UFC 3-320-03A
1 March 2005
Change 2, October 2010

UNIFIED FACILITIES CRITERIA (UFC)

STRUCTURAL CONSIDERATIONS FOR METAL ROOFING

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UNIFIED FACILITIES CRITERIA (UFC)

STRUCTURAL CONSIDERATIONS FOR METAL ROOFING

U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location
2	Oct 2010	Remove Appendix A and references to same

This UFC supersedes TI 809-29, dated 3 August 1998. The format of this UFC does not conform to UFC 1-300-01; however, the format will be adjusted to conform at the next revision. The body of this UFC is the previous TI 809-29, dated 3 August 1998.

FOREWORD

\1\
The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD(AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the more stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

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TI 809-29
3 August 1998

US Army Corps
of Engineers®

Technical Instructions

STRUCTURAL CONSIDERATIONS FOR METAL ROOFING

Headquarters
U.S. Army Corps of Engineers
Engineering Division
Directorate of Military Programs
Washington, DC 20314-1000

CEMP-E

TI 809-29
3 August 1998

TECHNICAL INSTRUCTIONS

Structural Considerations for Metal Roofing

Approved for public release; distribution is unlimited.

Record of Changes (changes indicated by \1\ ... /1/)

No.	Date	Page
1	30 August 1999	Foreword, page 2

This Technical Instruction supersedes EI 01S908, dated 1 June 1998.
(EI 01S908 text is included in this Technical Instruction and may carry EI01S908 identification.)

FOREWORD

These technical instructions (TI) provide design and construction criteria and apply to all U.S. Army Corps of Engineers (USACE) commands having military construction responsibilities. TI will be used for all Army projects and for projects executed for other military services or work for other customers where appropriate.

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FOR THE DIRECTOR OF MILITARY PROGRAMS:

/s/

KISUK CHEUNG, P.E.
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DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, DC 20314-1000

EI 01S908

CEMP-ET

Engineering Instructions
No. 01S908

1 June 1998

STRUCTURAL CONSIDERATIONS FOR METAL ROOFING

Table of Contents

STRUCTURAL CONSIDERATIONS FOR METAL ROOFING

1. PURPOSE AND SCOPE. This document prescribes the criteria and procedures for designing metal roofs for buildings.

2. APPLICABILITY. These instructions are applicable to all USACE elements responsible for designing military construction projects.

3. REFERENCES.

ASCE 7	(1995) American Society of Civil Engineers-Minimum Design Loads for Buildings and Other Structures
AISI	AISI Specification for the Design of Cold-formed Steel Structural Members
AA SAS-30	Aluminum Construction Manual Series, Section 1 Specifications for Aluminum Structures
ASTM E I592	Standard Test Method for Structural Performance of Sheet Metal Roof and Siding Systems by Uniform Static Air Pressure Difference
NRCA	National Roof Contractors Association Manual
SMACNA	Sheet Metal and Air-Conditioning Contractors National Association
UL 580	Tests for Uplift Resistance of Roof Assemblies

4. METAL ROOF TYPES.

a. General. Metal roofing consists of cold-formed, corrugated, fluted, or ribbed metal sheets attached to the exterior of a building to serve as the exterior covering of the structure. Metal roofing may be either structural or nonstructural. The structural metal roof is designed so the roofing panels support all out-of-plane applied loads. Forces in the plane of the roof, diaphragm loads, are typically resisted by supplemental decks or X-bracing. The nonstructural roof depends upon a substrate to carry the applied loads. Metal roof types may be further subdivided into types with lapped side seams and exposed fasteners, types with standing side seams and hidden metal clip fasteners, and hybrid types, such as those with snap seams or battens that fall somewhere in between. There are many types of metal roofing produced by the metal manufacturing industry and care must be exercised during design to ensure that the type specified is compatible with the main structural framing system or substrate.

(1) Detailing. Generic details of valley, expansion joints, flashing, underlayments, roof penetrations, curbs for mechanical equipment, eaves, ridges, intersections, and other unique situations of the roof system must be provided, along with necessary supporting framing, to assure viable roof performance. Excessive details to avoid are roof panel configurations and

other features that are not necessary to specify architectural requirements. The new NRCA manual (available in hardcopy and electronic versions) is one source for generic roofing details. While the NRCA manual is an excellent source for most roofing details, Structural Standing Seam Metal Roof (SSSMR) system details may have to be obtained from other sources, including reputable manufacturer's details if nonproprietary. Manufacturers will usually insist on using their details for their SSSMR system if they warrant the roofing system. This is acceptable if outlined in the specifications. As a minimum, each change of slope should be detailed. The details put on the contract drawings should be complete and include all fastening, sealing, or other requirements to fully construct the SSSMR system. If secondary flexible (EPDM or other flexible-type) flashings or other type secondary waterproof membranes are shown on the drawings, the manufacturer should be required to provide them.

(2) Color Considerations. White or light-colored roofing surfaces are much better at reflecting sunlight than darker surfaces. Light-colored surfaces keep roofs 20 to 35 degrees C (68 to 95 degrees F) cooler than dark-colored surfaces, which means less heat will be transferred to internal building spaces. Demonstration projects have shown that cooling energy use can be cut by as much as 40 percent when light-colored surfaces are used. Designers should avoid reflective metal finishes near aircraft runways due to potential reflective glare to pilots. Coordinate the use of light-colored roofing material with the architectural designer and/or user.

b. Structural Standing Seam Metal Roof System. An SSSMR is a system of metal roof panels supported and attached by clips fastened directly to the building structure. Clips are used to elevate the panels above the structural framing system allowing the roof to float. These panels are capable of spanning between the structural supports and can resist snow, dead, live, concentrated, and wind loads without benefit of any substrate material. SSSMR systems typically are installed over open purlins that use horizontal X-bracing to resist lateral loads, but may be installed over a metal deck diaphragm. When installed over a metal deck, the metal decking should be designed to run perpendicular to roof slope and the building supports (bar joist or other structural members). The purlins should be designed to fit into the bottom flute of the wide rib-metal decking (Type B). If rolled purlins are used, it may be necessary to invert the metal decking to accommodate the bottom flange of the purlin. The fasteners then would penetrate the metal decking and attach to the metal building structure below. If the roof structure is bar joist, the purlins will be connected with self-drilling/self-tapping fasteners through the metal decking into each upper chord angle of the bar joist. Fasteners should be placed a minimum two fasteners every 305 mm (12 inches) on-center into the metal decking for composite action with the building structural supports. Purlins/sub-purlins will be located a maximum distance of 750 mm (2 ft. 6 in.) in the high wind uplift edge zones \1\ as designed in ASCE 7, (eave, rake, corner, ridge, or hips) and a maximum distance of 1.5 m (5 feet) on-center for the remainder of the roof./1/ Users often want a roof that they can walk on for minor maintenance without excessive deflection. The best way to achieve this, plus providing the required insulation, is to use rigid polyisocyanurate on top of the metal decking. (Approximately 75 mm (3 in.) of polyisocyanurate insulation provides an R-20 value). To help assure a leak-free SSSMR system, an underlayment of 30# felt or an ice/water guard membrane underlayment may be installed on top of the insulation and is especially recommended along the roof edges, including valleys, ridges, and hips which are prone to leaking. The added cost of a waterproof underlayment is minuscule compared to the cost and exasperation of having, finding, and repairing a leaking roof. While the waterproof underlayment will not assure the SSSMR system will not leak, it usually results in the water not leaking directly into the building envelope but, to exterior of the building envelope causing far less problems. The SSSMR system is capable of incorporating a waterproof membrane on top of the substrate (metal decking), the same as for a nonstructural metal roofing system. Installation of mechanical, electrical, or other roof-mounted equipment should be avoided, but if it is necessary, the equipment should be supported by factory-fabricated, fully welded, insulated metal roof curbs, finished to match roof panels in color and type of finish (PVF), free to float with roof panels, and supported underneath with structural framing with no connection between the roof curb and structural supports. Roof access and metal walkways should be properly designed and provided when routine maintenance of roof-mounted equipment is required. Also included, as part of the SSSMR system, are the ridge, gable trim, eave trim, gutters, scuppers, fascia, soffit, and flashings necessary to produce a complete roof system. SSSMR systems commonly used are shown in figure 1.

c. Nonstructural metal roofing. Sometimes called Architectural Metal Roofing, this system of metal roof panels is attached by concealed anchor clips to a continuous solid support substrate. Panels carry no structural loads and are not capable of spanning between structural supports without benefit of substrate materials such as wood, metal, or concrete decks. Applied snow, dead, live, concentrated, and wind loads are resisted by the support substrate. Panel inward and outward loads are transferred to and resisted by the substrate material. The anchor clips hold panels in place and resist upward panel pressure. Loads applied to the substrate material are transferred into the building structural system. The panels serve primarily as an aesthetic water shedding material covering like shingles. Items such as the ridge, gable and eave trim, scuppers, fascia, soffit, and flashings are available from manufacturers, but are not normally considered part of the system.

d. Corrugated (through-fastened) Metal Roofing. This type consists of lapped, exposed, through-fastened metal roofing (in various shapes: corrugated, R-panel, M-panel, etc.) made of cold-formed metal roof panels that have lapped end and side seams. These panels are normally attached directly to the metal structural framing system. While these systems are less expensive than SSSMR systems or nonstructural SSMR systems, they are prone to leak over time due to the thermal expansion and contraction of the panels. Leaks occur when the expansion and contraction process elongates the fastener holes and loosens the fasteners which depend on a gasketed neoprene or EPDM fastener for a seal. This type roofing should be used for agricultural, industrial, warehouse, or utility metal buildings where a utilitarian look and performance is acceptable. Do not use this roofing for buildings that require office, classroom, or similar conditioned spaces. These lapped, exposed through-fastened metal roof panels span between supports spaced 750 mm to 1,500 mm (2 ft.6 in. to 5 ft.0 in.) on center and resist all out of plane applied loads and should be a minimum of 0.61 mm (0.024 in.) thick. Forces in the plane of the roof are resisted by cross bracing.

5. BASIS FOR DESIGN.

a. General. Panels are available in copper, steel, or aluminum. Steel is generally the most economical choice. Aluminum has applications in highly corrosive environments where steel is inappropriate. These materials should not be specified as optional materials, but should be specifically selected based on the requirements of the project.

b. Criteria. The roofing design will be in accordance with the following criteria.

(1) Steel. AISI Specification for the Design of Cold-Formed Steel Structural Members.

(2) Aluminum. AA SAS-30, Aluminum Construction Manual Series-Section 1 Specifications for Aluminum Structures.

(3) Tests for Determining Structural Performance. The approved methods for testing the panel assemblies are included in ASTM E 1592 for roof panels of SSSMR system.

6. DESIGN LOADS.

Design loads will be in accordance with ASCE 7. The design loads for the metal roofing will include snow, dead, live, concentrated, thermal, and wind loads. The minimum roof live load will not be less than 960 Pa (20 psf). Midspan deflections under maximum design live loads will be limited to L/180. The design wind pressure loads should be converted to maximum net inward and outward pressures for the roof system and will be shown on the contract drawings in diagrams or tables. This includes all areas of the roof, i.e., ridges, edges, corners, and midfield. A minimum design concentrated load of 1,335 N (300 pounds) will be used to simulate a construction load on roof panels. The concentrated load will be applied at the panel midspan and will be resisted by a single standing seam metal roof panel, or a 610-mm (24-inch) -wide corrugated metal panel, assumed to be acting as a beam. The undeformed shape of the panel will be used to determine the section properties. Down-slope forces should be considered for all roof slopes and for all roofing systems. Of particular concern are the roofs that have snow guards attached to the panel system since they have the potential for greatly increasing the down-slope forces.

7. SSSMR DESIGN REQUIREMENTS.

a. General Design Philosophy. SSSMR systems are procured using a performance specification. The system is designed by the manufacturer and a designated Registered Professional Engineer based on loads and other design requirements furnished in the contract documents. The structural designer for the project will show the design loads and structural support framing on the contract drawings. The contractor is responsible for the quality of the metal roofing system. The contractor may be required to install additional subframing members to meet design requirements for the roof panel assembly chosen for the stated project.

b. Seams. SSSMR systems with panels wider than 300 mm (12 in.) will have mechanically crimped side lap seams at panel-to-panel connections rolled during installation by an electrically driven seaming machine.

c. Fasteners. Fasteners for structural connections will provide both tensile and shear ultimate strengths of not less than 3,340 N (750 pounds) per fastener. Screws for attaching anchor devices will not be less than 6 mm (No. 14) diameter. Bolts will not be less than 6 mm (1/4 in.) diameter; bolts will be shouldered or plain shank as required with locking washers and nuts. Blind screw-type expandable fasteners will not be less than 6 mm (1/4 in.) diameter. Blind (pop) rivets will be not less than 7 mm (9/32 in.) diameter. Clips with two (2) fasteners will be capable of resisting the tributary area load of the clip times the design wind pressure applicable to that portion of the roof multiplied by a safety factor of 2.25. Clips with a single fastener with a minimum diameter of 9 mm (3/8 in.) will be allowed when the supporting structural members are pre-punched or pre-drilled. Clip spacing should be set so that single fasteners are capable of resisting the tributary area load of the clip times the design wind pressure applicable to that portion of the roof multiplied by a safety factor of 3.0.

d. Support Spacing. The supporting structural member spacing will not exceed 750 mm (2 ft. 6 in.) on-center at all roof edges including corners, eaves, and ridges of the roof and 1,500 mm (5 ft. 0 in.) on-center for the remainder of the roof (field or midfield). Roof zones including zone widths will be determined in accordance with ASCE 7. Panel manufacturers must provide laboratory testing in accordance with ASTM E 1592 verifying that the SSSMR system will meet the designated loads in all roof zones with the support spacing specified.\2~~\ Appendix A is a listing of SSSMR systems tested and approved by the Corps of Engineers in accordance with the requirements of CEGS-07416 (October 1991).~~ /2/

e. Roof Slopes and Seam Height. Roof surfaces will be provided with sufficient slope to prevent the accumulation of rainwater. Maximum slope should be limited to that recommended by the manufacturer, based upon design, gravity, snow, ice, wind, and down-slope forces.

(1) SSSMR will not be used on slopes less than ½ in 12.

(2) Mechanically crimped and sealed SSSMR system can be used for all roof slopes equal to or greater than ½ in 12 with a minimum standing rib height of 37 mm (1- ½ in.).

(3) Uncrimped (with factory-installed sealant) SSSMR system with panel widths less than or equal to 300 mm (12 in.) can be used for all roof slopes greater than or equal to 2 in 12 with a minimum standing rib height of 50 mm (2 in.).

(4) Uncrimped (with factory-installed sealant) SSSMR system with panel widths less than or equal to 300 mm (12 in.) with a standing rib height of 37 mm (1-½ in.) can be used for all slopes equal to or greater than 3 in 12.

(5) A minimum slope of 1-½ in 12 will be used in cold regions.

(6) A minimum slope of 1 in 12 will be used in highly corrosive environments.

f. Panel Thickness. The minimum thickness of panels will be 0.81 mm (0.032 in.) for aluminum and 0.61 mm (0.024 in.) for steel. The thickness of uncoated panels will not be less than 95 percent of the design thickness.

g. Deflection. Maximum deflection for metal roof panels under loads applied in combinations as specified in ASCE 7 will not exceed 1/180 times the span. Maximum deflections will be based on continuous sheets across three or more supports. Deflections will be calculated and measured directly below the standing seams.

h. Thermal Movement. Attachment clips will be capable of providing the fully anticipated thermal movement. The maximum temperature range for thermal movement will be stated in the project specifications. The clips will have the movement slots centered at the time of installation. Calculations to determine the maximum anticipated thermal movement will be included with the shop drawings. Expansion joints may be necessary on roof slopes longer than 30 m (100 ft.). The contract drawings will show the location of the expansion joints.

i. Load Test. Load tests will be performed in accordance with ASTM E 1592.

j. Structural Members. Fastener capacities are directly dependent on the strength and thickness of the supporting structural members. Cold-formed supporting structural members or subpurlins will have a minimum thickness of 1.5 mm (0.059 in.) and a minimum tensile yield strength of 345 Mpa (50,000 psi). Hot-rolled structural members will have a minimum thickness of 6 mm (1/4 in.) and a minimum tensile yield strength of 248 Mpa (36,000 psi).

k. Pull-out Test. For re-roof applications, pull-out tests should be made to check the tensile strength and anchorage of the fasteners securing the new roof purlins to the existing building's structural system. Fasteners used in multiples of 2 or more should resist a load consisting of the tributary area multiplied by a safety factor of 2.25. Single fasteners should use a safety factor of 3.0. Fasteners should meet the minimum size requirements contained in paragraph 7c. For re-roofing applications, attachment of retrofit framing must be to existing hot-rolled structural members only. Light-gauge cold-formed steel may be used for retrofit slope conversion. The design, including all connection details of the cold-formed steel, should be included on the contract drawings. Attachment to other substrates such as tectum, gypsum board, metal decking, or other than flange bracing of the retrofit purlins is not permitted.

8. NONSTRUCTURAL METAL ROOF DESIGN REQUIREMENTS.

a. General Design Philosophy. Nonstructural systems are procured using a performance specification. The design configuration of the system is performed by the designer. The manufacturer provides a system conforming to the performance requirements and matching the design configuration and structural requirements. The contractor is responsible for the qualify of the metal roofing system. The contractor is responsible for providing sufficient information to ensure design requirements have been met, and may have to provide added substrate support to adequately resist imposed loads.

b. Seams. Nonstructural systems should have seams located no wider than 400 mm (16 in.) apart. Seam height and type (crimped, batten, etc.) should be in accordance with manufacturer's recommendations necessary to enforce the specified weather tightness warranty. End seams in long runs should be manufacturer-detailed or shown in accordance with SMACNA details on the drawings.

c. Fasteners and Fastener Spacing. Fasteners should be concealed, corrosion resistant, compatible with panel materials, and capable of resisting imposed loads. Fasteners should be manufacturer-furnished or recommended for the intended purpose. The manufacturer's Underwriter's Laboratory (UL) Class 90 uplift classification number will be submitted for review and approval. Installation and spacing of fasteners will be in strict accordance with the classification description.

d. Roof Slopes. Nonstructural metal roofs are not waterproof membranes. They shed water by sheet runoff and require adequate slope to prevent buildup and seam inundation. Slopes 3 in 12 or greater are required.

e. Thermal Movement. Designers must give consideration to the panel color, building location, infrared heating and cooling effect of the roof radiating into the night sky. The designer should use a maximum temperature of 71 degrees C (160 degrees F) for an uninsulated roof to compensate for the differential movement between the roof panels and the substrate. For wood structures, insulated roofs and buildings that are temperature sensitive or are extreme climate areas, consider a greater temperature range. Dark roofs in mountain areas may be subject to a temperature of 116 degrees C (240 degrees F) or more. For lateral expansion the thermal movement may be assumed to be absorbed in the standing seam rib. Amount of thermal movement will affect the panel length and seam configuration required to accept clip movement.

f. Load Tests. The uplift resistance of the nonstructural standing seam metal roof system will be in strict accordance with performance testing UL 580. Test for uplift resistance of roof assemblies must show a class 90 approval for all system assemblies including components, fastening devices, and substrate applied to supporting structural roof framing members or structural deck.

g. Substrate. The roofing panels should be installed over a solid continuous substrate capable of supporting all design loads including live, dead, and collateral conditions. Wood, rigid insulation, and concrete deck are typical materials used as a substrate. The substrate material and its anchorage into the structural frame must be in complete accordance with a manufacturer's listed UL Class 90 uplift classification, or SMACNA criteria.

h. Pull-out Test. For re-roof applications, pull-out tests should be made to establish the tensile strength and anchorage capacity of proposed fasteners for the substrate anchorage to the structural system and for panel anchors' installation into an existing substrate for new metal cover. Fasteners used in multiples of 2 or more should resist a load consisting of the tributary area multiplied by a safety factor of 2.25. Single fasteners should be avoided where possible, or should use a safety factor of 3 when used. Substrates must be directly connected to the structural system and capable of proving equivalent fastener capacity for panel anchors.

9. CORRUGATED (THROUGH-FASTENED) ROOFING.

a. General Design Philosophy. The design loads and performance requirements should be shown on the contract drawings and/or included in the specifications. The design is typically performed by the manufacturer with results submitted in tabular form as part of the manufacturer's data sheets. Submitted tables should show suggested uniform loads for various spans and should be reviewed by a structural engineer to ensure that flexural and deflection criteria used to develop the tables are consistent with that specified and that all other performance requirements are met.

b. Roof Slopes. Roof surfaces will be provided with sufficient slope to prevent the accumulation of rainwater. Corrugated (through-fastened) metal roofing will not be used on slopes less than 2 in 12. In cold regions this minimum will be 3 in 12.

c. Panel Thickness Requirements. The minimum thickness of sheets for roofing will be 0.81 mm (0.032 in.) for aluminum and 0.61 mm (0.024 in.) for steel. The thickness of uncoated panels will not be less than 95 percent of the design thickness.

d. Thermal Movement. Design provisions should be made for thermal expansion and contraction consistent with the type of system used. Sheets in excess of 9 m (30 ft.) may require additional design provisions such as stepped expansion joints for thermal expansion and contraction.

10. COLD REGIONS CONSIDERATIONS.

a. In cold regions, roofs that drain over their eaves may develop icicles and ice dams in cold weather. Technically and economically, low slope membrane roofs with internal drains are often a better choice for large buildings in cold regions. When systems that drain over their eaves are chosen, ice that forms at eaves causes water to pond on roofs. If the roof is not completely waterproof (most are not) leaks are inevitable. Since building heat, not the sun, is the primary cause of ice dams, metal roofs placed over heated buildings should be well insulated and, whenever possible, ventilated.

b. Insulation versus Ventilation. Insulation alone will reduce, but not eliminate, icing problems. Serious ice damming has occurred on unventilated roofs with a thermal resistance (R-value) in excess of 5.3 K*m^2/W (30 degrees F*h*ft^2/Btu). Ventilation is not always easy to incorporate into metal roofing systems, but it is an appropriate feature for most metal roofs that slope to cold eaves in cold regions.

(1) Attic Ventilation. For reasonably well insulated roofs with no heat sources in the attic space, designers should use the 1/150 attic area rule used to size openings for natural ventilation as discussed in the ASHRAE Fundamentals Handbook. Continuous inlets are needed along eaves and continuous exhaust openings are needed along ridges. Large openings in far apart gable ends are not very effective at ventilating the central portion of large attics. Where motors, hot air ducts, or other heat sources exist in a cold attic, calculate the increase in ventilation needed to remove that heat in addition to rising heat from the heated building below. Dining facilities almost always require such calculations. Air handling ducts located in cold attics should be well insulated.

(2) Ventilation of Cathedral Ceilings. When ventilation is provided in narrow air ways between metal roofing and ceiling insulation, the 1/150 attic area rule may not provide enough ventilation to minimize icing when the length of the airway from the eaves to the ridge exceeds 6 m (20 ft.). Such narrow airways should be at least 38 mm (1-½ in.) deep for airway lengths up to 6 m (20 ft.). For longer airways, airway depth should be increased to a minimum depth of 76 mm (3 in.) for airways over 24 m (80 ft.) long. Whenever possible such airways should be interconnected, not isolated. Interconnections facilitate ventilation of valley areas and areas above and below large roof penetrations that block isolated airways.

(3) Design Temperatures for Ventilation. Ventilation needed to avoid serious ice damming should be based on maintaining the attic (or airway) temperature below -1 degree C (30 degrees F) when the outside temperature is -5.50 degrees C (22 degrees F). The calculation method presented in the ASHRAE Fundamentals Handbook is appropriate for these design temperatures. Such calculations may indicate that natural stack ventilation will not suffice for some buildings. If mechanical ventilation is used, it should supplement whatever natural ventilation can be provided. Mechanical ventilation should be thermostatically controlled so that it is energized only when the attic temperature is above -1 degrees C (30 degrees F) and the outside air temperature is below -5.50 degrees C (22 degrees F). By placing undampened exhaust fans near the ridge of roofs needing supplemental mechanical ventilation, the fan openings can also serve as exhaust openings for natural ventilation.

c. Sliding Snow. Icing at eaves can prevent snow sliding off slippery metal roofs. Because of this, ASCE 7 does not allow the metal roof of a heated building to qualify as a slippery surface from which snow will slide unless it has an R-value of at least 5.3K*m^2/W (30 degrees F* h*ft^2/Btu) if unventilated or at least 3.5K*m^2/W (20 degrees F*h*ft^2/Btu) if properly ventilated. The ability of metal roofs to shed snow by sliding can be an advantage and a disadvantage. When snow sliding off the roof does not damage the roof itself or create hazards to people, property, and lower roofs, sliding is beneficial since it reduces snow loads on the roof. However, sliding snow can create several hazards. It can drag plumbing stacks and other roof penetrations with it, ripping holes in the metal roofing, which voids the waterproofing sealants. Snow cornicing at eaves can create large overhanging loads. Cornices may grow large enough to curl around and damage wall and windows. They may break off and damage the building near the ground also.

d. Snow Guards. Snow guards may be needed to hold snow on slippery roofs and should be at the bottom of the roof, as the roofs are generally attached at the eaves and “float” at the ridge. Usually snow guards should not be mechanically attached through the metal roofing into purlin or other supporting members since that voids the “floating” features of most metal roofing and results in leaks. Adhesive systems can work well if properly installed. Peel and stick systems have not proven successful.

e. Electrical Heating Cables. Electrical heating cables are able to melt small drainage tunnels through ice dams. Properly isolated and ventilated metal roofing systems should not require electric heaters to prevent ponding behind ice dams. However, such heaters may be needed in some isolated areas such as valleys that are difficult to ventilate properly. Too much heat can increase icing instead of solving icing problems. Whenever possible, heating cables should be installed under the metal roofing to avoid the inevitable maintenance problems associated with exposed heaters. Attaching heating cables on top of metal roofing is difficult. Perforated stainless steel clips attached with special, neutral curing silicone adhesive works well. Such clips should support the heating cables directly. Indirect securing using plastic cable ties is not recommended since such ties survive only a few years at most. When the roof is heated, the metal fascia below must also be heated or large icicles will form. On fascia, icicles tend to form at the edges of heated tunnels melted by isolated heating cables. Vertical baffles, installed on either side of heating cables can prevent this, provided that additional cables are used to warm the baffles and the fascia between them. Fascias below valleys containing heating cables should be baffled and have a section at least 0.3 m (1 ft.) long fully heated so no ice can form on it. Much more heat is needed on the fascia than in the valley. If the drip edge of the fascia is not heated, icicles will form there also. Electrical heaters should be thermostatically controlled to activate only when the outside temperature in the shade is below 1 degree C (34 degrees F). When inexpensive thermostats are used, they are best set at 4 degrees C (40 degrees F) to achieve this control objective. Often snow guards are needed where heating cables are installed to prevent heater damage from sliding or creeping snow.

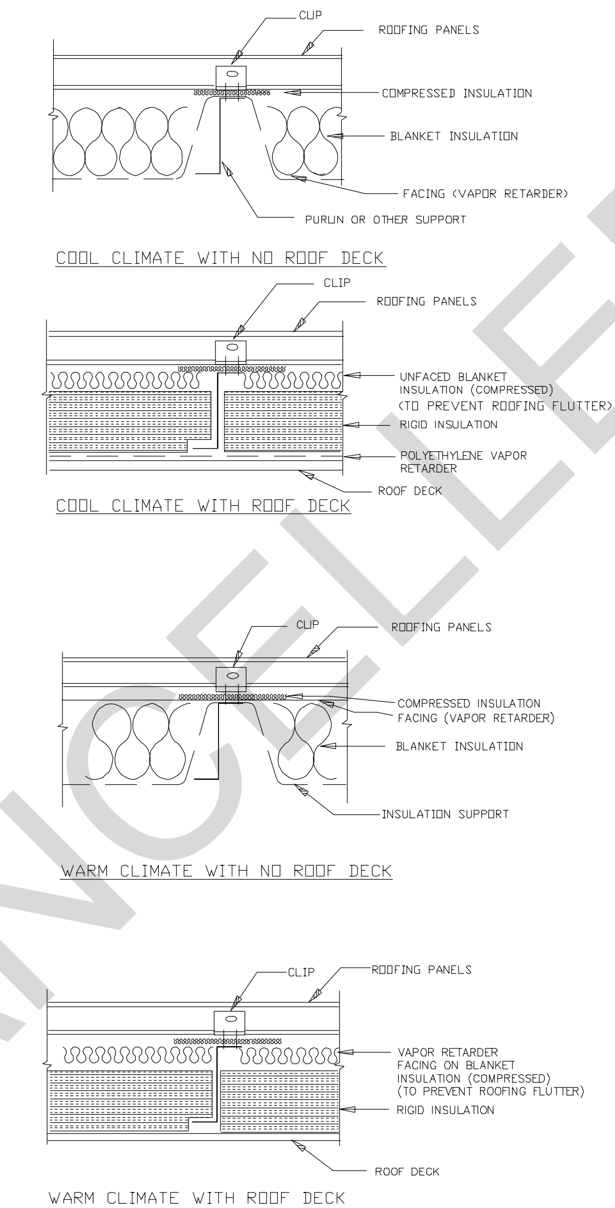

Figure 1. ROOF CONSTRUCTION - SSSMR SYSTEMS

APPENDIX A

APPENDIX A. U.S. ARMY CORPS OF ENGINEERS LIST OF APPROVED STANDING SEAM METAL ROOF SYSTEMS IN ACCORDANCE WITH CEGS 07416 (Oct. 1991)

System Name	Panel Span	Width	Gage No.	Design Load Based on Deformation[1] (psf)	Design Load Based on Failure[2] (psf)	Manufacturer	Date of Approval
MR-24	5' - 1" 2' - 6 ½"	24"	24-22 24-22	34.6 - 64.4* 53.8 -127.3*	33.8 - 64.1* 59.0 - 110.1*	Butler Co.	02-13-92
VSR	5' - 1" 2' - 6 ½"	16"	24 24	36.4 65.9	39.2 66.2	Butler Co.	07-22-92
CRP-16	5' - 1" 2 ' - 6 ½"	16"	24 24	42.0 76.8	38.8 66.8	CECO	10-01-92
SEAM-LOC 24	5' - 0" 2' - 6"	24"	24 24	32.1 46.8	32.2 47.6	Metal Sales Mfg. Co.	11-23-92
BattenLok	5' - 0" 2' - 6"	16"	24 24	38.4 43.9 - 58.8*	31.0 43.3 - 70.1*	MBCI	12-14-92
StarShield	5' - 0" 2' - 6"	24"	24 24	48.0 72.0	44.1 56.7	Star Bldg Systems	02-05-93
Shur-Lok	5' - 0" 4' - 0" 2' - 6" 1' - 8"	24" 24" 24" 24"	24 24 24 24	-- -- -- --	42.8 50.3 80.0 84.9	Gulf States Mfg. Co.	06-16-93
VP SSR	5' - 0" 2' - 6" 1' - 8"	24" 24" 24"	24-22 24-22 24-22	44.0 - 68.0* 72.0 - 96.0* 60.0	41.0 - 54.0* 65.0 - 85.0* 126.0	Varco-Pruden Buildings	06-28-93
264FL	5 '- 0" 2 '- 6"	16" 16"	24 24	51.2 88.0	40.3 69.3	Steelox Roofing Sys.	07-01-93
REMARKS				*See test results.			

Notes: [1] Test load with safety factor of 1.3 applied. [2] Test load with safety factor of 1.65 applied

CANCELED

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System Name	Panel Span	Width	Gage No.	Design Load Based on Deformation[1] (psf)	Design Load Based on Failure[2] (psf)	Manufacturer	Date of Approval
U/R/S-16	5' - 0" 2' - 6"	16"	24	55.53 103.15	43.70 81.27	Ultra Roof Inc.	08-04-93
Double-Lok	5' - 0" 2' - 6" 5' - 0" 2' - 6" 5' - 0" 2' - 6"	24" 24" 18" 18" 12" 12"	24 24 24 24 24 24	43.50 64.30 55.10 77.10 69.24 97.24	34.27 50.66 43.41 60.74 65.27 87.64	MBCI	08-12-93
Span-Lok	5' - 0" 2' - 6" 5' - 0" 2' - 6"	16" 16" 18" 18"	24 24 24 24	58.90 92.20 35.40 75.00	44.90 72.64 27.89 59.09	AEP-SPAN	10-01-93
Loc-Seam	5' - 0" 2' - 6"	16" 16"	24 24	41.2 - 43.2* 63.2 -120.0*	34.0 - 36.9* 56.1 - 94.5*	Amer Bldg Co	10-22-93
KPI RoofLok	5' - 0" 2' - 6"	16" 16"	24 24	36.60 100.52	28.83 79.20	KOVACH	10-26-93
Stand'N Seam	5' - 0" 2' - 6"	16" 16"	24 24	88.46 121.53	69.70 95.76	FABRAL/Alcan Bldg Product	01/12/94
REMARKS				*See test results.			

Notes: [1] Test load with safety factor of 1.3 applied. [2] Test load with safety factor of 1.65 applied.

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System Name	Panel Span	Width	Gage No.	Design Load Based on Deformation[1] (psf)	Design Load Based on Failure[2] (psf)	Manufacturer	Date of Approval
SA 16 x 2 AP 12x1.75 VERSALOK SSP 200	5' - 0" 2' - 6" 5' - 0" 2' - 6" 5' - 0" 2' - 6" 5' - 0" 2' - 6" 5' - 0" 2' - 6" 5' - 0" 2' - 6" 5' - 0" 2' - 6"	16" 16" 16" 16" 12" 12" 12" 12" 24" 24" 24" 24" 36" 36"	24 24 22 24 24 24 24 22 24/26 24/26	---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----	31.1 63.2 46.7 70.4 61.9 86.6 76.8 115.9 30.4 39.8 44.4 58.9 59.5 84.1	Carlisle Engineered Metals, Inc.	03-10-94 03-10-94 03-10-94 03-10-94
ZIP RIB (Aluminum)	5' - 0" 2' - 6"	12" 12"	0.040" 0.040"	---- ----	66.7 115.2	Merchant & Evans, Inc.	03-31-94
SRS-1.5	5' - 0" 2' - 6"	18" 18"	22 22	69.0 104.0	55.0 92.0	Smith Steelite	04-25-94
VicLoc 324	5' - 1" 2' -6 ½" 2' -6 ½"	24" 24" 24"	24 24 22	44.0 - 62.0* 56.0 - 100.0* 98.4 - 110.4*	34.7 - 48.9* 44.1 - 78.8* 77.5 - 87.0*	VicWest Steel	07-21-94
REMARKS				*See test results.			

Notes: [1] Test load with safety factor of 1.3 applied. [2] Test load with safety factor of 1.65 applied.

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System Name	Panel Span	Width	Gage No.	Design Load Based on Deformation[1] (psf)		Design Load Based on Failure[2] (psf)		Manufacturer	Date of Approval
Ultra Seam US-200S	5' - 0" 2' - 6" 5' - 0" 2' - 6"	12" 12" 16" 16"	.04" Alum. .04" Alum. 24 24	44.0 43.3	80.0 69.0	34.67 34.13	63.03 56.19	Architectural Metal Products, Inc.	08-03-94
Design Span 12"	5' - 0" 2' - 6"	12" 12"	24 24	47.3	56.5	37.28	44.53	BHP Steel Products U.S.A., Inc.	11-28-94
BR - 24	4' - 0" 2' -6 ½"	16" 16"	24 24	0.00	64.00	39.40	50.40	Berbice Corp.	01-05-95
Span-Lok	5' - 0" 2' - 6" 5' - 0" 2' - 6"	16" 16" 18" 18"	22 22 22 22	61.53 42.67	123.07 109.07	48.48 33.62	96.90 85.93	AEP-SPAN	02-06-95
Double-Lok	5' - 0" 2' - 6" 5' - 0" 2' - 6" 5' - 0" 2' - 6"	24" 24" 18" 18" 12" 12"	22 22 22 22 22 22	45.26 69.66 81.40	81.26 94.06 113.40	46.06 54.89 77.36	64.03 96.16 117.70	MBCI	02-08-95
Zee Lock	4' - 0" 2' - 0"	16" 16	24 24	70.00	88.00*	55.20	69.70*	Berridge Manuf. Co.	02-14-95
REMARKS				*See test results.					

Notes: [1] Test load with safety factor of 1.3 applied. [2] Test load with safety factor of 1.65 applied.

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System Name	Panel Span	Width	Gage No.	Design Load Based on Deformation[1] (psf)	Design Load Based on Failure[2] (psf)	Manufacturer	Date of Approval
Lock-Seam	5' - 0" 2' - 6"	16" 16"	24 24	36.00 84.00	31.50* 88.00*	American Bldg. Co.	03/07/95
Stand'N Seam (Aluminum)	5' - 0" 2' - 6"	16" 16"	0.032" 0.032"	61.54 84.62	48.48 66.67	FABRAL	06/05/95
MRD110 (Aluminum)	4' - 0" 2' - 6"	11" 11"	0.040" 0.040"	56.00 80.00	44.12 63.03	ATAS Alum. Corp.	06/08/95
Span-Lok SL-216	5' - 0" 2' - 6" 5' - 0" 2' - 6"	16" 16" 16" 16"	24 24 22 22	34.12 97.00 54.60 133.00	26.88 76.42 43.01 104.80	AEP-SPAN, United Dominion Co.	11/30/95
Mark 16 Roof	5' - 1" 2' - 6 ½"	16" 16"	22 22	60.0 - 80.0* 60.0 - 112.0*	47.27 - 63.03* 47.27 - 88.24*	HCI Steel Products Co.	11/30/95
VicLoc 216	5' - 1" 2' - 6 ½"	16" 16"	22 22	48.00 64.00	37.82 50.42	VicWest Steel	11/30/95
Master Span Roof	5' - 1" 2' - 6 ½"	16" 16"	24 24	36.0 - 50.0* 40.0 - 88.0*	2 8.36 - 39.40* 31.52 - 69.34*	Metal Sales Manuf. Co.	11/30/95
SSR-16	5' - 0" 2' - 6" 5' - 0" 2' - 6" 5' - 0" 2' - 6"	16" 16" 16" 16" 16" 16"	0.040"Al0. 040"Al 24 24 22 22	-- -- -- -- -- --	57.6 93.9 27.3 51.5 63.6 96.9	Morin Corp.	11/30/95
REMARKS				*See test results.			

Notes: [1] Test load with safety factor of 1.3 applied. [2] Test load with safety factor of 1.65 applied.

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System Name	Panel Span	Width	Gage No.	Design Load Based on Deformation[1] (psf)	Design Load Based on Failure[2] (psf)	Manufacturer	Date of Approval
Kirbylok 2000-MS**	5' - 0"	24"	24-22	43.50 - 45.26*	34.27 - 46.06*	Kirby Bldg Sys	11/30/95
	2' - 6"	24"	24-22	64.30 - 81.26*	50.66 - 64.03*		
	5' - 0"	18"	24-22	55.10 - 69.66*	43.41 - 54.89*	NCI Bldg Sys LP	
Weather Roof III**	2' - 6"	18"	24-22	77.10 - 94.06*	60.74 - 96.16*		
	5' - 0"	12"	24-22	69.24 - 81.40*	65.27 - 77.36*		
	2' - 6"	12"	24-22	97.24 - 113.40*	87.64 - 117.70*		
SS216**	5' - 0"	16"	24	38.40	31.00	NCI	11/30/95
	2' - 6"	16"	24	43.90 - 58.80*	43.30 - 70.10*		
REMARKS	**Licensed with MBCI			*See test results.			

Notes: [1] Test load with safety factor of 1.3 applied. [2] Test load with safety factor of 1.65 applied.