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METAL BUILDING SYSTEMS

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GENERAL INFORMATION

1.1 Introduction

During the last two decades, metal building systems have become an important part of the building construction industry. Today, almost 50% of the low-rise non-residential buildings under 150,000 square feet constructed in the United States, are metal building systems.[1] Low-rise non-residential buildings include, one to two story, manufacturing, commercial, community and agriculture buildings. Historically, metal buildings were typically found only in industrial parks and agricultural areas, but with recent advances in materials, architectural treatments and design methods, they are now evident almost everywhere in the community.

Although metal building systems have become a moving force in its market, significant resistance to their utilization still exists in many areas. Many communities have restrictive covenants and zoning regulations which limit their use, and many public officials still consider them cheap, unsafe and temporary in nature. This attitude towards these buildings also exists in the conventional building construction design professional community, many of whom do not even consider the professional engineers who design metal building systems to be true professionals.

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[1] Metal Building Manufacturers Association, MBMA Fact Book, Cleveland, 1987, p 1.

However, some of these attitudes are starting to change. The Metal Building Manufacturers Association (MBMA) has performed extensive research in many areas, such as wind loading and insulation effectiveness, which has not only resulted in some changes to current standards, but has also given the industry a measure of respectability with some design professionals. In addition, their cost competitiveness has also made them very attractive to many architects, who now routinely consider them in their design process. Additionally, a large metal building components industry has recently developed, which has created a hybrid structure that is about half metal building system and half conventional construction. As a consequence, the line between a pure metal building system and conventional construction has become very hazy.

This report will examine the metal building systems industry, investigate the reasons for its growth, identify some potential problem areas and attempt to forecast its future. It will also investigate some of the myths regarding metal buildings and some of the reasons why a poor opinion of them still exists.

1.2 The Evolution and Growth of the Metal Building Industry

In one form or another metal buildings have been around since the mid 1800's, when, in order to satisfy the lack of housing during the Gold Rush, pre-fabricated metal houses were manufactured in New England and shipped to California.[2] This initial use of the metal buildings did not

[2] Metal Building Dealers Association, and Metal Building Manufacturers Association, Metal Building Systems, Dayton, 1980, p 2.

experience long term success however, because with the excessive shipping costs which were incurred at the time in transiting around Cape Horn, they could not compete with the local lumber industry, once it was established.

The first significant manufacturer of standardized metal buildings was established in 1917, in Cleveland, Ohio.[3] This firm, which still exists today as the Austin Company, produced ten standard designs. An owner desiring to purchase one of these buildings could select one of the designs from a catalog and it was shipped to him unassembled. He then had to either assemble it himself or hire a contractor to do it. The company also established district sales offices around the United States to market its products.

During the 1920's and 1930's, the industry continued to slowly expand. However, it was during World War II that the metal buildings first became widely used. The most famous of these buildings was the Quonset Hut, which became the standard building used by the military during the war. These buildings, which were made of galvanized cold-formed corrugated sheet steel attached to a semi-circular steel frame, could be easily assembled and disassembled by unskilled labor. They were found to be extremely adaptable and were used for every imaginable application in every theater of the war.[4]

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[3] Ibid.

[4] Metal Building Dealers Association, op. cit., p 3.

Following World War II, the manufacturers of metal buildings began marketing their products through dealer/contractors, who were specially trained to both market and erect the buildings. This became particularly important as the structures became larger and more sophisticated, thereby requiring equipment and expertise not readily available to the average user. By 1947, sales of these buildings reached over $25 million.[5]

As the industry grew and became more sophisticated, the name pre-fabricated metal building was changed to pre-engineered metal building to highlight its increased complexity. Technological improvements, such as the coating of sheet steel before forming, also helped to increase the efficiency of the industry. Throughout the 1950's the industry continued to grow at an increasing rate and by 1966 annual sales reached over $250 million.[6]

Between 1975 and 1979 the Metal Building Manufacturers Association (MBMA), with the American Iron and Steel Institute (AISI) and the Canadian Steel Industries Construction Council, sponsored a series of comprehensive wind tunnel tests at the University of Western Ontario. These tests were conducted, because it was felt that the requirements of American National Standards Institute (ANSI) standard A58.1, published in 1972, greatly overestimated the wind forces acting on these buildings.[7]

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[5] Pratt, Donald H., "Pre-Engineered Metal Buildings: The Story Behind Their Rapid Growth", Civil Engineering, New York, March 1983, p 53.
[6] Ibid.
[7] Ellifritt, Duane S., "Performance of Metal Building in Houston-Galveston Area", Proceedings of Specialty Conference - "Hurricane Alicia", Aerospace Division, EM Division and ST Division ASCE, Galveston, august 16-17, 1984, p 117.

The results of this work were published in the 1981 Metal Building Systems Manual. The 1986 revision of this publication is the standard to which these buildings are designed today.

During this period most of the major manufacturers upgraded their plant capabilities, making them larger, highly automated and better equipped to custom fabricate parts.[8] They also greatly improved their geographical distribution system, thereby reducing problems encountered with shipping large members. A growth in use of custom designed projects using metal building systems led many manufacturers to staff select teams of registered professional engineers devoted exclusively to custom design.

Today, the term metal building system is used to describe this type of construction, since the building is designed as an integrated system and not a collection of independent parts. All of the major manufacturers now use computers extensively in the design process, which allows buildings to be individually tailored to the needs of the user.[9] Designers can now produce complete project designs, which meet the model building codes, including sections, structural calculations, bill of material, cost estimate and floor plans, in less than a day.[10] Many manufacturers also have their fabrication shop networked directly into the designer's computer, for rapid transfer of the production order. With the use of the

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[8] Pratt, Donald H., "Metal Buildings are Industrial Strength", Building Design and Construction, Boston, March 1983, p 86.

[9] "Special Report: Metal Buildings", Consulting Engineer, Barrington, December 1985, p 35G.

[10] Vonier, Thomas, "Beyond Shade and Shelter", Progressive Architecture, Cleveland, March 1982, p 132,

same exterior finishes used in conventional construction, modern metal building systems are no longer limited to the simple single story industrial buildings. They are now being used in wide variety of applications, including shopping malls, banks, offices, churches, public buildings, and large recreational and entertainment facilities.[11] Figure 1.1 shows the breakdown of the end uses of metal buildings in 1986. Improvements in corrosion prevention, such as Galvalume, siliconized

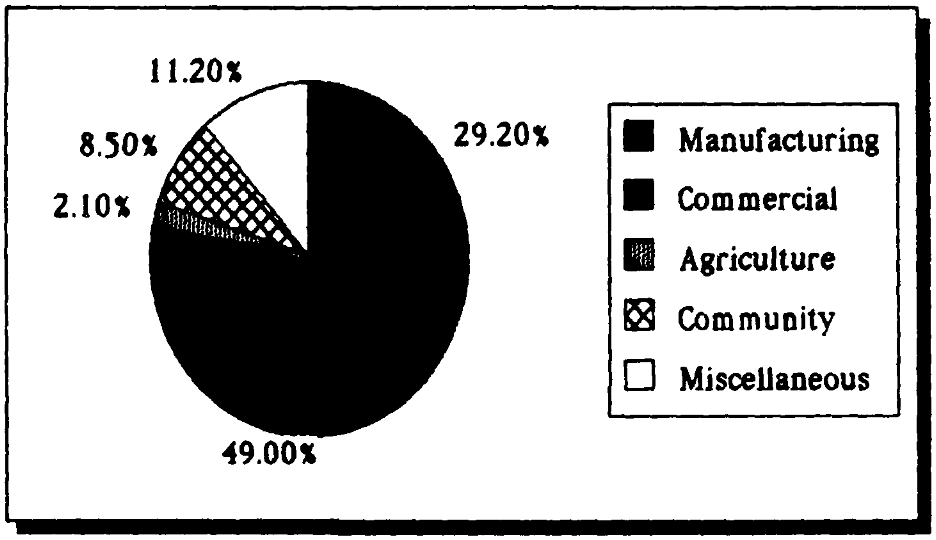

Figure 1.1 - 1986 Metal Building Systems End Uses[12]

polyester paints and fluorocarbon-based plasitisol laminate coatings, have greatly increased the useful life of these buildings, with 20 year warranties being common.[13] In addition, facilities can now be constructed with clear spans of up to 400 feet[14] and industry analysts

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11 Pratt, Civil Engineering, op. cit., p 52.

12 Metal Building Manufacturers Association, MBMA Fact Book, op. cit., p 5.

13 "Special Report: Metal Buildings", op. cit., p 35L.

14 Behlen Manufacturing Company, Behlen S-Span Building and Roof Systems, Columbus, p 2.

forecast buildings with up to 10 stories in the future[15]. The industry has continued to grow and in 1986 sales reached over $1.4 billion[16]. Figure 1.2 shows the increase in metal building systems share of the low-rise, non-residential building market under three stories and 150,000 square feet, from 1955 to 1985.

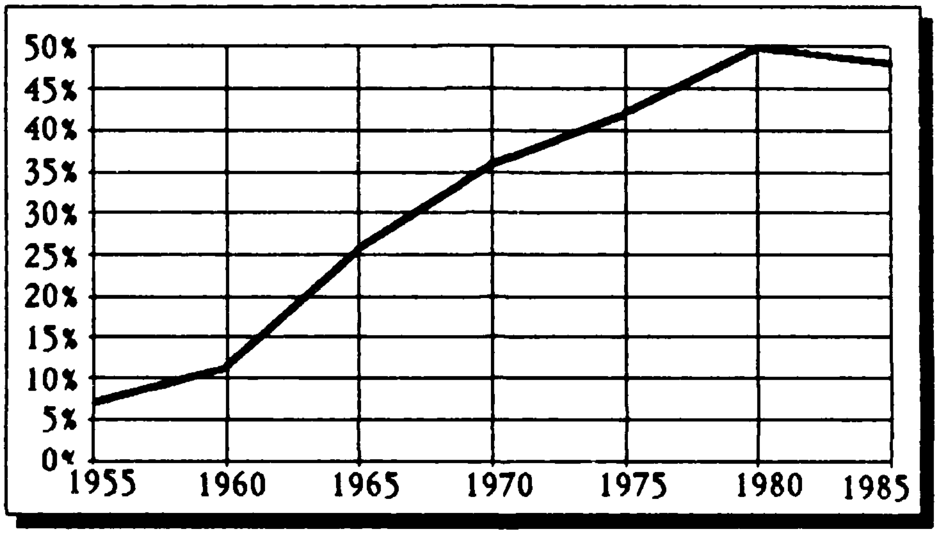

Figure 1.2 Growth of Metal Building Systems[17,18]

In 1956, the Metal Building Manufacturers Association was formed to fund basic research and promote the benefits of the industry. In 1987, it represented 25 member manufacturers, with 64 manufacturing plants, and 9,379 builder contractors[19].

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15 "Special report: Metal Buildings", op. cit., p 35G.
16 Metal Building Manufacturers Association, MBMA Fact Book, loc. cit.
17 Ibid.
18 Pratt, Civil Engineering, op. cit., p 53.
19 Metal Building Manufacturers Association, MBMA Fact Book, op. cit., p 6.

1.3 The Metal Building Systems Industry

The metal building systems industry functions very differently than the rest of the construction industry. In fact, in many areas it functions like the automobile industry, with an organized manufacturer, dealer, contractor and erector system. In many cases, one company may act in several of these capacities at the same time, that is, the manufacturer may act as the dealer or the contractor may act as the erector. The Metal Building Systems Association provides the following definitions of each of these parties[20].

> "Manufacturer - The party that designs and fabricates the materials included in the metal building system in accordance with the order documents.
>
> Contractor - The party that has responsibility for providing the materials and erection of the metal building system as specified by the contract documents.
>
> General Contractor - The party that has the overall responsibility for providing all materials and work for the construction project, including the metal building system, as specified by the contract documents.
>
> Erector - The party that erects the metal building system. Either dealer, contractor, general contractor or another party working under a subcontract may act as erector.

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20 Metal Building Manufacturers Association, 1986 Low Rise Building Systems Manual, Cleveland, 1986, p 122.

Dealer - The party that orders and purchases the metal building system from the manufacturer for resale. Dealer is an independent contractor and is not an agent for the manufacturer."

Although the Dealer is not a direct representative of the manufacturer, he is usually required to perform certain functions for them. He is normally required to promote the sale of the manufacturer's products, investigate customer complaints, advertise in the local "yellow pages", using the company trademark and maintain at least one staff member who has received training on the products and services offered by them. In return, the manufacturer agrees to provide basic building literature, sales promotional material, design manuals and erection guides. A copy of a typical Dealer sales agreement is provided in Appendix A.

1.4 The Systems Concept

A system can be defined as an assemblage or combination of things or parts forming a complex or unitary whole[21]. A metal building system clearly meets this requirement, but so does conventional construction. What sets the metal building system apart is that the whole is greater than the sum of the parts. In a conventional building, the load path of each of its elements is vertically aligned, that is, each member supports

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[21] Urdang, Laurence, The Random House College Dictionary, Random House, New York, 1973, p 1335.

only those members which are located above it.[22] This is not the case in a building system. The foundation, steel frame, girts, purlins, covering and bracing all act in conjunction with each other to support the structure. Figure 1.3 illustrates this concept. Whereas the frame of a

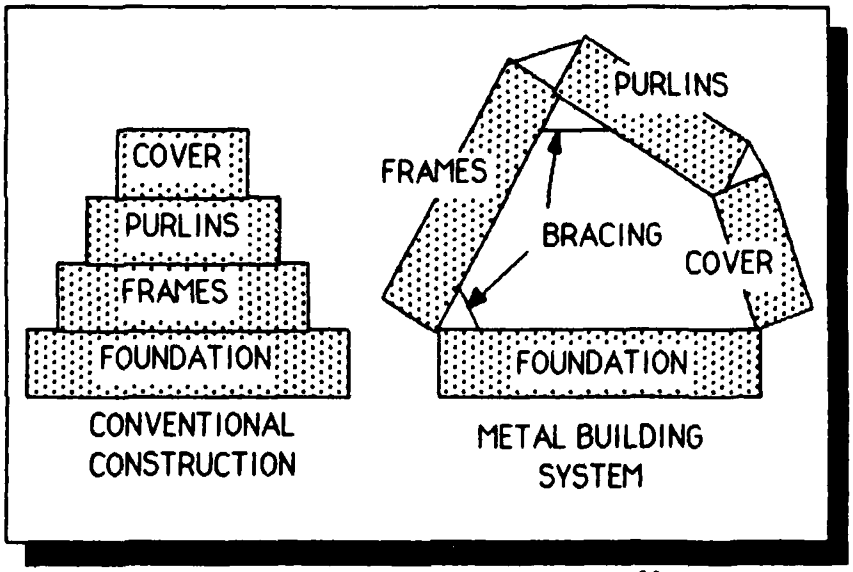

Figure 1.3 - Load Path for Buildings[23]

conventional building must be able to support the live and dead loads virtually on its own, the frame of a metal building system uses this mutual support to carry the load.

The key factor in metal building system design is that it must be designed as a system. The members are designed as if they are located in the completed building, with all mutual support and bracing in place. This is particularly important, because many members in metal building

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22 Ellifritt, Duane S., "What Makes a Building a System?", 16th Metal Building Systems Industry Exposition, Metal Building Manufacturers Association, Cleveland, January 18, 1981, p 3.
23 Ibid., pp 3-5.

systems, such as C or Z purlins, are not symmetrical about the axis of loading. This leads to twisting or sideways movement of the members, which is not normally encountered in conventional construction. Also, since plate girder tapered rigid frames are often used as the main structural members and they are characterized by great strength in the direction normal to loading and little in the perpendicular axis, bracing these members properly is critical. Therefore, the parts of a metal building system can be much lighter and less expensive.

There is an important factor which must be considered as a result of this high degree of interdependency. Metal building systems are particularly vulnerable to wind loads while under construction, and great care must be taken to ensure that temporary bracing is adequate or failure of the incomplete structure may occur.

CHAPTER TWO
COMPONENTS OF THE METAL BUILDING SYSTEM

2.1 Introduction

Although metal building systems are designed to behave as an integrated system during loading, they are made up of three main components, the structural system, the wall system and the roof system.[24] These components are then connected together using screws, bolts, tie rods and knee braces. The structural system refers to the major load bearing components, which supports the structure in two dimensions. The two structural systems most often used in metal building systems are cold-rolled shapes in small one to two story buildings and tapered rigid members in larger ones. On the other hand, the wall and roof systems,

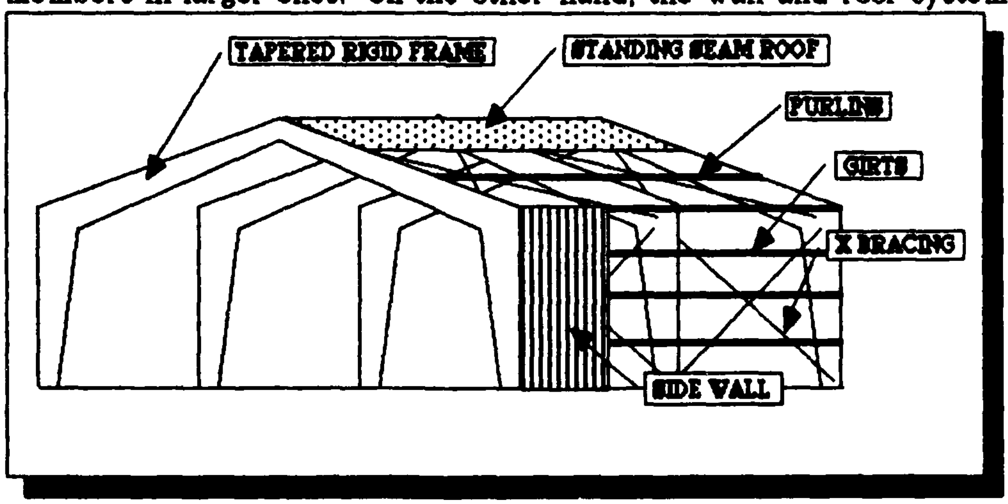

Figure 2.1 - Components of the Metal Building System

which are typically made of cold-formed steel, provide weather protection and structural rigidity in the third dimension. Figure 2.1 illustrates the basic metal building system nomenclature.

[24] Metal Building Dealers Association, op. cit., pp 31-37.

Metal building systems have many terms and definitions which are unique to the industry. Therefore, a copy of the glossary used by one manufacturer is included in Appendix B, to improve their understanding.

2.2 Tapered Rigid Frames

Although tapered rigid members have been used for many years, it is only since 1981 that a design method specifically formulated for these members has been available.[25] This was as a result of research sponsored by MBMA in 1977. The previous method, published by the American Institute of Steel Construction (AISC), was based on limited research and tended to be very conservative.

Unlike constant cross-section members, tapered rigid frames are structural members whose design places the maximum amount of

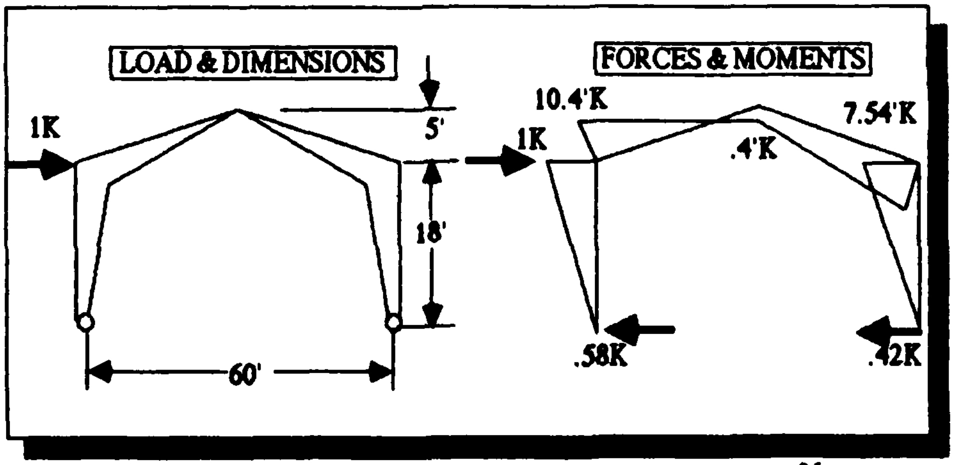

Figure 2.2 - Tapered Rigid Frame Loading Example[26]

[25] Lee, George C., R. L. Ketter, and T. L. Hsu, The Design of Single Story Rigid Frames, Metal Building Manufacurers Association, Cleveland, 1981, p1.
[26] Lee, op. cit., p 45.

strength at the locations of maximum moment (see Figure 2.2). This is done by varying the cross section along the length of the member and proportioning it so that it realizes its allowable elastic stress at several sections along its length simultaneously[27]. This process significantly lowers the weight of the members and thereby reduces the building's dead load and material cost. The design and fabrication of tapered members is however, more complex and costly, but the benefits far outweigh the disadvantages, when applied to metal building systems. This is primarily due to the repetitive nature of the industry. The building systems are designed with maximum flexibility, so that the same members can be used in many different applications. Members can then be designed, fabricated and stockpiled in quantity until needed.

Tapered members can be fabricated in a number of ways. The most common method is by welding three steel plates together into a plate girder, with the web plate being tapered along its length[28]. They can also be made by first cutting a hot-rolled beam along an axis not parallel to the flanges. The two pieces can then either be reversed and welded together or welded to a hot-rolled member that has been cut parallel to the flanges. Two brake-formed channels can also be welded back to back or a tapered truss girder can be made using structural tees. Once the tapered member has been made it must then have end plates attached.

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27 Lee, op. cit., p 3.

28 Lee, op. cit., p 6.

One of the advantages of using tapered plate girders is that the bottom flange can be a different thickness than the top. This allows additional flexibility in design, particularly when the depth of the member is an important consideration.

Typical primary frame types used by manufacturers are provided in Appendix C. The parameters for buildings, using that manufacturer's automated design system are also included.

2.3 Cold-Formed Steel

Cold-formed steel has been used in manufactured products for over 130 years[29]. Some of the most common uses have been in automobiles, railway coaches, storage racks, highway products, drainage facilities and metal buildings. Cold-formed steel used in buildings is designed using AISI Specification for the Design of Cold Formed Steel Structural Members, which is accepted by all three model building codes used in the United States[30]. In addition, cold-forming causes strain-hardening of the steel, which results in it being stronger than before forming.[31]

Cold-formed sections are usually fabricated by forcing the coiled steel sheets through a series of rollers that progressively form it into the required shape. Most cold-formed steel used in metal building systems is coated before forming, which further increases the efficiency of the

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29 Yu, Wei-Wei, Cold-Formed Steel Design, John Wiley & Sons, New York, 1985, p 2.

30 Yu, op. cit., p 26.

31 Vonier, Thomas, op. cit., p 130.

process. Up to 300 linear feet of sheet per minute can be produced, but the normal rate varies between 70 and 150 feet per minute, depending on the number of rollers and the complexity of the section. The usable thickness of steel sheets range from about 0.0149 to 0.25 inches[32]. Two types of members are produced, individual structural framing members, and panels and decks. Cold-formed steel can also be fabricated using a press brake for simple configurations and a bending brake can also be used in some cases.

Individual structural framing members can be used to provide the primary structural members in buildings or can be used to supplement hot-rolled shapes. The most common shapes are channels, Z-sections, angles, hat sections, I-sections, T-sections and tubular members. Generally, these members range in thickness from 0.048 to 0.25 inches and in depth from 2 to 12 inches. One of the great advantages of many of these shapes, particularly the Z-section, is that they fit inside of each other for easier transportation and storage. The Σ-section has also been found to possess superior load carrying capacity and larger torsional rigidity than standard channels[33].

Since many cold-formed shapes are unsymmetrical along the axis of loading, some understanding of how they react under load should be included. When a symmetrical section is loaded, it normally deflects in the direction of the load until some critical load causes buckling. This is not true of unsymmetrical cold-formed shapes. These sections begin to

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32 Yu, op. cit., p 1.

33 Yu, op. cit., p 4.

translate and deform immediately upon loading. The nature and magnitude of this movement is a function of the shape of the member and the restraint condition. Figure 2.3 illustrates an exaggerated example of the movement of channels and Z-purlins under load, both when the top flange is restrained and when it is unrestrained.

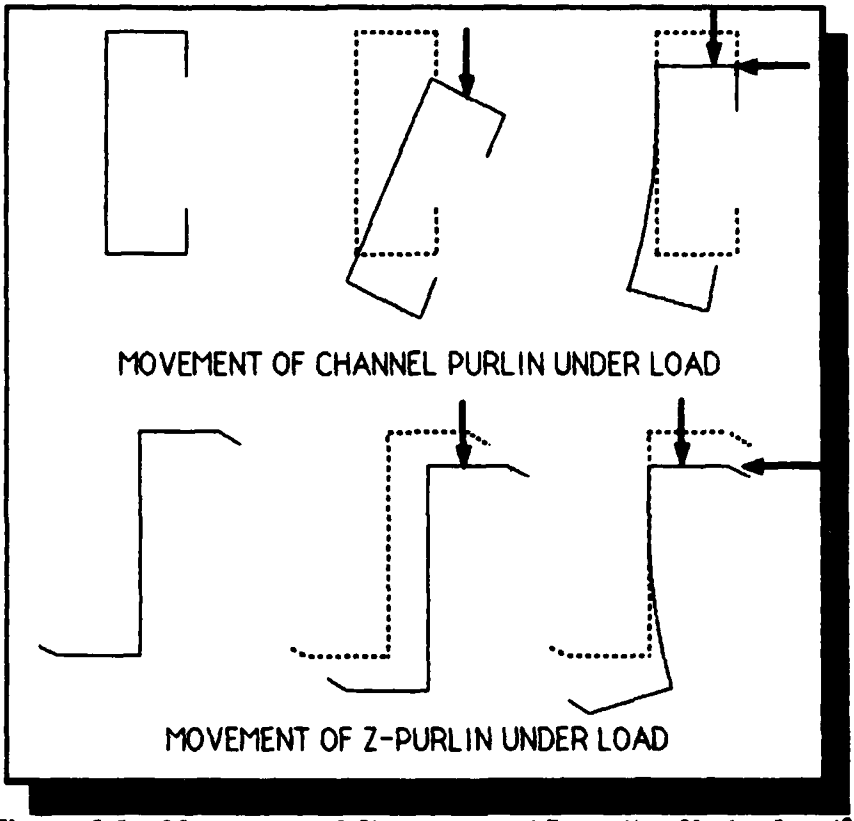

Figure 2.3 - Movement of Channels and Z-purlins Under Load[34]

Sheet steel is generally used for wall panels, floor decks and roof decks. The sheets are formed into corrugated panels, which can resist large loads in the direction normal to the panel. Early corrugated panels were simple arc or trapezoidal in shape. However, advances in forming

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[34] Ellifritt, 16th Metal Building Systems Industry Exposition, op. cit., pp 8-9.

technology and design methods have produced panels which have complex sections. Examples of typical wall and roof panel are illustrated in Appendix D. These panels provide both a weathertight exterior surface and the lateral structural stiffness and support needed to keep the structural framing members in proper position. They also provide substantial shear strength for resisting wind and snow loads. The panels are fabricated so that they fit into each for easier shipping and storage, and have interlocking connections to ensure structural integrity. Panel thickness usually ranges between 0.018 to 0.075 inches, with depths of 1.5 to 7.5 inches.[35]

2.4 Standing Seam Roof System

Although it is basically made of cold-formed steel, this system, which was first introduced at the 1934 Chicago World's Fair, warrants additional attention. A standing seam roof is a series of roof panels that are connected to the roof purlins by metal clips, which are hidden below a raised pressed seam. An entire building can be covered with a standing seam roof, without any penetration by fasteners.[36] These seams are normally formed by a mechanical, electrical or pneumatic seamer and are extremely water-tight. An additional feature of this roof system is its ability to accommodate thermal expansion and contraction. This is a result of the way the arrangement of the clips that hold the roof in place allow the panels to float with extreme temperature changes.[37] These

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[35] Ibid.

[36] Pratt, Civil Engineering, op. cit., p 55.

[37] Metal Building Manufacturers Association, MBMA Fact Book, op. cit., p 4.

roofs are not only used in metal building systems, but are also being specified as replacements for worn out membrane roofing.

CHAPTER THREE
DESIGN CONSIDERATIONS

3.1 Low Rise Building Systems Manual

The 1981 edition of the Metal Building Systems Manual, published by MBMA, incorporated many technological and research advances in building systems design, and standardized design within the industry. The current version of this manual is the 1986 Low Rise Building Systems Manual. This manual has five major sections, Design Practices, Commentary, Common Industry Practices, Nomenclature and the Appendix. It also has an extensive bibliography and index, and includes a guide specification.[38]

The Design Practices section specifies the standards to which metal buildings systems should be designed. It includes the design criteria for each load situation, combinations of loads and some design examples.

The Commentary section provides background information for each load situation specified in the design practices section. It is used in combination with that section to perform a specific design.

Common Industry Practices describes the metal building system industry and defines the design responsibilities of the owner, builder and manufacturer. It also specifies the materials standards and fabrication tolerances that are to be met in the manufacture of the building system. Finally, it gives erection standards to be followed.

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[38] Metal Building Manufacturers Association, 1986 Low Rise Building Systems Manual, Cleveland, 1986.

The Nomenclature section provides a detailed dictionary of the terminology used in metal building systems, some of which is unique to the industry.

Finally, the Appendix provides additional information which might be helpful in obtaining a better understanding of metal building systems design criteria and better ways to enhance the product. It includes sections on tapered members, bolted end-plate connections, energy conservation, wind loads, wind uplift ratings, lateral deflections due to wind, system fire ratings, crane systems and supports, roof expansion and contraction, addresses of technical organizations, and wind, snow, seismic and rain data by county.

3.2 Loads

3.2.1 Definitions

The following definitions are provided in order to better understand the effect of loading on a metal building system:[39]

> "Building dead loads - The weight of the building system, such as roof, framing and covered members.
>
> Collateral loads - The weight of additional permanent materials other than the building system, such as sprinklers, mechanical systems, electrical systems, partitions, and ceilings.

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39 Ibid., p 6.

Roof live loads - Loads that are produced (1) during maintenance by workers, equipment, and materials, and (2) during the life of the structure by movable objects but do not include wind, snow, seismic or dead loads.

Roof snow loads - The vertical load induced by the weight of snow, assumed to act on the horizontal projection on the roof of the structure.

Seismic loads - The lateral load acting in any horizontal direction on a structural system due to the action of an earthquake.

Wind loads - The load caused by the wind from any horizontal direction.

Auxiliary loads - Dynamic live loads such as those induced by cranes and material handling systems.

Floor live loads - Those loads induced on the floor system by the use and occupancy of the building."

Since, MBMA sponsored extensive wind loading research for the design of metal building systems and the results that were obtained represented a significant departure from that which was then believed to be true, this research and the subsequently adopted design method will be discussed in detail. In addition, differences which exist in snow roof, seismic and crane loads, as well as load combinations will be briefly described.

3.2.2 Wind Loads

The current wind loading criteria used in the design of metal building systems is based upon extensive research conducted at the University of Western Ontario between 1976 and 1985. This research discovered that the nature of wind pressures was very different from that which was predicted in the traditional methods. As a result, MBMA wind design criteria represented a departure from that which was then being used in conventional building construction. Consequently, this has caused a great deal of controversy and misunderstanding concerning the design parameters. This situation has been further clouded by failures of structures during high winds, that to the uninitiated design professional appear to be metal building systems, but which are actually metal clad buildings with inadequate support mechanisms.[40]

A number of innovations were introduced in the wind tunnel research conducted in Ontario.[41] First, state-of-the-art transducers, data acquisition systems and computer equipment were used in establishing an extensive data base. These transducers allowed, for the first time, the measurement of peak pressures at various locations on the structures. In addition, great care was taken to ensure that wind load criteria were based on the combined influence of building geometry, terrain exposure and wind direction. Finally, procedures were developed to evaluate the effect of the transient and fluctuating nature of wind pressures, in

[40] Vonier, op. cit., p 132.
[41] Metal Building Manufacturers Association, 1986 Low Rise Building Systems Manual, op. cit., p 210.

respect to both space and time. Figure 3.1 illustrates the combined effect of these pressures.

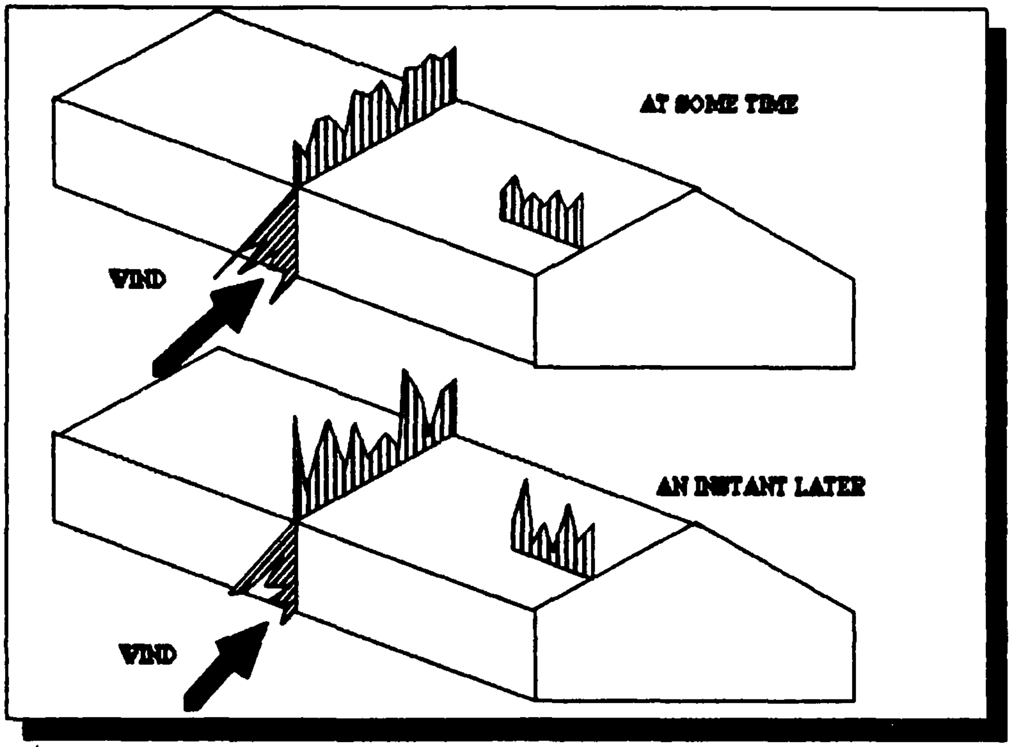

Figure 3.1 - Change in Wind Pressure with Time[42]

One of the most important aspects of the Ontario tests was the discovery that wind suction forces were much greater at the outer zones of the exterior surfaces.[43] This lead to the requirement that these zones be designed using different loading than the rest of the roof or wall. This concept is now used in both conventional and metal building systems design. Additionally, since peak wind pressures were measured at many locations, it was discovered that small portions of the surface might

42 Ibid., p 215.
43 Vonier, loc. cit.

undergo far greater loading for short durations, than the rest of the structure.[44] MBMA therefore decided that members with small tributary areas, such as girts, purlins and fasteners, should be designed to higher criteria than the main framing members.[45]

MBMA also recognizes that the number and size of openings in the walls of a building is a critical factor in the amount of internal pressure which is generated. Metal building systems are therefore classified in three categories, enclosed, partially enclosed and open.

3.2.3 Roof Snow Loads

The design of metal building systems for snow loads is similar to that used for conventional buildings, except that the ground load map used in ANSI A58.1-1982 has been modified for local conditions in some areas. The methodology used is slightly different, but the basic concept is essentially the same.

3.2.4 Seismic Loads

Metal building systems subjected to earthquakes have been found to perform much better than conventional buildings.[46] This is primarily due to their low dead load and flexibility. Their design for seismic loads is similar to that specified in ANSI A58.1-1982, except that the seismic

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[44] Metal Building Manufacturers Association, 1986 Low-Rise Building Systems Manual, op. cit., p 214.
[45] Ibid., p 105.
[46] Ibid., p 117.

zone map used is more conservative, which may be another reason for their better performance.

3.2.5 Crane Loads

Since many metal building systems are used in light industrial and manufacturing applications, MBMA has established special crane loading criteria.[47] These criteria consider the wheel load, vertical impact, lateral force and longitudinal force caused by the crane. The wheel load is created by the vertical auxiliary loads, including rated capacity, weight of hoist with trolley and total weight of the crane, and any collateral loads. Vertical impact recognizes the increased load caused by impact or vibration during crane movement. Lateral forces are caused by the movement of the trolley on the runway beam in a direction perpendicular to the rails. Longitudinal forces are created by the movement and braking of the crane bridge parallel to the rails.

3.2.6 Load Combinations

Generally, metal building systems are designed to the following load combinations.[48]

Dead + Live

Dead + Snow

Dead + Auxiliary

Dead + Wind (or Seismic)

Dead + Snow + Auxiliary

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[47] Ibid., p 34.

[48] Ibid., p50.

Dead + Snow + Seismic

Dead + 0.5 x Wind (or 1.0 x Seismic) + Auxiliary

Dead + Snow + 0.5 x Wind

Dead + 0.5 x Snow + Wind

This load criteria is significantly different and in most areas less conservative than that used in other construction.[49]

3.3 Energy Considerations

Since the oil crisis of the early 1970's, energy conservation has become a critical factor in building design. Today, most building codes require that a minimum level of energy efficiency be obtained. This efficiency is usually obtained through the use of thermal insulation.

Building thermal efficiency is measured in terms of its rate of heat transfer expressed in Btu's/Hr./SF/°F, which is known as its overall heat transmission co-efficient, or "U" value.[50] The measure of a material's resistance to heat transfer, expressed by the letter "R", which is commonly used on insulation materials, is approximately the reciprocal of "U". Therefore, the lower the "U" or the higher the insulation's "R" value, the more thermally efficient the building.

Since most of a metal building system is made of steel, which conducts heat extremely well, insulation efficiency is a very important

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49 American National Standards Institute, Minimum Design Loads for Buildings and Other Structures (A58.1-1982), New York, 1982, p 10.

50 Thermal Insulation Manufacturers Association, Understanding Insulation for Pre-Engineered Buildings, Littleton, January 1987, p 1.

factor in their design. Four basic methods are used to insulate metal building systems: fiber glass rolled insulation, sprayed-on insulation, foam sandwich panels and rigid foam boards. The decision of which type is best to use varies from building to building, and depends on location and utilization.

Fiber glass rolled insulation, which usually has a vapor barrier attached, has the advantage of low initial cost and easy installation. For these reasons, it is the most common method used in metal building systems. However, since it is normally installed over the purlins of the roof system, the insulation becomes compressed at the point of highest thermal transmission. This effect can be easily seen in winter, when snow on the roofs of these buildings, melts along every purlin. Various methods are employed to alleviate this problem, with most requiring some kind of two layer system, either with some type of rigid insulation placed between the purlins and the roof deck or with the purlins being wrapped in additional rolled insulation. Both of these methods greatly increase the cost of the system. Further, the effectiveness of this insulation material is greatly reduced if it becomes wet, either through condensation or water intrusion.

Sprayed-on insulation, which can be made of either cellulose or foam plastic is easiest to install and least costly. However, it is limited in its maximum "R" value and the quality of installation has a major effect on its thermal efficiency. Additionally, sprayed-on cellulose has been known to absorb water and cause corrosion problems, and exposed foam is prohibited by most building codes for fire safety reasons.[51]

Foam sandwich panels, which are sandwiched between interior and exterior surfaces, are costly and difficult to install. They are normally made of urethane, fiber glass or isocyanurate, and offer excellent insulation and water repelling properties.

Rigid foam boards are installed on the interior of the wall or ceiling, and when finished with surface treatments, can be used as the interior surface. They are usually made of urethane or isocyanurate and are less expensive than sandwich panels, but are more expensive than rolled fiber glass and more difficult to install.

In the mid 1970's, the masonry and concrete industry suggested that the mass of a building material had a significant effect on its thermal efficiency, separate from its thermal conduction properties. This so called mass effect or "M factor" is often used to increase the "U" of walls made of these materials. Basically, the principle is based on the assumption that massive walls and other structures retain more heat than lighter ones and therefore balance out the energy requirements, allowing a smaller and more efficient HVAC system to be used.

In 1976, MBMA asked the Midwest Research Institute to investigate the effect of mass. They analyzed four buildings, two one-story and two three-story office buildings, one each being metal and other masonry, in three cities, Minneapolis, Kansas City and Birmingham.

[51] Ibid., p 3.

These twelve buildings, which all had identical "U" values, were then studied for a complete year. The results indicated that, although the more massive masonry buildings showed a slight advantage during the heating season, when internal temperature was kept constant 24 hours per day, the metal buildings were much more efficient when a night setback of 10 °F was used.[52] These results appear to show that no general statement can be made concerning the affect of the structure's mass and thermal efficiency.

3.4 Foundation Design

Although metal building systems are significantly lighter and less massive than their conventional counterparts, foundation design is still a critical factor is their overall performance. In fact, it is due to their light weight that many foundation problems develop.

When wind causes uplift and horizontal forces on a conventional building, very little of the forces are transferred to the foundation. This is because the dead weight of the building is normally far greater than these forces. This is not the case in a metal building system. The lighter structure causes a great deal of the uplift and horizontal forces being resisted in the foundation. Metal building systems must therefore, be anchored to the surface through their foundations to resist these forces, or overturning and/or sliding of the structure may result.

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52 Metal Building Manufacturers Association, 1986 Low-Rise Building Systems Manual, op. cit., p 199.

The most common foundation used in metal building systems is the spread footing.[53] Where soil conditions are particularly unsatisfactory, mat, raft or pile foundations have also been used successfully. One of the best methods to counteract the uplift problem has been to bury the foundation deeper in the soil and use the weight of the backfill to resist the uplift. Sliding has been solved by providing tension ties or rods to connect the foundations together under the structure.[54]

3.5 Design Information Provided by the Manufacturer

The manufacturers of metal building systems normally provide the fabricated components, with the structural design guaranteed against errors and omissions, as long as the building is erected by an approved company. However, if the owner desires to have the design checked by an independent design professional, sufficient information will be provided to accomplish this. For example, the Ceco Company agrees to provide three sets of erection information, erection drawings, anchor bolt setting plan with frame reactions, wall framing plans (4 elevations), accessory schedule, printed packing list and three sets of computer generated structural calculations, signed and sealed by a professional engineer. A copy of the company's policy on drawings and calculations is provided in Appendix E, for review. In these situations however, the manufacturer usually will not fabricate any special parts required for the building, until the designs are returned approved.

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[53] Metal Building Dealers Association, op. cit., p 98.
[54] Ibid., p108.

CHAPTER FOUR
ECONOMICS

4.1 Introduction

Obviously, for metal building systems to have become so successful in such a competitive area as low-rise non-residential buildings, whose owners are usually very concerned about time and money, they must be attractive from an economic standpoint. The design and construction costs, as well as the time it takes from concept to completion, must be a key factor in their selection. In a survey conducted in 1984 by Building Design & Construction, the primary reasons their readers selected metal building systems for their projects were, the firm price of the project, single-source responsibility and firm time of delivery.[55]

4.2 Design and Construction Costs

Unlike conventional construction, an owner who desires to use a metal building system in his new project, does not have to obtain the services of a design professional for structural design, since the buildings are designed and structurally guaranteed by the manufacturer. Although this is changing, design professionals are normally only used for the design of the foundation, utilities, electrical and mechanical systems, and collateral areas, such as external veneer. This greatly reduces the cost of design, since the structural portion of the average metal building system can be completely designed by one engineer on a computer in several hours.

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[55] Wright, Gordon, "Pre-Engineered Building systems Reach Higher", Building Design and Construction, Boston, October 1984, p 138.

Construction costs are also reduced, often being 20% less than conventionally built projects.[56] In addition to material costs, two other reasons cause this, single source procurement and the lower labor cost experienced by the factory based metal building systems industry. Single-source procurement allows job progress to be much more predictable and work is more efficient. This affects not only the building systems portion of the project, but the specialty subcontractors as well. Therefore, with fewer variables and lesser risk, less contingency has to be included in bid prices. The effect of wages can be even more dramatic. According to the MBMA, factory structural steel fabricators earned an average of $9.01 per hour in 1986 nationally, while the average building materials worker on-site earned $13.03.[57] In addition, factory work does not suffer weather delays, which can add substantial cost.

Numerous examples can be cited to reinforce the economic benefits of metal building systems. In one case a six-story office, in Virginia Beach, Virginia, was being built on compressible soil. The architect who designed the project decided to use a metal building system because the lighter building, 1.8 million pounds less, allowed the use of a spread footing instead of piles, which reduced foundation costs by one-third.[58] In another project, the architect estimated that using a metal building system for a 61,980 SF warehouse/assembly plant in Solana Beach, California, reduced costs from $30 to about $22 per square foot.[59] In still

[56] Ibid., p 136.

[57] Metal Building Manufacturers Association, MBMA Fact Book, op. cit., p 5.

[58] Wright, op. cit., p 137.

[59] Wright, Gordon, "Pre-Engineered Systems Emphasize Adaptability", Building Design and Construction, Boston, May 1985, p 106.

another case, a 180,000 SF air-freight terminal at Miami International Airport was built using a metal building system after bids for conventional construction came in over budget.[60] The resulting facility cost $150,000 less than the original amount.

In 1980, the U. S. Army Corps of Engineers initiated a study to verify the cost effectiveness of metal building systems and their applicability to military construction.[61] Twenty facilities were selected in the Fiscal Year 1982 Army Military Construction Program (MCA) as potential sites for the study. Funding cuts resulted in only three of these projects being programed. The projects involved a battalion headquarters at Fort Drum, New York, a physical fitness center at Fort Benjamin Harrison, Indiana and a fire station at Fort Stewart, Georgia. All three projects were independently administered.

The two-step procurement process was selected as the vehicle to obtain these buildings. This process called for the submission of a technical proposal, with no restrictions as to the type of construction proposed. Then, the firms which met the technical requirements were asked to submit bids, with contract award to the lowest responsive bidder. Two of the three contracts awarded were for metal building systems. The study team determined that,

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60 Pratt, Building Design and Construction, op. cit., p 89.

61 Napier, Thomas R., and M. E. Lierman, Technical Report P-85/05: Industrialized Building System/Two-Step Procurement Pilot Projects: Three Case Studies, Construction Engineering Research Laboratory, U. S. Army Corps of Engineers, Champaign, January 1985.

"Preengineered building systems allowed significant cost savings over conventional construction methods in two of the three pilot projects. These savings are evident by comparisons with Government estimates for conventional construction and with bids in the same procurement. Furthermore, it must be noted that winning contractors proposed preengineered building systems by choice, recognizing that such an approach could give them a competitive advantage in each procurement. Advantages cited were (a) prefabrication and fast delivery, (b) standardization in construction procedures and simplified erection, and (c) single-source supply for most major building components."[62]

4.3 Project Time

Metal building systems can be procured and constructed up to 33% more quickly than conventional construction.[63] This is primarily due to the standardized nature of the industry. Structural designs can be produced much more quickly, as may structural material procurement and erection. Since the mechanical and electrical systems are designed and procured in the same manner as conventional construction, no time advantage is realized in these areas. This may be a critical factor in building completion, if these systems are complex and difficult to procure. However, the U. S. Army Corps of Engineers pilot project did not experience any unusual procurement difficulties in these areas.

In Corps of Engineers pilot project, the two buildings which were constructed using metal building systems were completed in 63% and

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62 Ibid., p 57.

63 Pratt, Civil Engineering, op. cit., p 56.

88% of the time forecasted.[64] The building which used conventional construction took 60% longer than expected.[65] At least in this limited sample, metal building systems clearly demonstrated that they have superior project completion times. This fact can be of critical importance to the typical user of this type of construction.

Many commercial projects have also experienced similar results. In one project, for a four-story motel in Clemson, South Carolina, the architect estimated that using a metal building system cut construction time from one year to nine months. The architect for a 106,000 SF commerce center in Westerville, Ohio, also estimated that construction time was cut by 45 to 50 days.[66]

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64 Napier, op. cit., p 19, 33.
65 Ibid., p 51.
66 Wright, May 1985, op. cit., p 108.

CHAPTER FIVE
SPECIFICATIONS AND CONTRACTS

5.1 Introduction

Since metal building systems are highly proprietary in nature, with each manufacturer producing a substantially different product, the type of contract specification used can be an important factor in their selection and success. Detailed specifications are very difficult to produce, without including something which will limit the competitiveness of the procurement. It appears however, that most guide specifications for metal building systems are not performance oriented, at least those which were obtained in researching this report. Only the U. S. Army Corps of Engineers pilot program used performance specifications.

5.2 Standard Guide Specifications

The 1986 Low Rise Building Systems Manual includes a guide specification section. This specification is very general in nature, since it is meant to be adaptable to the products of all its member manufacturers.

An example of the Ceco Buildings Division specification was obtained and compared. It follows the MBMA format and is very detailed. It is however, a proprietary specification, since it basically described the requirements of Ceco's metal building systems.[67]

The NAVFAC guide specification is also very detailed. When compared to the Ceco specification, it appears that a standard Ceco

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[67] Ceco Buildings Division, Ceco Buildings Division Products Manual, Columbus, January 1987, pp C1.1 - C1.24.

building will meet NAVFAC's criteria in all but one area. The NAVFAC specification includes a wind load design criteria that is unique. Although it is based upon the ANSI Standard A58.1, the wind loading design procedure has been modified.[68] A metal building system manufacturer might be discouraged from bidding a project which contained this specification, since he would have to alter his design method to meet this non-standard criteria.

The U. S. Army Corps of Engineers' guide specification basically follows the recommendations of the MBMA specification. A standard Ceco building should meet its requirements without modification. However, correspondence from the Construction Engineering Research Laboratory indicated that ANSI standards are usually followed in Corps of Engineers' projects.[69]

5.3 Two-Step Procurement

As previously stated, the Army Corps of Engineers' Construction Engineering Research Laboratory conducted a pilot program, which involved both metal building systems and two-step procurement, on three FY82 MCA projects.[70] Since these projects left the choice of building technology up to the contractor and a variety of conventional and metal building systems were proposed, it is worthwhile to look at this program more closely.

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68 Naval Facilities Engineering Command, Preengineered Metal Buildings (Rigid Frame), NFGS-13121, Alexandria, October 1983, p 14.

69 O'Connor, Michael J., Letter of March 28, 1988, Construction Engineering Research Laboratory, p 3.

70 Napier, loc. cit.

5.3.1 Fort Drum Project

The Fort Drum facility was a single-story, 14,850 SF administrative and training building. An A/E firm was hired to prepare a conceptual design and Request for Technical Proposal (RFTP), and to assist in the evaluation process. The conceptual design and cost estimate were based on a conventional steel frame building. The technical specifications were not true performance specifications, since the most probable types of construction methods, including metal building systems, were specified in detail, using COE guide specifications. Other than the requirement that the exterior walls be constructed of fluted concrete block, the contractors could propose any method which met the basic requirements of the RFTP.

Eight proposals were received, three using metal building systems, and all were judged to be adequate, after some minor corrections. All eight contractors submitted bids and the low bid, which was $842,800, 28% below the government estimate, called for a metal building system. The second low bidder also proposed a metal building system, with the lowest bid for conventional construction being 10% greater than the low bid.

The contractor experienced few problems with the construction of the project and the building was ready for occupancy only 250 days after contract award, 300 days less than specified. The contractor identified five factors for this:[71]

[71] Napier, op. cit., p 19.

"(1) combining design and construction responsibilities, (2) allowing construction to begin even though some documentation required revision, (3) awarding the contract late in the construction season - the building needed to be enclosed before winter arrived, (4) establishing a cooperative working relationship between the Area Office and the contractor, and (5) using a preengineered building system."

The project's final construction cost was $843,821, which was 2.5% greater than the bid price. Since the contractor was responsible for project design, he did not initiate any change orders. Government quality assurance personnel and the building's occupants are very pleased with the quality of the facility.

5.3.2 <u>Fort Benjamin Harrison Project</u>

This project called for a complete 48,000 SF physical fitness center, including a competition gymnasium, a natatorium, exercise and training equipment and handball/racquetball courts. Unlike Fort Drum, the Louisville District decided to perform the conceptual design and cost estimate in-house, based on a similar project recently completed at Fort Leonard Wood. Only floor plans, with overall building dimensions, the site plan and utilities were included, with no construction type or structural arrangement required. True performance specifications were used, based on model building codes and industry standards.

Thirteen proposals were submitted by ten different contractors. Ten of these submissions proposed either metal building systems or pre-cast concrete construction. Eight proposals were subsequently found to be technically adequate. The low bid was $2,546,000, which was 27%

below the government estimate, for a metal building system. The lowest bid for conventional construction was 20% higher than the winning bid.

Although the contract specified that the project had to be completed within 480 days of contract award, the facility was ready after only 350 days, 130 days early. The same five reasons, as on the Fort Drum project, were given as the cause for the early completion. There is one rather interesting aspect of this project. The general contractor was not a franchised metal building systems contractor, yet given complete design latitude, he determined that it was the best method to construct this particular facility.

5.3.3 Fort Stewart Project

This project called for a 9500 SF single-story fire station, including kitchen, dining, dayroom, sleeping, administrative and vehicle storage areas. The district hired an A/E to prepare a conceptual plan and RFTP, based on a similar facility at Fort Riley. Industry standards and performance criteria were specified, except that military standards were used for critical design areas, such as wind loading and seismic design. No dimensions were given and no particular type of construction was required.

Only two proposals were submitted, one for a conventional steel frame, masonry building and one for a metal building system. Both proposals were found to be technically adequate and the low bid was $864,000 for the conventional construction, 29% below the government estimate. The metal building system contractor bid $1,215,000, which was the exact amount of the maximum bid allowed in the IFB and the government estimate. This contractor later admitted that he had misunderstood the project's requirements and had thought extra credit was given for a more elaborate design.

The project initially proceeded ahead of schedule, until problems developed with the mechanical subcontractor, who eventually defaulted on his contract. This problem resulted in the contractor finishing 180 days late on the 300 day contract. Overall project cost was however, only 1.5% greater than bid price.

CHAPTER SIX
OTHER TOPICS

6.1 Metal Building Components Industry

The success of metal building systems has caused a growing collateral industry to develop, metal building components. These components are now being used in combination with all conventional building materials to produce a wide variety of structures. These facilities are a blend of the best aspects of each type, the efficiency of the metal building system, with the durability and aesthetics of conventional buildings. An A/E can now decide to use portions of a metal building system in his design and know that he will get a low-priced, high quality product, with a consistent delivery history. He must however, take total responsibility for the design. Metal building systems manufacturers will only certify buildings that they have completely designed, which means the A/E should cover this design with errors and omissions insurance.[72]

This use of metal building components has many in the metal building systems industry worried.[73] It is now possible to build a complete metal building by ordering the right parts from various different metal components manufacturers. What concerns the metal building systems manufacturers is, the designer of this building may not have the necessary expertise and computerized data base needed to properly understand the interdependence of the system. This situation could lead to a failure due to a misdesigned structure, with a great loss of

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72 Cassidy, Victor M., "Consolidation Wave Strikes Mature Metal Building Industry", Modern Metals, Chicago, august 1986, p 36.

73 Ellifritt, 16th Metal Building Systems Industry Exposition, op. cit., p 15.

life and property. Few who see such a failure would understand the difference between this building and a metal building system; therefore, the entire industry might suffer. It would not take the failure of many of these buildings to undermine the confidence that the industry has built up in its market.

6.2 Design Professional Resistance

Although the attitude is improving, a large portion of the design professional community still view metal building systems as, at best substandard solutions to project requirements and at worst, unsafe and dangerous. They also do not consider the engineers who design these buildings as professionals, even though they may be licensed professional engineers. In fact, in recent years over one-half of the engineers employed by the MBMA member metal building systems manufacturers are professional engineers.[74] Part of this belief comes from a lack of understanding of the design of building systems and part is due to economic concerns.

Engineers and architects who design conventional buildings tend to overdesign the facility.[75] There are two primary reasons for this, first at some point the benefit of designing a more cost effective building is outweighed by design costs and, second the designer does not know the source of the material to be used and the quality of workmanship, and must therefore increase the factor of safety to compensate. This latter

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[74] Ellifritt, Duane S., "Professionalism and Building Systems", Issues in Engineering, American Society of Civil Engineers, New York, July 1981, p 211.
[75] Ibid., p 208.

point is the principle upon which most industry standards, such as AISC or ACI, are based and the reason they also tend to be conservative.

The engineer who works for a metal building systems manufacturer, on the other hand, is driven by competition to work harder to make a more cost effective building. Extra time and money can be spent on closer investigation into the effects of loads and trimming as much unnecessary material as possible from designs, because the extra design costs can be spread over many buildings. In addition, since material fabrication is controlled by the manufacturer the designer works for, and erection is performed by specifically trained and licensed contractors, material quality and workmanship is not as much of a concern.

6.3 Government Engineer's Opinions

Mr. Gary Gallagher, the head of the Quality Assurance Branch of Southern Division, Naval Facilities Engineering Command, (SOUTHDIV) described metal building systems as not being compatible with the mission requirements of most naval facilities, because they often have highly congested industrial areas, with heavy lift cranes and special security needs.[76] He also indicated that they did not usually meet base architecture plans, often damage easily and have corrosion problems in the highly aggressive environment at most of these facilities. He further indicated that SOUTHDIV's A/E's are requested to consider them in their

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76 Gallagher, Gary, Quality Assurance Branch Head, Southern Division, Naval Facilities Engineering Command, Charleston, phone conversation of February 5, 1988.

designs and that value engineering evaluates whether they should be specified.

Mr. William H. Crone, the Deputy Director of the Engineering and Design Division, Atlantic Division, Naval Facilities Engineering Command (LANTDIV), which is responsible for publishing the NAVFAC pre-engineered building guide specification, indicated that these buildings were utilized whenever cost-effectiveness and mission needs deemed them appropriate, and he provided a list of seven projects in which they were being specified (see Appendix F). However, he stated that military facilities often contain special applications in the way of security, energy conservation, damage resistance, and structural requirements not evident in civilian construction. He further commented that MBMA design criteria did not meet the Navy's in certain areas.

Mr. Michael J. O'Connor, the Acting Chief, Facility Systems Division, U. S. Army Corps of Engineers (COE), Construction Engineering Research Laboratory, indicated that the COE uses metal building systems in standard practice for storage and maintenance facilities (see Appendix F). He also indicated that the COE has reservations about the loading conditions and criteria in the Metal Buildings Systems Manual and that they normally specify ANSI A58.1 in their projects. He further stated that he has experienced the resistance to metal building systems based on stereotyped impressions, but that he felt many developments in the construction industry are often slow to gain wide-spread acceptance.

CHAPTER SEVEN
SUMMARY AND CONCLUSIONS

7.1 Summary

Metal building systems have become a competitive and viable alternative to conventional buildings. They are used in almost all non-residential applications under six stories in height and have proved to be sturdy and durable. Today's metal building systems are the product of 130 years of evolution and are some of the most advanced structures built today. The industry has conducted extensive research and has soundly engineered and skillfully marketed its product.

The systems concept is the foundation of the industry. This concept allows the material weight of the building to be reduced, because the members are designed as part of an integrated system which is stronger than their individual strengths combined. This high level of design is possible, because its cost can be spread over many buildings. The system consists of three main components, the structural, wall and roof systems. When these components are connected with fasteners, and reinforced with the necessary bracing, they behave as a single unit.

Two structural systems are normally used in metal building systems. Smaller buildings mostly use cold-formed shapes, while larger buildings use tapered rigid frames. Tapered rigid frames have the largest moment of inertia where the largest moments occur. This results in great weight savings and lower material cost. The wall and roof systems, on the other hand are made of cold-formed steel shapes. This includes the secondary framing systems and exterior covering. These sections are quickly and economically produced in quantity and are stored until required for a particular project. The standing seam roof system, which is made of cold-formed steel, has become popular on both conventional buildings and metal building systems.

In order to produce a standard design method for the industry, MBMA publishes a Metal Building Systems Manual. Its current version, the 1986 Low Rise Building Systems Manual, includes design methods, industry practices and other information used in the design of metal building systems. Most loadings used in the manual are similar to those used in conventional construction, except wind load. MBMA conducted extensive wind loading research and produced criteria substantially different than ANSI standards. Load combinations also differ in many aspects.

Metal building systems can be designed to be as energy efficient as any other type of building. In addition, MBMA sponsored research determined, that the mass of a building did not have a consistent effect on its energy efficiency for all usage variations. Four types of insulation systems are used in these buildings, fiber glass rolled insulation, sprayed-on insulation, foam sandwich panels and rigid foam panels.

Foundation design for these buildings is often critical, and must consider wind uplift and lateral footing forces. This is due to their lighter weight, which does not fully compensate for wind forces.

Metal buildings systems have proven, in some applications, to be more cost effective than conventional buildings. This is the result of lower structural design costs, prefabricated components, single-source procurement, lower factory wage costs, predictable delivery schedules and lower erection costs. Project completion time is also much lower for many of the same reasons.

Most contract specifications for metal building systems are detailed and in some cases proprietary. However, in one pilot program, where performance specifications were used, project costs were greatly reduced.

The success of the metal building systems industry has given birth to a collateral metal building components industry. This industry provides a wide range of metal products that can be incorporated into conventional construction. A complete metal building can even be built using components from various manufacturers. This practice has some danger though, since its designer may not have the necessary expertise to fully incorporate the systems concept.

Many design professionals still have a low opinion of metal building systems and their designers. However, the extensive research conducted by the industry and the building's cost competitiveness has softened this attitude with some of them in recent years.

Surveyed U. S. Navy engineers believe that metal building systems have a limited use in MCN projects. They indicated that these buildings usually do not meet the unique mission and security requirements of Navy installations, and that the corrosive environment present also caused significant problems.

7.2 Conclusions

Metal building systems are an effective and efficient alternative to conventional buildings. The building systems produced today are both aesthetically pleasing and durable, and can be tailored to requirements of most owners. The industry is thoroughly professional in their design approach and markets its products very skillfully. A great deal of basic research has been performed by MBMA to improve their competitiveness and enhance their image. Gone are the days of the Quonset Hut!

The industry does have some problems. They've probably reached the limit of their design improvement, given the basic material properties present. Their share of the low-rise non-residential market has reached a plateau during the last five years and should not increase greatly in the near future. In this area they've become a victim of their own success. Not only have the concrete, masonry and other building material industries tried to recover some of this market, but the metal building components industry has fully entered the fray. The hybrid building is beginning to become a dominant force in this market as architects realize its potential. Owners have more choices today than ever before and will have even more in the future.

The results of the Army Corps of Engineers' two-step pilot project are both exciting and enlightening. There now exists a proven format to reduce the cost and time required to build military construction. Opening the procurements to metal building systems in a performance specification, not only provided a basis for cost comparison of the two products, but required all contractors who bid to consider their impact and sharpen their pencils accordingly. What the Army got as a result was the required facilities at a better price, and in two cases, sooner than expected. Further use of this procurement method, although it is not without some administrative difficulties, should lower the cost of new construction and improve project programming.

The current level of specifying metal building systems within NAVFAC is disappointing. Although they appear to be considered for basic applications, such as warehouses and gymnasiums, their full potential has not been utilized. Many of the Navy's buildings are now well past their useful lives. In addition, new mission requirements have developed the need for other new facilities. Although many of the Navy's administrative and industrial facilities do not have significantly different mission, congestion, environmental or security requirements from the civilian community, and metal building systems can meet almost any base architectural plan, most new construction is conventional. This is unfortunate, since increased use of metal building systems might result in significant cost savings and provide a means to program more projects. This might become particularly important if military construction funds dry up in the next administration.

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APPENDIX A

TYPICAL DEALER SALES AGREEMENT

Ceco Buildings Division Builder Agreement

SAMPLE

Ceco
Buildings
Division

The Ceco Corp./A Ceco Industries Co.

BUILDER AGREEMENT

This document is an agreement between Ceco Buildings Division, a Division of The Ceco Corporation, herein referred to as "CBD" or "Ceco," and

_______________________________, located at _______________________________, herein referred to as "Builder."

Upon acceptance by Builder and approval by CBD Profit Center General Manager or Sales Manager, this Agreement will constitute Builder's appointment as an authorized Builder for CBD. The conditions in this document will govern the responsibilities and obligations of each party.

Builder orders shall be submitted on standard CBD order forms and shall be governed by CBD specifications and standard terms and conditions in effect from time to time. Those currently in effect are attached hereto as "Exhibit A." CBD materials are F.O.B. CBD profit center at current published prices less applicable discounts at the time of the order acceptance, plus applicable taxes. All materials furnished are governed by CBD specifications only, and any variance or deviation must be so stated on the purchase order. The company reserves the right to refuse any variance or deviation from CBD specifications.

Builder shall at all times be an independent contractor and shall have no authority to act as an agent or employee of the company or power to bind the company to any person in any way. Builder shall not use any of the company's trademarks or trade names, or as a part of, the Builder's business or trade without the company's prior written consent.

Builder shall have a nonexclusive primary area of responsibility, referenced at the end of the document, and shall be responsible for promoting the sale of CBD products and services in this area, and in developing market share growth consistent with the goals of CBD and the Builder. CBD reserves the right to sell its products and services directly to a customer in Builder's primary area of responsibility without incurring any liability to Builder on said sale.

Builder will maintain a suitable place of business and appropriate support personnel sufficient to represent that Builder as a Construction Professional in its assigned area.

Builder will investigate all customer complaints and assist in the adjudication of those that are found to be valid.

Builder agrees to send one or more people to the next scheduled seminar after his appointment. Builder must maintain on staff an individual who has attended a CBD Product and Pricing Seminar.

Builder agrees to place "yellow-page" advertising in each principal town in its marketing area using an approved CBD "trademark ad." Builder further agrees to place such other advertising as may be necessary to develop the sales potential in its marketing area.

Payment fees for materials shall accompany this agreement. In exchange for this charge, CBD will provide the basic current builder literature, sales promotional material, design manuals, and erection guides to support the Builder's marketing of the CBD product.

The Builder may request assistance from CBD sales, engineering, customer service, or other departments to advise and assist in the preparation of estimates, quotes, Builder Purchase Orders, or Builder Change Orders. Nevertheless, it is Builder's responsibility to check the accuracy of all material submitted. Builder is completely responsible for all CBD estimates, quotes, purchase orders, and change orders submitted.

Builder assumes responsibility that the CBD product it provides is erected in accordance with CBD erection drawings instructions and in a first-quality manner, whether the erection is performed by Builder or its subcontractor.

It is the Builder's responsibility to communicate accurately to CBD the appropriate design loads, safety and occupancy requirements, and any other controlling factors that are appropriate for the geographic location of the building. The Builder takes complete responsibility to meet the controlling building codes. Furthermore, Builder agrees to indemnify, hold-harmless, and assume complete defense of CBD, its agents or employees against any actions, claims, damages, liabilities, costs and expenses whatsoever in matters arising out of Builder's failure to comply with the provisions of this paragraph.

Builder agrees to pay for purchases under terms agreed to by CBD. The release of each shipment is subject to approval by the company's credit department.

Builder agrees to submit its current audited financial statements, including its most recent Balance Sheet and one-year Profit and Loss Statement. Thereafter, Balance Sheet and Profit and Loss Statements must be submitted within sixty days of the close of the Builder's fiscal year. These financial statements are essential to the determination of the Builder's terms of payment, and failure to submit statements may result in a change or modification of Builder's credit terms.

Builder shall maintain in force for the term of this agreement such insurance as deemed appropriate by CBD. Builder's insurance carrier to forward to CBD a certificate of this coverage listing said endorsements and requiring carrier notification to CBD thirty (30) days prior to any change or termination of Builder's policy.

CBD will provide Builder pricing, policy, and procedure manuals necessary to the Builder's operation. These manuals are the property of CBD and shall be returned by Builder upon request from CBD. All such material furnished to Builder must be returned to CBD upon termination of this agreement.

After this Agreement has been in effect for six months, it may be terminated by any party, at anytime, with or without cause, with forty-five days' written notice. However, in the event of a default, CBD may cancel this agreement immediately. In the event of a default, Ceco may, at its option, without demand or notice, mature immediately all indebtedness due, or to become due by Builder to CBD, and same shall become immediately due and payable. A default is defined as failure of the Builder to pay in accordance with CBD's terms and conditions, or to perform any obligation under this agreement; insolvency of, or in the opinion of CBD, danger of insolvency of Builder, or any assignment by Builder for the benefit of its creditors; the filing of Bankruptcy proceedings by, on behalf of, or against Builder; and, the appointment of a receiver to manage all or a part of the Builder's assets.

In the event this agreement is terminated, Builder agrees to return to CBD all sales and advertising materials, and CBD will pay Builder the current value thereof and will purchase standard CBD products that the Builder may have acquired for stocking purposes, providing such products are in good condition as determined by Ceco. The purchase price of such products shall be the original cost to the Builder, less a restocking chage of 15%. Transportation costs associated with return of all materials will be paid by the Builder.

This agreement supersedes any prior builder or dealer agreement, written or oral, between CBD and the Builder. It shall also cancel any demands or claims under said prior agreement, with the exception of money owed in the ordinary course of business.

CBD's failure at any time, or from time to time, to require strict compliance by Builder with this Agreement shall neither waive or prejudice CBD's continued right to insist upon due and timely performance of this agreement and to avail itself of all remedies provided by law.

This agreement is between Builder and CBD and is not assignable. The terms hereof may only be changed by the Profit Center General Manager and Builder in writing.

CECO BUILDINGS DIVISION
A Division of The Ceco Corporation

_______________________________ (City, State)

_______________________________ By: _______________________________
Witness CBD Profit Center Manager or Sales Manager

Date: _______________________________ _______________

The undersign hereby accepts and agrees to the foregoing, this the ________ day of __________________________, 19_____.

Indicate which: Partnership ( ) Corporation ( ) Proprietorship ( )

Firm Name ______________________________

Address ______________________________

City, State ______________________________

BY: ______________________________

____
Witness

Date: ______________________________

Title ______________________________

Primary Area of Responsibility: ______________________________

____

"EXHIBIT A"
TERMS AND CONDITIONS

1. SELLER. When the word "Seller" is used in this document, it shall be construed to mean Ceco Buildings Division, a Division of The Ceco Corporation.
2. MATERIAL TO BE FURNISHED. This Contract covers only items specifically set out in this document. In the event of conflict between drawings and this document, only material listed herein will be furnished. All materials furnished are to be governed by Ceco Buildings Division specifications only, and any variance or deviation must be so stated on this document. All other material furnished will be at extra charge.
3. MBMA MANUAL. The Metal Building Manufacturers Association "CODE OF STANDARD PRACTICES" and "RECOMMENDED DESIGN PRACTICES MANUAL," current edition, is part of this Contract as though fully set forth herein. By execution of this Contract, Purchaser acknowledges receipt of a copy of this code and complete familiarity with the contents thereof.
4. TAXES. Except as otherwise expressly provided herein, all excise, privilege, occupation, sales, use, personal property, and other taxes applicable to the sale, purchase, construction, use or ownership of any of Seller's products and/or work provided herein, and for which Seller shall be liable to collect or pay, shall be added to the Contract consideration and shall be paid by Purchaser.
5. SHORTAGES AND DAMAGES. If, in the opinion of the Purchaser, any material is damaged prior to receipt by Purchaser to a degree that will prevent use of such material with minor field repair, delivery of damaged material shall be refused by Purchaser, noted by item as "damaged" on shipping documents and returned on delivering truck to Seller or to common carrier. Under no circumstances shall damaged material which cannot be used with minor field repair be unloaded at jobsite. Seller shall not be liable for the correction of errors in design, detailing, manufacturering or shipping if Purchaser does not strictly comply with the provisions of MBMA "CODE OF STANDARD PRACTICES" governing the correction of errors and repairs, and material count. It is specifically agreed that claims for errors, shortages, imperfections and deficiencies will not be entertained by Seller unless made in writing to the appropriate sales department of Seller within three days after receipt of goods, and Seller shall not in any event be liable for labor charges or consequential damages arising from the use of defective materials. It is further agreed that no back charges or offsets of any kind will be accepted by Seller unless agreed to in writing.
6. WARRANTY. SELLER MAKES NO WARRANTIES EXCEPT THAT SELLER'S MATERIALS AND/OR WORK ARE WARRANTED IN ACCORDANCE WITH SELLER'S STANDARD WARRANTIES, IF ANY, THAT ARE IN EFFECT AS OF THE DATE OF THIS PROPOSAL AND ARE MADE A PART OF THIS PROPOSAL AS THOUGH FULLY COPIED HEREIN. ALL OTHER WARRANTIES, INCLUDING WARRANTIES OF MERCHANTABILITY AND FITNESS FOR PURPOSE, EXPRESS OR IMPLIED, BY OPERATION OF LAW OR OTHERWISE, ARE EXCLUDED FROM THIS CONTRACT. SELLER'S LIABILITY IS LIMITED AS SET FORTH ON THESE STANDARD WARRANTIES, IF ANY, AND SELLER SHALL NOT BE LIABLE FOR ANY OTHER DAMAGES, WHETHER DIRECT OR CONSEQUENTIAL, INCLUDING LOSS OF USE, WHICH MAY BE SUFFERED BY PURCHASER. Seller shall comply with specifications governing material, workmanship, design procedure and design loads which are expressly provided herein. Materials of workmanship sold hereunder for which specifications are not expressly provided herein shall be subject to Seller's standard variances, tolerances and specifications current as of the date of this Contract.
7. DELAY. Seller shall not be liable for any direct, consequential, or liquidated damages, including loss of use, which Purchaser may suffer by reason of Seller's delays in performance of this agreement. Causes of such delays include, but are not limited to, strikes, fires, floods, storms, riots, differences with workmen, loss or damage of materials, inability to obtain workmen or materials, excessive backlog, or other circumstances beyond Seller's reasonable control. Should any work agreed to be performed by Seller be interrupted or delayed by Purchaser in excess of 60 days on account of factors beyond Seller's control, then upon notice by Seller of such interruption or delay, Purchaser will pay Seller the total of Seller's costs of materials and work performed, plus current overhead costs and 10% of the herein agreed consideration. Delivery time on materials not normally carried in the stock of Seller shall be predicated upon the availability to Seller of this particular type of material. In the event customer delays approval of drawings by more than sixty (60) days after receiving same or requests a delay in fabrication beyond thirty (30) days after approval of drawings, Seller may invoice customer for any services performed, and the price quoted herein shall be subject to revision at Seller's option. In the event customer delays delivery of building and/or parts 30 days after fabrication is complete and ready to ship, Seller will immediately invoice customer for the total FOB amount which shall be due and payable upon receipt of invoice. Seller also reserves the right to charge the customer for storage at prevailing rates.
8. INSURANCE. Seller agrees to carry Workmen's Compensation insurance as required by the laws of the State where the work is performed. Seller agrees to carry Workmen's Compensation insurance and Comprehensive General Liability insurance, including Property Damage, and Automobile Liability, covering work performed by Seller. Certificates of such insurance coverage will be forwarded upon request. All other forms of insurance will be carried by Purchaser, unless otherwise agreed to in writing. The Purchaser agrees that Purchaser or Owner will procure Builders Risk Insurance, without cost to Seller, covering Seller's material, equipment, and labor for standard all-risk perils of loss including collapse, and such policy shall contain a waiver of subrogation toward Seller. Seller shall receive a share of any payments of loss under such policy as its interest may appear and any deductible therein shall be to the Buyer's account. While Seller shall be responsible for actual damages caused solely by Seller's negligence, Purchaser agrees to defend and hold harmless Seller from any and all claims, suits, damages, losses and expenses arising out of or in connection with any alleged or real injury (including death or total destruction) to any person or property which results from the work performed or the materials supplied hereunder, the Purchaser acknowledging that Seller's work hereunder is performed in accordance with the order and specifications of Purchaser only. Without limiting the above, if retrofit materials and/or labor are supplied hereunder, Seller's negligence shall not include anything which results from the transfer of any load to the existing structure, the Purchaser acknowledging further that Seller has not performed any tests of suitability of the materials or work supplied hereunder and Purchaser has not relied on Seller's statement, promises or assurances in regard to such suitability.
9. TITLE. Title to materials shall remain in Seller's name either until payment is made in full, or until such materials are incorporated into a structure. Risk of loss or damage shall pass to Purchaser on delivery to the carrier, unless otherwise agreed in writing.

10. CREDIT. Reasonable doubt on the part of Seller of Purchaser's financial responsibility shall entitle the Seller to stop operations, decline shipment, without delivery of any material in transit, or to exercise any other rights or remedies granted to Seller under the provisions of The Uniform Commercial Code or other applicable law, without liability whatsoever unto Seller, until Purchaser shall have paid for all material referred to in this proposal, or satisfied Seller of its financial responsibility. It is further agreed that Purchaser will pay all costs of collecting or securing, or attempting to collect or secure any indebtedness which may be due hereunder, including a reasonable attorney's fee, whether the same be collected or secured by suit or otherwise. Should Purchaser fail to make payment upon the terms designated by the Seller, interest at the rate of 1½% per month (18% annual percentage rate) will be charged from maturity and for each 30-day period the invoice goes beyond the term of payment. If state law of Purchaser prohibits this rate, the interest charged in the annual percentage rate will be the maximum allowed by state law. Payment for all materials delivered shall become due immediately upon delivery in accordance with the terms on the front side hereof. In the event payment terms are not stated on the front side, all material becomes due on delivery or offer to deliver at the option of the Seller.
11. CODE COMPLIANCE. Purchaser agrees that it will be his responsibility to see that any building ordered from Seller meets the local codes or regulations. Seller guarantees only that the buildings will meet specific loadings from models outlined in sales contracts. Seller reserves the right to change design or make structural substitutions which do not materially affect the strength of the buildings covered under this proposal. Purchaser further assumes full responsibility for furnishing Seller adequate roadways to the construction site.
12. ACCEPTANCE AND CANCELLATION. This proposal is subject to Purchaser's acceptance within 30 days and to subsequent approval and signature of Seller. Thereupon, this proposal will become a Contract and final expression of agreement between Purchaser and Seller relating to the materials and/or work herein proposed to be sold. After acceptance and approval of this Contract by Seller, this Contract cannot be cancelled without mutual agreement of the parties, and payment to Seller of all costs and expenses incurred by it in preparation for construction under said Contract from the date of acceptance through the date of cancellation. This Contract cannot be modified except in writing signed by both parties. In the event of modification of this Contract, any such modification shall be deemed to include all of the provisions of this Contract.
13. ASSIGNMENT. Neither party shall assign this contract or sublet it as a whole without the written consent of the other.
14. ENFORCEABILITY. In the event that any one or more of the provisions contained herein shall for any reason be held to be unenforceable in any respect, such unenforceability shall not affect any of the provisions of this agreement, but this agreement shall be construed as if such unenforceable provision had never been contained herein. All questions of enforceability and interpretation which may arise under this agreement shall be construed in accordance with and determined by the provisions of the Uniform Commercial Code.
15. ENTIRE AGREEMENT. This writing is intended by the parties as a final expression of their agreement, and it is intended also as a complete and exclusive statement of the terms of their agreement. It is specifically understood and agreed that Seller shall have no liability whatsoever under any contract between Purchaser and other parties, unless Seller agrees thereto, in writing, at the time of acceptance of the proposal.
16. IT SHALL BE THE RESPONSIBILITY OF PURCHASER TO CAREFULLY CHECK ORDER ACKNOWLEDGMENTS IMMEDIATELY UPON RECEIPT AND TO NOTIFY SELLER OF ANY DISCREPANCY.

PERSONAL GUARANTY

In consideration of Ten Dollars ($10.00) and other good and valuable consideration and as an inducement to your extending credit to ________ ________________________________ on an open account basis for products and services sold and delivered by you from time to time to ____, the undersigned (hereinafter called "Guarantor") does hereby unconditionally and absolutely guarantee jointly and severally to Ceco Buildings Division, a Division of The Ceco Corporation (hereinafter referred to as "Ceco"), its successors and assigns, the full, faithful and prompt performance by Guarantor of all of the terms, covenants, conditions, obligations and agreements contained in the above and foregoing Ceco Builder Agreement, including the payment of any and all indebtedness or other liability which the Builder in the foregoing Builder Agreement may now or at any time hereafter owe Ceco, together with interest and a reasonable attorney's fee, whether such indebtedness or other liability arises under said Builder Agreement or in any other manner whatsoever.

It will not be necessary for you to notify us of your acceptance of this Guaranty or of the sale and delivery of any products to ______________ ______________________________________. You may, without notice to us, extend the account. Guarantor further covenants and agrees that Ceco may enforce the obligations of Guarantor by direct action against Guarantor and that Ceco shall not be required to institute any proceedings against Builder before instituting and prosecuting such an action against Guarantor, nor shall it be necessary to make Builder a party to any suit by Ceco against Guarantor.

As a further inducement to your extending credit to ____, we hereby subordinate any claim or claims for monies, advanced or otherwise, which we may now or hereafter have against ________________ ________________________________ to any claim or claims for merchandise bought by ________________________ from you. The indebtedness of ____ to you will continue to be superior to the claim or claims we may now or hereafter have against ____ until such indebtedness to you is paid. Guarantor further agrees that this shall be a continuing guaranty and apply to and cover the obligations, agreements and indebtedness and renewals thereof and further expressly covenants and agrees that the liability of the undersigned as set forth in this guaranty shall be primary and coordinate with that of the builder and that such liability to Ceco shall not be lessened, affected, diminished or impaired in any way by any extension of time, renewal, indulgence or forebearance that may be granted or allowed by Ceco.

In the event of the death of the Guarantor, the obligations of the Guarantor as herein set forth, which arise or are created prior to the date when Ceco shall have received notice in writing of such death, shall continue in force and effect against the Guarantor's estate. In the event Builder, (1) if a corporation, should be merged, consolidated, or dissolved, or, (2) if a sole proprietorship, should incorporate or become part of a partnership, or, (3) if a partnership, should dissolve, add or delete one or more partners, or incorporate, or, (4) regardless of business form, should be sold, this Guaranty shall continue as to Builder's successor in interest just as if such successor were the party executing the said Builder Agreement as Builder.

The undersigned agrees that this Guaranty shall be interpreted, construed and governed by the Uniform Commercial Code.

EXECUTED this ________ day of ________________________, 19_____.

GUARANTOR	GUARANTOR
GUARANTOR	GUARANTOR

SWORN TO AND SUBSCRIBED before me the ________ day of ________________________, 19_____.

My commission expires: ________________

NOTARY PUBLIC

APPENDIX B

GLOSSARY OF TERMS

The following is a list of terms frequently used in the Metal Building Systems Industry:

A

Accessory—An extra building product which supplements a basic solid panel building such as door, window, skylight, ventilator, etc.
AISI—American Iron and Steel Institute
AISC—American Institute of Steel Construction
AISE—Association of Iron and Steel Engineers
Aluminum Coated Steel—Steel coated with aluminum for corrosion resistance.
ANSI—American National Standards Institute
Anchor Bolts—Bolts used to anchor members to a foundation or other support.
Anchor Bolt Plan—Anchor Bolt Plans (a plan view) show the size, location, and projection of all anchor bolts for the components of the metal building system, the length and width of the foundation (which may vary from the nominal size of the metal building system) and column reactions (magnitude and direction). The maximum base plate dimensions may also be shown.
Approval Plans—Approval plans may include framing plans, elevations, and sections through the building for approval of the buyer.
ASCE—American Society of Civil Engineers
Astragal—A closure between the two leaves of a double swing or double slide door to close the junction.
Automatic Welding—A welding procedure utilizing a machine to make a weld.
Auxiliary Loads—All dynamic live loads required by the contract documents, such as cranes and material handling systems.
Axial Force—A force tending to elongate and shorten a member.

B

Base Angle—An angle secured to a wall or foundation used to attach the base of the wall paneling.
Base Plate—A plate attached to the base of a column which rests on a foundation or other support, usually secured by anchor bolts.
Bay—The space between the primary frames measured parallel to the ridge.
Beam—A member, usually horizontal, that is subjected to bending loads. There are three types: simple, continuous, and cantilever.
Beam and Column—A structural system consisting of a series of rafter beams supported by columns. Often used as the end frame of a metal building.
Bearing End Frame—See "Beam and Column"
Bearing Plate—A steel plate that is set on the top of a masonry support on which a beam or purlin can rest.
Bent—The main member of a structural system.
Bill of Materials—A list of items or components used for fabrication, shipping, receiving, and accounting purposes.
Bird Screen—Wire mesh used to prevent birds from entering the building through ventilators and louvers.
Blind Rivet—A small headed pin with expandable shank for joining light gage metal. Typically used to attach flashing, gutter, etc.
BOCA—Building Officials and Code Administrators International, Inc.
Brace Rods, Angles, and Cables—Braces used in roof and walls to transfer loads, such as wind loads, and seismic and crane thrusts to the foundation. (Also often used to plumb buildings but not designed to replace erection cables).
Bracket—A structural support projecting from a wall or column on which to fasten another structural member. Examples are canopy brackets, lean-to brackets, and crane runway brackets.
Bridge Crane—A load lifting system consisting of a hoist which moves laterally on a beam, girder, or bridge which in turn moves longitudinally on a runway made of beams and rails. Loads can be moved to any point within a rectangle formed by the bridge span and runway length.
Bridging—Structural member used to give weak axis stability to bar joists.
British Thermal Unit (BTU)—That amount of heat required to raise the temperature of one pound (2.2 kg) of water by 1° F (0.56° C.)

Building Code—Regulations established by a recognized agency describing design loads, procedures, and construction details for structures. Usually applying to designated political jurisdiction (city, county, state, etc.).
Building Line—See "Steel Line"
Built-Up Roofing—A roof covering made of alternating layers of tar and asphaltic materials.
Built-Up Section—A structural member, usually an "I" section, made from individual flat plates welded together.
Butt Plate—The end plate of a structural member usually used to rest against a like plate of another member in forming a connection. Sometimes called a splice plate or bolted end plate.

C

"C" Section—A member formed from steel sheet in the shape of a block "C", that may be used either singularly or back to back.
Camber—Curvature of a flexural member in the plane of its web before loading.
Canopy—A projecting beam that is supported and restrained at one end only.
Capillary Action—That action which causes movement of liquids when in contact with two adjacent surfaces such as panel side laps.
Cap Plate—A plate located at the top of a column or end of a beam for capping the exposed end of the member.
Caulk—To seal and make weathertight joints, seams, or voids by filling with a waterproofing compound or material.
Channel—Hot-Rolled—A "C"-shaped member formed while in a semi-molten state at the steel mill to a shape having standard dimensions and properties.
Clip—A plate or angle used to fasten two or more members together.
Closure Strip—A resilient strip, formed to the contour of ribbed panels and used to close openings created by metal panels joining other components.
Cold Forming—The process of using press brakes or rolling mills to shape steel into desired cross sections at room temperature.
Collateral Load—All additional dead loads required by the contract documents other than the weight of the metal building system, such as sprinklers, mechanical and electrical systems, and ceilings.
Column—A main member used in a vertical position on a building to transfer loads from main roof beams, trusses, or rafters to the foundation.
Component—A part of a metal building system.
Continuity—The terminology given to a structural system denoting the transfer of loads and stresses from member to member as if there were no connections.
Contract Documents—The documents which define the responsibilities of the parties involved in the sale, supply, and erection of a metal building system. Such documents normally consist of a contract and specification. Plans may be included.
Corner Post—An end wall column located at the corner of the building.
Covering—The exterior metal roof and wall paneling of a metal building system.
Crane—A machine designed to move material by means of a hoist.
Crane Rail—A track supporting and guiding the wheels of a bridge crane or trolley system.
Crane Runway Beam—The member that supports a crane rail and is supported by columns or rafters depending on the type of crane system. On underhung bridge cranes, runway beam also acts as crane rail.
Curb—A raised edge on a concrete floor slab or skylight.
Curtain Wall—Perimeter wall panels which carry only their own weight and wind load.

D

Damper—A baffle used to open or close the throat of ventilators.
Dead Load—The weight of the metal building system construction, such as roof, framing, and covering members.
Deflection—The displacement of a structural member or system under load.

Design Loads—The loads expressly specified in the contract documents which the metal building system is designed to safely resist.
Diagonal Bracing—See "Brace Rods"
Diaphragm Action—The resistance to racking generally offered by the panels, fasteners, and members to which they are attached.
"Dogleg"—An extension of an end post that is welded onto the outside flange of the column.
Door Guide—An angle or channel guide used to stabilize or keep plumb a sliding or rolling door during its operation.
Downspout—A conduit used to carry water from the gutter of a building.
Drift Pin—A tapered pin used during erection to align holes in steel members to be connected by bolting.

E

Eave—The line along the side wall formed by the intersection of the planes of the roof and wall.
Eave Gutter—See "Gutter"
Eave Height—The vertical dimension from finished floor to the eave.
Eave Strut—A structural member located at the eave of a building which supports roof and wall paneling.
Elastic Design—A design concept utilizing the proportional behavior of materials when all stresses are limited to specified allowable values.
End Bay—The bays adjacent to the end walls of a building. Usually the distance from the end wall to the first interior primary frame measured parallel to the ridge.
End Frame—A frame located at the end wall of a building which supports the loads from a portion of the end bay.
End Post—See "End Wall Column"
End Wall—An exterior wall which is perpendicular to the ridge of the building.
End Wall Column—A vertical member located at the end wall of a building which supports the girts. In beam and column end frames, end wall columns also support the beam.
End Wall Overhang—The projection of the roof past the end wall.
Erection—The on-site assembling of fabricated components to form a complete structure.
Erection Plan—See "Framing Plans"
Expansion Joint—A break or space in construction to allow for thermal expansion and contraction of the materials used in the structure.
Exterior Framed—A wall framing system where the girts are mounted on the outside of the columns.

F

Fabrication—The manufacturing process performed in a plant to convert raw material into finished metal building components. The main operations are cold forming, cutting, punching, welding, cleaning, and painting.
Facade—Architectural treatment given to the front or any exterior surface of a building.
Fascia—A decorative trim or panel projecting from the face of a wall.
Field—The "job site", "building site", or general marketing area.
Filler Strip—See "Closure"
Film Laminated Coil—Coil metal that has a corrosion resistant film laminated to it prior to the forming operation.
Fixed Base—A column base that is designed to resist rotation as well as horizontal or vertical movement.
Flange—The projecting edge of a structural member.
Flange Brace—A bracing member used to provide lateral support to the flange of a beam, girder, or column.
Flashing—A sheet metal closure which functions primarily to provide weathertightness in a structure and secondarily to enhance appearance.
Flush Frames—A wall framing system where the outside flange of the girts and the columns are flush.
Footing—A pad or mat, usually of concrete, located under a column, wall, or other structural member, that is used to distribute the loads from that member into the supporting soil.
Foundation—The substructure which supports a building or other structure.
Frame—Primary structural member (columns and rafters) which support the secondary framing.

Framed Opening—Jambs, headers, and flashing which surround an opening in the wall of a metal building.
Framing—The skeleton parts of a building which provide structural support and stability.
Framing Plans—Roof and wall framing (erection) plans that identify individual components and accessories furnished by the manufacturer in sufficient detail to permit proper erection of the metal building system.

G

Gable—The triangular portion of the end wall located above the elevation of the eave.
Gable Roof—A ridged roof that terminates in gables.
Galvanized—Steel coated with zinc for corrosion resistance.
Girder—A main horizontal or near horizontal structural member that supports vertical loads. It may consist of several pieces.
Girt—A horizontal structural member that is attached to side wall or end wall columns and supports paneling.
Glaze or Glazing—The process of installing glass in windows and doors.
Grade—The term used when referring to the ground elevation around a building.
Grade Beam—A concrete beam around the perimeter of a building.
Grout—A mixture of cement, sand, and water used to fill cracks and cavities. Sometimes used under base plates or leveling plates to obtain uniform bearing surfaces. Not normally used in conjunction with metal building systems.
Gusset Plate—A steel plate used to reinforce or connect structural elements.
Gutter—A gage metal member at an eave, valley, or parapet designed to carry water from the roof to downspouts or drains.

H

"H" Section—A steel member with an "H" cross section.
Hairpin—U-shaped reinforcing steel used to transfer anchor bolt shear (due to column thrust) to concrete floor mass.
Haunch—The deepened portion of a column or rafter designed to accommodate the higher bending moments at such points. (Usually occurs at the connection of column and rafter.)
Haunch Brace—A diagonal brace from the intersection of the column and rafter section of the rigid frame to the eave to prevent lateral buckling of the haunch.
Header—The horizontal framing member located at the top of a framed opening.
High Strength Bolts—Any bolt made from steel having a tensile strength in excess of 100,000 pounds per square inch (690 MPa).
High Strength Steel—Structural steel having a yield stress in excess of 36,000 pounds per square inch (250 MPa).
Hinged Base—See "Pin Connection"
Hip Roof—A roof which rises by inclined planes from all four sides of a building. The line where two adjacent sloping sides of a roof meet is called the Hip.
Hoist—A mechanical lifting device usually attached to a trolley which travels along a bridge, monorail, or jib crane. May be chain or electric operated.
Hot-Rolled Shapes—Steel sections (angles, channels, S-shapes, W-shapes, etc.) which are formed by rolling mills while the steel is in a semi-molten state.

I

ICBO—International Conference of Building Officials.
Ice Dam—A buildup of ice which forms a dam on the roof covering along the eave of the building.
Impact Load—A dynamic load resulting from the motion of machinery, elevators, craneways, vehicles, and other similar moving forces. See "Auxiliary Loads"
Impact Wrench—A pneumatic device used to tighten nuts on bolts.
Insulation—Any material used in building construction to reduce heat transfer.
Intermediate Bay—The distance between two primary frames within a building, other than end frames.

Internal Pressure—Pressure inside a building which is a function of wind velocity and number and location of openings.

J

Jack Beam—A beam used to support another beam, rafter, or truss and eliminate a column support.
Jack Truss—A truss used to support another beam, rafter, or truss and eliminate a column support.
Jamb—The vertical framing members located at the sides of an opening.
Jib Crane—A cantilevered boom or horizontal beam with hoist and trolley. This lifting machine may pick up loads in all or part of a circle around the column to which it is attached.
Jig—A device used to hold pieces of material in a certain position during fabrication.
Joist—A beam used for supporting floor or roof.

K

Kick-Out (Elbow)—(Turn-Out)—An extension attached to the bottom of a downspout to direct water away from a wall.
Kip—A unit of measure equal to 1,000 pounds (4.4KN).
Knee—The connecting area of a column and rafter of a structural frame such as a rigid frame.
Knee Brace—A diagonal brace designed to resist horizontal loads usually from wind or moving equipment.

L

Lean-To—A structure such as a shed, having only one slope and depending upon another structure for partial support.
Leveling Plate—A steel plate used on top of a foundation or other support on which a structural column can rest.
Liner Panel—A metal panel attached to the inside flange of the girts.
Lip—A flange stiffener.
Live Load—See "Roof Live Load"
Longitudinal—The direction parallel to the ridge.
Louver—An opening provided with fixed or movable, slanted fins to allow flow of air.

M

Main Frame—A frame located between end walls of a building which supports the loads from a portion of each adjacent bay.
Main Members—The main load carrying members of a structural system including columns, end wall posts, rafters, and other main support members.
Mansard—A tilted fascia system mounted to the wall, outside the steel line, and extending above the roof line to form a decorative fascia appearance and hide the roof line.
Masonry—Anything constructed of materials such as bricks, concrete blocks, ceramic blocks, and concrete.
Mastic—Caulking or sealant normally used in sealing roof panel laps.
MBMA—Metal Building Manufacturers Association
MBMA Code of Standard Practices—A listing of normal conditions that apply to the sale and erection of a metal building system.
MBDA—Metal Building Dealers Association
Metal Building System—A metal building system consists of a group of coordinated components, including structural members, exterior covering panels, fastening devices and accessories, which have been designed for specific loads, which will work together compatibly and which have been engineered so that they may be mass produced and assembled in various combinations, or in a combination with various collateral materials, to provide an enclosed or partially enclosed structure.
Mezzanine—An intermediate floor placed in any story or room. When the total area of any "mezzanine floor" exceeds 33 1/3 percent of the total floor area in that room, it will be considered as an additional story.
Moment—The tendency of a force to cause rotation about a point or axis.
Moment Connection—A connection designed to transfer moment as well as axial and shear forces between connecting members.

Moment of Inertia—A physical property of a member, which helps define strength and deflection characteristics.

Monolithic Construction—A method of pouring concrete grade beam and floor slab together to form the building foundation without forming and pouring each separately.

Monorail—A single rail support for a material handling system. Normally a standard hot-rolled I-beam.

Multi-Gable Building—Buildings consisting of more than one gable across the width of the building.

Multi-Span Building—Buildings consisting of more than one span across the width of the building. Multiple gable buildings and single gable buildings with interior columns are examples.

N

NBC—National Building Code

NC—North Carolina Code

Newton—SI unit of measure for force (N).

O

Overhead Doors—See "Sectional Overhead Doors"

P

Panels—Gage metal sheets usually with a ribbed configuration and used for roof and wall skin.

Parapet—That portion of the vertical wall of a building which extends above the roof line at the intersection of the wall and roof.

Pascal—SI unit of measure for force per unit area (N/m^2).

Peak—The uppermost point of a gable.

Peak Panel—Formed multi-rib panel located at the building peak.

Peak Sign—A sign attached to the peak of the building at the end wall showing the building manufacturer.

Personnel Doors—A door used by personnel for access to and exit from a building.

Piece Mark—A number given to each separate part of the building for erection identification. Also called mark number and part number.

Pig Spout—A sheet metal section designed to direct the flow of water out through the face of the gutter rather than through a downspout.

Pilaster—A reinforced or enlarged portion of a masonry wall to provide support for roof loads or lateral loads on the wall.

Pinned Base—A column base that is designed to resist horizontal and vertical movement, but not rotation.

Pin Connection—A connection designed to transfer axial and shear forces between connecting members, but not moments.

Plastic Design—A design concept based on multiplying the actual loads by a suitable load factor and using the yield stress as the maximum stress in any member.

Plastic Panels—See "Translucent Light Panels"

Ponding—The gathering of water at low or irregular areas on a roof.

Pop Rivet—See "Blind Rivet"

Portal Frame—A rigid frame structure so designed that it offers rigidity and stability in its plane. It is used to resist longitudinal loads where diagonal bracing is not permitted. (Also "Wind Bent").

Post (End Post; Corner Post)—See "End Wall Column"

Pre-Painted Coil—Coil metal which received a paint coating prior to the forming operation.

Press Brake—A machine used in cold forming metal sheet or strip into desired cross sections.

Pre-Stressed Concrete—Concrete in which the reinforcing cables, wires, or rods in the concrete are tensioned before there is load on the member, holding the concrete in compression for greater strength.

Primary Frame—See "Main Frame"

Prismatic Beam—A beam with uniform cross section.

Purlin—A horizontal structural member attached to the primary frames which supports roof panels.

Purlin Extension—See "End Wall Overhang"

R

Rafter—The main beam supporting the roof system.

Rails (Door)—The horizontal stiffening members of framed and paneled doors.
Rake—The intersection of the plane of the roof and the plane of the gable. (As opposed to end walls meeting hip roofs).
Rake Angle—Angle fastened to purlins at rake for attachment of end wall panels.
Rake Trim—A flashing designed to close the opening between the roof and end wall panels.
Reactions—The resisting forces at the column bases of a frame, holding the frame in equilibrium under a given loading condition.
Reinforcing Steel—The steel placed in concrete to help carry the tension, compression, and shear stresses.
Ridge—Highest point on the roof of the building which describes a horizontal line running the length of the building.
Ridge Cap—A transition of the roofing materials along the ridge of a roof. Sometimes called ridge roll or ridge flashing.
Rigid Connection—See "Moment Connection"
Rigid Frame—A structural frame consisting of members joined together with rigid (or moment) connections so as to render the frame stable with respect to the design loads, without the need for bracing in its plane.
Rolling Doors—Doors that are supported on wheels which run on a track.
Roll-up Doors—See "Rolling Doors"
Roof Covering—The exposed exterior roof skin consisting of panels or sheets.
Roof Live Load—Those loads induced by the use and occupancy of the building, not including wind load, snow load, seismic load or dead load.
Roof Overhang—A roof extension beyond the end wall or side wall of a building.
Roof Pitch—Ratio of rise to total width.
Roof Slope—The angle that a roof surface makes with the horizontal. Usually expressed in units of vertical rise to 12 units of horizontal run.
Roof Snow Load—That load induced by the weight of snow on the roof of the structure.
Ropeseal—See "Sealant"

S

Sag Member—A tension member used to limit the deflection of a girt or purlin in the direction of the weak axis.
Sag Rod, Strap, or Angle—See "Sag Member"
Sandwich Panel—A panel assembly used as covering consists of an insulating core material with inner and outer skins.
SBCCI (somtimes SBC)—Southern Building Code Congress International, Inc.
Screeding—The process of striking off the excess concrete to bring the top surface of the concrete to proper finish and elevation.
Sealant—Any material which is used to seal cracks, joints, or laps.
Section Modulus—A physical property of a structural member. It is used to design and basically describes the bending strength of a member.
Sectional Overhead Doors—Doors constructed in horizontally hinged sections. They are equipped with springs, tracks, counter balancers, and other hardware which roll the sections into an overhead position, clear of the opening.
Seismic Load—The assumed lateral load acting in any horizontal direction on a structural system due to the action of an earthquake.
Self Drilling Screw—A fastener which combines the functions of drilling and tapping. It is used for attaching panels to purlins and girts.
Self Tapping Screw—A fastener which taps its own threads in a predrilled hole. It is for attaching panels to purlins and girts and for connecting trim and flashing.
Shear—The force tending to make two contacting parts slide upon each other in opposite directions parallel to their plane of contact.
Shear Diaphragm—See "Diaphragm"
Sheet Notch—A notch or block-out formed along the outside edge of the foundation to provide support for the wall panels and serve as a closure along their bottom edge.
Shim—A piece of steel used to level base plates or square beams.

Shipping List—A list that enumerates by part number or description each piece of material or assembly to be shipped. Also called talley sheet, bill of materials, or packing list.
Shop Primer Paint—The initial coat of primer paint applied in the shop.
Shoulder Bolt—A fastener used to attach wall and roof paneling to the structural frame. It consists of a large diameter shank and a small diameter stud. The shank provides support for the panel rib.
Shot Pin—A device for fastening items by the utilization of a patented device which uses a powdered charge to imbed the item in the concrete and/or steel.
SI—The International symbol for the metric unit used by the United States (Le Systeme International d' Unités).
Side Lap Fastener—A fastener used to connect panels together at the side lap.
Side Wall—An exterior wall which is parallel to the ridge of the building.
Side Wall Overhang—A projection of the roof past the side wall.
Sill—The bottom horizontal framing member of an opening such as a window or door.
Sill Angle—See "Base Angle"
Simple Span—A term used in structural analysis to describe a support condition for a beam, girt, purlin, etc., which offers no resistance to rotation at the supports.
Single Slope—A sloping roof in one plane. The slope is from one wall to the opposite wall.
Single Span—A building or structural member without intermediate support.
Siphon Break—A small groove to arrest the capillary action of two adjacent surfaces. (Anti-Capillary Groove).
Skylight—A roof accessory to admit light, normally mounted on a curbed framed opening.
Slide Door—A single or double leaf door which opens horizontally by means of overhead trolleys.
Snow Load—See "Roof Snow Load"
Soffit—A metal panel which covers the underside of an overhang or mansard.
So. Fla.—South Florida Code
Soil Pressure—The load per unit area a structure will exert through its foundation on the soil.
Spall—A chip or fragment of concrete which has chipped, weathered, or otherwise broken from the main mass of concrete.
Span—The distance between supports of beams, girders, or trusses.
Splice—A connection in a structural member.
Square—The term used for an area of 100 square feet (9.29 M^2).
Stainless Steel—An alloy of steel which contains a high percentage of chromium. Also may contain nickel or copper.
Steel Line—The outside perimeter of structural steel or inside of wall panels.
Stiffener—A member used to strengthen a plate against lateral or local buckling. Usually a flat bar welded perpendicular to the longitudinal axis of the member.
Stiffener Lip—A short extension of material at an angle to the flange of cold formed structural members, which adds strength to the member.
Stiles—The vertical side members of framed and paneled doors.
Stitch Screw—A fastener used to connect panels at the side lap or to connect flashing to the panels.
Stress—A measure of the load on a structural member in terms of forces per unit area (kips per sq. in.) (MPa).
Strut—A brace fitted into a frame work which resists axial forces.
Stud—A vertical wall member to which exterior or interior covering or collateral material may be attached. May be either load bearing or non-load bearing.
Suction—A partial vacuum resulting from wind loads on a building which cause a load in the outward direction.

T

Tapered Member—A built up plate member consisting of flanges welded to a variable depth web.
Temperature Reinforcing—Light weight deformed steel rods or wire mesh placed in concrete to resist possible cracks from thermal expansion or contraction.

Tensile Strength—The longitudinal pulling stress a material can bear without tearing apart.
Thermal Block—A spacer of low thermal conductance material.
Thermal Conductivity, (k)—The rate of heat flow, in BTU's per hour, through a square foot of material exactly one inch thick whose surfaces have a temperature differential of 1° F.
Thermal Conductance (C)—The rate of heat flow in BTU's per hour, through a square foot of material or a combination of material whose surfaces have a temperature differential of 1° F.
Thermal Resistance (R)—Resistance to heat flow. The reciprocal of conductance. (C)
Thermal Transmittance (U)—The rate of heat flow per square foot under steady conditions from the air on the warm side of a barrier to the air on the cold side, for 1° F of temperature difference between the two (BTU/Ft^2/hr./1° F).
Thrust—The horizontal component of a reaction.
Tie—A structural member that is loaded in tension.
Torque Wrench—A wrench containing an adjustable mechanism for measuring and controlling the amount of torque or turning force to be exerted—often used in tightening nuts and bolts.
Translucent Light Panels—Translucent plastic panels used to admit sunlight.
Transverse—The direction perpendicular to the ridge.
Tributary Area—The area which contributes load to a specific structural component.
Trim—The light gage metal used in the finish of a building, especially around openings and at intersection of surfaces. Often referred to as flashing.
Track—A metal way for wheeled components; specifically one or more lines of ways, with fastenings, ties, etc. for a craneway, monorail, or slide door.
Truss—A structure made up of three or more members, with each member designed to carry a tension or compression force. The entire structure in turn acts as a beam.
Turnout—See "Kickout"
Turn-of-the-Nut-Method—A method for pretensioning high strength bolts. The nut is turned from the snug-tight position, corresponding to a few blows of an impact wrench or the full effort of a man using an ordinary spud wrench, the amount of rotation required being a function of the bolt diameter and length.

U

UBC—Uniform Building Code.
Uplift—Wind load on a building which causes a load in the upward direction. See "Suction"

V

Valley Gutter—A channel used to carry off water from the "V" of roofs of multi-gabled buildings.
Ventilator—An accessory, usually used on the roof, that allows the air to pass through.

W

Wainscot—Wall material, used in the lower portion of a wall, that is different from the material in the rest of the wall.
Wall Covering—The exterior wall skin consisting of panels or sheets.
Web—That portion of a structural member between the flanges.
Web Member—A secondary structural member interposed between the top and bottom chords of a truss.
Welded-Up Section—See "Built-Up Section"
Wind Bent—See "Portal Frame"
Wind Column—A vertical member supporting a wall system designed to withstand horizontal wind loads.
Wind Load—The load caused by the wind blowing from any horizontal direction.

Z

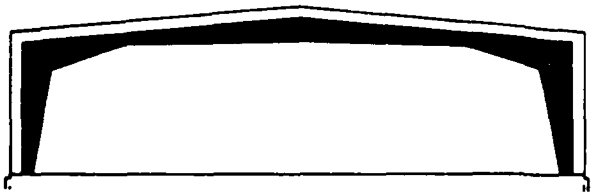
"Z" Section—A member cold formed from steel sheet in the shape of a block "Z".
Zinc-Aluminum Coated—Steel coated with zinc and aluminum for corrosion resistance.

Note: Primary source for this glossary is the 1986 "Low Rise Building System Manual" of the MBMA.

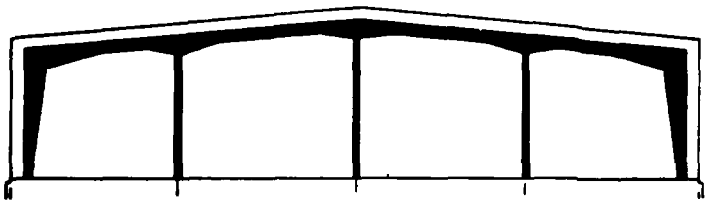
APPENDIX C

TYPICAL PRIMARY FRAMING SYSTEMS

PRIMARY FRAME TYPES AND USES



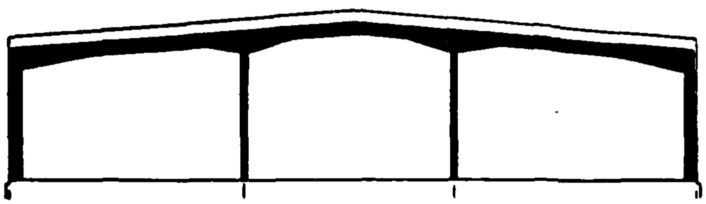
Rigid Frame Clear Span (RF)
Used where column-free floor area is required.



RF4 Illustrated

Rigid Frame Multi-Span (RF __*)
Used where interior columns do not impair function of building. Provides maximum width at lower cost than Rigid Frame Clear Span frames.

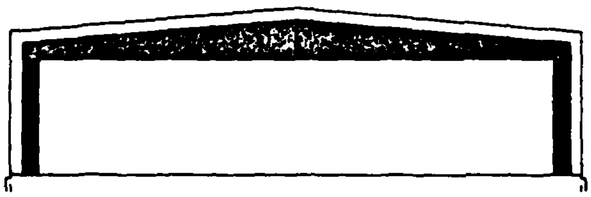
Flush Wall Clear Span (FW)
Used where column-free floor area is required, with the additional specification that columns must be contained within the girt space to allow side walls to be finished in an unbroken, straight line. Less economical than Rigid Frame Clear Span frames, which have no limitations on column depth.



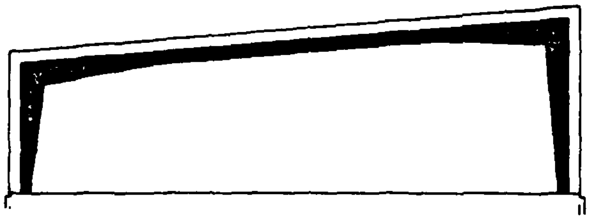
FW3 Illustrated

Flush Wall Multi-Span (FW __*)
Used where interior columns do not impair function of building, but where columns in exterior walls must be contained within the girt space to allow side walls to be finished in an unbroken, straight line. Less economical than Rigid Frame Multi-Span frames, which have no limitations on column depth.

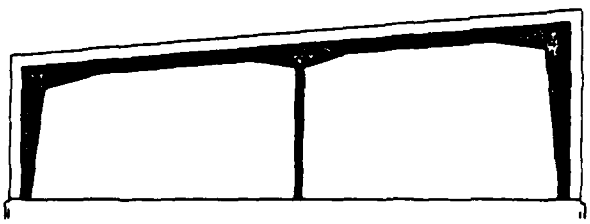
PRIMARY FRAME TYPES AND USES



Tapered Beam Straight Column (TB)
Used where column-free floor area is required. Provides greater interior clearance with less eave height. Smaller horizontal reactions can lower foundation costs. Economical only for shorter spans.

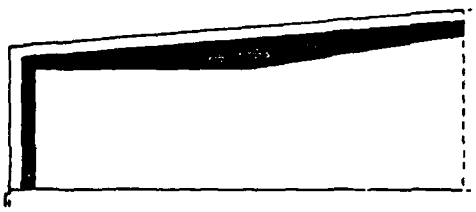


Single Slope Clear Span (SS)
Used where it is advantageous to have one-way roof drainage, and where column-free floor area is required.



SS2 Illustrated

Single Slope Multi-Span (SS _*)
Used where interior columns do not impair function of building, but where one-way roof drainage is advantageous. Provides maximum width at lower cost than Single Slope Clear Span frames.



Lean-To (LT)
Used as an economical way to increase width of existing or new buildings without the additional need of a valley gutter.

***Notes Concerning All Ceco Multi-Span Frames:**

1. Number of spans may vary from a minimum of two to a maximum of any number desired. Spans may be equal or variable.
2. Numerical digit in frame designation denotes the number of spans to be furnished.

PARAMETERS FOR AUTOMATED DESIGN BUILDINGS	
BLDG. WIDTHS	20 ft. to 160 ft.
EAVE HEIGHTS	Minimum = 9 ft. (Maximum eave height is limited by peak height)
PEAK HEIGHT	Maximum = 60 ft.
ROOF SLOPES	Minimum = ¼ : 12 Maximum = 6 : 12
BAY SPACINGS	10 ft. to 30 ft. either equal or mixed bays
NUMBER OF BAYS	Minimum = 2 Bays Maximum = 30 Bays
LENGTH	Minimum of 2 bays at 10 ft. = 20 ft. Maximum of 30 bays at 30 ft. = 900 ft.
GIRT TYPE	By-pass or Inset Girts
END WALL POST SPACING	Maximum = 30 ft.
GRAVITY LOADS	Maximum = 60 psf (Any combination of live load, snow load, collateral loads, etc.)
WIND LOAD	Minimum = 15 psf or 70 mph Maximum = 60 psf or 130 mph
CODES	MBMA, BOCA, SBC, UBC, N.C., So. FLA.

Clearances And Reactions

Due to the broad parameters available for Automated Design Buildings, it is impractical to give minimum clearances and column reactions for the multiple combinations of width, eave height, roof slope, bay spacing, load, and codes that are available. However, for representative samples of the information that Ceco can furnish, please refer to the tables on the following four pages.

For frame clearances and reactions for any specific building, please contact the nearest Ceco manufacturing facility. Telephone numbers for all regions are listed on page B1.5 of this manual.

PARAMETERS FOR AUTOMATED DESIGN BUILDINGS	
BLDG. WIDTHS	50 ft. to 500 ft.
SPANS	25 ft. to 80 ft. spans Maximum of 10 spans
EAVE HEIGHTS	Minimum = 9 ft. (Maximum eave height is limited by peak height)
PEAK HEIGHT	Maximum = 60 ft.
ROOF SLOPES	Minimum = ¼ : 12 Maximum = 6 : 12
BAY SPACINGS	10 ft. to 30 ft. either equal or mixed bays
NUMBER OF BAYS	Minimum = 2 Bays Maximum = 30 Bays
LENGTH	Minimum of 2 bays at 10 ft. = 20 ft. Maximum of 30 bays at 30 ft. = 900 ft.
GIRT TYPE	By-pass or Inset Girts
END WALL POST SPACING	Maximum = 30 ft.
GRAVITY LOADS	Maximum = 60 psf (Any combination of live load, snow load, collateral loads, etc.)
WIND LOAD	Minimum = 15 psf or 70 mph Maximum = 60 psf or 130 mph
CODES	MBMA, BOCA, SBC, UBL, N.C., So. FLA.

Clearances And Reactions

Due to the broad parameters available for Automated Design Buildings, it is impractical to give minimum clearances and column reactions for the multiple combinations of width, spans, eave height, roof slope, bay spacing, load, and codes that are available. However, for representative samples of the information that Ceco can furnish, please refer to the tables on the following four pages.

For frame clearances and reactions for any specific building, please contact the nearest Ceco manufacturing facility. Telephone numbers for all regions are listed on page B1.5 of this manual.

PARAMETERS FOR AUTOMATED DESIGN BUILDINGS	
BLDG. WIDTHS	20 ft. to 70 ft.
EAVE HEIGHTS	Minimum = 9 ft. Maximum = 20 ft.
ROOF SLOPES	Minimum = ¼:12 Maximum = 4:12
BAY SPACINGS	10 ft. to 30 ft. either equal or mixed bays
NUMBER OF BAYS	Minimum = 2 Bays Maximum = 30 Bays
LENGTH	Minimum of 2 bays at 10 ft. = 20 ft. Maximum of 30 bays at 30 ft. = 900 ft.
GIRT TYPE	Flush Girts Only
END WALL POST SPACING	Maximum = 30 ft.
GRAVITY LOADS	Maximum = 60 psf (Any combination of live load, snow load, collateral loads, etc.)
WIND LOAD	Minimum = 15 psf or 70 mph Maximum = 60 psf or 130 mph
CODES	MBMA, BOCA, SBC, UBL, N.C., So. FLA.

Clearances And Reactions

Due to the broad parameters available for Automated Design Buildings, it is impractical to give minimum clearances and column reactions for the multiple combinations of width, eave height, roof slope, bay spacing, load, and codes that are available. However, for representative samples of the information that Ceco can furnish, please refer to the tables on the following four pages.

For frame clearances and reactions for any specific building, please contact the nearest Ceco manufacturing facility. Telephone numbers for all regions are listed on page B1.5 of this manual.

PARAMETERS FOR AUTOMATED DESIGN BUILDINGS	
BLDG. WIDTHS	50 ft. to 250 ft.
SPANS	25 ft. to 75 ft. Spans Maximum of 10 Spans
EAVE HEIGHTS	Minimum = 9 ft. Maximum = 20 ft. Maximum eave height is also limited by peak height.
PEAK HEIGHT	Maximum = 35 ft.
ROOF SLOPES	Minimum = ¼ : 12 Maximum = 4 : 12
BAY SPACINGS	10 ft. to 30 ft. either equal or mixed bays
NUMBER OF BAYS	Minimum = 2 Bays Maximum = 30 Bays
LENGTH	Minimum of 2 bays at 10 ft. = 20 ft. Maximum of 30 bays at 30 ft. = 900 ft.
GIRT TYPE	Flush Girts Only
END WALL POST SPACING	Maximum = 30 ft.
GRAVITY LOADS	Maximum = 60 psf (Any combination of live load, snow load, collateral loads, etc.)
WIND LOAD	Minimum = 15 psf or 70 mph Maximum = 60 psf or 130 mph
CODES	MBMA, BOCA, SBC, UBL, N.C., So. FLA.

Clearances And Reactions

Due to the broad parameters available for Automated Design Buildings, it is impractical to give minimum clearances and column reactions for the multiple combinations of width, spans, eave height, roof slope, bay spacing, load, and codes that are available. However, for representative samples of the information that Ceco can furnish, please refer to the tables on the following four pages.

For frame clearances and reactions for any specific building, please contact the nearest Ceco manufacturing facility. Telephone numbers for all regions are listed on page B1.5 of this manual.

PARAMETERS FOR AUTOMATED DESIGN BUILDINGS	
BLDG. WIDTHS	15 ft. to 70 ft.
EAVE HEIGHTS	Minimum = 9 ft. Maximum = 30 ft.
ROOF SLOPES	Minimum = ¼ : 12 Maximum = 1 : 12
BAY SPACINGS	10 ft. to 30 ft. either equal or mixed bays
NUMBER OF BAYS	Minimum = 2 Bays Maximum = 30 Bays
LENGTH	Minimum of 2 bays at 10 ft. = 20 ft. Maximum of 30 bays at 30 ft. = 900 ft.
GIRT TYPE	By-pass or Inset Girts
END WALL POST SPACING	Maximum = 30 ft.
GRAVITY LOADS	Maximum = 60 psf (Any combination of live load, snow load, collateral loads, etc.)
WIND LOAD	Minimum = 15 psf or 70 mph Maximum = 60 psf or 130 mph
CODES	MBMA, BOCA, SBC, UBL, N.C., So. FLA.

Clearances And Reactions

Due to the broad parameters available for Automated Design Buildings, it is impractical to give minimum clearances and column reactions for the multiple combinations of width, eave height, roof slope, bay spacing, load, and codes that are available. However, for representative samples of the information that Ceco can furnish, please refer to the tables on the following four pages.

For frame clearances and reactions for any specific building, please contact the nearest Ceco manufacturing facility. Telephone numbers for all regions are listed on page B1.5 of this manual.

PARAMETERS FOR AUTOMATED DESIGN BUILDINGS	
BLDG. WIDTHS	20 ft. to 160 ft.
EAVE HEIGHTS	Minimum = 9 ft. Low Side Maximum = 60 ft. High Side
ROOF SLOPES	Minimum = ¼ : 12 Maximum = 6 : 12
BAY SPACINGS	10 ft. to 30 ft. either equal or mixed bays
NUMBER OF BAYS	Minimum = 2 Bays Maximum = 30 Bays
LENGTH	Minimum of 2 bays at 10 ft. = 20 ft. Maximum of 30 bays at 30 ft. = 900 ft.
GIRT TYPE	By-pass or Inset Girts
END WALL POST SPACING	Maximum = 30 ft.
GRAVITY LOADS	Maximum = 60 psf (Any combination of live load, snow load, collateral loads, etc.)
WIND LOAD	Minimum = 15 psf or 70 mph Maximum = 60 psf or 130 mph
CODES	MBMA, BOCA, SBC, UBL, N.C., So. FLA.

Clearances And Reactions

Due to the broad parameters available for Automated Design Buildings, it is impractical to give minimum clearances and column reactions for the multiple combinations of width, eave height, roof slope, bay spacing, load, and codes that are available. However, for representative samples of the information that Ceco can furnish, please refer to the tables on the following four pages.

For frame clearances and reactions for any specific building, please contact the nearest Ceco manufacturing facility. Telephone numbers for all regions are listed on page B1.5 of this manual.

PARAMETERS FOR AUTOMATED DESIGN BUILDINGS	
BLDG. WIDTHS	50 ft. to 500 ft.
SPANS	25 ft to 80 ft. Spans Maximum of 10 Spans
EAVE HEIGHTS	Minimum = 9 ft. Low Side Maximum = 60 ft. High Side
ROOF SLOPES	Minimum = ¼ : 12 Maximum = 6 : 12
BAY SPACINGS	10 ft. to 30 ft. either equal or mixed bays
NUMBER OF BAYS	Minimum = 2 Bays Maximum = 30 Bays
LENGTH	Minimum of 2 bays at 10 ft. = 20 ft. Maximum of 30 bays at 30 ft. = 900 ft.
GIRT TYPE	By-pass or Inset Girts
END WALL POST SPACING	Maximum = 30 ft.
GRAVITY LOADS	Maximum = 60 psf (Any combination of live load, snow load, collateral loads, etc.)
WIND LOAD	Minimum = 15 psf or 70 mph Maximum = 60 psf or 130 mph
CODES	MBMA, BOCA, SBC, UBL, N.C., So. FLA.

Clearances And Reactions

Due to the broad parameters available for Automated Design Buildings, it is impractical to give minimum clearances and column reactions for the multiple combinations of width, spans, eave height, roof slope, bay spacing, load, and codes that are available. However, for representative samples of the information that Ceco can furnish, please refer to the tables on the following four pages.

For frame clearances and reactions for any specific building, please contact the nearest Ceco manufacturing facility. Telephone numbers for all regions are listed on page B1.5 of this manual.

PARAMETERS FOR AUTOMATED DESIGN LEAN-TO'S	
BLDG. WIDTHS	10 ft. to 60 ft.
EAVE HEIGHTS (HIGH SIDE)	Must be same as eave height of supporting structure
EAVE HEIGHTS (LOW SIDE)	Minimum = 9 ft. Maximum for flush wall conditions = 20 ft. Maximum for non-flush conditions is limited by eave height high side.
ROOF SLOPES	Minimum = ¼ : 12 (Must be same as Maximum = 6 : 12 supporting structure)
BAY SPACINGS	10 ft. to 30 ft. either equal or mixed bays
NUMBER OF BAYS	Minimum = 2 Bays Maximum = 30 Bays
LENGTH	Minimum of 2 bays at 10 ft. = 20 ft. Maximum of 30 bays at 30 ft. = 900 ft.
GIRT TYPE	By-pass, Inset, or Flush Girts
LEAN-TO LOCATION	On side wall of supporting structure only. At eave line of supporting structure only.
END WALL POST SPACING	Maximum = 30 ft.
GRAVITY LOADS	Maximum = 60 psf (Any combination of live load, snow load, collateral loads, etc.)
WIND LOAD	Minimum = 15 psf or 70 mph Maximum = 60 psf or 130 mph
CODES	MBMA, BOCA, SBC, UBL, N.C., So. FLA.

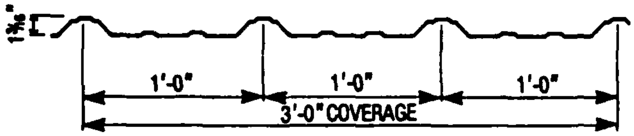
Clearances And Reactions

Due to the broad parameters available for Automated Design Buildings, it is impractical to give minimum clearances and column reactions for the multiple combinations of width, eave height, roof slope, bay spacing, load, and codes that are available. However, for representative samples of the information that Ceco can furnish, please refer to the tables on the following four pages.

For frame clearances and reactions for any specific building, please contact the nearest Ceco manufacturing facility. Telephone numbers for all regions are listed on page B1.5 of this manual.

APPENDIX D

TYPICAL WALL AND ROOF PANELS

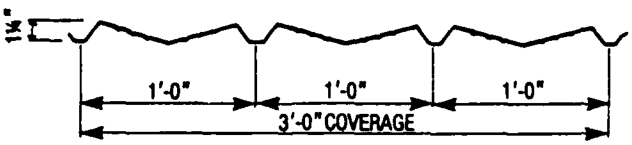


MVW (Versatile Panel)

MVW Wall Panels are roll formed from 50,000 psi yield steel in 26 gage. Panel coverage is 36 inches with 1$\frac{3}{16}$ inch deep major ribs at 12 inch centers and 2 intermediate minor stiffening ribs in each flat. The maximum panel length is 30 feet.

MVW Wall Panels may have a finish of Galvalume™ or any of Ceco's standard panel colors. These panels may also be used for wainscot, soffit, or fascia sheets.

This panel is produced at the Eastern, Southern, and Midwestern regional plants and can be supplied to all regions.

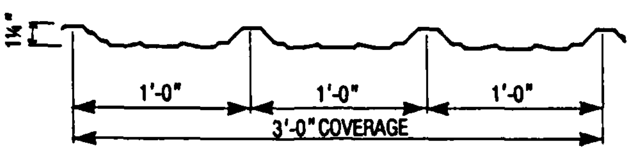


MSP (Shadow-Lite Panel)

MSP Wall Panels are roll formed from 50,000 psi yield steel in 26 gage. Panel coverage is 36 inches with 1¼ inch deep reversed major ribs at 12 inch centers and an intermediate break line plus 6 pencil ribs in each flat. The maximum panel length is 30 feet.

MSP Wall Panels may have a finish of Galvalume™ or any of Ceco's standard panel colors. These panels may also be used for fascia sheets.

This panel is produced at the Eastern, Southern, and Midwest regional plants and can be supplied to all regions.

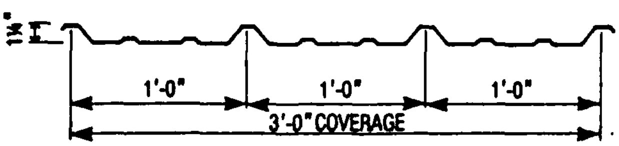


DCW (Decopanl)

DCW Wall Panels are roll formed from 50,000 psi yield steel in 26 gage. Panel coverage is 36 inches with 1¼ inch deep major ribs at 12 inch centers and intermediate break lines in each flat. The maximum panel length is 30 feet.

DCW Wall Panels may have a finish of Galvalume™ or any of Ceco's standard panel colors. These panels may also be used for wainscot, soffit, or fascia sheets.

This panel is produced at the Southwestern regional plant and can be supplied to all regions.



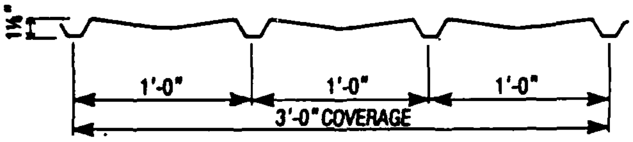
ANW (R Panel)

ANW Wall Panels are roll formed from 50,000 psi yield steel in 26 gage. Panel coverage is 36 inches with 1¼ inch deep major ribs at 12 inch centers and 2 intermediate minor stiffening ribs in each flat. The maximum panel length is 30 feet.

ANW Wall Panels may have a finish of Galvalume™ or any of Ceco's standard panel colors. These panels may also be used for wainscot, soffit, or fascia sheets.

This panel is produced at the Western regional plant and can be supplied to all regions.

WALL PANELS

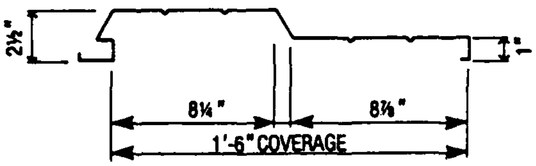


SUW (A Panel)

SUW Wall Panels are roll formed from 50,000 psi yield steel in 26 gage. Panel coverage is 36 inches with 1⅛ inch deep reversed major ribs at 12 inch centers and intermediate break lines in each flat. The maximum panel length is 30 feet.

SUW Wall Panels may have a finish of Galvalume™ or any of Ceco's standard panel colors. These panels may also be used for fascia sheets.

This panel is produced at the Western regional plant and can be supplied to all regions.

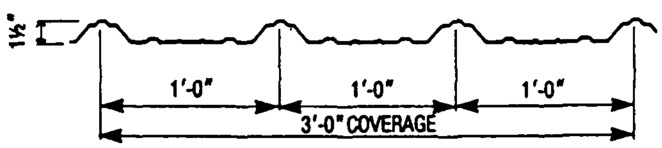


CFP (CF-2000 Concealed Fastener Panel)

CFP Wall Panels are roll formed from 50,000 psi yield steel in 24 gage. Panel coverage is 18 inches and the panel overall depth is 2½ inches. Each panel is formed with one inset and one outset plane, each approximately 8 inches wide. Two small grooves are in each flat. The panel edges interlock in a tongue and groove method, and all fasteners are completely concealed. Factory applied sealant is provided at each interlocking joint for weathertightness. The maximum panel length is 30 feet.

CFP Wall Panels have an embossed finish in colors of Burnished Slate, Light Stone, or Honey Buff. These panels may also be used as sheeting for some fascias (see Section H—Facades).

This panel is produced at the Eastern regional plant and is supplied to all regions.



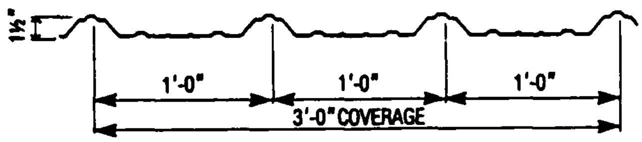
MAP (Architectural Panel)

MAP Wall Panels are roll formed from 50,000 psi yield steel in 26 gage. Panel coverage is 36 inches with 1½ inch deep major ribs at 12 inch centers and 2 intermediate minor stiffening ribs plus 2 pencil ribs in each flat. The maximum panel length is 30 feet.

MAP Wall Panels may have a finish of Galvalume™ or any of Ceco's standard panel colors. These panels may also be used for wainscot or fascia sheets.

This panel is produced at the Eastern, Southern, and Midwestern regional plants and can be supolied to all regions.

NOTE: Panel gages indicated are standard. Other gages are available upon request, provided quantity ordered is sufficient.

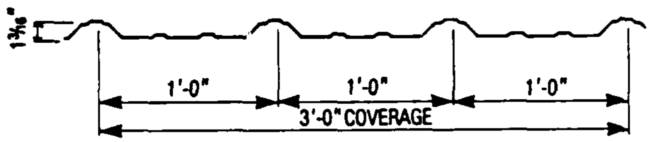


MAP (Architectural Panel)

MAP Roof Panels are roll formed from 50,000 psi yield steel in 26 gage. Panel coverage is 36 inches with 1½ inch deep major ribs at 12 inch centers and 2 intermediate minor stiffening ribs plus 2 pencil ribs in each flat. The maximum panel length is 42 feet.

MAP Roof Panels may have Galvalume™ or white finish. A UL90 wind uplift rating is available with 4 inch maximum blanket insulation.

This panel is produced at the Eastern, Southern, and Midwestern regional plants and can be supplied to all regions.

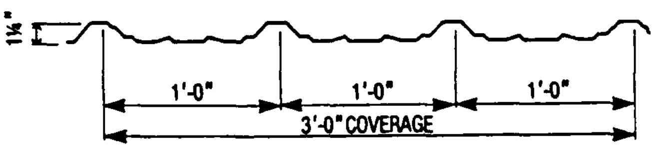


MVR (Versatile Panel)

MVR Roof Panels are roll formed from 80,000 psi yield steel in 26 gage. Panel coverage is 36 inches with 1³⁄₁₆ inch deep major ribs at 12 inch centers and 2 intermediate minor stiffening ribs in each flat. Panel has a preformed anti-capillary groove at side laps. The maximum panel length is 42 feet.

MVR Roof Panels may have Galvalume™ or white finish.

This panel is produced at the Eastern, Southern, and Midwestern regional plants and can be supplied to all regions.

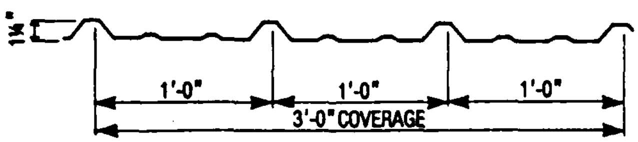


DCR (Decopanl)

DCR Roof Panels are roll formed from 80,000 psi yield steel in 26 gage. Panel coverage is 36 inches with 1¼ inch deep major ribs at 12 inch centers and intermediate break lines in each flat. Panel features a preformed anti-capillary groove at side laps. The maximum panel length is 42 feet.

DCR Roof Panels may have Galvalume™ or white finish. A UL90 wind uplift rating is available with 6 inch maximum blanket insulation.

This panel is produced at the Southwestern regional plant and can be supplied to all regions.

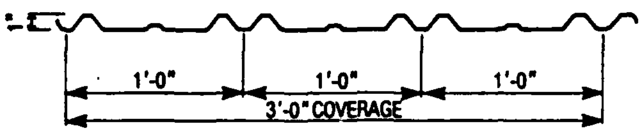


ANR (R Panel)

ANR Roof Panels are roll formed from 50,000 psi yield steel in 26 gage. Panel coverage is 36 inches with 1¼ inch deep major ribs at 12 inch centers and 2 intermediate minor stiffening ribs in each flat. The maximum panel length is 42 feet.

ANR Roof Panels may have Galvalume™ or white finish.

This panel is produced at the Western regional plant and can be supplied to all regions.

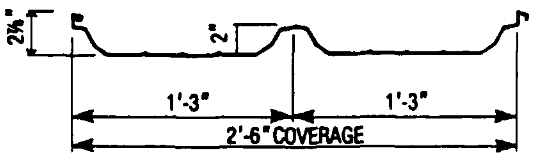


SUR (Twin Rib Panel)

SUR Roof Panels are roll formed from 37,000 psi yield steel in 26 gage. Panel coverage is 36 inches with 1 inch deep major rib pairs at 12 inch centers and an intermediate minor stiffening rib in each flat. The maximum panel length is 42 feet.

SUR Roof Panels may have Galvalume™ or white finish. A UL90 wind uplift rating is available with 3 inch maximum blanket insulation and a UL30 rating with 6 inch maximum blanket insulation.

This panel is produced at the Western regional plant and can be supplied to all regions.



CLP (Cecolok Standing Seam Panel)

CLP Roof Panels are roll formed from 50,000 psi yield steel in 24 gage. Panel coverage is 30 inches with 2⅞ inch deep ribs at seams and a 2 inch deep rib at the center of the panel. Three small pencil ribs are in each flat. The maximum panel length is 42 feet.

CLP Roof Panels are attached to secondary framing by concealed clips which are locked into the seamed ribs during the seaming process on the jobsite. Factory-applied sealant is provided at each seamed joint to assure weathertightness. Fasteners are installed through the panel only at eaves and end laps.

CLP Roof Panels may have Galvalume™ or white finish. Panel carries a UL90 wind uplift rating with 6 inch maximum blanket insulation.

This panel is produced at the Eastern, Southern, and Midwestern regional plants and is supplied to all regions.

NOTE: Panel gages indicated are standard. Other gages are available upon request, provided quantity ordered is sufficient.

APPENDIX E

POLICY ON DRAWINGS AND CALCULATIONS

Ceco Buildings Division

POLICY ON DRAWINGS & CALCULATIONS

INTRODUCTION

Contracts for all Ceco buildings include three sets of erection information mailed to the customer prior to the time of shipment by the Customer Service Department. Each set of erection information contains the following minimum data:

- Printed erection drawings: anchor bolt setting plan with frame reactions, roof framing plan, wall framing plans (4 elevations), cross-section, accessory schedule, and special details (if applicable)
- Printed Packing Lists (multiple pages listing all materials included and necessary for erection of buildings)

In addition one Construction Techniques Manual (which shows typical erection information and details) will be included with the erection information.

When requested, three sets of erection drawings will be furnished for approval. No further work will be done by Ceco until one set of these drawings is returned "Approved" or "Approved as Noted". Resubmittal of approval drawings will be only at the request of the customer; otherwise Ceco will incorporate the noted corrections in the final erection drawings before issuing for construction.

If required, three sets of computer generated structural calculations will be furnished for the customer's review and approval or just for his records. When calculations are required for approval, under no circumstances will Ceco begin fabrication until one set is returned "Approved". In lieu of (or in addition to) calculations, a Letter of Certification (signed and sealed by a Professional Engineer) will be furnished by Ceco at no charge if requested by the customer.

Drawings and/or calculations submitted for approval constitute an integral part of the contract between the customer and Ceco.

The contents of the approval erection drawings are intended specifically for the project at hand; therefore, in case of contradictions, they supercede any other information published for general use.

If approval drawings and/or calculations are required, anchor bolt plans will not be issued for construction until after receipt of signed approval drawings. Only drawings stamped "For Construction" shall be used for setting anchor bolts and for erection.

APPENDIX F

LETTERS FROM GOVERNMENT ENGINEERS

DEPARTMENT OF THE NAVY
ATLANTIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
NORFOLK, VIRGINIA 23511-6287

TELEPHONE NO.
(804) 444-9944
IN REPLY REFER TO:
04A:WHC:sgn
9 Feb 88

LCDR Kevin E. Mikula, CEC, USN
1810 NW 23rd Blvd.
Apartment 178
Gainesville, FL 32605

Dear LCDR Mikula:

Your letter of 24 January 1988 requested information pertaining to the selection, design and economic aspects of current metal buliding use within LANTNAVFACENGCOM and implied that these buildings are seldom specified for NAVFAC projects.

We utilize pre-engineered buildings whenever cost-effective and appropriate. For example, we currently have the following projects in various stages of in-house design:

Warehouse	MCAS NEW RIVER NC
Public Works Facility	NAVSECGRUACT AZORES
Gymnasium	NAVSECGRUACT NORTHWEST VA
Storage Shed/Issue Facility	NSC NORFOLK VA
Ggeneral Warehouse Y-100	NSC NORFOLK VA
A/C Component Storage Sheds	NSC NORFOLK VA
Warehouse	CLASSIFIED LOCATION

There are drawbacks when comparing civilian and military facilities. The category "low rise non-residential buildings" may be too broad, since military facilities often contain special applications in the way of security, energy savings, damage resistance, structural requirements, or other government criteria, depending on the location and use. To expand further, many military facilities are function specific (airfield, waterfront, training) and just do not fit under the more general civilian description.

One final comment; please be aware that the Metal Building Manufacturer's Association's (MBMA) structural design criteria fails to meet the Navy's in certain areas.

After completing your investigation and subsequent publication of your report, we would be most interested in receiving a copy.

Sincerely

WILLIAM H. CRONE, P.E.
Deputy Director
Engineering and Design Division

DEPARTMENT OF THE ARMY
CONSTRUCTION ENGINEERING RESEARCH LABORATORY, CORPS OF ENGINEERS
P.O. BOX 4005
CHAMPAIGN, ILLINOIS 61820-1305

REPLY TO
ATTENTION OF:

March 28, 1988

Facility Systems Division

LCDR Kevin Mikula, CEC, USN
1810-178 NW 23rd Blvd.
Gainesville, Florida 32605

Dear LCDR Mikula;

The Corps of Engineers uses pre-engineered metal buildings in standard practice. The typical applications are for utilitarian buildings such as storage or maintenance facilities. Corps of Engineers Guide Specification (CEGS) 13120, "Metal Buildings" addresses structural design and the qualities of structural materials, coverings, and accessories. A copy of CEGS 13120 is enclosed. USA-CERL has not conducted any research relative to the performance of life-cycle costs of metal building systems.

It is evident that pre-engineered metal building systems have much greater potential applications beyond simple metal buildings. The metal building industry has become more active in developing and promoting the versatility of its products for other than strictly utilitarian purposes. The development of low-slope roof systems, for example, enabled applications where a building of more conventional appearance was desired. Most manufacturers provide guidance and details for using their structural and roof systems with "collateral" wall materials such as masonry, precast panels, or architectural curtain wall systems. Several manufacturers (such as Butler, Armco, and others) have developed roof framing and deck systems intended for use with conventional load bearing wall construction, such as masonry, cast-in-place concrete, or precast concrete. Standing seam metal roof systems are now recognized as a high quality roofing technology with applications to conventional and pre-engineered construction as well as reroofing applications. The Metal Building Manufacturers Association (MBMA) and Systems Builder Association (SBA) may be able to provide information on current developments in pre-engineered building systems.

There have been some recent Corps projects that may be of interest to you. Enclosed is USA-CERL Technical Report P 85-05 "Industrialized Building Systems / Two-Step Procurement Pilot Projects: Three Case Studies". This report describes three Military Construction, Army (MCA) projects administered on a Design/Build basis; proposers were at their options to select the construction systems for the facilities. For two of the facilities, the most economical proposals utilized pre-engineered building systems. Pre-engineered building systems have also been incorporated into proposals in subsequent MCA Design/Build projects.

There are, however, reservations about metal building systems that exist in the Corps. The Corps generally observes ANSI A.58.1 for loading conditions and criteria. The MBMA Metal Building Systems Manual, however, describes loading criteria and load combinations that are different from and, some say, less rigorous than ANSI A.58.1. Therefore, the Corps will generally require conformance to the ANSI criteria instead of the MBMA criteria. This may be an issue you may find relevant to your studies.

It is difficult to make generalizations about the life-cycle cost characteristics of pre-engineered building systems. Essentially, life-cycle performance is a function of the performance of a building's components -- thermal envelope, mechanical systems, finish materials, etc. Given comparable design criteria, there ought not be a significant difference in life-cycle cost between pre-engineered systems and conventional construction methods. One consideration for pre-engineered building systems involves the quality levels and costs of the various coating systems available for metal roofing and siding materials.

Your hypothesis about a stereotype and resistance to metal building systems is quite true. Developments within the construction industry are often slow to gain wide-spread acceptance. The use of pre-engineered building systems in more sophisticated architectural applications seems to follow this trend. Perhaps the Architectural and Engineering community as a whole (working in both the private and military sectors) may not be completely current with regard to pre-engineered building systems' potential.

The periodical Building Design and Construction over the last few years has published several feature articles on more imaginative applications of pre-engineered metal building systems. Two other publications, Metal Architecture and Metal Construction News, are devoted entirely to metal building systems and components. You may find these publications be helpful in assessing the state-of-the-art in pre-engineered building systems.

Please contact Mr. Tom Napier, (217) 373-7263 or 1-800-USA-CERL ext. 263, if you have any questions or if we can be of any further assistance to your study.

Sincerely,

Michael J. O'Connor
Acting Chief, Facility Systems Division

Enclosures