

MBMA's Contributions to the Metal Building Industry

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Introduction

Metal buildings have evolved over the years from utilitarian tin sheds to highly attractive, multi-use structures that are not even recognizable as metal buildings. Many factors have contributed to the wider application and market growth of metal buildings over the decades. One significant reason that metal buildings have rapidly evolved is MBMA's focus on technical issues that confront the metal building industry. This includes sponsoring research to learn more about the structural behavior of metal buildings with an eye on optimizing material utilization and the appropriate loads that should be specified in the building codes. In fact, all low-rise construction has experienced improvements that are a direct result of research and building code changes that have been sponsored and promoted by MBMA.

Research in the 60's – Cold-Formed Steel and Tapered Member Behavior

Cold-Formed Steel Research

Since the mid-1960's, MBMA has been involved in improving the performance and efficiency of cold-formed steel, primarily metal roofing systems, through advances in AISI's *Specification for the Design of Cold Formed Steel Structural Members*. Early research was conducted at Cornell University, under the direction of Dr. George Winter and was sponsored by AISI, with MBMA serving in an advisory role.

The Cornell tests were performed on simple span C and Z-beams, with and without diaphragm bracing, for both uplift and gravity loads. Good correlation was achieved between the test results and their computer model predictions, except for the case of diaphragm braced beams for gravity loads. In this case, the actual tested capacity was considerably higher than the predicted values. Unfortunately, specific design recommendations were not finalized before the work by AISI came to an end. This is where MBMA stepped forward and sponsored additional work by Dr. Teoman Pekoz at Cornell to complete this important component of the research.

Tapered Member Research

MBMA first co-sponsored a major research project in 1966. This project was a study on tapered structural members that was conducted at the State University of New York at Buffalo by Dr. George Lee. Other sponsors were the U.S. Naval Facilities Engineering Command, American Institute of Steel Construction (AISC), and AISI. A joint task committee of the Column Research Council (now the Structural Stability Research Council) and the Welding Research Council was established to facilitate the study. This began a 15-year MBMA association with Dr. Lee and his tapered member research that led to the notable book, *Design of Single Story Rigid Frames*, published by MBMA in late 1980.

Don Johnson, now a consultant who retired from Butler Manufacturing in 1996, and who was a two-term MBMA Technical Committee chairman, headed the MBMA subcommittee that helped guide this research. Johnson recalls that, "it was a very complex problem, requiring Dr. Lee to come up with a very complex solution; but this helped advance our knowledge of the behavior of tapered members, particularly with regard to geometric limits on the taper."

The ultimate goal with any research is to positively influence the building codes or material specifications. Supplement No. 3 was released in 1974 for the AISC Specification that added Appendix D on Tapered Members that was based on Dr. Lee's research. This validated the work and provided an optional method to the designer when tapered members are used. MBMA recently sponsored the development of an AISC/MBMA *Design Guide on Frame Design Using Web-Tapered Members*, which will provide design practices that are consistent with the 2005 AISC Specification, but suited to today's computer methods of design.

Research in the 70's – Wind Loads and Bolted-End Plate Connections

Wind Load Research

In 1974, when the model building codes indicated interest in adopting the wind loads from the American National Standards Institute (ANSI) A58.1 *Minimum Design Loads for Building and Other Structures* (which became ASCE 7 in 1988), MBMA decided it was time to sponsor wind load research aimed at settling the differences in the various standards. Especially since the ANSI standard was completely based on testing of high-rise buildings and was inappropriate for low-rise applications. Until MBMA became involved, there was little concern about this from others. It is important to note that this was not just a metal building issue, it was a low-rise building issue, and the research had far reaching impact.

This pioneering work launched the first comprehensive investigation of wind action on low-rise buildings, which recognized both the importance of boundary layer flow and the action of turbulence. In 1976, additional sponsors joined the effort at the University of Western Ontario (UWO) - AISI, and the Canadian Steel Industry Construction Council. The task of trying to codify the extensive database of wind tunnel results for low-rise buildings was a very difficult one. But this is where Dr. Davenport's UWO team and MBMA may have made their greatest contribution.

The hard work finally paid off, when the Standard Building Code (SBC) first adopted the wind loads developed by Dr. Davenport's team. This was included as an alternate procedure in the 1982 SBC, which was notable since this code governs the design of buildings along most of the hurricane coastline in the United States. Then, in the 1986 SBC, these provisions became mandatory for low-rise buildings because of the improved performance of buildings designed to these provisions. The American Society of Civil Engineers Standard, *Minimum Design Loads for Buildings and Other Structures* (ASCE 7) finally made revisions in their 1995 edition, introducing the UWO primary framing loads for low-rise buildings. The wind load research was undoubtedly the most successful technical endeavor undertaken by MBMA.

Bolted End-Plate Connections

The metal building industry, with MBMA's leadership, pioneered the use of bolted end-plate connections in the United States. This was in large part due to the research program that established the design procedures that have been adopted for this type of

connection. MBMA began sponsoring research in 1971, when Dr. Krishnamurthy of Auburn University was selected to conduct the study on bolted end-plate moment connections that was cosponsored by AISC. Dr. Krishnamurthy later moved on to Vanderbilt University and to the University of Alabama – Birmingham, but the MBMA research continued under his direction at those institutions as well.

Dr. Thomas Murray of the University of Oklahoma and Virginia Tech followed Dr. Krishnamurthy's work for MBMA in 1982 to develop a new approach aimed at unifying the design approach for the most common end-plate connections utilized in the industry. Comparisons of test data to his design theory proved that this method produced accurate results, yet economical designs. The culmination of this work was realized in 2002 with the publication of the AISC/MBMA *Design Guide No. 16*. This is now the recognized standard for bolted end-plate design and serves the industry well.

Research in the 80's – Metal Roofing Systems and Wind Uplift Tests

Metal Roofing Systems

In 1980, MBMA recognized that it was increasingly necessary to look at the roof as a system with regard to purlin design for gravity and uplift loads, expansion and contraction behavior, and the impact of insulation. In fact, for purlin design, 22 separate roof system parameters were listed by the Technical Committee that could affect the behavior. Since it was expected that the work of Dr. Pekoz would lead to a design procedure for uplift, the new focus was to do more research for gravity loading.

MBMA selected Dr. Murray to begin the research on the behavior of roof systems under gravity loads in 1981. The objective of the research was to determine the quantitative effects on roof systems of such devices as sag members (intermediate braces), anti-roll clips, roof diaphragm, end anchorage of panels, and the effect of various insulation schemes on the ultimate load capacity under gravity loads.

Dr. Murray's work finally yielded a solution, whereby a simple span test could be used to predict purlin capacity in a continuous span system. This test came to be known as the Base Test and was adopted into the 1996 AISI Specification. This has been hailed as a breakthrough which finally solved the purlin capacity impasse.

Wind Uplift Tests (Static vs. Dynamic)

The UL 580 test that had been introduced in 1973 was a success in improving the performance of roofing assemblies by evaluating them in a simulated wind event. But this test was not designed to predict the actual uplift resistance. In 1988, ASTM began the development of the E1592 wind uplift resistance test. One advantage of this test was that it used a larger roof specimen, which is now recognized as a better test for standing seam roof systems. However, both of these tests utilized a uniform static air pressure over the roof specimen which does not represent true wind behavior. The real interaction of wind and structure is known produces wind loads that vary dramatically from one instant to the next, and over very short distances, on the roof surface.

MBMA initiated an effort in the late 1980's to try to better predict the actual performance of metal roofing against high wind uplift forces. A full-scale assembly of a metal roof corner was constructed and tested at Mississippi State University using the standard ASTM E1592 protocol to obtain the static uplift resistance. Then, a dynamic test using a grid of 34 electromagnets was used to simulate the actual non-uniform wind behavior. The electromagnets were programmed to reproduce independent time-history traces obtained from the detailed UWO wind tunnel analysis. The simulated wind event

was based on Hurricane Andrew. Load cells were placed at selected standing seam clip locations for both the static ASTM E1592 test and the dynamic electromagnetic wind simulation. The clip loads in both tests were evaluated to determine the true load that was being imparted to the roof system.

It was found that the E1592 uniform pressure test was a conservative estimate of the actual capacity under real wind uplift. This finding was incorporated into the 2007 AISI Specification by increasing the E1592 static capacity by 50% in the corners and edges of a standing seam roof.

Research in the 90's – Snow Load Research and OSHA/SENAC

Snow Load Research

Heavy snowfalls in the 1990's focused attention on snow loads. Roof failures and observations of accumulated snow drifts at the time of these collapses led investigators to believe that the building codes may not have been sufficiently capturing the observed loads. Roofs with slopes less than 15 degrees were not thought to provide the necessary conditions for snow to drift over the ridge of a gable roof. MBMA led the effort to sponsor research at Rensselaer Polytechnic Institute to determine if changes were warranted.

The research resulted in changes to ASCE 7 that required new unbalanced snow loads that were higher at the eave of the building and tapered off towards the ridge. Buildings designed to the latest codes where snow governs may exhibit heavier or deeper purlins at the eaves to resist this heavy snow load. Current research sponsored by MBMA is likely to change this again in the next code cycle where the drifting snow may not go all the way to the eave. This new data was based on water flume tests that simulate drifting snow on scale models.

OSHA/SENAC

In 1995, the Occupational Safety and Health Administration began work on a new safety standard for steel erection that focused on controversial fall protection requirements. OSHA utilized a new consensus building process called a negotiated rulemaking process. The Steel Erection Negotiated Rulemaking Advisory Committee (SENAC) was formed for this purpose. One of the issues raised during the deliberations of the OSHA/SENAC effort to update the steel erection safety standards was the presence of roll-forming lubricant residues on decking products and their potential to contribute to the slipperiness of deck during the erection operation.

At MBMA's urging, AISI coordinated the formation of a coalition of steel industry groups that would be affected by the proposed OSHA rule on slippery surfaces. A research effort was undertaken to evaluate methods to test slippery surfaces as well as to reduce or eliminate the presence of lubricant residues and the impact on corrosion and formability if these lubricants were eliminated or altered.

After years of study and evaluation, OSHA entered into a voluntary agreement with the steel industry coalition to implement specific recommendations to manufacturers of metal decking and roofing. This was a significant achievement in coming up with a solution to the issues raised without the imposition of controversial regulations on testing the slipperiness of these products.

Research in the 2000's – Seismic Research and Purlin Anchorage

Seismic Research

After the Northridge, CA earthquake in 1994, significant changes began to take place affecting the seismic design of steel moment frames. Welded moment connections typically used in mid- and high-rise buildings were found to be susceptible to cracks, and even though there were no catastrophic failures, an unprecedented federal research effort was launched to determine the cause and recommend new practices.

An initial MBMA effort led to the development of a seismic design guide for metal buildings which was published by the International Code Council to assist engineers and plan checkers in applying the new seismic requirements to metal buildings. A research project was subsequently undertaken at the University of California – San Diego to perform advanced analyses of typical metal building systems to better understand their behavior when subject to seismic events, leading to recommendations for appropriate code requirements.

Of particular interest are metal buildings with mezzanines and with concrete masonry or pre-cast tilt-up walls since these introduce larger seismic forces due to their mass. The research includes computer simulations as well as full scale shake table tests that are the most accurate and sophisticated way to determine the actual performance and behavior while undergoing a seismic event.

Purlin Anchorage

One topic that has received considerable attention is the capacity of purlins that are laterally braced by a standing seam roof. Z-purlins try to twist and roll over when subjected to loads in the plane of their webs. How these purlins are braced has a significant affect on their overall load-carrying capacity.

MBMA and AISI sponsored research was conducted at Virginia Tech to provide a more rational approach to determining bracing anchorage forces that need to be accounted for in a metal roof so that designers have more flexibility in providing a bracing system. The test setup being used is innovative in that a full scale roof system can be inclined at different angles and the bracing forces measured. New provisions were adopted into the 2007 AISI Specification and a new AISI design guide was developed to help explain the requirements.

Summary

This summary of MBMA contributions focused on one or two primary research thrusts for each decade. However, this is only a sampling of the research efforts sponsored by MBMA to better understand the loads that act on low-rise buildings as well as the structural behavior of metal buildings.