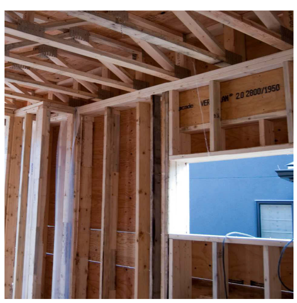
Guide to R-22+ Effective Walls in Wood-Frame Construction



Homeowner Protection Office
Branch of BC Housing

CITY OF VANCOUVER

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Preface

About this Guide

The *Guide to R-22+ Effective Walls in Wood-Frame Construction* is published by the Homeowner Protection Office (HPO), a Branch of BC Housing. This guide consolidates information on above and below grade wall assemblies for low-rise wood-frame buildings which are capable of meeting R-22 or greater effective thermal performance. This level of thermal performance is required by the 2014 Vancouver Building Bylaw and represents a significant increase in the required level of performance from previous codes. The guide is intended to be an industry, utility, and government resource with respect to meeting this thermal performance level, while not compromising other aspects of building enclosure performance, including moisture management, air leakage, and durability.

Scope

The information included in this guide applies to low-rise wood-frame residential detached, and semi-detached (e.g. duplex to quadplex), and row-houses/townhomes within British Columbia. Non wood-frame homes, manufactured homes, and multi-unit residential buildings are beyond the scope of this guide. Additionally, while this guide provides general guidance on assembly selection and key considerations, it does not provide information on detailing of the assemblies at transitions and penetrations.

It is important to note that each building and construction project is different and presents unique challenges and considerations. This guide presents an overview of potentially applicable assemblies to meet higher thermal performance targets, but it is likely that these methods will need to be modified to accommodate variations in each project. Furthermore, while in some cases specific walls are identified as inappropriate, the guide is not intended to be limiting. It is recognized that that alternative wall assemblies and arrangement exist beyond the scope of this guide.

Acknowledgements

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Building science, products, and construction practices change and improve over time, and it is advisable to regularly consult up-to-date technical publications on building envelope science, products, and practices rather than relying solely on this publication. It is also advisable to seek specific information on the use of products, the requirements of good design and construction practices and requirements of the applicable building codes before undertaking a construction project. Consult the manufacturer's instructions for construction products, and also speak with and retain consultants with appropriate engineering or architectural qualifications, and appropriate municipal and other authorities, regarding issues of design and construction practices. Most provisions of the building codes (British Columbia Building Code and the Vancouver Building By-law) have not been specifically referenced, and use of the guide does not guarantee compliance with code requirements, nor does the use of systems not covered by this guide preclude compliance. Always review and comply with the specific requirements of the applicable building codes for each construction project. The materials and colours shown as examples in the guide are not intended to represent any specific brands or products, and it is acknowledged that many product options exist.

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Introduction

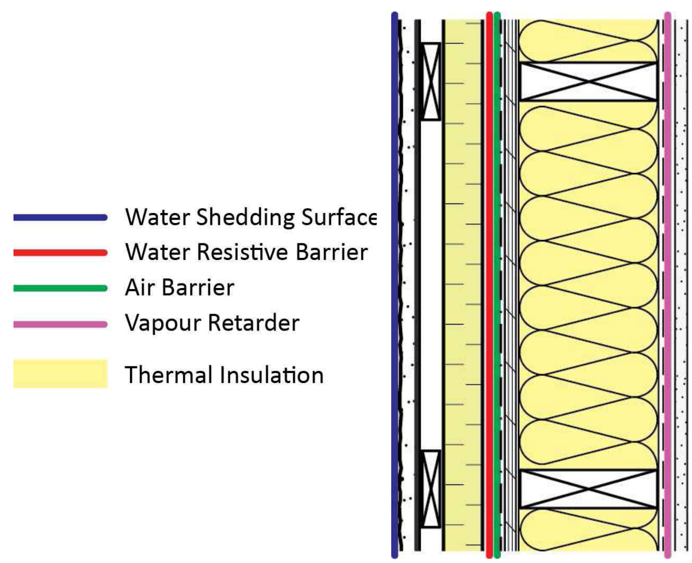
This section provides an introduction to the guide including sections on the following:

- Building Enclosures Overview
- R-Value Calculations
- Cladding Attachment
- Wall Thickness and R-value
- Air Barrier Systems
- Environmental Design & Rating Overview

Building Enclosures Overview

The building enclosure is a system of materials, components, and assemblies that physically separate the exterior and interior environments. It comprises various elements including roofs, above grade walls, windows, doors, skylights, below grade walls, and floors, which in combination must control water, air, heat, water vapour, fire, smoke, and sound. Additionally, the enclosure is an aesthetic element of the building.

To perform these functions, building assemblies typically use a series of layers, each intended to serve one or multiple functions within the building enclosure. As an example, for an above grade wall, cladding is typically installed to provide the aesthetic exterior finish as well as the primary water shedding surface. A water resistive barrier (WRB) is installed inboard of the cladding as a secondary barrier to moisture to prevent water ingress, and a drainage gap is installed between the cladding and WRB to allow drainage of water which penetrates past the cladding. This approach is commonly referred to as a rainscreen wall assembly. Insulation is installed to control the flow of heat (i.e. energy transfer) through the enclosure, and an air barrier is installed to control bulk air movement through the wall. A vapour barrier is also installed to control diffusion of water vapour through the wall assembly, and while typically a very impermeable material is used for this function (i.e. Type 1 vapour barriers less than ≈6 ng/(s · m² · Pa)), more permeable materials can also fulfill this function (i.e. Type 2 vapour barriers less than 60 ng/(s · m² · Pa) and smart vapour retarders). In many cases these functions can be provided in combination by a single layer within the assembly; for example, the WRB and air barrier may both be provided by the sheathing membrane. The relative position of these different elements of the enclosure assembly and appropriate detailing of the building enclosure systems at transitions and penetrations is fundamental to their performance.



This guide focuses on wall assemblies which can achieve an effective thermal performance of approximately R-22 (R-21.86, RSI-3.85) while still meeting the other performance requirements for enclosure assemblies. These relatively insulative wall assemblies help to reduce the transmission of heat energy through the building enclosure and consequently reduce the heating and cooling loads of the building, and the overall building energy consumption.

Note on BC Building Code (BCBC) and Vancouver Building Bylaw (VBBL) Compliance

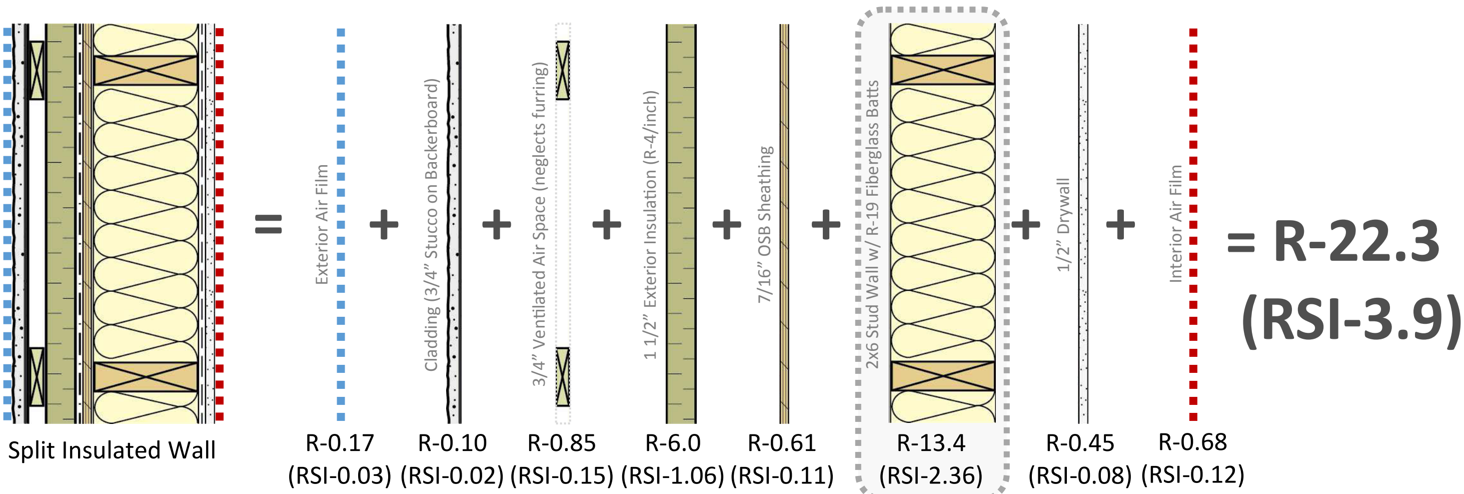
In many cases this guide indicates best practices with respect to air, vapour, and moisture management, rather than minimum requirements as specified by relevant building regulations. This approach is intended to promote the construction of effective and durable assemblies. Furthermore, in some cases the guide identifies materials, assemblies, or practices for which a registered professional (BC architect or engineer) may be required by the authority having jurisdiction to indicate equivalency for compliance with relevant building regulations. Relevant building regulations should be reviewed and complied with for each project.

R-Value Calculations

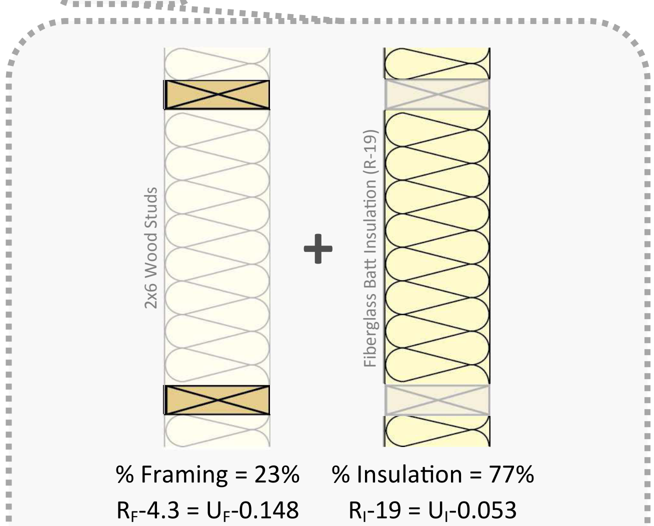
The thermal resistance of building assemblies is commonly indicated using R-value provided in imperial units of “ft² · °F · hr/Btu”, and can also be provided as RSI-values in metric units of “m² · K/W”. All R-values in this guide are provided in imperial units as the building industry is most familiar with these units. The higher the R-value, the better the thermal performance. U-values are another way of describing heat flow through a wall, and are the inverse of R-values. The lower the U-value, the better the thermal performance.

RSI-1 m²·K/W = R-5.678 ft²·°F·hr/Btu   R = 1/U

For low-rise wood-frame residential construction, R-values can be calculated according to Section 9.36 of the British Columbia Building Code (BCBC). (The City of Vancouver has not specifically adopted this section; however, it provides useful guidance for calculating compliance.) This section specifies that R-values will be calculated using the *Isothermal Planes* method. This method assumes that the boundary between each layer of a building assembly is at constant temperature, which is a relatively appropriate assumption for wood frame construction with relatively low conductivity structural members; however, with conductive structural members such as steel studs, this calculation method should not be used. The R-value of layers of the wall assemblies which include multiple components, such as insulated stud walls, should be calculated using the *Parallel Paths* method (i.e. area weighted U-value calculation). An example wall R-value calculation for an assembly and for the insulted stud layer of the assembly are shown below.



Material properties, air film properties, framing factors (% of the wall area which is framing), and the treatment of thermal bridges for calculating R-values (RSI-values) are provided in appendix Section A9.36.2.4 of the BCBC. For all calculations in this guide, a 23% framing factor was used corresponding with standard framing practices for 16” spaced studs. Part 9 of the BCBC does not require accounting of thermal bridging by discontinuous cladding supports through the exterior insulation such as fasteners or brick ties, or by other penetrating elements such as pipes, ducts, shelf angles, anchors and ties, and minor structural members that must partially or completely penetrate the building enclosure to perform their intended function. Major penetrations such as balconies, beams, and columns do not need to be included as long as they form less than 2% of the gross wall area, and the surrounding insulation is installed tight against the penetrating element. Continuous cladding supports such as strapping which penetrates the insulation should be accounted for. Thermal calculation requirements are different for buildings covered by Part 3 of the BCBC.



$$\left[\frac{U_F \cdot A_F + U_I \cdot A_I}{A_F + A_I}\right]^{-1} = \left[\frac{0.148 \cdot 23 + 0.053 \cdot 77}{23 + 77}\right]^{-1} = \textbf{R-13.4}$$

Cladding Attachment

Often exterior insulation is required to achieve R-22 thermal performance, and the associated cladding attachment and detailing may be new for some builders. In a conventional wood-framed wall assembly, cladding is attached either directly to the sheathing or over vertical strapping[1] fastened directly to the stud wall and wood sheathing. The addition of exterior insulation increases the distance between the sheathing and the cladding, thus changing the loading which must be supported.

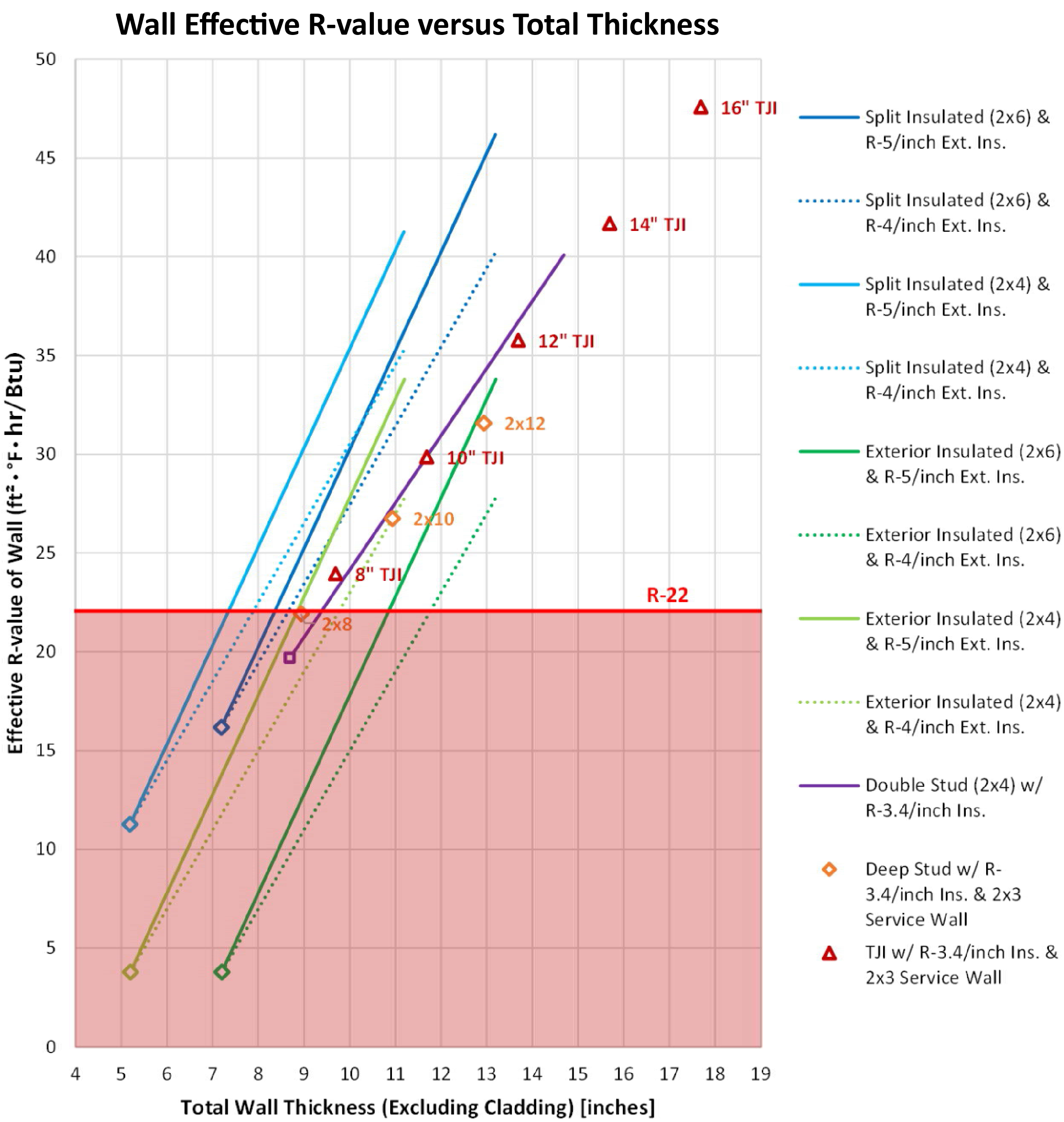
There are various approaches which can be used to support the cladding, and the selection of a method often depends on the structural loads which must be accommodated. The amount of thermal bridging (i.e. reduction in effectiveness of the exterior insulation) associated with each of these methods varies, and is also an important consideration. In all cases, it is important that other aspects of assembly design including the provision of drainage be considered.

- **Fasteners Through Insulation:** Cladding can be attached and supported by vertical strapping (i.e. furring) which is fastened with long screws or nails through the exterior insulation and into the framed wall. This is the most thermally efficient mechanically fastened cladding support option as thermal bridging of the exterior insulation is limited to the fasteners through the insulation. The strapping also creates a drainage space, capillary break, and ventilation cavity (i.e rainscreen cavity) which is consistent with effective moisture-management techniques. To support the cladding, the fasteners and the strapping on the rigid exterior insulation form a structural truss system. Additionally, friction between the insulation and the sheathed wall—created by the force applied by tension on the fasteners when installed into the sheathing or studs—provides additional support in the service load state. Extruded polystyrene (XPS), expanded polystyrene (EPS), polyisocyanurate, and rigid mineral fibre insulations (typically > 8 lbs/ft^3) are suitable for this attachment method.
- **Proprietary Thermally Efficient Spacers and Clips:** Proprietary thermally efficient spacer and clip systems can be used to facilitate installation and/or to support heavier claddings or resist larger wind loads. A number of systems exist, and selection should be made based on the thermal efficiency of the spacers in combination with the ability to support the required loads and accommodate the specified insulation thickness. Low conductivity materials such as fiberglass and stainless steel can provide excellent thermal efficiency. These spacer and clips systems provide the additional benefit of facilitating the use of semi-rigid (rather than rigid) insulation.
- **Continuous Strapping or Wood Spacers:** Cladding can also be supported using continuous wood strapping which penetrates the exterior insulation, or alternatively by standard strapping installed over wood spacers. When continuous wood strapping is used, the reduction of the thermal efficiency of the exterior insulation should be accounted for using a parallel paths approach, consistent with the approach for wood stud walls. Continuous strapping and wood spacers can also provide the additional benefit of facilitating the use of semi-rigid insulation, rather than rigid.
- **Masonry Ties:** In cases where masonry cladding is used, masonry ties are used to support the cladding in conjunction with bearing of the masonry on lintels or a shelf angle, consistent with standard practice for this cladding type. These ties can either be installed such that they penetrate the exterior insulation, or can be installed on the exterior face of thermally efficient spacer systems to reduce the thermal impact of the ties.
- **Structural Adhesive:** In some systems, such as Exterior Insulated Finish Systems (EIFS), structural adhesives can be used to attach the exterior insulation and integrated cladding. An advantage of this system is that no structural elements must penetrate the insulation, so consequently there is essentially no reduction in the insulation effectiveness. Historically moisture related issues have been experienced with face-sealed EIFS; however, adequate performance is achievable when installed using rainscreen principles including drainage behind the insulation and good detailing over a robust water resistive barrier.

[1]Note that for the purposes of this guide, the term “strapping” will be used to describe vertical wood furring used to create a capillary break and ventilation space (i.e. rainscreen cavity).

Wall Thickness & R-Value

When constructing relatively more highly insulated wall assemblies, a common concern is the increase in wall thickness compared to conventional (i.e. less insulated) assemblies. This increase in thickness can potentially have an impact on requirements with respect to floor space limitations and setback distances to property lines. To aid in selecting the optimal wall arrangement for a given project, the chart below indicates the total thickness and effective R-value of a number of the different assemblies in this guide. The values provided in the chart correspond with the tabulated R-values provided in each relevant section of the guide, and consequently, additional information on each of these assemblies is provided in the associated section.



This chart indicates that, of the assemblies discussed in this guide, a split insulated 2x4 wall provides R-22 effective thermal resistance in the least total wall thickness. Despite this, different wall assemblies will often be selected to meet other design criteria including water and vapour control, constructability, familiarity, and aesthetics.

Air Barrier Systems

An air barrier system is used to control the flow of air into and out of a building. Control of these airflows is important to limit energy loss due to exfiltration, to reduce the potential for air leakage and associated condensation, for occupant comfort, and for indoor air quality. In the City of Vancouver, new residential construction must achieve an airtightness of 3.5 ACH50[1]. No such requirement currently exists in the rest of British Columbia.

For an air barrier to be effective, it must meet five design requirements:

- All the elements (materials) of the air barrier system must be adequately air-impermeable.
- The air barrier system must be continuous throughout the building enclosure including at transition and penetration details.
- The air barrier system must be structurally adequate or be supported to resist air pressure forces due to peak wind loads, sustained stack effect, and mechanical equipment such as fans.
- The air barrier system must be sufficiently rigid or be supported so that displacement under pressure does not compromise its performance or that of other elements of the assembly.
- The air barrier system should have a service life as long as that of the wall and roof assembly component or alternately be easily accessible for repair or replacement.

A number of different systems exist which can fulfill these requirements, and each has potentially positive and negative attributes.

Interior Air Barrier Systems

Sealed Polyethylene (or Other Membranes) - In the sealed polyethylene sheet air barrier system approach, the polyethylene sheet installed to the interior of the stud cavity is sealed at all transitions and penetrations with tapes and sealants to provide a continuous air barrier system. The polyethylene sheet is clamped between the framing and the gypsum wall board which provide the necessary structural support. A similar approach can also be used with alternative sheet products such as smart vapour retarders or other appropriate plastic membranes.

Airtight Drywall Approach (ADA) - In the ADA, the interior gypsum wall board (i.e. drywall) provides the air barrier system, and continuity is maintained using sealants and/or gaskets. Special attention must be paid to ensure continuity at intersections of the exterior walls with partition walls, ceilings, and floors.

Exterior Air Barrier Systems

Sealed Sheathing - The sealed sheathing air barrier system approach consists of sealing the joints between sheathing boards using membrane, tape, or sealant so that the sheathing itself provides the air barrier. As the sheathing itself is rigid and fastened to the studs, no additional support is typically required for this system.

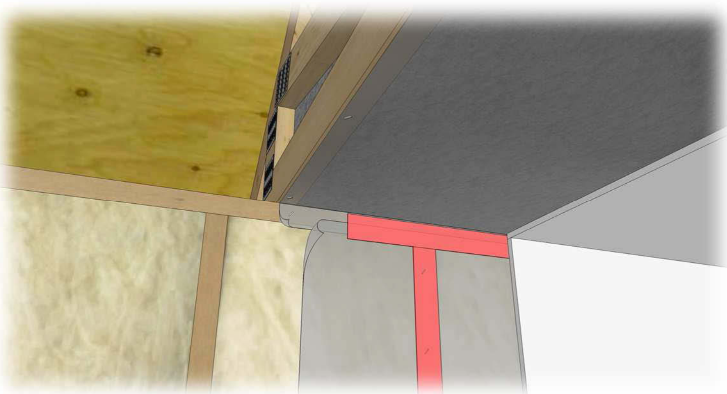
Sheathing Membrane - The sheathing membrane, which is usually installed as a water resistive barrier (WRB), can also be function as the air barrier. Both mechanically fastened and self-adhered sheet membranes can potentially be used. For mechanically fastened systems, the laps between sheets should be sealed, and in all systems penetrations and transitions should be sealed. While adhesion and fastening of these systems provides some support, often the wood strapping or exterior insulation provide improved support for these systems.

Spray Foam - Both open cell and closed cell spray polyurethane foams can be used as an air barrier, and are often used at penetrations and transitions to accommodate complex geometries; however, these products can also be used within the stud cavities or on the exterior to provide the main component of the air barrier system. Joints, cracks, and gaps that are too small to be effectively sealed with spray foam (such as between bottom plate and floor, or between double top plates) should be sealed with other sealants or adhesives.

[1]ACH50 means air changes per hour measured at a 50 Pa pressure difference across the exterior building enclosure. It is also possible to meet this requirement in Vancouver by sealing according to good engineering practice with visual confirmation by a Certified Energy Advisor.

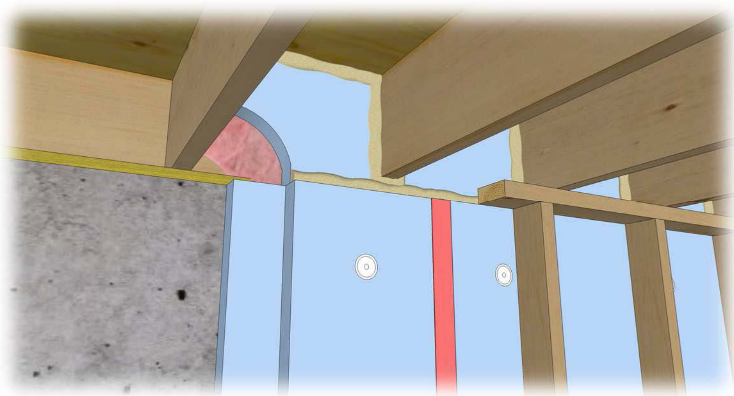
Interior Air Barrier Systems

Typically the most important consideration in designing an air barrier system is maintaining continuity at transition and penetration details. A selection of these key details are provided below, which graphically indicate potential methods for maintaining air barrier continuity. Note that various other important details exist, and alternate methods for ensuring continuity are possible. These details are for a polyethylene sheet air barrier, but other interior air barrier systems such as airtight drywall should also address continuity at these key locations. Various other resources with respect to air barrier detailing are provided at the end of this guide.



Roof to Wall Transitions

Compared to exterior air barrier systems, one advantage of interior air barriers is that typically the roof to wall transition is more straightforward. In the above detail, continuity at the transition is provided simply by taping the polyethylene sheet in the ceiling to the sheet in the wall.



Above Grade to Below Grade Wall Transitions

Where the above grade walls meet the below grade walls it is important to ensure that the air barrier system maintains continuity. In the above detail, blocks of air-impermeable insulation are cut and installed between the joists, and spray foam is used to seal around their perimeter.

Electrical Receptacles Penetrations

Penetrations through the air barrier should be sealed to ensure continuity. In the above detail, an electrical receptacle is sealed using a pre-made polyethylene boot, which is then sealed to the polyethylene sheet air barrier. When using interior air barrier systems, penetrations that require sealing are often numerous. They may include pipes, light fixtures, fans, and structural members.

Rim Joist Transitions

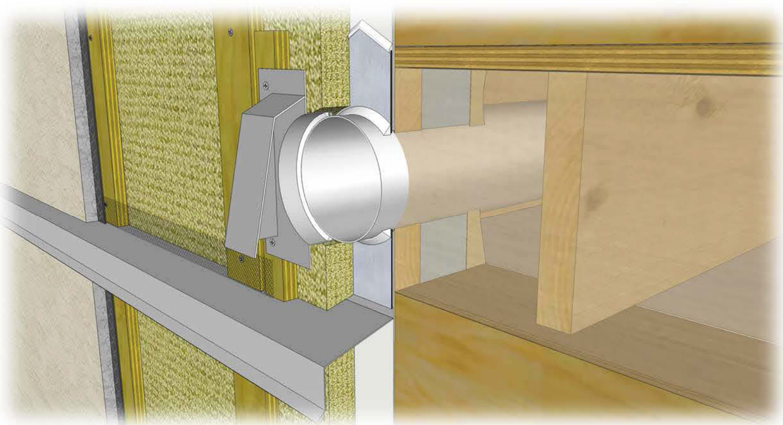
When using an interior air barrier system, floors of the building interrupt the air barrier and transition detailing is required. In the above detail, blocks of air-impermeable insulation are cut and installed between the joists, and spray foam is used to seal around their perimeter. These locations should be insulated to the same level as the adjacent wall.

Exterior Air Barrier Systems

While placing the air barrier on the exterior will typically simplify and reduce the number of air barrier transitions and penetration that must be dealt with, a variety of key details still exist which should be carefully considered. A selection of these key details are provided below which graphically indicate potential methods for maintaining air barrier continuity at these locations. Various other important details exist, and alternate methods for ensuring continuity are possible. These details are for a mechanically fastened sheet sheathing membrane, but can be adapted for other systems such as adhered sheathing membranes.

Roof to Wall Transitions

When an exterior air barrier system is used, often one of the challenging transition details is at the roof-to-wall interface. The adjacent detail indicates transition of the air barrier from the sheathing membrane to the polyethylene sheet in the ceiling via adhered membrane, sheathing, sealant, top plate, and then sealant. Alternative methods for this detail include pre-stripping a sheet air barrier material between the plates prior to installation of the roof truss.

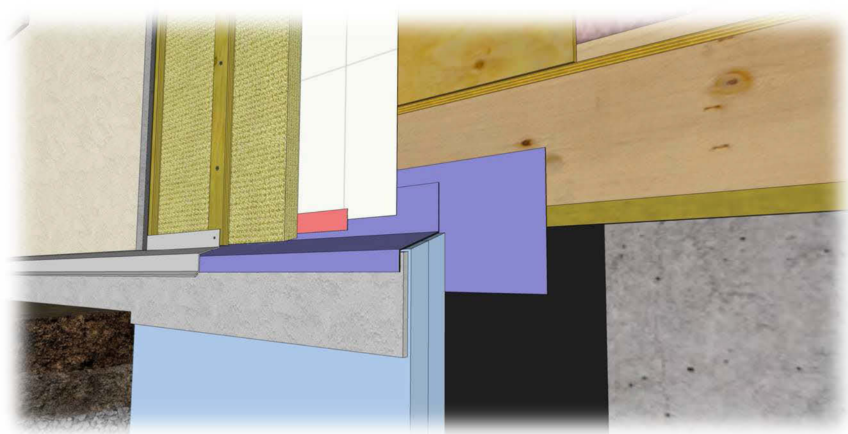


Mechanical Ducts or Other Penetrations

Penetrations through the air barrier should be sealed to ensure continuity. In the adjacent detail a duct penetration is sealed using a foil-faced transition membrane and sealant. The hood is also sealed to the duct to prevent the exhausting of humid air into the wall cavity. Other penetrations which should be sealed include pipes, wires, conduits, structural members, and decorative accessories.

Above Grade to Below Grade Wall Transitions

Where the above grade walls meet the below grade walls it is important to ensure that the air barrier system maintains continuity. In the adjacent detail a combination of sheathing tape and an adhered membrane are used to transition from the sheathing membrane to the below grade waterproofing membrane.



Environmental Design

While a wall R-value performance target of R-22 works to significantly reduce the energy consumption of the building as compared to buildings with less insulated walls, when selecting wall assemblies, it is also important to consider the overall environmental impact. This guide uses a three-leaf scale to indicate the relative complete life-cycle environmental impact of each of the wall assemblies. Each of the three leaves corresponds with a different part of the life-cycle of the wall assemblies: Materials and Construction, Ease of Modification, and End of Service Life. The evaluation with respect to these three categories is then combined to create a total cumulative score out of three (e.g. 0.75 + 1.0 + 0.75 = 2.5 out of 3 total). Above grade walls and below grade walls are evaluated on different scales, as they typically have significantly different constructions (i.e. wood versus concrete). Note that the selection of alternative materials and construction practices may influence these ratings, as will the predicted service life.


Acceptable


Good


Excellent

Leaf 1: Materials and Construction

This leaf accounts for the environmental impacts of the initial phase of a building assembly's life-cycle, including producing the materials and constructing the assemblies themselves. It accounts for factors such as primary resource harvesting and mining, transportation of materials to the factory and building site, material waste, and the energy used to produce and install the materials. This category was evaluated using Athena IE4B (see below).

Leaf 2: Ease of Modification

During the service life of a wall assembly, it is likely that modifications to the original structure will be desired, whether due to a different desired aesthetic, a change in use of the building, or simply to provide additional space. This leaf provides an indication of how easy it is to modify the assembly to accommodate changes to the building structure over its life, thereby facilitating continued use of the building. It takes into account aspects of construction including the ease of material removal (i.e. spray foam versus board or batt products) as well as the complexity of the construction. The performance of each assembly for this category was determined using a qualitative evaluation based on experience with the materials and assemblies.

Leaf 3: End of Service Life

At the end of the service life of a wall assembly, it is necessary to deconstruct the assembly and then safely dispose of its constituent materials. In some cases it may also be possible to reuse or recycle some or all of the materials in an assembly. This third leaf accounts for this phase of the wall assembly life-cycle including the environmental impacts associated with deconstruction, transport of the waste materials, and disposal of the materials. This category was evaluated using Athena IE4B (see below).

Athena Impact Estimator for Buildings

The Athena Impact Estimator for Buildings (Athena IE4B v.5.0.0105) is a life-cycle assessment software tool developed by the Athena Sustainable Materials Institute for the assessment of buildings and their assemblies. The tool provides a database of materials including the environmental impact associated with their production, installation, maintenance, and disposal through the life-cycle of a building. It includes consideration of a wide range of factors including global warming potential, acidification potential, human health particulates, ozone depletion potential, smog potential, and eutrophication potential. More information regarding the Athena Institute and a free download of IE4B (with registration) are available at www.athenasmi.org.

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Above Grade Walls

This section provides information about four different above grade wall assemblies that can achieve the R-22 thermal performance target:

- Split Insulated Walls
- Exterior Insulated Walls
- Double Stud Walls
- Deep Stud Walls with Service Wall

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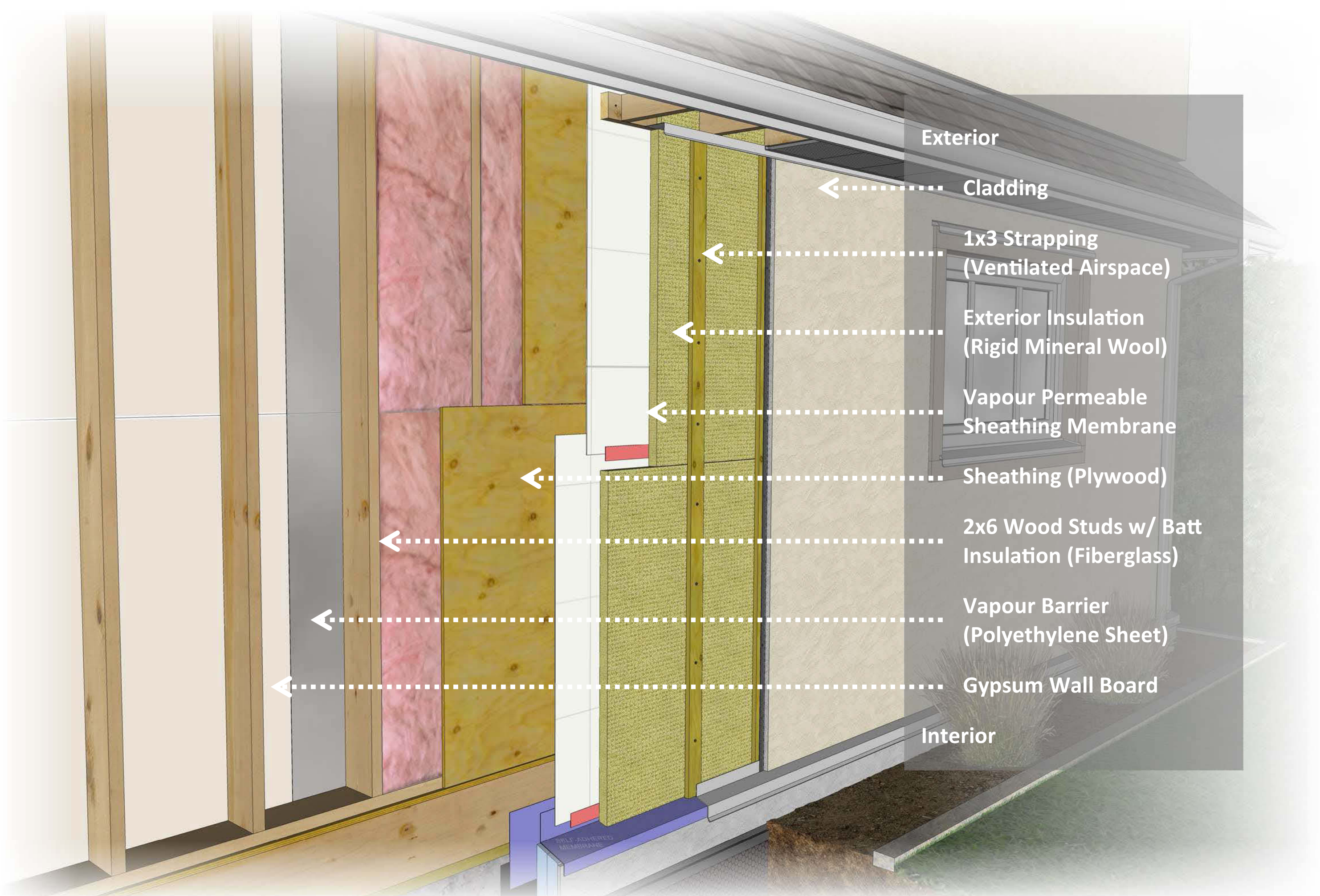
Split Insulated Walls

This above grade wall assembly consists of rigid or semi-rigid insulation placed on the exterior of a conventional above grade, insulated 2x4 or 2x6, wood-frame wall assembly. High effective R-values of the assembly are achieved by using continuous insulation outside of the structural framing and thermally efficient cladding attachments, in combination with insulation in the stud space. In most cases, cladding can be supported by furring fastened with screws or nails through rigid insulation; however, it is also possible to use thermally efficient cladding attachment systems. The exterior insulation product used in this arrangement should not be sensitive to moisture as it will be exposed to periodic wetting. In cold climates, insulation placed on the exterior of the stud wall increases the temperature of the moisture-sensitive wood sheathing and framing and consequently often improves the durability of the assembly by reducing the risk of condensation and associated moisture damage.



Key Considerations:

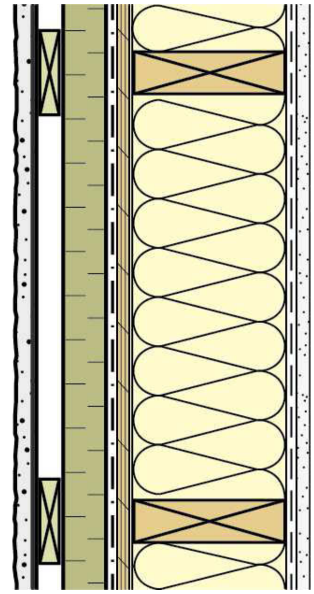
- The method of cladding attachment is important to limit thermal bridging through the exterior insulation while adequately supporting the exterior cladding.
- The vapour permeability of the sheathing membrane and exterior insulation should be carefully considered so as not to create a risk of condensation within the assembly, or to intolerably reduce the ability of the assembly to dry in the event that incidental wetting occurs.

Split Insulated Walls (cont.)

Above Grade Walls

Cladding

Any type of cladding can be used with this wall assembly. The selection of the cladding attachment strategy will depend on the weight and support requirements of the cladding. In many cases, the cladding can simply be attached to vertical 1x3 strapping (or similar) fastened through the exterior insulation and into the sheathing. In this arrangement, the rigid exterior insulation and fasteners will act in tandem to carry the cladding load by creating a truss system with the insulation being put in compression by bearing of the wood furring on the insulation surface, and the fasteners being put in tension. Thermally efficient cladding supports and brick ties can also be used with this assembly and would permit the use of semi-rigid exterior insulation products.



Water Resistive Barrier

A vapour-permeable sheathing membrane should be installed on the exterior of the wall sheathing, behind the exterior insulation. There are a variety of both loose (i.e. mechanically fastened) and self-adhered sheet products, as well as some liquid applied products that can be used in this application. The sheathing membrane should be vapour-permeable so as to facilitate some outward drying of the assembly. Where relatively impermeable foam insulation is used on the exterior, joints should be taped and sealed so that water does not penetrate through the insulation and potentially become trapped in the wall assembly. (Further discussion on next page.)

Air Barrier

This assembly can accommodate several air-barrier strategies; however, often the most straightforward is to use the sheathing membrane. If the sheathing membrane is to form the air barrier, it must be taped and sealed to ensure continuity. Structural support of the sheathing membrane is provided by the sandwiching of the insulation and sheathing on either side. Alternatively, a sealed sheathing approach can be used, or potentially airtight polyethylene on the interior of the stud wall or airtight drywall, though ensuring continuity of the latter approaches can be arduous. Continuity of the air barrier at transitions and penetrations is critical to its performance.

Vapour Barrier

The exterior insulation in this assembly increases the temperature of the sheathing and reduces the potential for condensation; however, a vapour barrier should still be installed on the interior of the stud wall unless the majority of insulation R-value is placed on the exterior of the sheathing. Typically, a polyethylene sheet is used as the interior vapour barrier in these types of assemblies, though other options including vapour barrier paint or smart vapour retarder sheet products may be appropriate. If sufficient exterior insulation is installed a more permeable options such as latex paint may be adequate. These more permeable options may be desirable if relatively impermeable exterior insulation products are used. (Further discussion on following pages.)

Effective Assembly R-value of Split Insulated Wall Assembly [ft² • °F • hr/Btu]

Thickness of Exterior Insulation	2x4 Stud Wall (R-12 Batts)		2x6 Stud Wall (R-19 Batts)	
	R-value/inch of Exterior Insulation			
	R-4.0	R-5.0	R-4.0	R-5.0
0”	11.3	11.3	16.2	16.2
1/2”	13.3	13.8	18.2	18.7
1”	15.3	16.3	20.2	21.2
1 1/2”	17.3	18.8	22.2	23.7
2”	19.3	21.3	24.2	26.2
2 1/2”	21.3	23.8	26.2	28.7
3”	23.3	26.3	28.2	31.2
3 1/2”	25.3	28.8	30.2	33.7
4”	27.3	31.3	32.2	36.2
4 1/2”	29.3	33.8	34.2	38.7
5”	31.3	36.3	36.2	41.2
5 1/2”	33.3	38.8	38.2	43.7
6”	35.3	41.3	40.2	46.2

A 23% framing factor is assumed which is consistent with standard 16” o.c. stud framing practices.

Split Insulated Walls (cont.)

Above Grade Walls

Interior Insulation Types

The stud space can be insulated using a variety of different insulation types, including batts (i.e. mineral wool or fiberglass), blown-in fibrous insulation (i.e. cellulose or fiberglass), or open-cell spray foam. With fibrous fill insulations, higher density blown products with integral binders can be used to prevent settlement. A combination of closed-cell spray foam and fibrous fill in a flash-and-fill application could also be considered to improve airtightness of the assembly and also reduce convective looping due to voids within the insulation between the studs.

Environmental Considerations

Split insulated walls typically have a relatively low environmental impact due to the limited material usage and ease of modification. The 2.5 rating provided for this assembly is the same regardless of the selected exterior insulation type as shown below. However, when closed-cell spray foam is used in the stud cavity instead of batts, the rating is significantly decreased. This decrease is in part due to the significant effort required to remove spray foam from the stud cavities to allow for modifications.

Mineral Wool Exterior Insulation

EPS Exterior Insulation

Closed-Cell Spray Foam in Stud Cavity with Mineral Wool Exterior Insulation

XPS Exterior Insulation

Polyiso Exterior Insulation

Other Considerations

When installing insulation on the exterior of the sheathing, typically wider strapping is used to distribute the cladding load to a wider area of the insulation to provide adequate support and avoid compression of the insulation. Either preservative-treated dimensional 1x3 lumber or preservative-treated plywood strapping cut to 2 ½" strips can be used in this application. Care should be taken to ensure that the necessary ventilation area is maintained when using wider strapping. Compatibility of fasteners with the strapping wood treatment should also be considered.[1]

Various types of sheathing can potentially be used with this assembly including both plywood and OSB; however, it is important to consider the structural implications of the sheathing selection. In addition to more common structural considerations such as shear resistance, the use of exterior insulation also necessitates that the sheathing strength be considered for pull-out of the strapping fasteners. Depending on the structural requirements of the cladding system selected, in some cases it may be possible to support the cladding using strapping only fastened to sheathing, and not necessarily to the studs.

[1]Borate treatments are often suitable for the treatment of wood strapping, and are recommended for most applications. Generally, to avoid potential material compatibility issues, stainless steel fasteners should be used when using alkaline copper quat (ACQ) treated wood, and either stainless steel or galvanized steel fasteners can be used when using chromated copper arsenate (CCA) treated wood. Caution should be exercised when using aluminum based materials in conjunction with copper based wood treatments such as ACQ and CCA.

Split Insulated Walls (cont.)

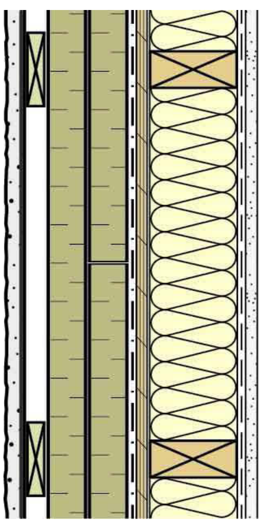
Exterior Insulation Types & Considerations

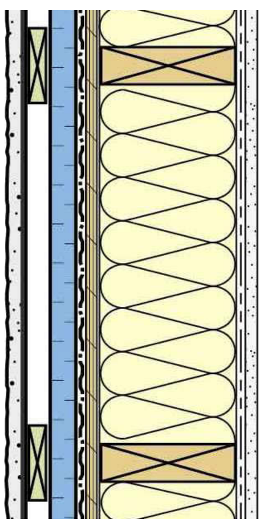
Various types of exterior insulation can potentially be used in split insulated wall assemblies, including permeable insulations such as semi-rigid or rigid mineral wool, or semi-rigid fiberglass, and relatively impermeable insulations such as extruded polystyrene (XPS), expanded polystyrene (EPS), polyisocyanurate (polyiso), and closed-cell spray polyurethane foam. While each of these insulation materials can provide adequate thermal resistance, the permeability of the materials is of particular importance with respect to the drying capacity of the wall assembly. A relatively impermeable foam plastic insulation will not allow for moisture in the wall to dry outwards. If this insulation is installed in conjunction with an interior vapour barrier (i.e. polyethylene sheet), the two vapour barriers can trap moisture that inadvertently gets into the assembly and can potentially lead to fungal growth and decay.

To avoid this situation, when impermeable insulation is used, the ratio of insulation outboard of the sheathing to insulation in the stud cavity should be carefully considered so as to maintain the temperature of the sheathing at relatively safe levels and avoid condensation. Also, a thin drainage layer can be installed on the exterior of the sheathing membrane to facilitate drainage of any water which may penetrate behind the insulation, and a relatively more permeable interior vapour barrier could be used to permit some amount of inward drying. **In general, a vapour permeable exterior insulation in combination with an interior vapour barrier typically provides a lower risk wall assembly than does an assembly using impermeable exterior insulation.**

Code Compliance Paths for Split Insulated Wall Assemblies

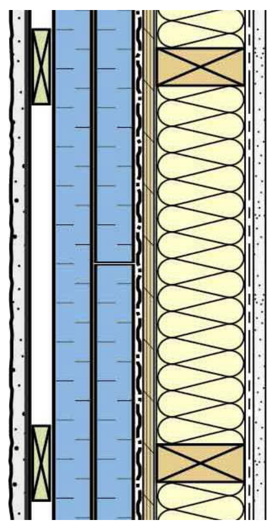
Relatively Permeable Exterior Insulation (> 60 ng/(s · m² · Pa))

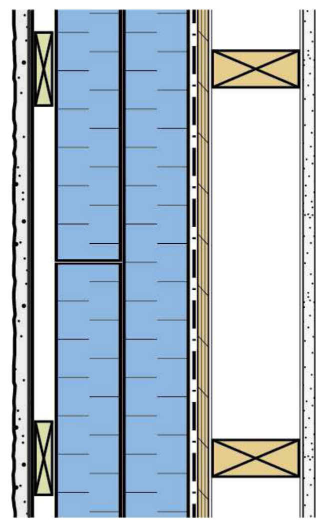




Using permeable exterior insulation (defined by code as > 60 ng/(s · m² · Pa)) does not trigger the requirements regarding placement of impermeable insulation products and consequently can comply with code. When using this approach it is important to consider the thickness of the insulation in determining its permeance. When exterior insulation with permeance relatively close to the code limit is used, it may be prudent to provide a drainage layer behind the insulation as well as a relatively permeable interior vapour barrier such as a smart vapour retarder or vapour retarder paint.

Exterior-to-Interior Insulation Ratio (Table 9.25.5.2)

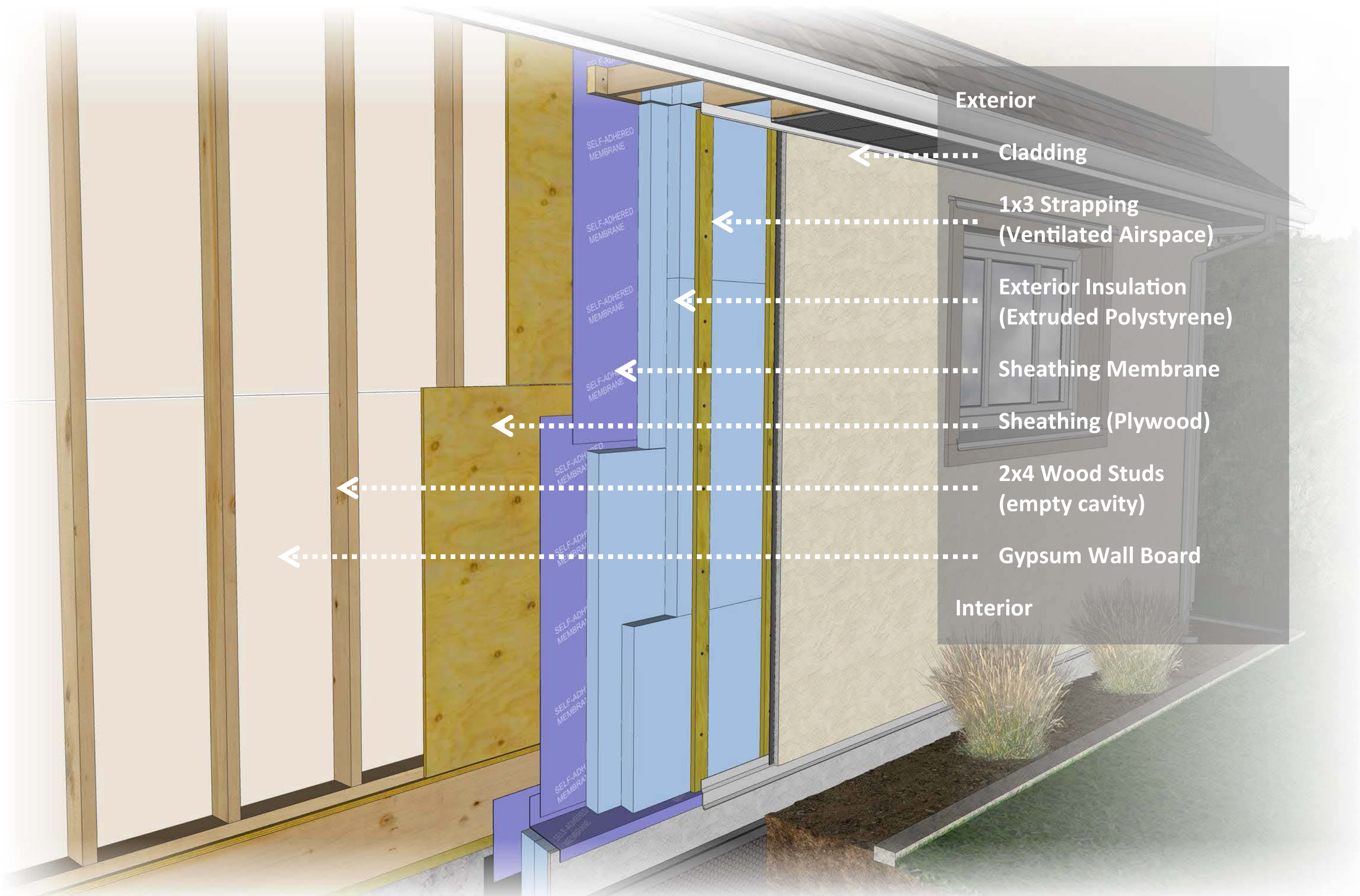




When impermeable exterior insulation is used, the wall can comply by meeting the insulation ratio requirements of Table 9.25.5.2 which are intended to limit the potential for condensation within the wall assembly. Since outward drying in these assemblies is limited by the impermeable insulation, it may be prudent to use a drainage layer behind the exterior insulation, as well as a relatively permeable interior vapour barrier such as a smart vapour retarder or vapour retarder paint. The exterior-to-interior insulation ratio can also be taken to an extreme such that only exterior insulation is used.

Exterior Insulated Walls

This above grade wall assembly consists of rigid or semi-rigid insulation placed on the exterior of a conventional above grade, uninsulated 2x4 or 2x6, wood-frame wall assembly. High effective R-values of the assembly are achieved by using continuous insulation outside of the structural framing in combination with thermally efficient cladding attachments. In most cases cladding can be supported by furring fastened with screws or nails through rigid insulation. It also possible to use thermally efficient cladding attachment systems. The exterior insulation product used in this arrangement should not be sensitive to moisture as it will be exposed some periodic wetting. In cold climates, insulation placed on the exterior of the stud wall increases the temperature of the moisture-sensitive wood sheathing and framing and consequently often improves the durability of the assembly by reducing the risk of condensation and associated moisture damage.

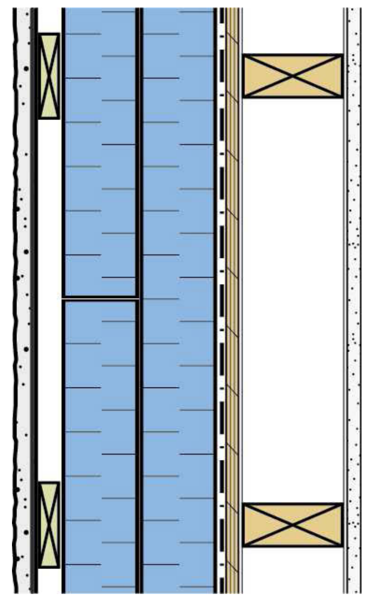


Key Considerations:

- The method of cladding attachment is important to limit thermal bridging through the exterior insulation while adequately supporting the exterior cladding.
- Since in this assembly the insulation is located entirely outside the framed wall, the typically used interior vapour barrier (i.e. polyethylene sheet, vapour barrier paint, etc.) should be removed.
- Vapour impermeable sheathing membrane can be used to provide both liquid water and vapour control (i.e. water resistive barrier and vapour barrier).

Exterior Insulated Walls (cont.)

Above Grade Walls



Cladding

Any type of cladding can be used with this wall assembly. The selection of the cladding attachment strategy will depend on the weight and support requirements of the cladding. In many cases the cladding can simply be attached to vertical 1x3 strapping (or similar) fastened with screws or nails through the exterior insulation and into the sheathing. In this arrangement, the rigid exterior insulation and fasteners will act in tandem to carry the cladding load by creating a truss system with the insulation being put in to compression by bearing of the wood furring on the insulation surface, and the fasteners being put into tension. Thermally efficient cladding supports and brick ties can also be used with this assembly and would permit the use of semi-rigid exterior insulation products.

Water Resistive Barrier

A vapour-impermeable sheathing membrane should be installed on the exterior of the wall sheathing, behind the exterior insulation, to provide the water resistive barrier for this assembly. Typically a self-adhered sheet product is appropriate for this application, and some liquid applied products can also be used. Where relatively impermeable foam insulation is used on the exterior, joints should be taped and sealed so that water does not penetrate through the insulation and potentially become trapped in the wall assembly.

While an impermeable membrane often provides the lowest risk and most easily constructed assembly, it is also possible to use a vapour permeable sheathing membrane in this assembly, though it is important that drainage be provided between the insulation and sheathing membrane in this arrangement.

Air Barrier

The most straightforward air barrier approach for this assembly is to use the self-adhered sheathing membrane. If a mechanically fastened sheathing membrane is used, it must be taped and sealed to ensure continuity. Structural support of a mechanically fastened sheathing membrane is provided by the sandwiching of the insulation and sheathing on either side. Alternatively, a sealed sheathing approach can be used. Continuity of the air-barrier at transitions and penetrations is critical to its performance.

Exterior Insulation Types

Various types of exterior insulation can potentially be used in this assembly including permeable insulations such as semi-rigid or rigid mineral wool, or semi-rigid fiberglass, and relatively impermeable insulations such as extruded polystyrene (XPS), expanded polystyrene (EPS), polyisocyanurate (polyiso), and closed-cell spray polyurethane foam.

Vapour Barrier

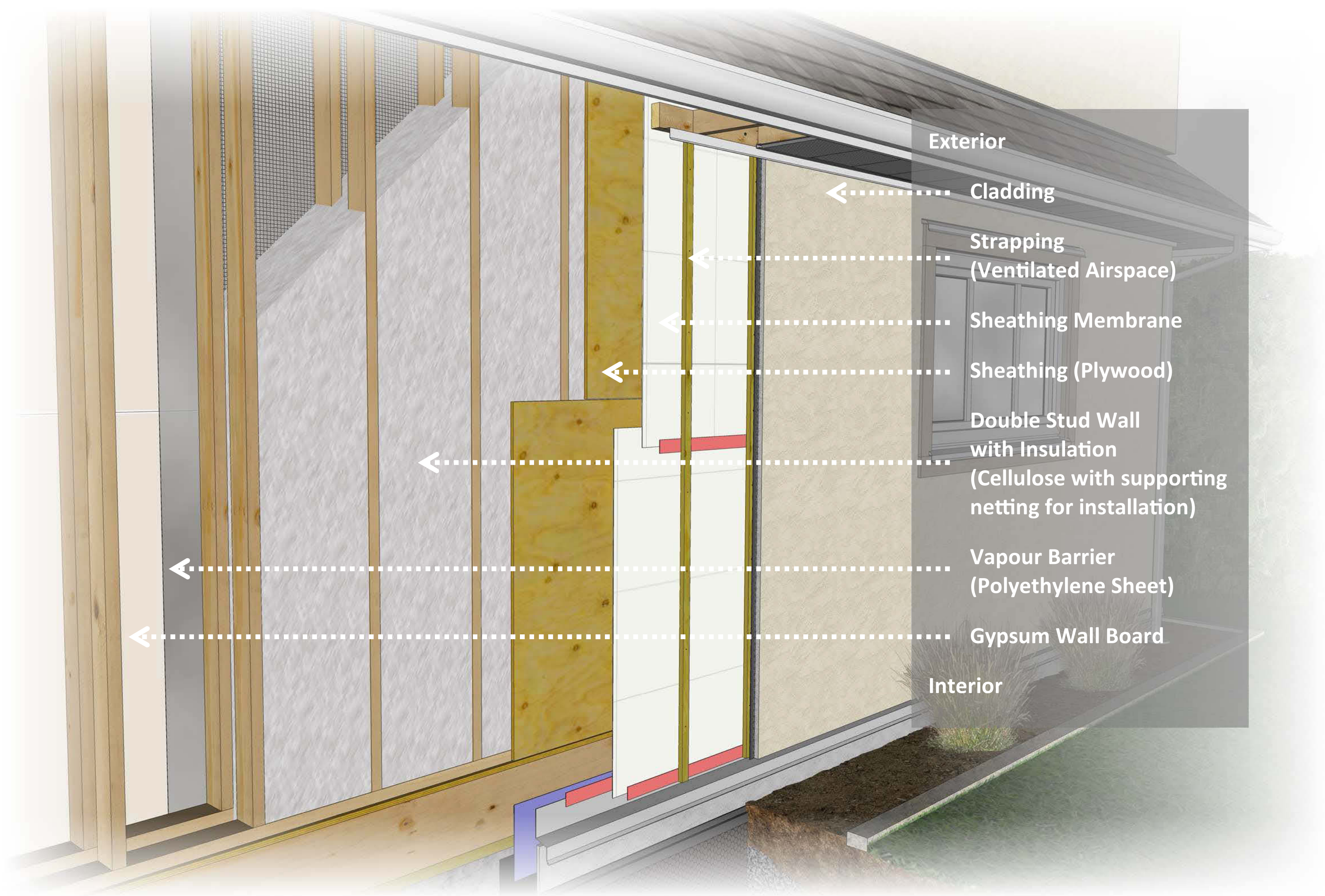
The exterior insulation in this assembly increases the temperature of the sheathing and nearly eliminates the potential for damage associated with condensation on the framing. Relatively impermeable sheathing membranes can be used as the vapour barrier in this assembly, and help limit the potential for inward vapour drive from incidental water trapped between the insulation and the sheathing membrane. A vapour barrier should not be installed to the interior of the exterior sheathing. (i.e. polyethylene sheet).

Effective Assembly R-value for 2x4 or 2x6 Exterior Insulated Stud Wall (No Batts) [ft² • °F • hr/Btu]

Thickness of Exterior Insulation	R-value/inch of Exterior Insulation	
	R-4.0	R-5.0
3 1/2”	17.8	21.3
4”	19.8	23.8
4 1/2”	21.8	26.3
5”	23.8	28.8
5 1/2”	25.8	31.3
6”	27.8	33.8
6 1/2”	29.8	36.3
7”	31.8	38.8

Double Stud Walls

This above grade wall assembly consists of a deeper stud cavity created by an additional framed wall installed to the interior of a conventional wood-frame wall. High effective R-values of the assembly are achieved by filling the increased cavity depth with either batt insulation, blown-in fibrous insulation, or spray foam insulation. There is no exterior insulation installed in this assembly, so cladding can be attached directly to the wall through vertical strapping (i.e. furring) using standard rainscreen detailing. In cold climates, the additional depth of insulation installed on the interior side of the exterior sheathing can slightly decrease the sheathing temperature and consequently increase the risk of condensation on the moisture-sensitive wood sheathing and framing. As a result, continuity of the air barrier and installation of an interior vapour barrier are critical to the performance of this assembly, as is the quality of the insulation installation to reduce airflow within the assembly (i.e. convective looping).

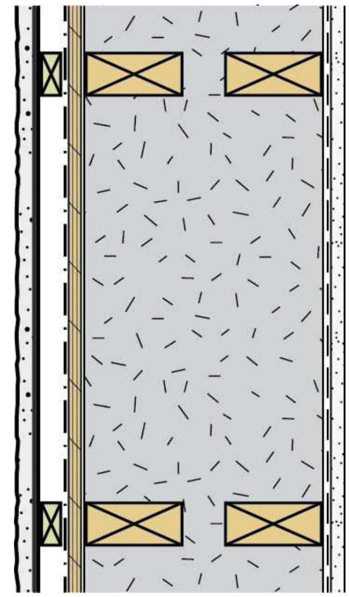


Key Considerations:

- ! The quality of the insulation installation is critical to limiting convective looping within the increased wall assembly depth which can reduce the effectiveness of the insulation and also contribute to moisture accumulation within the assembly.
- ! Continuity of the air barrier and installation of an interior vapour barrier are fundamental to the performance of this assembly as the slightly decreased exterior sheathing temperature (as compared to standard construction) increases the risk of condensation and related damage.

Double Stud Walls (cont.)

Above Grade Walls



Cladding

Any type of cladding can be used with this wall assembly and can be fastened directly to the wall using vertical strapping (i.e. furring) and standard rainscreen details. The cladding is intended to control the majority of bulk water, and any water that does penetrate past the cladding must be able to drain out via the cavity created by the vertical strapping.

Water Resistive Barrier

A vapour-permeable sheathing membrane should be installed on the exterior of the wall sheathing, behind the vertical strapping. There are a variety of both loose (i.e. mechanically fastened) and self-adhered sheet products, as well as some liquid applied products which can be used in this application. The sheathing membrane should be vapour-permeable to facilitate some outward drying of the assembly.

Air Barrier

This assembly can accommodate several air-barrier strategies; however, often the most straightforward is to use the sheathing membrane. If the sheathing membrane is to form the air barrier, it must be taped and sealed to ensure continuity. Structural support of the sheathing membrane is provided by sandwiching between the vertical strapping and sheathing on either side, or else through adhesion to the sheathing. Alternatively, a sealed sheathing approach can be used for the air barrier. In this approach, joints in the sheathing must be taped and sealed.

Due to the significant depth of the insulated space, an interior layer (i.e. polyethylene sheet or drywall) should also be detailed as airtight to provide a secondary air barrier to prevent flow of air into the insulated cavity from the interior and reduce the potential for convective looping.

Insulation Types

The stud space can be insulated using a variety of different insulation types including batt (i.e. mineral wool or fiberglass), blown-in fibrous insulation (i.e. cellulose or fiberglass), or open-cell spray foam. With fibrous fill insulations, higher density blown products with integral binders can be used to prevent settlement within the deep wall cavity. A combination of closed-cell spray foam and fibrous fill in a flash-and-fill application could also be considered to improve airtightness of the assembly and also reduce convective looping within the insulation between the studs.

Vapour Barrier

The relatively large amount of insulation installed to the interior of moisture-sensitive wood framing and sheathing increases the risk of moisture accumulation within this assembly. To control the outward flow of water vapour through this assembly an interior vapour barrier should be installed on the interior of innermost stud wall. Typically a polyethylene sheet is used as the interior vapour barrier in these types of assemblies, though other options including vapour barrier paint may be appropriate.

Other Considerations

In some cases, the studs of the interior framed wall are staggered relative to the exterior studs. By staggering the studs, the thermal bridging of the studs is slightly reduced; however, the R-value calculation method (i.e. isothermal planes) does not provide a benefit for this stagger. Typically the R-value benefit of staggering the studs is minimal once separated by at least one inch.

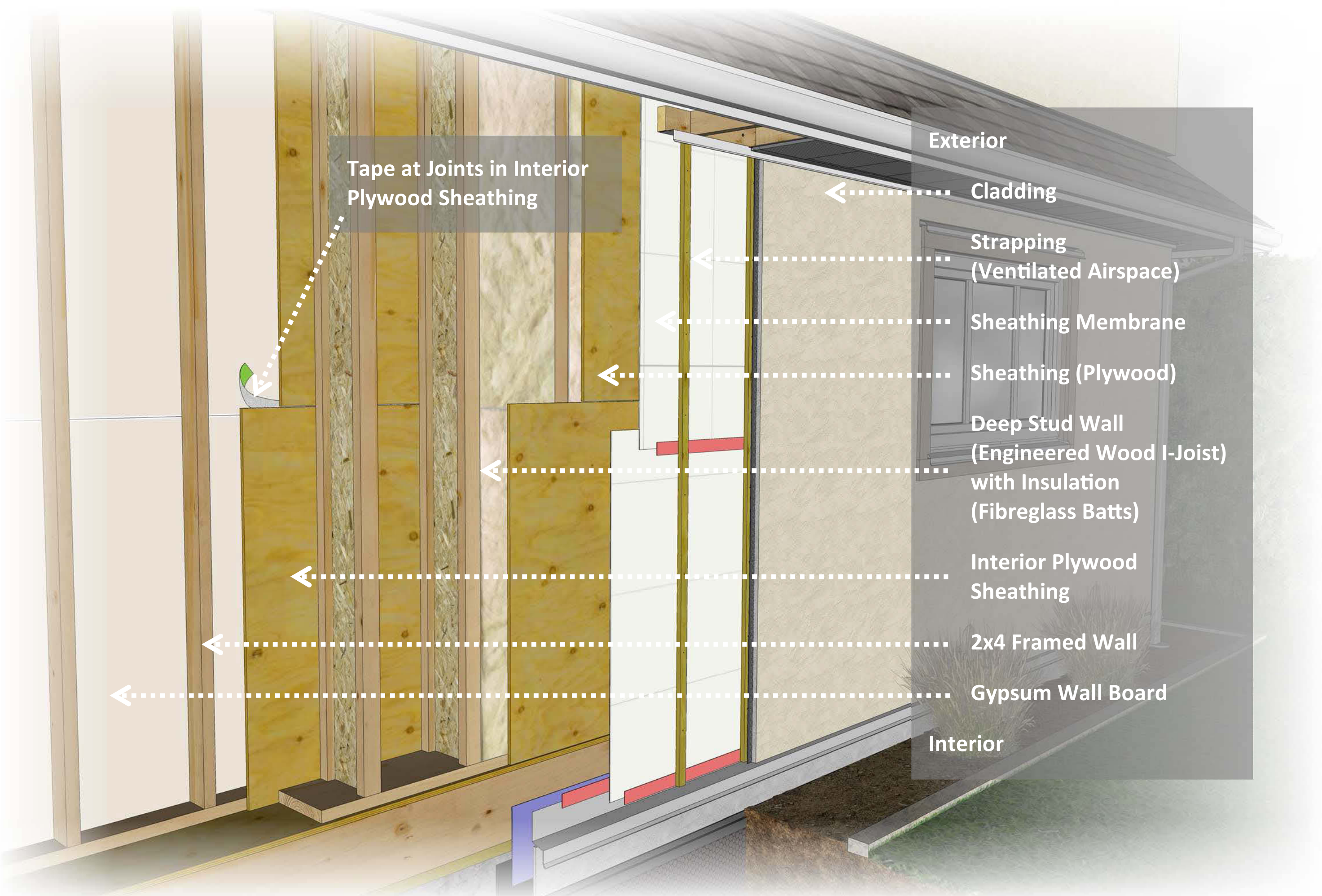
Effective Assembly R-value for Double 2x4 Stud Wall* [ft² • °F • hr/Btu]

Thickness of Gap Between Stud Walls	R-value/inch of Insulation		
	R-3.4	R-4.0	R-5.0
0”	19.7	21.2	23.3
1/2”	21.4	23.2	25.8
1”	23.1	25.2	28.3
1 1/2”	24.8	27.2	30.8
2”	26.5	29.2	33.3
2 1/2”	28.2	31.2	35.8
3”	29.9	33.2	38.3
3 1/2”	31.6	35.2	40.8
4”	33.3	37.2	43.3
4 1/2”	35.0	39.2	45.8
5”	36.7	41.2	48.3

*Assumes interior stud wall has same framing factor (23%) as exterior stud wall; however, less framing may be necessary since wall may be non-structural.

Deep Stud Walls with Service Wall

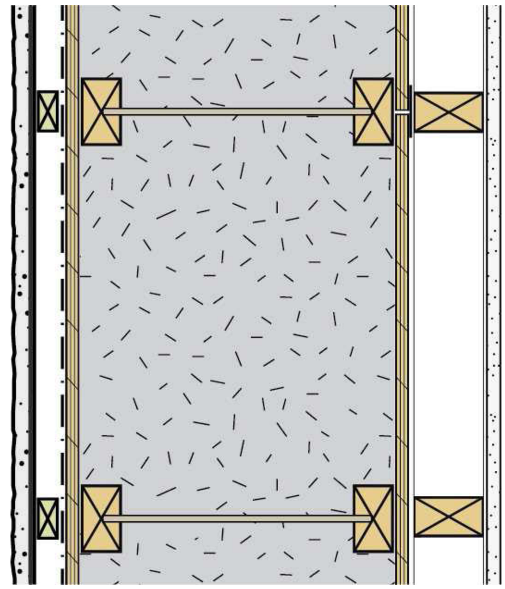
This above grade wall assembly consists of a deeper stud cavity created using either deep studs (2x10, 2x12) or engineered wood I-joists and an additional 2x4 service wall constructed on the interior to allow for running of electrical, plumbing, and HVAC services without penetrating the interior air barrier. These wall types will typically need to be engineered. High effective R-values of the assembly are achieved by filling the increased cavity depth with either batt insulation, blown-in fibrous insulation, or spray foam insulation. There is often no exterior insulation installed in this assembly, so cladding can be attached directly to the wall through vertical strapping (i.e. furring) using standard rainscreen detailing. In cold climates, the additional depth of insulation installed on the interior side of the exterior sheathing can slightly decrease the sheathing temperature and consequently increase the risk of condensation. As a result, continuity of the air barrier and installation of an interior vapour barrier are critical to the performance of this assembly, as is the quality of the insulation installation to reduce airflow within the assembly (i.e. convective looping).



Key Considerations:

- ! The quality of the insulation installation is critical to limiting convective looping within the increased wall assembly depth which can reduce the effectiveness of the insulation and also contribute to moisture accumulation within the assembly.
- ! Continuity of the air barrier and installation of an interior vapour barrier are fundamental to the performance of this assembly, as the slightly decreased exterior sheathing temperature (as compared to standard construction) increases the risk of condensation and related damage.

Deep Stud Walls with Service Wall (cont.)



Cladding

Any type of cladding can be used with this wall assembly and can be fastened directly to the wall using vertical strapping (i.e. furring) and standard rainscreen details. The cladding is intended to control the majority of bulk water, and any water that does penetrate past the cladding must be able to drain out via the cavity created by the vertical strapping.

Water Resistive Barrier

A vapour-permeable sheathing membrane should be installed on the exterior of the wall sheathing, behind the vertical strapping. There are a variety of both loose (i.e. mechanically fastened) and self-adhered sheet products, as well as some liquid applied products that can be used in this application. The sheathing membrane should be vapour-permeable so as to Ffacilitate some outward drying of the assembly.

Air Barrier

The interior sheathing between the service wall and deep stud (or engineered wood I-joist) wall should be detailed as airtight to provide the air barrier for this assembly. This interior air barrier will prevent the flow of air into the insulated cavity from the interior as well as reduce the potential for convective looping. In addition to the interior air barrier, a secondary exterior air barrier such as a vapour permeable self-adhered sheathing membrane or sealed sheathing can also be used to reduce wind penetration and improve the overall assembly airtightness.

Insulation Types

The stud space can be insulated using a variety of different insulation types including batt (i.e. mineral wool or fiberglass), blown-in fibrous insulation (i.e. cellulose), or open-cell spray foam. With fibrous fill insulations, higher density blown products with integral binders can be used to prevent settlement within the deep wall cavity. A cost effective combination of open-cell spray foam and fibrous fill in a flash and fill application could also be considered to improve airtightness of the assembly and also reduce convective looping within the insulation between the studs.

The service wall stud space can either be left empty, or it can be insulated to increase the assembly R-value.

Note specifically that some 2x8 framed wall assemblies will achieve R-22 thermal performance, while others will not. Achieving R-22 with this type of framing will depend primarily on the R-value per inch of the insulation, the framing factor, the presence of a service wall, and the cladding type.

Vapour Barrier

The relatively large amount of insulation installed to the interior of the sheathing increases the risk of moisture accumulation within this assembly. An interior vapour barrier should be installed on the interior of deep stud or engineered wood I-joist walls to control the outward flow of water vapour through this assembly. Plywood or OSB can be used as the interior vapour barrier in these types of assemblies.

Effective Assembly R-value for Deep Stud Walls [ft² • °F • hr/Btu]

Framing Type	Uninsulated Wood-Frame Service Wall			Insulated (R-12) 2x4 Service Wall		
	R-value/inch of Insulation			R-value/inch of Insulation		
	R-3.4	R-4.0	R-5.0	R-3.4	R-4.0	R-5.0
2x6	17.7	18.9	20.5	25.2	26.3	28.0
2x8	21.9	23.5	25.6	29.4	31.0	33.1
2x10	26.7	28.7	31.5	34.2	36.2	39.0
2x12	31.6	34.0	37.3	39.0	41.5	44.8
8” EWI*	24.0	26.2	29.6	31.4	33.7	37.1
10” EWI	29.9	32.9	37.5	37.3	40.4	45.0
12” EWI	35.8	39.6	45.4	43.2	47.1	52.8
14” EWI	41.7	46.3	53.3	49.1	53.8	60.7
16” EWI	47.6	53.0	61.1	55.0	60.5	68.6

A 23% framing factor is assumed which is consistent with standard 16” o.c. stud framing practices. Reduced framing factors may be possible. *EWI = Engineered Wood I-Joist

[1]Plywood and OSB have a dry cup vapour permeance of less than 60 ng/(s•m²•Pa), but are exempted from the requirements for placement of impermeable materials due to having significantly higher wet cup vapour permeance.

Below Grade Walls

▪Below Grade walls also form an important part of the thermal enclosure of buildings. This section provides information about two different methods for insulating these walls:

- Exterior Insulated
- Interior Insulated

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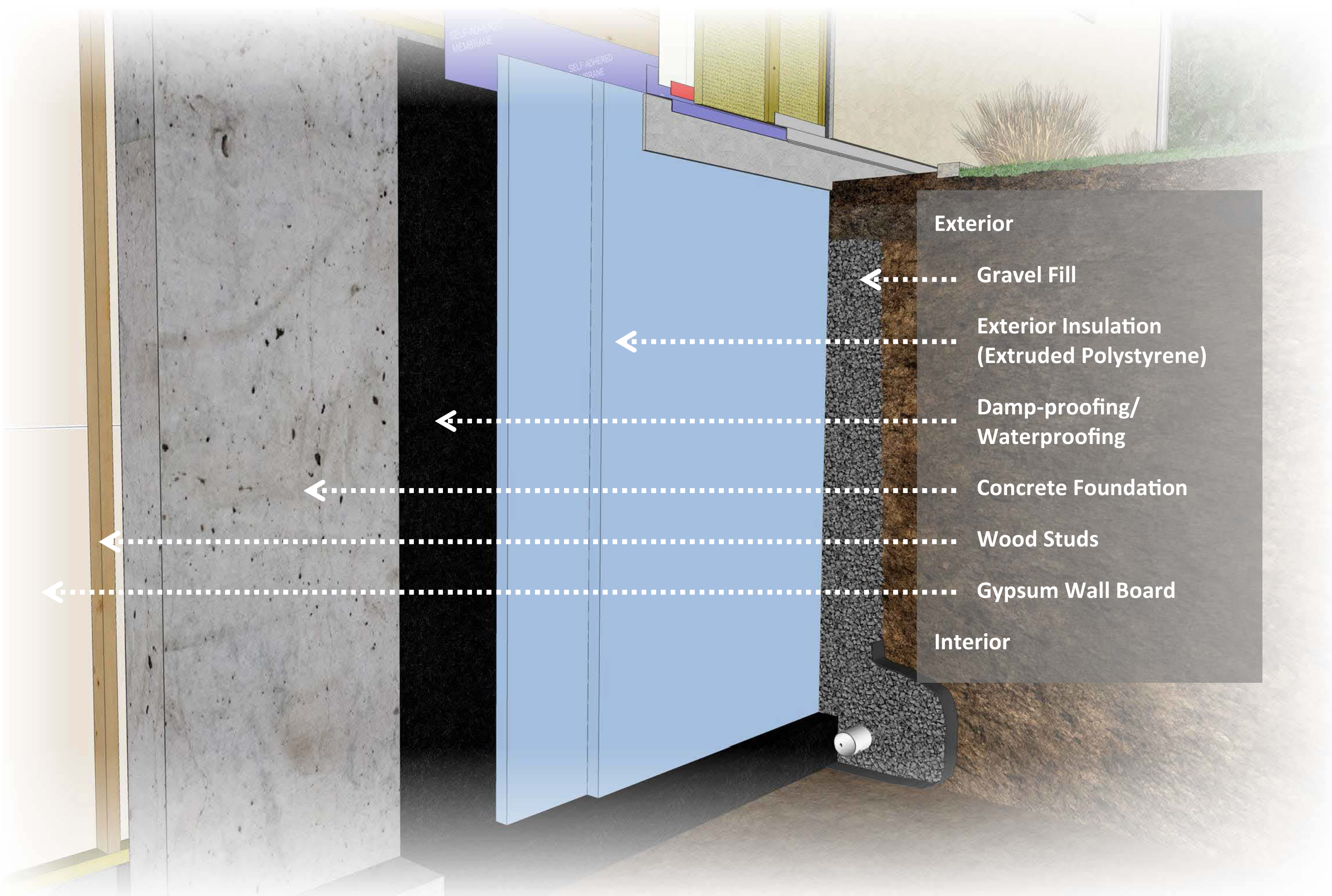
Exterior Insulated Walls

This below grade wall assembly consists of rigid insulation placed on the exterior of the concrete foundation wall. A wood stud wall is often constructed on the interior of the concrete wall to provide room for electrical and plumbing services. High effective R-values of the assembly are achieved by using continuous insulation outside of the concrete structure. The insulation product used in this arrangement should be highly moisture tolerant and suitable for below grade applications. In cold climates, insulation placed on the exterior of the wall increases the temperature of the concrete and consequently often reduces the risk of condensation and associated damage to moisture sensitive interior wall components and finishes. Drainage is provided at the exterior of the insulation to eliminate hydrostatic pressure on the wall assembly and reduce the risk of water ingress.

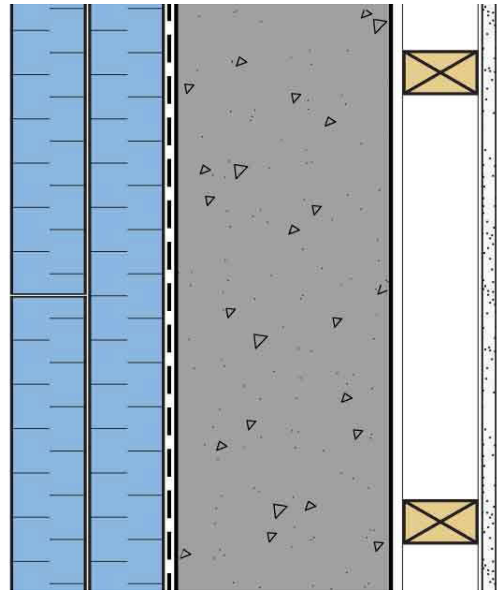


Key Considerations:

- Drainage to deflect water away from the foundation wall and to prevent hydrostatic pressures is important to the long-term performance of this wall assembly with respect to water penetration.
- Detailing of the wall to ensure continuity of the water resistive barrier, air barrier, vapour barrier, and insulation at the below grade to above-above grade wall transition is important to the overall performance.
- The exterior of foundation walls can be difficult and expensive to access post-construction; consequently, it is prudent to design these assemblies conservatively with respect to water penetration and to use durable materials.

Exterior Insulated Walls (cont.)

Below Grade Walls



Drainage

Adequate control of surface and ground-water is fundamental to the long-term water penetration resistance of this assembly. An impermeable surface at grade (i.e. clay cap) sloped away from the building in conjunction with porous media (i.e. gravel fill) and perimeter drainage at the base of the foundation wall (i.e. weeping tile) will direct water away from the wall assembly. In situations where there is potential for hydrostatic pressure to be experienced by the assembly, additional precautions must be taken including the use of a fully bonded waterproof membrane instead of a damp-proofing membrane.

Water Resistive Barrier (Waterproofing/Damp-proofing)

Where the wall assembly does not experience hydrostatic pressure, only relatively minor amounts of water will penetrate past the insulation. In these cases, a damp-proofing membrane is sufficient to resist water ingress when used in conjunction with appropriate joint and crack control details for the concrete wall. However, if hydrostatic pressure is present, a more robust waterproofing membrane should be used as it will be relied upon to prevent water ingress.

Air Barrier

The concrete wall is the most airtight element in this assembly and is usually the most straightforward to make continuous with adjacent building enclosure assemblies such as the concrete floor slab (or air barrier below the slab) and above grade walls.

Insulation

While extruded polystyrene insulation is typically used in this assembly, various types of insulation can be used including high density expanded polystyrene and rigid mineral wool. It is important that the selected insulation product is extremely moisture tolerant as it can potentially be exposed to significant wetting in this below grade application. The exterior insulation in this assembly will maintain the concrete structure at closer to indoor temperatures, consequently typically reducing the risk of condensation and associated damage.

Vapour Barrier

The concrete foundation wall and damp-proofing membrane provide the vapour control in this assembly. Given the below grade nature of this assembly and the generally wet nature of soil, negligible drying of this assembly to the exterior will occur. Consequently, no additional vapour barrier should be installed on the interior to facilitate drying of any minor incidental wetting.

Other Considerations

A gap or other capillary break should be provided between interior wood framing and the concrete foundation wall. Alternatively, preservative-treated wood can framing can be used. Direct contact of concrete and untreated wood framing members can lead to moisture related damage.

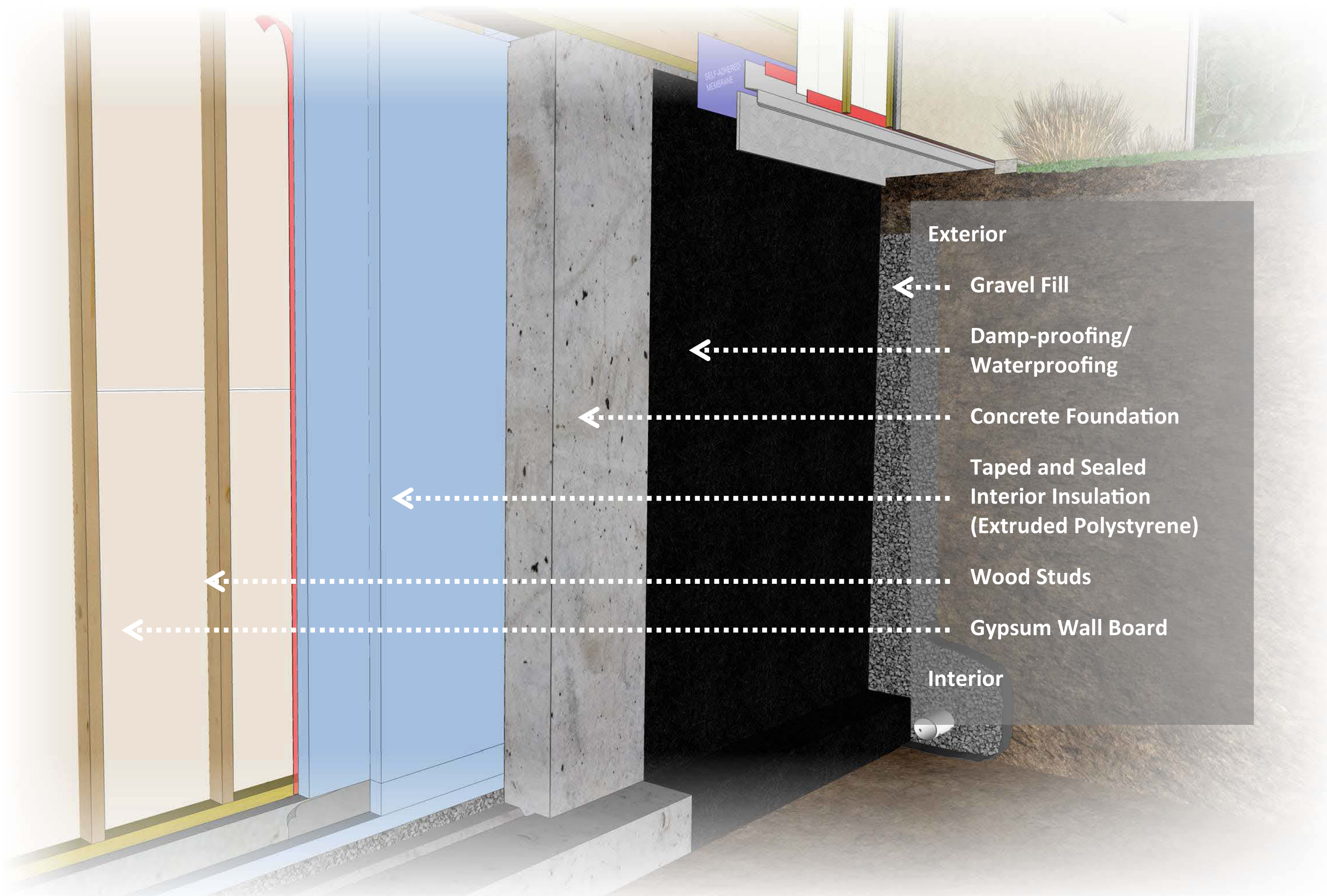
This assembly could potentially also be a split insulated assembly with insulation installed in the stud cavity as well as on the exterior of the concrete. In this arrangement the ratio of interior to exterior insulation should be considered so as to maintain the temperature of the interior concrete surface at relatively safe levels and avoid condensation. For this alternative, the building code requires that an interior vapour barrier be installed.

Effective Assembly R-value of Exterior Insulated Below Grade Wall Assembly [ft² • °F • hr/Btu]

Thickness of Exterior Insulation	R-value/inch of Exterior Insulation: R-4.0	R-value/inch of Exterior Insulation: R-5.0
3 1/2”	16.6	20.1
4”	18.6	22.6
4 1/2”	20.6	25.1
5”	22.6	27.6
5 1/2”	24.6	30.1
6”	26.6	32.6
6 1/2”	28.6	35.1
7”	30.6	37.6
7 1/2”	32.6	40.1
8”	34.6	42.6

Interior Insulated Walls

This below grade wall assembly consists of rigid or spray-in-place air-impermeable moisture tolerant insulation placed on the interior of the concrete foundation wall. Traditionally many below grade interior insulated walls have been insulated with batt insulation between wood-framing and a polyethylene sheet was used to provide air and vapour control; however, these wall assemblies pose an unacceptable risk, especially for high R-value walls (i.e. R-22 walls). High effective R-values of the assembly are instead achieved by using continuous insulation placed between the concrete foundation wall and an interior stud framed service wall. Placement of insulation on the interior of the concrete foundation wall results in cooler concrete interior surface temperatures and consequently an increased risk of condensation and associated damaged. A robust interior air barrier should be installed to limit this risk.

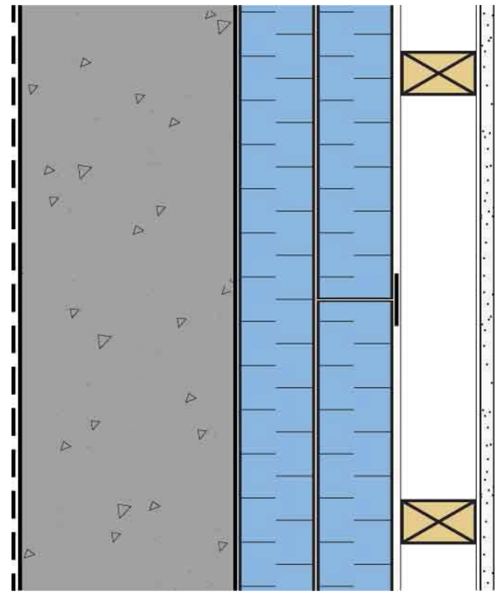


Key Considerations:

- Drainage layer to deflect water away from the foundation wall and to prevent hydrostatic pressures is important to the long-term performance of this wall assembly with respect to water penetration.
- Detailing of the wall to ensure continuity of the water resistive barrier, air barrier, vapour barrier, and insulation at the below grade to above-above grade wall transition is important to the overall performance.
- The exterior of foundation walls can be difficult and expensive to access post-construction; consequently, it is prudent to design these assemblies conservatively with respect to water penetration and to use durable materials.

Interior Insulated Walls (cont.)

Below Grade Walls



Drainage

Adequate control of surface and ground-water is fundamental to the long-term water penetration resistance of this assembly. An impermeable surface at grade (i.e. clay cap) sloped away from the building in conjunction with porous media (i.e. gravel fill) and perimeter drainage at the base of the foundation wall (i.e. weeping tile) will direct water away from the wall assembly. In situations where there is potential for hydrostatic pressure to be experienced by the assembly, additional precautions must be taken including the use of a fully bonded waterproof membrane instead of a damp-proofing membrane.

Water Resistive Barrier (Waterproofing/Damp-proofing)

Where the wall assembly does not experience hydrostatic pressure, a damp-proofing membrane is sufficient to resist water ingress when used in conjunction with appropriate joint and crack control details for the concrete wall. However, if hydrostatic pressure is present, then a more robust waterproofing membrane should be used as it will be relied upon to prevent water ingress.

Air Barrier

The concrete wall is the most airtight element in this assembly and is usually the most straightforward element to make continuous with adjacent assemblies such as the concrete floor slab (or air barrier below the slab) and above grade walls. However, with interior insulation approaches it is also important that an interior air barrier be maintained to limit the potential for relatively warm and moist interior air to flow past the insulation and come in contact with the interior surface of the colder concrete foundation wall. This is often achieved through sealing of joints between insulation boards or by use of spray foam products.

Insulation

Extruded polystyrene (XPS) and closed-cell spray polyurethane foam insulation are typically most appropriate for this application as they are both insensitive to potential moisture within the concrete and are also relatively air and vapour impermeable. Air permeable insulation products are not generally recommended unless other measures are considered.

Vapour Barrier

The relatively vapour-impermeable foam insulation (i.e. XPS or closed-cell spray foam) provide the vapour barrier in this assembly. No additional vapour barrier should be installed on the interior of the wood stud wall to facilitate drying of any minor incidental wetting.

Other Considerations

Instead of a wood stud wall it is also possible to use only strapping (i.e. furring) fastened through the insulation if a significant gap is not needed for services. An interior finish is required to provide fire protection for the foam plastic insulation, or alternatively an intumescent coating can be used in some jurisdictions for an unfinished basement.

Effective Assembly R-value of Interior Insulated Below Grade Wall Assembly [ft² • °F • hr/Btu]

Thickness of Interior Insulation	R-value/inch of Interior Insulation	
	R-5.0	R-6.0
3 1/2”	20.1	23.6
4”	22.6	26.6
4 1/2”	25.1	29.6
5”	27.6	32.6
5 1/2”	30.1	35.6
6”	32.6	38.6
6 1/2”	35.1	41.6
7”	37.6	44.6
7 1/2”	40.1	47.6
8”	42.6	50.6

Alternative R-22 Walls

This section provides a brief overview of alternative wall assemblies that could potentially be used to achieve the R-22 thermal performance target, but are not covered within this guide. These include:

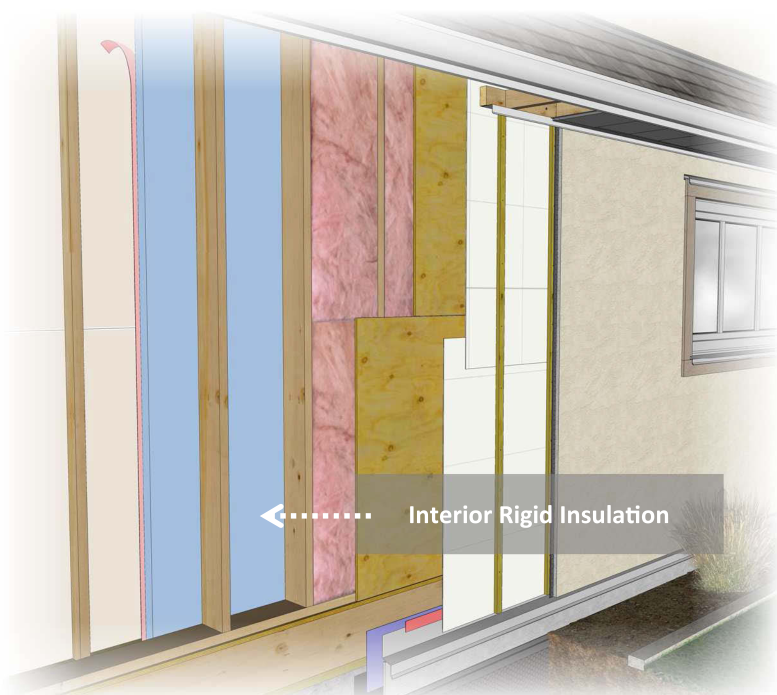
- Structurally Insulated Panels (SIPs)
- Interior Insulated Framed Wall
- Continuous Strapping
- Insulated Concrete Forms
- Insulated Concrete Forms (Below Grade)
- Interior Rigid Insulated and Batts (Below Grade)

Structurally Insulated Panels

This above grade wall assembly consists of manufactured structurally insulated panels (SIPs) consisting of continuous rigid insulation (typically EPS) sandwiched between two layers of OSB sheathing. These panels are then assembled to form the exterior enclosure of the building. Typically 5 1/2" of insulation would be required in this assembly to achieve R-22 or greater.

Addressing the joints between panels with respect to construction tolerances and air barrier continuity is an important consideration when using this system and manufacturers will typically provided the relevant details. Joints should be sealed on both the interior and exterior and the gap filled to prevent convective looping between panels . A sheathing membrane is typically installed on the exterior of this assembly to provide the water resistive barrier and the air barrier, or else the SIPs panels can be sealed to provide the air barrier. A stud wall can be constructed on the interior of the SIPs for services.

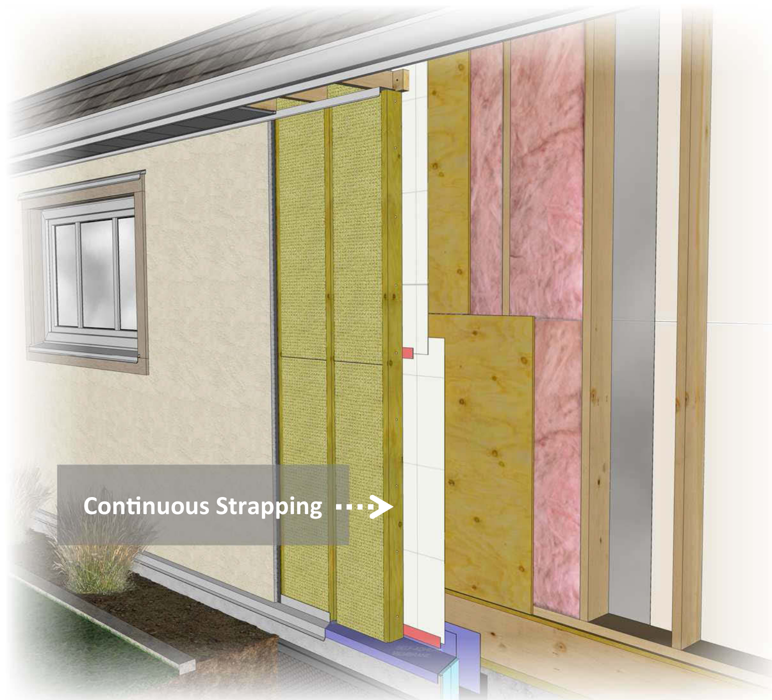
Interior Insulated Framed Wall



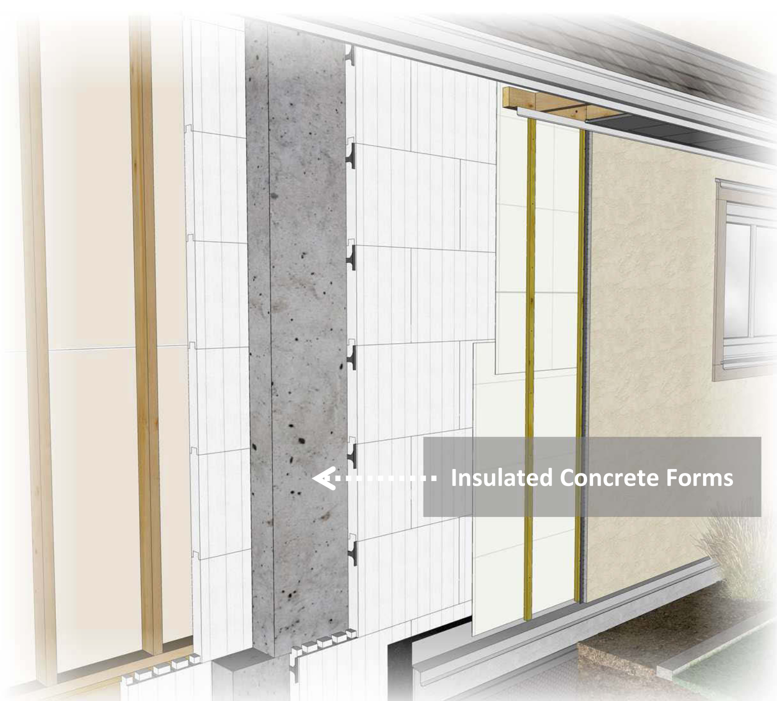
This above grade wall assembly consists of rigid insulation boards (typically extruded polystyrene) installed on the interior of the batt insulated stud wall. This assembly is similar in principle to the exterior insulation strategy for increasing the wall R-value, though successful application is often more difficult. In cold climates, the additional depth of insulation installed on the interior side of the exterior sheathing can slightly decrease the sheathing temperature and consequently increase the risk of condensation on the moisture-sensitive wood sheathing and framing. The rigid insulation should be sealed to provide the air barrier, and low permeability of the insulation boards is also adequate to provide the vapour barrier. Installation and sealing of electrical outlets and other service penetration can be difficult when using this wall assembly. Interior gypsum wall board can be installed on vertical strapping to provide an interior finish as well as fire protection.

Continuous Strapping

This above grade wall assembly consists of rigid or semi-rigid insulation placed on the exterior of a conventional above grade, insulated 2x4 or 2x6, wood-frame wall assembly; however, in this case the cladding support is provided using vertical strapping which continuously penetrates through the exterior insulation. While relatively uncommon, this method can provide additional cladding support as compared to only fasteners through the insulation. The continuous wood members which penetrate the exterior insulation must be considered in the calculation of the wall effective R-value in a manner similar to that used for stud walls (i.e. parallel paths). Due to the reduction of the insulation performance by the continuous strapping, additional insulation thickness is required for this assembly to achieve the same thermal performance as an exterior insulated assembly with only fasteners or thermally efficient clips through the insulation. Other considerations for this assembly are similar to those for the exterior insulated above grade assembly.



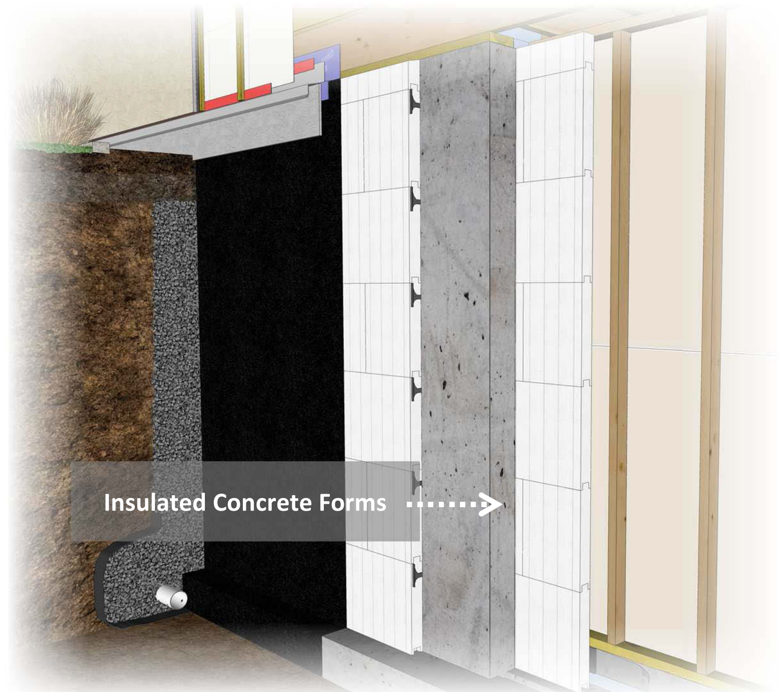
Insulated Concrete Forms



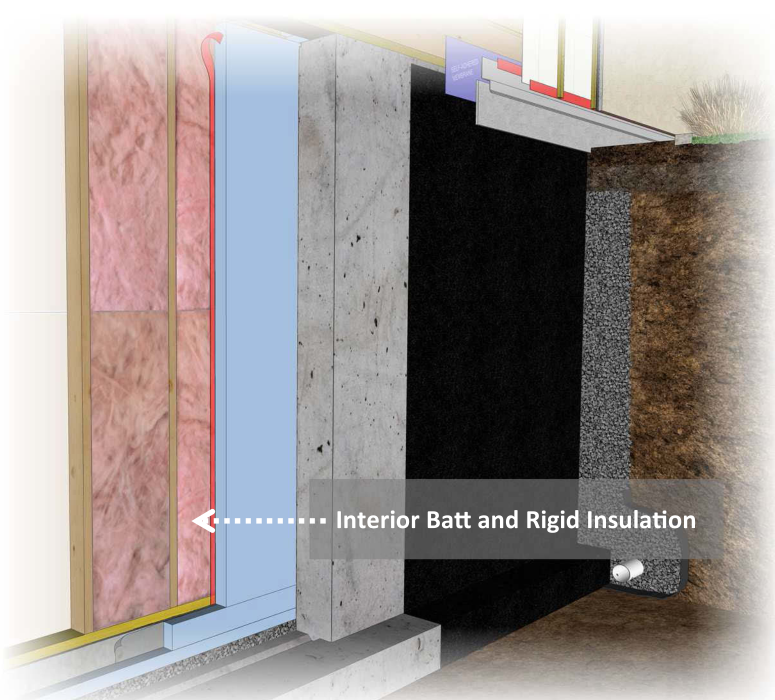
This wall assembly consists of Insulated Concrete Forms (ICFs) which are manufactured interlocking modular concrete formwork made of rigid expanded polystyrene (EPS) insulation. Once assembled, these forms are filled with concrete and remain in place to provide insulation. While typically this type of construction is used for below grade walls, it can also be applied to above grade walls. High effective R-values of the assembly are achieved by the combination of the interior and exterior form layers, and to meet R-22 typically at least 5" of total insulation thickness will be required. Often a stud wall is built to the interior of this assembly to provide a space for services and facilitate attachment of gypsum wall board for an aesthetic finish as well as fire protection of the foam plastic insulation. Some ICFs provide channels for services which can be used instead of constructing an interior stud wall.

Insulated Concrete Forms (Below Grade)

This wall assembly consists of Insulated Concrete Forms (ICFs) which are manufactured interlocking modular concrete forms made of rigid expanded polystyrene (EPS) insulation. Once assembled, these forms are filled with concrete and remain in place to provide insulation. While typically this type of construction can be used in above grade applications, it is more commonly use for below grade walls. High effective R-values of the assembly are achieved by the combination of the interior and exterior form layers, and a typical ICF will meet R-22 with a total insulation thickness of approximately 5”. In below grade applications a damp-proofing or waterproofing material should be applied to the exterior insulation. A stud wall is sometimes built to the interior of this assembly to provide a space for services and facilitate attachment of gypsum wall board. Some ICFs provide channels for services in the foam insulation which can be used instead of constructing an interior stud wall, and embedded fastening points for interior drywall.



Interior Rigid Insulation and Batts (Below Grade)



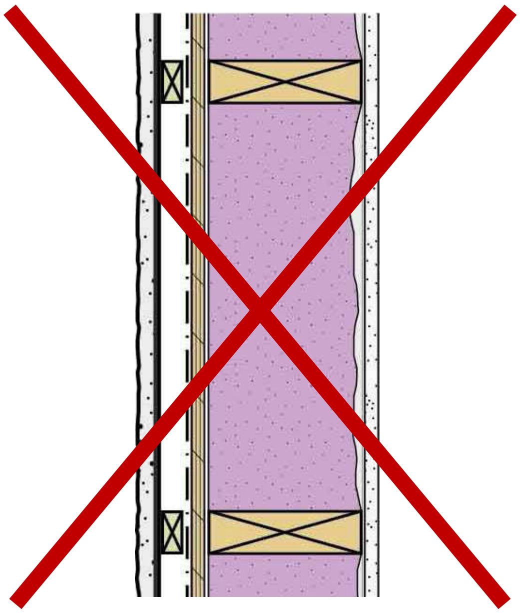
This below grade wall is similar to the interior insulated below grade wall assembly that is insulated with rigid or spray-in-place, air-impermeable, moisture tolerant, insulation placed on the interior of the concrete foundation wall. The primary difference is that that this wall also includes batt insulation in the stud cavity. Using batt insulation in the stud cavity can provide the required R-value while allowing for a reduction in the amount of rigid insulation which is required. The rigid insulation is used as the air barrier in this assembly, and an interior vapour barrier (interior of the batt insulation) is still required to meet code requirements. Given the limited outward drying capacity of this assembly, it may be prudent to use a relatively permeable interior vapour barrier such as a smart vapour retarder or vapour barrier paint. A minimum of 2” of rigid foam or spray foam insulation is required between the stud and concrete walls to achieve R-22 and limit the potential for condensation within the wall assembly.

Walls Less Than R-22

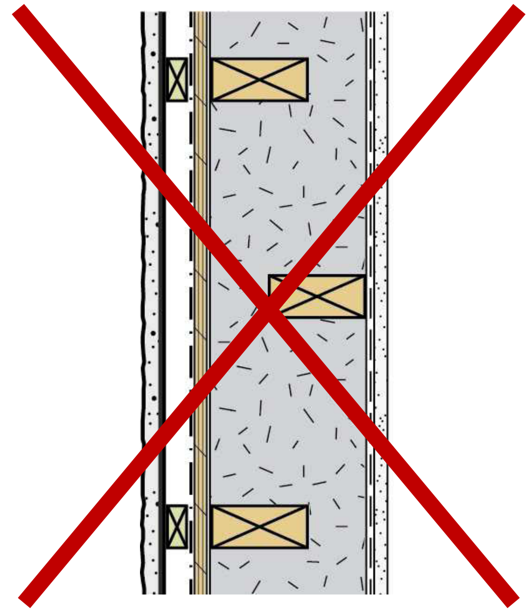
This section provides a brief overview of wall assemblies that would not be adequate to achieve the R-22 thermal performance target.

Walls Less Than R-22

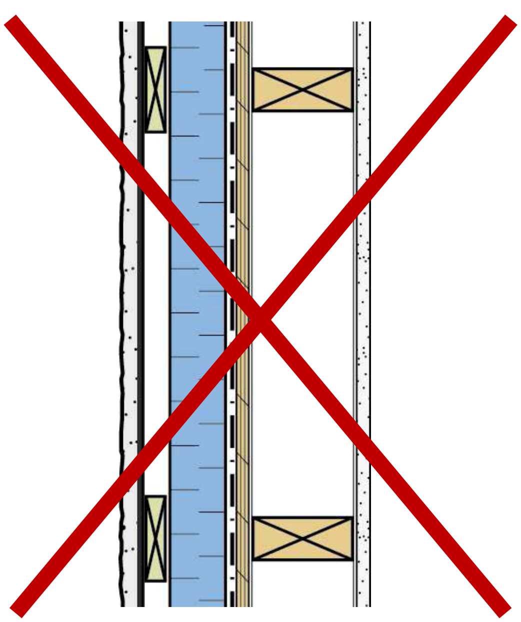
While the majority of this guide is dedicated to identifying walls which achieve the R-22 or greater thermal performance requirement of the 2014 Vancouver Building Bylaw, this section identifies assemblies which specifically do not meet this requirement, when constructed using standard framing practices. (i.e. 23% framing factor for 16" o.c. studs)



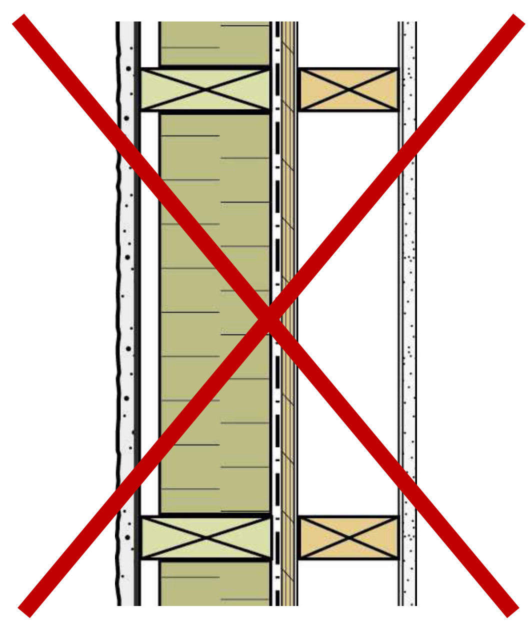
2x6 Stud Walls with Insulation Only in the Stud Cavity
(regardless of the insulation type)



2x4 Double Stud Wall on 2x6 with Staggered Overlapping Studs
(It is also nearly impossible to reach R-22 without a gap between the two stud walls)



Exterior Insulated Stud Wall with 3" or less of Insulation
(regardless of the insulation type)



Exterior Insulated Wall with Continuous Strapping and 4" or less of Insulation
(regardless of the insulation type)

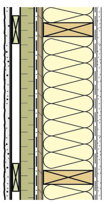
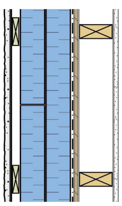
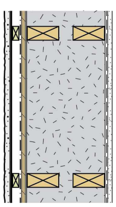
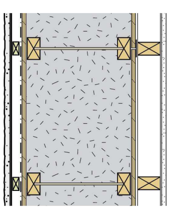
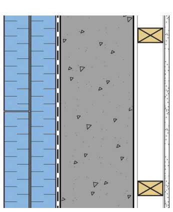
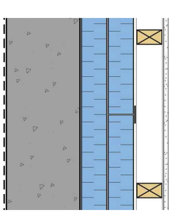
Summary

This section provides a summary of the wall assemblies covered in this guide including minimum insulation levels to achieve R-22 and also provides a list of other available resources to assist in the design of enclosure assemblies and systems.

- Summary of Walls
- Additional Resources

Summary of Walls

Detailed discussions of each assembly including thermal performance values have been provided throughout the guide. This section provides a summary of the minimum insulation levels required for each assembly to achieve R-22 effective as well as key considerations for ease of reference. It should be noted that the R-values of these assemblies will vary slightly depending on specific assembly layer selections (i.e. cladding), but that generally the values provided are intended to be slightly conservative.

		Minimum Insulation Levels to Achieve R-22 Effective	Key Considerations
Split Insulated		2x4 Studs (R-12 Batts) **+** 3” R-4/inch **or** 2 1/2” R-5/inch Ext. Ins. 2x6 Studs (R-19 Batts) **+** 1 1/2” of R-4/inch **or** R-5/inch Ext. Ins. 2x6 Studs (R-22 Batts) + 1” of R-5/inch Ext. Ins. 2x6 Studs (R-24 Batts) + 1” of R-4/inch Ext. Ins.	The vapour permeability of the sheathing membrane and the exterior insulation should be carefully considered so as not to create a risk of condensation within the assembly, or to intolerably reduce the ability of the assembly to dry.
Exterior Insulated		2x4 or 2x6 Studs (No Batts) **+** 5” R-4/inch **or** 4” R-5/inch	The method of cladding attachment is important to limit thermal bridging through the exterior insulation while adequately supporting the exterior cladding.
Double Stud		2x4 Double Stud Wall with No Gap and R-5/inch Insulation 2x4 Double Stud Wall with 1/2” Gap and R-4/inch Insulation 2x4 Double Stud Wall with 1” Gap and R-3.4/inch Insulation	Continuity of the air barrier and installation of a vapour barrier are fundamental to the performance of this assembly as the slightly decreased exterior sheathing temperature increases the risk of condensation and related damage.
Deep Stud		2x8 Stud Wall with R-4 or R-5/inch Insulation 2x10 Stud Wall with R-3.4/inch Insulation 8” Engineered Wood I-Joist with R-3.4/inch **or** R-4/inch **or** R-5/inch insulation	Continuity of the air barrier and installation of a vapour barrier are fundamental to the performance of this assembly as the slightly decreased exterior sheathing temperature increases the risk of condensation and related damage.
Exterior Insulated		5” R-4/inch Insulation **or** 4” R-5/inch Exterior Insulation	The exterior of foundation walls can be difficult and expensive to access post-construction; consequently, it is prudent to design these assemblies conservatively with respect to water penetration and to use durable materials.
Interior Insulated		4” R-5/inch Insulation **or** 3 1/2” R-6/inch Interior Insulation 2 1/2” R-5/inch + 2x4 Studs (R-12 Batts)	Detailing of the wall to ensure continuity of the water resistive barrier, air barrier, vapour barrier, and insulation at the below grade to above-above grade wall transition is important to the overall performance.

Additional Resources

This guide provides an overview of different assemblies which can potentially be used to meet an R-22 performance requirement; however, other resources are available which provide more detailed information regarding building enclosure systems and design.

Design Guides

- *Illustrated Guide—Energy Efficiency Requirements for Houses in British Columbia* published by the Homeowner Protection Office, a branch of BC Housing.
(Available at https://www.hpo.bc.ca/energy-efficiency-requirements)
- *Guide for Designing Energy-Efficient Building Enclosures for Wood-Frame Multi-Unit Residential Buildings* published by FP Innovations, the Homeowner Protection Office, a Branch of BC Housing, and the Canadian Wood Council.
(Available at fpinnovations.ca)
- *Building Envelope Guide for Houses* published by the Homeowner Protection Office, a branch of BC Housing.
(Available at www.hpo.bc.ca/building-envelope-guide-houses)
- *Building Enclosure Design Guide* published by the Homeowner Protection Office, a branch of BC Housing.
(Available at https://www.hpo.bc.ca/building-enclosure-design-guide)
- *Canadian Home Builder's Association Builders' Manual* published by the Canadian Home Builders' Association.
(Available at www.chba.ca/buildermanual.aspx)
- *Canadian Wood-Frame House Construction* published by the Canada Mortgage and Housing Corporation (CMHC).
(Available at http://www.cmhc-schl.gc.ca/en/)
- *Residential Construction Performance Guide* published by the Homeowner Protection Office, a branch of BC Housing
(Available at http://www.hpo.bc.ca/files/download/Res_Guide/Residential_Construction_Performance_Guide.pdf)
- Builder's Guide to Cold Climates published by Building Science Corporation.
(Available at http://www.buildingsciencepress.com/Builders-Guide-to-Cold-Climates-P91.aspx)
- Pathways to High-Performance Housing in British Columbia published by FPInnovations.
(Available at https://fpinnovations.ca/)

Technical Information

- *Study of Moisture-Related Durability of Walls with Exterior Insulation in the Pacific Northwest* by Building Science Corporation.
(Available at http://www.buildingsciencelabs.com/wp-content/uploads/2014/11/Clearwater-2013-Smegal.pdf)
- *Wall Thermal Design Calculator* by the Canadian Wood Council
(Available at http://cwc.ca/resources/wall-thermal-design/)
- *Building Envelope Thermal Bridging Guide* published by BC Hydro and the Homeowner Protection Office, a branch of BC Housing. (Available at https://www.bchydro.com/powersmart/business/programs/new-construction.html)
- *ASHRAE Handbook of Fundamentals 2013* published by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE).
(Available at https://www.ashrae.org/resources--publications/handbook**)**

Building Codes

- *Vancouver Building By-law (VBBL) 2014* published by the Queen's Printer for British Columbia
(Available at http://vancouver.ca/your-government/vancouver-building-bylaw.aspx)
- *British Columbia Building Code (BCBC) 2012* published by the Queen's Printer for British Columbia
(Available at http://www.bccodes.ca/building-code.aspx?vid=QPLEGALEZE:bccodes_2012_view)