Metal Building Systems: The Low-Rise Solution

Today's metal buildings are much more attractive and versatile than their more industrial forebears

By W. Lee Shoemaker, Ph.D., P.E.

The metal building systems industry has been an innovative leader in low-rise construction. Because the industry has grown and matured so rapidly, many misconceptions exist that are based on earlier predecessors of today's advanced systems. An entire article could easily be devoted to the historical evolution of this industry that has pioneered many practices that are becoming more widely utilized. The metal building industry was first in recognizing the advantage of combining engineering and fabrication to more effectively provide an optimally designed steel framed building. Also, the movement toward design/build has been an integral part of the metal building system industry since its inception.

The focus of this article is the engineered product furnished by metal building manufacturers that is the basis for the growth in their market share. Of the low-rise, non-residential buildings under 150,000 sq. ft., metal building systems are selected by building owners and architects in nearly 70% of new construction (as referenced in the *1996 Business Review*, Metal Building Manufacturers Association). This high market share is due, in no small part, to the engineering and quality assurance that contribute to the excellent performance of these buildings.

The Metal Building Manufacturers Association (MBMA) celebrated its 40th anniversary last year. Composed of 31 Manufacturer Members and 36 Associate Members, MBMA has taken the industry lead over the years in setting the standard for excellence. In fact, MBMA has decided to make AISC Certification a requirement for membership, effective in the year 2000. MBMA's Manufacturer Members are also Associate Members of AISC.

What is a Metal Building System?

Many outside the industry still harbor the notion that a metal building is selected from a catalog of standard designs, based on the size of the building.

In fact, most metal building manufacturers custom design a building by order to within 1/16" in any dimension, based on the building code in effect, the loading conditions, and material specified. MBMA member companies have registered professional engineers on staff who are highly skilled and apply sound engineering principles to the optimal design of metal building systems. Advanced computer methods are used to help facilitate this design customization and optimization. This is also why the industry has tried to eliminate past characterizations such as "pre-engineered metal buildings" in lieu of the more accurate identification of "metal building systems".

Metal building systems have evolved over the years into assemblages of structural elements that work together as a very efficient structural system. While there are many variations on the theme, the basic elements of the metal building system are constant: primary rigid frames, secondary members composed of wall girts and roof purlins, cladding, and bracing. Metal building system design may seem trivial at first, but experience shows that the complex interaction of these elements into a stable system is a challenging engineering task. MBMA member companies have demonstrated this expertise and are on the leading edge of systems design. The reality of this has been evident in post-disaster investigations where metal building system "look-a-likes" have suffered more extensive damage than engineered systems subjected to the same extreme loading. These metal buildings are not easily distinguished from a metal building system, however, they are not designed with regard to the interdependence of the structural elements. The individual components are usually purchased from one or more vendors and often shipped out as a complete metal building.

Leon's Carpet & Tile headquarters (above) in Austin, TX, and the Gold Shore Casino (opposite) in Biloxi, MS, demonstrate the versatility of today's metal buildings.

Optimization - The Bottom Line

In an AISC Marketing, Inc. publication (Myths and Realities of Steel Buildings), it is noted that "the cost of a structure is divided among four areas: design, material, fabrication and erection. The optimum structure has the lowest weight consistent with the greatest standardization of parts, the fewest number of pieces and the smallest amount of detail work." Metal building systems offer an excellent optimization solution, taking advantage of lower costs in all of the four areas noted.

Metal building manufacturers have developed design and fabrication techniques to optimize the primary frames and put the material where it is needed. Using welded plate members as opposed to hot-rolled sections provides this opportunity. Optimization is carried out by using tapered webs with increased depth in areas of higher moments, and by varying the web thickness and flange size as needed. Sections are also frequently used with unequal flanges (monosymmetric) to utilize a smaller flange where it might be in tension and/or a larger compression flange in an unbraced condition. The frame members are also designed with bolted end-plate connections for fast assembly in the field. MBMA has sponsored extensive research over the years to develop appropriate design methods for bolted end-plate connections. These connections are receiving new interest as a possible alternative to welded moment connections in seismic areas (for more information, see Ronald L. Meng's and Thomas M. Murray's paper, "Seismic Performance of Bolted End-Plate Moment Connections" in the Proceedings of the AISC National Steel Construction Conference, May 1997).

Cold-formed secondary members (purlins and girts) offer a high strength to weight ratio. Optimized sections can be roll-formed by the metal building system manufacturer to the required depth and thickness to carry the specified loads.

Structural Redundancy

Metal building systems are extremely redundant structures. Structural redundancy is the degree to which multiple load

Shown at top is the Transcypt building in Lincoln, NE, while pictured above is the interior of the Wilkof-Morris plant in Canton, OH.

paths exist within a structure. That is, if a local failure occurs in a member, does the member lose all capacity to carry additional load, or is the load redistributed and carried by the member in a different manner or carried by other members? All flexural members used in a metal building, including panels and purlins, are usually continuous members that permit redistribution of loads as opposed to simply supported members that provide no redundancy. The primary frames are indeterminate structures that offer additional redundancy.

MBMA is sponsoring a study to look into additional design requirements for overload situations, particularly abnormal snow loads. Current codes and standards, such as ASCE 7, require most buildings to be designed using loads that represent a 50-year mean recurrence interval. However, improved performance under abnormal snow load situations may be achieved through specific loading and/or design considerations. MBMA has also sponsored research to determine if the unbalanced snow load specified in most codes adequately reflects the propensity for snow to drift on low slope roofs. Revisions to ASCE 7 are being considered based on the results of this work that should lead to improved performance for all types of buildings with low-slope roofs.

Expansion/Change of Building Use

One of the reasons that metal building systems are an attractive economic alternative, as discussed above, is that materials are optimized for the specified loads. Obviously, if substantial new loads are introduced that were not accounted for in the original design, modifications may be required. An owner actually has three options with regard to a new building design: 1) the building can be overdesigned in anticipation of future potential loads, 2) the building can be economically designed with some consideration for future potential loads, or 3) the building can be designed for the current loads to provide the lowest initial cost. All three of these options are available with a metal building system and would be designed according to the applicable building code, depending on an owner's anticipated needs. The first option should be evaluated against the other two by comparing the initial costs versus modification costs in the future given the probability that the loads will actually be added. In reality, most building types that depend on a limited availability of standard rolled beams and other structural elements are overdesigned by the nature of the selection process (i.e. the next largest available size is used based on the required section). This is where the greater versatility of welded plate frames and cold-formed members provides lower material costs. The second option for future expansion capability is often provided for in a metal building design, by designing the end frame for additional future loads. However, even if this is not pre-planned in the design, using the third option for the lowest initial cost, alterations can readily be made working with the metal building manufacturer.

A session is tentatively planned for the 1998 AISC National Steel Construction Conference to identify how expansions or changes of building use can efficiently be carried out in a metal building system. This should be of interest to engineers involved in such projects, and should help identify the most cost-effective ways to alter a metal building system. This strategy of providing the most economic building to accommodate the specified structural loads, and cost-effective ways to provide for possible future expansion, should be compared to the alternative of overdesigning a building for loads that may not ever be realized.

Architectural Involvement

The growth of metal building systems is also attributable to more diverse applications that have evolved due to the increasing awareness by architects of what metal buildings offer. Many different architectural finishes may be utilized to provide the look required for applications such as churches, schools, shopping centers, office buildings, etc., while still offering the cost advantages of the metal building system. These architectural finishes, other than steel cladding, are typically not designed or provided by the metal building manufacturer. The role of the architect/engineer of record is important in ensuring that the design criteria, particularly the lateral drift and deflection of the primary frame and/or secondary supports, is consistent with the chosen wall finish. This is true of any type of construction, and is easily coordinated with the metal building manufacturer.

In recognition of the importance of serviceability criteria, MBMA jointly sponsored with the American Iron and Steel Institute (AISI) and AISC the development of the AISC Guide on Serviceability Design Considerations for Low-Rise Buildings (see AISC Steel Design Guide Series 3, "Serviceability Design Considerations for Low-Rise Buildings"). This reference establishes guidelines for many serviceability issues, including frame-supported cladding. For example, lateral drift of frames may range from H/60 for flexible metal cladding to H/200 for more brittle reinforced masonry walls. Additionally, MBMA has worked with the National Concrete Masonry Association in the development of its manual to address serviceability as well as structural design considerations when utilizing concrete masonry walls with metal buildings. The availability of these tools has helped give architects more confidence in blending different architectural finishes such as precast concrete, brick, stone, wood and glass with metal building systems. However, these wall finishes are not just used for aesthetic enhancements. For example, in many industrial or warehousing operations, masonry wainscoting can be employed to improve resistance to impact loading from vehicular traffic.

With regard to the trend away from "conventional" construction toward metal building systems, as reflected in the market share analysis, more engineering opportunities are anticipated for those working in this low-rise segment. An increasing number of applications will have an engineer of record or architect involved with the construction project. This design professional assists in the preparation of the design specifications for the project, including the metal building system and its erection, and where appropriate, assists in supervising the construction process for compliance with the contract documents. The metal building manufacturer is responsible only for the structural design of the metal building system it sells to the end customer and for supplying adequate evidence of compliance with the specifications, design criteria, and design loads to the design professional to incorporate the metal building system into the construction project. An engineer of record is not only involved in this incorporation of the metal building system into the project, but also typically has the design responsibility for the foundations, floor slabs, interior and exterior concrete masonry walls, or tilt-up walls, and the connection of these walls to the metal building framing. Engineers and architects who are interested in this growing market should consider this as an excellent opportunity to expand their professional services. MBMA will be sponsoring seminars and short courses in the near future to help inform interested design professionals on how they can better understand and interact with the metal building systems industry.

Standing Seam Roofs

The introduction and use of the standing seam roof by the metal building industry has provided one of the most efficient structural, weathertight systems available today. Over 2 billion square feet of standing seam roofing is installed annually. In fact, more than 50 percent of all commercial/industrial buildings are covered with metal. MBMA has worked with AISI over the last 25 years in sponsoring research to develop design and test procedures for standing seam roof systems. This research has provided new requirements for designing and testing purlins supporting standing seam roofs in the latest AISI Cold-Formed Specification. The bracing of purlins supporting standing seam roofs can be handled in several ways, and is one of the most important considerations for maintaining the struc-

tural stability of the system. In recognition of this significance, MBMA has worked with AISI to produce “A Guide for Designing With Standing Seam Roof Panels, CF97-1”, which addresses the design considerations for members supporting a standing seam roof.

Standing seam roofs are also providing new life for many buildings with flat roofs that have proved to be problematic. A standing seam roof can be designed to be applied directly over an existing flat, built-up roof using a substructure to provide a low-slope replacement, or a steeper slope for a new architectural appearance. The new standing seam roof will not only provide a superior weathertight covering, but life cycle cost analyses usually show them to be the best economic choice when considering lower costs involved with removing the old roof, minimal disruption of facility operations, and energy-saving capabilities of new insulation in the created “attic” space.

Durability

Metal building systems are extremely durable and require only minimal maintenance. The engineered coating systems that are available provide a long service life, even in extremely corrosive environments. The use of zinc, aluminum and aluminum/zinc alloy coatings has helped increase the life expectancy of steel cladding. In fact, a recent survey of 82 Galvalume roofs up to 22 years old located in the industrial North and along the South Gulf and Atlantic Coasts found them in excellent condition. Based on their appearance, they were projected to last 30 years or longer in most environments before requiring major maintenance. This survey supports the expectations that are the basis for the warranties typically supplied for paint coating performance. While the aluminum/zinc alloy coatings provide the corrosion protection, various types of paint coatings provide the architect with a veritable palette of cladding colors. These coatings include specialized painted fluorocarbons and siliconized polyester systems that perform extremely well, as evidenced by the warranties normally supplied to cover color retention, fading, and chalking for a specified period of time.

AISC Certification Program

As previously mentioned, MBMA will require AISC Certification as a requirement for membership beginning in the year 2000. This is a major endorsement of the quality that is expected of MBMA members and inherent in the AISC Certification program. The program ensures that a metal building manufacturer has achieved a high level of competency in all aspects of design and fabrication. The purpose of the program as stated by AISC is to “confirm to the construction industry that a Certified structural steel fabricating plant has the personnel, organization, experience, procedures, knowledge, equipment, capability and commitment to produce fabricated steel of the required quality for a given category of structural steel work.”

The certification program examines policies and procedures at each of the manufacturer’s facilities, and the application of those policies and procedures to randomly selected projects. It consists of nearly 200 questions covering the areas of general management, engineering and drafting, procurement, manufacturing, and quality control. Inspection and evaluation teams from an independent auditing firm annually observe and evaluate the manufacturer in almost every aspect of operation. In addition, unannounced and unscheduled inspections verify continuous compliance with the detailed certification standards established by AISC, which has been setting steel construction standards and writing specifications for more than 75 years. As a result of all of these measures, architects, design professionals, building code officials and the insurance industry can be assured that certified metal building systems manufacturers are capable of meeting the industry’s highest standards for product and design integrity.

Summary

Involvement in technical activities has been a hallmark of MBMA over the years. MBMA has helped advance the industry by taking the lead in sponsoring millions of dollars of research conducted by many eminent investigators at prestigious universities. This research has elevated the state-of-the-art in such areas as wind loads on low-rise buildings, tapered member analysis and design, bolted end-plate connections, and cold-formed steel design. These efforts have led to technically advanced systems that are some of the best low-rise construction alternatives available. The efficient use of materials is only surpassed by the performance of the metal buildings and the satisfaction of hundreds of thousands of building owners.

Continued advancements are planned to help take advantage of new design methodologies, new material advances, and new fabrication and construction techniques. The metal building systems of today bear little resemblance to the Quonset Huts or "tin-shed" ancestors that many still associate with the industry. This is in large part due to the progressive approach that has helped metal building systems remain on the leading edge of low-rise construction.

W. Lee Shoemaker, Ph.D., P.E. is Director of Research & Engineering with the Metal Building Manufacturers Association in Cleveland.