Existing Timber Structures

Repair and Upgrades to Bowstring Trusses

CL# WA – WESTEWS255JB | OR – 25152 | CA - 395054

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SPEAKER BIO

WHO IS THIS GUY?
Brentley Matthias, P.E.
Current president of Western Wood Structures, Inc.
Working at WWS for 26 years.
A licensed engineer for 22 years.
Real life experience on my grandpa's farm where we could fix anything with duct tape and bailing wire.

EDUCATION
Graduated from Oregon State University with an Honors Bachelor of Science in Civil Engineering in 2000.
After that it was the school of hard knocks at Western Wood Structures.

EXPERIENCE
Inspected existing timber structures all over the United States and Canada. Throughout this region, hundreds of roof trusses and thousands of roof beams have been evaluated. Expert implementation of tested and engineered repairs and upgrades.

BUSINESS
Western Wood Structures, Inc. has 57 years of experience with timber structures old and new. One part of the business focuses on existing timber structures. Leading with expertise in the evaluation, design, and installation of repairs and code upgrades of existing timber structures is unique in the construction community. No other company offers turn-key service including in-house design, material procurement, fabrication and installation of these systems.

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Purpose of Presentation

What we will cover

- What is a bowstring truss?
- Brief history of bowstring trusses.
- Common bowstring truss types.
- Failure mechanisms for each type.
- Evaluation of trusses.
- Repair and upgrade approaches.
- Specific project examples.
- Key takeaways
- Questions/discussion

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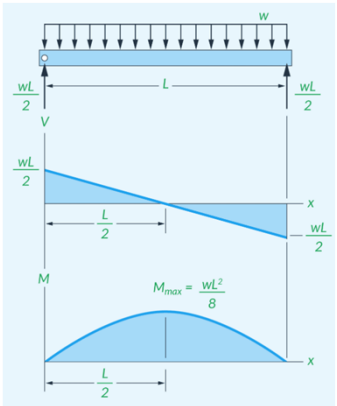
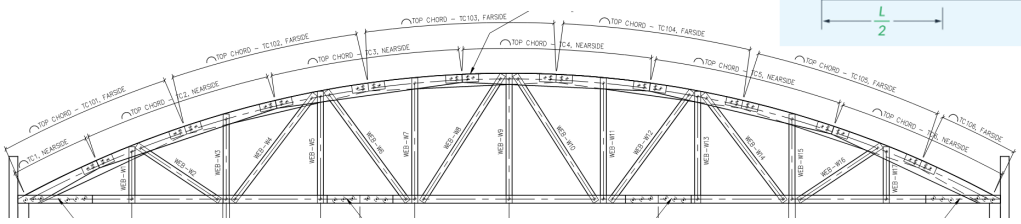
What is a Bowstring Truss?

What is a bowstring truss?

- Based on its name we can guess its shape.
  - Curved roof shape to buildings.





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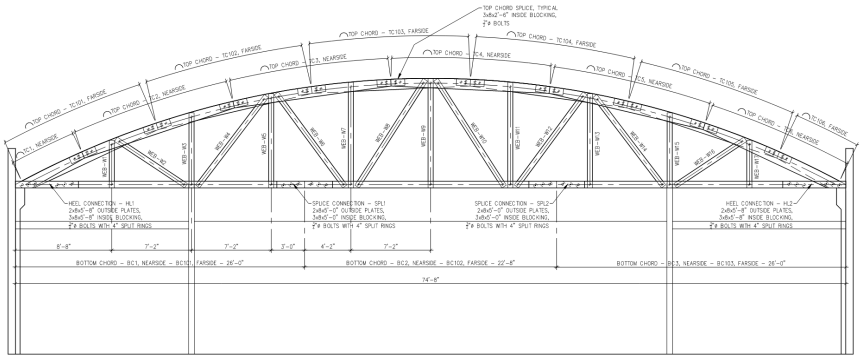
What is a Bowstring Truss?

What is a bowstring truss?

- What makes up a truss? Name it components.



1 TRUSS ELEVATION - EXISTING
VIEWED FROM NORTH LOOKING SOUTH

ALL TOP CHORD PIECES ARE 3x12 EXCEPT FOR MARKS TC1, TC101, TC6, TC106 WHICH ARE 3x14.
ALL WEBS ARE 3x6 EXCEPT FOR MARKS W8, AND W10 WHICH ARE 4x6
ALL BOTTOM CHORD PIECES ARE 3x8
HEEL AND SPLICES ARE CALLED OUT ON THE ELEVATION.

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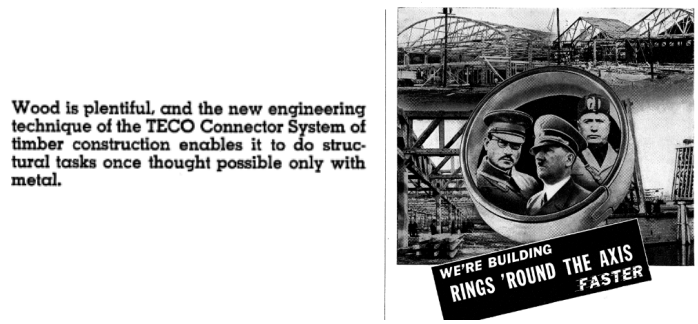
BRIEF HISTORY

Brief history of bowstring trusses

- Widely used from 1940's to the 1960's in commercial, industrial, gymnasium, and hangar buildings.
  - Can be found as early as the 1920's



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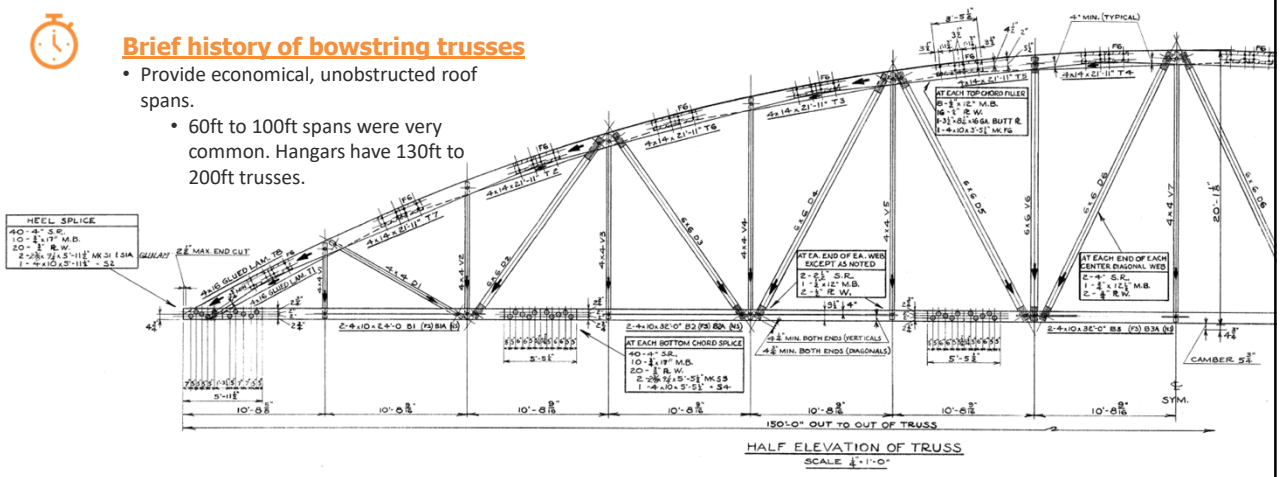
BRIEF HISTORY

Brief history of bowstring trusses

- Provide economical, unobstructed roof spans.
  - 60ft to 100ft spans were very common. Hangars have 130ft to 200ft trusses.



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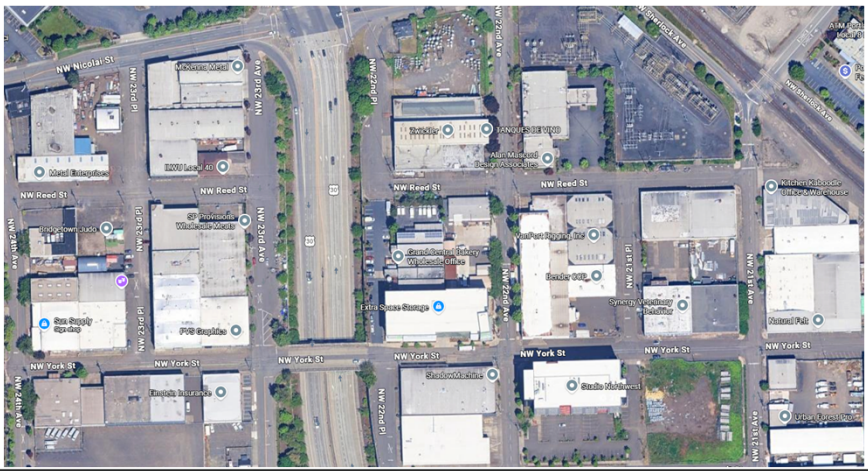
BRIEF HISTORY

Brief history of bowstring trusses

- Many buildings with these trusses remain in service today.

In these 15 blocks there are 20 roofs with bowstring trusses still in use.



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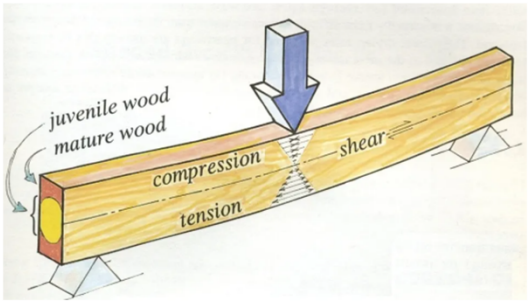
BRIEF HISTORY

Brief history of bowstring trusses

- Current building code is different from past codes.
  - Loading has changed
  - Strength of wood has changed. Why is the year 1980 important?



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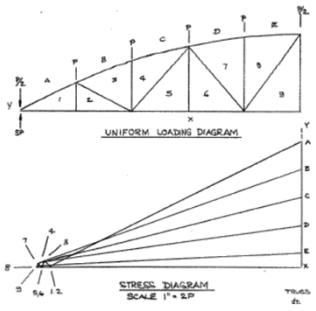
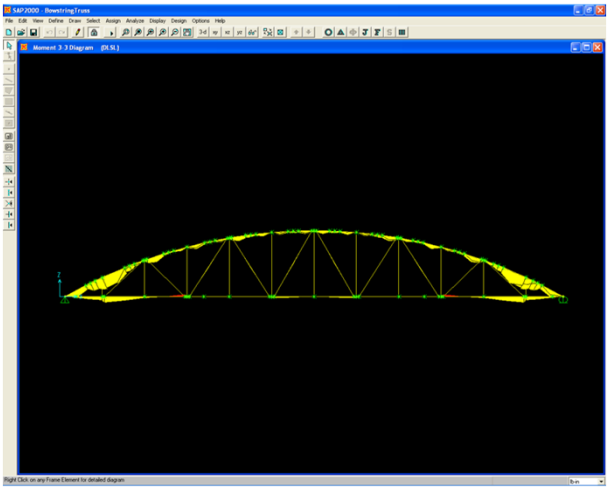
BRIEF HISTORY

Brief history of bowstring trusses

- Analysis methods have changed the way we look at these trusses.
  - Graphical method versus computer modeling.





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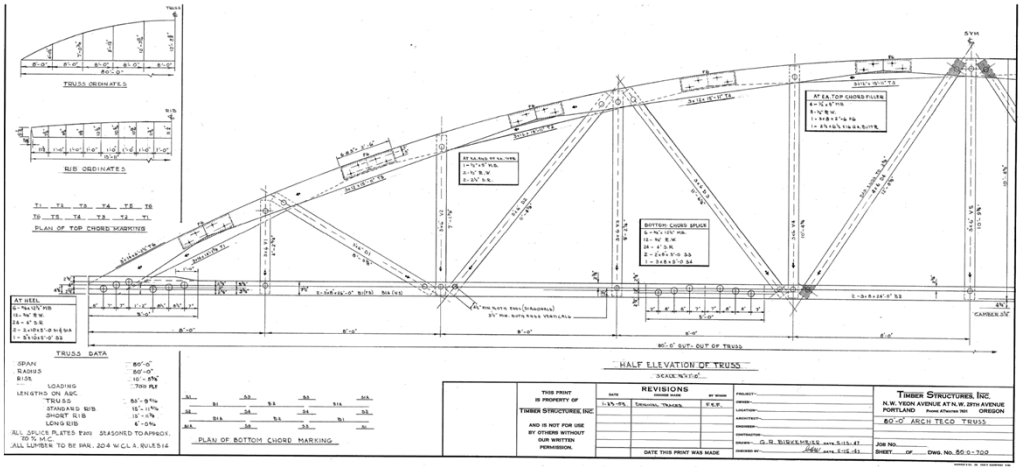
Common Bowstring Truss Types

Types of Bowstring Trusses

- TECO Truss
- Common Failures



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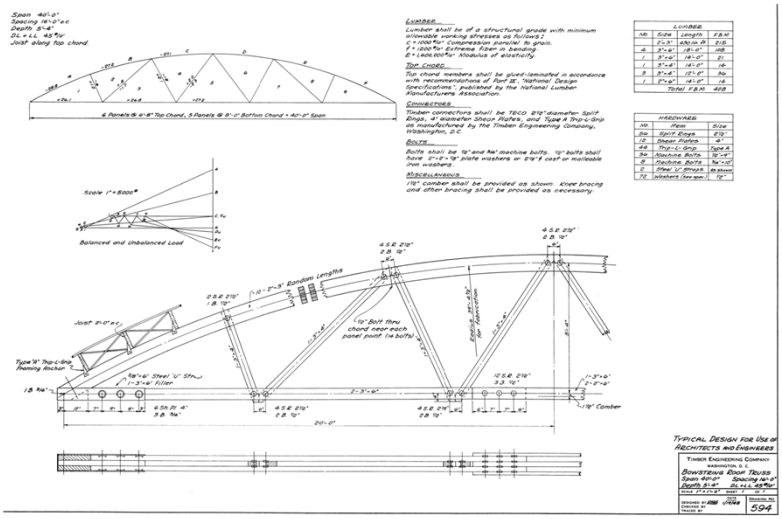
Common Bowstring Truss Types

Types of Bowstring Trusses

- Summerbell Truss
- Common Failures



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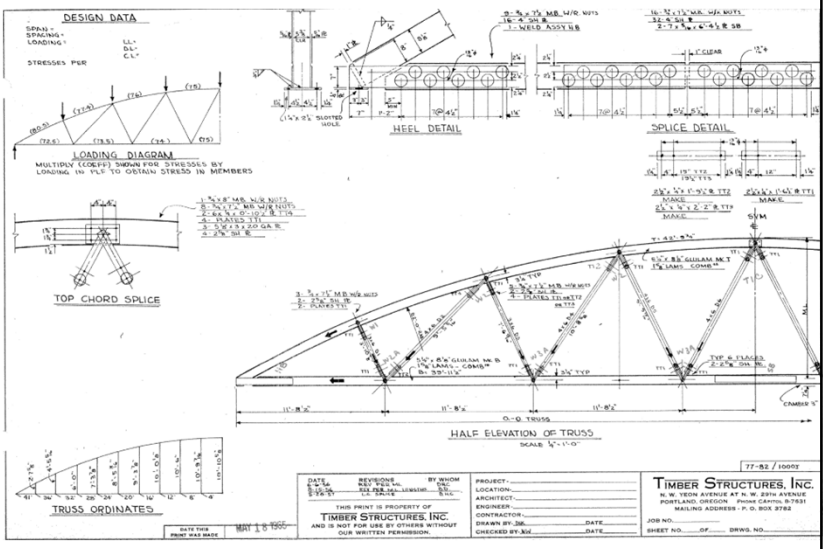
Common Bowstring Truss Types

Types of Bowstring Trusses
- Tim Truss
- Common Failures



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Common Bowstring Truss Types

Types of Bowstring Trusses
- Lattice Truss
- Common Failures

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Evaluation of Trusses

Main Drivers for required repairs and upgrades

- Inspection of trusses: upon inspection all these things must be considered.
- Starts with a thorough inspection. What must we look for?
  - Added loading.
  - Effects of environment.
  - Construction methods.
  - Change of occupancy.
  - In a potential 80-year life span of these trusses the buildings can see many changes. All of which affect performance.

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Evaluation of Trusses

Main Drivers for required repairs and upgrades

- Inspection of trusses: upon inspection all these things must be considered.
  - Increased loading due to changes of the building.
    - Examples: Multiple layers of roofing, Addition of HVAC units, Addition of solar array, Addition of suspended cranes, etc.

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Evaluation of Trusses

Main Drivers for required repairs and upgrades

- Effects of environment increase the possibility of localized problems.
  - Examples: Seasoning checks over time become splits, exposure to water leaks can decay wood over time, exposure to heat in production facilities, exposure to humidity (over pools, steam from machinery) can weaken wood overtime, ice build up in cold storage facilities, etc.

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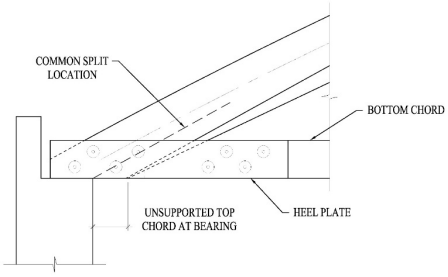
Evaluation of Trusses

Main Drivers for required repairs and upgrades

- Construction methods have proven detrimental over time.
  - Examples: Heels at TECO trusses, nail laminated top chords of Summerbell Trusses, web to chord steel on Tim Trusses, etc.



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Evaluation of Trusses

Main Drivers for required repairs and upgrades

- Change of occupancy in the building can affect the trusses.
  - Examples: Change from warehouse to grow facility, Change from warehouse to offices, Change from warehouse to brewery, etc.

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Evaluation of Trusses

Main Drivers for required repairs and upgrades

- Design analysis of trusses: through evaluation all these things must be considered.
  - Current code, then versus now.
  - Modern analysis and building code are results of evidence over time. In the engineering community we see changes through failures in structures as well as academic research and testing.
  - Differences in how we approach the design of timber trusses come from the following:
    - Changes to building code loading such as snow loads.
    - Changes to allowable strength of wood through testing efforts.
    - Changes to structural analysis through technology.
    - Changes to design of wood through academic research.
    - Changes to code standards for connections of the truss.

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Evaluation of Trusses

Main Drivers for required repairs and upgrades

- Design analysis of trusses: through evaluation all these things must be considered.
  - Current code, then versus now.
    - Portland-area example: snow load increased from 20 psf to 25 psf after late-1960s roof collapses. Oregon has seen a new round of roof collapses and has changed the snow load analysis once again. Snow load importance factors for many buildings increased.
    - ASCE 7 unbalanced snow provisions and snow drift create significantly higher localized forces in truss members.
      - Members originally designed for tension may experience compression under current load cases.
    - Roof snow loads increased in many jurisdictions over time.

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Evaluation of Trusses

Main Drivers for required repairs and upgrades

- Design analysis of trusses: upon inspection all these things must be considered.
  - Decrease in Tension Allowable stress in dimensional lumber.
    - The 1980s In-grade Testing Program evaluated full-size timber members to failure.
    - Testing showed small clear-sample methods did not always predict full-size member capacity accurately.
    - Allowable stresses were reduced for many grades and loading conditions.
    - Bottom chord tension capacity in wood trusses was significantly affected. Roughly 75% of originally believed capacity.

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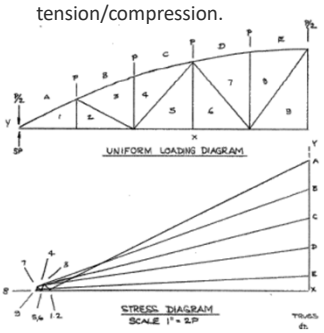
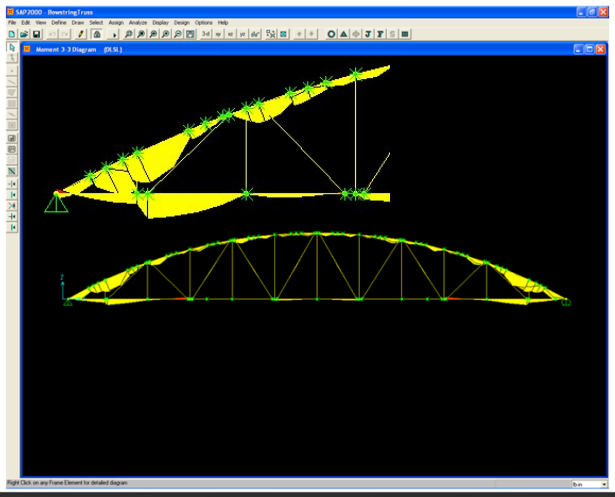
Evaluation of Trusses

Main Drivers for required repairs and upgrades

- Design analysis of trusses: upon inspection all these things must be considered.
  - Improved and more accurate computer analysis.
    - This leads to secondary moments due to eccentricity of connections.
    - Combined loading of bending plus tension/compression.





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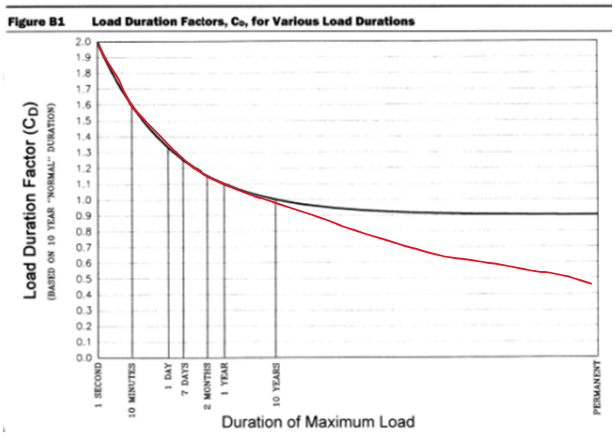
Evaluation of Trusses

Main Drivers for required repairs and upgrades

- Design analysis of trusses: upon inspection all these things must be considered.
  - Decreased strength due to duration of load factor.
    - Members may fail even without snow or live load present
      - Question: "Why did my truss fail without any load on it?
      - Answer: Most likely the duration of load factor we must apply to wood.
    - Revised duration of load should be considered in evaluation.
      - Current code has a factor of 0.9 for permanent load, where more recent research puts this factor closer to 0.6 for wood structures built in 1945.



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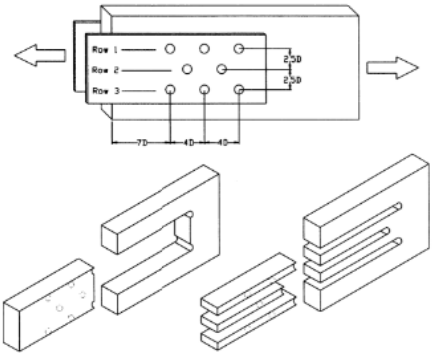
Evaluation of Trusses

Main Drivers for required repairs and upgrades

- Design analysis of trusses: upon inspection all these things must be considered.
  - Decreased capacity on connections with bolt groups.
    - Connection capacity may be governed by wood failure, not bolt capacity
    - Common at heel assemblies and bottom chord splices
    - Must be checked using modern timber connection provisions



Appendix E of NDS, Non-mandatory

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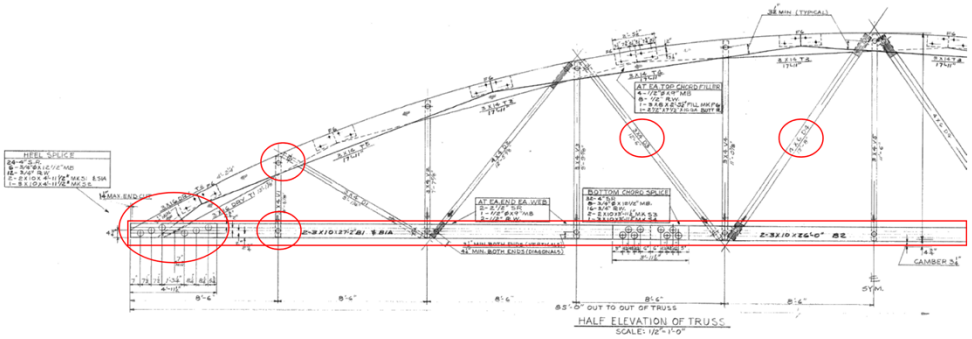
Repairs and Upgrades

Repair and Upgrade Approaches

- Where are the problem areas?
  - TECO Truss



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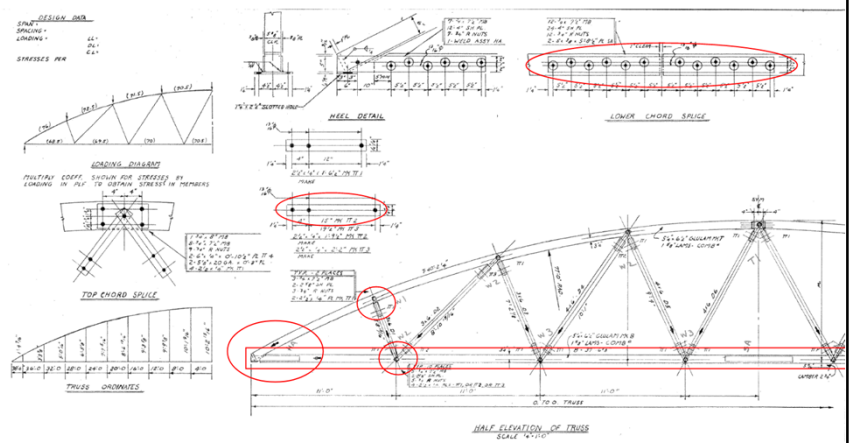
Repairs and Upgrades

Repair and Upgrade Approaches

- Where are the problem areas?
  - Tim Truss



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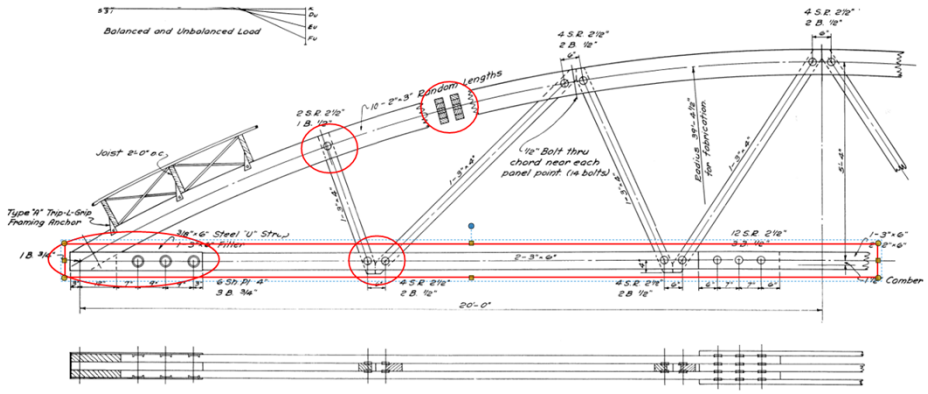
Repairs and Upgrades

Repair and Upgrade Approaches

- Where are the problem areas?
  - Summerbell Truss



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Repairs and Upgrades

Repair and Upgrade Approaches

- Sample Repair/Upgrade

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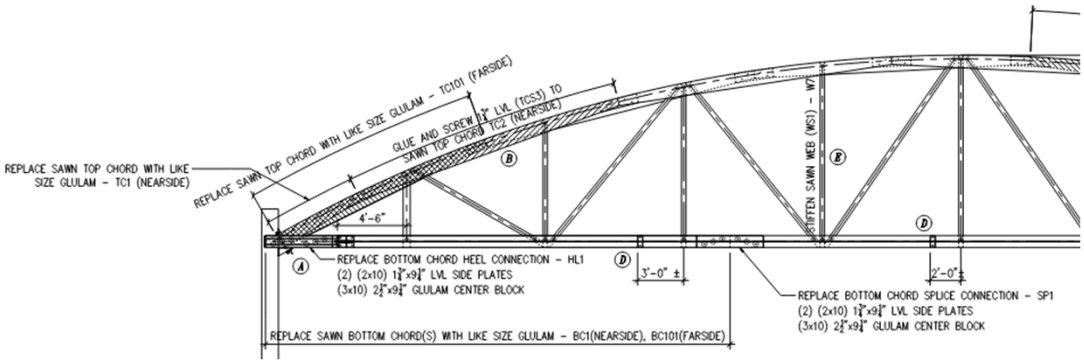
Repairs and Upgrades

Repair and Upgrade Approaches

- Sample Repair/Upgrade



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Project Examples

Specific Projects

- Alaska Airlines Hangar

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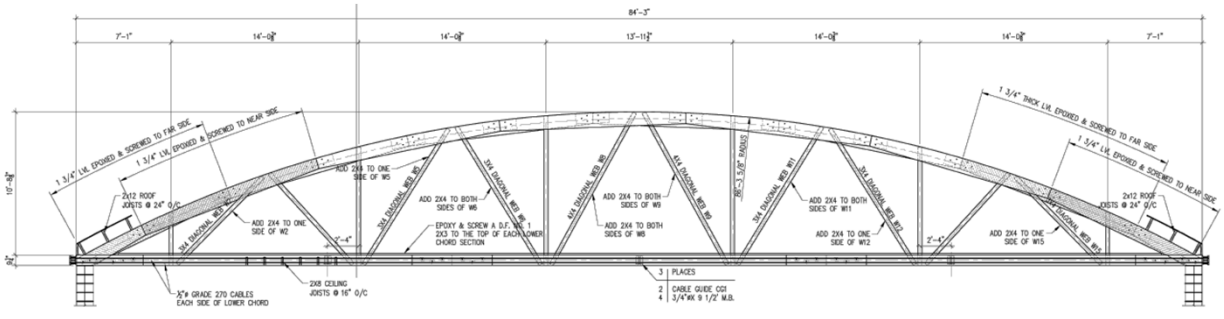
Project Examples

Specific Projects

- Tigard Bowl



ELEVATION OF TRUSS T3

VIEW FROM THE SOUTH LOOKING NORTH

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Project Examples

Specific Projects

- Smith Frozen Foods

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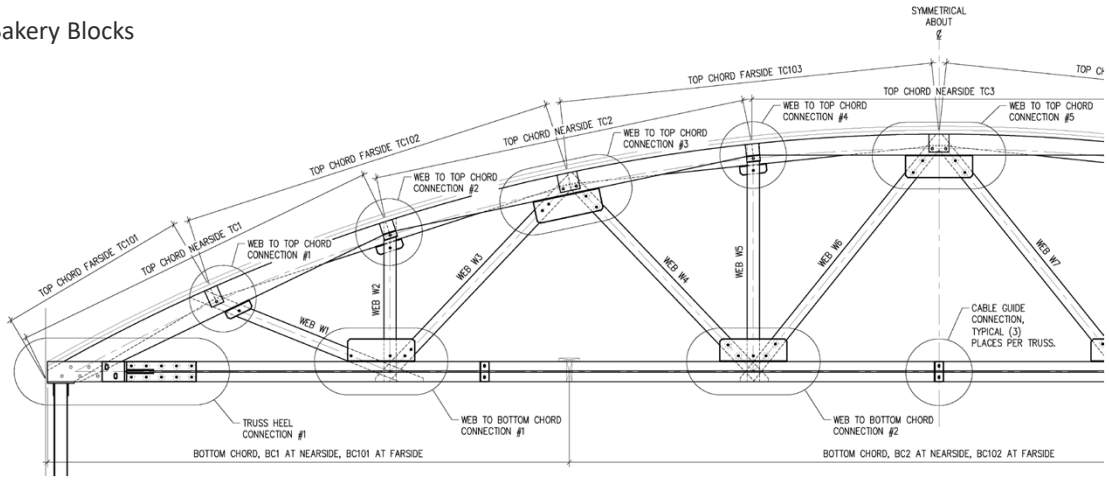
Project Examples

Specific Projects

- Bakery Blocks



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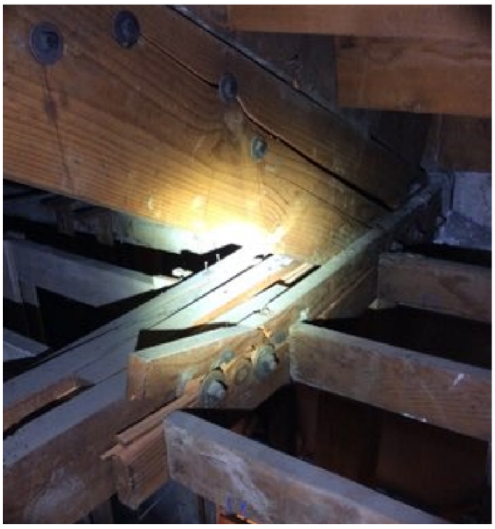
Project Examples

Specific Projects

- Pietro's Pizza



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Highlights

Key Takeaways

- Original code compliance does not ensure current adequacy.
- Historic bowstring trusses require careful evaluation.
- Failures are often caused by combined effects.
- Repair and upgrade can be practical, economical.
- Knowledge can put the customers' mind at ease.

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Questions

Questions/Discussion

- Inspection considerations
- Analysis assumptions
- Repair options
- Project-specific conditions

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