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DÖRKEN

High-Performance Building

Exterior Continuous Insulation – Part 2 of 2

AIA CES Course Number: K1812T4

Welcome to this continuing education seminar.

This is the second of two parts of the High-Performance Building series.

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of completion for both AIA members and non-AIA members are available upon request.

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

This presentation was prepared for Dörken Systems by:

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Course Description

"Effective thermal performance is replacing simple R-values in modern, high-performance commercial buildings. For most buildings, continuous exterior insulation will be the new normal. This presentation will help you understand thermal control fundamentals, changing codes and standards, and how to detail enclosures with continuous exterior insulation. You will come away with solutions to problematic thermal bridges and an understanding of how higher levels of thermal control affect enclosure design.

Learning Objectives

At the end of the this course, participants should be able to:

1. Determine the importance of thermal control for high-performance commercial buildings.

2. Apply the fundamental building science behind thermal control and continuous exterior insulation.

3. Explain alternate approaches to exterior insulation and know which insulation materials are appropriate for each.

4. Identify thermal bridging elements during design and understand common solutions.

High-Performance Building

Continuous Exterior Insulation – Part 2 of 2

What we will cover today:

- The basics: thermal control
- Changing thermal control requirements
- Important details for continuous exterior insulation

The Basics

Fundamentals of Thermal Control

History of Enclosure Control Functions

Older Buildings

- One layer does everything

Newer Buildings

- Separate layers
- Separate functions

A building enclosure’s basic function is to separate the outside from the inside.

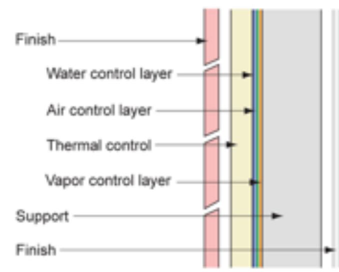
In old buildings, all functions are performed by a single layer.

In new buildings, the control functions are separated into different layers.

This means we can optimize the characteristics and performance of each control layer.

State of the Art: The "Perfect Wall"

- Support
  - Structure is anything that works
- Control <u>continuity</u>
  - Rain-control layer
    - Perfect barrier
    - Drained with gap
    - Storage
  - Air-control layer
    - Air barrier
  - Thermal-control layer
    - Aka insulation, radiant barriers
  - Vapor-control layer
    - Retarders, barriers, etc.
- Finish
  - interior and exterior



Fire control may be needed
Sound control optional

This is the "perfect wall" from a building science perspective. It describes how to choose and arrange the layers to accomplish the desired functions.

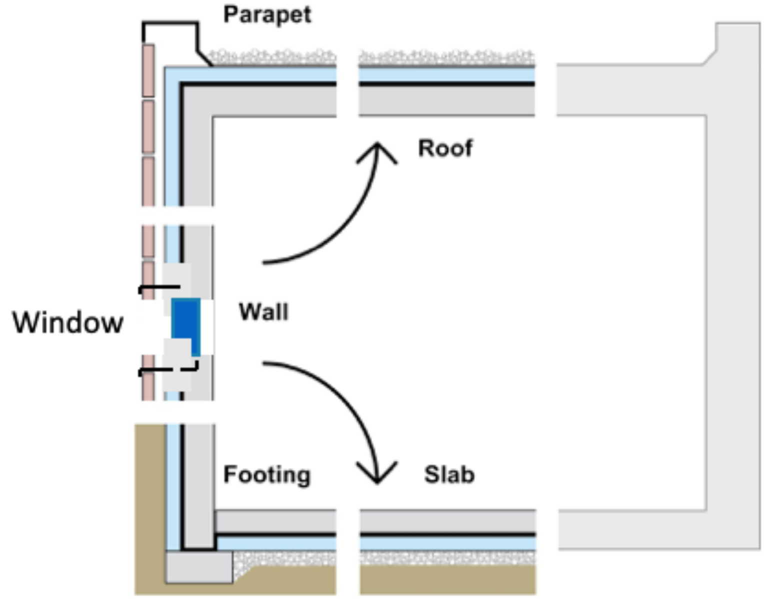
Every building must perform three main functions in this order of importance:

1. Support
2. Control continuity, including:
   - -Rain control
   - -Air control
   - -Thermal control
   - - Vapor control
3. The finish
   - -Interior and exterior

Control functions are listed in order of importance.

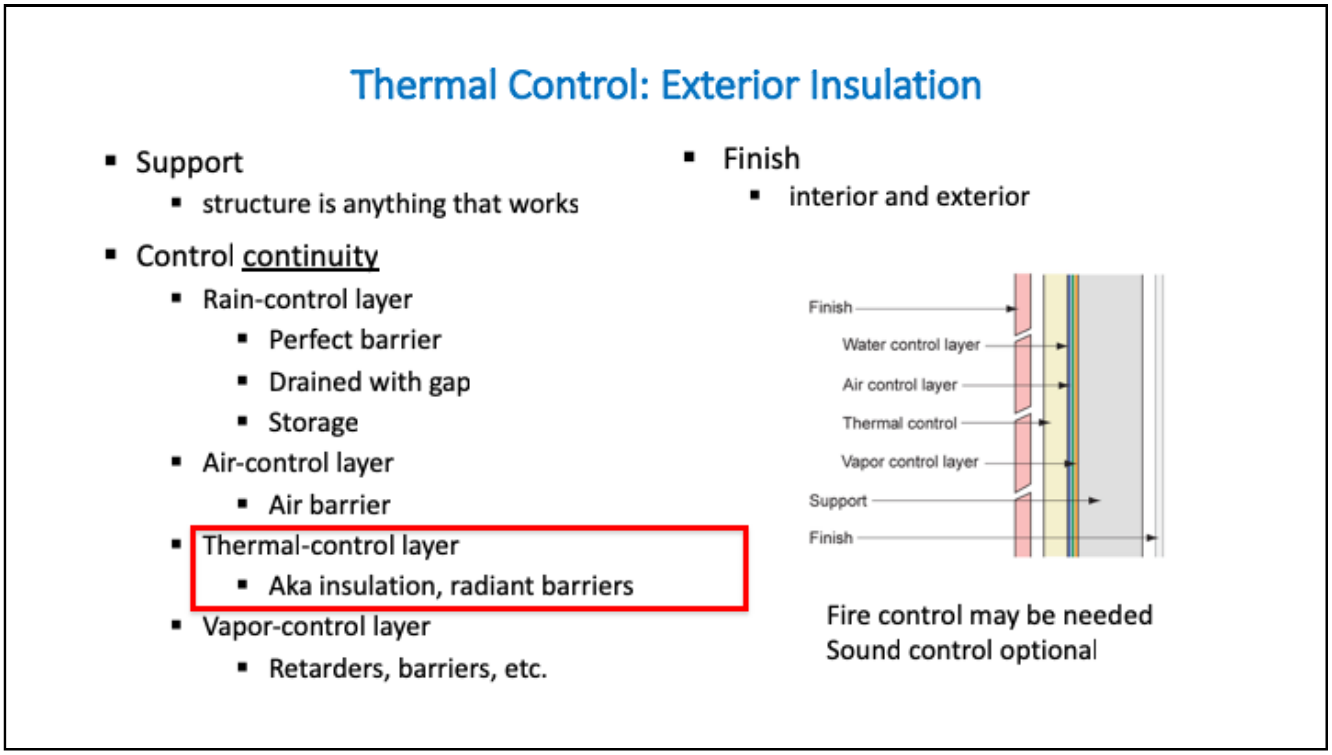
The "perfect wall" is a theoretical construct that provides a reference point for enclosure design decisions.

Each layer should be identifiable in a drawing and continuous around the building.



Even if the concept is named the “perfect wall,” it should be applied continuously on every assembly that is part of the building enclosure: walls, roofs, floors, and all transitions details.

It is important to realize that the physics don’t change, and that continuity is key.



The thermal-control layer is important, but not as important as the rain- and air-control layers.

A wet and leaky building cannot function, however well the thermal control layer is designed.

Why Do We Need Thermal Control?

- Ensure comfort
  - Avoid hot/cold interior surfaces
- Warms surfaces = durability
  - Avoids condensation in hot and cold weather
  - Hence, a durability and health strategy
  - Keep structure warm and dry and stable
- Save energy
  - Reduce heat flow

The biggest reason for thermal control is not energy savings but occupant comfort.

A building should serve its occupants in the first place, before addressing economic issues.

Comfort drives occupants more than energy savings.

Most people will spend money on energy to make a building more comfortable or last longer.

Generally, a designer must first meet two criteria before the third criterion can be addressed.

Improved thermal control will directly reduce the heat loss and heat gain of the building, providing energy efficiency and comfort benefits. Improved thermal control and the resulting control of surface temperatures within the building enclosure, also reduces the risk of condensation in hot and cold weather.

How to Do Thermal Control

- Conduction, convection, and radiation
- Insulation (conduction)
  - Slows heat flow in and out
- Windows (conduction, radiation)
  - Slow heat flow in and out
  - Control solar gain: allow or reject?
- Airtightness (convection)
  - Can bypass insulation
- Other important considerations:
  - "Cool" roofs (reduce solar gain)
  - Radiant barriers
  - Shading (radiation)
  - Thermal bridging of structure and mechanical penetrations

There are three ways thermal energy moves:

-Conduction

-Convection

-Radiation

Conduction will move thermal energy slowly. The R-value of building materials addresses this.

However, the airtightness of the building enclosure is an important part of improved thermal control because of the amount of energy that can be moved by air infiltration/exfiltration.

Commercial Buildings: exterior insulation is only practical solution

A continuous exterior insulation strategy is most likely to meet changing thermal control requirements for wood, steel, and concrete buildings in most climates. It is not practical to rely on stud cavity insulation alone.

* Continuous exterior thermal insulation (ci) is required to meet changing code requirements for thermal control.

Thermal Control Requirements

Thermal Resistance Terminology

- **Rated R-value:** The theoretical R-value of the insulation. Sometimes called the nominal or advertised R-value (e.g., R-13 batt; R-6/inch).
- **Effective R-value:** The functional R-value of the insulation as installed in the wall assembly, de-rated if necessary due to thermal bridging at framing members.
- **Total R-value:** The actual R-value of the wall assembly including not only the effective R-value of the insulation but also the R-values for other wall-system components, such as materials, air spaces, air films, etc.

A history of thermal control throughout the ages.

Several thousand years has brought us back to R-2.

In essence, more windows = lower real R-value.

Insulation

- How much? Use much more than normal practice
- Comfort and condensation resistance:
  - **True** R5–R10 is usually enough, but…
- For energy/environment:
  - As much as practical (e.g. R10–R20)
- "True" R-value is what matters
  - Control thermal bridging!
- Increased insulation should reduce HVAC capital as well as operating!

Using more insulation than normal practice is key to achieving a high-performance building. It prevents condensation problems, if done correctly, and leads to better tenant comfort.

Just adding more insulation is not sufficient. It matters how the insulation is placed. Thermal bridging must be controlled. This means that the "true" R-value that matters most.

Thermal Resistance Recommendations

Climate Zone	Wall	Vented Attic	Compact Roof	Foundation Wall	Exposed floor	Slab edge	Windows (U/SHGC)	Sub-slab
1	10	30	15	5	10	none	1.2 / < 0.25	none
2	10	40	20	5	20	5	1.2 / < 0.25	7.5
3	15	40	20	5	20	7.5	0.6 / < 0.25	10
4	20	40	20	5	30	7.5	0.40 / < 0.4	15
5	20	40	20	5	30	10	0.35 / < 0.4	15
6	20	40	20	10	30	10	0.35 / < .40	15
7	20	40	20	10	30	15	0.35 / --	20
8	20	50	20	10	40	20	0.35 / --	20

Table 3: Effective R-value Recommendations by Climate Zone for Steel-Framed, Commercial Construction, adapted from ASHRAE 90.1

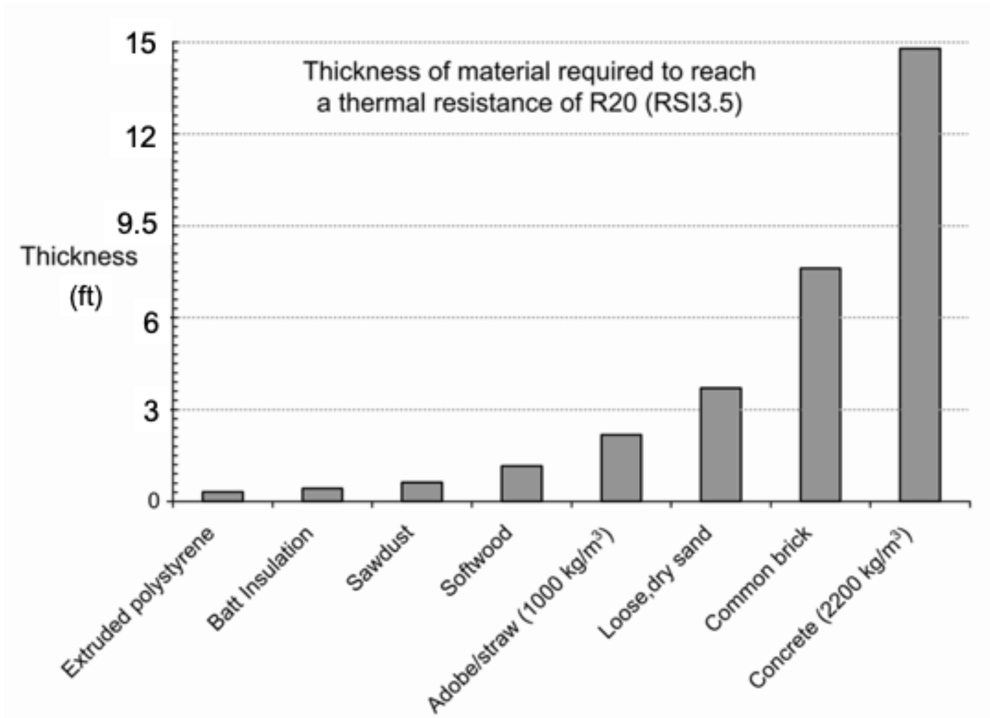
Codes require nominal R-values (material only).

This chart gives effective R-value (system R-value) based on ASHRAE 90.1 but a little higher.

Select the climate zone you are working in, then read across.

Find the thermal bridge

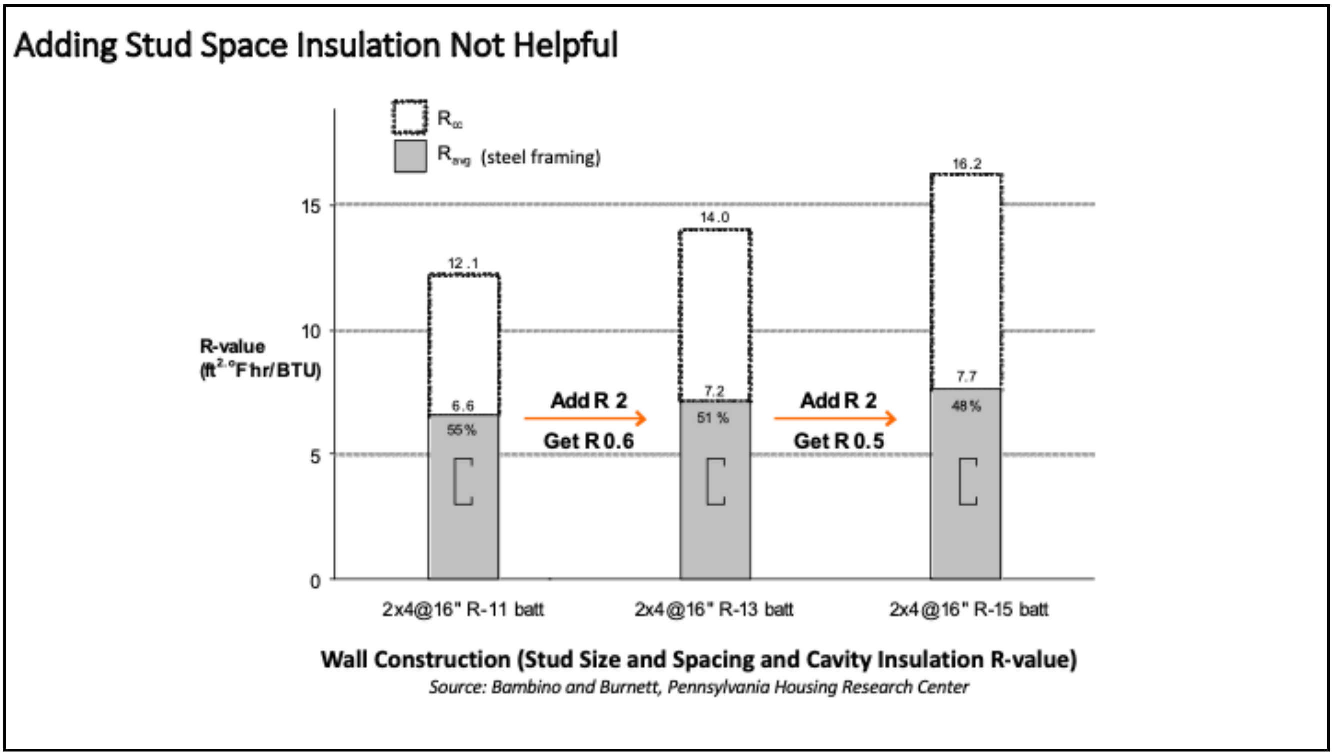
In the past, building codes used the R-value of the material to assess compliance. Changes to the codes have put the emphasis on the effective R-value of the enclosure assembly. This includes the impact of thermal bridging.



The difference in heat flow between materials we use for insulation and materials we use for structure.

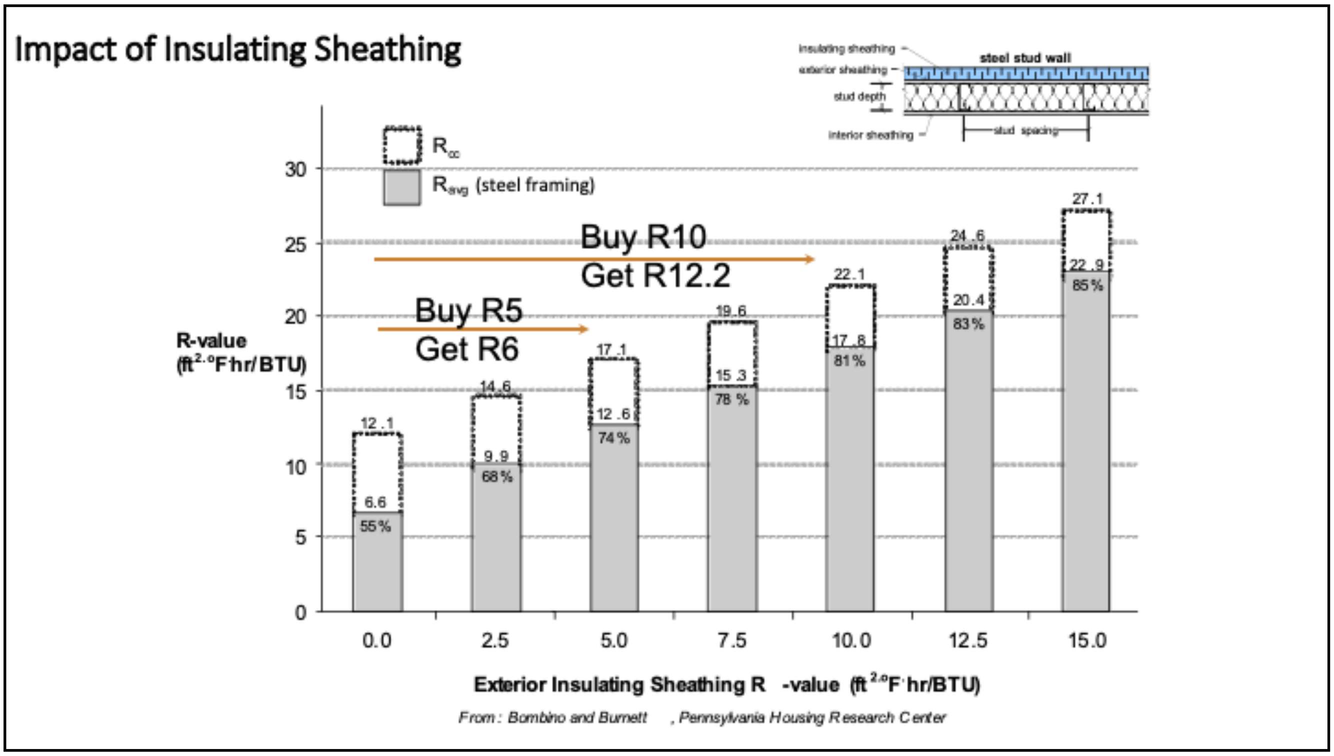
Steel's bar graph wouldn't fit on this chart.

The conductiveness of concrete is 15 times higher than polystyrene.



Steel stud thermal bridges can reduce effective R-value by 55 percent.

Just adding more stud space insulation has only an incremental effect on R-value. For example, adding an additional nominal R-2 to a stud space already containing an effective R-6.6 (nominal R11) only increases the effective R-value by R-0.6. Adding an additional nominal R-2 nets only another effective R-0.5.



Adding exterior insulation to reduce the influence of thermal bridging increases effective or composite R-value.

Exterior insulation is a better investment than more stud cavity insulation. In contrast to the previous example of adding more R-value to the stud cavity only, continuous exterior insulation has a much more dramatic effect. Adding an additional nominal R-5 of exterior insulation results in an additional R-6 of effective insulation.

This example based on extruded polystyrene (XPS) exterior insulation.

* Effective R-value is the performance of the assembly, not the material.

The thicker the thermal bridge, the greater the reduction of the R-value.

Thermal Continuity/Thermal Bridges

- Some short circuiting is normally tolerated
- High-performance walls tolerate few bridges
- Major offenders/weak spots
  - Penetrating slabs (<R1)
  - Steel studs (<<R1)
  - Windows (R2–R3)
- Small details are important

Avoiding all thermal bridging is impossible. A high-performance wall can tolerate some bridges.

Major thermal bridges are:

-Penetrating slabs

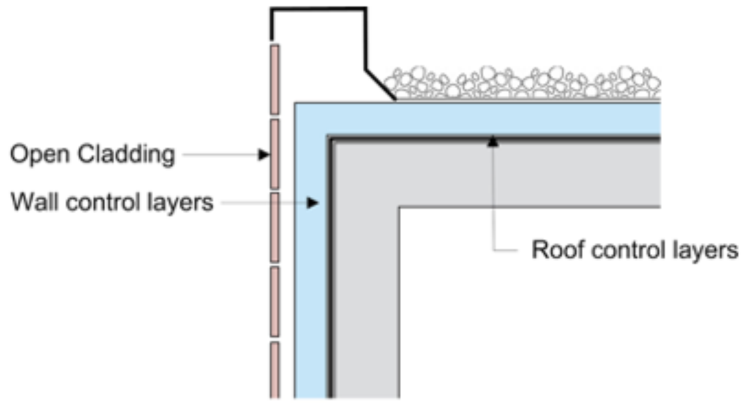
-Steel studs

-Windows

Small details can make a big difference.

Details

The “Perfect” Approach Is in the Details



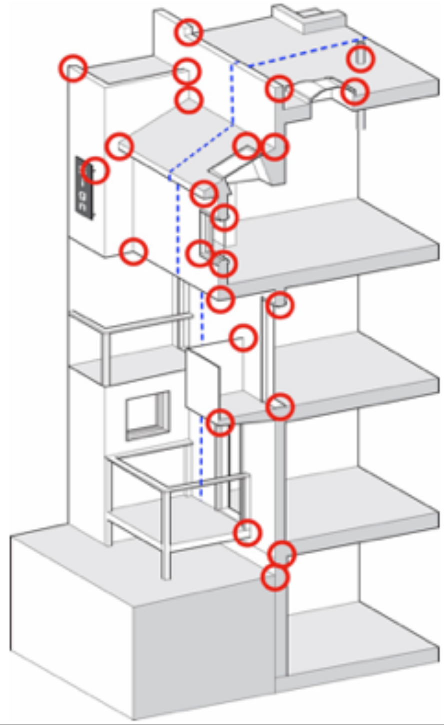
Connections: Who is in charge?

Different trades can be responsible for different areas.

It is Important to specify not just how connections are made, but by whom they will be performed.

Enclosure Details

- Details demand the same approach as the typical enclosure assemblies:
  - Support
  - Control
  - Finish
- Scaled drawings required at ○



Red circles represent critical detail areas that could be areas of typical failure. The blue dotted line represents the plane that many architects draw and detail. If it isn't made clear in the drawing what is to be done by the contractor at each of these critical detail areas, then the decision will be made by the contractor, if at all, sacrificing critical continuity. Every detail needs to be addressed.

Key Details for Continuous Insulation

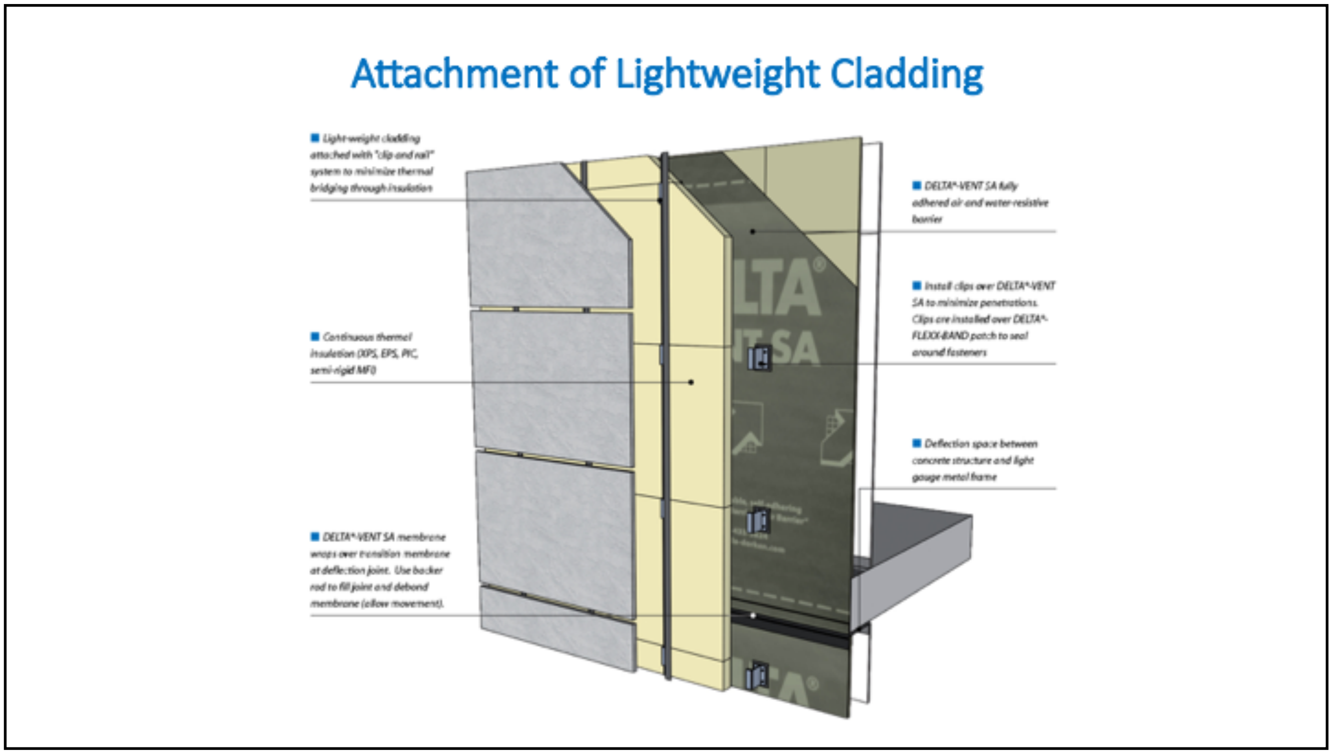
- Cladding attachment
  - Lightweight cladding (metal panel, fiber cement siding)
  - Heavyweight cladding (brick, stone)
- Structural penetrations
  - Parapets
  - Balconies
- Windows

The key details for continuous insulation include:

-Cladding attachment

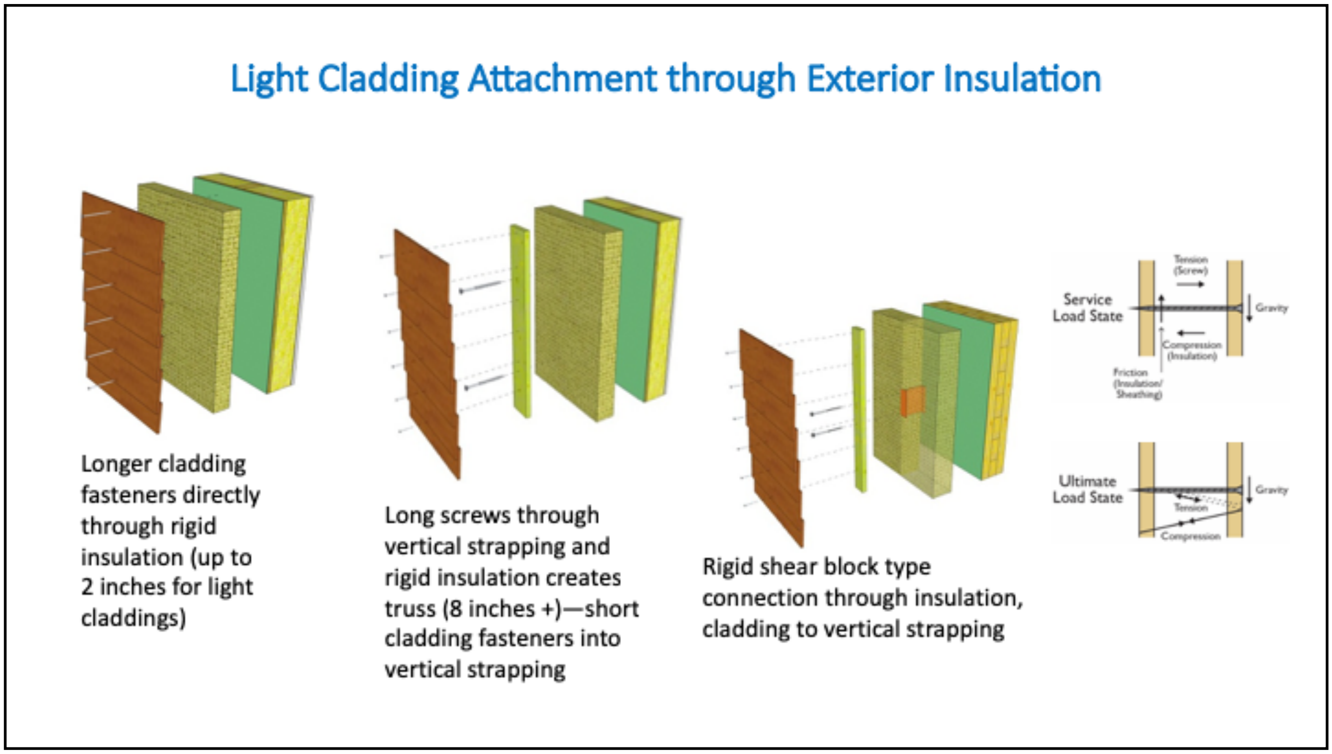
-Structural penetrations like balconies, parapets, etc.

-Windows



Example of lightweight cladding attachment with clips.

The benefit from this attachment is the small dimension of the penetration compared to linear attachments, which results in less thermal bridging.



To have even fewer thermal bridges, long screws can be used to fasten lightweight cladding.

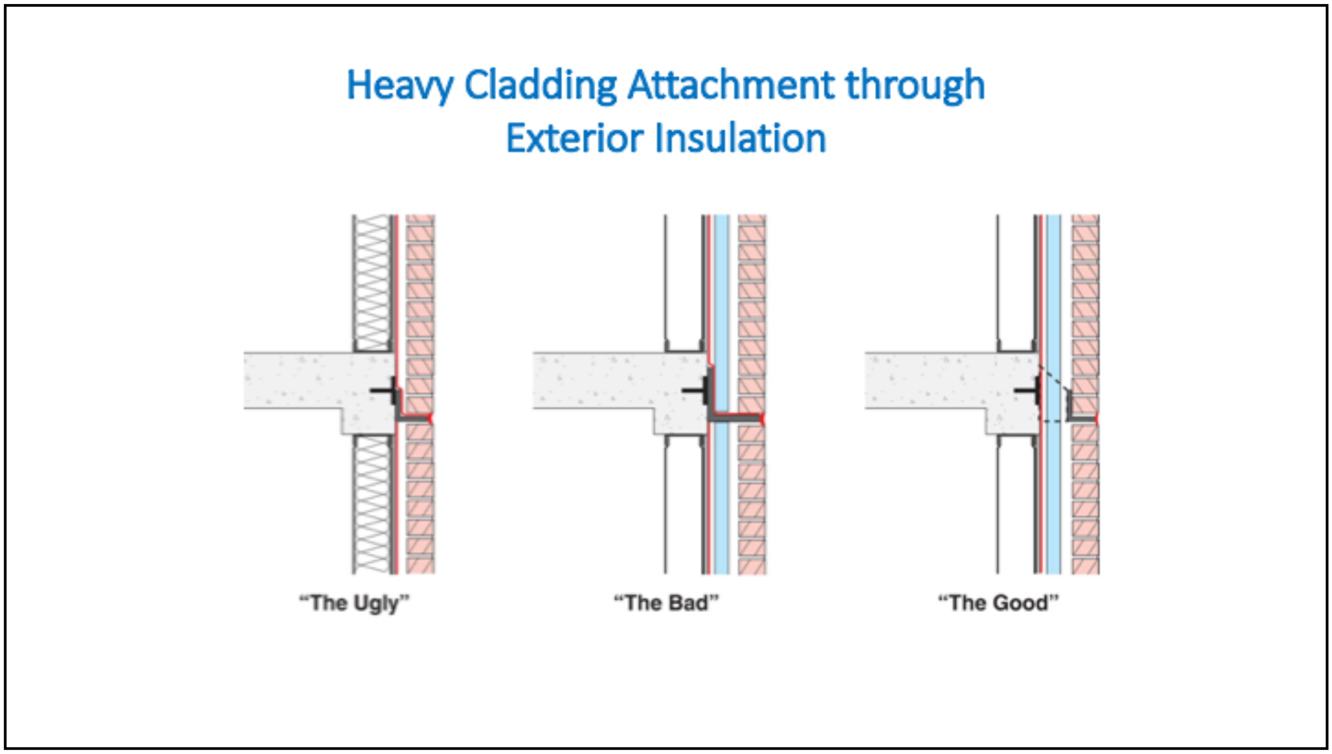
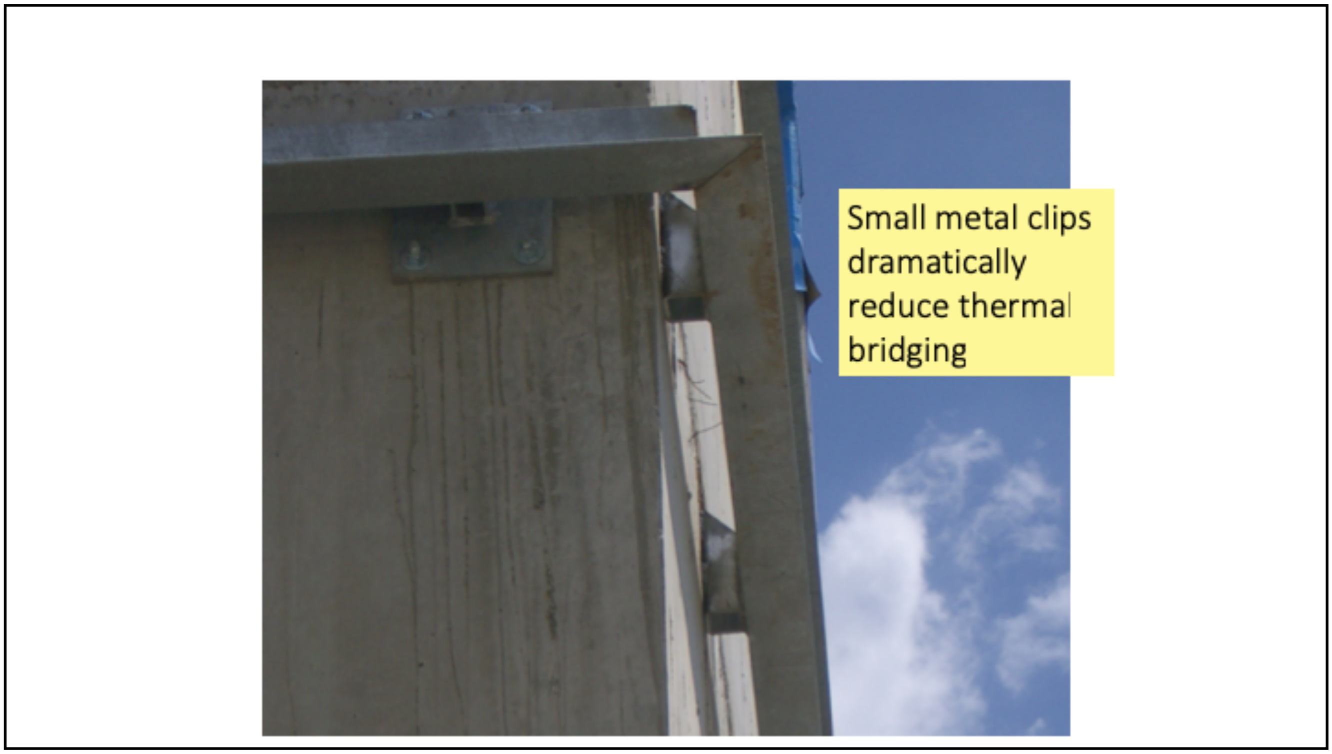


Image 1: Direct structural connection; creates serious thermal bridge

Image 2: Still has thermal bridge despite insulation

Image 3: Thermally broken attachment that also maintains air barrier continuity

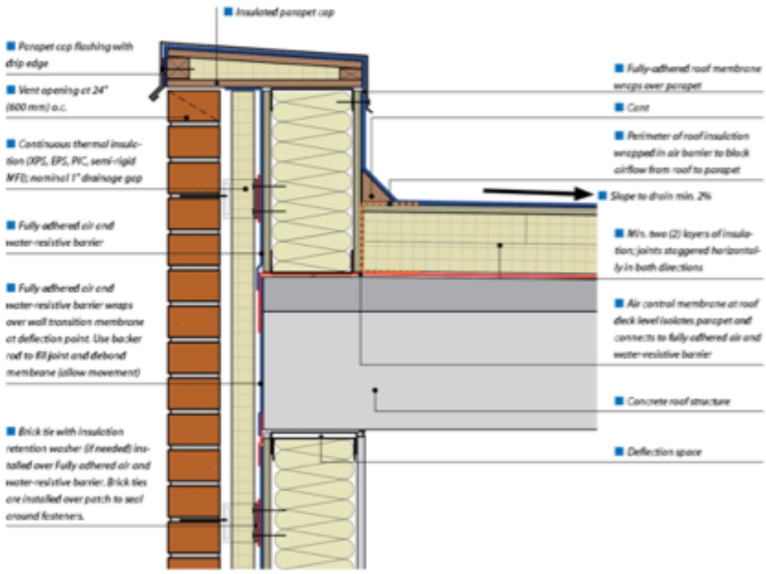


Small metal clips dramatically reduce thermal bridging.

Tube sections cast into concrete with girts welded on minimize thermal bridging and allows space for control layers behind.

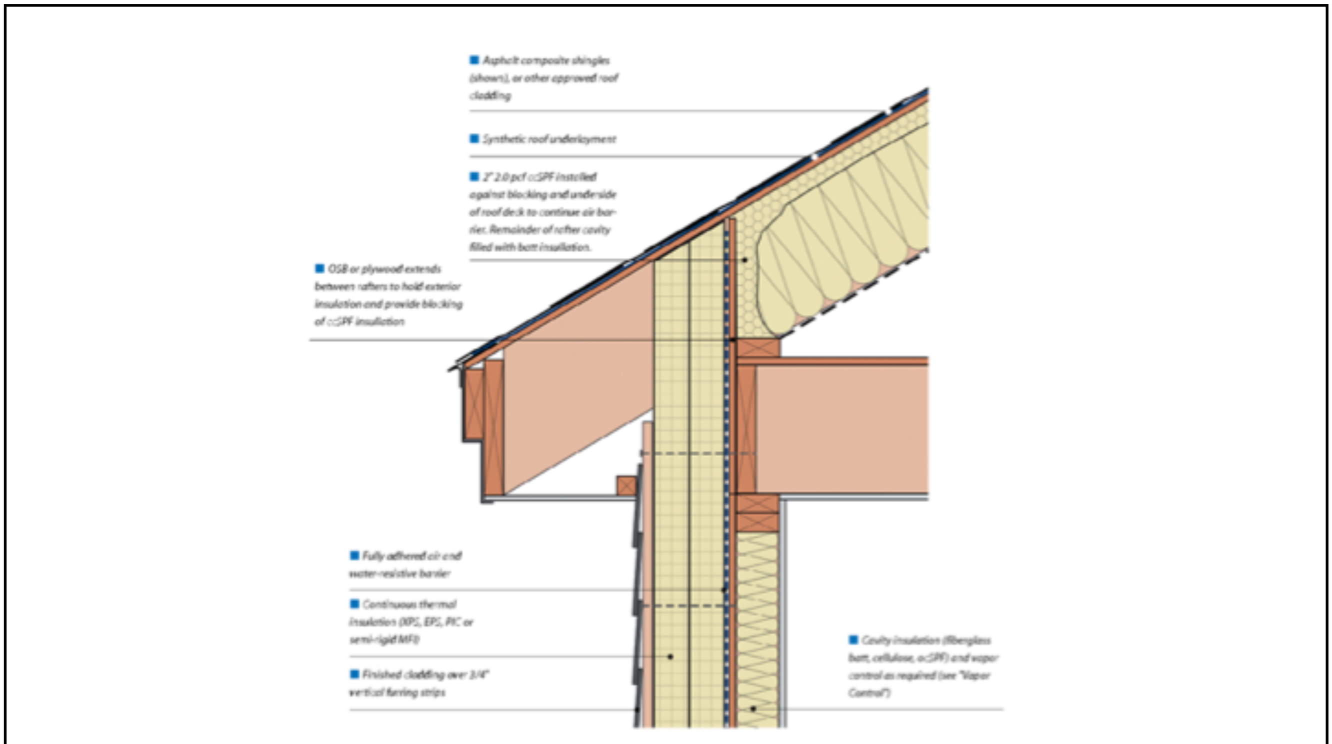
It has a shelf angle for structural support of cladding and has space for drainage.

Structural Penetrations through Exterior Insulation



The parapet is better as a separate structural element.

This makes achieving continuity and detailing easier without adding thermal bridges.



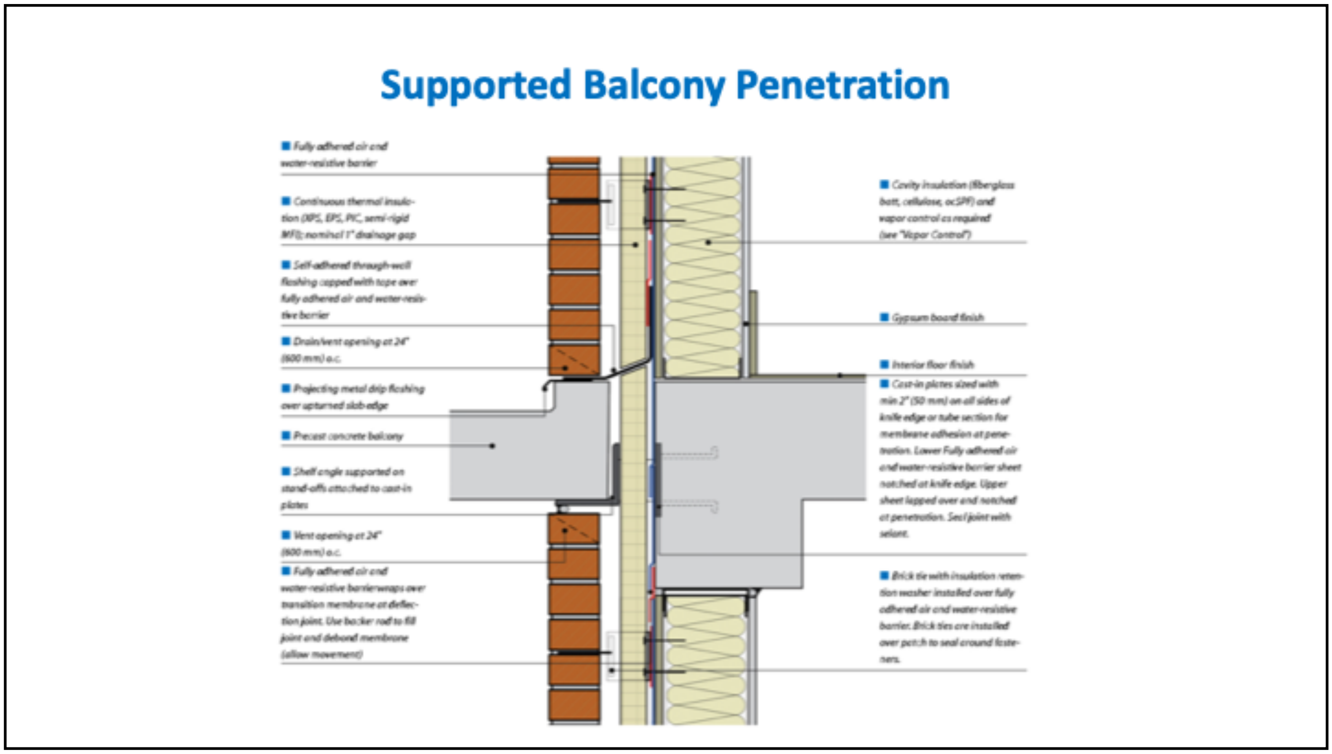
Unvented roofs in residential construction.

There are three different insulation materials are used to achieve continuity and eliminate thermal bridging.

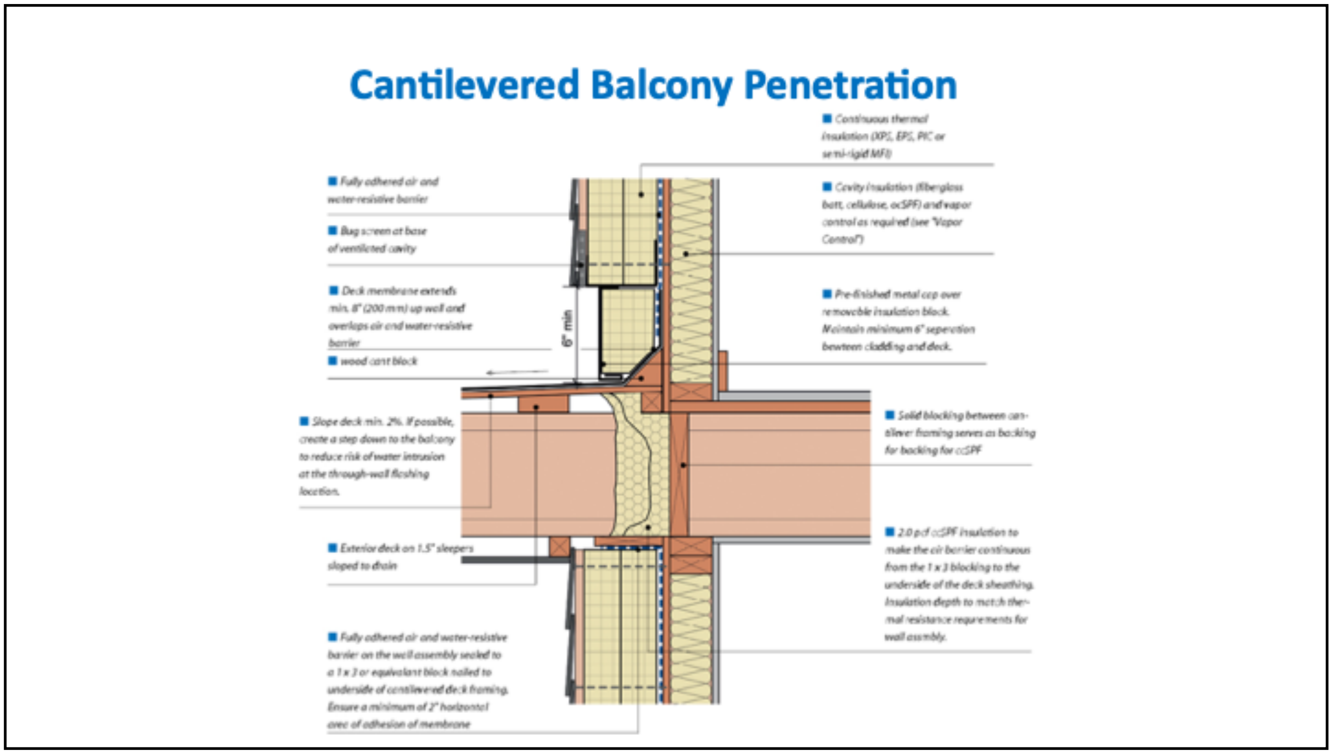
1. There is rigid insulation on the walls.
2. There is spray foam in the hard to reach space in the joists.
3. There is batt insulation between the joists and the roof.

Precast balcony supported on knife edge supports to limit thermal losses.

Precast balcony supported on knife edge supports to limit thermal losses.



The balcony is thermally broken with space to allow for continuity of control layers.



Spray foam helps maintain the continuity of air control layer in otherwise difficult areas.

This is typical residential construction.

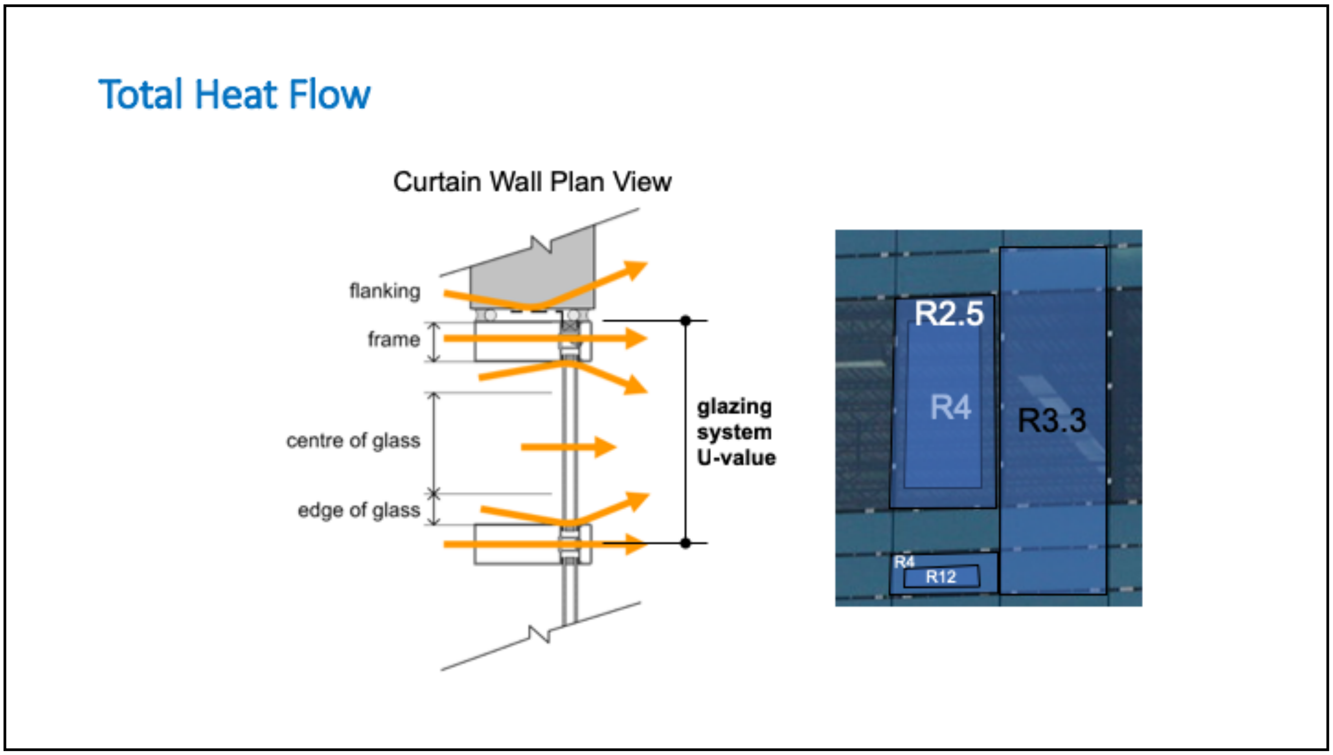
Addressing Windows

- Our most expensive thermal bridges
- Aluminum is four to five times as conductive as glass
- Difficult to buy commercial aluminum windows/curtain wall over R3
- Allow solar heat in
    - Useful in cold weather
    - Requires cooling in summer

Windows and curtain wall have a large impact on the thermal performance of the whole enclosure assembly. A high-performance enclosure design must address both the thermal performance of the glazing and the frame system, as well as the thermal resistance of the solid assemblies.

One must be cautious not to overload the building with thermal gain or loss, which is difficult when window-to-wall ratio is high.

As a general rule, most buildings don’t require as much glass as they have.



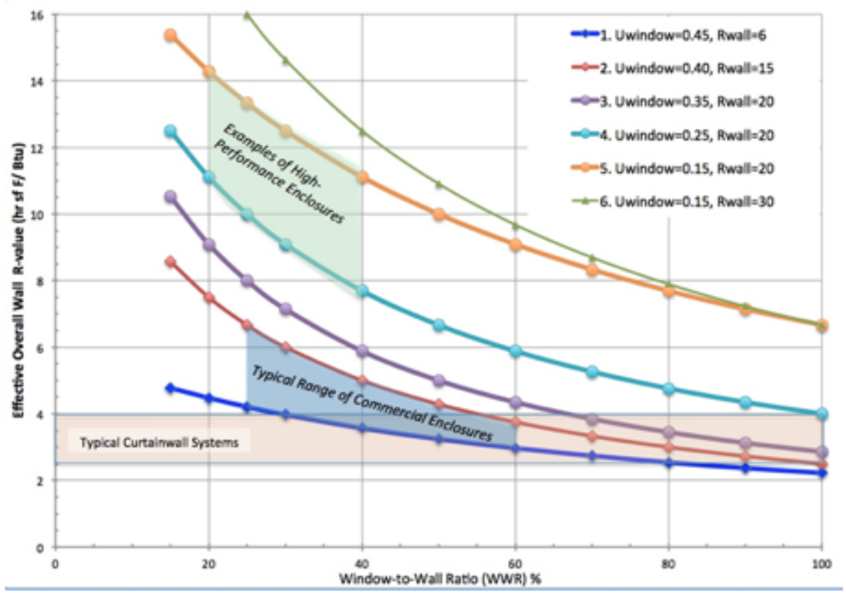
The center of a glass pane has the highest thermal resistance. The edges, where the glass is connected to a thermally conductive frame, have the poorest thermal resistance.

The U-value of a window is a measure of its thermal transmittance. It is the inverse of R-value; therefore the lower the number, the better the thermal performance.

U-Value is the inverse of R-value. Where a high R-value is desirable in a wall, a low U-value is desirable in a window.

Due to thermal bridging in the fastening and framing system, the perimeter of the glass has a lower R-value than the middle.

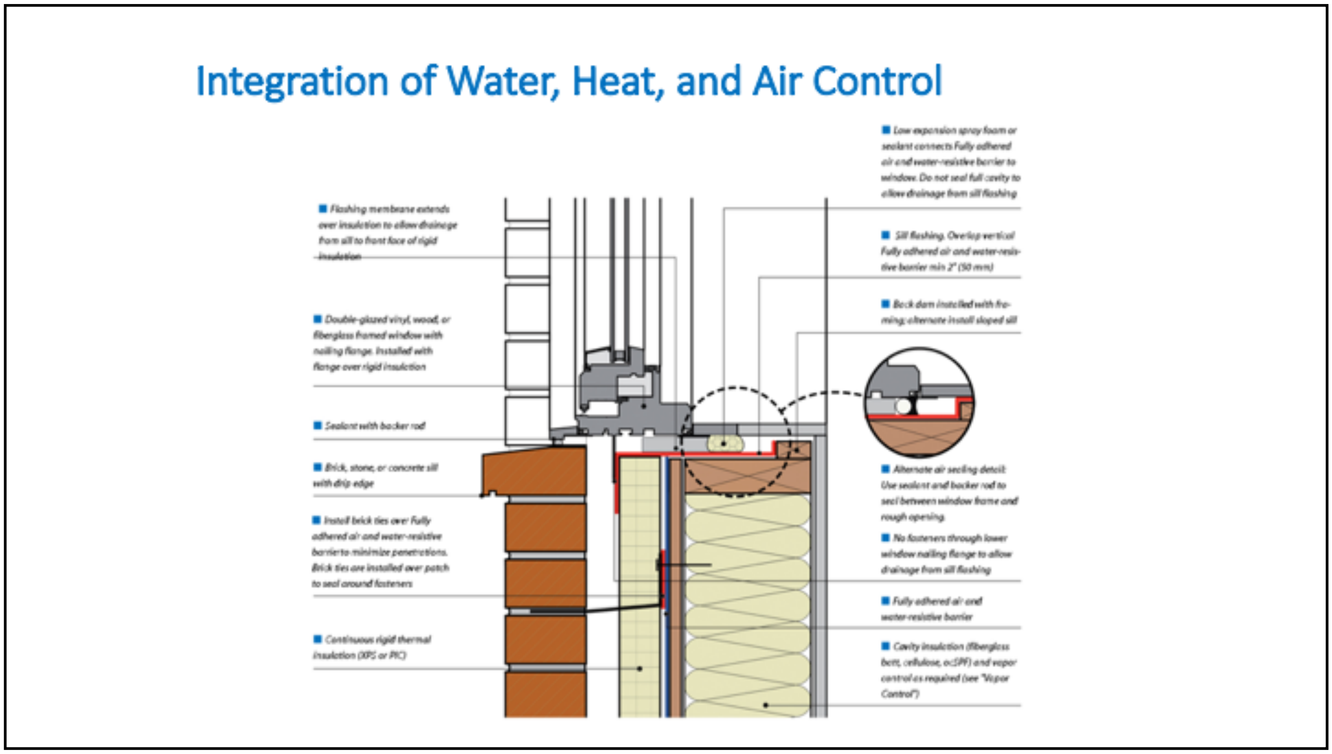
Therefore the entire window has a low effective R-value.



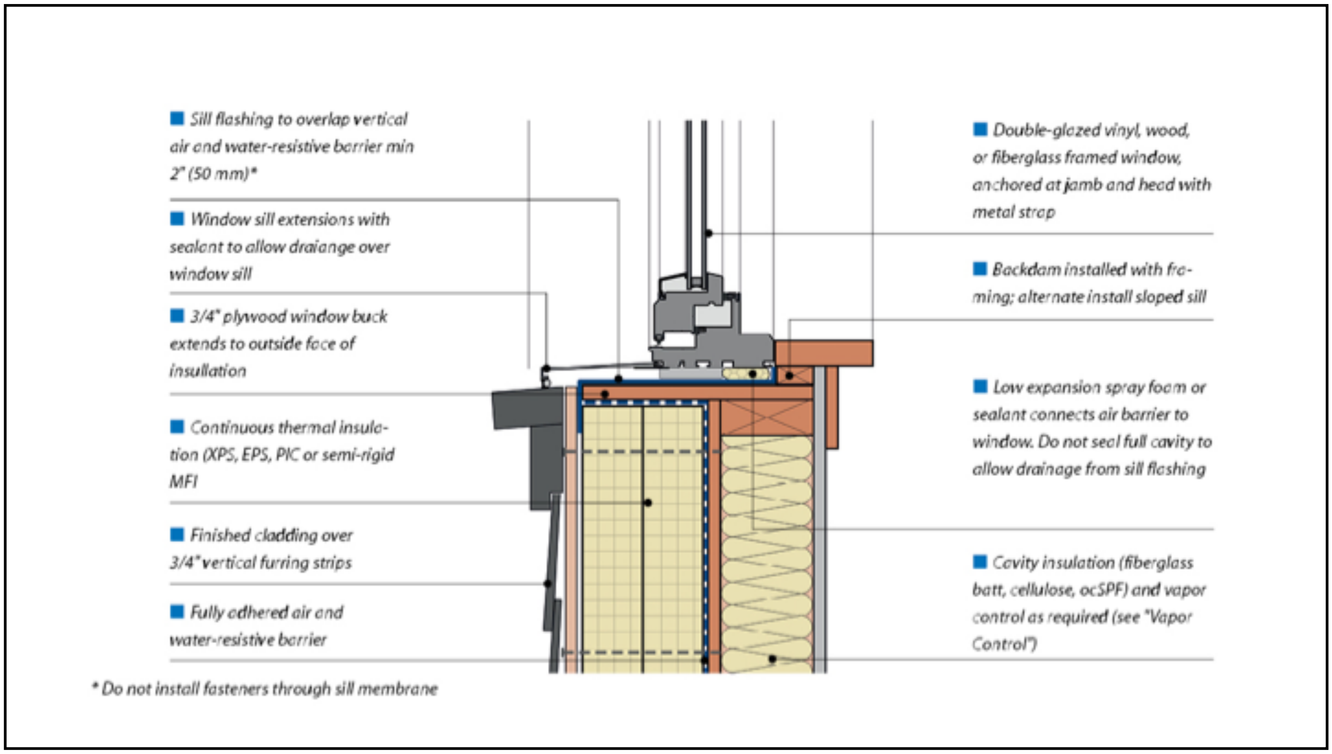
Ratio of window to wall affects the overall wall R-value.

As the amount of glass increases, the effective R-value of the overall wall system decreases.

Note that R10–R20 is the target range for whole building.



Window detailing becomes even more critical as it needs to be tied in to all the control layers, including reduction of thermal bridging and convective air flow.



Window sill detail with continuous insulation. Note that no cavity insulation is required when the connection between the exterior insulation and the window is continuous.

* A continuous insulation strategy must address the details.

Summary of Key Points

- With changing code requirements for thermal control, continuous thermal insulation will become required in most climate zones.
- Insulation is only one part of the puzzle—air-barrier systems and thermal bridging of structure increasingly important.
- Continuity requires that we “design out” thermal bridges or detail to reduce heat flow.
- Cladding attachment over exterior insulation can be challenging, but details exist and are becoming more common.

This concludes the American Institute of Architects Continuing Education Systems Course.

Thank you for completing this educational course by Dörken Systems.

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