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CFSEI
COLD-FORMED STEEL
ENGINEERS INSTITUTE

TECHNICAL NOTE
On Cold-Formed Steel Construction

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THERMAL ENERGY TRANSFER OF COLD-FORMED STEEL FRAMING

Summary: While the concepts of energy conservation and efficiency are not new, the demand for sustainable building is at an all-time high. Energy efficiency, and more specifically thermal energy transfer in steel stud construction, presents the construction team with a clear opportunity for reduction in thermal bridging. Advanced analysis of building thermal simulation through scientific thermal modeling programs illustrates that the construction team has the ability to significantly reduce thermal transfer. Use of cold-formed steel framing with a reduced thermal bridging area, in combination with increased spacing of the framing system provides, among other benefits, a significant and positive impact on thermal performance.

NEW CHALLENGES IN THE DEMAND FOR ENERGY EFFICIENCY

The modern demand for energy conservation and more stringent energy regulations is a major driving force of the sustainability movement in today's building construction industry. These demands translate to new challenges for architects, engineers, and contractors (the "AEC" community), each with their own separate roles and slightly different goals in the common construction effort. However, this can create confusion in the design process.

The need to design and construct more thermally efficient buildings is no exception. Thermal efficiency requirements often result in more complicated, expensive façade methodologies intended to decrease thermal bridging. Yet, these design challenges also provide an opportunity for the AEC group to present itself as a cohesive, preeminent team in developing design alternatives.

THE BASICS OF THERMAL ENERGY TRANSFER

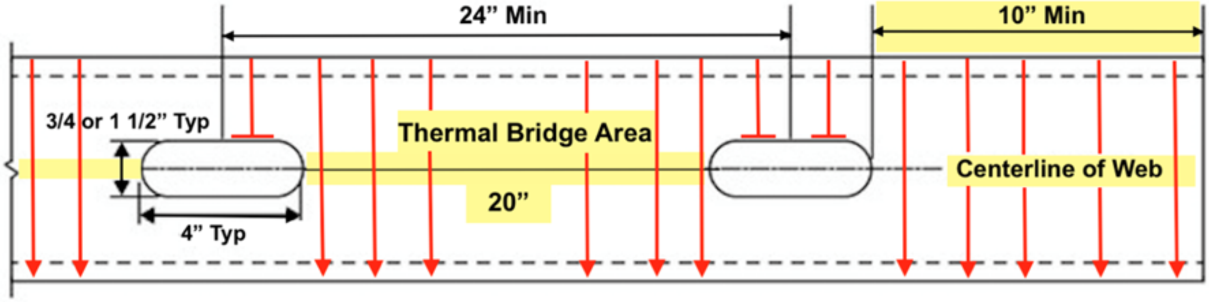
Understanding some of the basic principles of thermal transfer will help facilitate collaborative efforts within the AEC team. Steel exhibits numerous advantages over wood-framed construction, including improved design efficiency, time and cost savings, and long-term viability. Steel can be continually recycled into other steel products without the loss of quality, resulting in a minimum amount of waste on the construction site. Pertinent to building energy performance, steel is also a highly thermally conductive material, which results in additional "thermal bridging." Thermal bridges act as a pathway for heat to escape or enter a building more rapidly, subsequently impacting the entire building's energy performance. In the case of steel studs, the pathway, or thermal bridge, is any uninterrupted line across the web (the area forming the bridge between the two steel flanges). Thermal breaks can be used to block that pathway via any web opening in a steel stud that minimizes heat flow.

METHODOLOGIES

One of the most common ways to overcome thermal bridging is to block the heat flow path through the steel framing with continuous exterior insulation. However, this method still carries the risk of discontinuities in the insulation, particularly at junctions and around openings. Additionally, the AEC team should consider utilizing studs with a reduced thermal bridge area, coupled with an increased spacing of the framing members from 16 to 24 inches on center, where practical. Increasing the spacing of the framing system from 16 to 24 inches will require that the cold-formed steel framing system be more rigid, which could mean using heavier gauge studs and/or more cross-bracing or other methods to increase the load bearing capacity of the system, depending on the type of steel stud selected. Regardless, increased stud spacing results in a positive impact on thermal performance.

For example, thermal bridging of the wall system is dramatically reduced by using a 68-mil stud at 24 inches on center compared to a 54-mil stud at 16 inches on center. The design with the studs at 24 inches on center requires 1/3 less studs and, therefore, 1/3 less potential bridges for the energy to transfer.

An example of a 100-foot wall section, using 10-foot studs with 4-inch knock-outs centered at every 24 inches, leaves 20 inches of a Thermal Bridge Area between holes, plus the required 10-inch minimum area between the top and bottom. The resultant total conductive area is as follows:



Per the Steel Framing Industry Association's Technical Guide 2018, the axial and flexural loads at 25 psf and L/360 are as follows:[1]

A 10-foot 600S162-54 at 16-inch stud spacing will achieve 4.44 Kips
A 10-foot 600S162-68 at 24-inch stud spacing will achieve 5.71 Kips.

The conductive material (steel) in the thermal bridge of a 600S162-54 stud will have 100 inches of thermal bridging: 100 x 0.054 = 5.4 in^2 per stud.

The conductive material (steel) in the thermal bridge of a 600S162-68 stud will have 100 inches of thermal bridging: 100 x 0.068 = 6.8 in^2 per stud.

The number of 600S162-54 studs needed to complete the wall: 75 x 5.4 in^2 = 405 in^2.
The number of 600S162-68 studs needed to complete the wall: 50 x 6.8 in^2 = 340 in^2.

So, while the amount of conductive material (steel) is greater per stud for the 68-mil stud, the total amount of conductive material (or area) is approximately 15% less.

A 2019 study performed by Morrison Hershfield at the request of the author shows how the increase in spacing significantly affects the U-value of the wall assembly[2]. The above calculations of walls without continuous insulation on the exterior of the building envelope illustrate the positive impact of steel stud spacing on thermal results.

THERMAL MODELLING

Advanced analysis of building thermal simulation through building modeling programs is now more regularly utilized as a critical and powerful tool in the analysis and construction of high-performance buildings. The software programs that accomplish this have become more sophisticated, integrated, and user-friendly. This, in turn, helps the AEC team to coordinate data exchange, better understand and more accurately predict building performance in terms of energy optimization, and improve the decision-making process. The obtained analytical results provide the AEC team with early feedback about the impact of various building configurations.

While thermal modeling of the steel framing system is not a complete wall assembly analysis, it provides the basis of the entire design. The steel framing is a highly conductive thermal component within the wall assembly. A framing design with the least amount of thermal conductivity significantly reduces the amount of effort required to minimize the conductivity of the overall system/assembly.

The following thermal performance chart of increased stud space assembly scenarios, including the use of several cladding systems, was evaluated with Siemens' NX 3D thermal modeling analysis software package. This is a general-purpose computer-aided design (CAD) and finite element analysis (FEA) package. The thermal solver and modeling procedures utilized for this particular study were extensively calibrated and validated to within +/- 5% of hotbox testing for *ASHRAE Research Project Report RP-1365: Thermal Performance of Building Envelope Details for Mid- and High-Rise Construction* and for the *Building Envelope Thermal Bridging Guide*.[1]

The example below illustrates the potential benefits of applying thermal modeling and increased stud spacing.

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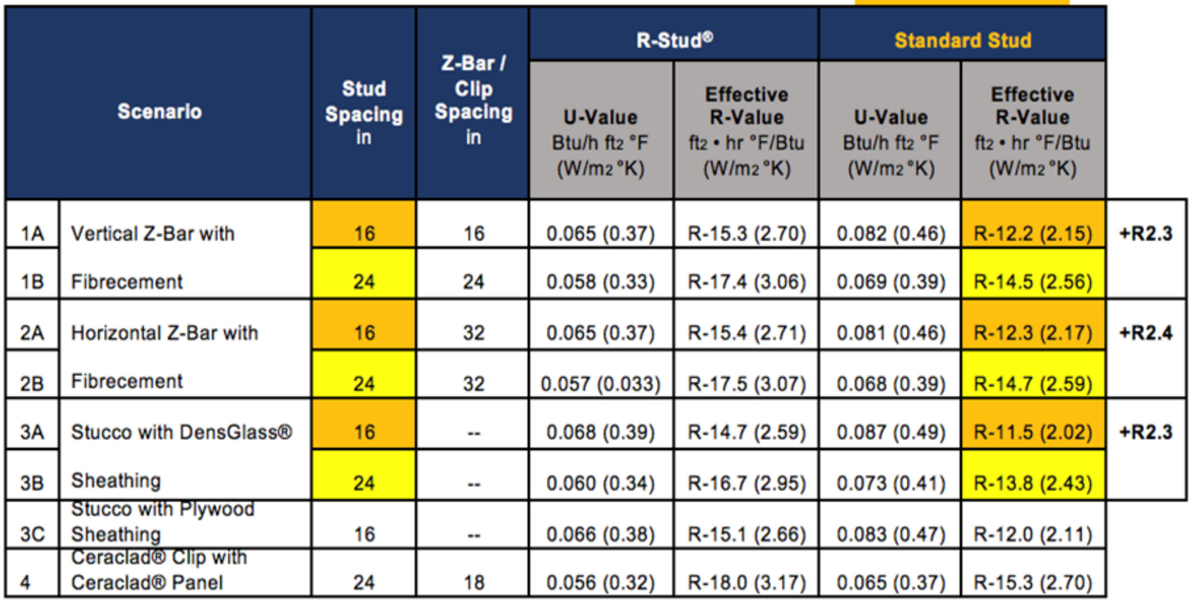
[1] Steel Framing Industry Association (SFIA). *Technical Guide for Cold-Formed Steel Framing Products*. 2018. https://sfia.memberclicks.net/assets/TechFiles/SFIATechSpec2018d1no5psf.pdf

[2] Morrison Hershfield. *R-Stud Thermal Analysis*. Report Number: 190426300. 2019. https://www.rstud.com/wp-content/uploads/2019/08/2019-08-19-R-Stud-Thermal-Analysis.pdf

THERMAL RESULTS

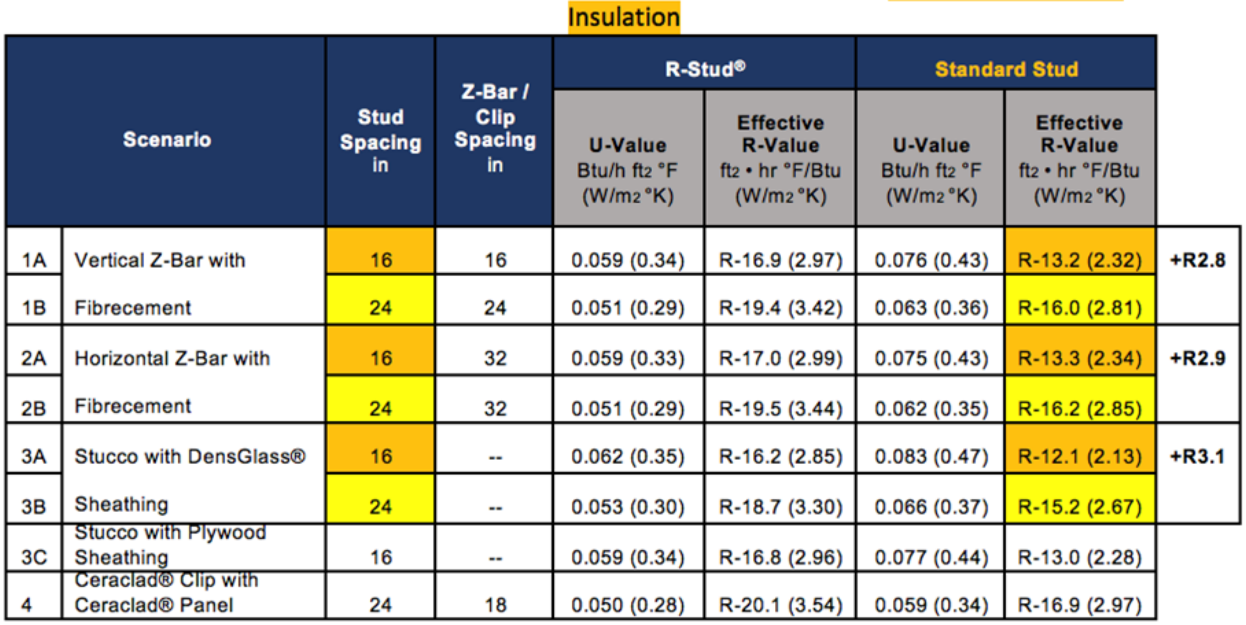
The U-values and effective R-values with R-21 batt insulation in the stud cavity are shown in Table 3.1. Results for scenarios with R-25.2 mineral wool insulation in the stud cavity are shown in Table 3.2. Example temperature profiles for each configuration are provided in the full report found here: https://www.rstud.com/wp-content/uploads/2019/08/2019-08-19-R-Stud-Thermal-Analysis.pdf

Table 3.1 Effective R-values of the Evaluated Wall Assemblies with R-21 Batt Insulation



Scenario		Stud Spacing in	Z-Bar / Clip Spacing in	R-Stud®		Standard Stud		
				U-Value Btu/h ft^2 °F (W/m^2 °K)	Effective R-Value ft^2 • hr °F/Btu (W/m^2 °K)	U-Value Btu/h ft^2 °F (W/m^2 °K)	Effective R-Value ft^2 • hr °F/Btu (W/m^2 °K)	
1A	Vertical Z-Bar with	16	16	0.065 (0.37)	R-15.3 (2.70)	0.082 (0.46)	R-12.2 (2.15)	**+R2.3**
1B	Fibrecement	24	24	0.058 (0.33)	R-17.4 (3.06)	0.069 (0.39)	R-14.5 (2.56)	
2A	Horizontal Z-Bar with	16	32	0.065 (0.37)	R-15.4 (2.71)	0.081 (0.46)	R-12.3 (2.17)	**+R2.4**
2B	Fibrecement	24	32	0.057 (0.033)	R-17.5 (3.07)	0.068 (0.39)	R-14.7 (2.59)	
3A	Stucco with DensGlass®	16	--	0.068 (0.39)	R-14.7 (2.59)	0.087 (0.49)	R-11.5 (2.02)	**+R2.3**
3B	Sheathing	24	--	0.060 (0.34)	R-16.7 (2.95)	0.073 (0.41)	R-13.8 (2.43)	
3C	Stucco with Plywood Sheathing	16	--	0.066 (0.38)	R-15.1 (2.66)	0.083 (0.47)	R-12.0 (2.11)	
4	Ceraclad® Clip with Ceraclad® Panel	24	18	0.056 (0.32)	R-18.0 (3.17)	0.065 (0.37)	R-15.3 (2.70)	

Table 3.2 Effective R-values of the Evaluated Wall Assemblies with R-25.2 Mineral Wool Insulation



Scenario		Stud Spacing in	Z-Bar / Clip Spacing in	R-Stud®		Standard Stud		
				U-Value Btu/h ft^2 °F (W/m^2 °K)	Effective R-Value ft^2 • hr °F/Btu (W/m^2 °K)	U-Value Btu/h ft^2 °F (W/m^2 °K)	Effective R-Value ft^2 • hr °F/Btu (W/m^2 °K)	
1A	Vertical Z-Bar with	16	16	0.059 (0.34)	R-16.9 (2.97)	0.076 (0.43)	R-13.2 (2.32)	**+R2.8**
1B	Fibrecement	24	24	0.051 (0.29)	R-19.4 (3.42)	0.063 (0.36)	R-16.0 (2.81)	
2A	Horizontal Z-Bar with	16	32	0.059 (0.33)	R-17.0 (2.99)	0.075 (0.43)	R-13.3 (2.34)	**+R2.9**
2B	Fibrecement	24	32	0.051 (0.29)	R-19.5 (3.44)	0.062 (0.35)	R-16.2 (2.85)	
3A	Stucco with DensGlass®	16	--	0.062 (0.35)	R-16.2 (2.85)	0.083 (0.47)	R-12.1 (2.13)	**+R3.1**
3B	Sheathing	24	--	0.053 (0.30)	R-18.7 (3.30)	0.066 (0.37)	R-15.2 (2.67)	
3C	Stucco with Plywood Sheathing	16	--	0.059 (0.34)	R-16.8 (2.96)	0.077 (0.44)	R-13.0 (2.28)	
4	Ceraclad® Clip with Ceraclad® Panel	24	18	0.050 (0.28)	R-20.1 (3.54)	0.059 (0.34)	R-16.9 (2.97)	

CONCLUSION

The AEC team should consider a coordinated effort at the outset of the design process, incorporating thermal modeling and including basic thermal analysis of different stud spacing options (i.e. both 16- and 24-inch spacings). In addition to a reduction in thermal bridging, there is another significant benefit of increased stud spacing: less steel equates to less embodied carbon. There is a reduction in both embodied carbon (released in manufacturing, production, and transportation of building materials) and operational carbon (the carbon load created by the use of energy to operate a building) – both of which will be the subject of a future paper. Finally, increased stud spacing reduces sound transmission through the wall assemblies, providing improved acoustic performance as well.

With the growing momentum of more energy-efficient and sustainable buildings, this holistic approach provides a unique opportunity for the AEC team to showcase itself as an industry leader in the innovative, cost-effective, streamlined, and more time-efficient design package.

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