PDHonline Course S237 (2 PDH)

Pre-engineered Metal Buildings: Secrets to Cost Reduction and Insights into the Trade

Instructor: Matthew R. Kromke, PE

2020

PDH Online | PDH Center

5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

An Approved Continuing Education Provider

Pre-engineered Metal Buildings:
Secrets to Cost Reduction and Insights into the Trade

Matthew R. Kromke, P.E.

COURSE CONTENT

1. Basics

For a project to end right it has to start right. Start with dimensions: The smallest building dimension should be the width, and the largest building dimension should be the length. As with any rule, there are a few exceptions. The first exception is when the layout of your building allows an interior column in the long direction, making the long direction a shorter span than the short direction (see figures 1a & 1b.) By reducing the span you will reduce the weight of the rigid frames. The second exception is when post and beam end frames can be used instead of rigid frames (see figure 2a & 2b.) Post and beam end frames are more economical than any other type of frame.

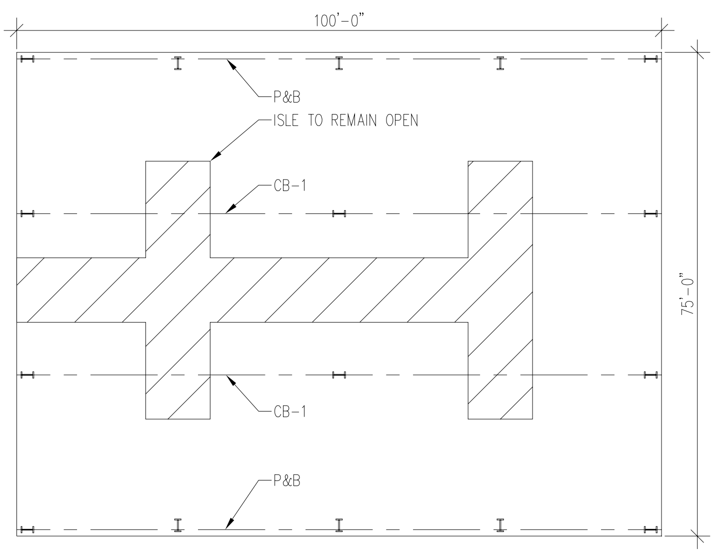


FIGURE 1A
(LAYOUT IS MORE ECONOMICAL)

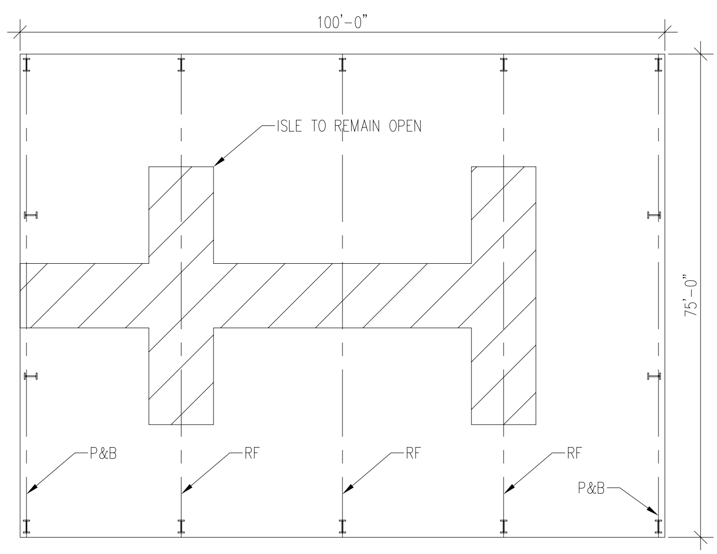


FIGURE 1B
(LAYOUT IS LESS ECONOMICAL)

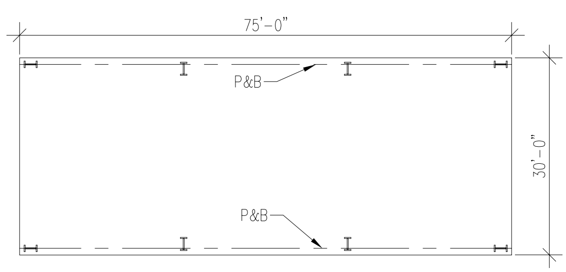


FIGURE 2A
(LAYOUT IS MORE ECONOMICAL)

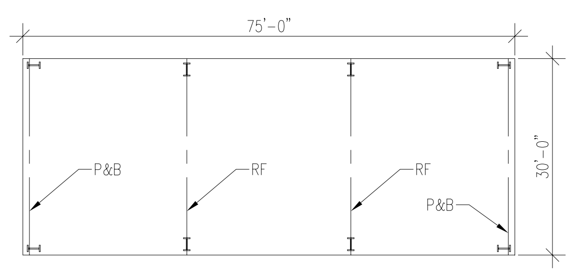


FIGURE 2B
(LAYOUT IS LESS ECONOMICAL)

2. Frame Types

From an efficiency standpoint, choosing the proper frame type for your building is one of the most important decisions. Not only does it affect the cost of the structure but it determines the clearances and functionality of the space. Below are some generalizations and tips that will help you in choosing the right frame for your project.

2A. Post and Beam Frames (P&B)

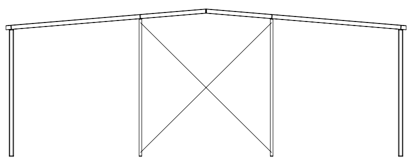


FIGURE 3
(POST & BEAM FRAME)

P&B frames are your first choice for end frames, but they are rarely thought of as interior frames. This is because they rely on either rod bracing or the diaphragm capacity of metal panel. However, there are two cases in which P&B frames are well suited for an interior frame application. The first is when there is an interior partition wall. The partition wall panel can provide the required diaphragm or a convenient place for rod bracing. The second case is when you have an interior masonry wall. Masonry walls are often placed on the interior of a structure to act as fire walls, containment walls such as those used in wash bays, or for sound deadening partitions. If you have a masonry wall directly under an interior frame and do not positively attach to it, you must provide a gap between the masonry and the frame. This gap, which can be quite large, provides the necessary clearance for the differential deflection between the frame and the masonry. A major setback to having this gap is the fireproofing required to fill it. Fireproofing material is both expensive and unsightly. Another problem to having a gap between the frame and the masonry is that masonry walls require bracing in the weak direction. The bracing at the top of an interior masonry wall can become quite elaborate and expensive. Interior masonry walls with short heights can be designed as cantilever walls, removing the need for bracing at the top. However, cantilever masonry walls will have larger footings. In addition, the larger footing and the wall will both require additional reinforcing. Train yourself to think about P&B frames anytime you encounter interior partitions. Your wallet will thank you.

Rod bracing in the roof is purposely broken at end post locations so that the load at the top of the end post gets into the bracing system. When end posts don't line up, additional breaks in the rod bracing is required. Therefore, whenever possible, line up the end posts on either side of the building. This will clean up your grids and reduce the cost of the bracing system. (See figure 4a&4b)

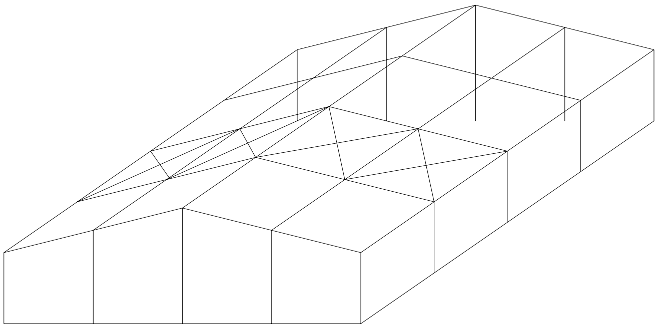


FIGURE 4A
(END POSTS LINE UP ON EITHER SIDE OF THE BUILDING)

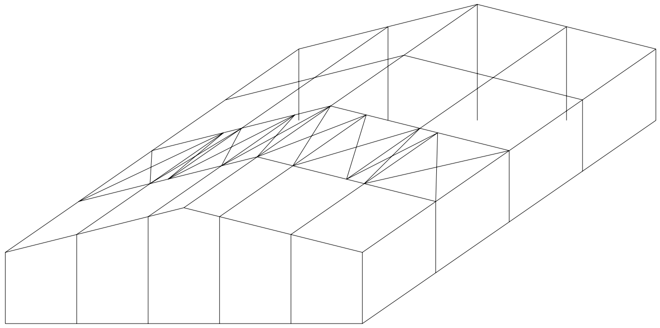


FIGURE 4B
(END POSTS DO NOT LINE UP ON EITHER SIDE OF THE BUILDING)

Use larger spacing between your end posts. Larger end post spacing will reduce the number of end posts, foundations, and bays of girts. Not only will this reduce the cost of the structure but it reduces installation time as well. 25 to 30 foot end post spacing is a reasonable distance for girts to span.

2B. Rigid Frames (RF)

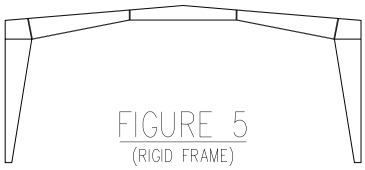


FIGURE 5
(RIGID FRAME)

In general, higher slopes are more economical than lower slopes. For example, 1 on 12 is better than ½ on 12 and 2 on 12 is better than 1 on 12. However, a slope of 3 on 12 and greater tends to increase the overall project cost.

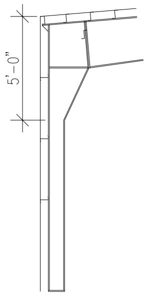
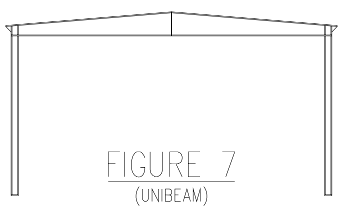


FIGURE 6
(SUPERMARKET COLUMN)

Avoid using straight columns. If straight columns are required, use the maximum depth allowed. A difference of only 2 inches in column depth can save hundreds of dollars per frame. An alternative to using straight columns from top to bottom is to use supermarket columns (see figure 6). For example, in large retail stores, such as supermarkets (hence the name) or home improvement stores, the owner may want straight columns for the first 8 to 10 feet to allow for fixtures. Beyond that, the main reason for high eave heights is for signage and lines of sight. By using a supermarket column you'll reduce cost, improve horizontal drift, and lower the horizontal kick at the base. Be aware that there are minimum heights for the tapered section that manufacturers need in order to fabricate supermarket columns. These minimums vary depending on the ability of the manufacturer's welding equipment to connect the web to the flange. As a general rule, the distance from the eave to the top of the straight portion of the column should be no less than 5 feet.

Optimization software has come a long way since earlier versions. However, nothing can replace the optimization performed by a seasoned technician. Therefore, if your metal building supplier has provided you with software, it would be wise to send your model to the customer service representative for fine tuning. This is especially important when you encounter long spans, buildings with high eave heights, or large asymmetrical concentrated loads.

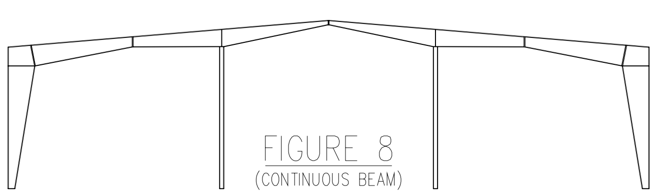
2C. Unibeam Frames (UB)



UB frames are competitive with rigid frames for spans up to 50 feet and are the preferred frame in buildings with spans 20 feet or less with low eave heights.

When metal building systems manufacturers went to automated design software, this frame quickly went out of style. Not because it is less cost effective, but because determining whether the UB or RF is more economical requires two runs of their software. Therefore, if you want to ensure the metal building systems manufacturer is considering this type of frame, be sure to ask them to provide you with a cost comparison. UB frames offer many advantages like straight, usually shallow columns and increased horizontal and vertical clearances. The increased vertical clearance may allow a shorter eave height. One overlooked advantage to the UB frame is the relatively low horizontal kick reactions they produce. This phenomenon reduces the size of the required foundations. The savings in the foundation cost will not appear in the cost comparison from the metal building systems manufacturer. So if the costs of the two frame types are close, you would be making a prudent choice by going with the UB frame.

2D. Continuous Beam (CB)



CB frames are usually more economical than rigid frames at spans over 60 feet. In general, lower slopes are more economical than higher slopes. For example, ½ on 12 is better than 1 on 12 and 1 on 12 is better than 2 on 12. However, there are minimum slopes required for different types of roof panels. Check with your metal building supplier for the minimum slope required for your project. In no case shall you use a slope less than ¼ on 12 to avoid issues with ponding water. Watch for minimum slopes on hip frames such as those in the corner of "L" shaped buildings. Hip frames will have a lower slope than the typical frame because it has a longer span. For example, to maintain a minimum slope of ¼ on 12 for a hip frame, the slope of the typical frames must be 3/8 on 12. If the minimum required slope needed to be ½ on 12 for the hip frame, the typical frames would need a slope of ¾ on 12.

Remember to consider the cost of the foundations required by interior columns when comparing the price of RF to CB frames or CB frames with more columns. Because metal buildings are very efficient they are also very light in weight. Foundations for most metal buildings are dictated by uplift forces from wind. The presence of a frost wall along the exterior of the building helps significantly reduce the required size of footings. Interior columns do not have a frost wall nor are they covered with significant amounts of soil to help decrease the size of the footing. For these reasons, along with greater tributary areas, interior footings are typically wider and thicker than exterior footings. So keep in mind that the cost of footings may offset the savings you'll receive with additional interior columns when comparing the cost of frame types.

When using interior columns, choosing the correct shape is important. Above 35 feet, square tube columns are the most economical. Pipe columns, while more economical than 3 plate columns above 35 feet, should be avoided whenever possible. This is because of the relatively low yield strength and smaller second moments of inertia that are inherent with pipe. Up to 35 feet in length, 3 plate interior columns are the most economical. This may surprise many people familiar to conventional buildings. For conventional buildings, square tube columns are, hands down, the cheapest shape available. However, metal building manufacturers produce 3 plate members so efficiently, and in such high quantities that the finished cost of a 3 plate member is lower than a lighter weight square tube section. Like UB frames, most industry optimization software requires two runs in order to determine the most economical interior column shape. In order to determine the most efficient interior column shape for your project, be sure to inform your supplier that you would like them to consider square tube columns.

Fixing, or making the connection moment resisting, at the top of interior columns will help reduce horizontal drift as well as reduce the size of the haunch and its connections. Fixing will also increase the vertical clearance of the frame under the haunch allowing you to use a lower eave height. Whenever you see extraordinarily deep haunches, or have finishes or equipment that require low horizontal deflection, it is wise to investigate fixing the top of interior columns.

Interior column placement plays a great role in determining the cost of frames. Try to keep the exterior bays smaller than the interior ones. For example, in a 120 foot wide CB frame with two interior columns, three bays at 40 feet is more costly than one with the outside bays at 35 feet and the interior at 50 feet.

2E. Masonry Walls

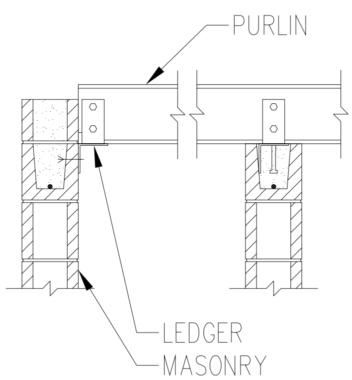


FIGURE 9
(PURLINS BEARING ON MASONRY)

Masonry walls may completely replace interior or end frames by attaching the purlins and girts to ledger angles (see figure 9.) Not only will you save on the frame cost, but you will remove unsightly columns from interior spaces, eliminate the required top of wall bracing, and reduce the cost of fireproofing. However, scheduling constraints may hinder you from using masonry as a bearing wall, especially in winter conditions.

Masonry often gets a bad reputation for delaying a project. However, masonry organizations throughout the country will argue that masonry should not be the critical path. They argue that the required time for steel buildings to be fabricated, delivered, and erected is longer than the time required for them to deliver and erect their finished walls. Regardless of your opinion on this matter, there are some actions that can help you reduce the time to erect a completed building. For example, pour separate strip footings for masonry walls instead of placing them on the top of thickened slabs (see figure 10.)

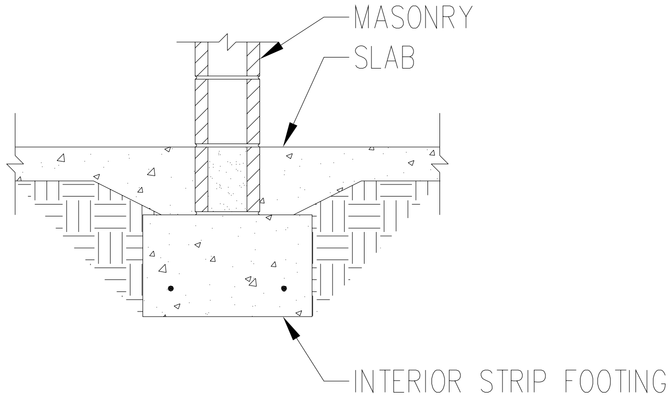


FIGURE 10
(MASONRY ON INTERIOR STRIP FOOTING)

A tip for engineers is to use higher strength masonry in your design. In many parts of the country, regardless if you specify low strength masonry units or not, you may receive high strength block on your project. By utilizing the higher compression strength blocks, you will reduce the amount of steel reinforcement required. Contacting one of the many masonry organizations, such as the International Masonry Institute or National Concrete Masonry Association, can quickly help you determine what is available for your specific location.

3. Mezzanines

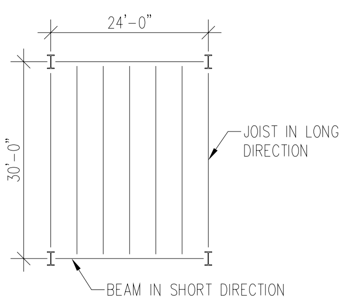


FIGURE 11
(MEZZANINE LAYOUT)

For mezzanine framing, run the beams in the short direction and the bar joists in the long direction (see figure 11.) This allows the more efficient joists to carry a greater share of the work and will also reduce the required floor to floor height. In order to estimate the required floor to floor heights, keep in mind that as a rule of thumb the length of the beam in feet is the depth of the beam in inches. So if the beam span is 24 feet the approximate depth of the beam is 24 inches. The Steel Joist Institute requires that half the length of joist in feet is the depth in inches. For example, a 30 foot long joist must be at least 15 inches deep. However, this rule is not the most economical way to go, and it does not guarantee that the depth will be adequate for a given load. Steel framed mezzanines are notorious for problems with vibration. Be sure that your metal building supplier conducts a vibration analysis according to the American Institute of Steel Construction (AISC) *Design Guide number 11* to avoid this common problem.

As an alternative to metal joists consider precast concrete plank. Precast concrete plank offers reduced floor to floor heights and vibration problems are virtually eliminated. On the down side, precast concrete plank typically requires deeper, more expensive, beams. However, plank can be dapped so that the top of the beam is even with the top of the plank, allowing for greater head room. Oftentimes dapping the plank can achieve a greater head height than metal joists. Because of the torsion that is created when plank does not sit on top of a beam it is common for Hollow Structural Steel rectangular beams to be used for support instead of wide flanged sections. Precast concrete plank becomes a very good option for buildings with masonry walls in or around the mezzanine that allow the plank to bear on it. Figure 12 shows some of the common bearing conditions for precast concrete plank.

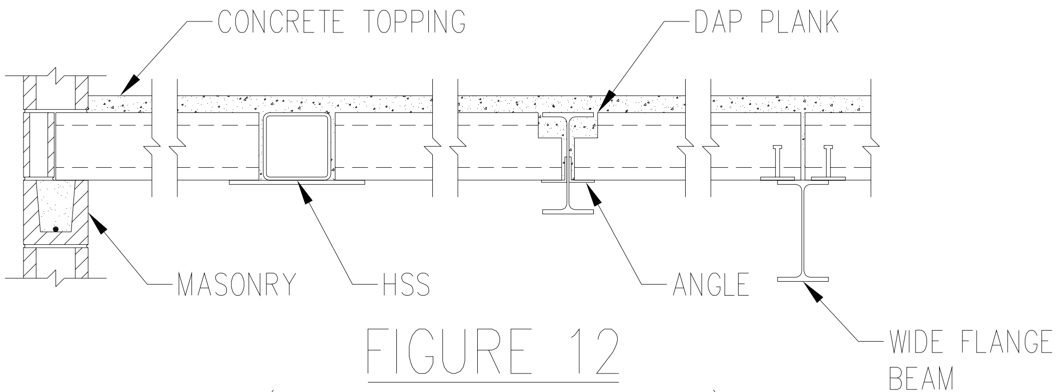


FIGURE 12
(TYP. PLANK BEARING CONDITIONS)

4. Bracing

Rod bracing is always the most economical bracing system. See figures 13-17 for alternative rod bracing schemes that can help you avoid the use of more expensive bracing systems.

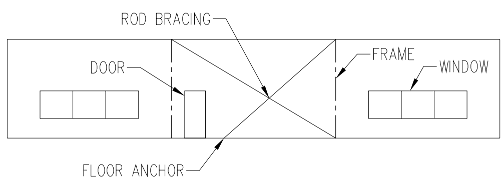


FIGURE 13
(ELEVATION OF A FLOOR ANCHOR)

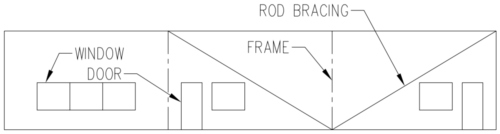


FIGURE 14
(ELEVATION OF "V" BRACING)

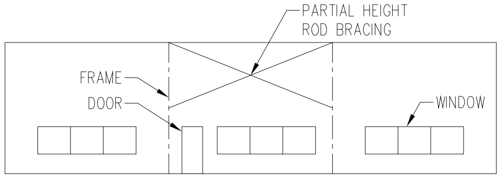


FIGURE 15
(ELEVATION PARTIAL HEIGHT BRACING)

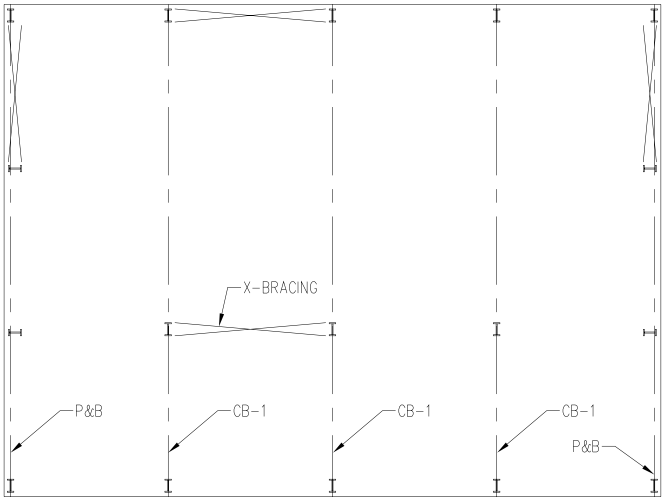


FIGURE 16
(PLAN OF INTERIOR COLUMN BRACING)

Torsional bracing is allowed when one wall can not be braced at all (see figure 17.) However, metal building specifiers and designers need to be aware of the allowable deflection that interior and exterior finishes can tolerate. Because of the risk of high deflections that torsionally braced metal buildings can experience, be sure to ask your supplier if torsional bracing is feasible for structures with high eaves, wide spans, high roof pitches, and areas with high winds.

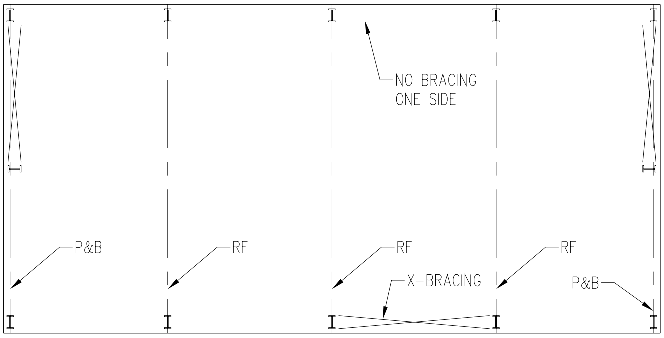


FIGURE 17
(PLAN OF TORSIONAL BRACING)

After one particular hurricane in Florida, investigations were performed on metal buildings that had suffered severe damage or collapse. One observation was that rods were pulling right through the beam or column webs. In order to prevent this from occurring in future metal buildings, Florida Building Code section 2223.10.1 bans the use of cable and rods as lateral bracing. Metal building manufacturers typically address this by substituting angle bracing, since it is a logical replacement for rods. However, because some manufacturers do not understand the reason for the code provision, they reduce connection costs by using angles with rods welded at the ends. By doing this they create the same condition that the code was trying to avoid. Many Florida building inspectors are aware of this issue but some are not. Be sure your metal building manufacturer does not provide connections that use welded rods at the end of angle bracing.

5. Purlins and Girts

Purlins are the zee shaped members on the roof. Girts are the zee, or sometimes used cee, members on the walls. By keeping the end bays of your structure slightly shorter than the interior bays you will reduce the positive moment in the purlins and girts in the end bays. In other words, you will reduce the required size of the end bay purlins and girts as well as the required lap splice. Buildings with high snow loads or long bays will see the greatest results from shortening the end bays. For buildings in high wind regions this may also help reduce the size of the second frame in from the ends. This is in part because current building codes require higher wind loads in the corner zones of buildings. While it is difficult to provide accurate guidelines on how much to reduce the end bay to see any cost savings, a good estimate is to try to reduce the end bay size by 5 to 10 percent. For example, let's look at a building that is 125 feet long with 5 equal 25 foot bays (see figure 18.) You will see a 28 percent reduction in the positive moment of the purlin in the end bays if instead you use 23 foot end bays with three 26'-4" bays in the center. When you find that you have to increase your purlin depth above 8", this is a good indicator that your project will benefit from shortening the end bay. However, one must use caution with buildings of short length. By decreasing the end bays, the interior frame tributary width increases. The increase in frame cost may offset the savings in the purlins and girts.

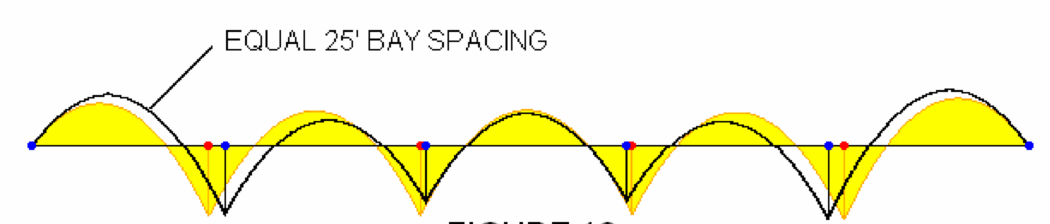


FIGURE 18
(MOMENT DIAGRAM)

Girts that bypass columns are more economical than those that are flush with the outside face of the column. Bypass girts create a continuous span, allowing lap splices to place more steel where it is necessary and reducing steel where it isn't. Further, the connections for bypass girts are less costly to produce than for simple span girts.

Vertical lift doors require jambs to extend the height of the door above the opening. If at all possible do not interrupt the continuity of the girts. Instead, place members between the girts for track attachment (see figure 19.) This will keep girts continuous and reduce the member sizes.

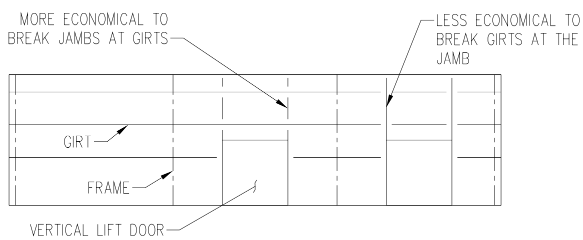


FIGURE 19
(ELEVATION OF VERTICAL LIFT DOOR)

Utilize vertical lift or overhead doors instead of roll up doors. Not only are rollup doors more expensive but they require very heavy jambs. Often times the rollup door manufacturer will require minimum 3/8 inch thick jambs for their track fasteners to attach to. Because rollup doors are extremely flexible they produce extremely large catinary loads. A catinary load is when the door pulls the jambs toward one another. This load is widely misunderstood by contractors and door distributers. The catinary load becomes very evident during periods of moderate to high winds as improperly designed jambs begin to rotate. Also, it is often the source of unexplained problems with rollup doors. Be sure to inform your metal building manufacturer anytime you intend to use rollup doors. A good indicator that catinary loads have not been addressed is when you see hot or cold rolled door jambs in combination with rollup doors.

Girt strapping are metal straps made of light gauge material that run vertically from the floor to the eave (see figure 22.) Their function is to brace the inside flange of the girts. Most major manufacturers have done away with the use of these unsightly, inconvenient, rarely installed correctly components. However, some manufacturers cling to them because it has a significant effect on the cost of the girts. This is one of the ways they become the low bidder. Be sure to specify that girt strapping is not allowed if you want to get a better comparison of the prices from different manufacturers.

Consider using a snow girt along the walls of buildings that are adjacent to parking lots or driveways. A snow girt is a girt that is placed approximately 3 feet above the finished floor in high snow load areas when a masonry wainscot or concrete knee wall is not utilized. Snow pushed against a wall, usually by a plow, exerts a horizontal force that oftentimes causes the metal panel to buckle. Since there are no codes that specify that this condition must be addressed, manufacturers place their first girt slightly over seven feet to catch the jambs of personnel doors. No panel or snow girt can withstand a direct impact from a plow. The snow girt's purpose is only to reduce or eliminate panel damage from the impact of snow thrown by plows passing by and snow piles pushed against the side of the building.

6. SHEATHING

If you are directly responsible for ordering a metal building, consider sheathing over the openings. Sheathing over openings will help protect the interior from the elements. Instead of creating temporary enclosures or waiting for windows and doors to arrive, you can pour your slab or begin to erect interior finishes with the confidence that rain, snow, and cold will be kept safely outside. Another advantage is that sheathing over openings provides security in high theft areas. A blank wall serves as a great deterrent to thieves trying to get inside, while temporary enclosures advertise themselves as entry points.

Opening placement in a concealed fastener panel system is very important. Without placing openings on module the manufacturer will be required to use significantly more trim. Not only is this costly for the manufacturer but the erection will require more labor.

The insurance industry has long recognized that metal buildings are prone to wind damage. In most cases, damage results from improper design of the roof assembly. Underwriters Laboratories UL 580 has been written to create a method of testing the uplift resistance of roof assemblies. By specifying a specific UL 580 class 30, 60, or 90 rated roof assembly, the owner can have peace of mind that they are receiving a roof that will not be damaged during a wind storm.

Be careful when using translucent panels on the roof. OSHA 1926.502(i)(2) states "[C]overs shall be capable of supporting, without failure, at least twice the weight of employees, equipment, and materials that may be imposed on the cover at any one time." Most translucent panels cannot meet this requirement. Be wary of manufacturers who claim that their panels meet this requirement. More often than not, the panels will degrade in the sun over relatively short periods of time. This presents a real and serious danger of someone falling through the roof. Interestingly, many translucent roof panel manufacturers place labels warning of this hazard on their products. Although erectors are trained to avoid walking on the translucent panels, panels that are lightly covered in snow can often be mistakenly stepped on. Look carefully at roof warranties because they may exclude the translucent panels. Furthermore, a translucent panel's thermal expansion rate is very different than the metal panels around them. Over time, this often causes the seals around the panels to wear out or screw holes to enlarge. This may permit rain water into the building. Another problem is that condensation easily accumulates on the uninsulated variety of translucent panels. This moisture corrodes the metal around a panel's perimeter and/or drips onto whatever is below the panel.

7. Expansion of Existing Buildings

Place sidewall expansions at the eave. This will eliminate snow drifts, reduce purlin and rafter sizes, and reduce foundation requirements (see figure 20.) Also, trim conditions will be reduced or eliminated. This will reduce the erection cost and provide greater protection against leaks. However, if the new addition is made by a different manufacturer, or you are using a different roof panel, you should not connect at the eave but move the connection down a small but reasonable distance. This is because the panels will not line up nor seal properly.

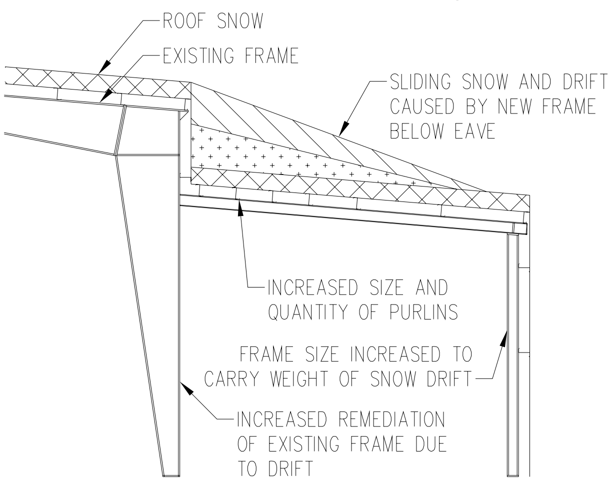


FIGURE 20
(SIDEWALL EXPANSION)

When performing endwall expansions, consider extending the profile of an existing lower structure in order to avoid remediation of the existing building due to drifting snow (see figure 21.) Remediation of existing structures is time consuming, disruptive, and expensive. By keeping the same profile you eliminate any new loads from being imposed on the existing building.

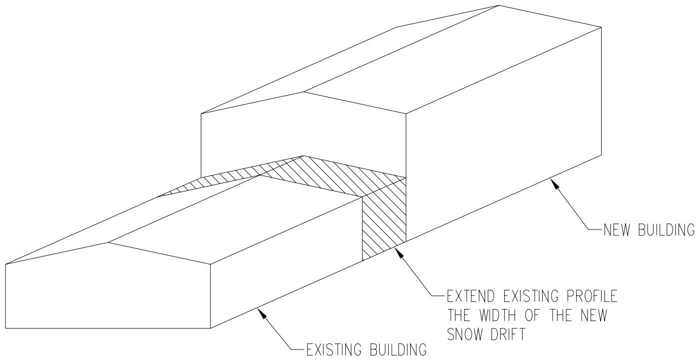


FIGURE 21
(ENDWALL EXPANSION)

8. Foundations

Don't use continuous trench drains along the entire length of the building. Break the drain for a few feet at each column location and place it close to the exterior wall. This will allow the engineer to use hairpins in the concrete slab to resist horizontal kick from the frames. Without the use of hairpins, foundations will be quite large and expensive.

Drop the bases of columns 8" below the finished floor. By doing this you will be able to pour your slab on grade at a later time. Not only will this speed things up, but it will allow the roof and walls to be in place to protect the slab from the elements while it is curing. It also hides the base plate and anchor rods which allows easier boxing in of the column using metal studs.

Whenever a metal building has a wash bay for vehicles, raise nearby column bases at least 8 inches from the finished floor and use concrete or masonry knee walls to raise the bottom of the panel. This will prevent the steel from sitting in standing water which will quickly propagate corrosion.

Omitting grout below column base plates is common in the pre-engineered metal building trade. However, whenever there are cranes or fixed base plates, grouted base plates should be used. Anytime there is an overhead crane, leveling nuts are required so that the erector can level the track. If the erector does not erect the runway to the appropriate tolerances, the crane wheels will wear faster or jump the track. For fixed base plates, axial compressive forces must be evenly distributed or the concrete will be crushed. Grout is the only method to insure that even distribution occurs. In addition, gaps under the base plate may allow rotation of the joint to occur, thus turning it into a pin condition instead of moment resisting.

OSHA 1926.755 (b)(1) Anchor rods (anchor bolts) shall not be repaired, replaced or field-modified without the approval of the project structural engineer of record.

A well performed soils investigation has many advantages. In areas of moderate to high seismic activity soil borings may justify a better soil classification. A good soil has the potential to take a building from a seismic design category D to a C. This small but significant jump in category has huge repercussions. The cost of the metal building will be significantly lower. Erection will not require pretensioned bolts nor certain code required inspections, therefore resulting in lower fees. Foundations and anchor rods will be considerably smaller. Other possible advantages of a soils investigation is the use of trench footings (see figure 23), thinner or less reinforced concrete slabs on grade, and smaller foundations. Appreciably large areas of the United States have expansive soils or other poor soil conditions such as peat or loose sand. It is better to know of these conditions early in the project than when you've begun to excavate.

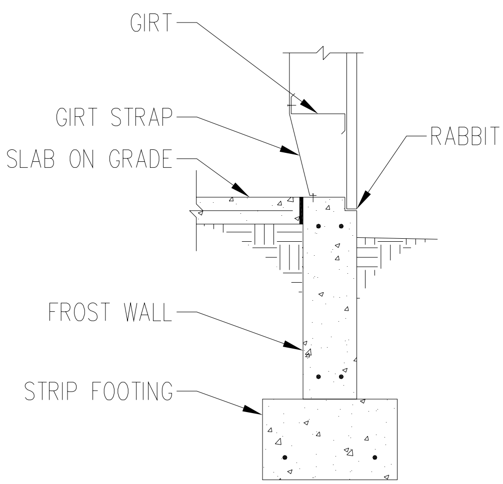


FIGURE 22
(CONVENTIONAL FOOTING)

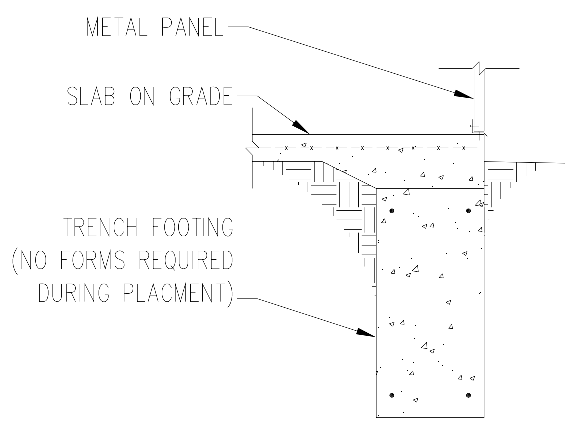


FIGURE 23
(TRENCH FOOTINGS)

9. Quality Control

Specifying the appropriate vertical deflection and horizontal drift limits for your project is very important. Failure to do so will cause noticeable cracking of finishes. Large deflections may also cause cranes to jump their track or dangerously shift their loads. While a full discussion of deflection tolerances is beyond the scope of this document, it is important to note that the metal building community follows AISC *Design Guide #3*. In order to ensure you are receiving a building that meets the requirements of your project, you should become very familiar with this document. For example, *Design Guide #3* provides a set of drift criteria that is based on detailing your masonry in a particular way. The majority of suppliers will provide you with the lowest set of criteria regardless of the way you detail your masonry. So it is up to you to ensure that the manufacturers are providing a building that meets the requirements of your project. This too, is a way low bid manufacturers get their foot in the door.

Unfortunately, there are erectors and manufacturers out there that give the metal building industry a bad name. Some erectors put up many different manufacturers' buildings but specialize in none. In certain cases, you may need a certified erector for the manufacturer's warranty to be valid. The best way to ensure you have a qualified erector for your project is to specify an erector that has obtained certificates for each product the manufacturer is providing. Because smaller manufacturers do not have formal training programs, you can alternatively specify an erector that has a long track record with the specific manufacturer of your project. Likewise, the best way to ensure you receive a quality metal building, is to specify the manufacturer is certified by the International Accreditation Services program for manufacturers of metal building systems. Manufacturers used to be certified by AISC but AISC chose to discontinue their certification program for metal building manufacturers. To become certified, manufacturers must pass rigorous testing and biannual inspections covering everything from design to fabrication. Being certified eliminates the need for the inspections required by the International Building Code chapter 17. These inspections are mandatory by law but are rarely enforced for uncertified manufacturers. However, this lapse in oversight does not release the owners' representative (special inspector, engineer of record, or architect) from his/her responsibility to ensure that the building code is enforced. The cost of obtaining and maintaining certification places certified manufacturers at an unfair disadvantage when bidding projects. This disadvantage quickly disappears if you consider the additional cost and inconvenience of in factory inspections required by code.

10. Cranes

No discussion of metal buildings is complete without a discussion on cranes. This is because, more than any other piece of equipment, cranes have the most impact in the construction of a metal building. It is important to recognize that the metal building is made around the crane and not the crane around the building. If the building is rushed to production without due consideration of the crane, either the crane or the building may have to be modified after fabrication. You may also find that you are making concessions in the operational areas of the crane due to unexpected clearance or safety requirements. Because most owners, architects and engineers do not deal with cranes on a regular basis, they do not understand the many considerations that must be made for a proper crane installation. While a full discussion of crane requirements is beyond the scope of this course, below are some items to consider before you layout your building envelope.

First, determine the requirements of the crane. Encourage the owner to perform a detailed analysis of their operations to determine the following:

- **How much weight does the crane need to lift?** In other words, what crane capacity is required? Remember to add the weight of packing material, lift/spreader beams, magnets, or any other accessories below the hook, to the weight of the lifted load. You may be shocked that you can perform operations that exceed the rated capacity of the crane by as much as 25% in what is called an "Engineered Lift." Engineered lifts are infrequent, carefully preplanned, and highly controlled. They should be performed under the supervision and consent of a registered Professional Engineer. One illustration of when an engineered lift may be appropriate is when a piece of equipment whose weight is 64 tons requires a vertical lift with no horizontal movement once a year for scheduled maintenance. Cranes typically come in 60 or 75 ton capacities but not 64. However, you need not purchase a crane and a metal building capable of handling 75 tons if you use an engineered lift. This represents significant savings in the crane, metal building, maintenance, and power costs. The fee for a professional engineer's services is well worth the cost of investigation in such a case.

- **Which class of crane is required?** The Crane Manufacturers Association of America defines the classes as follows:
    - **Industrial Class A (Standby or Infrequent Service) -** This service class covers cranes which may be used in installations such as power houses, public utilities, turbine rooms, motor rooms and transformer stations where precise handling of equipment at slow speeds with long, idle periods between lifts are required. Capacity loads may be handled for initial installation of equipment and for infrequent maintenance.

    - **Industrial Class B (Light Service) -** This service covers cranes which may be used in repair shops, light assembly operations, service buildings, light warehousing, etc., where service requirements are light and speed is slow. Loads may vary from no load to occasional full rated loads with two to five lifts per hour, averaging ten feet per lift.

- **Industrial Class C (Moderate Service) -** This service covers cranes which may be used in machine shops or paper mill machine rooms, etc., where service requirements are moderate. In this type of service the crane will handle loads which average 50 percent of the rated capacity with 5 to 10 lifts per hour, averaging 15 feet, not over 50 percent of the lift at rated capacity.

- **Industrial Class D (Heavy Service) -** This service covers cranes which may be used in heavy machine shops, foundries, fabricating plants, steel warehouses, container yards, lumber mills, etc., and standard duty bucket and magnet operations where heavy duty production is required. In this type of service, loads approaching 50 percent of the rated capacity will be handled constantly during the working period. High speeds are desirable for this type of service with 10 to 20 lifts per hour averaging 15 feet, not over 65 percent of the lifts at rated capacity.

- **Industrial Class E (Severe Service) -** This type of service requires a crane capable of handling loads approaching a rated capacity throughout its life. Applications may include magnet, bucket, magnet/bucket combination cranes for scrap yards, cement mills, lumber mills, fertilizer plants, container handling, etc., with twenty or more lifts per hour at or near the rated capacity.

- **Industrial Class F (Continuous Severe Service) -** This type of service requires a crane capable of handling loads approaching rated capacity continuously under severe service conditions throughout its life. Applications may include custom designed specialty cranes essential to performing the critical work tasks affecting the total production facility. These cranes must provide the highest reliability with special attention to ease of maintenance features.

- **Mill Duty -** Service classification covered by AISE Standard No. 6 *"Specification for Electric Overhead Traveling Cranes for Mill Service."*

- **Which areas of the building need to have crane hook access?** Hook coverage does not extend to the limits of the crane runway. This is due to side clearance requirements of the trolley and the end approach of the bridge. Also, be aware that side clearances are not necessarily symmetrical due to hoist motor orientation and the presence of runway electrical conductors. Many people are caught off guard when the crane manufacturer provides the hook coverage area. They simply did not anticipate how large the side and end clearance requirements can be. There is no method to significantly increase the side and end approach requirements of cranes. You simply have to enlarge your building envelope.

- **At what height is the bottom of the hook needed?** To determine this the owner needs to know the following:
  - The clearance required below the bottom of the lifted equipment. For example, they may want 5' clear to load an ordinary flatbed trailer. 15' or more may be required to stack loads on an ordinary flatbed trailer.
  - Height of the equipment
  - Sling height

Once the above information is provided to the crane manufacturer they in turn will be able to provide the metal building manufacturer with answers to the following additional questions.

- **Will an under running or top running crane be utilized?** Under running cranes have end trucks supported by the bottom flange of runway beams. Top running cranes have end trucks supported by rails on the top of the runway beams. In general, under running cranes are less expensive. However, under running cranes have higher maintenance costs, slower speeds, and smaller lifting capacities.

- **Will the configuration of the crane have a single or double girder?** Single girder cranes typically cost less but have smaller capacities and slower speeds than double girder cranes.

- **What is the crane span?** This determines the required width of the building as well as any restrictions on the depth of the crane.

- **What type of rail is being used?** Some crane manufacturers like to use a 2"x2" solid bar instead of the traditional ASCE, ARA, or AREA rails. Be aware that there is quite a debate in the crane industry about the use of solid bar as rail. Among other things, some argue that it wears out the wheels faster and is not as durable as ASCE rail. In order to provide the necessary rail tolerances and field adjustment, all rails, including solid bar, should be field installed and not shop welded. Be prepared for different views from different crane manufacturers on this issue. Using the solid bar can theoretically reduce the size of the runway beam if properly detailed and welded to the top flange. However, there are some difficulties in overcoming thermal expansion, splices, and column joints. Proper welding of the solid bar includes an engineered weld pattern and preheating of the solid bar and the beam flange. Oftentimes the preheat is omitted to save installation costs. However, this is in direct violation of AWS D1.1 which is mandatory per code. Without preheating the solid bar, the welds may cool too quickly, making them susceptible to fatigue and shrinkage cracking. If you decide that solid bar is right for your project and are convinced that you can overcome its detailing challenges, you may want to price out the runway beams to be supplied by the crane manufacturer. Most metal building manufacturers will avoid the challenges of solid bar rails by not providing the rail nor do they account for the extra capacity solid bar provides. They leave it up to the owner to decide on a type of rail and its attachment to the runway beam. If the owner is comfortable with the solid bar concept, they may be able to get lighter less costly runway beams through the crane manufacturer than through the metal building manufacturer.

- **What is the top-of-rail dimension?** This will help determine the eave height.

- **What is the wheelbase?** The larger the wheelbase the smaller the runway beam and metal building frames. The wheelbase should not be less than 1/7 the bridge span of a double girder crane or 1/8 the bridge span of a single girder crane.

- **What are the wheel loads?** Wheel loads are not the same from one side to the other. Factors that cause loads to differ on either side of the crane are: use of a cab, side clearance of the trolley, motor configuration of the trolley, and auxiliary hoists.

- **Are there multiple cranes on one runway?** If so, what is the minimum distance between the cranes? If manufacturing operations permit, a spacer bar mounted to one of the cranes can prevent multiple cranes from riding on a runway beam at the same time. This will reduce the runway beam and metal building frame sizes, thereby reducing costs.

- **What are the clearance requirements?** In other words, what is the minimum distance from the face of the column to the center of the rail, and the minimum height from the top of the rail to the bottom of the rafter? It should be clarified whether or not the dimensions provided include the mandatory 3" overhead clearance and the 2" side clearance per OSHA 1910.179(b)(6)(i).

- **Who is providing the crane stops?** If the metal building manufacturer is providing the crane stops, they will need to know the load to be resisted, the height of the bumper, and the required area of plate for bumper coverage. In order to provide field adjustment and allow proper attachment of the rail to the runway beam, crane stops should be field installed.

Metal building manufacturers understand that their customers don't always know exactly what they want. They have become quite good at making educated guesses. However, guesses vary from one metal building manufacturer to another. They even vary from one engineer to another at the same metal building manufacturing company. Remember that engineers are usually conservative in their assumptions, so in order to lower the cost of the project you need to provide accurate information. It is well worth the time to answer the above questions before asking the metal building manufacturer for a price. In order to compare apples with apples in a bidding situation, provide very specific criteria that each manufacturer should follow in their bid.

In order to avoid costly change orders, avoid ambiguity by making sure that there is clear instruction on who is providing and installing the following:

- Independent crane columns, their braces to the metal building, and their anchor rods
- Crane runway beams and bolts
- Crane runway rails
- Runway rail clamps/clips. Be sure to specify if you want bolted or welded
- Rail splice connections
- Crane stops
- Runway conductors

Erection tolerances are very stringent and very important for buildings with cranes. Because metal buildings have relatively large erection tolerances, metal building erectors are not accustomed to the precision required for crane runways. Some possible consequences of a poorly erected runway are reduced wheel life, end trucks that squeak, wheels that come off the track, reduced motor life, and loads that lurch. Crane wheels and many other parts of a crane are proprietary. This makes them very expensive to replace. It is therefore in the interest of the owner to have an independent agency verify that the runway is erected within the specified tolerances of CMAA Specification No. 70 and 74 as well as AIST Technical Report No. 13.

Electrical panel placements within the building and power requirements have significant cost repercussions. Where the power enters the building will determine the conductor size and how the electricity gets from the main electrical panel to the runway conductors. Be sure your electrical engineer is in contact with the crane manufacturer so that costs can be kept to a minimum. In addition, you want to make sure that the utility company provides you with enough power to run your crane. Adding additional or larger lines to the building at a later date can really increase costs.

Some portions of overhead cranes are covered by OSHA requirements and NFPA 70 *"National Electric Code."* However, there is no governing code that covers all portions of an overhead crane. Even the CMAA Specifications No. 70 and 74 are not mandatory by law. For example, all complete joint penetration welds on a metal building must be inspected per IBC chapter 17. Since the IBC does not apply to cranes, crane manufacturers consider weld inspection an additional service. This is interesting in light of the fact that the welds on a crane will see more load cycles than a metal building ever will. Since there is no governmental oversight, each crane manufacturer can follow their own standard for the design and fabrication of a crane if they choose to do so. In addition, there currently exists no quality assurance program for crane manufacturers that is similar to the International Accreditation Services program for manufacturers of metal building systems or the AISC certification program for conventional steel fabricators. This means it is up to the owner to thoroughly investigate a crane manufacturer before the crane is purchased.

Course Summary

This course has presented various ways to reduce the cost of metal building systems and their foundations. Also included was a discussion of methods to help you with your next project involving pre-engineered metal building systems. The topics included: The basics of laying out a building, main frame configurations, mezzanine layouts, bracing systems, purlins and girts, expansion of existing buildings, sheathing, the role of masonry in a metal building, foundations, quality control, and cranes.