Investigation of the July 13, 2007 Collapse of Roof Trusses in Township of Franklin, NJ

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Occupational Safety and Health
Directorate of Construction
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REPORT

Investigation of the July 13, 2007 Collapse of Roof Trusses in Township of Franklin, NJ

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REPORT

On July 13, 2007 at approximately 2:10 p.m. the wood roof trusses suddenly collapsed and fell over the first floor of a new medical office building under construction at 32 Worlds Fair Drive, Township of Franklin, NJ. The trusses were erected that morning and employees were installing temporary and permanent bracings and purlins at the time of the incident. Most significantly, shortly before the incident, three bundles of 2x6s were placed over the top chord of the center trusses to be used as purlins and braces. At the time of the incident, approximately seven employees were reported to be working on the trusses near the center of the bay. Two employees were seriously injured.

The one-story building with basement is owned by Franklin Professional Park, LLC. The following were the key participants in the project:

Owner:	Franklin Professional Park, LLC
Architect:	William J. Doran of Kendall Park, NJ
Structural Engineer:	Harrison-Hamnett, PC of Pennington, NJ
General Contractor:	Abatare Builders Inc., of Brick Township, NJ
Roof Truss Supplier:	Builders General of Towns Rivers, NJ
Roof Truss Manufacturer:	P.D.J. Components Inc. of Chester, NY.
Roof Truss Designer:	MiTek Industries, Inc. of Chesterfield, MO
Truss Erection Subcontractor:	Farrah Builders, Inc. of West Long Beach, NJ
Truss Erector:	Peter Donoghue of Pete Donoghue Construction of Neptune, NJ (Sub to Farrah Builders)
Truss Erector:	Steve York of York Framing (Sub to Peter Donoghue)
Truss Erector:	Cantaffa Construction Company, Inc., of Oceanport, NJ (Sub to Peter Donoghue)

Truss Erector: Andrew Hayden of AMH Contracting
(Sub to Peter Donoghue)

This report is limited to the roof area where the incident occurred. The roof trusses spanned approximately 81' between supporting steel beams over steel columns. There were a total of 41 trusses consisting of 16 "Drop TC Hip" trusses and 25 trusses known as "Hip" trusses. On the top of the 25 hip trusses, 25 gable trusses were to be mounted at the top to meet the architectural roof configuration. At the time of the incident, gable trusses were yet to be erected but all 41 drop TC hip trusses and hip trusses were set in place, see Fig. 1.

On Thursday, July 12, 2007, the erectors consisting of five companies, namely Farrah Builders Inc., Pete Donoghue Construction, York Framing, AMH Contracting, Contaffa Construction Co. Inc., began setting the roof trusses and sloping rafters on the north and south side. First, they erected two triple trusses, HGIR, one on the north and one on the south side and then connected the sloping rafter trusses. They also erected five "Drop HC Hip" trusses marked H1SD1 thru H1SD5 on the north and south side (total of 10 trusses). During interviews with OSHA, the employees reported that the temporary braces for the top and bottom chords, and the webs were installed on the ten trusses as soon they were set in place.

On Friday, July 13, 2007, the truss erectors and their employees reported to the site at approximately 6:30 a.m. and began setting the remaining trusses called "Hip" trusses, marked H1SDBase. By lunchtime, all 25 hip trusses, weighing 718 pounds each, were set in place. The erectors reported that all temporary top chord, bottom chord and diagonal bracings were also installed on the hip trusses as soon as they were erected.

After lunch, the erectors began to install 2x6 purlins on the top chords of the hip trusses. The gable trusses were later to be erected over the hip trusses and nailed and supported over the 2x6s. Some of the crew members began to install temporary and permanent braces. Three bundles of 2x6x12' long pieces, each bundle containing 20 pieces, were hoisted by the crane and placed over the top chord of the hip trusses to be nailed to the top chord as purlins. Also, there were

reported to be 50 pieces of 2x4x24' long pieces spread over the bottom chord. There were approximately seven employees on the trusses near the center of the trusses. Shortly after the three bundles were placed the employees observed. at approximately 2:10 p.m. that the roof trusses, except for the five trusses on the south side, suddenly collapsed at the center. The employees reported that the trusses fell just in the middle in a vertical direction, see Figures 2 to 5. The ends of the trusses remained generally connected to the supporting beams.

Abatare ordered the roof trusses from Builders General who contacted P.D.J. components to manufacture the trusses. Builders General provided a set of architectural and structural plans to P.D.J. P.D.J then designed the roof trusses using structural design software provided by MiTek and forwarded their design to MiTek to review and stamp the drawings with a seal of a professional engineer. After MiTek's review, PDJ manufactured the trusses in their facility and shipped them to the site on July 9-10, 2007. PDJ also provided standard bracing instructions to Abatare to follow during erection.

Engineering Evaluation

It is a standard industry practice to maintain structural stability of roof trusses by providing temporary bracings, i.e., top and bottom chord lateral and diagonal bracings, and web diagonal bracings during erection until the entire structure has been completed. The responsibility to provide these bracings rests solely with the erector. Roof trusses are light structural members, highly susceptible to instability and lateral torsional buckling without adequate temporary bracings. Due to the lack of adequate lateral and diagonal bracings of top chords, bottom chords, and web members, the installed trusses were in a state of instability, ready to collapse either due to buckling or under any significant lateral and gravity loads. Further, standard industry practice requires that materials should not be placed on trusses during erection unless proper evaluation is done, see Attachment B.

Details of the required bracings for trusses up to 60' in span are provided in "Building Component Safety Information – Guide to Good Practice for Handling, Installing, Restraining, & Bracing of Metal Plate Connected Wood Trusses i.e., BCSI –B1. 2006 edition (see attachment

A), produced by Truss Plate Institute (TPI). For trusses over 60' in span, the industry requires that a professional engineer determine the type, size and location of temporary bracings.

Structural analyses were performed to determine:

1. Whether the roof trusses were designed properly for code prescribed loads.
2. Whether the roof trusses would be overstressed if the top chords were braced at every panel point.
3. Whether the roof truss would be overstressed under the load of three bundles of 2x6s placed over its top chord in combination with other loads.

The structural analysis of the roof's hip truss was performed using the commercially available software program STAAD.Pro 2007 to obtain the member forces. The following assumptions were used in the analysis.

- The member properties of the hip truss were obtained from the MiTek drawing.
- The truss was considered supported at one end on a hinge support and at the other end on a roller support.
- Three bundles of 2x6s, each containing 20 12' long pieces, were placed over the top chord of the truss.
- There were 50 2x4x20' long pieces spread over the bottom chord of the truss.
- The weight of the truss was 718 pounds.
- As part of the live load, minimum two employees weighing approximately 200 pounds each were considered to be working on the installed trusses.
- The analysis was done without load and strength reduction factors.
- The analysis considered the recommended TCTLR minimums at each panel joints. Thus, the entire panel length was considered as a fully unbraced length in both major axes. The effective unbraced length for the analysis was considered to be 80% of the panel length.
- Wind load was not considered in the analysis.

The analyses indicated the following:

1. The roof trusses were properly designed to meet the code-prescribed loads.
2. If the top chords were braced at every panel point, the compressive stress would have been within the permissible limits under its own dead load plus the weight of two employees.
3. With the combination of the weight of three bundles of 2x6s, two employees on a truss, and a number of 2x4s spread over the bottom chord, the top chord experienced a compressive force far greater than its allowable capacity as well as its ultimate strength. Thus, the top chord failed due to lateral torsional buckling. After the failure of the top chords, failure of other members was triggered. The result of the analyses is summarized in Table 1.

Post-incident examination revealed that the actual number of bracings provided to ensure the stability of the trusses was far less than is required by the industry practice, see Table 2.

TABLE 1

SUMMARY OF MAXIMUM AXIAL FORCE IN TOP CHORD MEMBER			
Loading condition	Maximum axial compressive force without load factor	Ultimate axial capacity in compression* without strength reduction factor	Remarks
Dead load (DL) of the truss	804 pounds	2090 pounds	O.K.
DL of truss + minimum two employees	1360 pounds	2090 pounds	O.K.
DL of truss + minimum two employees + three bundles of 2x6 + loose 2x4 pieces	2167 pounds	2090 pounds	**Failure imminent**

* Based on an effective unbraced length of 7'-2".

TABLE 2

REQUIREMENTS OF TEMPORARY BRACING DURING TRUSS INSTALLATION AS PER INDUSTRY PRACTICE*	
Items	**No. of bracings required**
Top chord lateral bracing @ east face of the truss	10, each @ 4'-0" apart maximum
Top chord lateral bracing @ west face of the truss	10, each @ 4'-0" apart maximum
Top chord diagonal bracing @ east face and west face of the truss	1st bracing covering five trusses and subsequent braces covering four trusses
Bottom chord lateral bracing	10`-0" to 15`-0" apart maximum
Bottom chord diagonal bracing	20`-0" apart maximum
Web diagonal bracing	10`-0" to 15`-0" apart (located at each of the bottom chord lateral bracings) and 20'0" apart in a transverse direction
Ground bracing	20 (to be located at each of the top chord lateral bracings)

* Based on Attachment A.

Conclusions:

1. The cause of the incident was the placement of three bundles of 2x6x12` long pieces over the top chord of the hip trusses shortly before the incident. The weight of the bundles in combination with the weight of the employees working on the trusses, and other 2x4s spread over the bottom chord of the truss caused the compressive stress of the top chord to exceed its ultimate capacity. The failure was caused by lateral torsional buckling of the top chord.
2. The truss erector did not consult a professional engineer to design and determine the size and location of temporary bracings, as is required by the industry practice if the truss span exceeds 60 feet. The span of the failed trusses was 81 feet.
3. The temporary bracings provided by the erector were considered inadequate as per the industry requirements, even for trusses having spans 60` or less. The inadequacy was observed in the temporary web and diagonal bracings of the trusses.
4. Wind was not a causal factor.

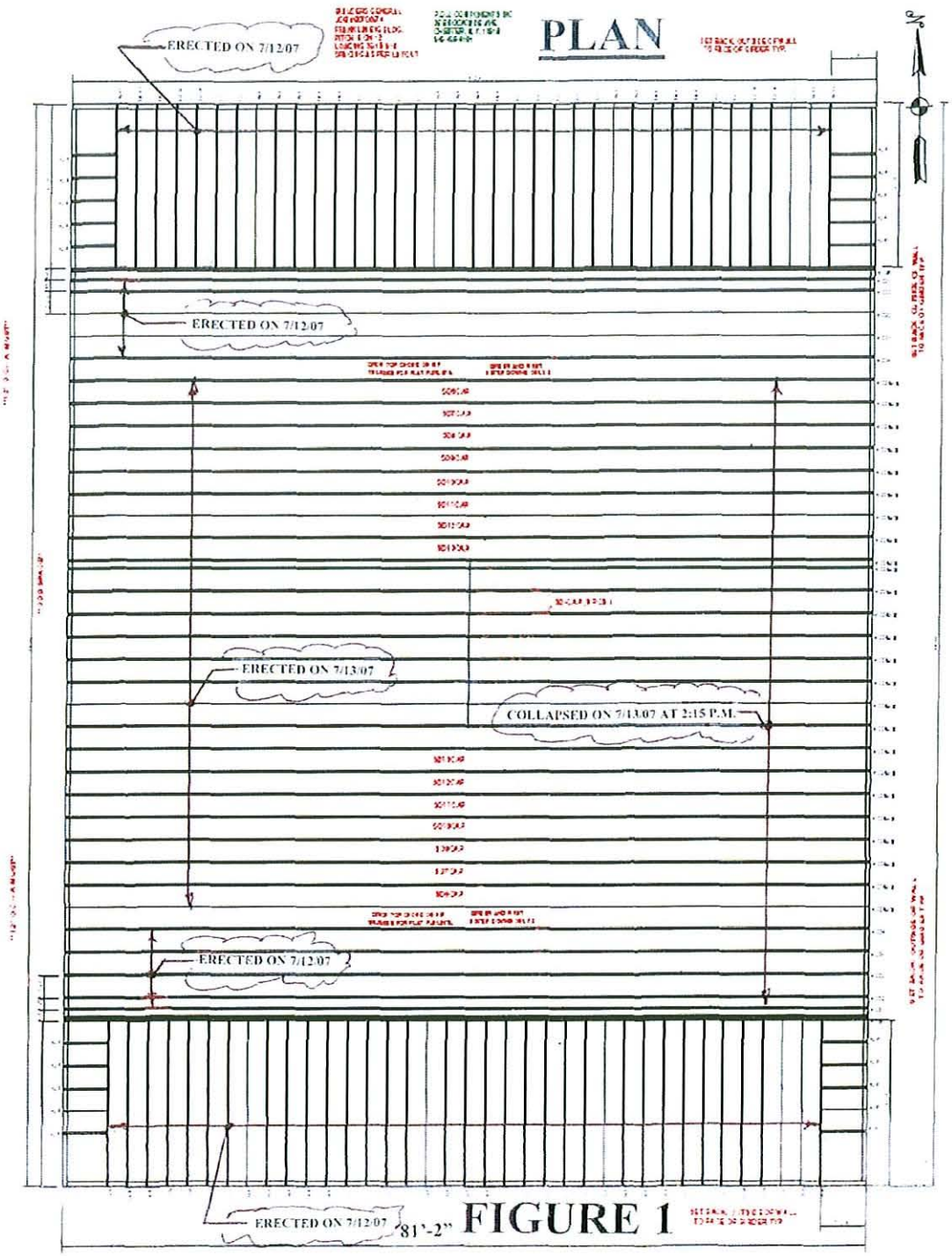

PLAN
ERECTED ON 7/12/07
ERECTED ON 7/12/07
ERECTED ON 7/13/07
COLLAPSED ON 7/13/07 AT 2:15 P.M.
ERECTED ON 7/12/07
ERECTED ON 7/12/07
81'-2"

FIGURE 1

FIGURE 2

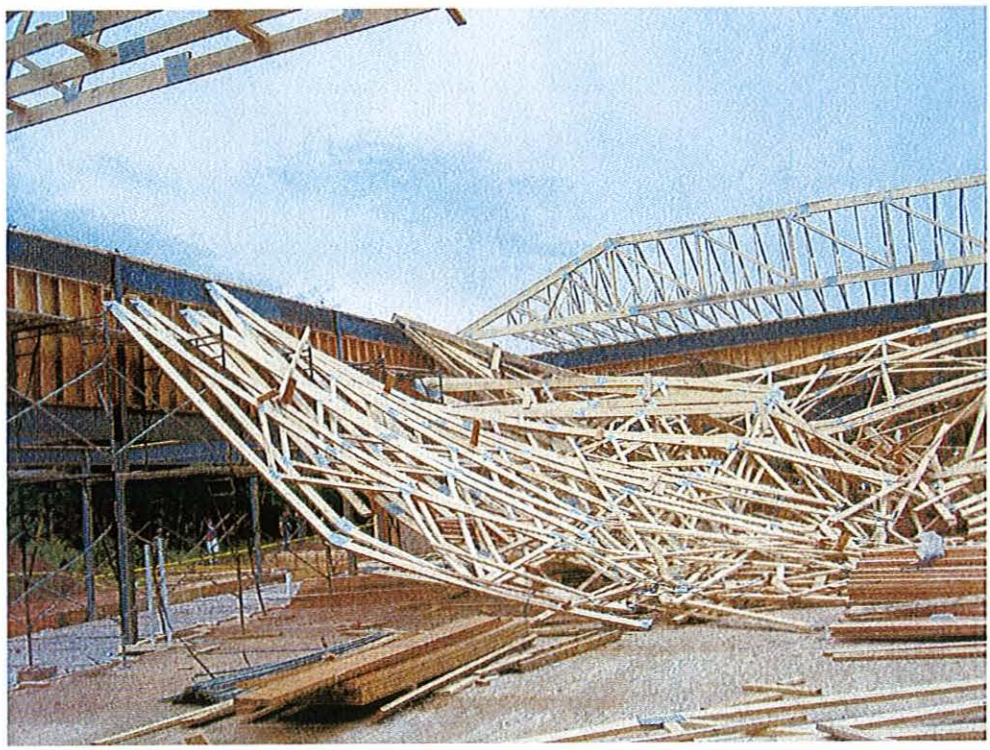


FIGURE 3

FIGURE 4

FIGURE 5

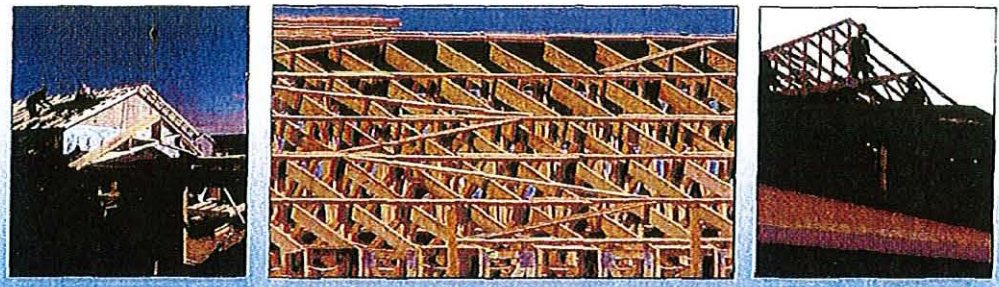
IMPORTANT SAFETY INFORMATION

ATTACHMENT A
(SHEET 1 OF 3)

BCSI

BUILDING COMPONENT SAFETY INFORMATION

Guide to Good Practice for Handling, Installing, Restraining & Bracing of Metal Plate Connected Wood Trusses



HAZARD! WARNING! CAUTION! DANGER! ALERT! SAFETY!

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TRUSS PLATE INSTITUTE

2006 EDITION PUBLISHED OCTOBER 2006

TEMPORARY INSTALLATION RESTRAINT/BRACING REQUIREMENTS FOR THE VARIOUS PLANES OF A ROOF TRUSS

☑ Temporary Installation Restraint/Bracing must be applied to **ALL** of the following planes of the trusses to ensure stability:

1) Top Chord Plane (roof plane)
2) Web Member Plane (sloping or vertical plane perpendicular to trusses)
3) Bottom Chord Plane (ceiling plane)

⊘ **WARNING!** IT IS CRITICAL TO INSTALL LATERAL RESTRAINT AND DIAGONAL BRACING FOR THE TOP CHORD AND WEB MEMBER PLANE IMMEDIATELY to prevent out-of-plane buckling of the truss.

☑ 1) **TOP CHORD TEMPORARY INSTALLATION RESTRAINT/BRACING** *is the most important step for the Contractor. Truss top chords are susceptible to lateral buckling.* See **BCSI-B2** for more information.

☑ THE TOP CHORD LATERAL RESTRAINT AND DIAGONAL BRACING APPROACH PROVIDED BELOW APPLIES TO ALL SLOPING CHORD TRUSSES, SCISSORS TRUSSES, 2X_ PARALLEL CHORD TRUSSES AND PIGGYBACK TRUSSES. **Note:** 2x _ trusses with depths less than 1/15th of the span at *all locations away from bearings require more complex* Temporary Installation Restraint/Bracing. Consult a Professional Engineer.

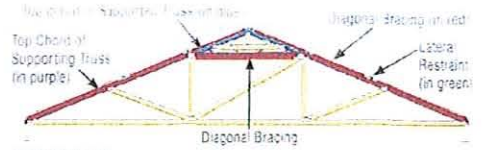


FIGURE B1-23

Maximum Top Chord Temporary Lateral Restraint Spacing	
Truss Span	**Top Chord Temporary Lateral Restraint (TCTLR) Spacing**
Up to 30'	10' on-center maximum
30' - 45'	8' on-center maximum
45' - 60'	6' on-center maximum
60' - 80' *	4' on-center maximum

*Consult a Professional Engineer for trusses longer than 60'

TABLE B1-4

⚠ **EXACT SPACING BETWEEN TRUSSES SHOULD BE MAINTAINED AS THE LATERAL RESTRAINT AND DIAGONAL BRACING IS INSTALLED** to avoid the hazardous practice of trying to remove this material to adjust spacing. This act of "adjusting spacing" can cause trusses to topple if the restraint and bracing is disconnected at the wrong time.

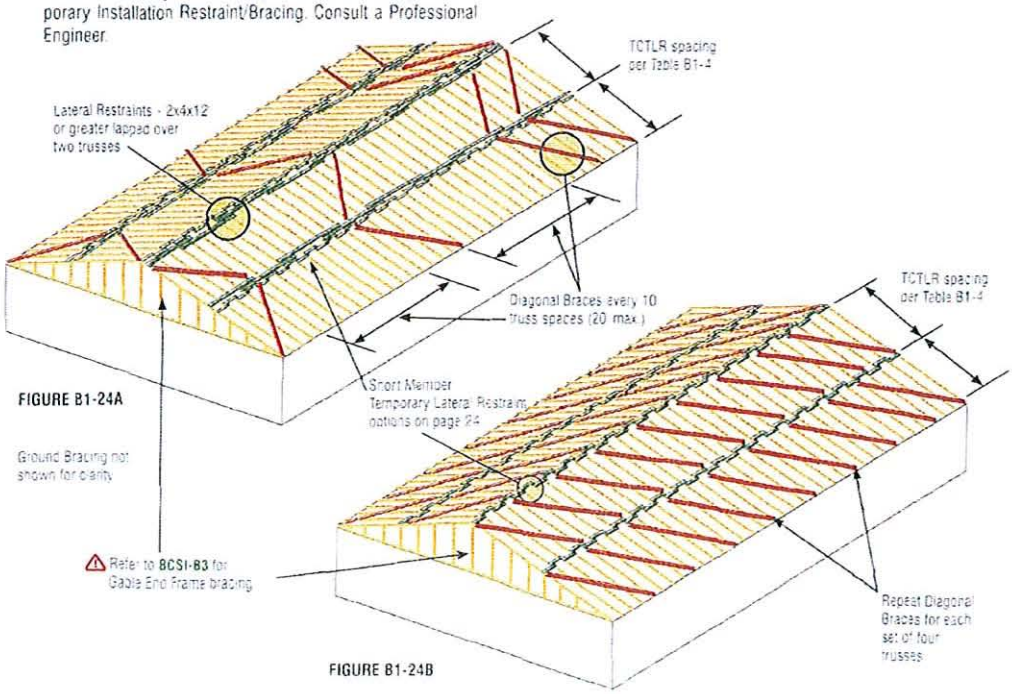
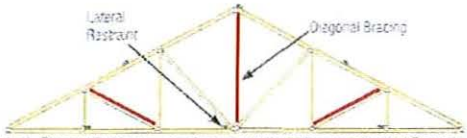


FIGURE B1-24A

FIGURE B1-24B

☑ 2) **WEB MEMBER PLANE** requires temporary/permanent Lateral Restraint and Diagonal Bracing, as shown in Figures B1-25 and 26. It is critical in preventing trusses from leaning or dominoing. Install Diagonal Bracing on web members (vertical webs whenever possible), at or near bottom chord Lateral Restraint. Structural Sheathing can be substituted for both the Lateral Restraint and Diagonal Bracing. See **BCSI-B2** and **BCSI-B3** for additional information pertaining to web member restraint and bracing.



Apply Diagonal Bracing to webs that are near the bottom chord Lateral Restraint. See "**IMPORTANT NOTE**" at right for spacing of bottom chord Lateral Restraint.

FIGURE B1-25

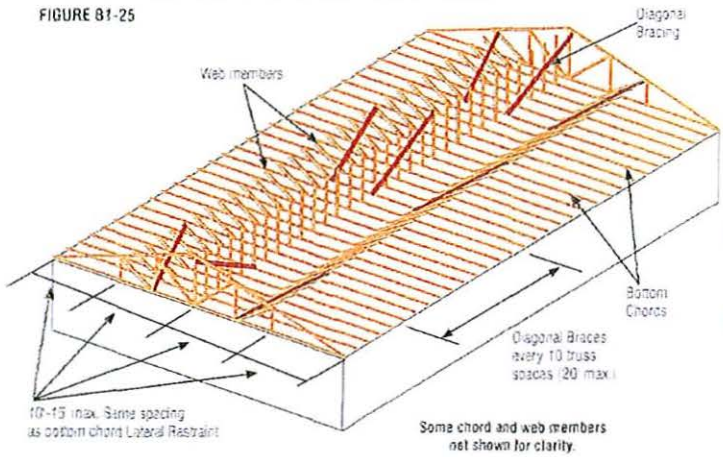


FIGURE B1-26

☑ **Webs that require Continuous Lateral Restraint (CLR) must also be Diagonally Braced for rigidity. Installing the CLR and Diagonal Bracing as the trusses are installed saves time.**

Note: Web members that require more than one row of CLR shall have the CLRs and Diagonal Bracing installed as the trusses are installed.

☑ 3) **BOTTOM CHORD TEMPORARY LATERAL RESTRAINT AND DIAGONAL BRACING** is required to maintain on-center spacing for the bottom chord and to laterally "stiffen" the group of trusses. Place Continuous Lateral Restraint and Diagonal Bracing on top of the bottom chord (Figures B1-27 and 28). This material can be removed after the permanent ceiling Diaphragm is in place or remain to become part of the Permanent Building Stability Bracing system.

FIGURE B1-27

"**IMPORTANT NOTE:** Install bottom chord Temporary Lateral Restraint in rows no more than 15' on center. Install bottom chord permanent Lateral Restraint at the locations required by the TDD and Construction Documents. The maximum on-center spacing of permanent Lateral Restraint is 10' but can be less if required by the TDD and/or Building Designer.

☑ Connect end of restraint to end wall. Add Diagonal Bracing at each end and every 10 truss spaces (20' maximum).

☑ Long spans, heavy loads or truss spacings greater than 2' on center often require closer spacing of Lateral Restraint and Diagonal Bracing. Consult the Building Designer or **BCSI-B10**.

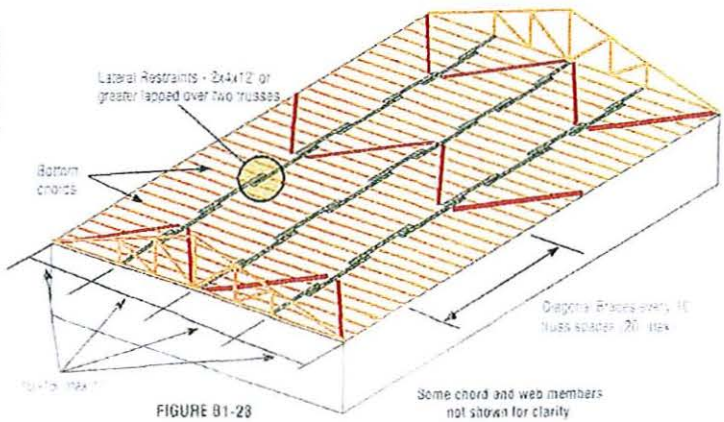


FIGURE B1-28

CONSTRUCTION LOADING

ATTACHMENT B
(SHEET 1 OF 2)

The term "construction loading" is typically used to describe loads from workers and building materials on an unfinished structure; for example, when builders temporarily stack bundles of panel sheathing or gypsum board on installed trusses during the construction process.

☑ Make sure that the truss assembly is properly restrained and braced according to the guidelines in **BCSI-B1** and **BCSI-B2**.

☑ Construction loads shall be placed only on fully restrained and braced structures.

⚠ **WARNING!** Trusses by themselves are very unstable and have NO CAPACITY to carry load until they are properly restrained and braced. Placing loads on trusses that have not been properly restrained and braced is hazardous and prohibited. Property damage, personal injury and/or death are possible if this warning is not heeded.

☑ Use extreme caution when placing construction loads and only stack reasonable amounts of materials (see Table B4-1).

⚠ **WARNING!** Stacking excessive amounts of construction materials on floor or roof trusses is an unsafe practice.

☑ *Trusses that have been over-stressed due to excessive construction loading will usually show excessive sagging (deflection) and at least a portion of this deflection will remain even after the load has been removed. In more severe cases, excessive construction loading will cause broken webs and/or chord members or web or chord members that have pulled away from the truss plates.*

CONSTRUCTION LOADING DOS AND DON'TS

⊘ **DON'T** stack materials on unbraced trusses.

☑ **DO** stack a reasonable amount of material that will not overload the trusses.

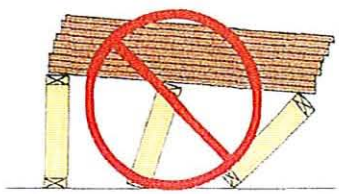


FIGURE B4-1

Maximum Stack Height for Material on Trusses	
Material	**Height**
Gypsum Board	12"
Plywood or OSB	16"
Asphalt Shingles	2 bundles
Concrete Block	8"
Clay Tile	3-4 tiles high

TABLE B4-1

1. This table is based on trusses designed with a live load of 40 psf or greater.
2. Stack heights assume short-term duration of load. Install stacks of materials as quickly as possible.

Note: Heavy roofing tile such as clay or stone slate is often "dry-stacked" on the roof for a period of time to allow the roof/ceiling assembly time to "settle" before the finished ceiling is installed. Limit stack heights to those provided in Table B4-1 and stacking periods to approximately one week, unless alternative information is provided by the Building Designer, Truss Designer or Truss Manufacturer.

⊘ **DON'T** exceed stack heights listed in Table B4-1 unless alternative information is provided by the Building Designer, Truss Designer or Truss Manufacturer.

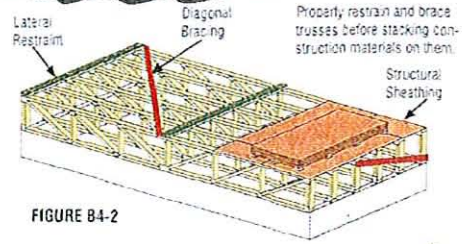


FIGURE B4-2

⊘ **DON'T** allow the stack to lean against walls.

⊘ **DON'T** stack materials in concentrated areas so that they overload a single or small group of trusses.

FIGURE B4-3

☑ **DO** stack materials along exterior supports or directly over interior supports of properly restrained and braced structures.

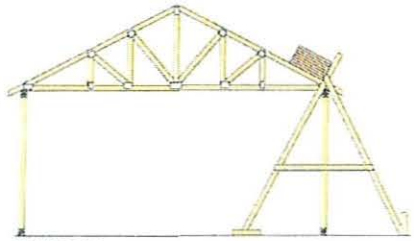


FIGURE B4-4 Truss bracing not shown for clarity.

⊘ **DON'T** overstack materials midway between supports. Never exceed stack heights per Table B4-1, page 53, unless alternative information is provided by the Building Designer, Truss Designer or Truss Manufacturer.

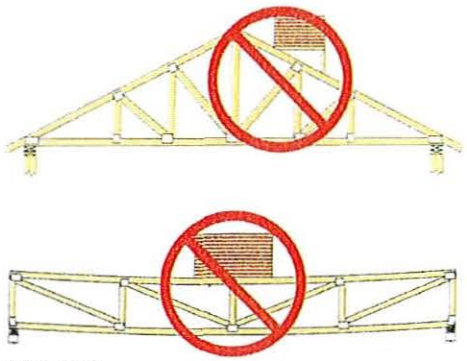


FIGURE B4-5

☑ **DO** distribute loads over as many trusses as possible. Position stacks of materials flat with the longest dimension perpendicular to the trusses as shown.

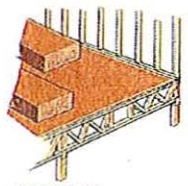


FIGURE B4-6

⊘ **DON'T** drop loads of any materials on trusses. Truss damage from the impact is possible even if the weight of the material is small.

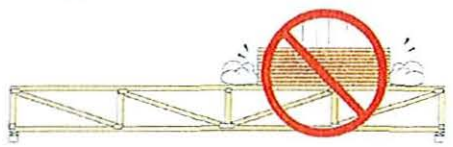


FIGURE B4-7

☑ **DO** leave construction materials on lifting equipment until installation if possible.

PHOTO B4-1

⊘ **DON'T** stack materials at locations that will produce instability, such as on cantilevers or near truss-to-girder connections.

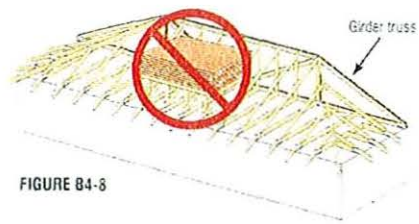


FIGURE B4-8

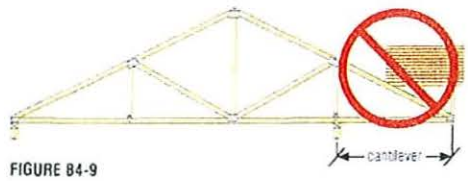


FIGURE B4-9

⚠ **WARNING!** Excessive construction loads on floor or roof trusses is an unsafe practice and shall be avoided. Property damage, serious personal injury and/or death are possible if these recommendations are not followed.

⊘ **DON'T** pile cut-off tile and/or other construction waste on truss roofs.

PHOTO B4-2