WHITE PAPER

CRITERIA FOR THERMALLY AND GEOMETRICALLY INDUCED LOADING OF IMPS

OVERVIEW

Insulated Metal Panels (IMPs) are composite panels that combine both transverse load resistance and insulation for buildings in a single assembly. This unique approach requires special consideration during both the design and installation to ensure good product performance. This is obviously true for resistance to code-mandated design loads such as wind. But it is just as true for resistance to loads induced by temperature gradients or framing deviations as well.

Unlike design loads, which a building may never experience during its service life, thermally and geometrically induced loads occur under everyday conditions. The primary effect of these induced loads are surface waves on the exterior (or fascia) skin. Although these waves rarely impact panel strength, they are aesthetically unpleasing and avoidable through application of best practices.

This Technical Bulletin will provide these best practices and related simplified criteria to building designers and installers addressing these complex issues in the context of IMP wall panels of polyurethane cores.

DISCUSSION

General

Under loading, the composite nature of IMPs induces axial stress on the metal skins and shifts most of the required shear resistance to the core, particularly when the panels skins are flat. In this context, "flat" means that profile depth of the exterior (fascia) skin is small compared to the panel core thickness. Flat panels are in contrast to panels where the exterior (fascia) skin is heavily profiled. This paper will use the convention described below and as illustrated in Figure 1 to refine the criteria presented:

- *True-flat* panels are defined as those where the fascia skin has little to no profiling. (i.e., <= 1/8 inch) These panels are typically used in architectural applications in a horizontal orientation, where surface waves are more visible to the bystander.
- *Profiled panels* have fascia profiles 1 inch deep or greater. They are traditionally vertically oriented in commercial or industrial applications. However, they are gaining use is similar applications as true-flat panels, as industrial motif facades are becoming popular.

- *Near-Flat* panels are defined as those where the fascia skin profile is greater than 1/8 inch but less than one inch. Like profiled panels. They are primarily oriented vertically but horizontal is not uncommon either. Either way, they are a popular choice and widely used in commercial, industrial and architectural applications.

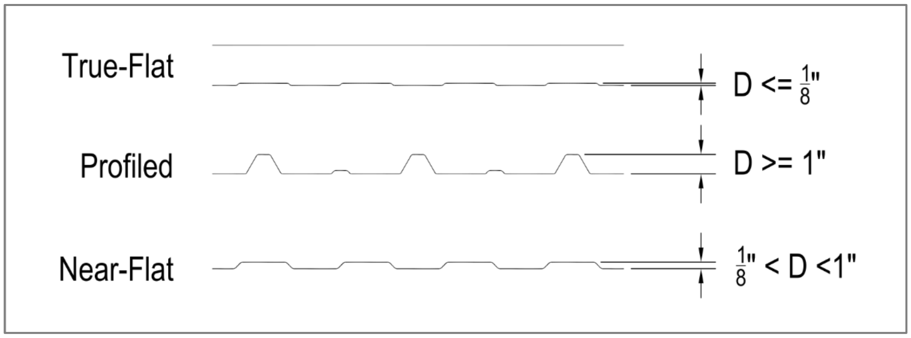

Figure 1: Fascia Skin Profile Examples

Thermal Gradients

IMP foam cores usually provide enough insulation capacity to meet energy code requirements. This means that a thermal gradient acting through the panel thickness will nearly always be present. In summer daytime/interior cooled conditions, this gradient is worsened by solar radiation acting to increase the fascia temperature well above ambient conditions.

Table 1 shows the results of a thermal model using EnergyPlus developed for a hypothetical 50’ x 100’ x 20’ tall building in 90° F ambient conditions with little to no wind and an interior temperature of 70° F. It was run with various solar reflectance values subjected to different solar insolation levels. This table shows that even under moderate conditions, a 40° F difference can develop and 80° F or more is attainable.

Table 1: Thermal Model Results

Solar Reflectance	500 Watt/ft^2 Solar Insolation		250 Watt/ft^2 Solar Insolation	
	Fascia Skin Temperature above ambient, °F	**Panel Delta-T, °F**	**Fascia Skin Temperature above ambient, °F**	**Panel Delta-T, °F**
0.9	9	24	5	20
0.75	23	38	11	26
0.5	45	60	23	38
0.25	66	81	35	50

How an IMP responds to a thermal gradient depends mostly upon the stiffness of the fascia skin relative to that of the entire panel, which is represented here using the previously defined terms true-flat, near-flat, and profiled.

True-Flat Panels

Thermal waves on true-flat panel skins tend to happen in the field of the panel, (i.e., away from the support) and often those waves are transient, meaning they appear and disappear as thermal conditions change.

Because of the lack of profiling, surface waves usually occur in the elastic region of the steel and generally do not impact panel functionality. However, the lack of profiling also visually accentuates these waves, sometimes leading to aesthetic anomalies.

Profiled Panels

For profiled panel fascia skins, the physics of the panel skin stress changes. While these panels offer greater resistance to thermal waves and do not visually telegraph them as much as true-flat panels, they are not immune to the phenomenon, and it may be less transient when it does occur. However, it tends to be more localized and as such, has little consequence to panel strength outside of extreme situations. Ironically, profiled panels can sometimes be so stiff, they are less forgiving to large framing variances over a short span.

Near-Flat Panels

Near-flat panels behave in a way characterized by both flat and profiled behavior mostly depending upon the span-to thickness ratio and the size of the flats in which profiling is present. They will often telegraph surface waves visually, although less so than true-flat panels. Because they are hybrids of the two extremes, diagnosing the cause of surface waves in these panels can be difficult.

Geometrical Deviations

Panel stresses due to framing misalignment is a completely separate phenomenon from thermally induced stresses and the effects may be additive to or subtractive from the thermal effects. It is very important to minimize framing misalignment in any IMP installation. Ideally, all framing should be in near-perfect alignment, but that is not a realistic expectation.

For true-flat and near-flat panels, MCA guide specifications stipulate a maximum outward out-of-plane deviation of 1/8 inch per 6-foot panel run, and an absolute maximum of 3/16 inch outward anywhere along line cast between panel ends. There is no acceptable level of inward variation.

For profiled panels, MCA guide specifications stipulate a maximum out-of-plane deviation of ±1/8 inch per 6-foot panel run with an absolute maximum of ±3/16 inch outward anywhere along line joining the panel ends.

Combined Effects

Meeting tolerances given here mitigates the impact of geometric deviations. But when the chance of thermal waves is increased due to darker fascia skin color, high ambient temperature, and/or span configuration, any misalignment present in the framing significantly increases the chances of surface waves appearing at a later time.

This illustrates a very important point. <u>Every measure must be taken to mitigate both thermal gradient and geometrical deviation interactions because together, they may create problems months after the installation is complete.</u>

Panel Response

It is difficult to predict the conditions under which waves will develop. The general behavior is that thicker skins and deeper profiles are more resistant to surface waves. But there are other factors as well. Good adhesion between the skin and the core is analogous to a brace on a column and is essential. IMP manufacturers go through great lengths to maximize adhesion quality. However, adhesion can be negatively impacted by improper handling and installation long after a panel has left the manufacturing facility. That loss may not be detectible until a thermal gradient is applied months or even years later.

Common examples of this include:

- Careless lifting or rough handling of panels when removed from flatbed trailers or containers.
- Single-point lifting of long panels into position for staging or installation
- Use of straps or chains to lift in lieu of vacuum lifts or carriages
- Dimples caused by dropped tools or foot traffic while the panel is stored horizontally
- Dimples due to overdriven screws during installation

Illustrative Model

To illustrate the effects of thermal gradient and geometrical deviations together, a finite element model for a near-flat panel was created and run several times for various conditions. The subject spans were 5 feet, 7.5 feet, 10 feet and 12.5 feet. Each of these configurations were subjected to a thermal gradient of 35° F and a support misalignment of 3/8 inch both separately and in conjunction. The maximum fascia compressive stress was calculated for each combination. The results are shown in Table 2.

Table 2: FE Model Results

Span (feet)	Case	Delta-T (°F)	Support Displacement (inches)	Fascia Axial Compressive Stress (ksi)	Fascia Axial + Bending Compressive Stress (ksi)
15	1	40	0.5	6.26	7.60
	2	40	0.0	4.56	5.45
	3	0	0.5	1.77	2.2
10	4	40	0.5	6.55	8.57
	5	40	0.0	3.56	4.58
	6	0	0.5	3.03	4.07
5	7	40	0.5	7.28	11.74
	8	40	0.0	1.67	2.52
	9	0	0.5	5.6	8.97

Plotted out, this data shows an interesting phenomenon. Compressive stress due to thermal gradient decreases with span while it increases with support deflection. Combined, they are relatively independent of span. This illustrates why the cause of surface waves is not always obvious and expert valuation is needed to correctly remedy the situation.

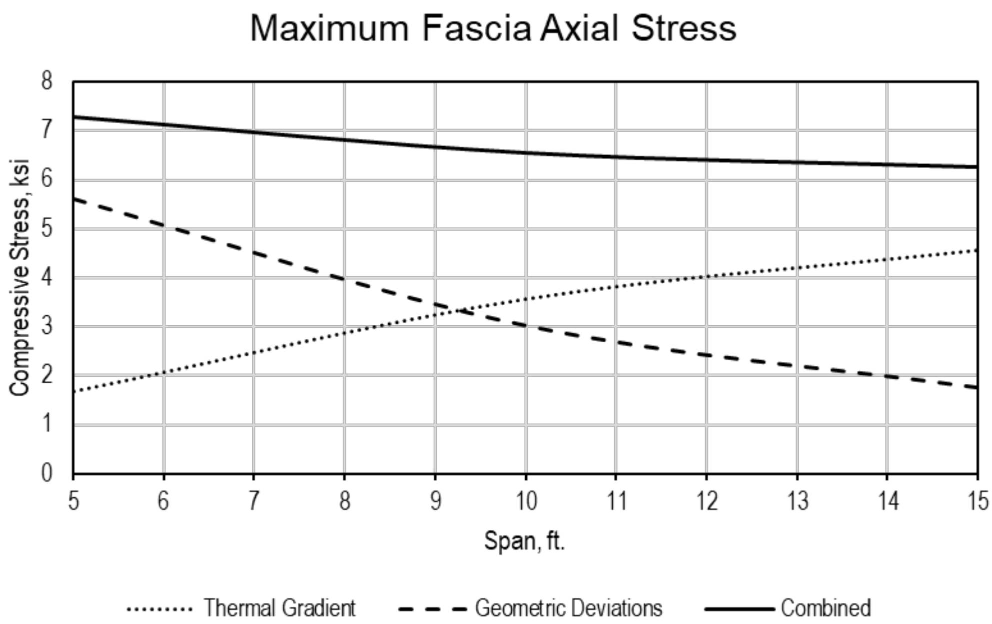

Figure 2: Effect of Span on Stress Caused by Thermal Gradient and Framing Misalignment

BEST PRACTICES

Every manufacturer has their own requirements and recommendations on this subject, and they will always govern on a given project over this paper. However, MCA recognizes that designers and installers need general guidance prior to product selection to avoid the issues discussed here from the beginning. The experience of MCA members has led to the development of best practices, which are presented here for both design and installation phase activities.

Design Phase

Designers should keep in mind that any IMP exterior wall will be subjected to thermal gradients and that mitigation, not elimination, is key. The most important mitigation factors are color choice, skin profile and gauge selection as follows:

- For true-flat panels, use 22-gauge minimum skins and panel widths 36″ or less. Choose colors with SR values of 0.8 or higher. Remember that micro rib profiles will generally have 1/8″ or less relief and should be treated as true-flat panels. Use embossed fascia skins to mitigate telegraphing of low-amplitude waves with minimal aesthetic impact.
- For near-flat panels, use 24-gauge minimum skins and panel widths 42″ or less. Choose colors with SR values of 0.7 or higher. Using embossed fascia skins mitigates telegraphing of minor waves with minimal aesthetic impact.
- For Profiled panels, use 26-gauge minimum skins with an SR of 0.5 or higher. These panels are less subject to problems due to thermal gradients and have fewer restrictions in this sense. However, they

can be less forgiving of geometric deviations, and it is important to avoid using much shorter spans than those needed for strength to avoid binding.

For all panel types:

- Specify the framing tolerances provided here and require pre-installation framing inspections to ensure they are met.
- Use framing systems with built-in adjustability after assembly.
- Carefully adhere to manufacturer span and color limitations, not just due to code-mandated loads but also in consideration of thermal gradients as this is not often addressed in standard issue load tables.

Installation Phase

Field practices and related quality control is paramount for good product performance, especially for mitigation of the geometric deviations that happen in a real-world environment. MCA offers the following best practices:

- Store panels in strict compliance with panel manufacturer recommendations. Keep them covered and staged away from high-traffic areas.
- Prior to installation, check framing tolerances given above using high-quality tools such as laser guides. Keep these tools in calibration and protect them when not in use.
- When horizontal Z-girts are used, Use temporary blocking to stabilize the girts near mid-span and keep in place until installation is complete.
- Installers should handle all panels with extreme care. Pick up panels longer than 25 feet using multi-point lifts and utilize vacuum lifts whenever possible.
- Prevent fastener overdrive through strict quality control and monitoring of operators as installation progresses. Calibrate installation processes at the beginning of each day of installations, especially when there is crew turnover.

SUMMARY

Insulated Metal Panels have been proven to deliver excellent results in structural and thermal performance. However, being made of composite materials, they require additional considerations compared to non-composites. This includes resistance to induced compressive loads caused by thermal gradients and geometrical deviations, which may result in unsightly surface waves weeks or months after installation. Although the science behind this phenomenon is complex, designers and installers alike can effectively mitigate this risk by carefully following these best practices and criteria.

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MCA's marketing and technical activities create awareness of metal, its applications, and its benefits. MCA also works to eliminate barriers to metal's use in construction by supporting product performance testing, initiating research, and monitoring and responding to codes and regulations that affect metal.

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