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Visual Acceptance Parameters for Insulated Metal Panels (IMP) and Panel Systems

Overview

Though building and fire codes primarily address structural and fire performance of Insulated Metal Panel (IMP) cladding materials, other performance indicators are often used in the construction industry to define an “acceptable” application. The primary indicator discussed herein is the visual appearance of the cladding system. Visual appearance is generally based on architectural requirements and there are no specific criteria within the code that quantify an “acceptable” installation.

This document outlines the general practices of the IMP manufacturer members of the Metal Construction Association (MCA) in determining visual acceptance parameters of their products. This document is only intended as general guidance and does not supersede any documentation issued by the manufacturer. If this guide conflicts in any way with the warranties, contract terms, drawings (including all notes), installation instructions, CSI guide specifications and/or similar documents, those documents shall overrule information provided here.

Background

Many exterior cladding performance requirements relating to public safety and basic building performance are defined within the International Building and Fire Codes. Fire performance, structural integrity, and allowable deflection limits are specifically defined however, other criteria such as flatness and localized issues, such as denting, “oil-canning” and colorfastness, are not specifically addressed within the codes. The performance requirements for these items may only be defined in the architectural specification and oftentimes, they are not provided at all. Seldom are they an issue unless there is a visual problem with the finished building. The intent of this document is to highlight common industry acceptance standards for perceived aesthetic concerns in IMP installations.

Discussion

The International Building and Fire Codes identify the minimum performance standards required for construction however, these codes do not address every facet of construction and variations may still exist in the final product. Requirements for these variations or anomalies are often contained in the specifications. The primary areas of concern for this document are all in the area of visual appearance. These visual appearance items include the following:

- **Manufactured Flatness**
- **Installation Flatness**
- **Thermal Bow**
- **Paint Finish Variations**

There are most definitely a different set of guidelines for Manufactured Flatness and Installed Flatness. The panel manufacturer cannot typically oversee installation; however, they can define the quality of the base IMP material that is delivered to the field.

Manufacturing Flatness

Flatness deviation of IMP is for the most part due to some surface irregularities inherent in the facing material. These issues affecting flatness can often be traced back to the materials used in manufacturing or to installation issues affecting thermal expansion and contraction. Many designers seek large IMP sizes as wide and long as possible combined with highly reflective paint finishes such as mica and metallic. When implementing this approach, it is important for designers to understand that the visual impact of the standard flatness tolerance of IMPs might lead to unexpected results compared to 1/8" to 3/16" metal plate panel systems or post-fabricated metal composite material (MCM) systems. Considering that IMPs have built-in insulation and are far easier to install than these other systems, they represent a cost-effective option when a perfectly flat appearance is not critical.

The IMP manufacturing process focuses on reducing the degree of irregularities, however issues of flatness and surface irregularities can be evident to some degree in the finished product. Wider and/or longer metal panels, darker colors, and metallic colors will be more susceptible to these conditions. In general, the greater the surface area and the more reflective the finish, the higher the risk becomes for flatness and visual imperfection detection. Lighting and angle of viewing play a crucial factor and the industry acceptable standards will be addressed later in this paper. Certain lighting conditions will tend to magnify the visual aspects of even very minor surface irregularities. These same panels may appear to be perfectly flat at different times of the day or under lower lighting conditions.



Same panels shown under the same lighting conditions from different angles
Dark colored, smooth highly reflective surface magnifies minor inconsistencies
(This condition would not constitute a case for rejection)

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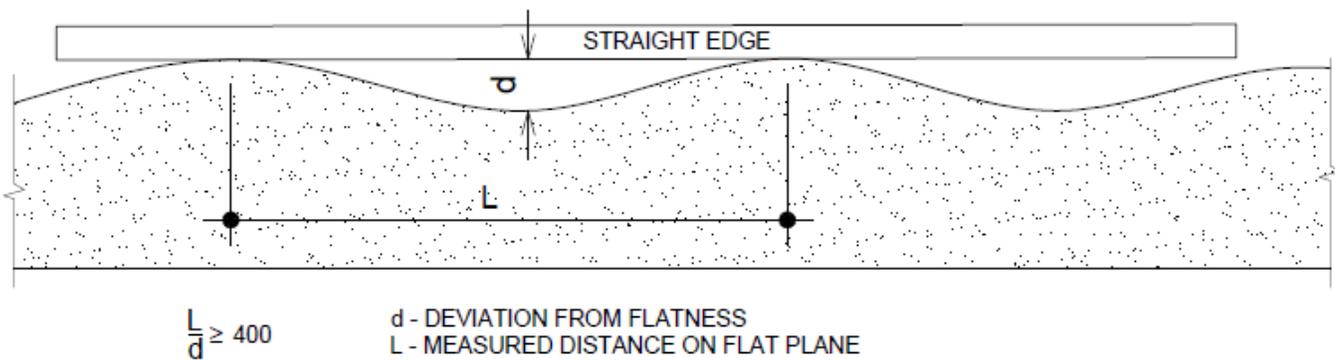
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Many IMPs contain minor face profiling such as planking or striations which all serve to minimize the visual impact of surface irregularity while providing a visually appealing aesthetic. However many architectural IMPs have no such profiling, being flat across the entire face width to meet design requirements. As such, IMPs without profiling are more expensive to produce because they typically use heavier gauge exterior facings and higher-density foams to minimize visual irregularity. Flat Panels may be embossed to prevent surface irregularities. Embossing will be discussed more later in this report. It is important for designers to use the correct product for the application at hand and keep aesthetic expectations in line with the capabilities of the product they are specifying, especially during value-engineering cycles.

In North America, there are currently no national or code standards written for IMP flatness and general appearance. Manufacturers normally establish their own standards of acceptance for these issues. Furthermore, these standards are rarely published in promotional literature for the product nor are they commonly written into project specifications.

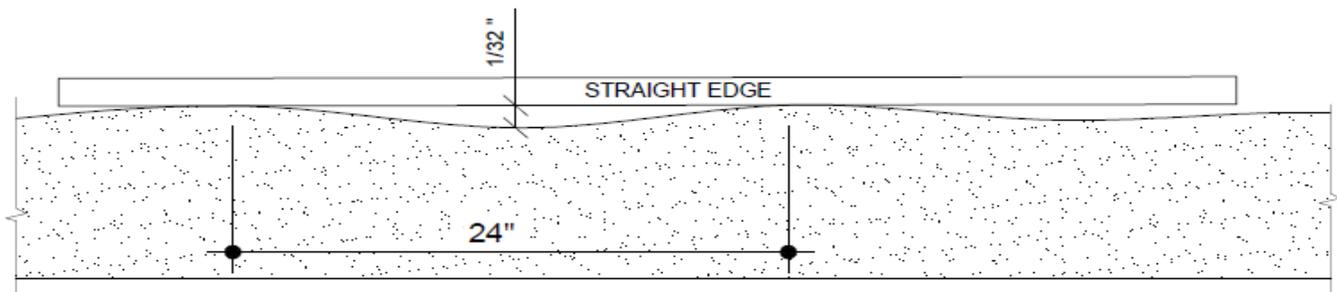
Typical industry standards call for the IMP flatness to be measured with a straight edge and taper gauge. (Figure D.1) The results of these measurements are expressed as a ratio of deformation over a length. A limit of acceptance is established using this ratio. A generally accepted ratio in the industry for industrial and commercial projects that are not subject to special aesthetic requirements is $L/400$ with an absolute limit of $1/16''$ over the width of the panel. For architectural projects, however, this limit may not be adequate. Consult the manufacturer’s product documentation for projects that require flatter panels.

FIGURE D.1
LONGITUDINAL FLATNESS



Example 1: A straight edge laid across a panel section with the taper gauge slid underneath reveals a deformation of $1/32''$ ($0.03125''$) between “peaks” that are $24''$ apart. That degree of panel flatness would then be expressed as $L/768$ ($24/0.03125 = 768$). In this case, the manufacturer may qualify that deformation not exceeding $L/400$. The panel would be considered acceptable and not a cause for rejection.

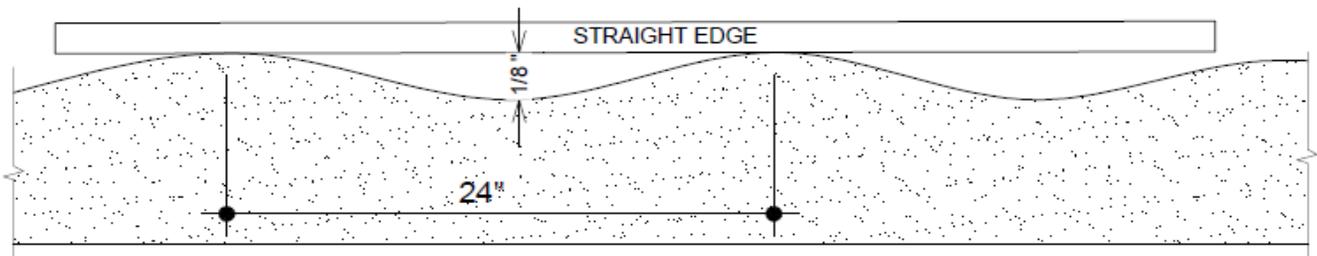
EXAMPLE 1
LONGITUDINAL FLATNESS - PASS



$$24/0.01325 = 768 > 400 \rightarrow \text{Pass}$$

Example 2: In another case, a straight edge laid across a panel section with the taper gauge slid underneath could reveal a deformation of 1/8" (0.125") between "peaks" that are 24" apart. That degree of panel flatness would then be expressed as L/192 (24/0.125 = 192). In this case, the deformation does exceed L/400 and would be considered a cause for rejection.

EXAMPLE 2
LONGITUDINAL FLATNESS - FAIL



$$24/0.125 = 192 < 400 \rightarrow \text{Fail}$$

This same procedure may be used to measure both convex and concave bow across the panel width (Figure D.2 and D.3)

FIGURE D.2
CONVEX BOW

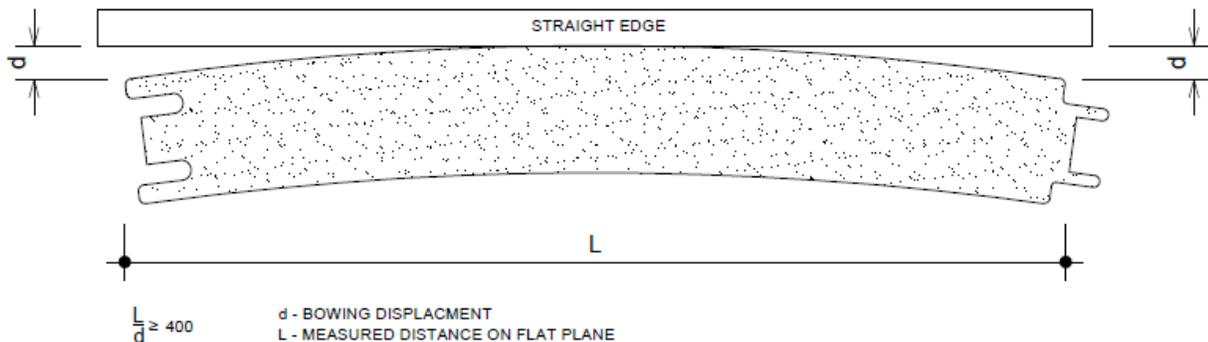
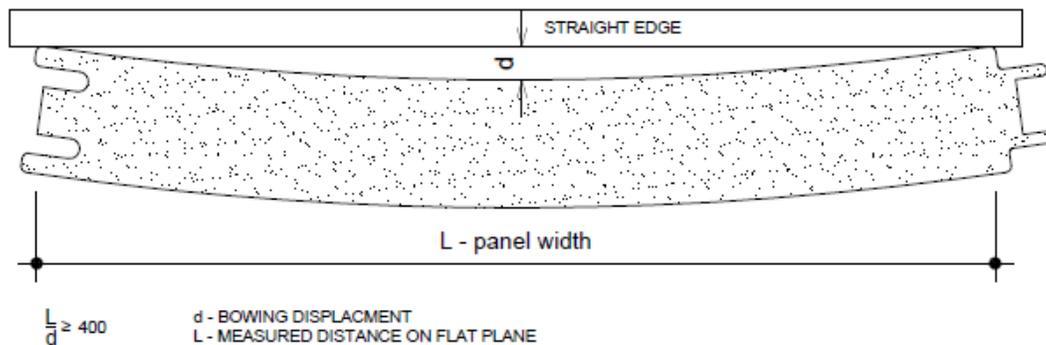


FIGURE D.3
CONCAVE BOW



This flatness check is typically performed on the product prior to installation, after the panels are unpacked and allowed to come to ambient temperature. When planking or striations are present, it is important to perform this check such that there is consistency between the ends of the bar and the point where the measurement is taken. In other words, if one end of the bar is at a high point in the profile, then the other end of the bar and the point at which the “d” dimension is taken should be at high points as well.

Another common method of quantifying metal flatness is a system known as I-Units. The I-Unit is a relationship of wave interval and height of wave off dead flat. A small numerical I-Unit corresponds to flatter metal surface with a larger numerical I-Unit corresponding to a metal surface exhibiting bowing. A typical I-Unit chart is shown on the following page. According to the information provided by most domestic steel mills, “acceptable” commercial steel flatness is considered as 42 I-Units or less. Above 42 I-Units is out-of-tolerance. Flatness critical steel applications require 20 I-Units or less. Tension leveling (a post process of stretching coil to a condition slightly beyond its yield point) is one process that can be used to improve flatness.

Considering the previous example, the L/400 ratio would be equated to a steel flatness of about 2 I-Units. An IMP flatness of 2 I-Units is a threshold that can still be quite visible in many cases. Manufacturers of architectural and commercial IMP often struggle to produce panels flatter than 2 I-Units, hence expectations of flatter, or “dead flat” IMP should be deemed as unreasonable unless the specific manufacturer can assure or guarantee that level of quality prior to execution of the contract.

I-UNITS

I-Units are found by measuring the height of the off flat condition and the interval between each peak.
Find the I-Unit on the chart below.

Peak to Peak (in)	WAVE HEIGHT OF THE OFF FLAT CONDITION (INCHES) MEASURED WITH A STEP GAUGE													
	1/32	1/16	3/32	1/8	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1
	0.031	0.063	0.094	0.125	0.188	0.250	0.313	0.375	0.438	0.500	0.625	0.750	0.875	1.000
5	9.6	38.5	86.7	154.1	346.6	616.2	962.9	1386.5	1887.2	2464.9	3851.4	5546.0	7548.8	9859.6
6	6.7	26.7	60.2	107.0	240.7	427.9	668.6	962.9	1310.5	1711.7	2674.6	3851.4	5242.2	6846.9
7	4.9	19.7	44.2	78.6	176.9	314.4	491.3	707.4	962.9	1257.6	1965.0	2829.6	3851.4	5030.4
8	3.8	15.0	33.9	60.2	135.4	240.7	376.1	541.6	737.2	962.9	1504.5	2166.4	2948.7	3851.4
9	3.0	11.9	26.7	47.5	107.0	190.2	297.2	427.9	582.5	760.8	1188.7	1711.7	2329.9	3043.1
10	2.4	9.6	21.7	38.5	86.7	154.1	240.7	346.6	471.8	616.2	962.9	1386.5	1887.2	2464.9
11	2.0	8.0	17.9	31.8	71.6	127.3	198.9	286.5	389.9	509.3	795.7	1145.9	1559.7	2037.1
12	1.7	6.7	15.0	26.7	60.2	107.0	167.2	240.7	327.6	427.9	668.6	962.9	1310.5	1711.7
13	1.4	5.7	12.8	22.8	51.3	91.2	142.4	205.1	279.2	364.6	569.7	820.4	1116.7	1458.5
14	1.2	4.9	11.1	19.7	44.2	78.6	122.8	176.9	240.7	314.4	491.3	707.4	962.9	1257.6
15	1.1	4.3	9.6	17.1	38.5	68.5	107.0	154.1	209.7	273.9	427.9	616.2	838.8	1095.5
16	0.9	3.8	8.5	15.0	33.9	60.2	94.0	135.4	184.3	240.7	376.1	541.6	737.2	962.9
17	0.8	3.3	7.5	13.3	30.0	53.3	83.3	119.9	163.3	213.2	333.2	479.8	653.0	852.9
18	0.7	3.0	6.7	11.9	26.7	47.5	74.3	107.0	145.6	190.2	297.2	427.9	582.5	760.8
19	0.7	2.7	6.0	10.7	24.0	42.7	66.7	96.0	130.7	170.7	266.7	384.1	522.8	682.8
20	0.6	2.4	5.4	9.6	21.7	38.5	60.2	86.7	117.9	154.1	240.7	346.6	471.8	616.2
21	0.5	2.2	4.9	8.7	19.7	34.9	54.6	78.6	107.0	139.7	218.3	314.4	427.9	558.9
22	0.5	2.0	4.5	8.0	17.9	31.8	49.7	71.6	97.5	127.3	198.9	286.5	389.9	509.3
23	0.5	1.8	4.1	7.3	16.4	29.1	45.5	65.5	89.2	116.5	182.0	262.1	356.7	466.0
24	0.4	1.7	3.8	6.7	15.0	26.7	41.8	60.2	81.9	107.0	167.2	240.7	327.6	427.9
28	0.3	1.2	2.8	4.9	11.1	19.7	30.7	44.2	60.2	78.6	122.8	176.9	240.7	314.4
32	0.2	0.9	2.1	3.8	8.5	15.0	23.5	33.9	46.1	60.2	94.0	135.4	184.3	240.7
36	0.2	0.7	1.7	3.0	6.7	11.9	18.6	26.7	36.4	47.5	74.3	107.0	145.6	190.2
40	0.2	0.6	1.4	2.4	5.4	9.6	15.0	21.7	29.5	38.5	60.2	86.7	117.9	154.1
44	0.1	0.5	1.1	2.0	4.5	8.0	12.4	17.9	24.4	31.8	49.7	71.6	97.5	127.3
48	0.1	0.4	0.9	1.7	3.8	6.7	10.4	15.0	20.5	26.7	41.8	60.2	81.9	107.0
54	0.1	0.3	0.7	1.3	3.0	5.3	8.3	11.9	16.2	21.1	33.0	47.5	64.7	84.5
60	0.1	0.3	0.6	1.1	2.4	4.3	6.7	9.6	13.1	17.1	26.7	38.5	52.4	68.5
66	0.1	0.2	0.5	0.9	2.0	3.5	5.5	8.0	10.8	14.1	22.1	31.8	43.3	56.6
72	0.0	0.2	0.4	0.7	1.7	3.0	4.6	6.7	9.1	11.9	18.6	26.7	36.4	47.5
78	0.0	0.2	0.4	0.6	1.4	2.5	4.0	5.7	7.8	10.1	15.8	22.8	31.0	40.5
84	0.0	0.1	0.3	0.5	1.2	2.2	3.4	4.9	6.7	8.7	13.6	19.7	26.7	34.9

■ Stretcher Level 5 I-Units or less
 ■ Flatness Critical 20 I-Units or less
 ■ Commercial Flatness 42 I-Units or less
 ■ Out of Tolerance 42 I-Units or more

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Embossed Metal

The use of an embossed metal facing for an IMP will greatly reduce the visual perception of other common surface irregularities. Embossing breaks up intense light reflection off metal surfaces, providing a softer, more even light diffusion. Non-directional or directional stucco embossing is a mild texturing of the metal that will control visual appearance of the IMP by (1) rigidizing the metal surface, and (2) diffusing the light reflection. At normal building viewing distances of 50 feet or more the embossing will not be visible to the naked eye. Surface irregularities on the other hand may be visible for hundreds of yards under certain lighting conditions when embossing is not incorporated into the exterior facing material. An example of this effect can be seen in the photos below (courtesy of Rigidized Metals Corporation). The flat metal sheet on the right has 50% *MORE* surface deformation than the sheet on the left. The smooth sheet on the left is, in reality, much flatter than the sheet on the right.



Photo #1: Flat smooth metal, no embossing

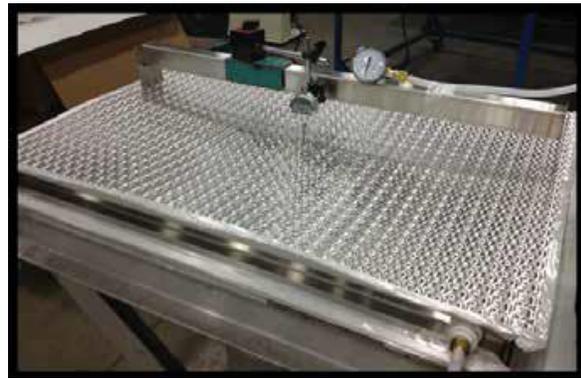


Photo #2: Deeply embossed metal

Embossing that is typically used on commercial IMP is a shallow milder pattern that is depicted in Photo #3.



Photo #3: Typical embossing for IMPs, viewing distance 18 inches.

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Photo #4 below shows two different IMP samples, both with Valspar Silversmith Metallic paint finishes. The panel on the left is embossed, while the panel on the right is smooth. Note the mild embossing of the surface is barely visible to the naked eye at the viewing distance of 20 feet. Even at a viewing distance of 10 feet as referenced by AAMA 2605 (Reference the Determining Visual Imperfections Section), the embossing effect is quite muted.



Photo #4:

Viewing Distance – 10 feet

Viewing Distance – 20 feet

Embossed IMP (left) vs. Smooth IMP (right), Metallic colors, for both photos

Installation Flatness

Installation techniques and anchorage systems may also impact the visual acceptance of the IMP both immediately after installation and after exposure to temperature cycling. The following installation considerations may add to visual surface irregularities on the project:

- Misalignment of the Support System – Structural supports including structural steel, steel studs, subgirts, and concrete embedded anchorage points (typically angles and plates) must be fabricated and installed within AISC or AISI allowable tolerances as applicable. Additional support framing tolerances must be held as well. These tolerances are derived from practice, vary between manufacturers and sometimes between products within the same manufacturer. **It is very important to consult the manufacturer’s installation instructions for these tolerances. Actual field values must be checked against these requirements prior to installation of the IMP.**

Even though a given wall may meet the manufacturer’s published tolerances, the resulting connection points may still not be sufficient for an IMP that has strict flatness requirements. Traditional panel shims may be used to adjust the anchorage points, however there are certain instances where the support system is so far out of alignment that addition of shims is not a reasonable solution. These conditions may create a non-planer or contoured bearing surface. Facing stresses introduced to the IMP while conforming to this surface can contribute to visual imperfections.

- Panel Orientation – Horizontal IMPs typically require maintaining more stringent tolerances to ensure a positive, slightly convex outer face. Care should be consistently taken to assure the structural elements are plumb and do not camber or sweep inboard of the theoretical wall plane.
- Over-Driving of Anchorage Fasteners – This operation may create stresses in the panel and provide a “reading line” at the fastener level.
- No Allowance for Longitudinal Expansion - Surface temperatures of any exterior building element can vary greatly over time and IMPs are no exception. This is because the radiant heat from the sun can elevate the temperature of the exterior facing far above the ambient temperature, which can be even more evident in darker colored panels. This temperature variation and cycle depend on many variables including, project location and orientation, cloud cover, panel inclination, surface finish or color, and system thermal insulation characteristics.

As the exterior facing of an IMP heats up, it will expand just like every other material. Meanwhile, the interior facing temperature remains relatively constant and does not expand significantly. For the rare single span installation, this is generally not a problem because the IMP will simply bow outward temporarily and return to its original shape upon cooling. This is called thermal bow and no significant thermal stress is introduced in this scenario. However, for multi-span installations, this movement is prevented at the interior supports and induces compressive stress in the exterior facing. Usually, this effect is temporary and relieves when the exterior facing cools because the stresses are not high enough to permanently deform the steel. However, if the stress gets high enough, it will buckle the outer panel face. Direct sunlight may also accentuate the effect, particularly when bright colors are used.

Waviness may also be amplified by uneven fastener restraint along the panel. Such restraint is common on concealed fastener systems having fasteners along one edge and an interlock along the other. Waviness caused by thermal forces can appear and disappear as the sun moves causing the angle of light to change around the building.

- Movement of Primary Structure – Excessive differential deflection, racking, drift, or settlement within the primary structure can cause noticeable waviness within panel flat areas.
- Environmental Influences – As mentioned above, temperature changes may have a significant temporary impact on panel flatness. Panel color and reflectivity may impact the overall temperature of the exterior face. This increased temperature may cause the exterior facing material to expand at a greater rate than the interior facing. This effect is temporary and the panel will go back to flat as the face/liner equalize in temperature. Based on the insulating value of the IMP, the time to reach relative equilibrium can vary.
- Handling – Transporting individual panels in the flat direction or twisting of panels can induce a wavy appearance to a previously flat panel. Twisting can occur if the panel is lifted or removed from a bundle by one corner of a panel rather than evenly lifted at both ends.
- Fabrication Operations – Metal forming induced variances, center buckle or edge wave, may result in surface irregularities and should be addressed with the manufacturer during fabrication and prior to installation.

Other Surface Imperfections

Other types of surface imperfections may be seen in IMP materials that use a metal facing other than steel. Unpainted metals such as stainless steel may have slightly different shading from panel to panel due to the organic nature of the base metal. Routine cleaning and maintenance should be employed to remove any fingerprinting, oil marks or grease marks from the surface.

For highly visible applications, exposed bare Galvalume or galvanized steel, with a clear coating, can show differences in the spangle of the base metal surface.

Painted Finishes

While not specifically addressed in the building codes, finish criteria are often defined in detail in the project specifications. Performance characteristics including, but not limited to, hardness, impact resistance, wear resistance, humidity and corrosion resistance are defined by various ASTM and NCCA standards.

Color fastness is measured under laboratory conditions and compares a sample of the project panel to a production control sample using one of several standard test methods. CIELAB and the Hunter L, a, b scale are often defined as typical standards to measure the color (red, yellow, blue, green) and the lightness/darkness of the panel. The control sample is defined as the origin of a 3-dimensional grid and the panel measurement defines the relative position the project panel. The distance between these points is measured in units called “Delta E” (dE).

Lot-to-lot variation depends on the finish type. Flake-containing formulations are more variable than solid finishes and therefore materials from different paint lots should not be mixed on a single building elevation

Grain Directionality (flake orientation) within metallic- or mica-based coatings is often the source for unappealing visual appearance when using coil coated facing material. Though the nature of the metallic elements suspended within organic coatings is not 100% controllable, current application technology has vastly improved consistency. Still, proper documentation and control by the finish applicator and the continuance of this control throughout the design, fabrication, and installation of the IMP system is a must. Designers and architects must be aware that module control and limitation is critical when dealing with metallic-based coatings in order that these critical control techniques can be employed.

Typical finish warranties allow as much as 5 dE units of color change over the life of the warranty. Many factors affect the scope and term of the warranty including color choice, application type (coil coating vs. spray application), geography, and type of project finish. Further information on color fastness and finish performance should be obtained from the specific project panel supplier as there is a wide range of finishes and performances.

Field painted low gloss dark or “hot” color accent bands are generally not recommended for IMP systems. This treatment may cause the panel facing to expand in a non-uniform manner in a concentrated area resulting in excessive facing stress. This stress is naturally relieved either through facing distortion or blistering. The blisters can be exaggerated at higher altitudes and on heat load elevations (typically south and west facing). In order to minimize the potential for any cosmetic

deficiencies where a horizontal accent strip is desired, it is reasonable to incorporate one of the following methods:

1. Horizontally install colored accent panels with stack joints in lieu of field painting an accent band (industry standard detail).
2. Make a continuous relief cut through the exterior facing and trim the bottom of accent band location after building panels are in place and prior to field painting.
3. Install factory formed accent trim strip after building panels are in place.

Acceptable Panel Deflection

When viewing IMP systems, there is an acceptable amount of deflection that is allowed by the building code. Deflection resulting from wind load is allowable and specifically defined within the International Building Code (IBC). Table 1604.3 shows the deflection limits of various building components. The allowable deflection generally used for IMP is $L/180$, where “L” is the length of panel in any direction between supports.

Determining Visual Imperfections

Several different visual imperfections have been discussed within this document. At issue though is how to determine whether the status of the IMP is acceptable once installed. Three methods are currently being used in the field to make this determination and while not specifically directed at IMP systems, these are the only methods that have been generally accepted if the question of visual imperfections arises on a project.

- AAMA 2605 Section 5.2 - Voluntary Specification, Performance Requirements and Test Procedures for Superior Performing Organic Coatings on Aluminum Extrusions and Panels.
- Insulated Glass Manufacturers Association’s insulating glass units (IGU) Guide

Both describe a visual inspection made when standing 10 ft from the surface at a 90° angle. The inspection of the project typically is made under natural exterior lighting conditions. Imperfections are identified when viewing the cladding perpendicular to the plane of the building and should be indicated to the installer for possible remediation or replacement. The MCA recommends the following similar procedure but suggests a 20’ viewing distance for typical installations:

- Place panel in position of intended use, under good light, and view at 90 degrees from the closest accessible as-installed distance or 20 feet, whichever is greater. If imperfection is not noticeably visible, the panel is deemed acceptable.

The Insulated Metal Panel Council of the MCA has agreed that the “ $L/400$ ” standard be established as quantitative means of determining an acceptance limit for flatness of metal-faced insulated foam core panels unless the manufacturer’s criteria provide a different flatness requirement. This standard can be implemented using a flat bar of any desired length so long as the same ratio is employed. (Refer to examples under “Manufactured Flatness”) Although this check is performed on the panel prior to installation, a conforming panel installed on a structure within tolerance using proper fastening techniques should regularly result in a product that will meet these visual inspection procedures.

MCA Comments

MCA has adopted these standards and definitions of evaluation as acceptable industry-wide guidelines for visual acceptance parameters specifically for IMP and IMP systems. Following the industry standards identified within this bulletin, the architect can be reasonably assured of a level of panel quality and the expected level of panel performance. Variations in such areas as workmanship, field modifications to address unplanned variation, and site specific requirements cannot be addressed in a single document. The experience, installation practices, and quality control program of a specific manufacturer and installer must be considered as a primary influence on installation quality.

Summary

When selecting IMPs for exterior cladding, the designer should consider the following parameters as those which will serve to reduce the degree of visual surface irregularities:

- Narrower panels
- Shorter panel lengths
- Heavier gauge exterior facing
- Lighter colors
- Non-metallic or low reflective colors and finishes
- Embossed metal
- Selection of face profiling

High Risk Parameters which lead to more visual surface irregularity in IMPs:

- Wider panels
- Longer lengths
- Lighter “thinner” gauge exterior facing
- Darker colors
- Metallic or highly reflective colors and finishes
- Smooth un-embossed metal
- Flat profile (no face profiling)

The designer should also be aware that combining too many of the higher risk parameters into the design can result in dissatisfaction of the building owner with little or no recourse of corrective action.

Since many uncontrollable factors are causes for surface irregularities, no manufacturer can realistically assure the total elimination of the phenomenon. With careful attention to the production and selection of material, to the panel design and to installation practice, surface irregularities can be minimized.

Founded in 1983, the Metal Construction Association brings together the diverse metal construction industry for the purpose of expanding the use of all metals used in construction. MCA promotes the benefits of metal in construction through:

- Technical guidance

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