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Standing Seam Metal Roofs
The State of the Art in Engineering Roofs

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Introduction

Standing seam metal roofs were first introduced in the 1930's and have been increasingly used by metal building systems manufacturers as well as in retrofit roof applications over the last several decades. Additionally, metal roofs are increasingly being used in new construction for conventional structures. Standing seam metal roofing panels are attached to the supporting purlins with a clip that is concealed in the seam. This offers advantages over the alternative through-fastened metal roof in improved water tightness and enabling thermal movement. Construction statistics indicate that metal roofs now account for two-thirds of the low-rise nonresidential market and standing seam roofs are specified in over 60% of these applications. The superior performance and aesthetics appeal of standing seam metal roofs will continue to make them a popular choice of building owners and architects.

Roof Loading Considerations

Environmental forces such as wind loads and snow loads that generally govern a roof design are determined through statistical predictions based on historical data. Building codes and industry standards establish the design load requirements based on a probabilistic analysis to yield a high reliability against overload. This means that during the 50 year design life of a structure, the probability of the applied loads exceeding the design loads in any given year is very low. Building codes have historically used a 50 year storm which means that there is a 2% probability that applied load will exceed the design load in any given year. Even going to a 100 year storm would mean that there still is a 1 in 100 chance of an overload occurring. For this reason, margins of safety are also specified to provide additional capacity so that the structural members can actually carry more load than the design load. However, it is statistically inevitable that on rare occasion, the applied loads will not only exceed the design load, but will be of such a magnitude that they exceed the capacity of the structure, and failures can result. Even this does not mean that a total collapse will necessarily occur, but that the stresses may go beyond the elastic limit and permanent deformations could possibly result.

As the use of in-place standing seam roofs continues to grow, there will be more square footage exposed to extreme loading conditions such as the hurricane, tornado, or "snowstorm of the century" that will statistically occur. This happened in the winter storms of 1993 and 1994 in the South and Northeast that produced record accumulations of snow in conjunction with high winds that resulted in severe drifting. The snow also was extremely wet and the low temperatures caused very high density snow and ice buildups. The resulting roof loads exceeded the code design loads by substantially more than the required margins of safety in many areas and produced some collapse. These failures occurred with all forms of construction, including conventional as well as metal building construction.

Insurance Considerations

Factory Mutual Engineering and Research (FM), the technical arm of Allendale, Arkwright, and Protection Mutual Insurance has for some years published a series of Loss Prevention Data Sheets that contain FM's recommendations for design and construction. The design loads specified in these Data Sheets in many cases exceed the governing building code loads. This should be clear to prospective building owners since the intent to use one of the Factory Mutual insurance companies will possibly result in higher design loads than required by the governing building code and have an impact on the initial construction costs. If this is not communicated at the time the building is designed, the governing building code loads will typically be used and Factory Mutual may recommend additional reinforcement to meet their more conservative criteria.

Factory Mutual has been concerned with the losses

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experienced in the severe winter storms of 1993 and 1994. They have embarked on a plan to mitigate their losses if there is a recurrence of these abnormally high snow loads that exceeded the 50 year storm specified by the governing building codes. MBMA is also investigating severe loading conditions that occasionally occur and their impact on building performance. For example, an MBMA bulletin offering guidelines on roof snow removal is currently under development. Also, MBMA and the American Iron and Steel Institute (AISI) are cosponsoring research that is looking into the unbalanced snow loads caused by drifting on gable roofs to see if the codes are properly accounting for this loading condition. Additionally, as indicated below, metal building systems manufacturers are working with Factory Mutual on ways of meeting FM's enhanced requirements of most building codes.

Structural Support Design Considerations

Any metal roof system is composed of roof panels and purlins which transfer the applied loads to the primary structural frames. Purlins are commonly cold-formed steel "Z" or "C" sections and for longer spans, open web joists are used. Cold-formed steel purlins are designed according to the AISI Specification for the Design of Cold-Formed Steel Structural Members, 1989 Addendum to the 1986 Edition. All three model building codes (i.e. International Conference of Building Official's Uniform Building Code, Building Officials & Code Administrator's National Building Code, and Southern Building Code Congress International's Standard Building Code) stipulate the use of this latest edition of the AISI Specification for design of cold-formed steel structural members.

A purlin, like any other structural component, needs to be properly designed and constructed to perform properly. This means that (1) purlins must be adequately connected to the roof panel to assure lateral stability of the top flange if this is counted on in the design, (2) purlins must be properly connected to the main framing, (3) adequate overlap must be provided where purlins are assumed continuous at span breaks, and (4) purlins must be adequately braced. MBMA is a proponent of a systems design approach where all of the roof and building components are designed as a unit so that all of these details are carefully examined and therefore properly work together to carry the expected loads.

It has long been recognized that the type of roof panel fastening system used has an effect on the design of the purlins. The manner in which the panel is attached to the purlin affects the lateral support that the roof panel provides to the purlin. For standing seam roofs, this interaction is complex and an analytical method is not feasible. The designer can assume no lateral support is provided by the clips, or otherwise <u>must</u> conduct tests to determine the increased strength that the clips provide to the purlin. MBMA and AISI have sponsored research to determine the requirements and procedures for such a test. Either approach provides a rational, engineering method to design the supporting framework for the roof system.

Factory Mutual is seeking to increase the margin of safety in the purlins that support the standing seam roof panels over and above what is required by most building codes. Factory Mutual may propose additional bracing as a means of increasing the load carrying capacity of a purlin. Metal building systems manufacturers are working with FM to determine if additional bracing does increase the strength of the purlins in their particular roof system. One of the design assumptions that affects the bracing requirement in purlin design is related to the lateral support provided by the concealed clip that must be determined by testing. Metal building systems manufacturers are working with Factory Mutual in the review of these test results to validate the assumptions that may have been used in the design. An owner of an existing building may be asked by Factory Mutual to contact the manufacturer to obtain upgrade suggestions to provide the increased margin of safety that is now being recommended by Factory Mutual companies.

Conclusion

The research projects cited above are only some examples of the substantial research that has been sponsored by MBMA, AISI, and others at highly regarded universities to better understand the loads acting on low-rise buildings and to optimize the performance of metal building systems and standing seam roofs. The research conducted on loads has advanced the state of knowledge and has led to improvement in the model building codes. MBMA will continue to be a leader in sponsoring research that has enabled metal building systems to be on the forefront of building construction technology and building code improvement.

The systems approach, promoted by MBMA and its member companies, produces the most engineered of all low-rise buildings. These buildings are composed of components which act together as a system with a behavior that is understood and predicted by virtue of years of experience and extensive research and testing. This emphasis on engineering and commitment to research will continue to make metal building systems and standing seam metal roofs the structures of choice when evaluating performance, cost, and aesthetics.

Committee on Specifications Actions

February 1 through 4, 1995 the AISI Committee on Specifications and its subcommittees convened for their biannual meetings. The subcommittees have been working with great intensity to develop a combined ASD and LRFD specification and commentary. The anticipated publication date for public review of the combined document is late 1995.

To achieve the desired combined specification, the subcommittees deliberated on the results of 12 proposed changes to the specification. The 12 ballots addressed both required technical alterations based on recently completed research, as well as changes that provide for consistent ASD and LRFD design provisions.

The following is a compilation of the affected specification sections:

Section A General Provisions

To accommodate a combined ASD and LRFD specification, the general provision section was restructured to provide for the use of both design philosophies. In a general sense, the LRFD strength requirements are defined in Section A5.1.1, while the ASD strength requirements are summarized in Section A6.1.1.

Paramount to accommodating both design philosophies is the recognition of the varying nominal loads and their load factors and load combinations. The newly approved general provisions section reflects loads and load combinations for ASD and LRFD.

Section B4.2 Uniformly Compressed Elements with an Edge Stiffener

For stiffeners other than simple lip stiffeners, the term D/w is meaningless, and the restriction of 5.25-5(D/w) is unnecessary. A new equation format distinguishes between the simple lip stiffener and other types of edge stiffeners.

Section C3.1.2 Lateral Buckling Strength

The provisions for strength determination for discretely braced beams have undergone two major modifications.

Historically, the lateral buckling strength of I- and Z-sections bent about the centrodial axis perpendicular to the web have recognized a yielding plateau, thus enabling the definition of a bracing interval for which yielding of the section could be achieved. For C-sections, this plateau was not previously recognized. Based on recently completed studies at Cornell University, the yield plateau is also justified for C-sections. Thus, the next edition of the specification will contain yield plateau design provisions for C-sections.

For non-uniform moment diagrams, a more liberal design expression for C_b has been adopted for the AISI specification. The C_b change was prompted by similar action taken for the AISC LRFD specification.

Section C3.1.1 Beams Having One Flange Through-Fastened to Deck or Sheathing

The reduction factor R, which forms the basis for the design strength determination is empirically based. Full-scale tests performed at Virginia Tech demonstrated that the limitations for lap length, that is the distance from center of support to end of lap, for Channel sections need be no greater than for zee sections. Subsequent publications of Section C3.1.1 will reflect this knowledge.

Section D3.2.2 Neither Flange Connected to Sheathing

Because of the broad design provisions for lateral buckling per Section C3.1.2, the need to prescribe braces to be attached to the top and bottom flanges of the section at its ends and quarter points was deemed unnecessary. The revised bracing requirements of Section D3.2.2 admonishes the design engineer to attach braces in such a manner as to prevent deflection of both flanges at the ends and at any intermediate brace points.

Section C4 Concentrically Loaded Compression Members

For sections having unstiffened flanges, the nominal strength was determined by the smaller P_n as determined by Sections C4.1 through C4.3, and Eq. C4-5. Research findings have demonstrated that not only is Eq. C4-5 unduly conservative, but unnecessary to consider. Sections having unstiffened flanges will, therefore, only be required to conform to the design rules of Sections C4.1 through C4.3.

For all sections, C4 will evaluate the nominal bucking stress, F_n, by using equations that are taken from the AISC LRFD specification. Cornell research has shown this change to be justified.

Section C5 Combined Axial Load and Bending

The interaction equations of Section C5 have historically been developed to address the combined loading of compression and bending. Engineers employed judgement when applying the equations to a combination of axial tension and bending. Because of approved specification changes, future specification editions will be prescriptive for axial tension and bending design conditions.

Section D5 Diaphragms

To ensure agreement between the ASD and LRFD design methodologies, consistent ϕ and Ω values were developed and approved. The specification recognizes the reliability of screws versus welds, as well as the probability of wind versus earthquake loads.

SURVEY ON CENTER ACTIVITIES

You are cordially invited to participate in a survey on the Center activities. Please use the following form to make any suggestions or recommendations for the improvement of the Center's services and activities:

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