PROCEEDINGS

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Understanding Low-Sloped (Hydrostatic) Standing-Seam Metal Roofs

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Abstract

This presentation will address performance issues associated with low-slope (hydrostatic) standing seam metal roofs (SSMRs) and the industry standards related to these roofs. Examples will be provided of new insights into their failures, and standards applying to them will be clarified. SSMRs are increasingly being used in applications once reserved for built-up and single-ply roofing, and many of these roofs are blowing off, leaking, and failing prematurely. The objectives of this presentation are to:

- Explain the differences between hydrostatic and hydrokinetic SSMRs
- Explain the performance requirements of hydrostatic SSMRs
- Explain the mechanisms of failures of hydrostatic SSMRs
- Provide the attendee an understanding of the industry standards and the nuances in the standards for hydrostatic and hydrokinetic SSMRs
- Provide the reader guidelines for specifying and constructing hydrostatic SSMRs that perform

This presentation brings together the unique collaboration of a consultant/engineer and manufacturer who collectively have designed countless SSMRs, as well as investigated hundreds of hydrostatic SSMR failures. This collaboration brings together manufacturing, field performance, testing, and design experiences to address the serious performance issues and design challenges associated with hydrostatic SSMRs.

Speakers

Stephen L. Patterson, RRC, PE — Roof Technical Services, Inc.

STEPHEN L. PATTERSON is a licensed engineer and registered roof consultant with 40 years of experience in the roofing industry, including work in manufacturing, as a contractor, and as a roof consultant. Patterson founded Roof Technical Services, Inc., an architectural and engineering firm specializing in roofing and waterproofing, in 1983. He coauthored *Roof Design and Practice*, a roof design textbook published by Prentice Hall in 2001, as well as two design monographs published by the RCI Foundation: *Roof Drainage* and *Wind Pressures on Low-Sloped Roofs*. Patterson has consulted on some of the most complex low-sloped metal roofs in the Southwest, including the American Airlines Wide-Body Hanger at Alliance Airport and Terminal D at DFW.

Charles L. Smith Jr. — McElroy Metal/Architectural Building Components

CHARLIE SMITH founded Architectural Building Components in 1989, when he purchased the equipment of a small Houston, Texas-based metal roofing manufacturing business. Over the next 23 years, the company grew into an industry-leading metal roofing and wall system solution provider specializing in the use of metal to recover existing low-slope roofs. In 2012, Architectural Building Components became a part of McElroy Metal, which enabled Charlie to focus on educational and product development efforts to help the roofing industry design creative solutions with metal. He recently cowrote the new RCI metal roofing course with Brian Gardiner. He is a member of NRCA and RCI.

Understanding Low-Sloped (Hydrostatic) Standing-Seam Metal Roofs

OVERVIEW

There are serious performance problems with and a general lack of understanding of the design and construction standards associated with low-sloped standing-seam metal roofs (SSMRs). Historically, SSMRs were used for steep-sloped (hydrokinetic) roof applications, and these roofs performed extremely well. Today, SSMRs are commonly used in low-slope (hydrostatic) applications with widely varying results. These roofs often leak, blow off, and fail prematurely.

The industry standards for SSMRs used in low-sloped, hydrostatic applications are generally misunderstood. Surprisingly, many of the SSMR systems that are commonly specified for hydrostatic roof applications do not meet the basic industry standards for hydrostatic roofs. The objectives of this paper are to provide an overview of low-sloped SSMR systems, a thorough discussion of the problems associated with them, an understanding of the industry standards for these roofs, and guidelines for specifying and constructing low-sloped SSMRs that will perform.

INTRODUCTION

Metal roofing has a long history. Copper and lead roofing have been successfully used for centuries in a variety of styles. Copper roofing was used on the New York City Hall in 1763 and on the Maryland State House in 1774.[1] Copper roofing has had a long and successful history and is one reason metal roofing is considered to be one of the best roofing systems available. Double-lock standing-seam copper roofs were the standard for many years. Historically, these roofs were formed into pans from sheets of metal, and the side-laps were formed into vertical or standing-seam seams; hence, the name standing-seam. These roof panels were formed from standard sheet metal panels that varied in size but were commonly 3 by 10 ft. in size. The end laps were lapped and hemmed, and the panels were attached to the structure (normally wood) with cleats.

Historically, SSMRs were used for steep roofing situations, generally referred to as hydrokinetic roofing applications where water sheds off quickly enough to prevent penetration through the roof system when subjected to low-sloped, hydrostatic roofing applications. Low-sloped metal roofs were typically flat-seam roofs—sometimes referred to as flat-lock seam roofs. Historically, these roofs were formed into relatively small panels with hemmed edges that were interlocked into place and soldered to provide the waterproofing required to prevent water penetrations from hydrostatic water pressure common to low-sloped roofs. *Figure 1* is an excerpt from *Roof Design and Practice* showing typical standing-seam and flat-seam metal roof details.

Tin plating and galvanization of steel roofs were important innovations in metal roofing that lead to a reduction in the cost of metal roofs and increased the popularity of metal roofing. SSMRs were first adapted to low-sloped applications when sealants were introduced within the seam to provide waterproofing to prevent water from penetrating the system when subjected to hydrostatic water pressure associated with low-

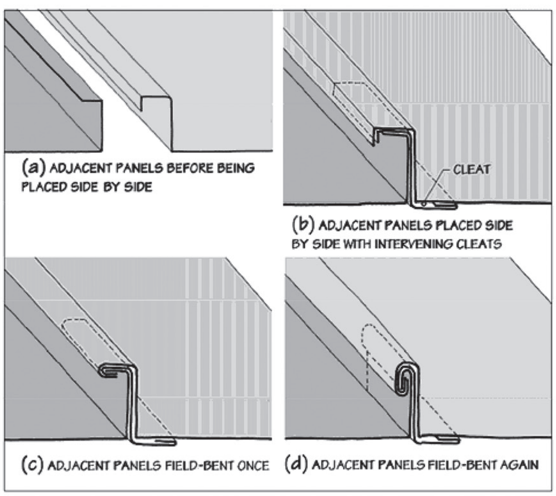
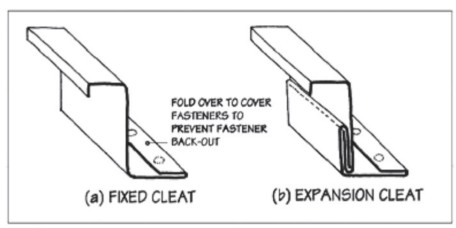
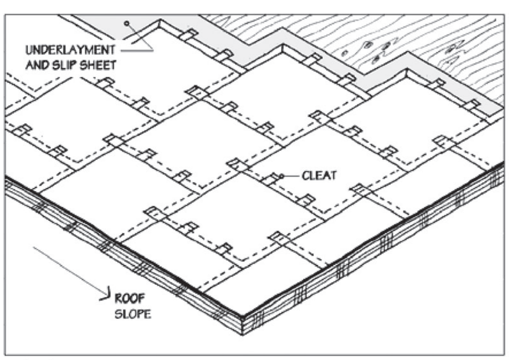


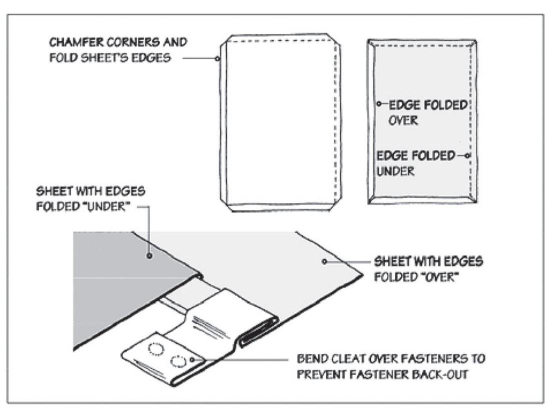
Figure 1 – Excerpt from **Roof Design and Practice.**



14.9 *Fixed and expansion cleats used with double-lock standing seams.*



14.12 *Sheet layout with flat seams.*



14.13 *Details of flat seams.*

sloped applications. Metal building and metal building component manufacturers began promoting and manufacturing standing-seam roofs specifically for low-sloped applications in the 1960s. Butler introduced the trapezoidal SSMR in 1969, which led to the common use of SSMRs in low-sloped roof applications. Today, there are a variety of low-sloped SSMRs, and the purpose of this paper is to discuss the issues related to low-slope SSMRs.

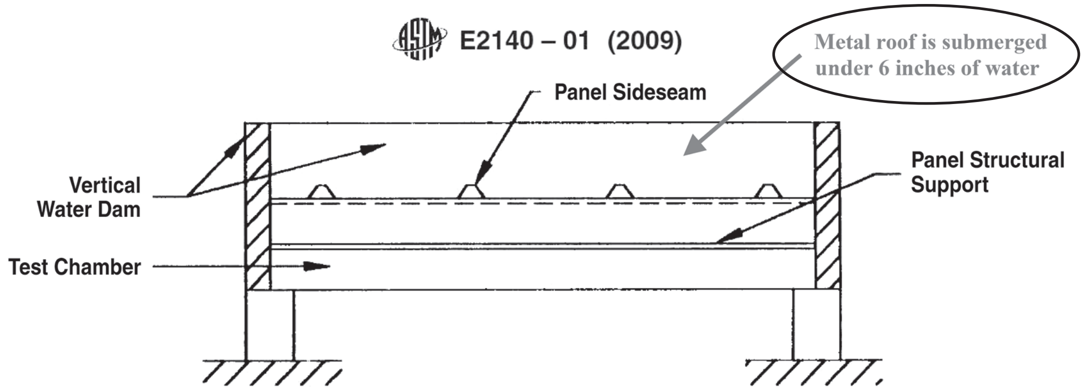


Figure 2 – Excerpt from ASTM E2140 showing test apparatus.

Standards for Low-Sloped Metal Roofs

There are two general categories of roof systems: hydrokinetic and hydrostatic. Hydrokinetic roof systems are water-shedding systems that rely upon water running off quickly enough to prevent leaks. Hydrokinetic roofs are also referred to as steep roofs. Generally, hydrokinetic roofs are considered to be roofs with slopes of 3:12 or more. Hydrokinetic standing-seam roofs include a wide variety of SSMRs, all snap-together architectural panels, snap-together trapezoidal metal panels, and mechanically seamed panels. The category for low-sloped roofing is "hydrostatic" roofs, which are roofs that must be waterproof and must be able to withstand hydrostatic water pressure, defined as submersion of the roof under water. Unfortunately, there are SMMR systems with snap-together seams being marketed for use in low-slope hydrostatic applications, yet which do not meet the standards for hydrostatic roofs. The Metal Building Manufacturers Association (MBMA) establishes standards for metal buildings that utilize low-sloped metal roofs. Below is a quotation from the MBMA *Metal Roofing Design Manual* (1st Edition)[3] identifying the hydrostatic requirements for low-sloped applications:

> Low-slope applications are also sometimes called hydrostatic metal roofing systems. This term is also appropriate, as "low slope" within the context of metal roofing generally means very low slope—almost flat, hence details and joinery must tolerate periods of submersion (or hydrostatic exposure). The term "functional" implies that the purpose of the roof is solely that of waterproofing and not one of aesthetic enhancement—more or less reciprocal to steep-slope metal roofing where "form" is of equal importance to "function."

The American Society of Testing and Materials (ASTM) is the recognized organization that establishes standards for building materials and systems. ASTM established testing procedures for building components of metal roof panel systems, which include low-sloped SSMRs. ASTM E2140-01[4] is the *Standard Test Method for Water Penetration of Metal Roof Panel Systems by Static Water Pressure Head.* This is the recognized standard for low-slope (hydrostatic) metal roofs, including low-sloped SSMRs. Following is a quotation from paragraph 1 of ASTM E2140, identifying the ASTM hydrostatic requirements:

> 1. Scope
>
> 1.1 This laboratory test method covers the determination of the resistance to water penetration of exterior metal roof panel system sideseams, endlaps, and roof plane penetrations when a specified static water pressure head is applied to the outside face of the roof panel.
>
> Note 1—This test method is intended to evaluate water-barrier (not water-shedding) roof system joints and details. These systems are also referred to as hydrostatic roof systems.

The test procedure for ASTM E2140 involves the submersion of the test assembly of the roof system under 6 in. of standing water for six hours. In order to pass, no water may penetrate through the roof during the test. *Figure 2* is an excerpt from ASTM E2140 showing test apparatus. The circled notation was added for clarity.

The 2012 International Building Code[5] provides minimum slope standards for metal roofing, as well. Below is a quotation from the 2012 International Building Code (IBC), Section 1507.4, Metal Roof Panels:

> **1507.4.2 Deck slope.** Minimum slopes for metal roof panels shall comply with the following:
>
> 1. The minimum slope for lapped, nonsoldered seam metal roofs without applied lap sealant shall be three units vertical in 12 units horizontal (25-percent slope).
> 2. The minimum slope for lapped, nonsoldered seam metal roofs with applied lap sealant shall be one-half unit vertical in 12 units horizontal (4-percent slope). Lap sealants shall be applied in accordance with the approved manufacturer's installation instructions.
> 3. The minimum slope for standing-seam of roof-systems shall be one-quarter unit vertical in 12 units horizontal (2-percent slope).

The performance standards for low-sloped metal roofing are consistent and well established. Low-sloped roofs must be waterproof and able to resist hydrostatic water pressure in order to function as low-sloped roofs. While it is unlikely that these roofs will become submerged, there are

Figure 3 – Submerged SSMR after hailstorm.

circumstances when they will leak as a result of hydrostatic water pressure due to capillary action; wind-associated pressure differences; and intense rains, ice, and snow. *Figure 3* is a photograph showing the unusual circumstance when a SSMR becomes submerged. In this instance, 10 in. of hail fell in a short period in June on a roof in Colorado. The result was the hail melted faster than the water could run off the roof and there was a significant period of time where the water was well above the height of the standing-seam, resulting in hundreds of leaks in an 18-year-old roof that had previously been problem-free.

Low-sloped metal roofs should also meet standards similar to other low-sloped roofing systems, including those for wind and fire. Wind resistance for low-sloped roofs is also an issue, and the roof system must be able to resist wind uplift pressures as well as remain watertight. The standards for established wind uplift pressures are provided in the American Society of Civil Engineering (ASCE) and Structural Engineering Institute's (SEI) ASCE/SEI 7, *Minimum Design Loads for Buildings and Other Structures*. The low-sloped metal roof assembly should be able to resist these uplift pressures. The standard wind uplift test for ASCE/SEI 7 is ASTM-E1592. There are also recognized testing agencies like Factory Mutual (FM) and Underwriters Laboratories (UL) that provide testing of metal roofing assemblies to show that these systems meet established wind uplift pressures. Fire-rating requirements are established in the IBC, and agencies like FM and UL also provide testing to the established standards.

Types of Low-Sloped Metal Roofs

There are three basic types of low-sloped metal roofs. There are low-sloped metal roofs that are lapped and sealed, commonly referred to as exposed fastener systems. There are SSMR systems which come in a variety of shapes; and there is the flat-seam metal panel, which is not discussed in this paper. The most commonly used exposed fastener systems panels are corrugated, R-panels, and U-panels. *Figure 4* shows examples of the three different types of metal panels.

There is a wide variety of SSMR profiles used on low slopes. Examples of three types of standing-seam panels are in the following illustrations. *Figure 5* is an illustration of a double-lock standing-seam metal panel roof, sometimes referred to as an asymmetrical vertical rib panel.

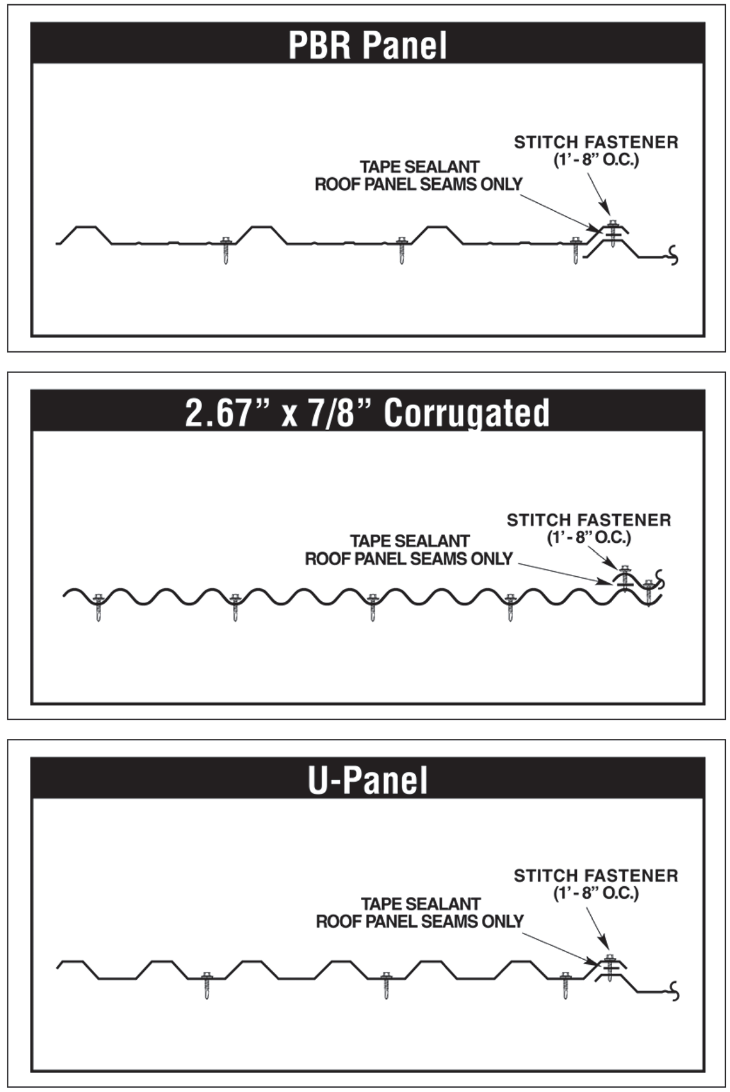


Figure 4 – Examples of three common types of metal panels.

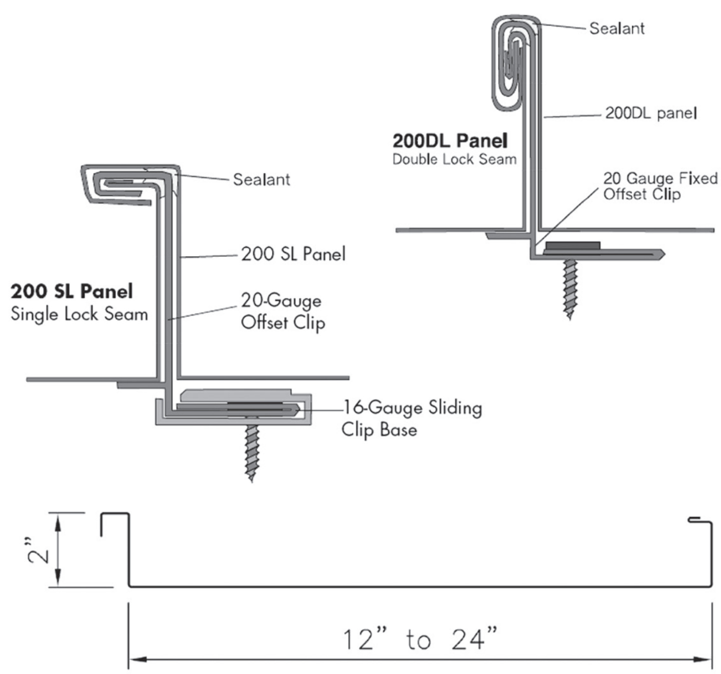


Figure 5 – Double-lock standing-seam metal panel roof.

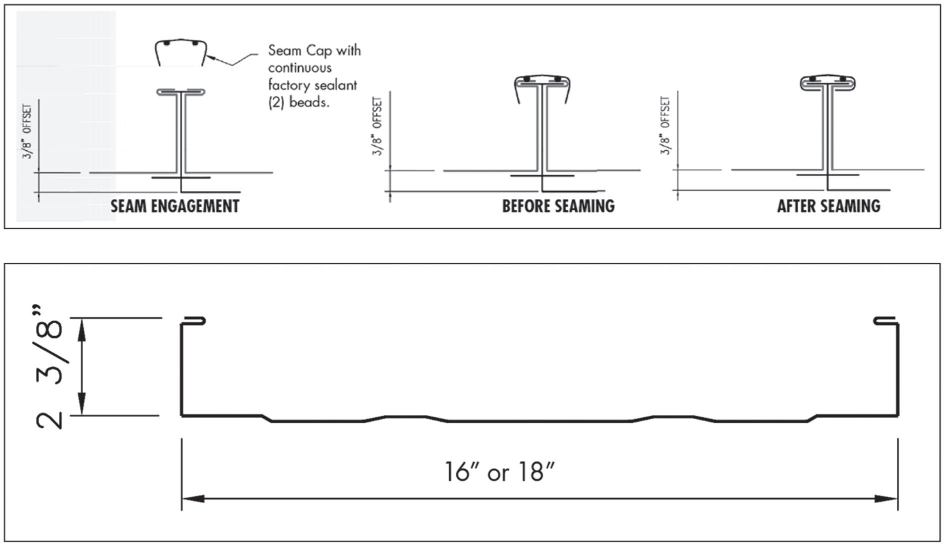


Figure 6 – Standing-seam T-panel roof or symmetrical T-shaped vertical rib.

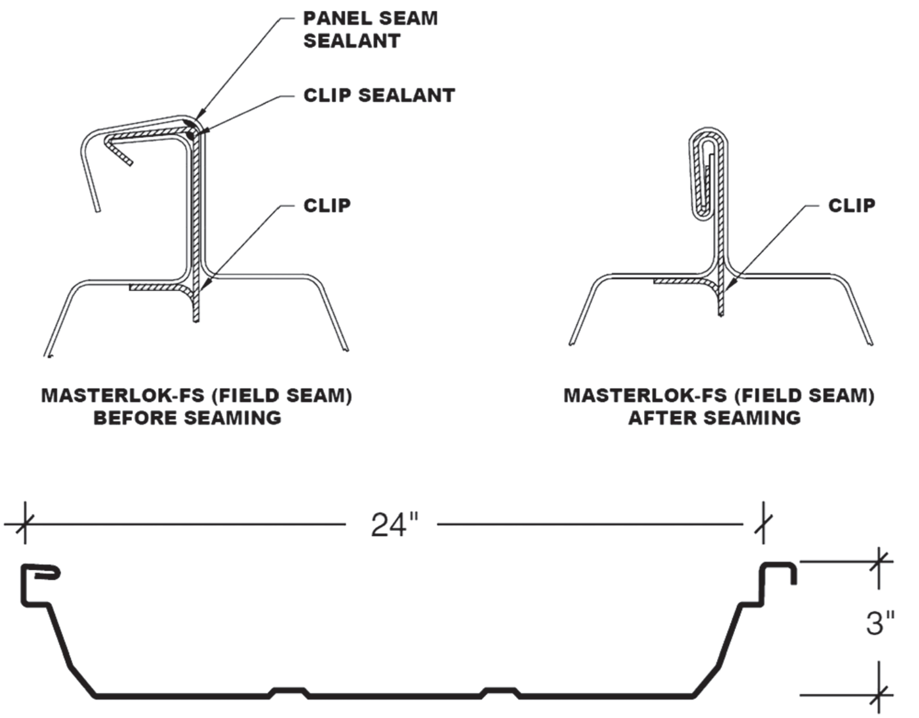


Figure 7 – Field-seamed trapezoidal double-lock standing-seam metal panel roof.

Figure 6 is an example of a standing-seam T-panel roof, which is sometimes referred to as a symmetrical T-shaped vertical rib. This panel provides continuous sealant beads and eliminates the area of discontinuity in the sealant bead, which will be discussed later.

Figure 7 is an illustration of a field-seamed trapezoidal double-lock standing-seam metal panel roof. This is the standard hydrostatic trapezoidal metal panel.

There is another style of trapezoidal standing-seam metal panel that utilizes a snap-together seam. The snap-together trapezoidal standing-seam roofs are hydrokinetic roofs, and seams typically do not meet ASTM E2140, the standard for hydrostatic metal roofs. It is extraordinarily difficult to maintain a watertight seam that will withstand hydrostatic water pressures with any snap-together standing-seam metal panels. *Figure 8* is an illustration showing a typical snap-together trapezoidal standing-seam metal panel.

Waterproofing Issues With Low-Sloped Metal Roofs

As stated above, these roof systems must be resistant to hydrostatic water pressure in order to be used in low-sloped applications, which are defined as slopes less than 3:12. The ASTM standard that applies to metal roofs requires metal roofs to resist water penetration when submerged in 6 inches of water for six hours. Below is a quotation from ASTM E2170 describing the test procedure. This is a rigorous test that simulates conditions that may occur on low-sloped roofs during certain intense, wind-driven rains or during ice and snow events.

9. Procedure

9.1 Remove any sealing material or construction that is not normally a part of the typical panel assembly.

Note 5—When full-length brake-forming is available, the test panels at the side rails can be bent upward to form effective side seals.

Note 6—Nonhardening mastic compounds or pressure-sensitive tapes can be used effectively to seal the test panel assembly to test chamber.

Note 7—The perimeter seals between test panel specimen and test chamber do not have to duplicate actual building perimeter details.

9.2 Load the test specimen to approximately 3 in. (75 mm) of water pressure head. Maintain water level for a minimum of 5 min.

Note 8—The use of room-temperature water is recommended to avoid condensation, which may interfere with the observations of water leakage.

9.2.1 Examine perimeter seals and repair as necessary. Restore water pressure head to approximately 3 in. (75 mm) if required and maintain for a minimum of 5 min.

Note 9—A small amount of perimeter seal leakage is permitted, provided that it does

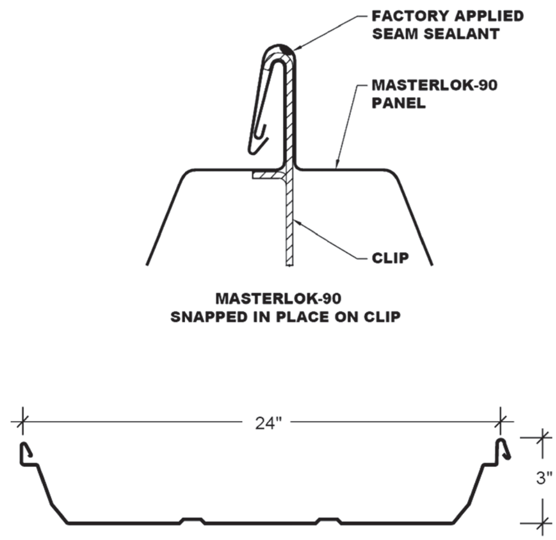


Figure 8 – Snap-together trapezoidal standing-seam metal panel.

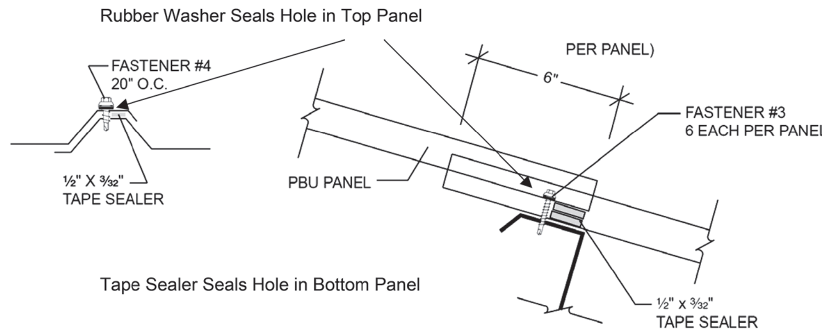


Figure 9 – Appropriate lap in a metal panel.

not impede the determination of water leakage on the inside face of the roof panel specimen.

9.3 Increase the water pressure head to 6 in. (150 mm).

9.3.1 Maintain the 6-in. (150-mm) ± .2-in. (5-mm) water pressure head for a period of 6 hr.

9.3.2 Record the water pressure head and observe for water leakage on the inside face of the roof panel specimen 1 hr. after the start of the test, 3 hr. after the start of the test, and immediately prior to test termination.

9.3.3 The test procedure shall be terminated after 6 hr. or upon observation of water leakage on the inside face of the roof panel specimen.

9.4 Remove all water from test specimen area. Observe and record condition of panels, panel endlaps, and panel sideseams.

The minimum slope of exposed fastener systems allowed in the IBC is 0.5:12. Exposed fastener systems are typically comprised of panels that provide 36 in. of coverage and are attached to the underlying structure using fasteners that penetrate the panels and are lapped and sealed. The key to waterproofing these systems is to have sealant between the laps in the panels and gaskets on the fasteners. Tape sealant is applied between the side and end laps and on the dry side of the lap. The key is to prevent water from entering at the lap and through the screw holes. *Figure 9* is an illustration showing the appropriate lap in a metal panel.

SSMRs can be used on slopes as low as 0.25:12, which is generally the minimum slope allowed by the IBC. Four conditions that make waterproofing a low-slope standing-seam roof a challenge are the end laps, seam sealant, valleys, and curbs. End laps are one of the most common sources of leaks on low-sloped metal roofs. The waterproofing issues related to the end lap are essentially the same as on the exposed fastener systems. The profile of a standing-seam panel makes sealing the end lap more difficult due to the geometry. *Figure 10* is an illustration showing the end lap in a trapezoidal metal panel.

The end lap has to be 100% waterproof and able to resist hydrostatic water pressure. Even a relatively small depth of water results in hydrostatic water pressure that forces water under a lap. For example, the hydrostatic water pressure from ¼ in. of water will back water up a foot under the lap of a panel on a ¼-in./ft. slope. Water also tends to pond behind the lap on low-

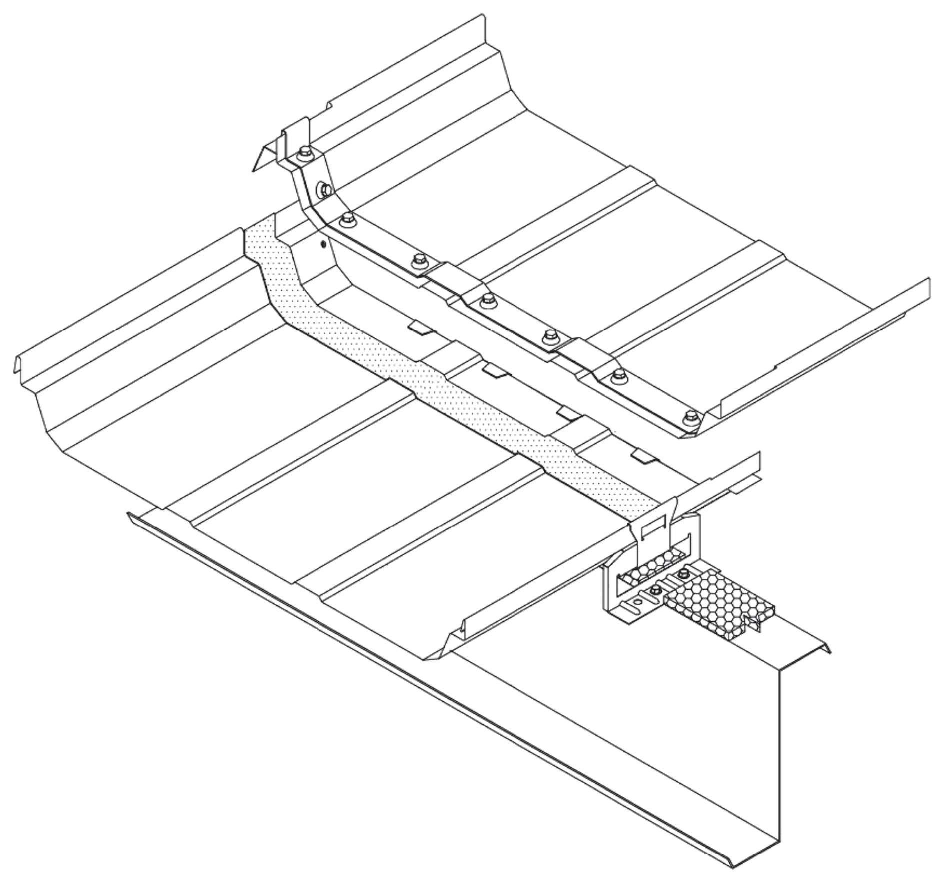


Figure 10 – The end lap in a trapezoidal metal panel.

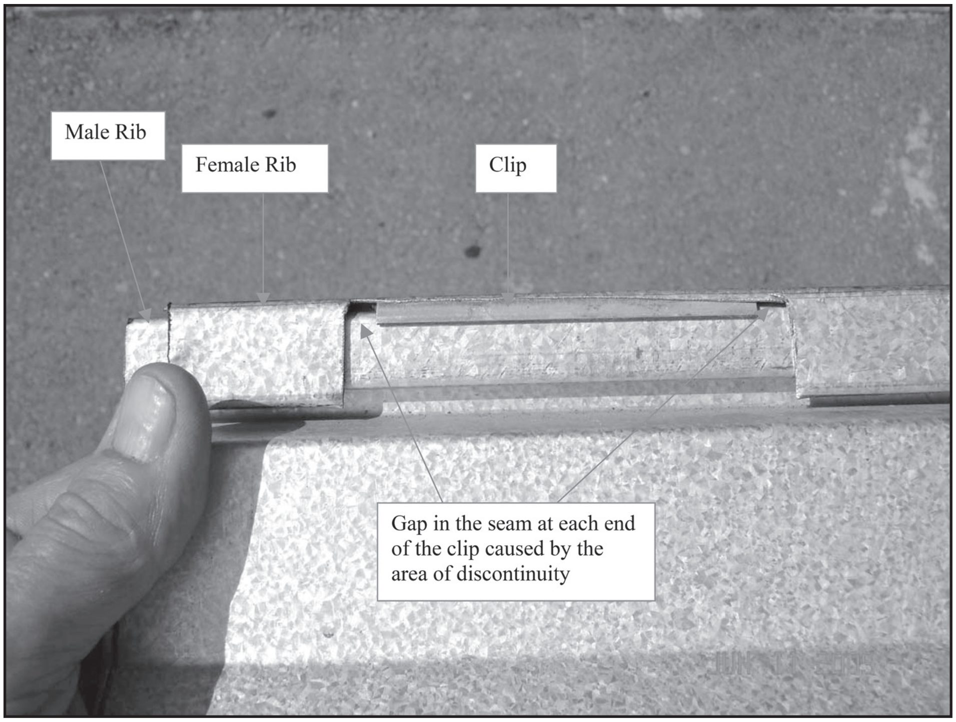


Figure 11 – A portion of the rib is cut away, exposing the clip.

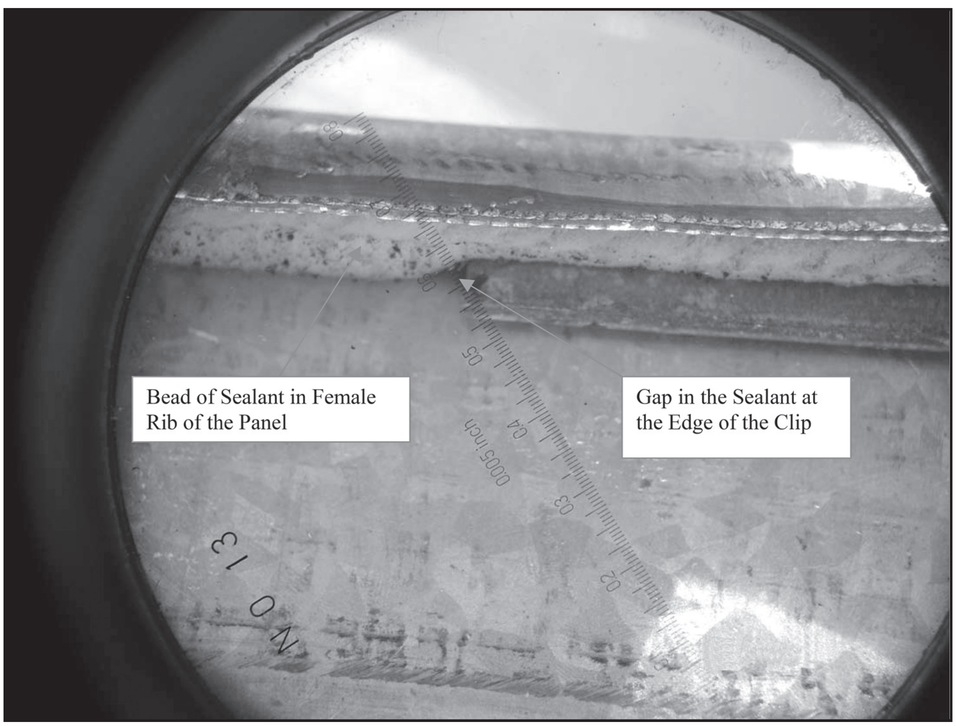


Figure 12 – Close-up of the gap in the adhesive.

sloped metal roofs, exacerbating the problem with leaks at end laps.

The standing seam must also be watertight, and there must be continuous sealant in the seam in order to resist hydrostatic water pressure without leaking. The sealant is normally factory-applied to the inside of the rib, and the sealant is held in place when the rib is formed. It is critical for the sealant to be continuous and fill the void in the rib in order to maintain the rib in a watertight condition over the life of the roof. ASTM E1514, *Standard Specification for Structural Standing-Seam Steel Roof Panels*, provides standards for metal panel roofs, and Section 9.3.1.1 deals with the sealant requirements. Below is an excerpt from ASTM E1514, Section 9.3.1.1:

> 9.3.1.1 The sealer shall be of sufficient size and shape to fill the maximum void to be sealed and to assure compression after engagement. The minimum compression shall be 30% by volume, or the adhesion plus webbing characteristics shall be as required to maintain watertightness.

Section 9.3.1.2 in ASTM E1514 deals with resilience of the sealant; below is an excerpt from 9.3.1.2:

> 9.3.1.2 The sealer shall be sufficiently resilient to maintain the seal after movement of joints due to fluctuation in external load, or expansion and contraction, or combination thereof.

The conventional standing-seam rib has a cleat or clip in the rib that holds the panel in place and allows for expansion and contraction. This clip creates a discontinuity in the rib that can result in voids in the sealant. *Figure 11* is a photograph showing a portion of the rib cut away exposing the clip.

Figure 12 is a close-up of the gap in the adhesive. In this case, the sealant was not of sufficient size and shape to fill the maximum void to be sealed and to assure compression after engagement. The result of this void is a leak in the seams of the trapezoidal panel.

The symmetrical T-shaped panel eliminates this discontinuity in the rib and allows for a continuous uninterrupted sealant bead on either side of the rib.

Perhaps the biggest challenge in preventing water penetration through low-sloped metal roof systems involves valleys. This is particularly true with the trapezoidal panels. The geometry of the rib makes it difficult to seal the opening of the panel at the valleys. The opening at the end of the panel is large and irregular, making it difficult, if not virtually impossible, to waterproof the panels at a valley. The hip flashing is also a difficult condition, in a manner similar to the valley.

It is also important to understand that the slope of the valley is less than the slope of the roof. A 0.25:12 slope is a slope of approximately 2.1%, and the slope of a valley on a roof with a 0.25:12 slope is only

1.5%, which is almost 30% less slope in the valley. Water also tends to build up in the valleys because water is flowing into the valley from two directions, resulting in a larger drainage area than with a typical panel. The water flow from two directions also increases turbulence that adds to the water buildup in the valleys. For this reason, it is always a good idea for the valley to be below the plane of the roof panels on lower-sloped roofs.

Generally, all penetrations and transitions are difficult issues for low-sloped metal roofs. Large penetrations typically have a large drainage area on the upslope side of the roof, which results in substantial water flowing into the back of the penetration. These types of penetrations also can result in expansion and contraction issues. Roof panels are generally fixed on one end and allowed to float on the other end to eliminate excess stresses in the panels from expansion and contraction. In many cases, the panels are attached on both sides of the penetration (upslope and downslope side of the penetration), which results in the panels' being fixed on both ends and resulting in excess stress from expansion and contraction in the panels. Like a panel end lap, most curb penetrations rely upon exposed fasteners and tape sealant to join the roof panels to the curb, providing many opportunities for leaks.

The design of low-slope metal roofs must take into consideration hydrostatic water pressure at all conditions, including the end laps, seams, valleys, and penetrations. The industry standard test is to submerge the system in 6 inches of water for six hours. The seams, laps, valleys, and penetrations are the "Achilles heels" of the low-slope SSMR. The roof designer can dramatically improve the performance of low-slope metal roofs by eliminating all of the conditions or as many of these conditions as possible. A properly designed and installed low-slope metal roof can provide years of maintenance-free roofing, but conversely, an improperly designed or installed low-sloped metal roof can be among the biggest problems in roofing. *Figure 13* is a photograph showing a roof design that has zero end laps and zero fasteners penetrating into the building envelope. The penetrations have been redesigned using transverse-mounted panels uphill of the curbs to eliminate the issues with water draining into the back of the penetrations.

Figure 13 – A design with no end laps or fasteners penetrating the envelope.

Wind Uplift Issues With Low-Sloped Metal Roofs

Low-sloped metal roofs must be designed and installed to meet the wind uplift requirements included in the IBC. The wind uplift requirements in the IBC are based on ASCE's *Minimum Design Loads for Buildings and Other Structures* (ASCE 7). These standards have evolved over the years and are quite rigorous. It is important to understand that the wind uplift pressures are greatest in the corners and along the perimeter of the roof. Often, the roof panels meet the wind uplift in the field but do not meet the wind uplift along the perimeter or ridge without decreasing the purlin spacing. The snap-together trapezoidal panels are prone to unsnapping during wind. The panels tend to lift in the middle, causing the seams to rotate and unsnap. *Figure 14* is an illustration showing the rotation of a trapezoidal panel during wind. Over time, the seams can loosen and leak.

Wind uplift for low-sloped standing-seam metal panels is dependent on the clip, the seam design, the width of the panel, the gauge of the panel, and—in the case of structural panels—the purlin spacing. The typical 24-gauge, 24-in.-wide trapezoidal panel installed over purlins spaced 5 ft. on center will come apart at around 60 to 75 psf. A typical 16-in.-wide double-lock standing-seam panel on purlins spaced 5 ft. on center will come apart at around 90 psf. These are probably the most commonly used configurations for low-sloped metal

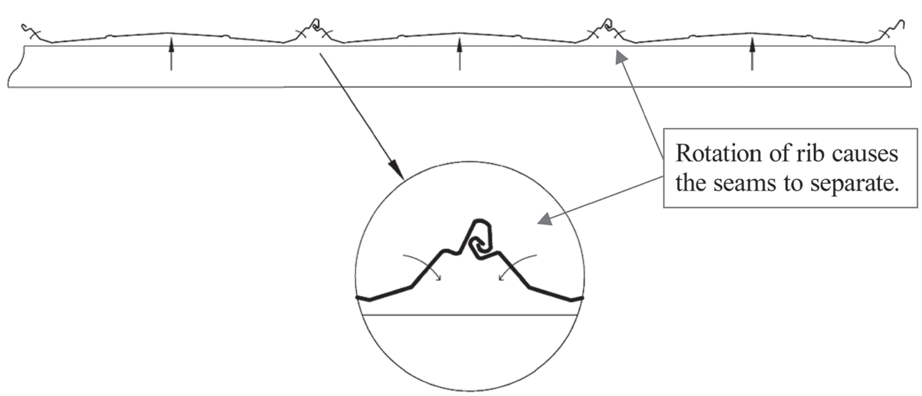


Figure 14 – The rotation of a trapezoidal panel during a wind event.

roofs; yet, in many cases, these configurations will not meet the higher wind uplift requirements, particularly in the higher wind uplift zones on the roof.

There are several ways to increase the wind uplift capacity on a SSMR. The more common methods include increasing the gauge of the panels, decreasing the panel width, or adding purlins to decrease the clip spacing. For example, increasing the thickness to 22-gauge will increase the uplift capacity approximately 20 to 25%. However, in cases where there are relatively high wind uplift requirements, it may be necessary to go to a system that incorporates a continuous clip.

Thermal Movement Issues

Expansion and contraction due to changes in temperature is a significant issue in all metal roofs. The failure to properly allow for expansion and contraction can result in premature failure of the system. The first edition of *Copper and Common Sense* was published in 1945 following a joint study of copper roofing failures going back to the early 1900s.[8] *Copper and Common Sense* provided design and construction guidelines for copper roofs, including standing-seam copper roofs. Fundamental in these design and construction guidelines were provisions for expansion and contraction.

Historically, SSMRs were fabricated from sheets of metal that were 10 ft. long, and there were far fewer issues with expansion and contraction with these roofs than the modern low-sloped SSMRs. This is particularly true of the continuous-length metal panels, which can be formed in extremely long panels. Care must be taken to allow for the expansion and contraction in the design and construction of these roofs.

During design, consideration should also be given to expansion and contraction at rooftop equipment and large penetrations, as the attachment of the panels at these penetrations can result in a roof panel being restricted on both ends. Typically, a panel is fixed at one end and is allowed to expand and contract at the other end. All too often, the panels are fixed on both ends of the equipment, resulting in a section of roof panel being fixed at both ends.

CONCLUSIONS

SSMRs can provide long-term economic performance on low-sloped applications typically reserved for conventional built-up, modified-bitumen, and single-ply installations. However, it is important to understand the dynamics of SSMRs and to avoid the pitfalls associated with many of the typical industrial applications of low-sloped metal roofs. It is essential that the roof be properly designed to meet the hydrostatic requirements of low-slope applications and to make sure the roof meets the code requirements, including the wind uplift requirements. The designer should be aware that there are significant limitations on many of the most commonly used standing-seam metal panels when designed for low-slope, hydrostatic conditions. Below are some keys to properly designing low-sloped metal roofs.

Panel Selection

Use only panels that meet the ASTM E2140 requirements for hydrostatic applications. The longer the run, the more likely the panels will develop problems. Panels with areas of discontinuity within the rib are more likely to leak than panels with continuous sealants.

End Laps

Eliminate end laps wherever possible. Use continuous length panels where possible.

Expansion/Contraction

All standing-seam roof panels will undergo some level of expansion and contraction from changes in temperature. The longer the panels are, the greater the amount of movement that occurs. All perimeter flashings and trim must be designed to provide for thermal movement. On lower slopes, it is best to fix the panel at the eave with a watertight, compression-sealed connection to the structure. Panels that are hooked on the eave trim like an architectural eave detail will have a high propensity to leak on a low slope or come unhooked if the panels are long. Expansion is then directed toward the ridge and along the sidewall or gable conditions. The ridge and curb conditions must allow for thermal movement of the panels.

Large Penetrations

Eliminate large penetrations wherever possible or design the roof to eliminate long runs of panel that terminate into the back of these penetrations. Always provide for free flow of water around penetrations, and do not restrict the movement of the panels by fixing the panels on both sides of penetrations.

Ponding Water/Hydrostatic Water Conditions

The designer must be aware of and avoid conditions where water can build up on a SSMR, whether it is behind a penetration, at a lap, at a valley, or at a transition.

Valleys

Eliminate hips and valleys wherever possible. In cases where valleys are required, design the valleys so that the valley is recessed to eliminate hydrostatic water pressure. A metal roof may not be appropriate on complex low-sloped applications.

Wind Uplift

Make certain the panels meet the wind uplift requirements for the eaves, rakes, and ridges.

Understanding the requirements for low-sloped SSMRs is critical in designing low-sloped metal roofs. Properly designed and installed low-sloped metal roofs can provide many years of low-cost, low-maintenance, and leak-free roofing protection for building owners.

REFERENCES

1. *One Hundred Years of Roofing in America*, NRCA, 1986.
2. *Roof Design and Practice*, Prentice Hall, 2000.
3. *MBMA Metal Roofing Design Manual* (1st Edition), MBMA, 2000.
4. American Society of Testing and Materials, ASTM E2140.
5. 2012 International Building Code, IECC.
6. American Society of Testing and Materials, ASTM E1514.
7. American Society of Civil Engineers, Minimum Design Loads for Buildings and Other Structures, ASCE 7-10.
8. *Copper and Common Sense*, Revere Copper Products, Inc., 2005.