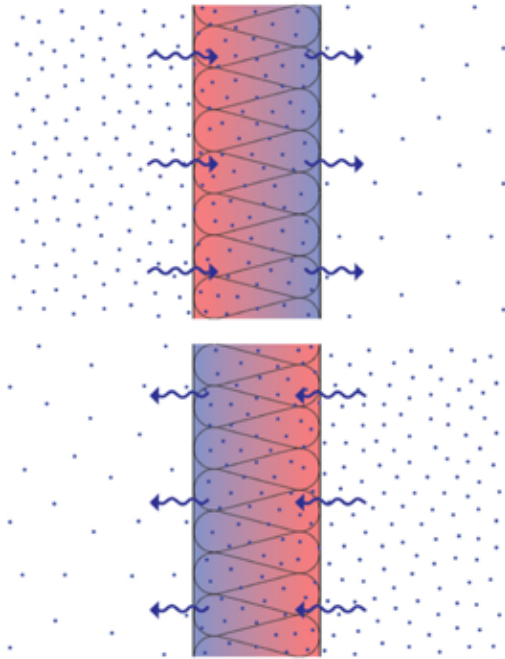


Interior insulated concrete masonry unit (CMU) wall (left), and split insulated steel stud wall with moisture storing brick cladding (right) are other examples of wall assemblies that provide different challenges and benefits with respect to vapor diffusion depending on the climate.



Exterior insulated (left), split insulated (middle), and stud cavity insulated (right) steel stud walls are three ways to insulate the building enclosure, but these walls can provide significantly different performance with respect to vapor diffusion and condensation.

The following schematics show the inward and outward vapor drives for hot and cold climates, respectively. The temperature through the wall is illustrated by the temperature gradient, and the relative humidity is indicated by the density of the dots which schematically represent the relative number of water vapor molecules in the air.



Example wall assembly showing inward (top) and outward (bottom) vapor drive for hot and cold climates, respectively.

Overall, the direction of the vapor drive has important ramifications with respect to the placement of materials within a wall assembly. What works in Toronto or New York likely won't work in Miami! Improper use of vapor impermeable materials within a wall can lead to condensation on colder surfaces and lead to damaged materials and fungal growth. This bulletin provides guidance on the selection and placement of materials within wall assemblies to avoid issues related to vapor diffusion.

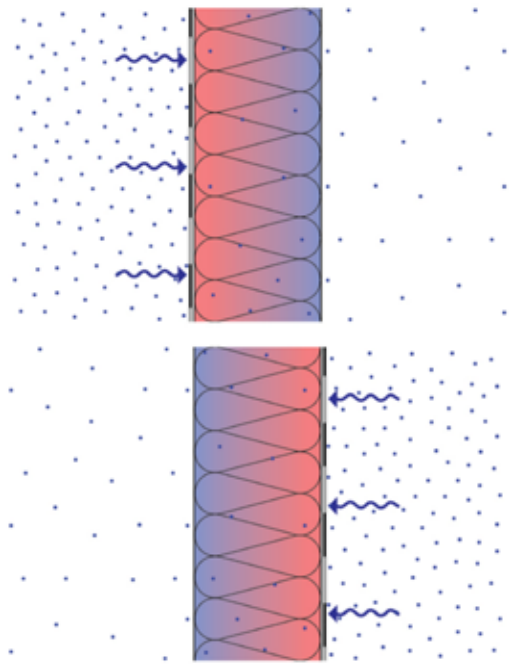
Understanding Vapor Barriers & Retarders

To control vapor diffusion within wall assemblies, vapor retarding materials are used. All building materials provide some resistance to vapor diffusion that varies depending on the properties of the material. These properties can change with the relative humidity and moisture content, age, temperature and other factors. Vapor resistance is commonly expressed using the inverse term "vapor permeance" which is the relative ease of vapor diffusion through a material. The metric units for vapor permeance are "ng/Pa·s·m²" or in IP units are "grains/inHg·ft²·hr", the latter of which is more commonly known as a "US perm." Both units are a measure of the mass flow over time per the vapor pressure difference and area of wall or other assembly. One US Perm is the same as 57.4 ng/Pa·s·m².

Building codes have grouped materials into classes (Classes I, II, III) depending on their vapor permeance values. Class I (<0.1 US perm), and Class II (0.1 to 1.0 US perm) vapor retarder materials are considered impermeable to near impermeable, respectively, and are known within the industry as "vapor barriers." Some materials that fall into this category include polyethylene sheet, sheet metal, aluminum foil, some foam plastic insulations (depending on thickness), self-adhered (peel-and-stick) bituminous membranes and many other construction materials. Class III (1.0 to 10 US perm) vapor retarder materials are considered semi-permeable and typical materials that fall into this category include latex paints, plywood, OSB and some foam plastic insulations (depending on thickness).

The Class of vapor retarder (I, II, or III) is used within many building codes and building enclosure design publications to provide guidance for the selection of appropriate vapor control layers within wall assemblies in North American climate zones. This guidance is also based on the expected indoor conditions for certain building types which is related to exterior climate, indoor moisture generation rates combined with ventilation rates. This guidance is not reiterated here, and should be consulted for the selection of appropriate vapor retarder materials along with consideration for other issues as covered within this bulletin.

The following graphics illustrate how a vapor retarder can be used in a cold or a hot climate to control the diffusion of vapor through the wall assembly.



Schematic vertical cross-section showing how a vapor barrier on the interior (left) side of a wall assembly (top) and on the exterior (right) side of a wall (bottom) can control vapor diffusion through the assembly in a hot a cold climate, respectively.

Vapor Diffusion Drying

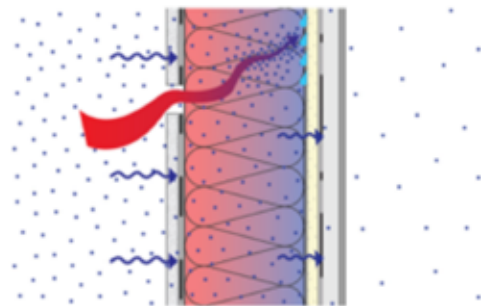
Vapor diffusion is typically thought of as a negative phenomenon, one that needs to be completely stopped. In reality, vapor diffusion is also a positive mechanism that can be used to a designer's benefit, and is a very important drying mechanism for a wall assembly. In fact, vapor diffusion is the only process through which the interiors of most wall assemblies are able to dry in service. The control of vapor diffusion within a wall assembly is therefore a balance of minimizing or managing wetting sources and maximizing drying potential should the wall be constructed wet, or somehow be wetted in-service. This is particularly important with highly insulated wall assemblies as more insulation means less heat energy is available to dry moisture from within assemblies.

Understanding Air Leakage in Walls

While vapor diffusion is a relatively slow process which can take extended periods to accumulate enough water to be of concern, air leakage in wall assemblies can act much more quickly and deposit large amounts of water in a short period of time. Air leakage is driven by air pressure differences between the interior and exterior of a building, which can be created by a number of different factors including ventilation systems, wind and stack effect (created by indoor to outdoor temperature differences). These pressures drive air through wall assemblies from the high pressure side to the low pressure side. Importantly, air pressure differences are not the same as the vapor pressure differences which drive vapor diffusion.

To control air leakage in building enclosure assemblies like walls, an air barrier is installed. Unlike diffusion, air leakage is not typically governed by material properties of this air barrier. Instead, air leakage most often occurs at discontinuities (i.e. holes) in the air barrier. Consequently, prevention of air leakage depends primarily on detailing, material compatibilities and quality control during both the design and construction process. Notably, air leakage can bypass the vapor barrier and consequently is an independent phenomenon from vapor diffusion.

When air leakage does occur, it can carry moisture with it, and if this air then comes in contact with a surface that is below the dew point temperature of the air, condensation can occur. The dew point temperature is the temperature at which the air is 100% saturated with moisture, and consequently if the air is cooled below this temperature, it can no longer hold all of the moisture it contains and it will deposit the moisture on these colder surfaces. Condensation from air leakage can deposit significant amounts of moisture within a wall and potentially lead to fungal growth and/or degradation.

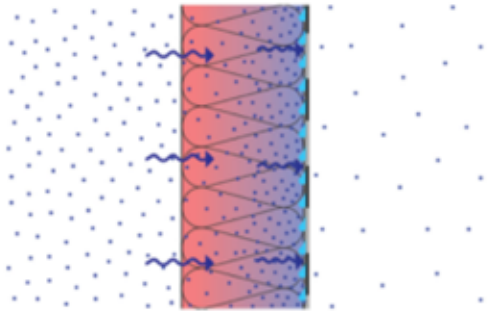


Schematic vertical cross-section of wall with air leakage condensation occurring on the interior face of the exterior gypsum sheathing.

Wrong Side and Double Vapor Retarders

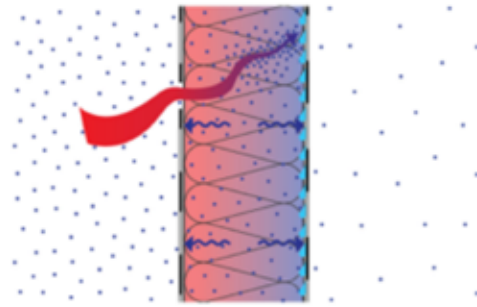
While vapor retarders can be used to control vapor diffusion and consequently prevent condensation, installation of these types of materials at the wrong location within an assembly can also cause significant moisture problems. Typically, there are two conditions which can be created which are detrimental: wrong side vapor retarders, and double vapor retarders.

Wrong side vapor retarders refers to when a vapor retarder is placed on the low vapor pressure side (typically the cold side) of a wall assembly. Locating a vapor retarder in this way restricts vapor diffusion through the wall and creates a potential condensing plane within the wall assembly.



Schematic vertical cross-section showing condensation of moisture on a vapor retarding material placed on the wrong side of a wall assembly.

Double vapor retarders refers to when a vapor retarder is installed at two different locations in an assembly such that any moisture which manages to get between them is unable to dry effectively. When the materials between the vapor retarders are moisture sensitive, this trapped moisture can potentially lead to damage. Moisture between the vapor retarders may be the result of air leakage, rainwater ingress or built-in construction moisture. The following figure illustrates a schematic double vapor barrier situation restricting the drying of a wall assembly.



Schematic vertical cross-section showing moisture trapped within a wall assembly due to the presence of two vapor barriers.

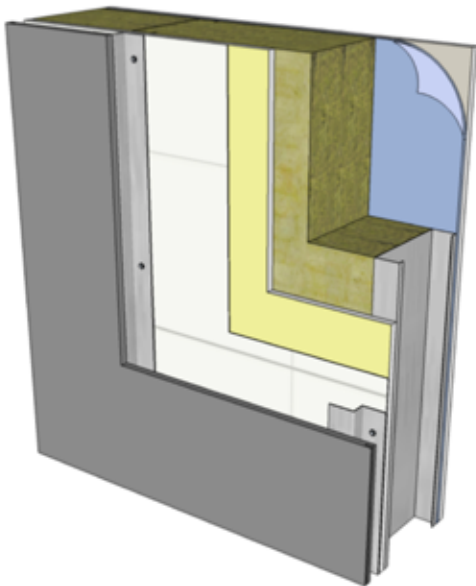
Vapor Diffusion and Wall Assembly Design

Stud Cavity Insulated Walls

Walls which are insulated only within the stud cavity provide vapor control in different ways depending on the type of climate. Cold climates will provide a vapor retarder on the interior side of the assembly, while warm climates provide this towards the exterior.

Stud Cavity Insulated Walls – Cold Climates

For wall assemblies in cold climates, interior vapor control is often provided using a polyethylene sheet vapor barrier, though other options such as vapor barrier paint, kraft paper and smart vapor retarder products are also used. This interior vapor retarder limits the diffusion of moisture through the wall assembly towards the exterior. Outward vapor diffusion drying can still occur from within the wall cavity through the sheathing, membrane and cladding.

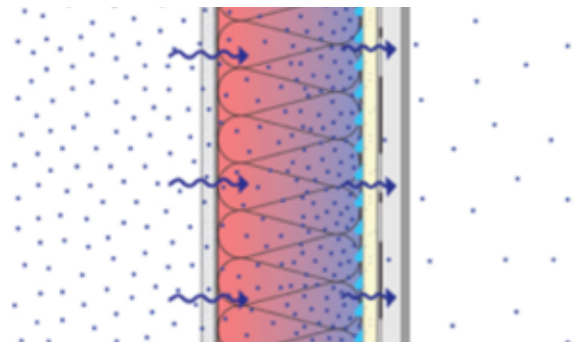


Stud insulated wall assembly using mineral wool batt insulation is relatively standard and straightforward.

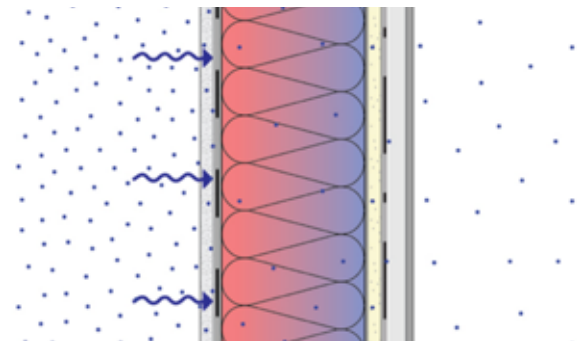
If this vapor retarder is not provided, vapor could diffuse from the interior towards the exterior. As the temperature drops across the insulation, for the same absolute humidity level (moisture) within the air, the relative humidity (RH) will increase, and when it comes in contact

with a cold surface (below the dew point temperature), water can condense within the assembly. Most commonly this occurs on the interior face of the exterior wall sheathing. Note that if the indoor vapor pressure is low (low indoor RH) then condensation may not occur at the sheathing. This explains why in older homes with high air leakage, high ventilation rates and lower RH levels, vapor diffusion may not have caused wetting, though in a more airtight new home it can. Even where condensation does not form, high RH levels are conducive to fungal growth on building materials, so it is ideal to keep the RH below 80% the vast majority of the time.

The two following figures illustrate how interior vapor control in a stud cavity insulated wall can help prevent condensation within the wall assembly in cold climates. Condensation can also occur if air leaks from the interior to the back of the sheathing. Often this can cause more significant localized damage than can vapor diffusion alone.

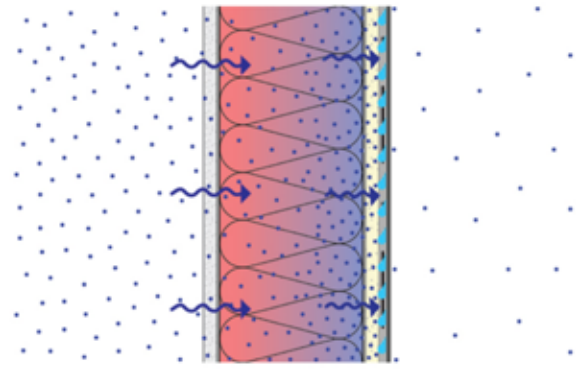


Schematic vertical cross-section of wall without interior vapor control in a cold climate resulting in condensation on the interior face of the exterior gypsum sheathing.



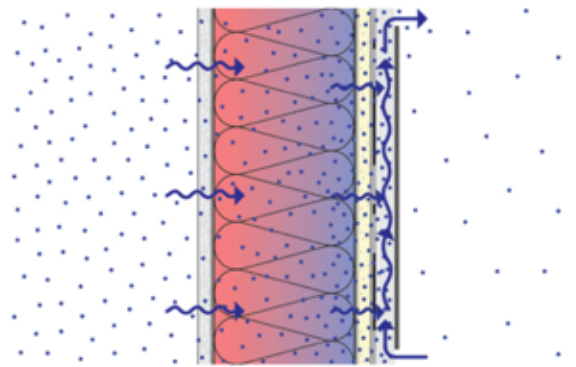
Schematic vertical cross-section of wall with interior vapor control in a cold climate preventing diffusion of moisture into the wall assembly.

For comparison with the previous scenario, consider a stud insulated wall assembly in a cold climate with a vapor retarder material installed on the exterior side of the insulation under wintertime conditions. Vapor diffusion in this scenario occurs from the interior to the exterior; however, moisture is prevented from diffusing outwards and will accumulate in the form of condensation, leading to damage. This is an example of what can happen when a vapor barrier is installed on the wrong side of an assembly. The vapor barrier in this scenario could be created by the wrong type of sheathing membrane, the use of excessive self-adhered bituminous membrane application at penetrations and details or the installation of a vapor impermeable cladding such as fiber cement panel, glass cladding or metal siding. The following schematics illustrate examples of this situation and illustrate why correct vapor barrier placement is important.



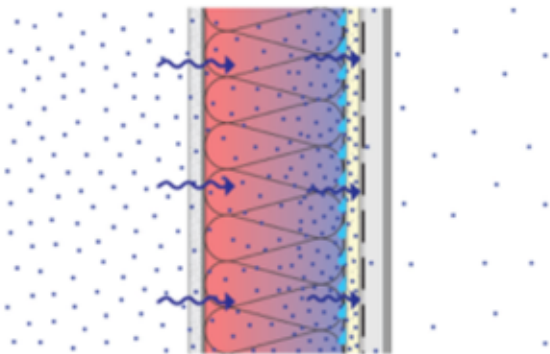
Schematic vertical cross-section of wall with vapor impermeable unvented cladding located in a cold climate.

A straightforward way to address vapor impermeable claddings is to provide an airspace and ventilation behind the cladding so that airflow from the outdoors will remove moisture deposited on the cladding by outward vapor diffusion. As many commercial claddings are impermeable (i.e. metal, concrete veneer, etc.), this is commonly achieved by the construction of a drained and ventilated rainscreen cavity. In some building codes, the requirement for venting behind impermeable claddings was implemented at the same time interior vapor barriers were introduced. Venting of an impermeable cladding is illustrated in the following figure.



Schematic vertical cross-section of wall with vapor impermeable cladding located in a cold climate with venting behind the cladding to allow for dissipation of moisture.

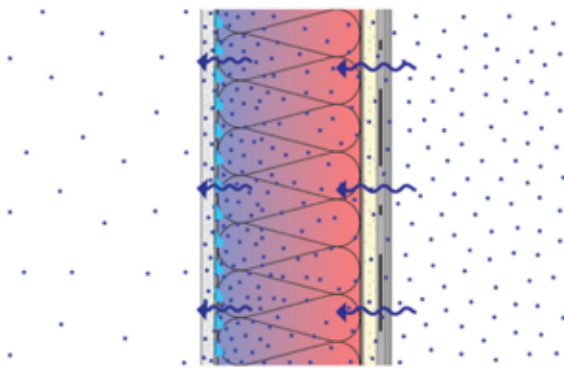
Vapor Diffusion Drying
 Importantly, vapor diffusion also aids in the drying of assemblies if they become wetted due to condensation or air or water leaks. In a cold climate, the more vapor permeable the sheathing, sheathing membrane and cladding layers, the faster this moisture can dry out, and consequently the risk of damage is reduced. This is why in some cases walls without vapor barriers can perform adequately – the drying ability exceeds the wetting.



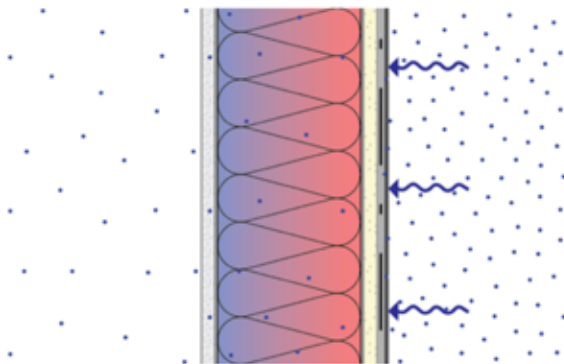
Schematic vertical cross-section of wall with vapor barrier membrane on exterior wall sheathing located in a cold climate.

Stud Cavity Insulated Walls – Warm Climates

For warm climates, installing an interior vapor retarder can create a substantial risk of condensation within the wall assembly. A common unintentional example of this is the use of vinyl wallpaper. The vinyl wallpaper acts as an interior vapor retarder and in combination with inward vapor drive can lead to moisture accumulation within the wall assembly. Alternatively, in warm climates where air conditioning is provided, diffusion occurs primarily from the exterior to the interior and an exterior vapor retarder such as an impermeable self-adhered membrane, rigid foam-plastic insulation (i.e. XPS, medium density sprayfoam, etc.) or concrete should be provided. The following two figures show the effect of an exterior vapor retarder versus an interior vapor retarder for a stud insulated wall assembly in a warm climate.



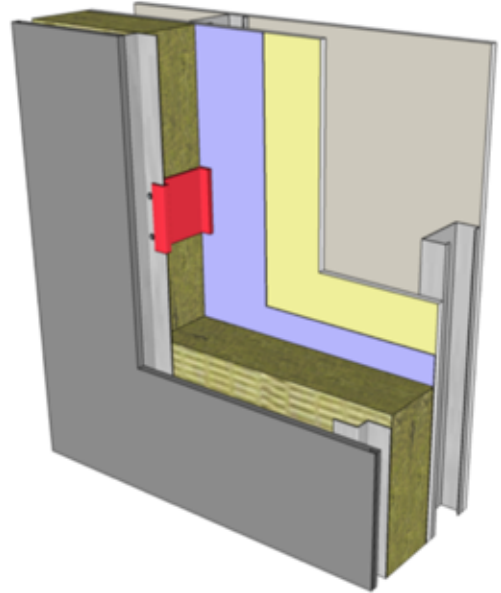
Schematic vertical cross-section of wall without exterior vapor control in a warm climate resulting in condensation on the exterior face of the interior gypsum sheathing.



Schematic vertical cross-section of wall with exterior vapor control in a warm climate preventing moisture from accumulating within the wall assembly.

Exterior Insulated Walls

Instead of insulating walls within the stud cavity, exterior insulation can be used, and this approach to insulating wall assemblies can also be effective for concrete or CMU (concrete masonry unit) walls. In these walls, insulation is installed on the exterior of the wall sheathing or, less commonly in commercial buildings, is installed as the wall sheathing itself. This section primarily addresses the case where it is installed exterior of the sheathing.

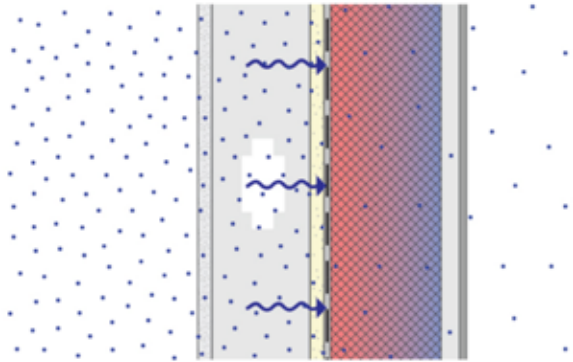


Exterior insulated wall assembly using semi-rigid mineral wool insulation can provide effective and efficient ways to insulate a wall, and also can be highly durable with respect to vapor diffusion and condensation.

Exterior insulation is often considered an effective way of achieving highly insulated wall assemblies, and can substantially reduce thermal bridging. In addition to these thermal benefits, exterior insulation can also provide a robust assembly with respect to vapor diffusion and condensation.

The use of exterior insulation changes the temperature profile through the wall assembly and consequently the back-up wall, be it sheathed steel stud, concrete or CMU, is maintained relatively close to interior conditions. Additionally, since typically a sheathing membrane is applied to the back-up wall behind the insulation in these assemblies, moisture-sensitive materials are generally all located on the interior side of the insulation and sheathing membrane where they remain both warm and dry, resulting in a very durable wall assembly in all climates.

In cold climates, a vapor impermeable sheathing membrane can be used to control vapor diffusion through these wall assemblies. As moisture in the air diffuses from the interior towards the exterior, the sheathing membrane restricts this diffusion while still on the warm side of the insulation and consequently prevents condensation within the exterior insulation. This is illustrated in the graphic below.



Schematic vertical cross-section of an exterior insulated wall with vapor barrier membrane on the exterior wall sheathing located in a cold climate.

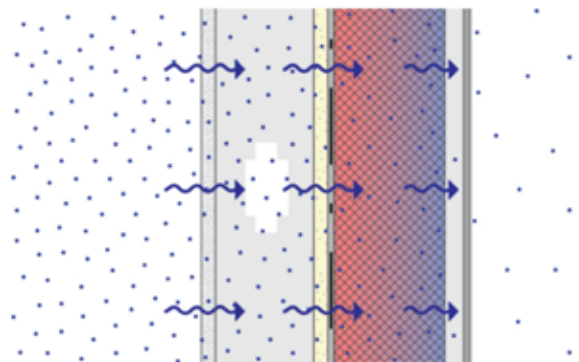
Interestingly, an advantage of fully exterior insulated wall assemblies is that in many cases vapor diffusion control is actually not required. For example, in a cold climate, if a vapor permeable sheathing membrane is used instead of a vapor impermeable membrane, vapor from the interior will be able to diffuse from the interior to the exterior relatively unrestricted. This vapor will likely condense as it moves outward on a surface such as the back of the cladding; however, materials installed on the outside of the sheathing membrane should be durable to wetting, and consequently the amount of moisture deposited from vapor diffusion condensation is unlikely to be detrimental. To accommodate this potential wetting, exterior insulated assemblies without a vapor control layer (i.e. "vapor open") should include venting of the cladding to allow drying. Where more extreme humidity levels exist, such as pools, this vapor open approach may not be appropriate, and a vapor barrier would likely be required.

Similarly, in a warm climate, as moisture diffuses inward through the assembly it will reach a cold surface at the sheathing membrane. This membrane is intended to prevent liquid water intrusion from the exterior building, and consequently wetting of this surface by condensation is within the expected performance characteristics of the

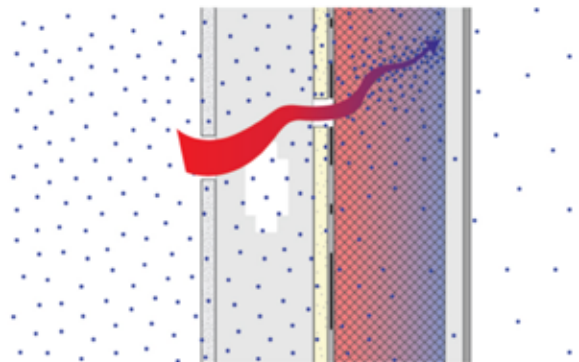
material and is unlikely to cause damage. Similar to a cold climate, the area between the sheathing membrane and cladding should be designed to allow for drainage and drying of any moisture which accumulates.

An important aspect of exterior insulated walls is that their design makes them highly durable with respect to condensation due to air leakage. While air leakage in a stud cavity insulated wall can often lead to damage, this risk is substantially reduced in an exterior insulated assembly. For example, in a cold climate, if warm, humid interior air were to leak through an exterior insulated assembly, it is unlikely to condense on any moisture-sensitive surfaces inboard of the insulation. Instead, it will condense on exterior materials such as the cladding, and these materials are durable to wetting. One notable exception to this is when the exterior temperature is below freezing. In this case, leakage of interior air to the exterior can create substantial ice build-up on cold surfaces such as the cladding, and this ice may damage the assembly.

The following graphics illustrate exterior insulated walls where no vapor retarder is provided, and where air leakage occurs.



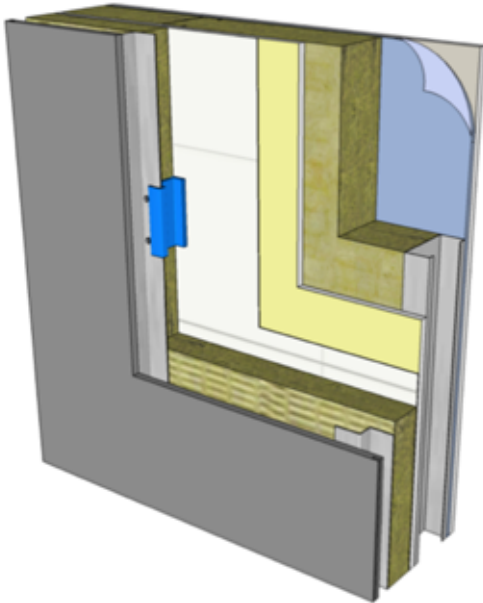
Schematic vertical cross-section of an exterior insulated wall located in a cold climate with no vapor barrier.



Schematic vertical cross-section of an exterior insulated wall located in a cold climate with no vapor barrier and air leakage.

Split Insulated Walls

In some cases it can be advantageous to use split insulated wall assemblies; that is, assemblies where insulation is provided both in the stud cavity and on the exterior of the sheathing (or less commonly as the sheathing itself in commercial buildings). Usually these are used as they can provide the necessary R-value in a relatively compact (i.e. thinner) assembly. As one might guess, these walls essentially provide a mixture of the performance of stud cavity insulated and exterior insulated wall assembly, but there are a number of important considerations.



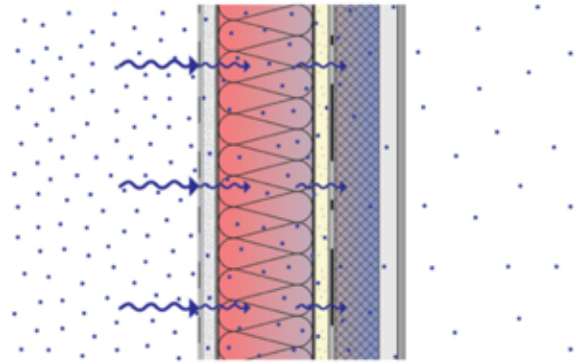
Split insulated wall assembly using semi-rigid mineral wool insulation to provide a combination of the performance of stud insulated and exterior insulated walls. These walls can provide good performance with respect to vapor diffusion and air leakage, but it is important to use the correct type of insulation on both the exterior and within the stud cavity, and also the correct type of sheathing membrane.

As noted previously, the addition of exterior insulation will keep the sheathing closer to interior temperature. In a split-insulated assembly, the more insulation placed outboard of the sheathing compared to the insulation within the stud cavity, the closer to interior conditions the sheathing will be, and consequently the closer these walls will be to exterior insulated walls. This concept is often expressed in terms of a nominal-outboard-to-total-insulation ratio. For example, if R-6 of rigid insulation is placed outboard of R-14 batt insulation within the stud space for a total insulation amount of R-20 nominal, the approximate ratio is 30% (or 3:10) of outboard insulation excluding other materials. Overall, the lower this ratio, the closer the performance will be to an insulated stud wall, and the higher the ratio, the closer the performance will be to an exterior insulated wall.

Given that split-insulated walls fall somewhere between insulated stud wall and exterior insulated walls with respect to performance, there are important considerations with respect to vapor diffusion. Generally, the exterior insulation will keep the sheathing closer to interior conditions, but if it is a relatively small fraction of the overall insulation in the wall, the sheathing will still operate at conditions similar to the exterior. In this situation, the vapor permeability of the insulation should be considered.

Vapor Permeable Insulation

The split insulated wall scenario is shown in the figure below under wintertime conditions in a cold climate.



Schematic vertical cross-section of a split insulated wall located in a cold climate, showing outward vapor drive through the wall with a Class III vapor retarder on the interior.

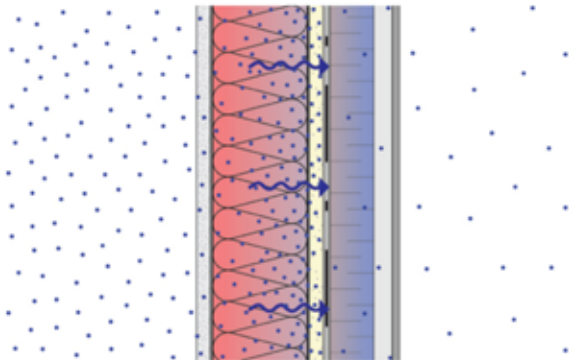
Vapor permeable mineral wool insulation has been placed outboard of the sheathing. This has the effect of warming the stud space and exterior sheathing – the more exterior insulation, the warmer the cavity and sheathing. No interior or exterior vapor barrier material has been used, though a Class II or III vapor retarder may be necessary to prevent condensation or high RH levels from occurring, depending on the thickness of exterior insulation and the vapor pressure gradient (expected interior and exterior conditions). For moderately cold climates and most indoor conditions within commercial buildings, the installation of a few inches of mineral wool outboard of an insulated 6" stud wall is sufficient to ensure good performance when a Class III vapor retarder (latex paint) is used on the interior of the drywall. Good performance can generally be taken to mean maintaining the RH at the sheathing below 80%. For buildings with high interior humidity levels such as pools or museums, a Class I or II vapor barrier would likely still be required.

The vapor pressure difference from interior to exterior within this scenario is the same as the previous cases, and is not affected by the exterior insulation; however, the temperature within the stud cavity is warmer, and consequently the RH at the sheathing does not increase as much. As a result, condensation does not form within the cavity and the vapor passes through the sheathing and vapor permeable insulation without harm. The RH within the cavity behind the sheathing will depend on the insulation ratio and on the rate at which drying occurs through the sheathing. Therefore, the more vapor permeable the sheathing and insulation, the lower the RH within the cavity.

Because the sheathing temperature is increased, the risk of air leakage condensation is reduced which further improves the durability of this wall. With vapor diffusion and air leakage wetting addressed, the only risk to moisture damage is from an external leak. However, because the sheathing is kept warmer by the insulation, it is able to dry out faster, and in this wall assembly moisture will dry both inwards and outwards by vapor diffusion through the relatively vapor permeable materials.

Vapor Impermeable Insulation

Consider the same wall assembly as in the previous scenario but with vapor impermeable foam insulation (e.g. XPS, polyiso, medium-density spray polyurethane foam, etc.) used to the exterior of the sheathing. These insulation materials can be considered a Class I or II vapor retarder depending on type, density, thickness and facings.



Schematic vertical cross-section of a split insulated wall located in a cold climate with impermeable exterior insulation.

Vapor impermeable foam insulation with the same R-value as in the previous scenario placed outboard of the sheathing has the effect of warming up the rest of the cavity – the more exterior insulation, the warmer the cavity and sheathing.

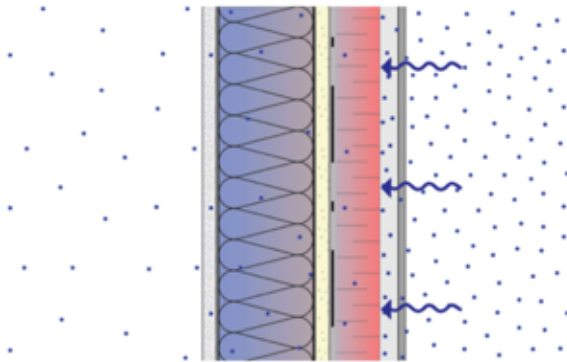
No interior vapor barrier has been installed in this scenario, nor would be recommended, as the inclusion of a vapor barrier (Class I or II) at the interior in conjunction with the exterior foam would create a double vapor barrier situation that would substantially restrict drying. This wall, therefore, relies on vapor diffusion drying towards the interior, as vapor diffusion drying through the exterior insulation is limited. In terms of balancing wetting sources and drying ability, this is a more sensitive wall than the previous scenario as a result of using impermeable exterior insulation.

This is particularly important if the indoor humidity is elevated within the building or the outdoor climate is wet, which can create higher indoor relative humidity levels during cold periods of the year. Even higher indoor wintertime RH levels of 40-60% (such as in coastal climates or in commercial buildings with high interior moisture generation rates such as restaurants, pools, museums, etc.) can create a challenge for this assembly due to the increased outward vapor diffusion and reduced drying potential.

The vapor pressure difference from interior to exterior within this scenario is the same as in the previous scenarios; it hasn't been affected by the presence of the exterior insulation. While vapor diffusion outwards is significantly slowed, or stopped, condensation does not occur within the wall cavity because the temperature is warm enough to keep the RH below 100%. While condensation does not form within the cavity of this assembly, moisture is prevented from travelling through the exterior insulation, which can be an issue in the event of a leak or if there is not enough insulation outboard to prevent air leakage condensation. The RH within the cavity behind the sheathing will depend on the insulation ratio and the effective vapor permeance of the foam insulation. With this assembly, it is generally safer to have more exterior insulation (or a higher insulation ratio) than with vapor permeable insulation so that the RH is kept below 80% to reduce the risk of fungal growth.

Similar to the exterior insulated wall with vapor permeable insulation, the risk of air leakage condensation is reduced for this wall due to the increased sheathing temperature. If vapor diffusion and air leakage wetting are addressed by placement of sufficient exterior insulation, the only risk of moisture damage is from an external leak. In the event of a leak, drying outwards by vapor diffusion is restricted by the foam, and drying can only occur in the inward direction. Solutions to improve outward drying include providing a small drainage layer behind the foam or using more vapor permeable insulation. The relative tightness in which the rigid foam board insulation is installed and how the joints are sealed will also affect the outward drying ability.

In a warm climate where the vapor drive is primarily inward, the use of impermeable exterior insulation can provide an effective vapor control strategy. In this case, the exterior insulation restricts the diffusion of water vapor through the wall assembly as shown in the following figure.

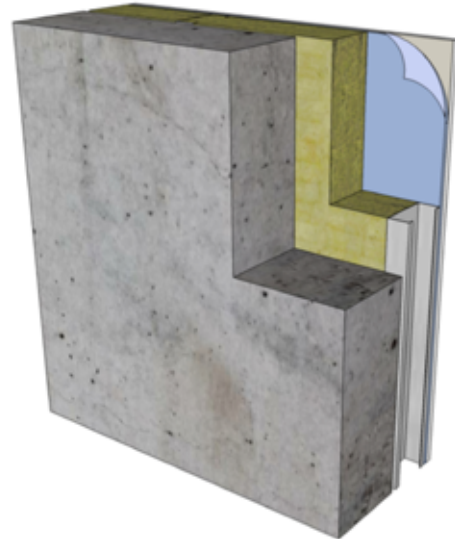


Schematic vertical cross-section of a split insulated wall located in a warm climate with impermeable exterior insulation.

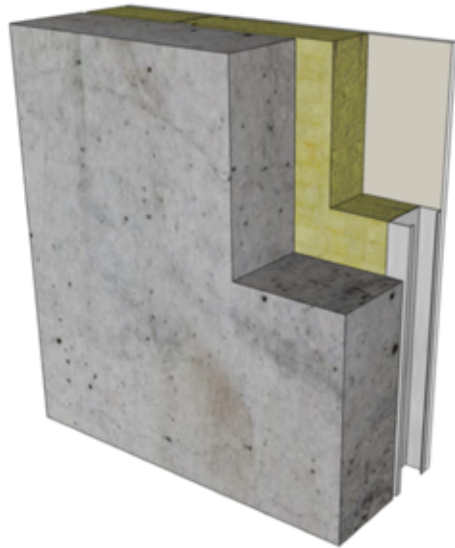
No interior vapor retarder would be provided in this scenario so that the wall assembly can dry effectively to the interior.

Exposed Concrete Interior Insulated Walls

In commercial construction, another type of wall is also commonly used; architectural or exposed concrete, or in some cases concrete masonry units (CMU). These walls are insulated on the interior and create a different situation than the other types of walls discussed. The figures below show these types of walls for cold and hot climate.

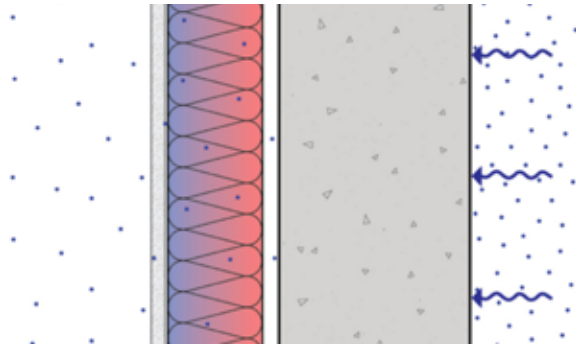


Exposed concrete wall assembly insulated on the interior as would be typical for a cold climate.



Exposed concrete wall assembly insulated on the interior but with no polyethylene sheet vapor barrier on the interior. This type of assembly can provide durable performance in warm climates.

Exposed concrete and CMU create a vapor retarder on the exterior of the wall assembly, which works well for warm climates where the primary vapor drive is inward. The concrete will restrict the flow of vapor through the assembly and consequently prevent condensation and high humidity levels within the assembly. The image below illustrates this schematically.

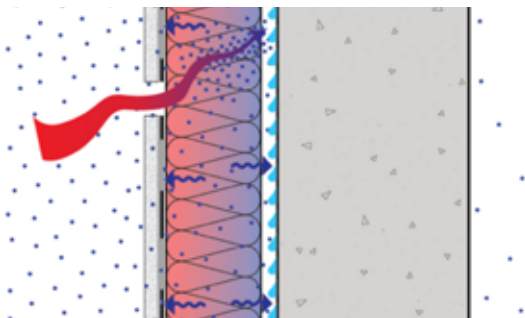


Exposed concrete wall assembly insulated on the interior but with no polyethylene sheet vapor barrier on the interior. This type of assembly can provide durable performance in warm climates.

Using a vapor permeable insulation on the interior of concrete walls in warm climates can also allow any incidental moisture to dry to the interior. By comparison, an impermeable insulation product would restrict drying to the interior.

In cold climates, the exterior vapor retarder created by the concrete means a risk of condensation within the assembly. Additionally, as this would typically be installed with an interior vapor retarder in a cold climate, a double vapor barrier situation is created, which limits drying.

The following figure illustrates an exposed concrete wall with batt insulation and a poly vapor barrier on the interior. This approach is not recommended as it creates a double vapor barrier.



Schematic vertical cross-section of an interior insulated exposed concrete wall with an interior vapor barrier showing how air leakage can cause moisture accumulation within the assembly, which is unable to dry due to the double vapor barriers.

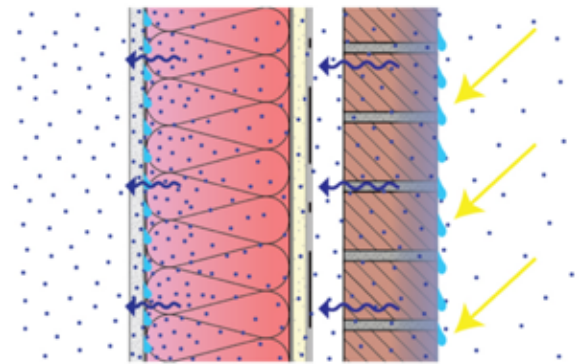
A number of alternative methods exist for insulating these types of walls in cold climates. Spray polyurethane foams can be applied directly to the concrete, CMU or precast, or in some cases taped XPS or polyisocyanurate insulation could also be used. In both cases the insulation provides vapor control and an air barrier so that air does not leak from the interior and condense on the back of the concrete. In some cases, using a smart vapor retarder instead of poly sheet may also reduce the risk associated with interior insulated concrete assemblies.

Generally, exposed concrete or CMU walls provide robust durability in warm climates, but can provide some challenges when used in cold climates.

Moisture Storing Claddings & Inward Vapor Drive

Another unique situation for vapor diffusion is when moisture storing claddings such as masonry or precast concrete are used. When these types of claddings are exposed to wetting, they can absorb and store significant amounts of moisture. Then, if the sun comes out and heats up these wet claddings, this can create a high humidity condition on the exterior of the building which will cause significant inward vapor drive even in a cold or mixed climate. In other words, when moisture storing claddings are used in cold climates, sometimes the direction of vapor diffusion can reverse.

As discussed for the other wall types with respect to the differences between warm and cold climates, when the vapor drive reverses, the design with respect to vapor diffusion control changes. The figure below illustrates this reversal of vapor drive for a wall with a moisture storing cladding.



Schematic vertical cross-section of a stud insulated wall with a moisture storing cladding resulting in inward vapor drive despite being located in a cold climate.

This reversal of the vapor drive creates a problem, because typically walls are designed to deal with vapor diffusion in only one direction. There are a number of different ways to design a wall to accommodate this effect.

- Provide a well-ventilated cavity between the moisture storing cladding and the back-up wall
- Use an exterior insulated wall assembly
- Use a split insulated wall assembly with suitable quantity of exterior insulation
- Use a moderately permeable sheathing membrane (i.e. approx. 8 to 18 US perms) to provide some inward vapor control
- Use a smart vapor retarder on the interior of the wall instead to provide adaptive vapor diffusion control to allow for inward drying

Overall, this reversal of the vapor drive for walls with moisture storing cladding is typically less of a concern than is the more consistent outward vapor drive.

Summary

The control of vapor diffusion within walls is a balance between minimizing wetting and maximizing drying ability. Correctly placed vapor control layers prevent excessive moisture from diffusing into wall assemblies and potentially condensing, while vapor permeable materials allow moisture to diffuse out and are beneficial to drying performance. In the design and construction of commercial walls in cold climates, it has been common practice to install a polyethylene sheet vapor barrier at the interior of the insulation to control vapor flow (and often air flow) and therefore limit vapor diffusion wetting while using vapor permeable materials to the exterior to encourage drying. In warm climates, the opposite approach is used, and impermeable materials on the exterior such as concrete, CMU or metal claddings restrict the diffusion of vapor through the wall assembly, and permeable materials on the interior such as drywall and mineral wool insulation allow for drying to the interior.

When insulation is added to the exterior of the walls, as in the case of a split-insulated or exterior insulated wall, this insulation maintains the temperature of the stud cavity and exterior sheathing closer to interior conditions, reducing the potential for vapor diffusion and air leakage condensation to occur within the cavity. The more

insulation that is installed outboard of the sheathing, the closer to interior conditions the stud cavity will be. Wherever possible, the exterior insulation ratio should be maximized, and fully exterior insulated walls work well in both cold and warm climates.

In cold climates, the type of insulation installed outboard of the sheathing (or as the sheathing) has an important impact on the vapor diffusion drying capability of the wall. Vapor permeable insulation such as mineral wool or fiberglass will allow for greater outward drying than can be achieved with vapor impermeable insulation such as foam plastics; XPS, polyiso and spray polyurethane foam insulation. This greater drying ability generally results in improved durability of the wall assembly.

In some cases, the change in temperature profile due to the addition of exterior insulation means that a vapor barrier may no longer be needed at the interior in cold climates, and alternate strategies such as a latex paint may be used instead of polyethylene. When a vapor impermeable exterior insulation is used in cold climates, an interior vapor retarder should be avoided to prevent trapping moisture within the wall assembly, or potentially an adaptive permeance smart vapor retarder material could be used. In warm climates, vapor impermeable exterior insulation will work to restrict the flow of vapor through the wall and prevent moisture accumulation within the assembly.

While walls with vapor impermeable materials on the exterior are typically not recommended for cold climates, these types of walls can provide durable performance in warm climates where the primary vapor drive is reversed. For example, exposed concrete walls insulated on the interior with vapor permeable insulation such as stone wool or fiberglass can provide highly durable performance in warm climates.

Other types of walls such as walls with moisture storing claddings create unique conditions with respect to vapor diffusion, and require careful consideration and design. When designing these walls, double vapor barrier situations are to be avoided such that drying can occur.

Overall, the correct selection and placement of vapor impermeable materials within wall assemblies is fundamental to their durability in both cold and warm climates. Failure to correctly account for the impacts of vapor diffusion can lead to damage and premature failure of wall assemblies.

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