Thermal Bridging From Cladding Attachment Strategies Through Exterior Insulation

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1 Introduction

Passive House standards call for highly insulated wall assemblies with effective insulation values in the range of R-40 to R-60 or higher. Recent shifts in construction have resulted in a more common use of continuous exterior insulation installed outside the primary structure and behind the cladding. The use of exterior insulation can result in more efficient wall assemblies that have less thermal bridging caused by the structural elements; however, the cladding attachment systems connecting the cladding back to the structure through the insulation have a wide range of thermal bridging effects and can significantly affect effective R-values.

This paper presents the results of three dimensional thermal modeling which quantifies the actual impact of thermal bridging in typical exterior insulated wall assemblies. Results are presented for several different types of cladding attachment strategies through exterior insulation, with a focus on discrete clips and fasteners that aim to reduce the thermal bridging through the insulation. This paper is intended to provide guidance on efficiently insulated wall assemblies and will be useful to help designers select more thermally efficient cladding attachment strategies as they aim to achieve Passive House standards.

2 Methods

The thermal analysis and determination of effective R-values was undertaken using HEAT3 (www.blocon.se). HEAT3 is a three-dimensional finite element thermal analysis software package used by the building industry to analyze building assemblies in three dimensions which two-dimensional analysis tools (such as THERM) cannot accurately analyze. It allows for the more detailed analysis of building assemblies including the impact of fasteners, discrete clips, and other construction realities. The R-values provided in this paper are estimates of the effective R-values of the assemblies and account for a number of factors including air-films, materials conductivities, and assembly geometry.

The boundary conditions used for this modeling are industry standard ASHRAE winter exterior and interior boundary conditions with temperatures of 0 °F and 70°F and surface films of 0.17 $ft^2 \cdot °F \cdot hr/BTU$ and 0.68 $ft^2 \cdot °F \cdot hr/BTU$ respectively (ASHRAE, 2013). The material conductivities used for the modeling are provided in Table 1.

Table 1: Material Thermal Conductivity

Material	*Thermal Conductivity [W/m·K]*		*Material*	*Thermal Conductivity [W/m·K]*
Fibre Cement Board	0.3		PVC	0.17

Semi-Ventilated Cavity	0.45		Neoprene	0.23
Galvanized Steel	62		Aerogel	0.015
Stainless Steel	14.3		Plywood	0.11
Aluminum	160		Wood (SPF)	0.14
Fiberglass Frame	0.3		Exterior Gypsum Board	0.13
Semi-Rigid Mineral Fiber Insulation (R-4.2/in)	0.0343		Fiberglass Batt Insulation (R-3.3/in)	0.0437
Mineral Fiber Batt Insulation (R-4/in)	0.0355		Interior Gypsum Board	0.16

The thermal modeling results presented in this paper are for clear field center-of-wall areas that do not include potential additional thermal bridging that may occur at floors and slab edges, penetrations, interfaces, additional framing, windows, and other details. Thermal modeling was completed using a standard 2x6 wood stud backup wall at 16" on center with R-22 batt insulation, and a 3-5/8" steel stud backup wall at 16" on center with R-12 batt insulation. The backup walls represent two common residential and commercial wall types and show a wide range of thermal performance for walls using a split insulated assembly (that is insulation both outboard of the structure and between the studs). For this analysis the walls include semi-rigid exterior mineral wool insulation over plywood (wood stud wall) or exterior gypsum sheathing (steel stud), and interior gypsum wall board. Other types of exterior insulation including EPS, XPS, Polyisocyanurate, or spray polyurethane foam could also be used in the assemblies, though were not specifically modeled here.

The thermal modeling results show that continuous exterior insulation can significantly contribute to the effective thermal resistance of wall assemblies; however, structural loads from the cladding elements (dead, wind, seismic) need to be transferred through the insulation layer to the primary structure. There are numerous commonly used methods to transfer cladding loads through the insulation layer to the structure, and structural cladding support systems reduce the effective thermal resistance of the exterior insulation; however, the amount of thermal bridging through different cladding attachment systems varies significantly. Cladding attachment systems used in the modeling were designed based on existing generic building components and proprietary clip systems, with slight modifications to each system in order to accommodate insulation thicknesses up to 12". The thermal modeling and analysis was completed with 4", 8", and 12" exterior insulation thickness to meet a range of Passive House R-values. Each cladding attachment system is intended to provide support and securement for the exterior insulation and uses a continuous vertical strapping component to provide a rainscreen cavity and a cladding attachment substrate outside the insulation. The attachment systems modelled are as follows:

- Stainless steel and galvanized screws through wood or metal strapping
- Intermittent stainless steel and galvanized Z-girt clips
- Fiberglass clips
- PVC isolated galvanized clips
- Aluminum clips

All discrete clips and screw fasteners were modelled at 16" on center horizontal spacing, attached through exterior semi-rigid mineral wool insulation (R-4.2/in) to the stud framing, and with varying vertical spacing from 12" on center up to 48" on center. Closer vertical spacing represents walls where heavier weight cladding such as cultured stone veneer or stucco is used, with larger spacing representing the use of lightweight cladding such as fiber cement board or metal panel. The results show a range of thermal performance for different cladding attachment spacing.

In addition, walls using vertical and horizontal 14 gauge galvanized Z-girts through exterior insulation were modelled in order to illustrate the significant thermal bridging through exterior insulation when discrete cladding attachment is not used.

The effective R-value of the whole wall and the corresponding percentage thermal degradation of the exterior insulation are presented for each wall type for varying thicknesses of exterior insulation. In both the wood stud and steel stud assembly, the results focus on the thermal efficiency of the cladding attachment strategy with regards to thermal bridging through the exterior insulation. The results are intended to present a comparison of discrete cladding attachment systems in order to give guidance on choosing thermally efficient systems when using exterior insulated or split insulated wall assemblies. The percentage thermal degradation of the exterior insulation is a relative measurement of the heat loss through the components penetrating the exterior insulation compared to an equivalent wall with no exterior penetrating elements. It is an indication of the relative thermal performance of each cladding attachment strategy. In addition, the thermal point transmittance *chi* (χ, BTU/hr) is provided for each wall type using discrete clips or fastener systems. The χ-value is the additional amount of heat flow through the wall assembly due to the discrete cladding attachment components (ISO, 2007). It is determined by subtracting the heat flow of the clear field center-of-wall (Q_o) from the heat flow through same assembly (Q_a) with the cladding attachments components in place. The χ-value for each cladding attachment strategy will in most cases be a constant value, independent of the attachment spacing, and can be used to determine the thermal performance of the wall assembly using different attachment spacing apart from what is directly accounted for by the thermal modeling.

3 Results

The thermal modeling shows how the different materials, attachment configurations, and the attachment spacing have a range of impact on the thermal performance of the enclosure. The results also show diminishing returns for thicker exterior insulation, with the percentage thermal degradation increasing with the insulation thickness. See Figures 1 and 2 for the complete thermal modeling results.

Assemblies using the wood frame backup wall with R-22 batt insulation in the stud cavity achieve higher assembly effective R-values compared to the steel stud backup wall. This is due mainly to the reduced wall cavity batt insulation thickness (R-12 in the steel stud wall) and the increased thermal bridging due to the steel stud framing. In addition, the contact resistance between the cladding attachment fasteners, in most cases galvanized steel, and the galvanized steel studs leads to increased heat flow through the components penetrating the exterior insulation. The wood framing backup wall using 8" of exterior insulation and stainless steel screws spaced at 16" vertically results in R-53 $ft^2 \cdot °F \cdot hr/BTU$ effective (3.5% thermal degradation), while the same steel stud wall achieves R-40 $ft^2 \cdot °F \cdot hr/BTU$ (7.6% thermal degradation).

Stainless steel screws result in the lowest thermal bridging compared to the other cladding attachment systems modelled, resulting in between 3% and 4% thermal degradation for the wood stud wall, and between 7.5% and 8% thermal degradation for the steel stud wall, depending on spacing and insulation thickness. The aluminum T-clip resulted in the highest thermal bridging out of all the discrete cladding attachment systems, resulting in between 16% and 31% thermal degradation for the wood stud wall, and between 40% and 52% thermal degradation for the steel stud wall. Similar results can be seen with the intermittent galvanized Z-girts. The fiberglass clips resulted the lowest thermal bridging of the discrete clip systems (excluding screws) for both the wood stud and steel stud backup wall assembly with between 7% and 15% thermal degradation for the wood stud wall and between 18% and 20% thermal degradation for the steel stud wall. The PVC isolated galvanized clip and intermittent stainless steel Z-girt resulted in similar decreased thermal bridging, though slightly higher than the fiberglass clip.

The χ-value for each discrete cladding attachment system is directly proportional to the percent thermal degradation. The stainless steel screws resulted in the lowest χ-value of between 0.0017 and 0.0020 BTU/hr for the wood stud wall and between 0.0042 and 0.0089 for the steel stud wall. The aluminum T-clip system resulted in the highest χ-value of between 0.0129 and 0.0219 for the wood stud wall and between 0.0721 and 0.0825 BTU/hr for the steel stud wall. Graphs showing point transmittance in Figures 1 and 2 show only values for closer attachment spacing,

The horizontal and vertical continuous Z-girts produced significant thermal degradation through the exterior insulation. Horizontal continuous Z-girts resulted in between 40% and 63% thermal degradation for the wood stud wall and between 56% and 72% thermal degradation for the steel stud backup wall. Vertical continuous Z-girts resulted in between 67% and 79% thermal degradation for the wood stud and between 77% and 84% thermal degradation for the steel stud backup wall.

4 Discussion

Wall assemblies using stainless steel screws through strapping and insulation achieve the highest effective R-value of the whole wall compared to other discrete cladding attachment systems. The screw installation may however present difficulties as long screws are required through thick insulation and are installed at the same time as the insulation. In some cases the installation may require additional screws to attach portions of insulation (i.e. through 6" of insulation where 12" is needed) for ease of installation, which will lead to increased thermal bridging at the screws. In addition, the screws through exterior insulation may not result in an assembly that can adequately support heavier weight cladding at greater exterior insulation thicknesses. In general, screws through insulation can support lightweight non-brittle cladding; however, there may be a risk of long term deflection damage for heavyweight brittle cladding materials.

Where the screws cannot be used due to installation challenges and limited structural capacity, a proprietary clip system designed to provide the required structural support with minimized thermal loss is a good alternative. The fiberglass clip, PVC isolated galvanized clip, and stainless steel intermittent Z-girt system all perform reasonably well compared to other proprietary and standard cladding attachment systems and would be a good choice, especially for walls using thicker exterior insulation levels. Continuous Z-girts should not be used due to their significant thermal degradation of the exterior insulation compared to other cladding attachment systems.

Walls that use exterior insulation and thermally efficient discrete cladding attachment systems can achieve effective insulation levels that reach Passive House standards.

5 References

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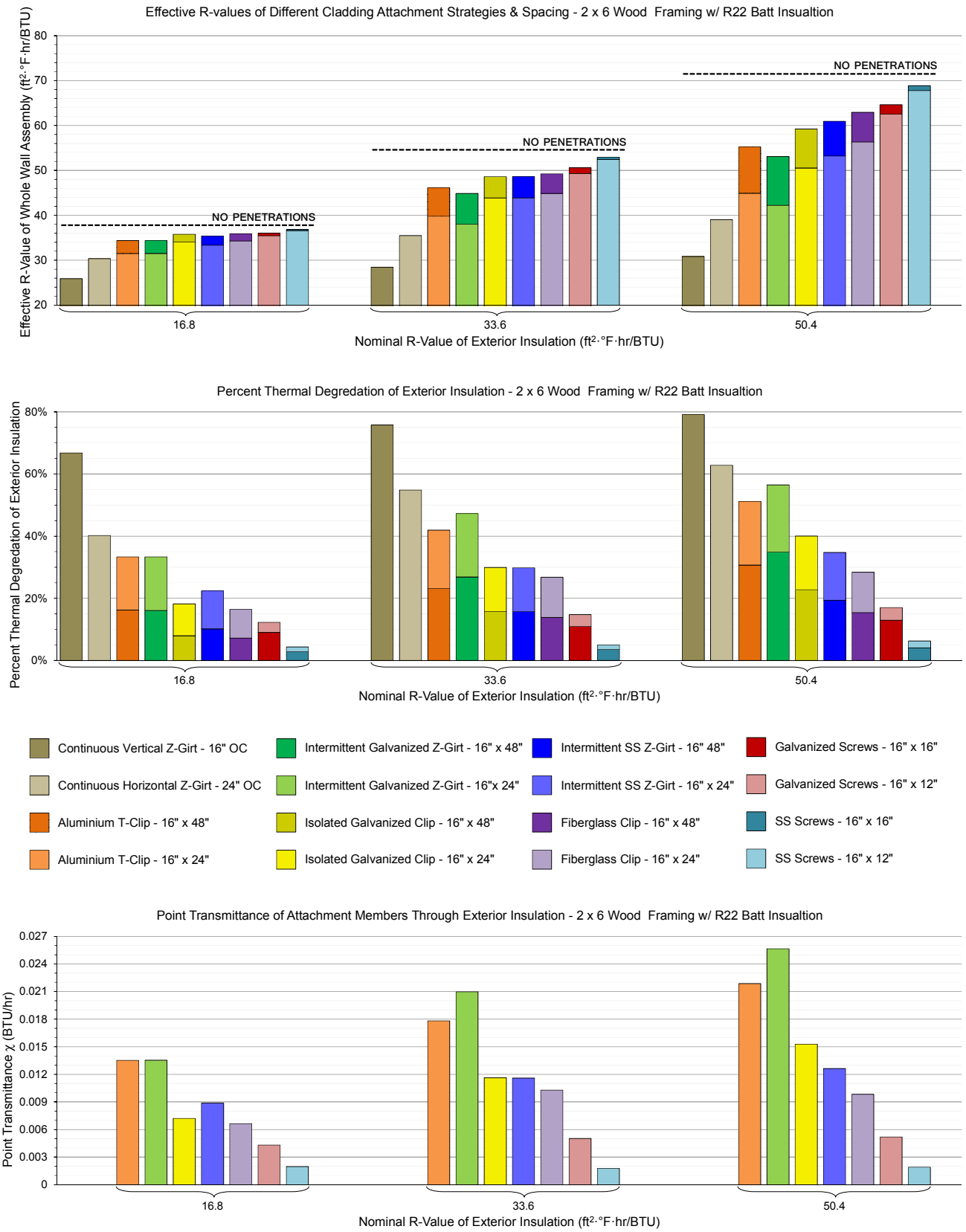

Figure 1: Effective R-Values, Percent Thermal Degradation, and Point Transmittance for wood stud backup walls with 4", 8", and 12" exterior insulation, with stacked columns showing spacing adjustments.

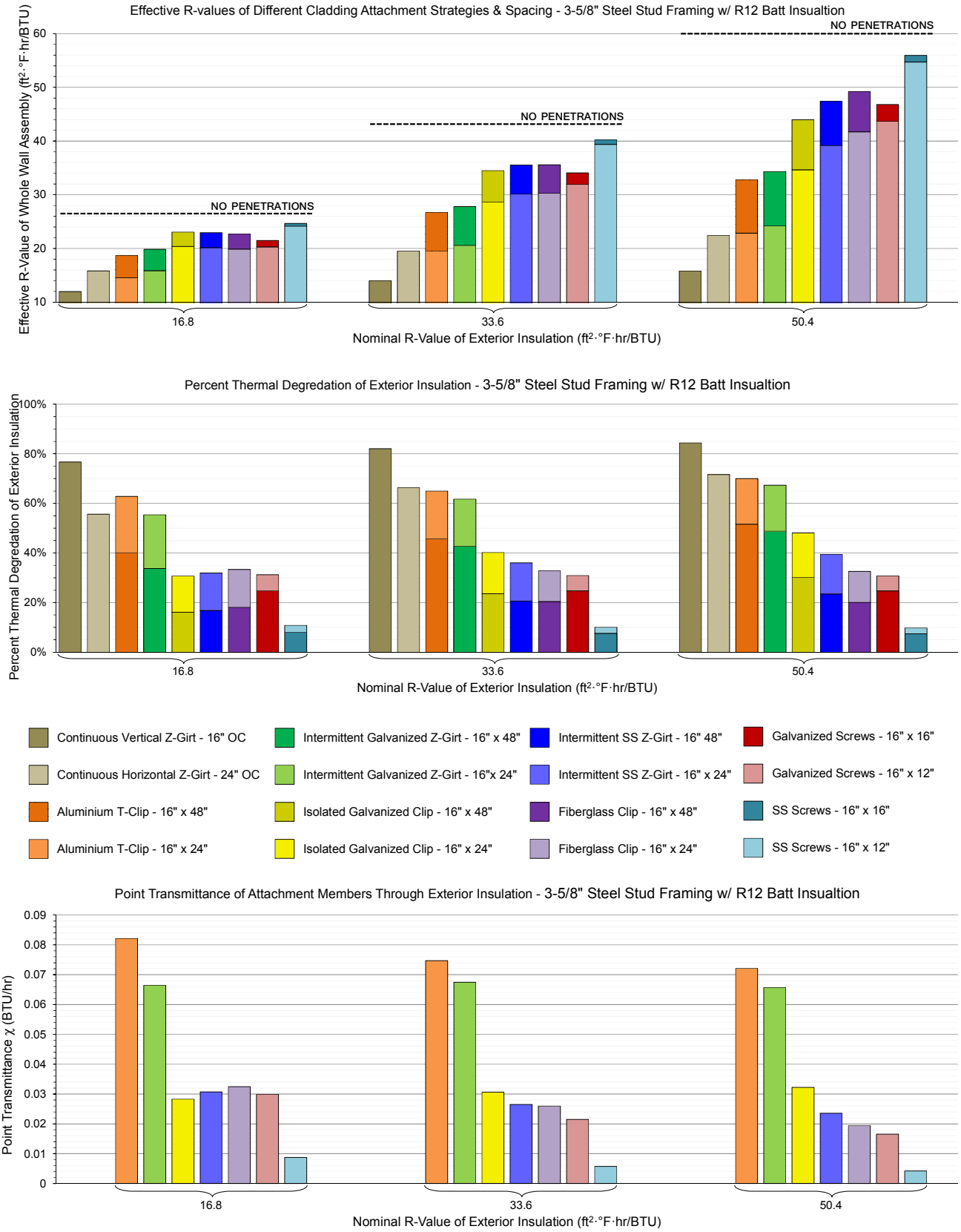

Figure 2: Effective R-Values, Percent Thermal Degradation, and Point Transmittance for steel stud backup walls with 4", 8", and 12" exterior insulation, with stacked columns showing spacing adjustments.