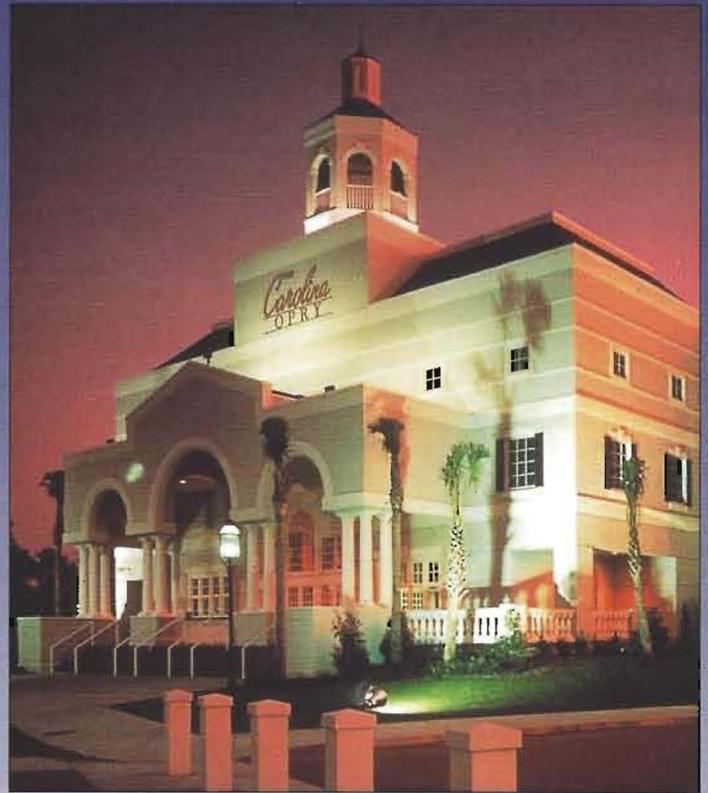




IN ASSOCIATION WITH  
THE METAL BUILDING MANUFACTURERS ASSOCIATION PRESENTS...



# AN INTEGRATED DESIGN APPROACH OFFERS FLEXIBILITY, ECONOMY, DURABILITY

## *An Evaluation of Metal Building Systems*

**M**etal building systems provide an integrated set of interdependent elements and assemblies. Yet, each system is unique—custom-designed and engineered, produced by the manufacturer, and then erected on the construction site. Interface with CAD, along with the ability to clad the buildings in brick, precast concrete, stone, wood, architectural metal, or glass, allows great flexibility in design aesthetics.

The process of creating a successful structure begins with a basic understanding of the various elements and options available on the market today, as well as energy efficiency and acoustical considerations. Once these are assimilated, design creativity can begin. With this in mind, the Metal Building Manufacturers Association (MBMA) offers this compendium, in association with the AIA/ARCHITECTURAL RECORD Continuing Education Series. Architects can earn two continuing education credits by reading the section,

studying the learning objectives, and answering the questions on page 164.

Metal building systems comprise nearly 70 percent of the one- and two-story, nonresidential building market in the U.S. The MBMA was founded in 1956 to address issues relating to structural design, fire insurance, building codes, transportation, and safety in such buildings. MBMA member companies provide engineering design, structural steel framing systems, metal wall and roofing systems, and accessory equipment for low-rise nonresidential construction. MBMA works closely with the American Institute of Steel Construction, American Iron and Steel Institute, American Society of Civil Engineers, and the model building code organizations in maintaining and improving national design standards. For more information contact: MBMA, 1300 Sumner Ave., Cleveland, Ohio 44115-2851. (216) 241-7333. Or visit MBMA's website at <http://www.taol.com/mbma>.

## LEARNING OBJECTIVES

After reading *An Integrated Design Approach Offers Flexibility, Durability, Economy* and completing the following exercise, you will be able to:

1. Identify how today's metal buildings differ from the metal building systems of the past with regard to design options and process.
2. Explain nine advantages of metal building systems design and fabrication.
3. Identify the benefits of a metal building systems industry certification program offered by the American Institute of Steel Construction.
4. Identify one or more building component types with their corresponding applications.
5. List at least four steps for preventing condensation degradation of insulation.

# METAL BUILDING SYSTEMS

The metal building systems industry was born to fulfill an urgent need—to house troops during World War II. The most famous example, the Quonset Hut, was a half-round structure that could be easily constructed by unskilled labor using only hand tools and then disassembled and transported to a new location. After the war, the first standard metal building kits were mostly utilized for industrial and agricultural purposes. By the late 1960s, the industry had gained a reputation for its economy and speed of production and delivery and was used for wider applications. The systems, however, lacked any flexibility in design. So as demand grew from architects, engineers, and building owners for greater systems flexibility, manufacturers of metal building systems retooled their factories offering more systems options. Today, metal building systems dominate the one- to two-story nonresidential building market, comprising nearly 70 percent of the market.

The great opportunity for change, growth, and development paralleled the rise of computer technology and the use of CAD systems in architecture and engineering. In effect, the term "pre-engineered metal buildings" has become a misnomer. The standardization inherent in systems-based buildings make it a natural application for computer-aided design and engineering. There are, in fact, no standard buildings anymore. Each is custom designed as a unique project.

Greater flexibility than ever before is now possible. Designers can select straight or tapered columns, variable or odd-sized bays or modules, single-slope or double-slope buildings, with centered or off-center ridges. These systems can be integrated with a wide variety of wall materials, such as block, brick, tilt-up concrete, curtain wall, or metal. Flat, conventional roof design has given way in popularity to a water-shedding design, in which a sloped roof element is a key part of the overall image of the structure. Size can vary tremendously: the average is 10,000 to 20,000 square feet, but can range to more than one million square feet.

Critical to the engineering/design process is determining the safe loads which the structure must be able to support—such as dead load, roof live load, roof snow load, wind load, seismic load, and auxiliary load. The architect should consult

local building code requirements. The MBMA publishes the Low-Rise Building Systems Manual that defines and recommends minimum design loads for metal building systems. In addition, formulas for calculating wind pressure and suction for various building geometries are given. Values of lateral, tractive, and impact loads for overhead cranes are also listed.

While computer technology has streamlined the design and engineering process, real economies still come through the fabrication of structural elements.

Completion of a metal building systems structure is possible in roughly two-thirds the time of a conventional building. Since all elements are factory fabricated, pre-cut and prepunched under controlled factory conditions, where efficiency and quality can be exercised to a much greater degree than in the field, waste material is minimized. And it is generally easier to predict erection costs and erection time than with conventional construction. Typically, the buildings are shipped within six to eight weeks from the date an order is received.

The design professional reaps the benefits of single source responsibility, since the metal building systems company takes responsibility not only for engineering and fabrication, but also the performance of the entire building shell. It is important for the design professional to ensure that the design criteria, particularly lateral drift and deflection of the primary frame and/or secondary supports, are consistent with the chosen wall materials. Manufacturers can provide a "letter of certification" with each building that assures the metal building system has been designed in accordance to specified state and local codes and/or specified project design requirements. A variety of warranties are offered on metal building systems. These may include finish warranties on roof and wall systems and weathertight warranties on roof systems.



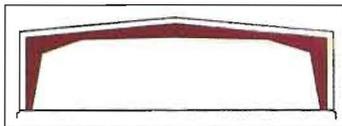
# METAL BUILDING SYSTEMS ELEMENTS

Metal building systems offer a completely integrated set of interdependent elements and assemblies, which, taken together, form the total building. Included are primary and secondary framing elements, covering components, and accessories. These building block parts come in many different configurations, as illustrated below.

## Framing Systems

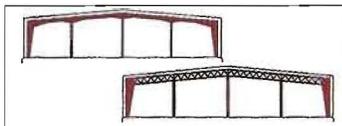
### *Rigid frame clear span:*

Provides a column-free interior or space 20 feet to 160 feet and wider. Recommended applications include auditoriums, gymnasiums, warehouses and aircraft hangars.



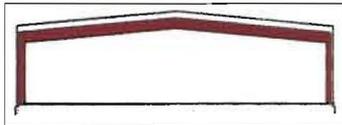
### *Ridge frame multi-span (solid web rafter) and modular open web (open web rafter) — 50 feet to 500 feet and wider.*

Used where interior columns do not impair the function of the building. Interior columns shorten the spans of the rafter beam, thereby often reducing the frame cost. Recommended applications include manufacturing facilities and warehouses.



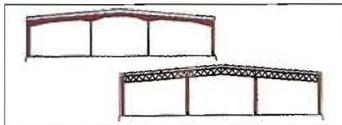
### *Flush wall clear span—20 feet to 70 feet and wider.*

Offers not only column-free interior floor space but also uniform depth columns. The secondary wall structural systems (girts) are totally flush with the interior flanges of the columns. This allows interior sidewalls to be finished without the frame columns protruding into the interior wall line. Recommended applications include retail stores, branch banks, and office facilities.



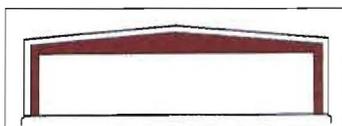
### *Flush wall multi-span—50 feet to 250 feet and wider.*

Available with solid or open web rafters. Uniform depth exterior columns with girts are totally flush with the inside column flange. Interior columns reduce span lengths, thereby reducing costs. Recommended applications are buildings where interior sidewalls are to be finished for office areas or for warehouses and distribution centers where "close to wall" palletizing is required.



### *Tapered beam straight columns—15 feet to 70 feet and wider.*

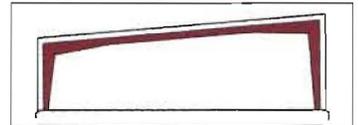
Clear span with uniform depth columns. Greater vertical and horizontal clearance at column/rafter connection than rigid frame clear span. This system is economical for narrow widths. Recommended applications include offices, retail stores, and buildings with bridge crane systems.



### *Single slope clear span—20 feet to 160 feet and wider.*

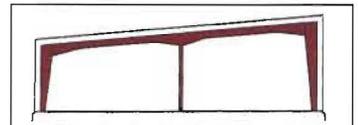
Available with solid or open web rafters. This system provides single direction roof slope for rainwater runoff control. It is

often used for shopping centers and office complexes where rainwater must be directed away from parking areas.



### *Single slope multi-span—50 feet to 200 feet and wider.*

Available with solid or open web rafters. The single slope design facilitates rainwater runoff control. This system is used in facilities where interior columns do not impair building function. Recommended applications—manufacturing, warehousing, and distribution centers, retail shopping centers, and office complexes.



### *Lean-to—10 feet to 60 feet and wider.*

Used primarily for wing units and additions to existing facilities. A lean-to can be used with any of the above framing types.



## Wall Systems

Wall systems typically consist of a wall panel and girt. Girts are cold-formed "C" or "Z" sections and are attached to the columns of the primary frame to support the wall panel against lateral loads. They may frame into the column webs, or be attached to the outer flange. Flush framing provides more usable building floor area. The panel and girt act in concert to resist pressure and suction placed on the system by heavy winds.

Panels are available in a variety of textures, with embossed and sand-finished metal available. Manufacturers stock standard colors and can obtain special colors from their suppliers to match architectural requests. Often, the exteriors of the panels are integrated with another material—brick, precast concrete, glass, stone, or wood.

Two types of wall assembly methods are available, field assembly or factory assembly.

**Field Assembled Systems.** The system consists of optional interior liner panels, exterior metal panels, and insulation, usually blanket fiberglass insulation. Advantages include rapid erection of panels, cost competitiveness and quick and easy replacement. Openings for doors and windows can be created quickly. In addition, the panels are lightweight, so heavy equipment is not required—nor are large foundations or heavy spandrels. Acoustic surface treatments can be easily added to interior panel walls at reasonable cost.

**Factory Assembled Panels.** This system consists of an outer panel and an interior face formed over an insulating core, usually a foam material. It is normally fastened outside

**METAL BUILDING SYSTEMS ELEMENTS** continued...

the girt. Panels providing insulating values are available from several manufacturers. This system has a lightweight, hard surface interior liner connected to the panels by side lap fasteners that are normally concealed to produce a clean appearance.

Two types of fastener systems are available, exposed fastener or concealed fastener systems.

**Exposed fastener systems.** Panels vary in depth and are available in widths of two feet to four feet and thickness ranges from 26 gauge to 20 gauge steel. The most common wall panel thickness is 26 gauge. Wall panels are attached to "C" or "Z" girts with self-tapping screws, self-drilling screws, or expanded fasteners, and joined to each other at their sides and ends in lap joints. Profile panels range in depth from 1 inch to 2 inches and are available in widths from 28 inches to 40 inches with varied patterns and colors.

**Concealed fastener systems.** Designed with edge joints that conceal the fasteners, the panels are available in many different profiles and finishes. These panels usually have deeper cross sections and can allow longer spans between girts.

**Roof Systems**

Roof systems are made up of two components: purlins and roof panels.

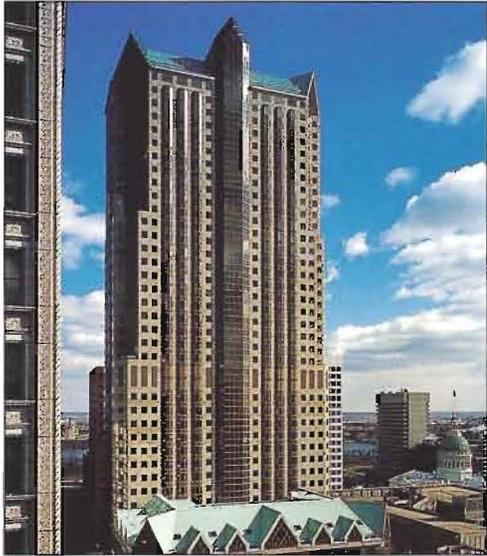
**Purlins.** Two types of purlins support the weight of the roof and any applied loads—cold-formed steel (either "Z" or "C" sections) and open web joist. The purlins work to transfer these loads to the primary structural system. The "Z" or "C" sections can either be simple spans, or more commonly used as continuous beams between frames. They can be used on spans of up to 30 feet. For spans greater than 30 feet, open web joists or deep "Z" sections may be used for purlins. Open web joists are utilized as simple spans.

**Roof panels.** Panels are fabricated from light gauge steel as a lap seam roof or a standing seam roof system. The panel of a lap seam roof is typically 1 inch to 1-1/2 inches deep, 26 or 24 gauge thick, and connected together by lapping. A sealant is installed between the panels at the sidelaps and end laps and fasteners are used to secure them. The selection of panel depth and thickness is affected by the roof load, purlin spacing, and insurance considerations.

**Standing seam panels.** The seam between two panels is made in the field with a device that produces a cold formed weathertight joint at the sidelap of each panel. The panel is attached to the purlins with a clip concealed inside the seam, which allows a secure attachment while permitting thermal expansion or contraction. Since a majority of the through-the-roof fasteners have been eliminated, a continuous single skin membrane results. Thermal spacer blocks can be placed between the panels and purlins in order to provide a consistent thermal barrier. The metal standing seam roof can be used to renovate and restore old, leaking flat roofs to better than original condition by adding a slope—in other words,

turn a flat roof into a water-shedding one. Various finishes and colors are available. The products can be used in either a structural, low slope application or a highly visible architectural metal roof situation.

**Bracing Requirements.** To complete the roof system, metal building manufacturers typically provide bracing for the purlins. Depending on the design assumption used, different types and arrangements of bracing may be utilized. Bracing systems include "straps," channels, or sag angles. All of these systems span from purlin to purlin. For a standing seam roof system, the amount of lateral support provided by the panels to the purlins has to be determined through testing, if it is to be included in the design. That is why a standing seam roof system from one manufacturer may have more visible bracing than another.



**Special Design Considerations**

**Frame shape and peak location.** Both can be important components of the design. The majority of buildings supplied today are the traditional rectangular shape, yet many other shapes are possible—L's, T's, U's, and octagons. The majority of metal buildings supplied are single slopes or gable buildings with the ridge on center of the frame. The peak can be moved off center, however, to almost any location on the frame. A single slope building can be positioned with the high or low side facing the front, depending upon drainage or architectural requirements. When frames with multiple ridges or with a valley instead of a ridge are specified, an interior drainage system will be designed by the metal building manufacturer.

**Bay sizes.** While in the past only two or three bay sizes were commonly offered, any bay size is now possible. When the building has interior columns, the interior columns can be of different spacing patterns.

**Column shapes.** Tapered perimeter columns are often the most economical choice, but straight columns can be used at the perimeters. The perimeter columns are normally fabricated H-shape and can be parallel or tapered. Interior columns can be supplied in many different shapes, including hollow structural shapes, hot rolled H-shapes, and fabricated H-shapes.

**Column heights.** Heights can vary to provide a step in roof elevation or in floor elevation.

**Accessories.** A variety of structural and nonstructural accessories can be included: insulation, gutters, downspouts, roof ventilators, roof openings, interior liner panels, wall vents, wall openings, windows, pedestrian doors, overhead doors, canopies, skylights, fascia, and trim. These elements can add aesthetic variety.

**Expandability.** Metal building systems are easily expanded. This usually involves the removal of an end or sidewall, the erection of additional structural frames, and the addition of matching wall and roof coverings. Manufacturers routinely perform assessments of adding on to a metal building system, including structural and roof drainage analysis.



## ENERGY EFFICIENCY & ACOUSTICAL CONSIDERATIONS

Energy considerations and controlling condensation is an important part of providing an energy efficient building. Condensation can lead to long-term detrimental effects including corrosion and degradation of insulation. Condensation occurs when warmer moist air comes in contact with cold surfaces such as framing members, windows and other colder regions within the insulation envelope. Warm air, having the ability to contain more moisture than cold, loses that ability when it comes in contact with cold surfaces or regions. When this happens, excessive moisture in the air is released in the form of condensation. If this moisture collects in the insulation, the insulating value is decreased since wet insulation has about the same heat conductance value as water. Condensation problems are most likely to occur in climates where temperatures frequently dip below 35° F over an extended period of time.

A practical guide to providing energy efficiency and protection against condensation within a wall or roof assembly includes:

- Knowledge and control of the air temperature and relative humidity inside the building and knowledge of outdoor temperatures.
- Installation of an integral vapor retarder on the warm side of the assembly (under winter conditions). The main function of the vapor retarder is to slow down the flow of moisture through a roof or wall assembly. Permeability is measured in perms. The lower the permeance, the more effective the vapor retarder is. A 0.02 perm is recommended.
- Installation of sufficient insulation thickness (between the outside skin and the vapor retarder) to keep the temperature of the vapor retarder above the dew point temperature of the environmental air inside the building.
- Whenever possible, vent the insulated spaces to the outdoors to provide an escape path for moisture that gets past the vapor retarder.

**Acoustics.** Another important consideration in selecting insulation is acoustics, often viewed as a problem with metal building systems. Both the

level of interior and exterior noise can be greatly reduced by several types of thermal insulation. The insulation's noise absorption properties help prevent the transmission of exterior noises, such as rain, hail, aircraft, and traffic. In addition insulation helps to quiet noise within the building by absorbing reverberating sound. This is especially important in manufacturing buildings where there may be high noise levels.

Types and thickness of insulation have the largest influence on thermal efficiency of a building as insulation traps still air and slows down conductive heat transfer. Two basic types of insulation are most commonly used for metal building systems: fiberglass, and rigid board.

Fiberglass blankets are the most common types of insulation used in roof and walls of metal buildings because of their low cost, fire and sound resistance, and ease of installation. The insulation is placed on the outside of the purlins and girts and the panels are applied over them. In the case of the standing seam roof, an "insulation block" may be placed over the purlins to eliminate any heat loss due to the compressing of the blanket insulation.

A second form of roof insulation is rigid board, usually made out of polyisocyanurate material. Most often a metal liner panel is installed over the purlins, the rigid board is laid in place with a vapor barrier, and the standing seam roof installed over it. The clip rests on a bearing plate over the insulation and the fastener goes through the board insulation into the underlying structure. This is referred to as a "composite roof."

## DESIGN FLEXIBILITY AND AESTHETICS

Current uses of metal building systems include malls, shopping centers, offices, plants, warehouses, recreational centers, or any other use appropriate for a low-rise building. What distinguishes this type of construction today is a surprising aesthetic variety, due to the flexibility allowed through different combinations of the system's basic elements as well as the ability to clad the buildings in brick, precast concrete, stone, wood, or glass. Following are several examples of the aesthetic qualities possible to achieve through the use of metal building systems.

*Continued...*

## CERTIFICATION

Designers may want to give consideration to the American Institute of Steel Construction (AISC) comprehensive certification program for the metal building systems industry. To maintain a high level of credibility, the program includes a rigorous third-party examination of the engineering and manufacturing policies and procedures of metal building systems manufacturers, as well as quality assurance and control standards.



**DESIGN FLEXIBILITY AND AESTHETICS** *continued...*

**Bay Industries Corporate Headquarters  
Green Bay, Wisconsin**

The new corporate headquarters for Bay Industries illustrates the versatility of metal building systems. Located on 26 acres of land in Green Bay, Wis., the building consolidates the operations of the company into a new facility. It was designed to be functional and economic and accommodate future expansion—and to meet the requirement of Bay Industries President Arnie Schmidt to be “housed in the most attractive building in Green Bay.”

Designed by Steve Klessig, architect, of Kaukauna, Wis., the building makes extensive use of limestone, masonry and glass to achieve a traditional yet timeless appearance. It features a 5,000-square-foot, octagonal-shaped, skylight entrance, flanked by two 30,000 square foot office wings. A 130,000 square foot manufacturing and warehouse building extends south of one of the wings.

“We looked at all the various methods of construction,” Klessig says, “including conventional steel, precast concrete, masonry systems, and some panel systems. We recommended a metal building system not only because it was the most economical, but because it offered the greatest flexibility in creating custom designs and architectural elements.”

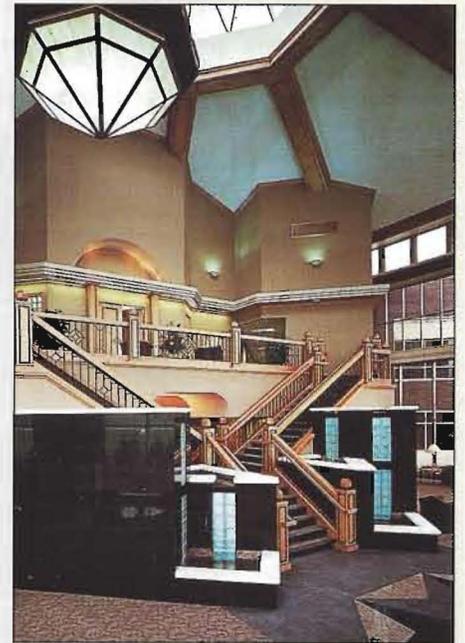
The focal point of the design is the octagonal lobby, which rises 58 feet and is topped by a glass dome. Radiating from it are the two office wings, which visually creates a sense of symmetry and balance. The use of concrete, masonry, and glass lends a banded appearance to the exterior.

Adding to the visual variety is the roofing system. “We didn’t want the silver-colored roof to be entirely visible, but thought we could create an interesting look if we emphasized certain parts of the roof,” Klessig says. “So we accented the canopy, the hipped roof on the octagonal entranceway, and two front building corners and the middle sections of the office wings with a concrete tile roof. This technique created a dynamic contrasting appearance via the use of different materials.”

Soon after construction began, the Schmidts decided to enlarge the warehouse by 62,000 square feet, a simple process because of the metal building

systems construction. “Since the structure was already designed for future expansion,” Klessig says, “all we had to do was order additional framing and roofing materials. It was easy to duplicate the frame design because the width of the building hadn’t changed. The engineering was already complete. It just became an additional fabrication job for the metal building systems manufacturer.”

The architect, contractor, and owner agree that the project, which was finished on time and within its budget, benefited from the single-source responsibility that defines metal building systems construction. The group worked closely with the metal building systems manufacturer and its structural engineers from the beginning—and throughout—the project.





**DESIGN FLEXIBILITY AND AESTHETICS** continued...

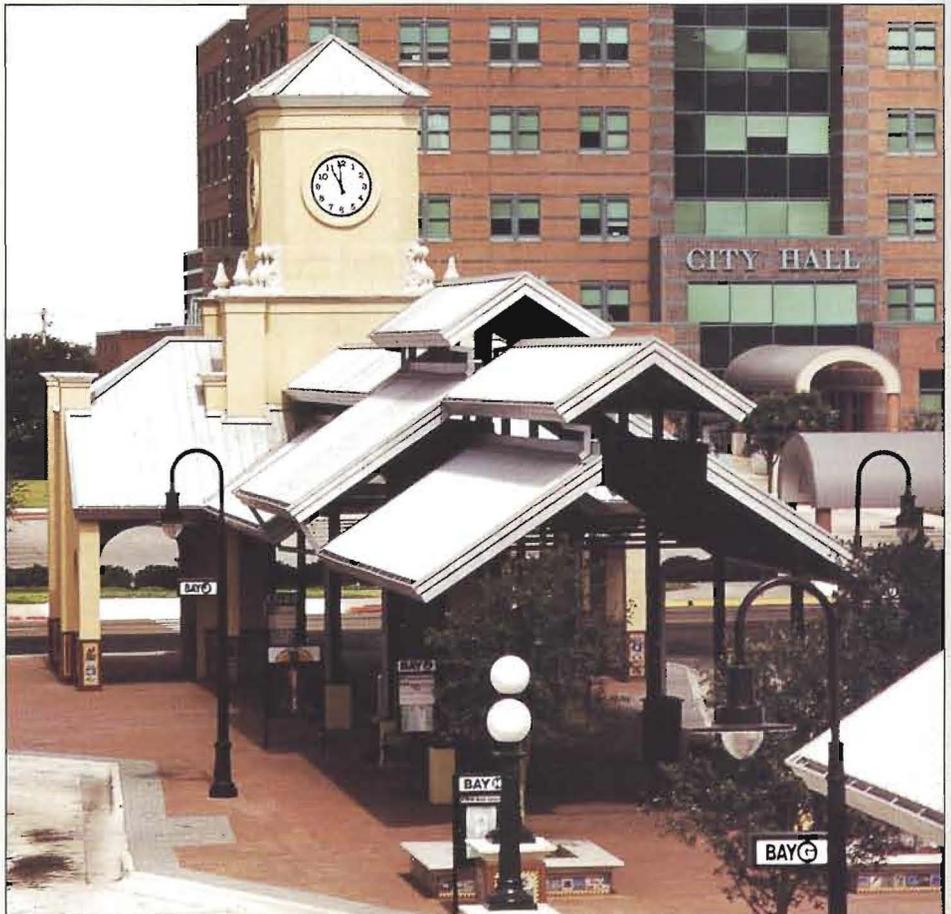
**Bouchaine Vineyards  
Napa, California**

In Napa, Calif., the Bouchaine Vineyards used the slab of its original building and on it reconstructed a new metal building systems winery. Architect William Turnbull Associates, of San Francisco, obtained great visual variety through the use of a sloping shingle roof, exterior walls of re-sawn redwood wine barrels, windows, stone façade detailing, and a recessed entrance. Three cupolas allow for ventilation. The utilitarian nature of the interior is evident in the work areas, while the offices have more elegant wood and concrete masonry partitions. Construction of the 24,000-square-foot winery was phased so as not to disrupt the winery's operations.



**Staples Street Station  
Corpus Christi, Texas**

The Staples Street Station was the first new station designed when the regional transportation authority decided to consolidate transfer points. Designed by John R. Wright, Architect, the station features a metal building systems roof, which gains visual attraction by fragmenting its sloped elements. This shed-like structure provides shade and protection from rain for transit passengers; about 3,000 bus passengers and 13 bus routes pass through the transit stop during weekdays. It was designed in an open concept approach so that a clear line of sight is provided through the entire structure, a design to promote a sense of personal security. The metal roofed shed is connected to a masonry head house featuring a clock tower.





## LEARNING OBJECTIVES

After reading *An Integrated Design Approach Offers Flexibility, Durability, Economy* and completing the following exercise, you will be able to:

1. Identify how today's metal buildings differ from the metal building systems of the past with regard to design options and process.
2. Explain nine advantages of metal building systems design and fabrication.

3. Identify the benefits of a metal building systems industry certification program offered by the American Institute of Steel Construction.

4. Identify one or more building component types with their corresponding applications.

5. List at least four steps for preventing condensation degradation of insulation.

## QUESTIONS

1. List at least 10 attributes that illustrate flexible design options in metal buildings.

Answer

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2. What role does computerization play in metal building design?

Answer

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3. Describe the cost and time efficiencies that make metal buildings attractive options.

Answer

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4. What does the American Institute of Steel Construction comprehensive certification program cover?

Answer

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5. List the framing options suggested for each of the following applications:

a) Auditoriums and gymnasiums:

Answer

b) Manufacturing facilities and warehouses

Answer

c) Retail stores, branch banks, and office facilities

Answer

d) Office areas

Answer

e) Wing units and additions to existing facilities for any of the other framing types

Answer

6. Outline a four-prong strategy for preventing condensation within metal wall and roof assemblies.

Answer

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1. Metal building systems are composed of mutually dependent components and assemblies including primary and secondary framing, cover, and accessories. Systems can be produced in a variety of colors and shape. Designers can select straight or taper columns, variable- or odd-sized bays or modules, single slope or double slope buildings with centered or off-centered ridges. These systems can be integrated with conventional wall materials, such as block, brick, tilt-up concrete, or pre-cast metal walls. Metal building systems roofs are designed to shed water. Size can range to over one million square feet. 10,000 to 20,000 square feet, but can range to over more than one million square feet.

2. Programs can now be easily standardized to fit the structural types, standard loads, and load combinations that had formerly been laboriously cranked out on a desk calculator. The structural analysis, design, bill of material, fabrication drawings, and erection drawings are usually produced by computer.

3. Metal building systems construction takes place in the factory, a process which improves quality, reduces waste, and saves on typical job site material costs. Strength-to-weight ratios are maximized. Metal systems design and fabrication saves up to a third of the construction and erection time of non-metal buildings. Occupancy can occur sooner. Manufacturers test their products. Buildings are packaged and shipped to the jobsite. The manufacturer also sends a comprehensive parts list and erection drawings to the erector or building/contractor. Further savings are realized because a less extensive foundation is required by metal building framing systems with walls that are nonload bearing.

4. The American Institute of Steel Construction comprehensive program for the metal building systems industry requires a rigorous third-party examination of a manufacturer's engineering and manufacturing policies and procedures, as well as its quality assurance and control standards.

5. a) Rigid frame clear span  
b) 1. Rigid frame multi-span (solid web rafter) and modular open web (open web rafter)-50 feet to 500 feet and wider  
2. Single slope multi-span-50 feet to 200 feet and wider  
c) 1. Flush wall clear span-20 feet to 70 feet and wider  
2. Tapered beam straight columns-15 feet to 70 feet and wider  
d) 1. Flush wall multi-span-50 feet to 250 feet and wider  
2. Single slope clear span-20 feet to 160 feet and wider  
e) Lean-to-10 feet to 60 feet and wider

6. a) Control the indoor air temperature and humidity particularly relative to outdoor temperatures.  
b) Install an integral vapor retarder with a 0.02 perm on the war side of the assembly  
c) Install sufficient insulation  
d) Vent insulated spaces to outdoors.

## ANSWERS

Answers refer to *An Integrated Approach Offers Flexibility, Economy, Durability* (page 152) and to the questions on this page. After completing the answers, fill out the self-report form (page 248) and submit it to receive two AIA Learning Units.