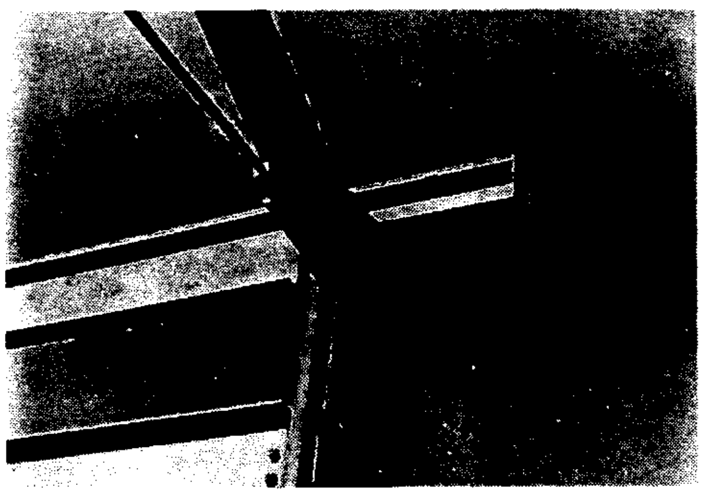
TECHNICAL PUBLICATION NO. 63

A CONTINUING EDUCATION PROGRAM ON THE SAFE ERECTION OF ROOF TRUSSES

SPONSORED BY A GRANT FROM THE BUILDING

CONSTRUCTION INDUSTRY ADVISORY COMMITTEE



ANTHONY SECTION

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63

A CONTINUING EDUCATION PROGRAM ON THE SAFE ERECTION OF ROOF TRUSSES

CE 87-30

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This continuing education project was sponsored by the Building Construction Industry Advisory Committee under a grant from the State of Florida Department of Education.

Executive Summary

The research related to the course development identified three main causes of roof truss collapses. First, that the required manufacturer suggestions in Bracing Wood Trusses BWT-76 are either not used or are not understood by the erection contractor. Second, because the print on the BWT-76 "green sheet" (delivered with the trusses) is too small and poorly organized, its recommendations are often ignored on the job. Also that the bracing drawings as presented are easily misinterpreted. Third, that the temporary bracing installed by the erection contractor is inadequate or not installed properly.

The overall recommendations are to redesign BWT-76 for simplicity and to develop the bracing drawings in three dimensions. Most important, is to require that erection contractors be certified and that the person holding the certification be present to supervise the erection and bracing of wood trusses. To fulfill this requirement, an effort should be made to educate the people involved in the design and erection of wood trusses. It is suggested that this training program be offered to architects, engineers, contractors, and building inspectors at state, regional and local educational conferences.

Copies of this final report may be obtained by contacting:

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Southern Pine Inspection Bureau

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PREFACE-USE OF THIS MANUAL FOR PRESENTATION

The arrangement of this instructor's manual is in a format which will permit one familiar with wooden roof trusses to present the material contained herein with a minimum amount of preparation. It is recognized that each instructor will possess unique knowledge of the subject and will have his own style of delivery. To facilitate this, each lesson is outlined in a manner which organizes the salient points within each section - yet allows the presenter the latitude to emphasize particular topics or inject personal experiences.

Each chapter begins with instructor notes which contain an outline of the lesson, approximate time for lesson presentation, and list of 35 mm slides used in that lesson. The narrative contains the information on that lesson's aspect of wood trusses which should be brought out in the presenter's delivery. The slides are blended into the narrative to illustrate items within the lesson.

By advancing the slides and reciting the script which follows, the instructor will present the material in an orderly, and logical sequence. It is hoped that the notes provided will be the basis for the instructor's delivery initially, but that as familiarity with the subject matter increases, less reliance on the notes will be required.

OUTLINE FOR WOOD TRUSS SEMINAR

I. Introduction (15 mins.)
   - A. Research Objective, Statement of the Problem.
   - B. Fatal Facts Example.
   - C. Construction Collapse Committee Report Findings.

II. Pre-erection (20 mins.)
   - A. Shipping
   - B. Unloading
   - C. Storing

III. Erection (45 mins.)
   - A. Preparation
   - B. Inspection
   - C. General Erection
   - D. Manual Erection
   - E. Mechanical Erection
   - F. Truss Connections/Anchors

IV. Bracing (1 hr.)
   - A. General Bracing
   - B. Temporary Bracing
   - C. Permanent Bracing

V. Conclusion (1 hr.)
   - A. Accident Review
   - B. Recommendations
   - C. Questions and Answers

Total - Approximately 3 hours, 20 minutes.

INSTRUCTOR NOTES FOR LESSON I, INTRODUCTION

1. SUBJECT Introduction for Training Program.

2. OBJECTIVE Each attendee will become familiar with and understand:

   a. An outline of the training program material.

   b. The objective of the training program.

   c. A statement of the problem in erecting and bracing wooden roof trusses.

   d. Background on the problem of roof trusses.

   e. An example of an accident involving roof trusses.

3. LESSON OUTLINE

SUBJECT	TIME REQUIRED
a. Program Outline/Admin. Remarks .	5 mins.
b. Statement of Problem/Background .	5 mins.
c. Accident Example	5 mins.
	15 mins.

SLIDES FOR INTRODUCTION. Slides are numbered (I-#) followed by description. Text slides are in uppercase letters.

A. Program Outline/Administrative Remarks

(I-1) Outline for Wood Truss Training Program

I. Introduction
- A. Research objective, statement of the problem.
- B. Fatal Facts example.
- C. Construction Collapse Committee report findings.

II. Pre-erection
- A. Shipping
- B. Unloading
- C. Storing

III. Erection
- A. Preparation
- B. Inspection
- C. General Erection
- D. Manual Erection
- E. Mechanical Erection
- F. Truss Connections/Anchors

IV. Bracing
- A. General Bracing
- B. Temporary Bracing
- C. Permanent Bracing

V. Conclusion
- A. Accident Review
- B. Recommendations
- C. Questions and Answers

(I-2) Truss system in place.

B. Statement of Problem/Background

(I-3) Collapsed trusses.

(I-4) TEXT - Intended results of training program.

THE INTENDED RESULTS OF THIS TRAINING PROGRAM ARE:

A. SAFER CONSTRUCTION.

B. DECREASED CONSTRUCTION FAILURES.

C. DECREASED CONSTRUCTION INJURIES.

D. FEWER BUSINESS LIABILITIES.

E. AN EFFECTIVE REFERENCE FOR CONTRACTORS, ARCHITECTS, AND BUILDING OFFICIALS.

(I-5) Cover of Construction Collapse Committee (CCC) report.

(I-6) Figure 1 from CCC report.

(I-7) TEXT - OBSERVATIONS FROM THE CCC REPORT.

OBSERVATIONS FROM THE CCC REPORT

A. INADEQUATE TEMPORARY BRACING CAUSES AT LEAST 60% OF TRUSS ACCIDENTS.

B. THE NEXT GREATEST PROBLEM WITH WOOD TRUSSES DURING CONSTRUCTION IS THE OVERLOADING OF THE TRUSSES, ESPECIALLY BEFORE THE PERMANENT BRACING IS INSTALLED.

C. NO CERTIFICATION CURRENTLY EXISTS FOR WOOD TRUSS INSTALLERS. SOME OF THE ACCIDENTS STUDIED IN THE REPORT LISTED OWNERS AND CHURCH PARISHIONERS ATTEMPTING TO INSTALL TRUSSES.

D. THE INDUSTRY-ACCEPTED, DETAILED INSTRUCTIONS, THE TRUSS PLATE INSTITUTE'S BRACING WOOD TRUSSES, (BWT-76) FOR THE BRACING OF TRUSSES,

IS FURNISHED WITH EACH LOAD OF TRUSSES DELIVERED TO A JOB SITE, BUT IS TOO EASILY LOST OR IGNORED.

C. Accident Example

(I-8) Drawing and description from Fatal Facts publication.

(I-9) Fallen trusses with cut out area.

I. INTRODUCTION

A. Program Outline/Administrative Remarks

Slide I-1, Program outline.

The instructor should open the training program by reviewing the program outline and covering all administrative and conduct of the course items.

Slide I-2, Truss system in place.

This presentation is the result of a grant from the Building Construction Industry Advisory Committee of the Florida Department of Education, to provide a continuing education program that will educate building contractors, engineers, architects, and building officials with the safe erection of roof trusses.

B. Statement of the Problem/Background.

Slide I-3, Collapsed roof trusses.

Recently there has been concern in the state of Florida about the safe erection of roof trusses. The problems have been related to unloading, transporting, and repairing the trusses on the job site before erection, as well as bracing, loading, nailing plywood to the frame, and anchoring during the erection process. There is definitely a need for a continuing education program to train the contractor and inspectors on the proper and safe erection and handling of roof trusses.

Slide I-4, Intended results of training program.

THE INTENDED RESULTS OF THIS TRAINING PROGRAM ARE:

A. SAFER CONSTRUCTION.

B. DECREASED CONSTRUCTION FAILURES.

C. DECREASED CONSTRUCTION INJURIES.

D. FEWER BUSINESS LIABILITIES.

E. AN EFFECTIVE REFERENCE FOR CONTRACTORS, ARCHITECTS, AND BUILDING OFFICIALS.

In 1985 the Florida Department of Professional Regulation (DPR) appointed the Construction Collapse Committee (CCC) to investigate the growing number of construction collapses within the state of Florida. The committee devised a questionnaire which was then given to selected DPR field investigation offices throughout the state.

Slide I-5, Cover of CCC report.

Their findings and recommendations were published in the 1986 Construction Collapse Committee Report.

Slide I-6, Figure 1 from CCC report.

Figure one shows the results of that questionnaire. For the construction accidents investigated during the five year reporting period, wood truss accidents accounted for 46% of those accidents. Truss accidents were responsible for 16% of the deaths and 17% of injuries in accidents investigated.

Slide I-7, TEXT - CCC report's observations.

The following were among the observations listed in the Construction Collapse Committee's report:

OBSERVATIONS FROM THE CCC REPORT

A. INADEQUATE TEMPORARY BRACING CAUSES AT LEAST 60% OF TRUSS ACCIDENTS.

B. THE NEXT GREATEST PROBLEM WITH WOOD TRUSSES DURING CONSTRUCTION IS THE OVERLOADING OF THE TRUSSES, ESPECIALLY BEFORE THE PERMANENT BRACING IS INSTALLED.

C. NO CERTIFICATION NOW EXISTS FOR WOOD TRUSS INSTALLERS. SOME OF THE ACCIDENTS STUDIED IN THE REPORT LISTED OWNERS AND CHURCH PARISHIONERS ATTEMPTING TO INSTALL TRUSSES.

D. THE INDUSTRY-ACCEPTED, DETAILED INSTRUCTIONS, THE TRUSS PLATE INSTITUTE'S BRACING WOOD TRUSSES, (BWT-76) FOR THE BRACING OF TRUSSES, IS FURNISHED WITH EACH LOAD OF TRUSSES DELIVERED TO A JOB SITE, BUT IS TOO EASILY LOST OR IGNORED.

C. Accident Example

Slide I-8, Drawing and description from Fatal Facts.

A report from an OSHA-produced Fatal Facts publication related a roof-truss collapse that occurred in Florida in 1984. The accident description read,

"Five employees were installing wooden roof trusses with a span of 63 feet. Thirty-four of 49 wood trusses were installed without lateral bracing other than two hip trusses, each secured by 2-16d nails to the header truss. The trusses collapsed in a 'falling domino' pattern, crushing one employee underneath and injuring four others that were on top."

Slide I-9, Fallen trusses with cut out area.

The hole in the middle of these trusses was sawn to remove the trapped dead man from the truss wreckage.

The material presented here will address the recommendations of the CCC report and other areas of safety relating to the erection of roof trusses. It is hoped that this attempt to educate the you on the recommended methods of handling, erecting, and bracing wood trusses will create a safer and more productive construction work environment. This report does not attempt to affix responsibility for past truss accidents, but rather to use past incidents to point out possible areas for improvement on the part of designers, truss manufacturers, truss erectors, and building inspectors regarding their involvement with wooden roof trusses.

END OF INTRODUCTION

INSTRUCTOR NOTES FOR LESSON II, PRE-ERECTION

1. SUBJECT Pre-erection includes the shipping, unloading, and storing of trusses.

2. OBJECTIVE Each attendee will become familiar with and understand:

   a. Banding of trusses for delivery.

   b. Acceptable unloading practices for trusses.

   c. Proper storage techniques for trusses.

   d. Guidance publications available for pre-erection topics.

3. LESSON OUTLINE

	SUBJECT	TIME REQUIRED
a.	Shipping	5 mins.
b.	Unloading	5 mins.
c.	Storing	10 mins.
		20 mins.

SLIDES FOR PRE-ERECTION. Slides are numbered (II-#) followed by description. Text slides are in upper case letters.

A. Shipping

(II-1) Close-up of steel bands on trusses.

(II-2) Trusses lifted onto truck with forklift.

(II-3) Cover of Bracing Wood Trusses, BWT-76.

(II-4) Green sheet.

B. Unloading

(II-5) Cover of Handling and Erecting Trusses, HET-80.

(II-6) Stub truss engineered drawing.

(II-7) Truss layout drawing.

(II-8) TEXT - TRUSS DELIVERY CHECK

1. OBVIOUS STRUCTURAL DAMAGE.
2. TRUSS CONFIGURATION.
3. ROUGH DIMENSION CHECK.

(II-9) Trusses unloaded close to building site.

C. Storing

(II-10) Correct horizontal and vertical storage.

(II-11) Correct vertical storage.

(II-12) Dumped trusses, incorrect storage.

(II-13) Leaning trusses. Hazardous condition.

(II-14) Scissors truss engineered drawing.

(II-15) Long-term storage in plastic with no ventilation.

(II-16) HET-80.

LESSON - II PRE-ERECTION

A. Shipping

Slide II-1, Close-up of steel bands.

In the truss yard, finished trusses are usually banded with steel strapping into manageable-sized bundles. The steel banding helps to maintain the truss alignment and the banding strength minimizes damage during delivery to the job site.

Slide II-2, Trusses lifted onto truck with forklift.

Banded trusses for delivery are normally loaded on flatbeds, special trailers or dump trucks, and are securely strapped or chained for transportation to the job site.

Slide II-3, Cover of BWT-76.

The Truss Plate Institute (TPI) has provided a publication which contains valuable information on the correct procedures for bracing and erecting wood trusses. This publication, Bracing Wood Trusses: Commentary and Recommendations, or BWT-76, should be in the hands of the erection contractor before he attempts to set wood trusses.

Slide II-4, Green sheet.

BWT-76 is printed in its entirety on what is called the green sheet. It is normally attached to a set of trusses prior to delivery. It is of the utmost importance that the truss erector receive this document prior to truss erection. Some truss manufacturers insure that the delivery driver hand-delivers this document to the erection contractor.

B. Unloading

Slide II-5, Cover of HET-80.

Prior to truss on-site delivery, the truss erection contractor should review the truss engineered drawing, truss lay-out drawing, and another TPI publication - Handling and Erecting Wood Trusses, or HET-80. HET-80 contains useful, general information on the delivery, storage, and erection of trusses.

Slide II-6, Stub truss engineered drawing.

Slide II-7, Truss layout drawing.

The truss engineered drawing and the truss lay-out drawing contain specific information for the configuration of the trusses being delivered. As trusses are unloaded, the erector should make a cursory inspection of the trusses for any pre-delivery damage.

Slide II-8, TEXT - Items for cursory inspection:

TRUSS DELIVERY CHECK

1. OBVIOUS STRUCTURAL DAMAGE.
2. TRUSS CONFIGURATION.
3. ROUGH DIMENSION CHECK.

As it is beneficial to leave trusses banded until just prior to erection, this inspection should be limited to obvious structural damage, truss configuration, and a rough dimension check. A more thorough inspection will be made prior to truss erection.

The utmost care should be taken so as not to allow trusses to bend excessively, or to allow tipping or toppling while the trusses are unloaded.

Slide II-9, Trusses unloaded close to building site.

Trusses should be left banded and unloaded as close to the building site as possible to minimize handling. They should not be unloaded on rough terrain that would cause undue lateral strain resulting in distortion of the truss joints. Rough terrain can also cause damage or breakage of overhangs, soffit returns, and other parts of the truss. The dumping of trusses is an acceptable practice provided that it is done exercising reasonable care and that the trusses are not damaged or excessively stressed while being dumped.

C. Storing

Slide II-10, Correct horizontal and vertical storage.

The truss manufacturer will normally store trusses vertically in racks or horizontally on blocking to prevent lateral bending.

Slide II-11, Correct vertical storage.

The critical item in truss storage is to avoid bending the trusses. Even small amounts of lateral bending can loosen the teeth of the metal connector plates and compromise joints. Excessive bending can break the truss lumber.

The builder should provide protection for the trusses from damage that may be caused by on-site construction activity. If trusses fabricated with fire retardant treated wood must be stored prior to erection, they should be stored in a vertical position to prevent water from standing on the plates. Moisture will leach fire retardant salts from the treated lumber and corrode metal connector plates, thus destroying the truss joint connections.

If trusses are to be stored for more than one week, they should be blocked above the ground to protect them from ground water. Blocking must be solid to prevent toppling or sliding. For horizontal storage, the blocking should be on eight to ten foot centers or as required to prevent lateral bending.

Slide II-13, Leaning trusses. Hazardous condition.

Trusses stored vertically should be supported in a manner that will prevent tipping or toppling in order to avoid injury. Stored trusses - especially leaning or teetering trusses - are an inviting play area for children. Leaning trusses have toppled onto and crushed children.

Generally, cutting of the delivery banding is done just prior to erection. Banding that tends to bend the bottom chord of the trusses, however, should be cut prior to long-term storage of trusses. Great care should be taken in banding removal to avoid individual trusses sliding or tipping.

Slide II-14, Scissors truss engineered drawing.

Extreme care should be exercised when storing scissors type trusses vertically due to their inherent instability. Similar care should be shown to any standard truss stored in an inverted (peak down) position.

Slide II-15, Long-term storage in plastic with no ventilation.

During long term storage trusses should be protected from weather in a manner that provides for adequate ventilation. If tarpaulins are used, the ends should be left open for ventilation. Plastic is an undesirable tarpaulin since it can trap moisture.

Slide II-16 Cover of HET-80.

The complete guide for the unloading and storing of wood trusses is the Truss Plate Institute's Handling and Erecting Wood Trusses, also known as HET-80.

END OF PRE-ERECTION

INSTRUCTOR NOTES FOR LESSON III, ERECTION

1. SUBJECT Erection includes the preparation, inspection, erection methods, connections, and anchors for wood trusses.

2. OBJECTIVE Each attendee will become familiar with and understand:

   a. References which contain information for any set of trusses.

   b. What to look for in inspecting a set of trusses.

   c. Methods of erecting trusses.

   d. Truss connections and anchors for trusses.

3. LESSON OUTLINE

	SUBJECT	TIME REQUIRED
a.	Preparation	5 mins.
b.	Inspection	5 mins.
c.	General Erection	5 mins.
d.	Manual Erection	10 mins
e.	Mechanical Erection	10 mins.
f.	Truss connections/anchors . .	10 mins.
	Total	45 mins.

SLIDES FOR ERECTION. Slides are numbered (III-#) followed by description. Text slides are in uppercase letters.

A. Preparation

(III-1) Truss system in place.

(III-2) Truss lay-out drawing.

(III-3) Girder truss engineered drawing.

(III-4) BWT-76 and HET-80 together.

B. Inspection

(III-5) Truss engineered drawing. Three grades of lumber in upper left corner.

(III-6) Bundled web members showing grade marks.

(III-7) Web members laid out. Note #3 quality lumber and length of web members.

(III-8) Stacked trusses with flush connector plates.

(III-9) Single connector plate.

(III-10) Second connector plate. Web member wane not under plate.

(III-11) TEXT - ANY QUESTIONS ON THE CONDITION OF TRUSSES SHOULD BE DIRECTED TO THE TRUSS MANUFACTURER. THE MANUFACTURER WILL REPAIR OR REPLACE THE SUSPECT

TRUSS. DO NOT ATTEMPT FIELD REPAIRS OF SUSPECT TRUSSES WITHOUT THE MANUFACTURER'S APPROVAL.

C. General Erection

(III-12) Truss system in place.

(III-13) Drawing of cantilevered truss.

D. Manual Erection

(III-14) Manual truss erection (1 man).

(III-15) Manual truss erection (2 men).

E. Mechanical Erection

(III-16) Excessive lateral bending from incorrect lifting method.

(III-17) Mechanical erection - less than 30 foot span.

(III-18) Mechanical erection - 30 to 60 foot span.

(III-19) Mechanical erection - greater than 60 foot span.

(III-20) TEXT - Advantages of using mechanical lifting method for trusses over 40 feet long:

MECHANICAL LIFTING ADVANTAGES

A. LESS CHANCE OF INJURY DUE TO SOMEONE SLIPPING OR NOT BEING ABLE TO HOLD HIS PART DURING ERECTION.

B. EASE WITH WHICH MACHINERY CAN HANDLE TRUSSES AS OPPOSED TO STRAIN AND DANGER INVOLVED WITH MANUAL HANDLING.

C. FEWER PEOPLE ARE NECESSARY TO COMPLETE SAFE AND SECURE JOB DURING ERECTION USING LIFTING EQUIPMENT.

D. LESS CHANCE OF DAMAGE TO TRUSS BY MISHANDLING.

E. GENERALLY, MECHANICAL HANDLING OF TRUSSES DOES NOT COST AS MUCH AS MANUAL HANDLING.

(III-21) Tag lines attached to truss.

F. Truss Connections/Anchors

(III-22) Truss engineered drawing for girder truss. Note at top center.

(III-23) Girder truss; three plies bolted together.

(III-24) Manufacturer's detail on truss hangers. Note recommended nailing schedule.

(III-25) Common truss hanger in use. Note suspect fastening of the three girder trusses.

(III-26) Manufacturer's detail on hurricane anchors. Note recommended nailing schedule.

(III-27) Hurricane anchors installed.

(III-28) Truss engineered drawing for scissors truss.

INSTRUCTOR NOTES FOR LESSON III, ERECTION, CONTINUED

(III-29) Special anchor for allowing horizontal movement.

(III-30) Section of vaulted ceiling truss.

LESSON III - ERECTION

A. Preparation

Slide III-1, Truss system in place.

The erection of wood trusses combines several different elements which take place simultaneously at the time of setting trusses, and all of which the erection contractor must be intimately familiar with prior to setting the first truss. These elements include erection methods, temporary truss bracing, permanent truss bracing, fastening schedules, and anchoring systems. Lesson III will not address permanent and temporary bracing as this is the subject matter of the next lesson.

The erection contractor can find all the information he needs to erect any wood truss system from four sources:

1. The truss lay-out drawings.
2. The truss engineered drawings.
3. The Truss Plate Institute's Handling and Erecting Wood Trusses, HET-80.
4. The Truss Plate Institute's Bracing Wood Trusses, BWT-76.

Whereas a review of these documents is helpful in unloading and storing wood trusses, these four documents should be STUDIED prior to truss erection.

Slide III-2, Truss lay-out drawing.

From the truss lay-out drawings, the erector can determine general lay-out, number, and configurations of trusses to be set.

Slide III-3, Girder truss engineered drawing.

From the truss engineered drawing, the erector can determine design specifications, spacing requirements, required permanent bracing, bearing requirements, nailing schedules for web stiffeners or multiple girder trusses, and connector plate and lumber specifications for truss members. Any critical note dealing with PERMANENT splices, braces to reduce buckling lengths, or fasteners will be shown here. The drawing should bear the certificate and seal of the design engineer and state of registry.

Slide III-4, BWT-76 and HET-80 together.

BWT-76 and HET-80 are the Truss Plate Institute's publications which contain general guidelines for the use of wood trusses. HET-80 contains important information on the storing and erecting of trusses. BWT-76 contains the erection information of HET-80 and provides the erecting contractor with the critically important guidelines for the erection bracing of wood trusses.

B. Inspection

Slide III-5, Truss engineered drawing with varying grades of lumber.

Several grades of lumber can be used in a single truss design. Note from the engineered truss drawing that web members are usually made of a lesser grade of lumber than the top and bottom chord members. The lumber of the web members, which are of inferior quality compared to top and bottom chord members, will preform up to the specifications listed on the truss engineered drawing.

Slide III-6, Bundled web members showing grade marks.

In inspecting wood trusses, it is common for the grade marks to be absent on web members.

Slide III-7, Web members laid out. Note #3 quality and length.

In the cutting of the web members at the yard, grade marks are often cast aside.

Slide III-8, Stacked trusses with flush connector plates.

Connector plate teeth should be buried entirely into wood members; there should be no gap between metal plate and wood components.

Slide III-9, Single connector plate.

Lumber directly under the metal connector plate should be 90% free of knots and wanes.

Slide III-10, Second connector plate.

Slide III-11, ANY QUESTIONS ON THE CONDITION OF TRUSSES SHOULD BE DIRECTED TO THE TRUSS MANUFACTURER. THE MANUFACTURER WILL REPAIR OR REPLACE THE SUSPECT TRUSS. DO NOT ATTEMPT FIELD REPAIRS OF SUSPECT TRUSSES WITHOUT THE MANUFACTURER'S APPROVAL.

C. General Erection

Slide III-12, Truss system in place.

Trusses may be erected either manually or mechanically, depending on the span and wall height. Always refer to the truss lay-out plan for proper location of trusses. Do not simply install them as they come off the pile.

Slide III-13, Drawing of cantilevered truss.

Cantilevered and asymmetrical trusses are designed for use in one orientation only. They can not be installed backwards and perform as designed. Refer to the truss elevation drawings for proper locations of cantilever trusses.

D. Manual Erection

Slide III-14, Manual truss erection (1 man).

When erected by hand, the trusses are slid into position over the side wall and rotated into position using a fork-like pole.

Slide III-15, Manual truss erection (2 men).

Two men should be used for erecting trusses greater than 20 feet. With spans greater than 20 feet, more men may be necessary to avoid lateral strain on the truss. The truss should be supported at the peak or the 1/4 points.

Building a slide from the ground to top plate of building using 2x8's, 10's, or 12's turned on edge makes large heavy trusses easy to get up to plate height without straining to lift the trusses in place. Trusses should be shoved up the slide with the peak pointing down.

E. Mechanical Erection

Slide III-16, Excessive lateral bending from incorrect lifting method.

Trusses large enough to be erected by mechanical means (cranes, forklifts, etc.) must employ adequate slings, tag lines, booms, and/or spreader bars to control movement of the truss and prevent lateral bending.

Trusses may be erected singly or in pre-assembled groups of four or five on the ground and then lifted into place. There are three recommended lifting procedures which are based on the length of the trusses to be erected. These methods apply to roof trusses and parallel chord, or floor trusses.

Slide III-17, Mechanical erection - less than 30 foot span.

The first suggested lifting procedure for spans up to 30 feet uses a sling with two chokers attached at 1/4 points of the truss. The angle formed by the two chokers at the main lifting cable should be less than 60 degrees.

Slide III-18, Mechanical erection - 30 to 60 foot span.

The second suggested lifting procedure for spans between 30 and 60 feet uses a spreader bar with chokers that toe-in to 1/6 to 1/4 pickpoints. Chokers which toe-out will tend to buckle the truss.

Slide III-19, Mechanical erection - greater than 60 foot span.

The suggested lifting method for trusses over 60 feet in length uses a strong-back. The strong-back should be attached to the top chord and web members at intervals of approximately 10 feet. The strong-back should be at or above the mid-height of the truss so as to prevent overturning and can be of any material with sufficient strength to safely carry the weight of the truss, and sufficient rigidity to adequately resist bending of the truss.

It is recommended that all large trusses (over 40 feet) and trusses with very high centers of gravity (steep pitch on conventional trusses) be erected mechanically due to the following:

Slide III-20, TEXT - Advantages of using mechanical lifting method for trusses over 40 feet long:

MECHANICAL LIFTING ADVANTAGES

A. LESS CHANCE OF INJURY DUE TO SOMEONE SLIPPING OR NOT BEING ABLE TO HOLD HIS PART DURING ERECTION.

B. EASE WITH WHICH MACHINERY CAN HANDLE TRUSSES AS OPPOSED TO STRAIN AND DANGER INVOLVED WITH MANUAL HANDLING.

C. FEWER PEOPLE ARE NECESSARY TO COMPLETE SAFE AND SECURE JOB DURING ERECTION USING LIFTING EQUIPMENT.

D. LESS CHANCE OF DAMAGE TO TRUSS BY MISHANDLING.

E. GENERALLY, MECHANICAL HANDLING OF TRUSSES DOES NOT COST AS MUCH AS MANUAL HANDLING.

Slide III-21, Tag lines attached to truss.

Regardless of truss length or mechanical lifting method, always use one or more tag lines to avoid a free swinging truss situation, and to aid in final truss placement.

F. Truss Connections/Anchors

Slide III-22, Truss engineered drawing for girder truss. Note at top center.

Engineered drawings will show all PERMANENT connections, bracing, or fasteners which are part of the truss design.

Slide III-23, Girder truss; three plies bolted together.

Girder trusses must be spiked or bolted together as required by the truss designer on the engineered truss drawing. The truss engineered drawing will specify fastener type and spacing required. At a minimum, 16d nails are required to fasten multiple girder trusses.

Slide III-24, Manufacturer's detail on truss hangers. Note recommended nailing schedule.

Common trusses are typically fastened to girder trusses through the use of truss hangers. The erector should adhere to the recommended nailing schedule for size of nails and nail spacing.

Slide III-25, Common truss hanger in use. Note suspect fastening of the three girder trusses.

Slide III-26, Manufacturer's detail on hurricane anchors. Note recommended nailing schedule.

Model building codes require that in roof construction, rafters and trusses shall be securely fastened to the exterior walls with approved hurricane anchors or clips. Erectors should follow the manufacturer's recommendations for size and number of nails when using hurricane anchors.

Slide III-27, Hurricane anchors installed.

Slide III-28, Truss engineered drawing for scissors truss.

Engineered truss drawings for scissors trusses will require that the erector provide for horizontal movement.

Slide III-29, Special anchor for allowing horizontal movement.

Special clips which provide for horizontal movement should be used for scissors trusses.

Slide III-30, Section of vaulted ceiling truss.

Over interior load bearing walls, trusses may need to be shimmed up in order to form a common ridgeline. Trusses should not be pulled down to rest on any type of partition. The trusses will tend to return to original camber eventually and the drywall will require repair at the joint between the ceiling and wall.

END OF ERECTION

INSTRUCTOR NOTES FOR LESSON IV, BRACING

1. **SUBJECT** Bracing includes general commentary on truss bracing, temporary bracing, and permanent bracing.

2. **OBJECTIVE** Each attendee will become familiar with and understand:

   a. The definition of bracing for trusses.

   b. Bracing as it is applied to the three planes of trusses.

   c. The difference between temporary and permanent bracing.

   d. Useful references for information on truss bracing.

3. **LESSON OUTLINE**

	SUBJECT	TIME REQUIRED
a.	General Bracing	10 mins.
b.	Temporary bracing	35 mins.
c.	Permanent bracing	15 mins.
	Total	60 mins.

SLIDES FOR BRACING. Slides are numbered (IV-#) followed by description. Text slides are in upper case letters.

A. General Bracing

(IV-1) Green, orange, and blue bracing shown on roof truss system. Note that left side top chord bracing is left out for clarity.

(IV-2) Top chord of roof truss system (green).

(IV-3) Web member planes in roof truss system (orange). Top chord is green, bottom chord is blue.

(IV-4) Bottom chord of roof truss system (blue).

(IV-5) Same as IV-1. Note structural triangles formed in top, web member, and bottom chord planes by bracing.

(IV-6) Bracing triangles shown in bottom chord. Typical pattern for bottom, web member, and top chord bracing.

(IV-7) Same as slide IV-1.

(IV-8) Top chord lateral bracing on underside of top chord.

(IV-9) Diagonal bracing in three planes.

(IV-10) X-bracing in web member plane.

(IV-11) Drawing of complex roof system.

B. Temporary Bracing

(IV-12) Green, orange, and blue bracing shown of roof truss system.

(IV-13) Collapsed floor truss system.

(IV-14) Bracing Wood Trusses, BWT-76.

(IV-15) BWT-76 in green sheet form.

(IV-16) Cover of Standard Building Code.

(IV-17) TEXT - "THE BRACING OF METAL PLATE CONNECTED WOOD TRUSSES SHALL COMPLY TO THEIR APPROPRIATE ENGINEERED DESIGN. IN THE ABSENCE OF SPECIFIC BRACING REQUIREMENTS, TRUSSES SHALL BE BRACED IN ACCORDANCE WITH THE TRUSS PLATE INSTITUTE'S BRACING WOOD TRUSSES, BWT-76. TRUSSES SHALL NOT BE CUT OR ALTERED." Standard Building Code, 1708.2.3.

(IV-18) Cover of the 1988 South Florida Building Code.

(IV-19) Truss manufacturer note from truss engineered drawing.

(IV-20) Truss manufacturer note from truss layout drawing.

(IV-21) End truss bracing (black dot, upper right).

(IV-22) End truss bracing (side elevation).

(IV-23) End truss bracing (note in upper right).

(IV-24) King post (scab) face-nailed to end wall.

INSTRUCTOR NOTES FOR LESSON IV, BRACING, CONTINUED

(IV-25) Top chord of roof truss system (green).

(IV-26) Top chord continuous, lateral bracing with diagonal bracing at ends.

(IV-27) Labelled and dimensioned top chord continuous,lateral bracing with diagonal bracing at ends.

(IV-28) Use of short spacer cleats.

(IV-29) Top chord continuous, lateral bracing on underside of top chord.

(IV-30) Top chord continuous, lateral bracing with diagonal bracing for parallel chord, or floor truss system.

(IV-31) Labelled and dimensioned top chord continuous, lateral bracing with diagonal bracing for floor truss system.

(IV-32) Cross bracing (X-bracing) in web member plane.

(IV-33) Drawing depicting ability of trusses without web member cross bracing to move laterally.

(IV-34) Same as IV-31.

(IV-35) Diagonals used to resist overturning in floor truss system.

(IV-36) Strongback used in floor trusses to negate overturning.

(IV-37) Bottom chord of roof truss system (blue).

(IV-38) Continuous, lateral bracing in bottom chord plane.

(IV-39) Diagonal bracing in bottom chord plane.

(IV-40) Continuous, lateral bracing and diagonal bracing in bottom chord plane.

(IV-41) Continuous, lateral bracing and diagonal bracing in bottom chord plane (overhead view).

C. Permanent Bracing

(IV-42) Piggy-back truss engineered drawing requiring permanent continuous, lateral brace.

(IV-43) Top chord of roof truss system.

(IV-44) Workmen applying top chord sheathing (plywood).

(IV-45) Purlins butted end to end.

(IV-46) Drawing illustrating top chord buckling without diagonals installed.

(IV-47) Same drawing as IV-45 with diagonals installed.

(IV-48) Purlins with diagonal bracing installed.

(IV-49) Web member plane permanent continuous, lateral bracing X-brace end anchoring.

(IV-50) Drawing illustrating web member buckling without end anchoring installed.

(IV-51) End anchoring into concrete or masonry wall.

(IV-52) End anchoring by means of diagonal brace.

(IV-53) Typical web member with permanent bracing using continuous, lateral bracing and X-bracing for end anchoring.

(IV-54) Truss engineered drawing of stub truss.

(IV-55) Note from stub truss engineered drawing requiring continuous, lateral brace.

(IV-56) Continuous, lateral bracing with diagonal end anchoring in a multipanel truss (end view).

(IV-57) Truss engineered drawing of fan truss.

(IV-58) Note from fan truss engineered drawing requiring "T" brace stiffener.

(IV-59) Floor truss engineered drawing.

(IV-60) Detail from floor truss engineered drawing of strongback.

(IV-61) Note from floor truss engineered drawing requiring 2X6 strongback.

(IV-62) Strongback in floor truss system.

(IV-63) Bottom chord of roof truss system (blue).

(IV-64) Bottom chord permanent continuous, lateral bracing with end diagonal bracing.

(IV-65) Bottom chord permanent diagonal bracing.

(IV-66) Bottom chord permanent continuous, lateral bracing with end diagonal bracing (end view).

LESSON IV - BRACING

A. General Bracing

Slide IV-1, Green, orange, and blue bracing shown on roof truss system. Note left side top chord bracing omitted for clarity.

The theory of bracing is to apply sufficient support at right angles to the plane of the truss to hold every truss member in the position assumed for it in design. There are two types of bracing. Temporary bracing is used during erection to hold the trusses until permanent bracing, sheathing, and ceilings are in place. Permanent bracing makes the truss component an integral part of the roof and building structure. Both types of bracing includes diagonal, cross, and lateral bracing.

The permanent and temporary bracing of trusses pertain to three planes of reference:

Slide IV-2, Top chord of roof truss system (green).

a. The top chord (or sheathing) plane is the plane formed by adjacent top chords of similar trusses.

Slide IV-3, Web member planes in orange. Top chord is green, bottom chord is blue.

b. The web member plane is the plane formed by like web members in adjacent similar trusses.

Slide IV-4, Bottom chord of roof truss system (blue).

c. The bottom chord (or ceiling) plane is the plane formed by adjacent bottom chords of similar trusses.

Slide IV-5, Same as IV-1.

The key to adequate bracing is a network of 2x4 lumber triangles within each of the three planes of a truss design. These bracing triangles provide the structural rigidity to the truss system just as the truss design itself uses triangles to support its loads. Diaphragms, as in sheathing material, may serve as a substitute for a network of 2x4 lumber triangles for a given plane.

Slide IV-6, Bracing triangles shown in bottom chord.

Typical pattern bottom, web member, and top chord bracing.

Slide IV-7, Same as slide IV-1.

All permanent and temporary bracing members should be at least 2x4 and nailed with two 16d nails at each cross member.

Slide IV-8, Top chord lateral bracing on underside of top chord.

Both permanent and temporary continuous lateral bracing should be lapped over two trusses. The bracing may be applied to the top or bottom side of a particular plane.

Slide IV-9, Diagonal bracing in three planes.

Diagonal bracing in all planes should be placed at approximately 45 degree angles and nailed to at least three trusses.

Slide IV-10, X-bracing in web member plane.

Note that an X-brace is made of two diagonal braces.

Slide IV-11, Drawing of complex roof system.

Complex roof systems may incorporate several types of trusses. Where a change of levels, an offset in framing plan alignment, or a change of truss configuration occurs, separate sets of bracing must be installed for each group of trusses.

B. Temporary Bracing

Slide IV-12, Green, orange, and blue bracing shown of roof truss system.

Temporary bracing is the bracing which the erector must apply to hold the trusses plumb, in alignment and in a safe condition until the permanent bracing, decking, and/or sheathing can be installed.

Slide IV-13, Collapsed floor truss system.

John E. Meeks, consulting engineer and nationally recognized expert on wood truss accidents estimates

80% of the 150 truss accidents that he has investigated over 15 years can be attributed to insufficient temporary bracing. The complete responsibility for applying temporary bracing belongs to the erector.

Slide IV-14, Bracing Wood Trusses, BWT-76.

Since 1976, the Truss Plate Institute has been publishing Bracing Wood Trusses, BWT-76 in an effort to educate truss erectors inthe proper technique for erecting and bracing trusses.

Slide IV-15, BWT-76 in green sheet form.

Trusses are normally delivered with a copy of BWT-76 printed in its entirety on a single green sheet. Many truss manufacturers' also include the green sheet with ordering and shipping documents.

Slide IV-16, Cover of Standard Building Code.

Of the major building codes, only the Standard Building Code (SBC) references specific use of the guidelines of BWT-76.

Slide IV-17, TEXT - "THE BRACING OF METAL PLATE CONNECTED WOOD TRUSSES SHALL COMPLY TO THEIR APPROPRIATE ENGINEERED DESIGN. IN THE ABSENCE OF SPECIFIC BRACING REQUIREMENTS, TRUSSES SHALL BE BRACED IN ACCORDANCE WITH THE TRUSS PLATE INSTITUTE'S BRACING WOOD TRUSSES, BWT-76. TRUSSES SHALL NOT BE CUT OR ALTERED". Standard Building Code, 1708.2.3

Slide IV-18, Cover of 1988 South Florida Building Code.

Designers, manufacturers, and erectors should reference all local building codes for any additional requirements regarding the use of wood trusses. The 1988 South Florida Building Code, in addition to referencing use of the guidlines of BWT-76 for erecting trusses, further stipulates design, materials, and fabricator requirements and specifications for wood trusses.

Slide IV-19, Truss manufacturer note from truss engineered drawing.

This note attached to a truss engineered drawing directs the erector's attention to BWT-76 as a reference for temporary bracing.

Slide IV-20, Truss manufacturer note from truss layout drawing.

Truss layout plans refer to the erecting contractor's use of the guidelines of BWT-76 in the general notes section.

Again, the placement and amount of temporary bracing used is exclusively the responsibility of the builder or erection contractor. Temporary bracing is not shown on engineered truss drawings or the designer's framing plans. The erection contractor should familiarize himself with all required permanent bracing before erecting trusses. This permanent bracing is shown on truss engineered drawings and framing plans. Whenever possible, temporary bracing should be installed to coincide with the permanent bracing requirements in order to save time and materials.

Temporary bracing can be subdivided into the following four categories:

1. End truss bracing.
2. Top chord bracing.
3. Web member bracing.
4. Bottom chord bracing.

1. End truss temporary bracing.

Slide IV-21, End truss bracing (black dot upper right).

It is most important to brace the first truss at the end of the building securely. All other trusses are tied to the first truss, thus the bracing system depends to a great extent on how well the end truss is braced.

The preferred bracing method for the first truss is to attach vertical and diagonal braces from the ground to the top chord. The diagonal braces must be anchored to stakes driven into the ground and securely anchored.

Slide IV-22, End truss bracing (side elevation).

Slide IV-22, End truss bracing (side elevation).

It is acceptable to scab 2x members together in order to attain the required lengths needed for the vertical and diagonal braces. The greater the length of the anchored to ground 2x member, the greater the need to brace the bracing. It is mandatory that the diagonal braces from the top chord to the ground be braced against buckling in all directions.

Slide IV-23, End truss bracing (note in upper right).

Subsequent trusses are now set connecting each truss with continuous lateral bracing on the top chord. All rows of top chord continuous lateral bracing should be located directly in line with ground braces. Otherwise, the top chord of the first truss can bend sideways and allow the trusses to shift. With even the slightest shift of the trusses, the weight of the trusses would then be added to any wind force or construction load on the truss system, and a total truss collapse could occur.

Slide IV-24, King post (scab) face-nailed to end wall.

It is not recommended to nail <u>only</u> scabs to the end of the building to brace the first truss. This technique uses a nailing pattern which loads nails in withdrawal as opposed to lateral loading. These nails may easily pull out of the wall or through the post if subjected to shifting trusses. The scabs used in this slide could easily break off and cause a total collapse.

The pre-assembly of groups of trusses on the ground into structurally braced units which are then lifted into place as assemblies is an acceptable alternate to the above method of lifting trusses one-at-a-time into position.

After the end truss is securely anchored, subsequent trusses may be erected. It is important to note that top chord, web member, and bottom chord erection bracing should occur simultaneously as these next trusses are set.

2. Top chord temporary bracing.

Slide IV-25, Top chord of roof truss system (green).

The erection bracing applied to the top chord plane is critical to the erection contractor because the truss top chords are highly susceptible to lateral buckling before they are sheathed.

Slide IV-26, Top chord continuous, lateral bracing with diagonal bracing at ends.

Continuous lateral bracing should be installed in line with ground bracing and within 6 inches of the ridge line and at approximately 8 to 10 feet intervals between the ridge line of sloped trusses and the truss heel.

Slide IV-27, Labelled and dimensioned top chord continuous, lateral bracing with diagonal bracing at ends.

Diagonals, located between the lateral bracing and set at approximately 45 degree angles, form the triangles required for stability in the plane of the top chord. Note from the slide that temporary bracing lumber should be nailed with two double headed 16d nails at every intersection with the braced member. Diagonal temporary bracing should cross at least 3 trusses and also be nailed with double-headed 16d nails to each truss.

Slide IV-28, Use of short spacer cleats.

Temporary bracing should be <u>not less than 2x4 dimension lumber</u> and should be as long as practical for handling. The use of short spacer pieces of lumber between adjacent trusses is <u>not recommended</u>, unless used temporarily in preparation for immediate installation of longer continuous bracing (minimum 8-foot length).

Slide IV-29, Top chord continuous,lateral bracing on underside of top chord.

If possible, the continuous lateral bracing for the top chord should be placed on the underside of the top chord so that it will not have to be removed as the roof sheathing is applied.

Slide IV-30, Top chord continuous, lateral bracing with

diagonal bracing for parallel chord, or floor truss system.

It is equally important for the erection contractor to install bracing in the plane of the top chord for flat roof or floor trusses. This same bracing pattern is recommended for all flat trusses.

Slide IV-31, Labelled and dimensioned top chord continuous, lateral bracing with diagonal bracing for floor truss system.

3. Web member temporary bracing.

Slide IV-32, Cross bracing (X-bracing) in web member plane.

To prevent lateral movement of the top chord and possible dominoeing of trusses, cross bracing should be installed in the plane of the webs as the trusses are erected.

Slide IV-33, Drawing depicting ability of trusses without web member cross bracing to move laterally.

Without diagonal bracing in the web member plane, the continuous lateral bracing of the top chord will maintain truss on center spacing, but may still move laterally as a plane and collapse.

Slide IV-34, Same as IV-31.

If permanent diagonal web bracing is required, it should be installed as the trusses are set. That bracing will suffice as temporary web bracing for truss installation. If the building designer's architectural plans do not specify permanent web diagonal bracing (required as part of the building designer's roof framing plan), temporary web bracing should be installed as trusses are set.

The spacing between two sets of diagonal bracing should not exceed 20 feet, or twice the horizontal run of the diagonal bracing.

Slide IV-35, Diagonals used to resist overturning in floor truss system.

Floor truss systems also require erection web member plane bracing, but temporary diagonal bracing is often impractical for floor trusses.

Slide IV-36, Strongback used in floor truss system to negate overturning.

Rows of 2x6 strongbacks are often required on truss drawings as part of the floor truss permanent bracing. This bracing may suffice as erection bracing if it is placed as the trusses are set.

4. Bottom chord plane temporary bracing.

Slide IV-37, Bottom chord of roof truss system (blue).

In order to hold proper spacing on the bottom chord, temporary bracing is recommended in the plane of the bottom chord.

Slide IV-38, Continuous, lateral bracing in bottom chord

plane.

Continuous lateral bracing at no greater than 8 to 10 feet on center along the truss length is recommended for the full length of the building. This bracing should be nailed to the top of the bottom chord.

Slide IV-39, Diagonal bracing in bottom chord plane.

Diagonal bracing between laterals placed at approximately 45 degrees is recommended for stability of the bottom chord.

Slide IV-40, Continuous, lateral bracing and diagonal bracing in bottom chord plane.

The temporary diagonal bottom chord bracing should be repeated at 20 feet intervals.

Slide IV-41, Continuous, lateral bracing and diagonal bracing in bottom chord plane (overhead view).

If permanent diagonal bottom chord bracing (required as part of the building designer's roof framing plan) is installed as trusses are set, that bracing will suffice as temporary bottom chord bracing for truss installation.

C. Permanent Bracing

Slide (IV-42, Piggy-back truss engineered drawing requiring permanent continuous, lateral brace.

Permanent bracing makes the truss component an integral part of the roof and building structure. Both during building design and truss design phases, individual truss members are examined for structural analysis. Accordingly, the need for permanent bracing may originate with either the building designer or the truss designer (manufacturer).

Most truss designs have inherent continuous top and bottom chord lateral support from plywood sheathing and ceilings. The most frequent requirement for permanent bracing is in the web members of the truss in order to reduce the buckling length of individual web members. Permanent bracing to reduce the buckling length of web members is determined by the truss manufacturer and it will only be specified on the truss engineered drawing.

Web member bracing to reduce buckling length requires end anchoring in order to prevent all connected web members from bowing together. <u>The end anchoring method must be specified by the building designer</u>.

The building designer is also responsible for indicating any additional permanent bracing to resist wind, portal, and seismic forces; or any other loads imposed on the building. Permanent bracing to counter these forces will typically be diagonal braces placed in the bottom chord plane.

Permanent bracing will be examined for the top, web member, and bottom chord planes individually.

1. Top chord plane permanent bracing.

Slide IV-43), Top chord of roof truss system.

Top chord permanent bracing is designed to resist lateral movement of the top chord.

Slide IV-44), Workmen applying top chord sheathing (plywood).

If rigid roof sheathing is properly applied with staggered joints and adequate nailing, a continuous diaphragm action is developed and additional permanent bracing in the top chord plane is generally not required.

Slide IV-45, Purlins butted end to end.

Top chord diagonal bracing is usually required for fiberglass or metal roof systems using purlins. The purlins should be installed on the top of the top chord.

Slide IV-46, Drawing illustrating top chord buckling without diagonals installed.

The sheathing used in this case is not strong enough to create a diaphragm for the top chord. The purlins will maintain the truss spacing but, without diagonal bracing, the trusses may buckle due to wind forces or other loads.

Slide IV-47, Same drawing as IV-45 with diagonals installed.

Diagonal braces placed on the underside of the trusses will form the triangulation required to stabilize any movement in the top chord.

Slide IV-48, Purlins with diagonal bracing installed.

The diagonal bracing attached to the underside of the top chord creates a rigidly braced group of trusses at both ends of the roof system. The purlins connect the interior trusses to the end truss groups so that the roof system is stable.

2. Web member plane permanent bracing.

Slide IV-49, Web member plane permanent continuous, lateral bracing with X-brace end anchoring.

Web member permanent bracing is designed to shorten the buckling length of a web member, distribute unequal loading to adjacent trusses, and to spread lateral forces to diaphragms or shear walls. Permanent bracing installed in the web member plane is used frequently in truss design and is the most common permanent bracing that the erecting contractor will need to install.

Slide IV-50, Drawing illustrating web member buckling without end anchoring installed.

Continuous, lateral bracing installed properly in the web member plane is not enough to keep the connected web members from bowing together in response to loading. Without an end anchoring method the continuous, lateral bracing will merely maintain the on center spacing while allowing the web members to deflect.

Slide IV-51, End anchoring into concrete or masonry wall.

One method of providing end anchoring is to embed a connection at one end of the continuous, lateral brace into a substantial, as in concrete or masonry, wall.

Slide IV-52, End anchoring by means of diagonal brace.

The more common method for providing end anchoring for continuous, lateral bracing is to install diagonal bracing at the ends of the lateral brace; repeating the diagonal brace approximately every 20 feet.

Slide IV-53, Typical web member permanent bracing using continuous, lateral bracing and X-bracing for end anchoring.

Note that X-bracing uses two diagonal braces in anchoring the ends of the continuous, lateral brace. The result is a lateral brace more resistent to buckling and added stability to the three trusses connected by the X-bracing.

Slide IV-54, Truss engineered drawing of stub truss.

Permanent bracing to reduce the buckling length of web members will only be shown on the truss engineered drawing.

Slide IV-55, Note from stub truss engineered drawing requiring continuous, lateral brace.

The engineered drawing will only note the need for bracing the specific web members and will not specify any means for end anchoring. The design for end anchoring is the responsibility on the building designer and must be shown of the building designer's plans.

Slide IV-56, Continuous, lateral bracing with diagonal end anchoring in a multipanel truss (end view).

Note that the continuous, lateral bracing and the end anchoring diagonal bracing are on opposite sides of the web member being braced. Cross bracing will require blocks on the ends of the outer diagonal. Notching of the diagonals at their intersection is not recommended.

Slide IV-57, Truss engineered drawing of fan truss.

In some roof system designs, continuous, lateral bracing may be impractical and permanent web stiffeners may be used in lieu of continuous, lateral bracing with end anchorage. Stiffeners are practical for use where a change of levels or offset occurs due to valleys, or where dissimilar trusses are used in a roof system.

Slide IV-58, Note from fan truss engineered drawing requiring "T" brace stiffener.

This method reduces the buckling length of individual web members by stiffening the web member in its smaller dimension.

Slide IV-59, Floor truss engineered drawing.

Slide IV-60, Detail from floor truss engineered drawing of strongback.

In parallel chord trusses, cross-bracing (bridging) is important for proper load distribution between adjacent trusses during the life of the building and should be specified by the building designer as permanent bridging. The truss engineered drawing may direct the erector to install a strongback (typically 2X6) as permanent web bracing where cross-bracing would be impractical.

Slide IV-61, Note from floor truss engineered drawing requiring 2X6 strongback.

Slide IV-62, Strongback in floor truss system.

3. Bottom chord permanent bracing.

Slide IV-63, Bottom chord of roof truss system (blue).

Slide IV-64, Bottom chord permanent continuous, lateral bracing with end diagonal bracing.

The purpose of bottom chord permanent bracing is to transfer lateral forces due to wind or seismic loads into side walls, shear walls or other resisting structural elements. Permanent truss bracing and connection details due to wind or seismic loads, or due to other design factors, must be indicated by the building designer on the building designer's framing plan as part of the design drawings.

Slide IV-65, Bottom chord permanent diagonal bracing.

Generally, ceiling sheathing forms a horizontal diaphragm which provides sufficient rigidity to the bottom chord to counter wracking forces. It is recommended, however, that one complete bay of permanent diagonal bracing be installed at each end of any building. For longer structures, these diagonals should be repeated at specified intervals no greater than 20 feet.

Slide IV-66, Bottom chord permanent continuous, lateral bracing with end diagonal bracing (end view).

END OF BRACING

INSTRUCTOR NOTES FOR LESSON V, CONCLUSION

1. SUBJECT The conclusion includes slides of actual truss accidents and incorrect methods of truss erection and bracing. Last in this lesson are recommendations for the building designer, truss manufacturer, truss erector, and building inspector.

2. OBJECTIVE Each attendee will become familiar with and understand:

   a. Through the review of the mistakes leading to truss collapses, the correct procedures for erecting and bracing wood trusses.

   b. Through the recommendations of the report, the problem areas in truss design, manufacturing, erection, and bracing which need to be addressed and satisfactorily resolved.

3. LESSON OUTLINE

	SUBJECT	TIME REQUIRED
a.	Accident Review	20 mins.
b.	Recommendations	20 mins.
c.	Questions & Answers	20 mins.
	Total	60 mins.

SLIDES FOR CONCLUSION. Slides are numbered (V-#) followed by description. Text slides are in upper case letters.

A. Accident Review

1. Residential Collapse

(V-1) Fallen scissors trusses.

(V-2) Close-up of spacer stick.

(V-3) Close-up of short cleat ("killer cleat").

(V-4) Overview of collapse. Note "killer cleats" on in place trusses at rear.

2. Small Commercial Building

(V-5) Fallen triple Howe trusses. Note single nails protruding from 1X4 bracing member.

(V-6) Lateral 1X4 web braces can be seen in wreckage.

3. Large Commercial Building

(V-7) Fallen parallel chord trusses. Note stacks of plywood and four rows of short cleats.

(V-8) Close-up of plywood and snapped short cleats.

(V-9) Side walls pulled in due to long span of trusses.

(V-10) Incorrect diagonal bracing averted total collapse.

4. Large Commercial Building

(V-11) Fallen piggy-back trusses. Note bent connector plates caused by incorrect sling use at lower screen.

(V-12) Short 1X3 killer cleats. Note split end of cleat.

(V-13) Broken short cleats among wreckage.

(V-14) Unauthorized field repair of truss.

(V-15) Close-up of bent connector plates.

5. Large Commercial Building

(V-16) Fallen triple Howe trusses.

(V-17) Lateral 1X3 spacer cleats used on top chord.

(V-18) Erect trusses exhibiting strain from fallen section of trusses.

6. Large Commercial Building

(V-19) Fallen piggy-back trusses.

(V-20) Spacer cleats with single 16d nail.

Miscellaneous Slides

(V-21) Excessive bending in hoisted parallel chord truss.

(V-22) Trusses stored on top of framed wall.

(V-23) Extremely bowed 2X10 top chord member.

(V-24) King post pulled free from end wall.

(V-25) End truss bracing stakes pulled out of ground.

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Recommendations

(V-28) Recommendations for building designer.

(V-29) Recommendations for truss manufacturer.

(V-30) Recommendations for truss manufacturer, continued.

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(V-32) Recommendations for truss erection contractor, continued.

(V-33) **Recommendations for building officials and inspectors.**

LESSON V. CONCLUSION

A. Accident Review

The previous three lessons have reviewed the correct methods of handling and erecting roof trusses. What follows are slides from several truss collapses and some unrelated examples of improper truss handling, erecting, and bracing. The single greatest contributor to wood truss accidents, inadequate erection bracing, is well represented in these slides.

1. Residential Collapse

Slide V-1, **Fallen scissors trusses.**

These slides are from a residence which was designed to use scissors trusses. Recall that scissors trusses are inherently unstable due to their high center of gravity.

Slide V-2, **Close-up of spacer stick.**

Spacer sticks are used as a template to set trusses according to their on center spacing. Too often they are left in place and relied upon as erection bracing.

Slide V-3, **Close-up of short cleat ("killer cleat").**

Three rows of 1x3 short cleats attached with a single 8d nail were used for lateral bracing. Some of these were cut from plywood. Short cleats like these and spacer cleats used to suffice as erection bracing can be nicknamed "killer cleats" as they are instrumental in causing truss collapses. These short cleats split at the ends when proper nailing (2-16d) is used. To avoid this, erectors use single or smaller nails which nets the same result - insufficient holding strength in the lateral bracing.

Slide V-4, Overview of collapse. Note killer cleats at trusses in rear.

In this house, no diagonal or bottom chord bracing was used at all for temporary bracing.

2. Small Commercial Building

Slide V-5, Fallen triple Howe trusses. Note single nails protruding from 1X4 bracing.

In this collapse, the contractor installed 46' span triple howe trusses. No top chord bracing was used during erection. Instead, he applied a continuous 1x4 lateral brace at the top of two web members with a single 16d nail.

Slide V-6, Lateral 1X4 web braces can be seen in wreckage.

There was no triangulation in the planes of the trusses and a 'dominoing' collapse followed.

3. Large Commercial Building

Slide V-7, Fallen parallel chord trusses. Note stacks of plywood and four rows of short cleats.

Partial failure of a large commercial building. Trusses had a 55 foot clear span with 6 foot overhangs on each end. The erector used short 1x6 spacer cleats in four rows across the top chord.

Slide V-8, Close-up of plywood and snapped short cleats.

The cleats were attached with two 8d nails on each end. There was no bracing at the ends.

Slide V-9, Side walls pulled in due to long span of trusses.

Heavy loads of plywood sheathing applied concentrated loads on the trusses and the partial collapse occurred.

Slide V-10, Incorrect diagonal bracing averted total collapse.

The section of trusses that did not fall were saved by incorrectly placed (not positioned at optimal 45 degrees) diagonal bracing. This bracing is still incomplete with no bottom chord lateral bracing. The triangulation for adequate bracing is absent.

4. Large Commercial Building

Slide V-11, Fallen piggy-back trusses. Note bent connector plates caused by incorrect sling use at lower screen.

These trusses had a clear span of 60 feet with a 4 foot overhang on each end. As the top chord sloped up and out of reach of the installers, the contractor installed the remainder of the cleats to the web members.

Slide V-12, Short 1X3 killer cleats. Note split end of cleat.

The erectors nailed 1x3 spacer cleats with two 6d nails to the top chord, starting near the heel of the trusses.

Slide V-13, Broken short cleats among wreckage.

The cleats on the webs were about 4 feet down from the top chord. This pattern resulted in no top chord bracing for over two-thirds the length of the top chord.

Slide V-14, Unauthorized field repair of truss.

Additionally, several trusses had been broken and repaired with plywood without consulting the truss manufacturer.

Slide V-15, Close-up of bent connector plates.

These bent connector plates are irrefutable evidence of incorrect erection techniques.

5. Large Commercial Building

Slide V-16, Fallen triple Howe trusses.

A partial collapse of triple Howe trusses with a clear span of about 65 feet. Five rows of 1x3 spacer cleats with two 8d nails were used on the top chord.

Slide V-17, Lateral 1X3 spacer cleats used on top chord.

Some web member diagonals were evident, but no bottom chord lateral bracing was used in the collapsed section - the required triangulation for adequate bracing was not complete.

Slide V-18, Erect trusses exhibiting strain from fallen section of trusses.

One diagonal brace on the top chord prevented a complete collapse. There is obvious lateral strain on the remaining top chord members.

6. Large Commercial Building

Slide V-19, Fallen piggy-back trusses.

This large commercial building had a 79 foot clear roof span. The trusses were built in two pieces which were supported at the center on scaffold while vertical field splices were installed. Flat portion of the roof was to receive another section of trusses (piggy-backs) set directly above the supporting trusses. To accommodate the piggy-backs, 2x4 lateral bracing at 2 feet on center was specified on the truss engineered drawings for the flat top portion of the trusses. The scaffold was removed before all of the 2x4's were installed.

Slide V-20, Short cleats with single 16d nail.

Erection bracing consisted of short 2x4 cleats and light gauge metal spacers (unacceptable for bracing). These trusses sagged over a period of several days and finally collapsed upon the breaking of a single member.

All of the above accidents could have been prevented had the erection contractor used the erection and bracing techniques spelled out in the Truss Plate Institute's Bracing Wood Trusses: Commentary and Recommendations - BWT-76. The most important piece of information to be gained from this lesson is that BWT-76 is the best, one-source publication to aid field personnel with the erection of wood trusses.

Miscellaneous Slides

What follows are some examples of the wrong way to install wood trusses.

Slide V-21, Excessive bending in hoisted parallel chord truss.

As this contractor was tidying up the wreckage of a truss collapse, he demonstrated the buckling effect that occurs to trusses when incorrect lifting techniques are used. Had this method of lifting been used to erect the trusses, it surely would have placed great strain on the connector plates, and weakened the joints of the truss.

Slide V-22, Trusses stored on top of framed wall.

This truss was left on top of this wall for a stormy weekend. It could have easily been blown off and damaged the truss and anything else below.

Slide V-23, Extremely bowed 2X10 top chord member.

A contractor did not understand the need to sheathe the top chord of a truss which was to be covered by a false dormer. He did not realize that the omitted sheathing was needed as permanent bracing for the top chord of the truss to accept the load of the false dormer.

Slide V-24, King post pulled free from end wall.

This kingpost was face-nailed to a cinderblock wall. The nails, which were loaded in withdrawal, held in this case, but the force on the end truss was sufficient to push the kingpost out - pulling the nails through the kingpost. The erector was lucky to have avoided a truss collapse.

Slide V-25, End truss bracing stakes pulled out of ground.

Another end truss bracing incident, these stakes which were used for end truss bracing were driven about 6 inches into the ground - not enough to resist the collective lateral force of the connected trusses.

Slide V-26, Permanent 1X4 web member lateral brace with knot area.

This 1X4 permanent lateral brace has less than an inch of lumber available to restrain buckling of the web compression members.

Slide V-27, Masonry placed around truss.

This masonry technique certainly violates the building code and hopefully this chimney flue will not get too hot, but it illustrates that the mason did know one important rule for the field - DO NOT CUT TRUSSES!

B. Recommendations

What follows are the recommendations of the authors of this training program for designers, fabricators, erectors, and building officials who all play a part in the use of wood trusses in construction. The intent is not to increase the liability of any element in the design, manufacturing, erecting, and inspecting sequence. It is instead to focus on and attempt to rectify problem areas not clearly defined. The recommendations are listed in the order of building designer, manufacturer, erector, and inspector.

RECOMMENDATIONS FOR THE BUILDING DESIGNER.

Many architects have relied too heavily on the truss manufacturer to require permanent bracing whereas only the building designer has the complete knowledge of a structure's function and placement. Wind bracing, portal bracing, seismic bracing, diaphragms, shear walls, and other load transfer elements and their connections to wood trusses can only be considered by the building designer. Structural bracing to counter these stresses are separate from permanent bracing to reduce buckling truss member lengths, and should be shown on the building designer's framing plan as part of the design drawings.

The truss manufacturer's truss design software can only specify permanent braces to reduce buckling lengths. Since the exact internal configuration of trusses (web members) is seldom specified by architects, the truss manufacturer can rightfully experiment with several truss configurations for economy of design. Because the truss manufacturer will determine this web configuration, he needs to direct the placement of lateral bracing to reduce buckling lengths of the web members for his truss design.

Should permanent lateral bracing be required by the truss fabricator, the building designer must specify the placement of the end anchoring method. The opportunity for omission of the end anchoring method is very real. Improved communication between the building designer and the truss manufacturer is the only solution to assuring that the two parties are working together and not against each other.

Slide V-28, Recommendations for building designer. TEXT - THE ARCHITECT OR BUILDING DESIGNER SHOULD ASSUME ALL RESPONSIBILITY FOR THE DESIGN OF ALL PERMANENT BRACING FOR HIS BUILDING. HE SHOULD WORK CLOSELY WITH THE TRUSS FABRICATOR SO AS TO BE AWARE OF THE NEED FOR ANY PERMANENT WEB MEMBER BRACING DUE TO TRUSS DESIGN. THE ARCHITECT OR BUILDING DESIGNER SHOULD DETERMINE THE SIZE, LOCATION, AND METHOD OF CONNECTIONS FOR PERMANENT BRACING; AND THE METHOD OF END ANCHORING IN THE CASE OF PERMANENTLY INSTALLED LATERAL BRACING.

RECOMMENDATIONS FOR THE TRUSS FABRICATOR

The truss manufacturer's role is to build components to the building designer's specifications, maintain quality control on his premises, and to deliver trusses in good condition to the job site.

Since the truss fabricator provides the trusses, the erection contractor looks to him for erection bracing information. The manufacturer should aggressively insure that every load of trusses leaving his yard has a copy of BWT-76 attached in the form of a green sheet.

Truss manufacturers should stop specifying 1X material for use as permanent web stiffening bracing. Though failure of 1X4's as permanent bracing is not a common occurrence, the use of 1X material as any kind of truss bracing should be eliminated. Field personnel may inadvertently take the cue from the example of manufacturers and believe that 1X lumber is sufficient for erection bracing needs.

All truss bracing should be a minimum of 2X material as 2X is stress-tested lumber and 1X is not. Knots and wanes in 1X bracing material can result in less than a cross-sectional inch of bracing material.

The fabricator should request that the Truss Plate Institute print an easier to read green sheet with three dimensional drawings indicating recommended erection bracing methods. A revised BWT-76 could emulate The Wood Truss Council of America's poster version of BWT-76 which is larger, with clearer drawings, and is easier to read.

Slide V-29, Recommendations for truss manufacturer.

TEXT -

1. INSURE THAT EVERY SET OF TRUSSES LEAVING THE YARD HAS

A GREEN SHEET ATTACHED.

2. USE 2X4 LUMBER AS A MINIMUM FOR ALL PERMANENT LATERAL BRACING ON TRUSS ENGINEERED DRAWINGS.

3. PAINT SIMILAR ENDS OF TRUSSES TO SHOW ERECTION ORIENTATION. THIS IS USEFUL IN ALIGNING SYMMETRICAL TRUSSES AND CRITICAL IN ASYMMETRICAL TRUSSES.

Slide V-30, Recommendations for truss manufacturer, continued TEXT -

4. ATTACH THE TRUSS PLATE INSTITUTE'S SAFETY AND SPECIALTY LABELS TO TRUSSES. THESE FLORESCENT RED AND GREEN TAGS CAUTION AGAINST CUTTING TRUSSES OR ALTERING TRUSSES. THEY ALSO INDICATE BEARING LOCATIONS, ORIENTATION, PERMANENT LATERAL BRACING, FIELD SPLICES, ETC.

5. REQUEST OF THE TPI THAT THE GREEN SHEET BE REVISED. A REVISED BWT-76 SHOULD BE STREAMLINED TO REFER ONLY TO ERECTION BRACING TECHNIQUES. IT SHOULD BE IN LARGER PRINT AND WITH 3-D DRAWINGS. A SEPARATE SHEET (DIFFERENT COLOR) SHOULD BE CREATED TO CONTAIN HIGHLIGHTS OF THE TPI'S HANDLING AND ERECTING WOOD TRUSSES, HET-80.

6. INSURE THAT THEIR DRIVERS ARE TRAINED TO UNLOAD TRUSSES SAFELY AND WITHOUT DAMAGING THE TRUSS MEMBERS OR PLATE JOINTS.

RECOMMENDATIONS FOR THE TRUSS ERECTION CONTRACTOR

The correct temporary bracing procedures in the field will reduce the current number of truss related accidents by up to 80 percent. Temporary bracing is solely the responsibility of the erection contractor. Strict compliance with the recommendations of bwt-76 will virtually eliminate truss accidents. The pervasive construction site philosophy, "this is how we've always done it", in resisting what is perceived as new techniques are obstacles to progress. Industry and state truss erection certification programs have been discussed as a remedy to truss collapses and may well be an inevitable solution.

Slide V-31, Recommendations for truss erection contractor.

TEXT -

1. **INSTALL ERECTION BRACING IN ACCORDANCE WITH BWT-76. ALL OF THE INFORMATION A TRUSS ERECTOR NEEDS FOR TEMPORARY BRACING IS IN THIS PUBLICATION. SPECIFIC CRITICAL ITEMS IN BWT-76 ARE:**

    A. **BRACE TRUSSES AS THEY ARE ERECTED BY FORMING 2X4 TRIANGLES WITHIN EACH OF THE THREE PLANES IN A TRUSS SYSTEM. ATTACH BRACING ONLY WITH 2-16D DOUBLE-HEADED NAILS AT EACH CROSSING TRUSS.**

    B. **DO NOT USE SHORT CLEATS OR SPACER PIECES OF LUMBER BETWEEN ADJACENT TRUSSES UNLESS THEY ARE REPLACED IMMEDIATELY BY MINIMUM 8 FOOT 2X4 LUMBER.**

2. **REVIEW THE CONTENTS OF HET-80 BEFORE TRUSSES ARRIVE ON**

THE JOB.

Slide V-32, Recommendations for truss erection contractor, continued. TEXT -

3. REVIEW ALL ENGINEERED DRAWINGS, TRUSS LAYOUT PLANS, AND BWT-76 BEFORE ERECTING THE FIRST TRUSS.
4. DO NOT STACK FULL BUNDLES OF PLYWOOD SHEATHING ON TRUSSES. A MAXIMUM OF 8 SHEETS CAN BE SAFELY STACKED ABOVE SUPPORTING WALLS.
5. DO NOT ATTEMPT TO FIELD REPAIR TRUSSES WITHOUT CONSULTING THE TRUSS FABRICATOR.

RECOMMENDATIONS FOR BUILDING OFFICIALS AND INSPECTORS

The 1988 Standard Building Code requires that, in the absence of any other specific bracing requirements, trusses shall be braced in accordance with the Truss Plate Institute's BWT-76. Building Officials must be familiar with BWT-76 and enforce compliance within their jurisdictions.

The Building Official, as protector of the public's life, health, and welfare should have a greater degree of knowledge of the design and fabrication of wood trusses. Inspectors should be familiar with the Truss Plate Institute publication, Quality Standard for Metal Plate Connected Wood Trusses, or QST-88. This publication includes information on connector plate sizes, plate centering, tolerances for truss design, and lumber quality minimums.

Slide V-33, Recommendations for building officials and inspectors. TEXT -

1. **INSPECTORS SHOULD HAVE ALL TRUSS ENGINEERED DRAWINGS AND LAYOUT PLANS IN HAND FOR TRUSS INSPECTION.**
2. **BUILDING OFFICIALS SHOULD ENFORCE THE RECOMMENDATIONS OF BWT-76 FOR ERECTION BRACING.**
3. **IN ORDER TO COMPETENTLY INSPECT WOOD TRUSSES, INSPECTORS MUST BE FAMILIAR WITH THE TOLERANCES FOR WOOD TRUSSES CONTAINED IN THE TRUSS PLATE INSTITUTE'S METAL PLATE CONNECTED WOOD TRUSSES, QST-88.**

C. Questions and Answers.

The instructor should entertain questions at this time.

END OF TRAINING PROGRAM

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