FORESNICS - METAL BUILDING COLLAPSE DURING ERECTION

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ABSTRACT

Metal building systems are a common method of providing covered, enclosed space quickly at a competitive cost. Because of the system design approach, all components of the structure interact with each other to provide the required level of structural safety. Metal building systems are most vulnerable to collapse during erection, when all components are not yet installed. It is most important at this time to ensure that all bracing called for by the building manufacturer is properly installed. This paper reports on the collapse of a metal building system consisting of a 206 ft (62.8 m) span rigid frame during erection due to inadequately installed bracing, and explains proper erection procedure with regard to lateral bracing of the rigid frames. The circumstances of the collapse are discussed and recommendations are provided.

INTRODUCTION

Metal building systems, also known as pre-engineered metal buildings, are an economical, rapid method of providing one- or two-story enclosed space for industrial, commercial, and community buildings. Clear spans of up to 400 ft (120 m) are available from some building manufacturers, and multiple-span buildings exceeding this are also possible.

The systems building approach, in which design methods are replicated many times, allows the design to be refined to optimize economy within building code restrictions. The result of this design method is a building whose actual factors of safety for the entire structure approach the limits stated in the applicable codes. As a result of this refinement, the customer receives a quality, finished product at a very competitive price.

One important implication of this refinement in design is that the structure must be erected in strict compliance with the plans and guidelines set forth by the building manufacturer. This paper reports on the consequences of not erecting a metal building system in accordance with a manufacturer's guidelines, and it points out the engineering significance of these actions.

METAL BUILDING SYSTEM BEHAVIOR

A pamphlet published by the Metal Building Manufacturers Association (MBMA) sums up the metal building system philosophy:

> *If a building is to be turned into a building system, then it also must be designed as a system. What does this mean? It means that all elements of the system are designed as they will exist in the completed building, with all the necessary bracing assumed to be in place and the interaction among all elements—the building synergy—assumed to be well understood.*
>
> *However, between the time the frame is erected and the purlins attached, the frame is vulnerable and temporary bracing should be used.*
>
> *What the definition [of a rigid frame] in the nomenclature section of the Metal Building Systems (1980) manual says is that no additional bracing is needed in the plane of the frame. What it does not say, but is crucial to the proper performance, is that bracing perpendicular to the plane of the frame is essential.* (Ellifritt 1981).

It should therefore be noted that bracing is perhaps the most crucial element in designing and constructing a systems building.

CASE STUDY: METAL BUILDING COLLAPSE

In June 1990, a metal building system in north central Florida collapsed during erection. This building was a rigid-frame structure with a clear span of 206 ft (62.8 m). The end walls were normal post-and-beam end walls. The frames were designed for a live load of 12 psf (0.57 kPa) and a wind speed of 100 mph (161 km/hr). No snow load is called for in this particular area. Frames spanned in the north-south direction, and were spaced 25 ft (6.1 m) in the east-west direction.

Normal erection procedure for a building of this type is to first erect the first braced interior bay, installing all sidewall and roof bracing, then erect and brace the end wall in its plane, then brace the endwall back to the interior bay, supplementing the manufacturer's bracing with temporary bracing as necessary (Fig. 1).

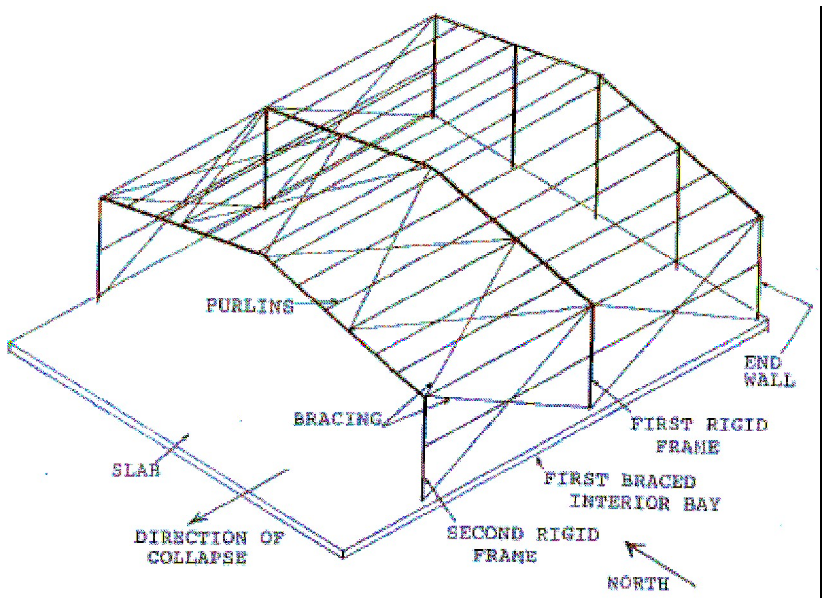

FIG. 1. Metal Building System Nomenclature

This procedure was not followed in this instance. Instead, the post-and-beam end wall at the east end was erected first, without bracing; then the first rigid frame was erected. At this point bracing between the end wall and the first rigid frame was installed, but only in the sidewalls. Next, the second rigid frame was erected. At this time no further erection should have taken place until full bracing between the rigid frames was installed in the plane of the roof and the sidewalls. Such bracing was specified in the erection drawings.

Instead, no bracing between the rigid frames was installed. Purlins were installed spanning between the two rigid frames and the endwall. Flange stays to brace the bottom flange of the frames were not installed. Flange stays would have been crucial to adequately brace the inner flange near the frame knee against compression from gravity loads during erection.

As the third rigid frame was being erected the entire structure leaned westward and collapsed, pulling the end wall down with it. One eyewitness reported a slight gust of wind immediately prior to the collapse. Part of the third frame was attached to the rest of the structure by two purlins between the second and third frames. Fortunately, no loss of life or injury occurred.

The structure suffered extensive damage, causing most of the erected steel to be scrapped. Figs. 2, 3, and 4 show the extent of damage to the structural steel. The foundations were also extensively damaged (as shown in Fig. 5), requiring major repairs.

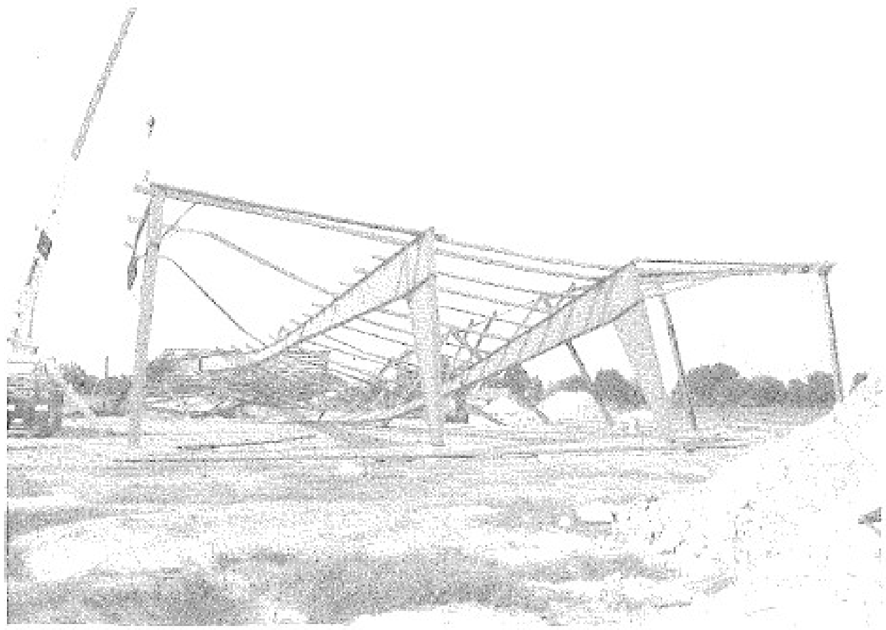

FIG. 2. Collapsed Rigid Frames

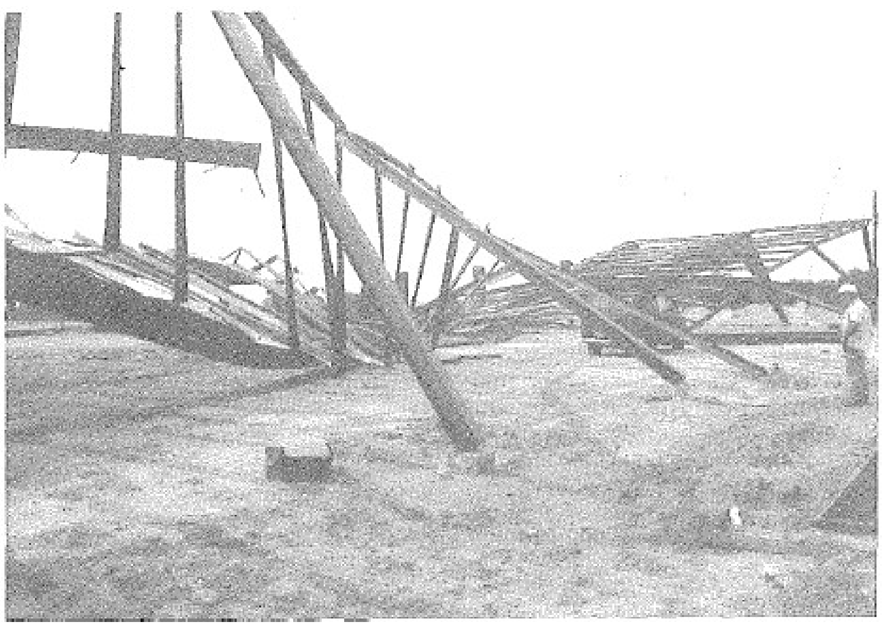

FIG. 3. Collapsed Post-and-Beam End Wall

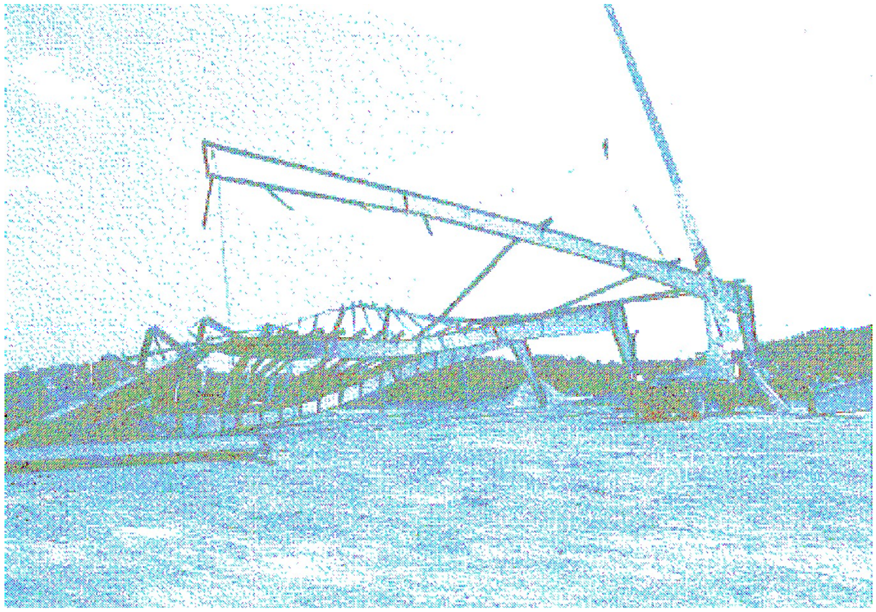

FIG. 4. Partially Erected Third Rigid Frame

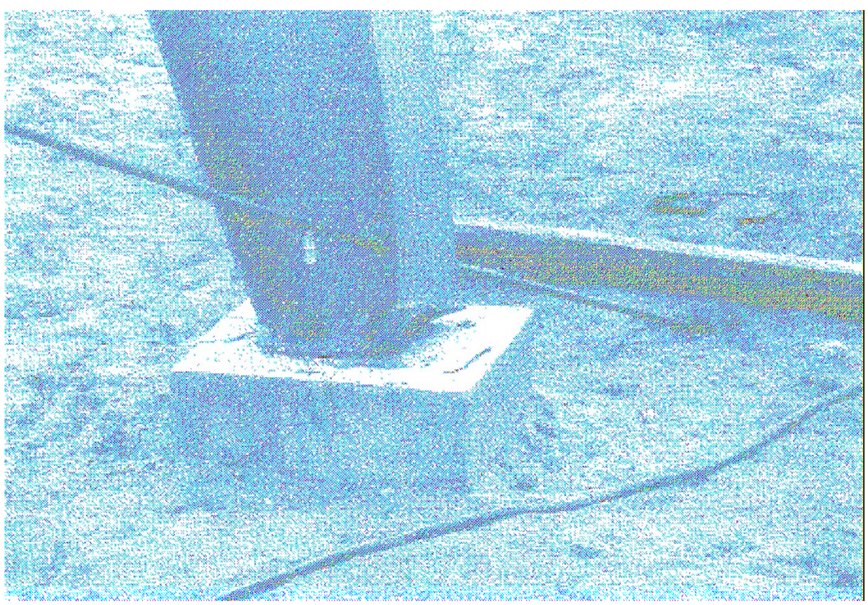

FIG. 5. Damaged Foundation for Rigid Frame

CAUSE OF COLLAPSE

The most likely cause of the collapse was instability of the rigid frames caused by the lack of bracing in the plane of the roof and sidewalls during erection. The erection drawings clearly showed full bracing in the plane of the roof and sidewalls, between the first two main bents, at this stage of erection. "MBMA Common Industry Practices" [section 6.2.1 of (Low 1986)] additionally notes that:

> *The erector furnishes: Temporary guys and bracing where needed for squaring, plumbing, and securing the structural framing against loads, such as wind loads acting on the exposed framing and seismic forces comparable in intensity to those for which the completed structure is designed, as well as loads due to erection equipment and erection operation, but not including loads resulting from the performance of work by others. Bracing furnished by the Manufacturer for the Metal Building System cannot be assumed to be adequate during erection* (Low 1986).

This last requirement places all responsibility for erection bracing, and therefore frame stability under construction conditions, on the erection contractor.

It appears that the 206 ft (62.8 m) rafters, without the roof bracing and flange stays being installed, became marginally unstable under dead weight alone. At this point of incipient instability only a slight force would have been necessary to precipitate buckling and collapse of the frames. That force could have been as slight as a 5 mi/hr (8 km/hr) wind, a bump while installing the third frame, or perhaps uneven heating from the sun shining on only one side of the rafter.

Once the frames began to buckle and lean, all forces were transmitted through the only installed cross bracing into the two corner end wall foundations. It is little wonder that these end wall foundations, being designed for only 4 kips (17.8 kN) of thrust, were unable to support the structure. As a result, the entire end wall was pulled down with the rest of the structure.

The key to this failure was the lack of bracing in the plane of the roof; secondary to this was the lack of flange stays, allowing for lateral buckling of the frames. When the roof bracing was not available to resist the lateral translation forces from buckling, the entire structure translated westward. Had the full bracing been installed as was called for in the erection drawings any lateral force would have caused the two erected rigid frames to lean on each other. It should be noted that additional bracing, in excess of that noted on the erection drawings, should probably have been in place considering the intermittent high-intensity winds that accompany thunderstorms, common in that locality at that time of year.

CIRCUMSTANCES OF COLLAPSE

The contract for the metal building was a subcontract for a larger development. This subcontract included providing the structure and erecting it on foundations provided by another subcontractor. The building subcontractor, a metal building manufacturer/dealer/erector that sold its products directly, used an in-house erection crew.

Due to the size and expected occupancy of the structure, a "threshold" inspector was required to monitor construction. In Florida, a specially licensed threshold inspector must periodically inspect building construction exceeding a certain threshold size. This inspector is an employee of the owner who reports to the local building authority on compliance with the submitted project plans and specifications. The threshold inspector generally has no authority to make on-the-spot corrections, only noting deficiencies for latter action by the project designers.

During a site visit, the threshold inspector noticed the lack of installed bracing, made a note of it, and brought it to the attention of the erection crew as a courtesy. This warning did not elicit any action on the part of the erectors to correct this deficiency. The next day, the building collapsed due to erection instability.

The situation was resolved without litigation within a day. When faced with the facts of the situation, the metal building subcontractor admitted that the cause of the collapse was lack of required bracing. The subcontractor assumed all responsibility and liability. Since this case was solved without litigation, exact costs associated with the collapse were not available, but they were in excess of $55,000. Likewise, a detailed postmortem of the collapsed structure was impossible, since removal of the debris was complete within three days of the collapse in order to permit the project to continue.

Two points should be stated. Neither the erection manual nor the erection drawings for this building were in the possession of the erection crew prior to the collapse. Additionally, from later conversations, it was learned that this particular erection crew had never erected a building approaching this magnitude. The shortcuts that worked for the erection of 60 ft (18 m) frames failed for the erection of this vastly larger structure.

RECOMMENDATIONS

Since metal building systems are most vulnerable to collapse during erection, the building erector must take extreme care during this phase. The erector should have a copy of the manufacturers' erection manual on site and refer to it as erection progresses. All bracing called for on the erection drawings should be installed as in the drawings and the erection manual. Additional temporary bracing should be installed as required by the building configuration or site conditions. If the erector has any question as to the need for additional temporary bracing, the services of a structural engineer familiar with metal building systems should be engaged.

Local site conditions such as wind and daily temperature fluctuations should be considered when determining the need for additional temporary bracing.

Probably the most generally understated point is that speed of erection is no cure for lack of adequate bracing during erection. Erectors may use the excuse that they are under a deadline and are omitting bracing in order to complete the job in time. The lateral force that causes failure may occur at any time, regardless of the speed of the erection crew. Omission of bracing can cause great losses, monetarily, and in personal injury and loss of life.

CONCLUSIONS

Metal building systems are an economical method of providing enclosed space for one- or two-story applications. Because of the nature of system design, the erection of the structure must be done in strict accordance with the manufacturers' guidelines, with particular attention paid to bracing during erection. Inadequate bracing during erection probably contributes to more metal building system collapses than all other factors combined. Attention to detail in erection will help to assure a serviceable product for the consumer.

REFERENCES

Ellifritt, D. S. (1981). *What makes a building a system?* Metal Building Manufacturers Association, Cleveland, Ohio.

Low rise building systems manual. (1986). Metal Building Manufacturers Association, Cleveland, Ohio.

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QUIZ

FORESNICS - METAL BUILDING COLLAPSE DURING ERECTION

1. Metal building systems are most vulnerable to collapse during _________ .

    a. windstorms
    b. snowstorms
    c. erection
    d. earthquakes

2. _________is (are) perhaps the most crucial element in designing and constructing a systems building.

    a. Frame connections
    b. Bracing
    c. Anchor rods
    d. Purlin anchors

3. The first part of a metal building system which should be erected is ______.

    a. a post and beam endwall
    b. an interior braced bay
    c. an interior unbraced bay
    d. none of the above, start anywhere

4. Temporary guys and bracing are provided by the ______________.

    a. Erector
    b. Building Manufacturer
    c. General Contractor
    d. Structural Engineer

5. Bracing provided by the metal building manufacturer for the metal building system is________.

    a. adequate under all conditions
    b. cannot be assumed to be adequate during erection
    c. not necessary to be installed in the completed building
    d. none of the above