WJE

Inspecting Covered Bridges

Best Practices for Inspection, Condition Assessment, and Repair Recommendations

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Learning Objectives

- Understand the Basics of Wood Construction, Deterioration Methods, and Inspection Techniques
- Understand the Components and Function of a Covered Bridge
- Discuss a Recent Inspection of a Covered Bridge

Covered Bridge Components

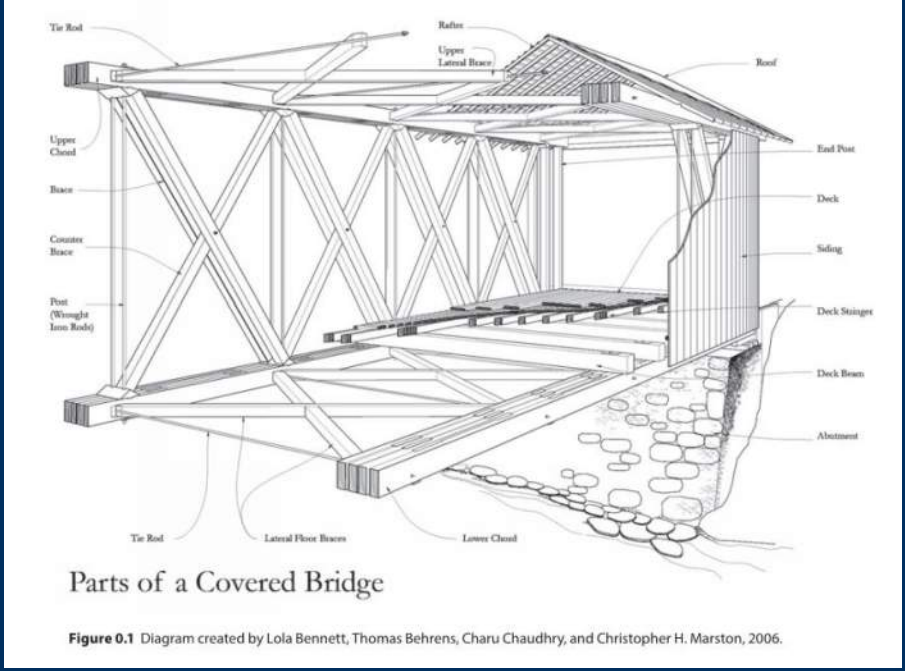
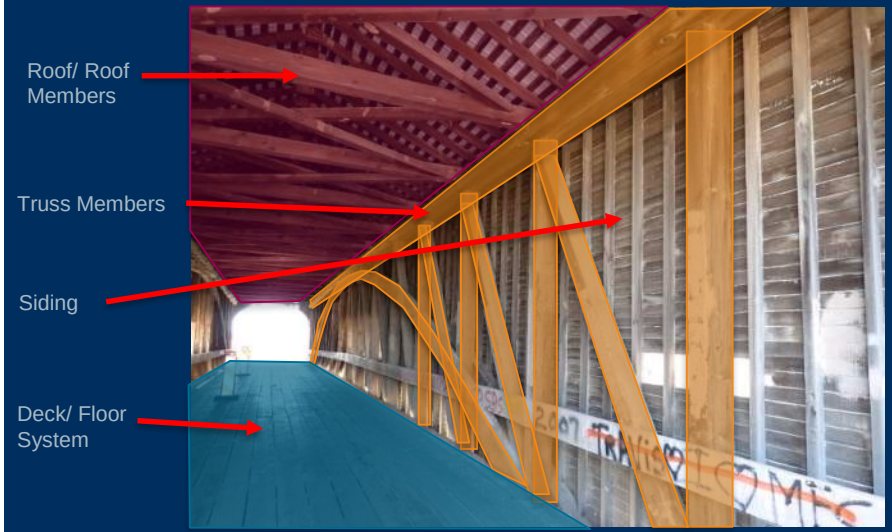


Figure 0.1 Diagram created by Lola Bennett, Thomas Behrens, Charu Chaudhry, and Christopher H. Marston, 2006.



from *Covered Bridges and the Birth of American Engineering*, Christianson, J. et. al., 2015, Figure 0.1

Wood Basics

Remember It's Not Designed, It's Harvested

Basic Definitions

- **Dimension Lumber**:

  Nominal thickness from 2 through 4 inches and nominal widths 2 inches and wider.

- **Heavy Timber**:

  5x5 and larger

Heavy Timber

- Solid Sawn Timber
- Glued Laminated Timber (Glulam)
- Parallel Strand Lumber (PSL)
- Heavy timber decking (solid sawn or laminated)
- Mass timber construction
  - Cross laminated timber
  - Nail laminated timber

Solid Sawn Timber

- Beams and Stringers
  - Pieces 5 inches and thicker, rectangular width more than 2 inches greater than the thickness
- Posts and Stringer
  - 5x5 and larger with width not more than 2 inches greater than the thickness

* Definitions from WCLB Grading Rule

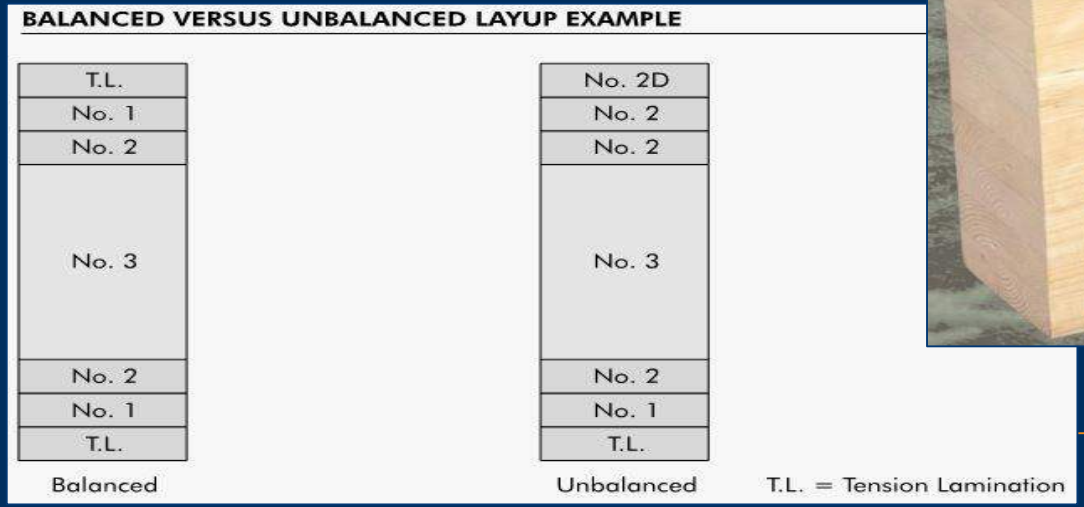
Glued-Laminated Timber

- Dimension lumber (2x) laminations bonded with adhesives
- 1 3/8 in. thick for Southern Pine and 1 ½ in. thick for western species
- Glulam is typically produced at a moisture content below 8 percent.

The glulam grade defines the layup for the beam and the allowable stresses

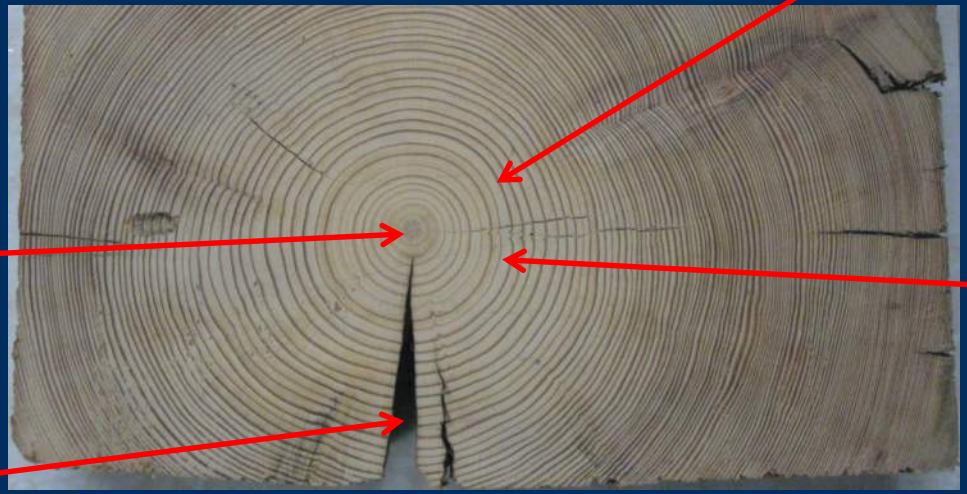
Top of beam identified for unbalanced layups

Lamination Layup: Balanced and Unbalanced

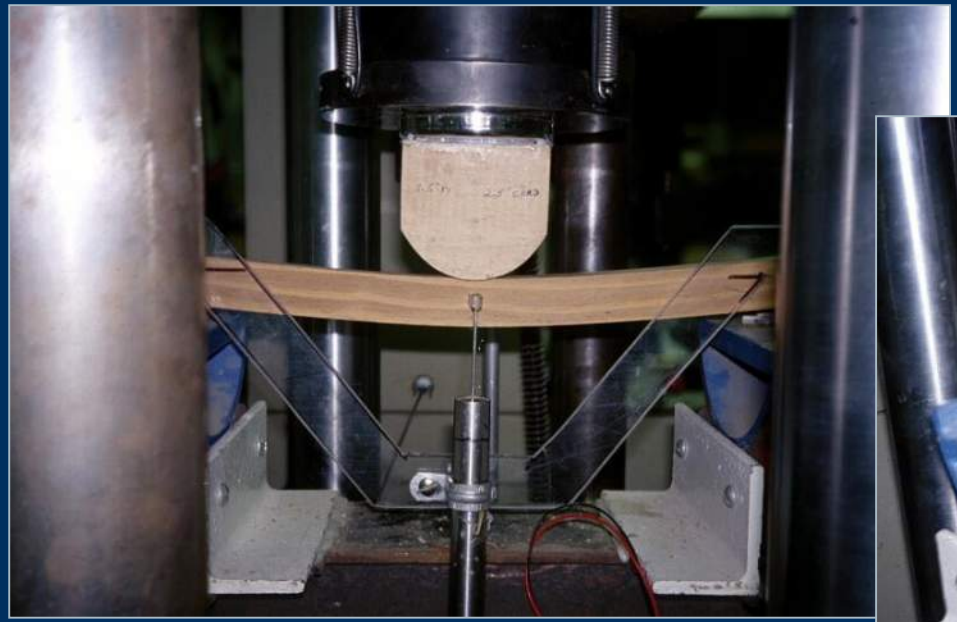


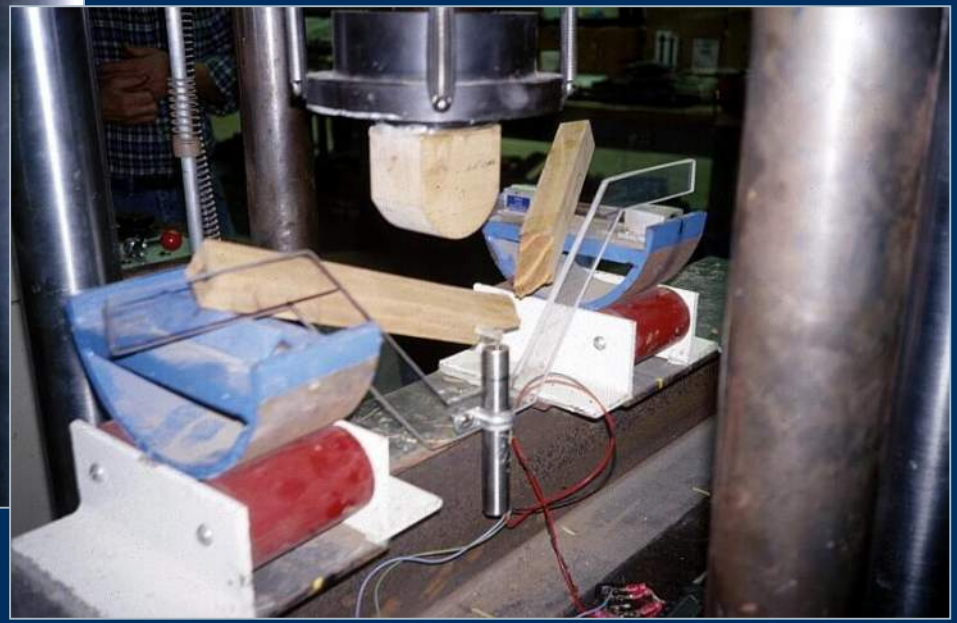
More Definitions

- Density
  - Based on number of growth rings per inch
  - Percentage of summerwood vs. springwood



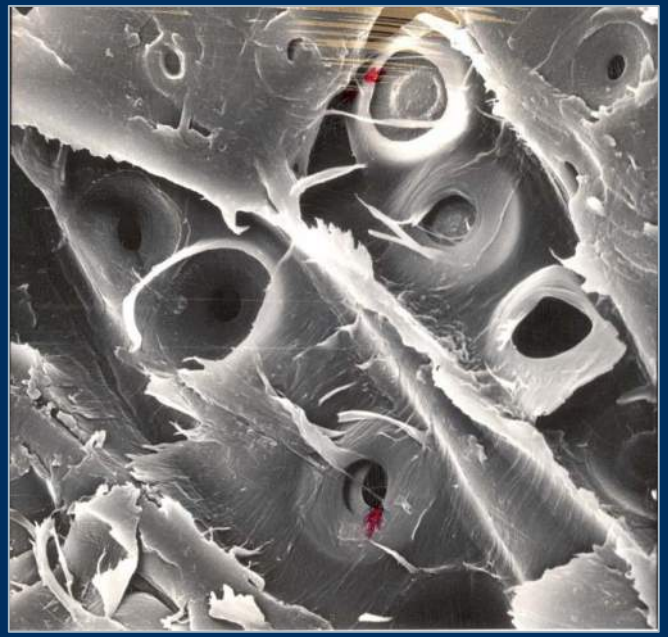
Wood Properties and Characteristics





Wood Volume Change

- Dimensionally stable above fiber saturation point (~30% M.C.)
- Changes dimensions below the fiber saturation point
- Shrinks when dried and expands when wet



- Wood equilibrium moisture content is correlated with the relative humidity and temperature.
- The greatest volume change occurs perpendicular to grain

Naturally Occurring Defects/*Characteristics*
Knots

Centerline Knot

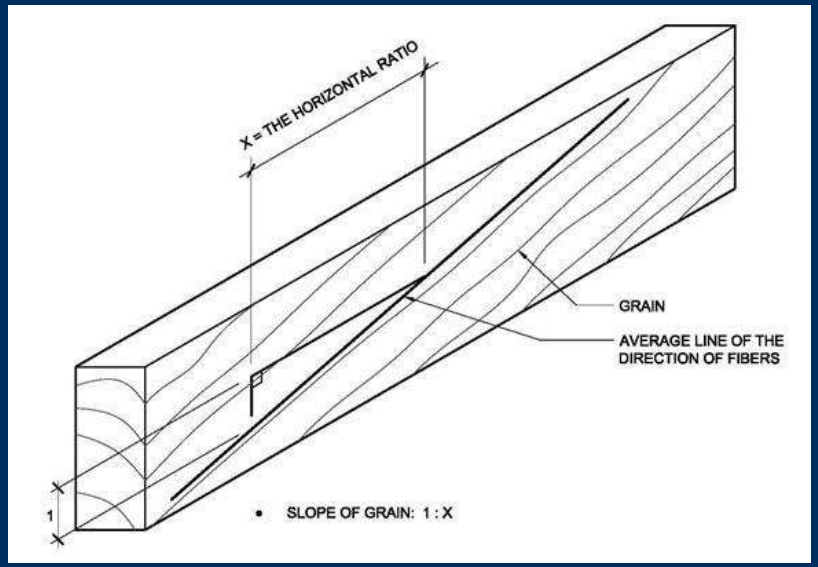
Edge Knot

Hole

Corner Knot

Spike Knot

Wood *Characteristics: Slope of Grain*



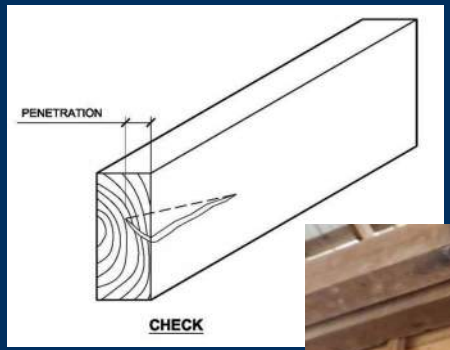
Beam and Stringer Requirements

Select Structural:	1:12	(1:15 at middle 1/3)
No.1 Grade:	1:8	(1:12 at middle 1/3)
No. 2 Grade:	1:6	

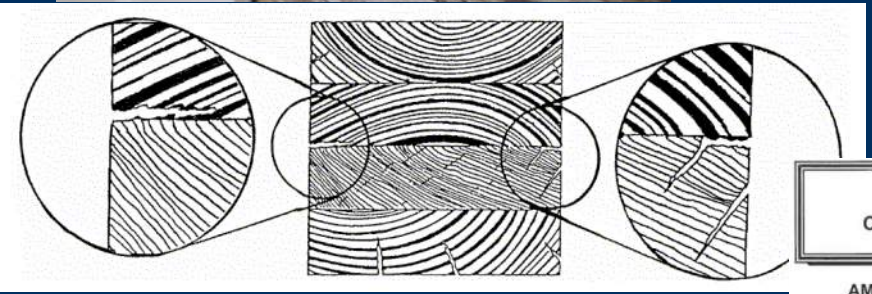
Poor slope of grain

Naturally Occurring Defects/*Characteristics*
Seasoning Checks

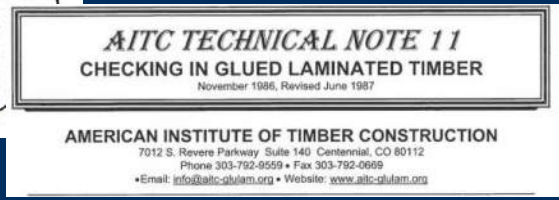
Seasoning Check – *separation of wood across or through rings of annual growth (usually the result of seasoning)*

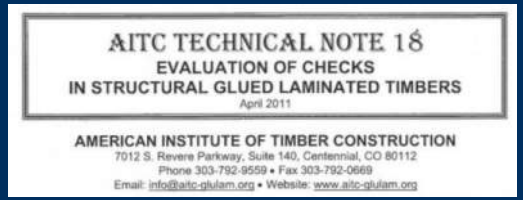


Checks in Glued-Laminated Timber



- Checking is possible for glulam members if the moisture content increases and then subsequently dries in an uncontrolled manner.
- Checks that occur in glulam members are usually located at the glue joints (see AITC Tech Note 11)
- These checks can be mistaken for glue line failures.
- Inspect the interior of the check and measure the depth to confirm. (See also AITC Tech Note 18)


AITC TECHNICAL NOTE 11
CHECKING IN GLUED LAMINATED TIMBER
November 1986, Revised June 1987
AMERICAN INSTITUTE OF TIMBER CONSTRUCTION
7012 S. Revere Parkway Suite 140 Centennial, CO 80112
Phone 303-792-9559 • Fax 303-792-0669
•Email: info@aitc-glulam.org • Website: www.aitc-glulam.org


AITC TECHNICAL NOTE 18
EVALUATION OF CHECKS
IN STRUCTURAL GLUED LAMINATED TIMBERS
April 2011
AMERICAN INSTITUTE OF TIMBER CONSTRUCTION
7012 S. Revere Parkway, Suite 140, Centennial, CO 80112
Phone 303-792-9559 • Fax 303-792-0669
Email: info@aitc-glulam.org • Website: www.aitc-glulam.org

Allowable Check Depths from Timber Grading Rules

Compare to combined check depth at a given elevation

-Southern Pine Timber (SPIB):

-Select Structural & No. 1 – 3/8 thickness (2 ¼” for 6x14; 3” for 8x10)

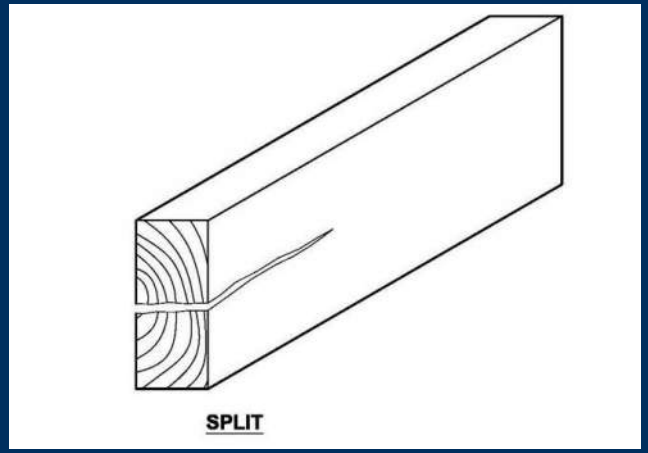
-No. 2 - 1/2 thickness (3” for 6x14)

-West Coast Timber (WCLIB):

-Select Structural & No.1 – 1/4 thickness (1 1/2” for 6x14; 2” for 8x10)

Measuring Depth of Seasoning Checks

Naturally Occurring Defects/*Characteristics*



Split – *separation of the wood through the piece to the opposite surface or adjoining surface due to the tearing apart of wood cells*

Wane

Wane - *bark or lack of wood from any cause, except eased edges, on edge or corner of a piece of lumber*

Wood Deterioration and Investigation Techniques

- Decay
- Fire
- Insect attack

Decay

The Growth of Wood Destroying (Rotting) Fungi Depends on:

- Favorable temperature (76 to 86 ° F is optimum)
- A supply of oxygen
- An adequate amount of moisture
- The presence of a suitable food supply (the wood)

Decay

Moisture Requirements:

- The optimum moisture condition for the growth of fungi in wood is slightly above the fiber saturation point (approximately 30 percent)
- The growth of wood rotting fungi is retarded at 25 to 30 percent moisture content
- Wood rotting fungi growth is stopped at 20 percent

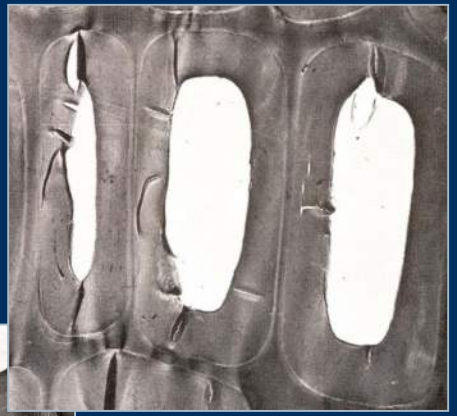
How to Prevent Wood Decay

Eliminate one of the three requirements:

1. Food – Fill the wood with poison (preservative treatments).
2. Moisture – Keep wood moisture content below 20 percent.
3. Oxygen – Generally not possible.

Wood Rotting Fungi are Classified as:

- White Rot:
  - Commonly associated with hardwoods
  - Attack both cellulose and lignin
  - Affected wood white or yellow to light brown
- Brown Rot:
  - Commonly associated with softwoods
  - Attacks primarily cell wall carbohydrates
  - Affected wood is brown in color
  - Dry rot is a special type of brown rot
  - Just because the wood appears dry and has rot does not mean it is "Dry rot"
- Soft Rot:
  - Surface of wood softened



No Decay

Decayed

Fruiting Bodies

- When serious decay develops in wood, sometimes fruiting bodies are formed.

- Fruiting bodies produce spores which are distributed by wind or insects

Fruiting Bodies

Decay at Treated Members

For Douglas Fir, the depth of treatment is equal to the depth of the incising.

Due to the large cross-section of timber piles, the center of the pile cross-section is typically not treated and subjected to decay.

Decay Investigations

- What to look for
- Helpful techniques
- Advanced techniques
  - Moisture measurements
  - Sample removal and testing

Decay – Check at Locations where Water if Present Cannot Easily Dry

Repairs with Bolted Steel Plates can Trap Moisture

Bolt holes can be a path for Moisture

Decay – Check at Locations where Water if Present Cannot Easily Dry

Joint between bottom chord and web member

Joint between wall stud and arch

Decay- Sound Timber Members with a Flat Head Hammer to Identify Hollow Areas

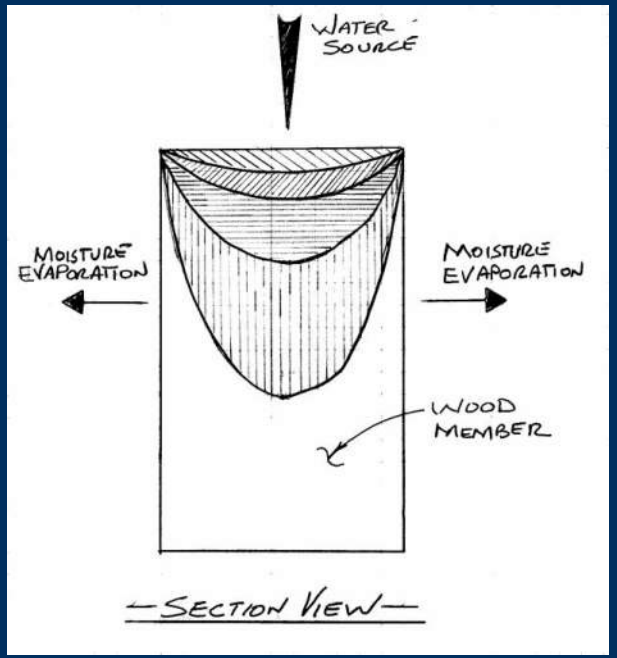
Decay – Probe Suspected Decay Area to Determine Extent of Decay

Decay- Suspect Areas Can be Probed with a Thin Drill Bit

Suspect areas can be probed with long thin drill bits (12 in. long x 1/8 in. diameter) to look for soft pockets of wood

Why we probe when decay is suspected

Decay at center of joist leaving thin un-decayed sides (shell)



Water Source at Top of Member

Advanced Investigation Tools

Moisture Measurement

Delmhorst Wood Moisture Meters

Advanced Investigation Tools

Sample Removal

5/8 in. O.D. Single chisel wood core bit (plug cutter) with extensions

3/8 in. dia. Core, with 5/8 in. dia. hole

Fire Damage

- Wood is combustible

Fire Damage – Investigation Techniques

Measurement of Char Thickness

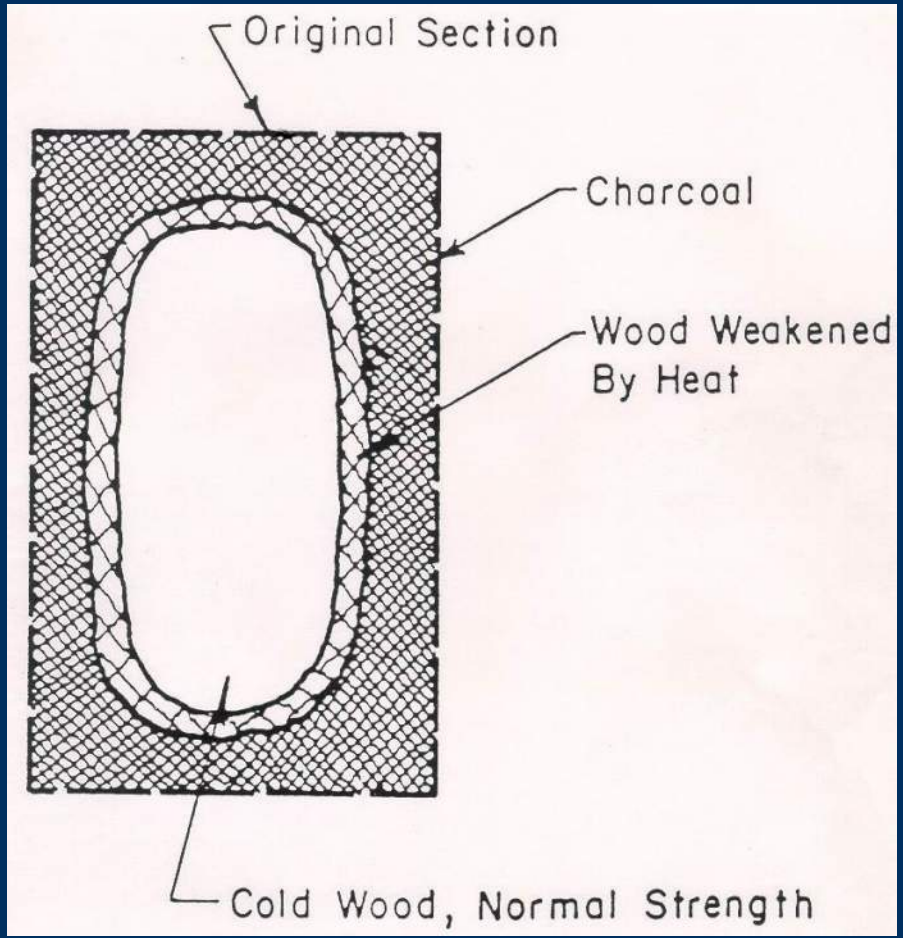
Chisel and Calipers

Scrape char in small square area with a sharp wood chisel down to solid wood

Measure thickness of char with the end of calipers (plunger) at edge of scraped

Fire Damage

- To calculate the remaining strength, remove thickness of char plus thickness of wood weakened by heat
- Thickness of heat weakened wood:
- For compression:
  - ¼ in. with remaining wood at 100%
- For tension:
  - ¼ in. to 5/8 in. at 90% with remaining wood at 100%



Insect Attack

- Termites
- Carpenter Ants
- Powder Post Beetles

Three groups of termites in U.S.

-Subterranean Termites*

  -Colonies (nest) in ground

  -Most common & destructive

-Dry Wood Termites

  -Restricted to deep south and west coast

  -Enter wood from air during swarming

-Damp Wood Termites

  -Attack mainly wood buried in ground

* Most Common

Subterranean Termites

Attack both sapwood and heartwood

A – Northern limit of
Subterranean termites

B – Northern limit of
Dry wood termites

Figure 17–8—*A*, The northern limit of recorded damage done by subterranean termites in the United States; *B*, the northern limit of damage done by dry-wood termites. (M134 686)

A – Winged swarming
Subterranean termite

B – Winged ant

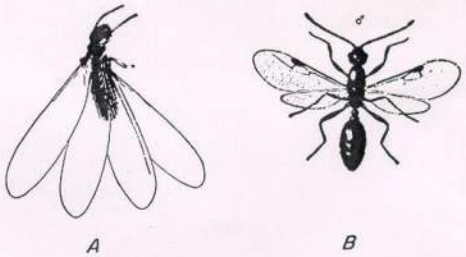
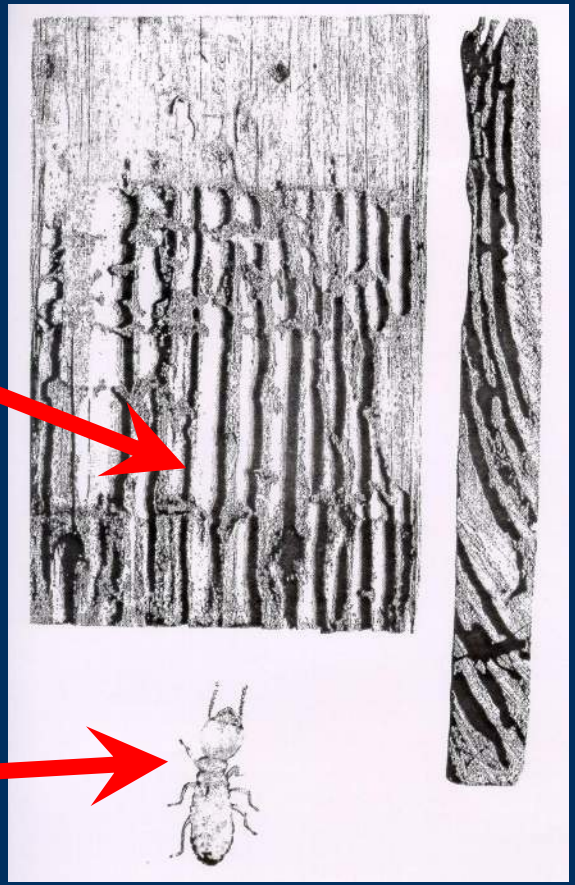


Figure 17–9—*A*, Winged termite *B*, winged ant (both greatly enlarged). The wasp waist of the ant and the long wings of the termite are distinguishing characteristics. (M137 348)

Subterranean Termites

Workers consume interior of wood leaving a thin shell for protection

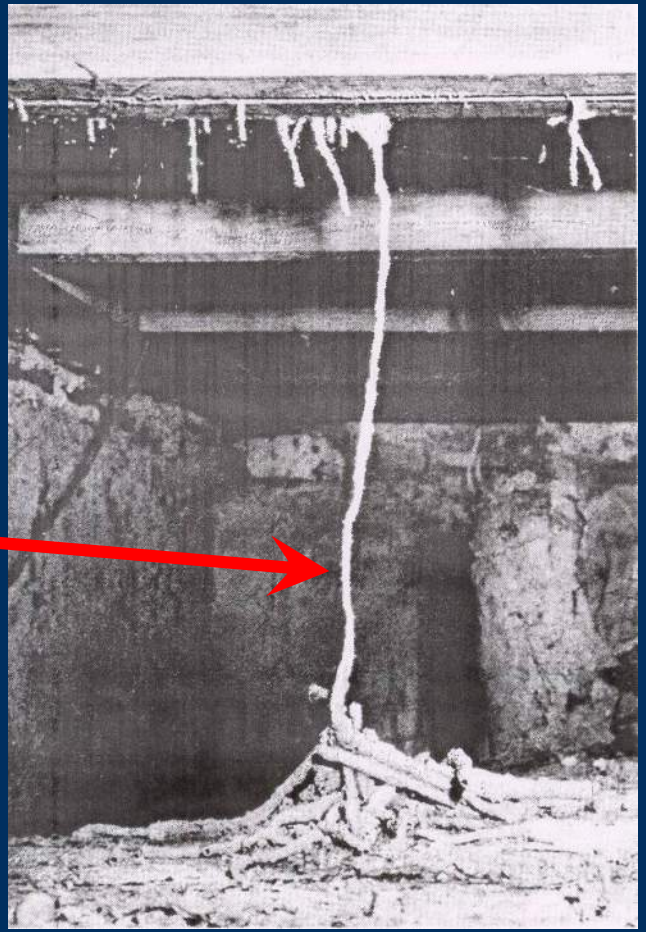
Worker termite



Subterranean Termites

To reach wood not in contact with soil workers construct shelter tubes

Tubes provide moisture and protect termite from direct exposure to light and air



Termites

Subterranean Termites

Shelter tubes on surface

Interior damage

Insect Damage – Termites

Damage hidden behind molding

Shelter tubes between boards

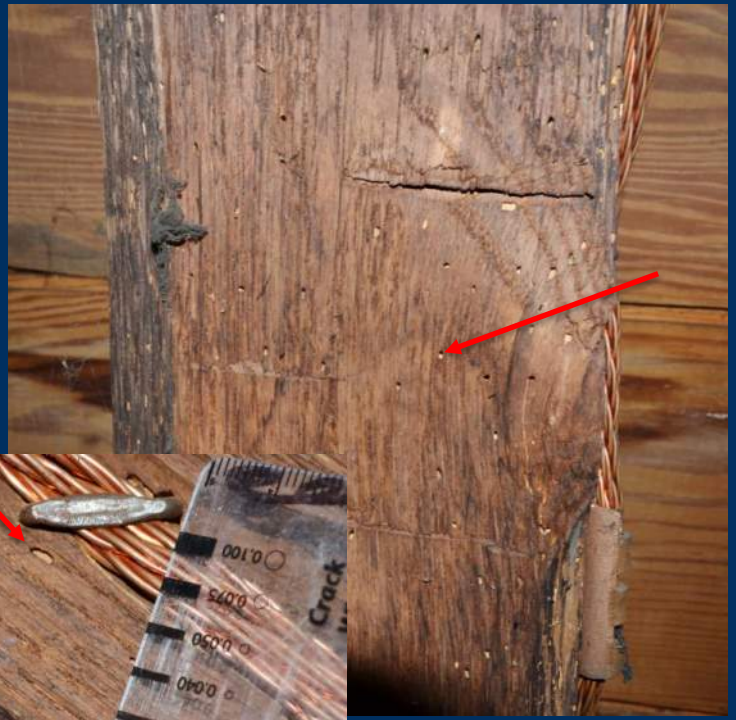
Carpenter Ants

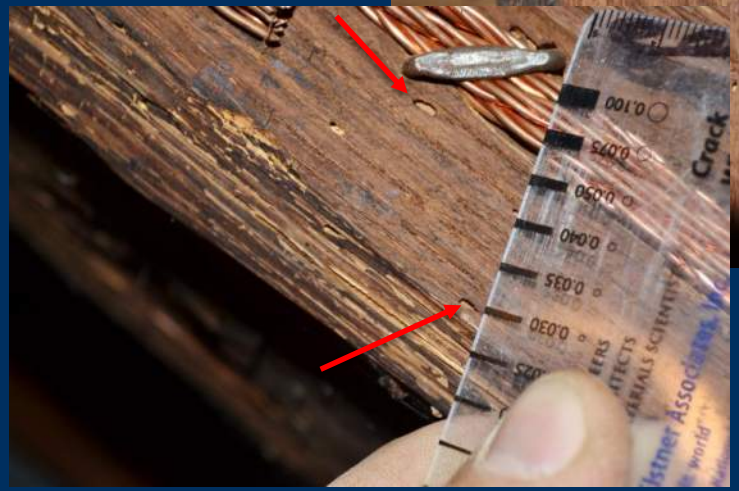
*Look for Sawdust

- Build tunnels to live in wood
- Do not eat wood

Powder Post Beetle

- The Powder Post Beetle (Lyctidae) larvae bore through substantial quantities of wood to get the nutrients they require, which produces large volumes of fine wood dust.
- Attack of American Powder Post Beetles is mainly confined to hardwoods.
- Powder Post Beetles attack only sapwood, however adults can emerge through heartwood.



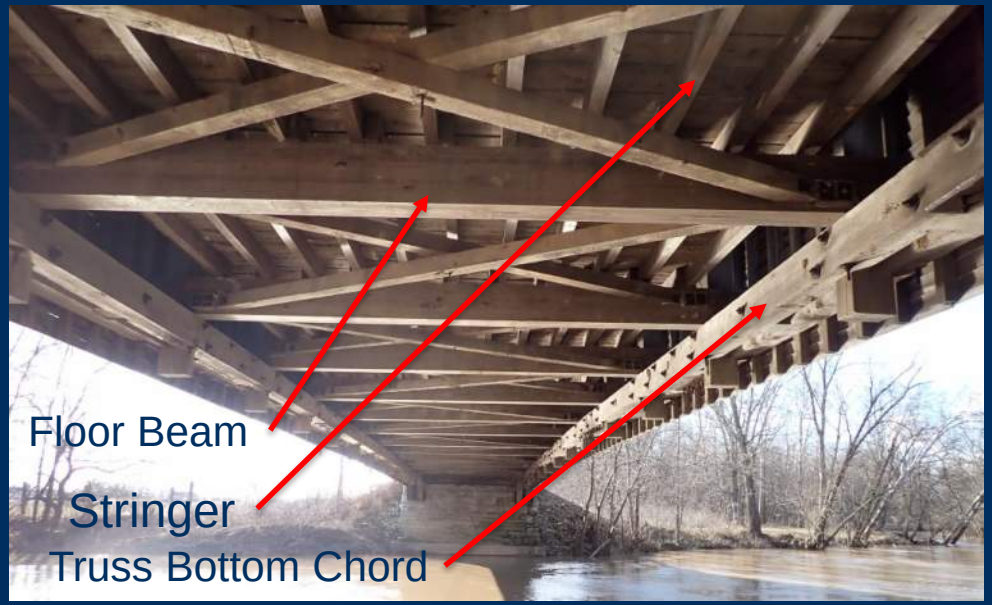


Don’t Confuse Other Probe Marks for Insect Attack

Covered Bridge History and Functionality

- Most originally constructed in 1800's and early 1900's
  - Solid sawn timber members originally used
  - Repairs/ rebuilds may use glulam timber
- Truss configurations allowed for some spans over 100 feet

Covered Bridge History and Functionality



- Floor systems of timber deck planks, stringers and floor beams transfer live load to trusses
- Trusses support loads between abutments

Why Did We Cover Our Wood Bridges?

a. If we kept them long enough they would eventually attract tourists to the state.

b. They looked nice and coordinated with some of the local houses.

c. To make sure our children kept dry when they were carving their initials in the timber members.

d. To keep the wood structure dry.

So What is the Concept?

- Provide a roof to protect the structure from direct rain or snow.
- Provide walls to protect the structure from wind driven rain or snow.
- Provide ventilation openings to allow quick drying of the structure from any incidental wetting and prevent condensation.

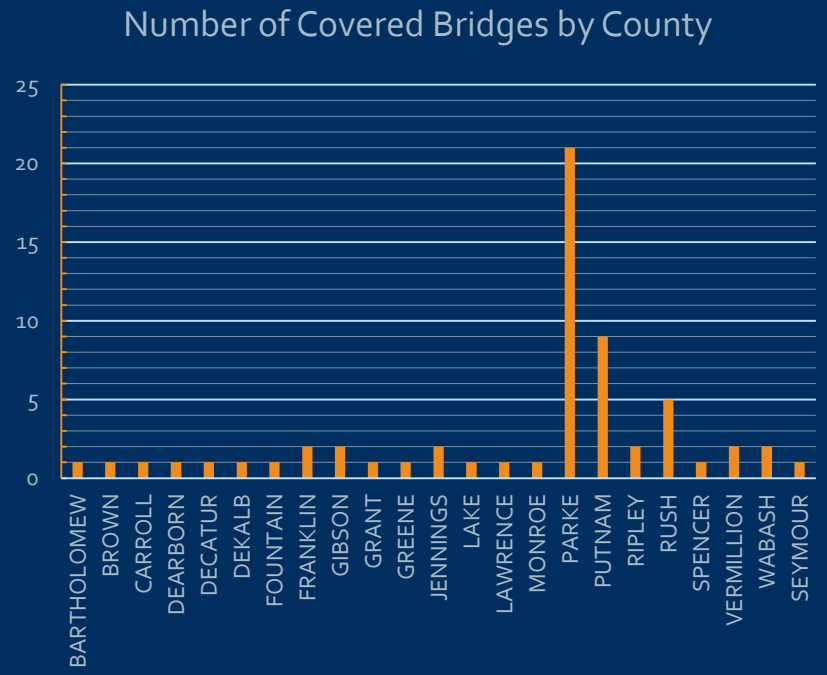
Cover All Areas to Shed Water from the Structure

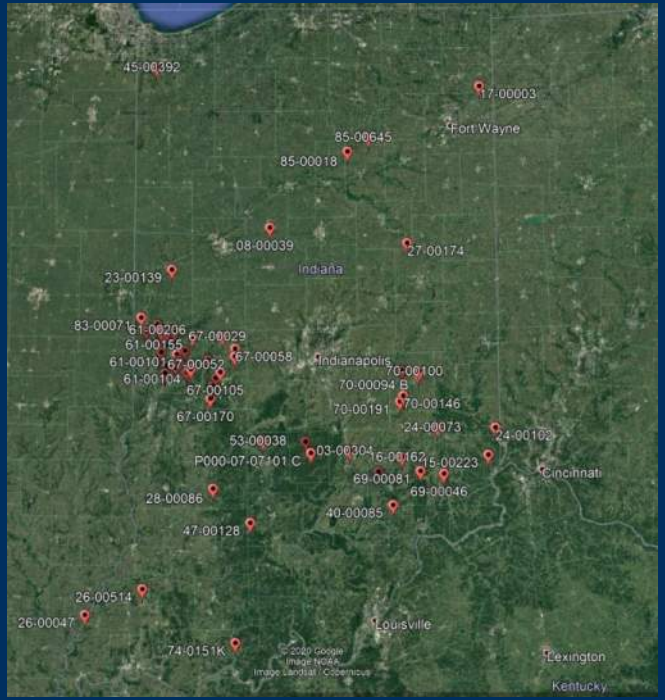
Arch End Covering Intact

Arch End Covering Missing

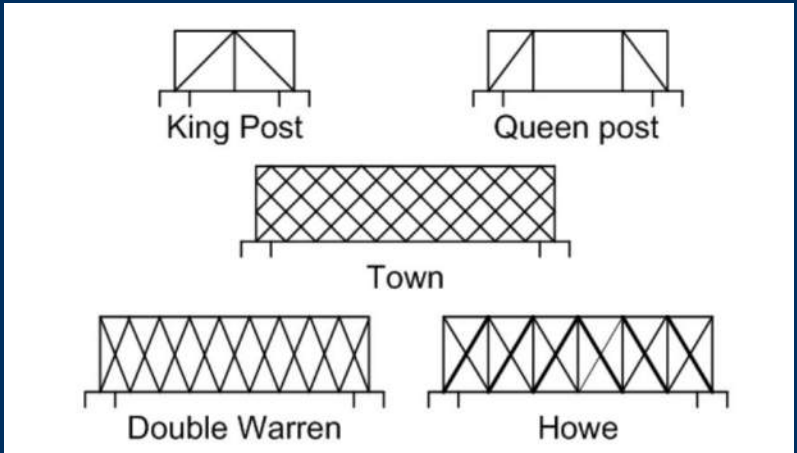
What is the First Thing to Look At?

Covered Bridges in Indiana

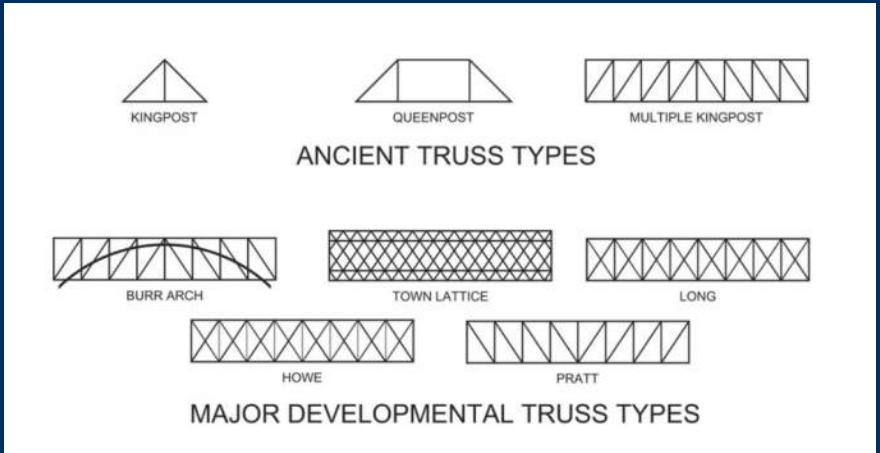




Common Covered Bridge Truss Types



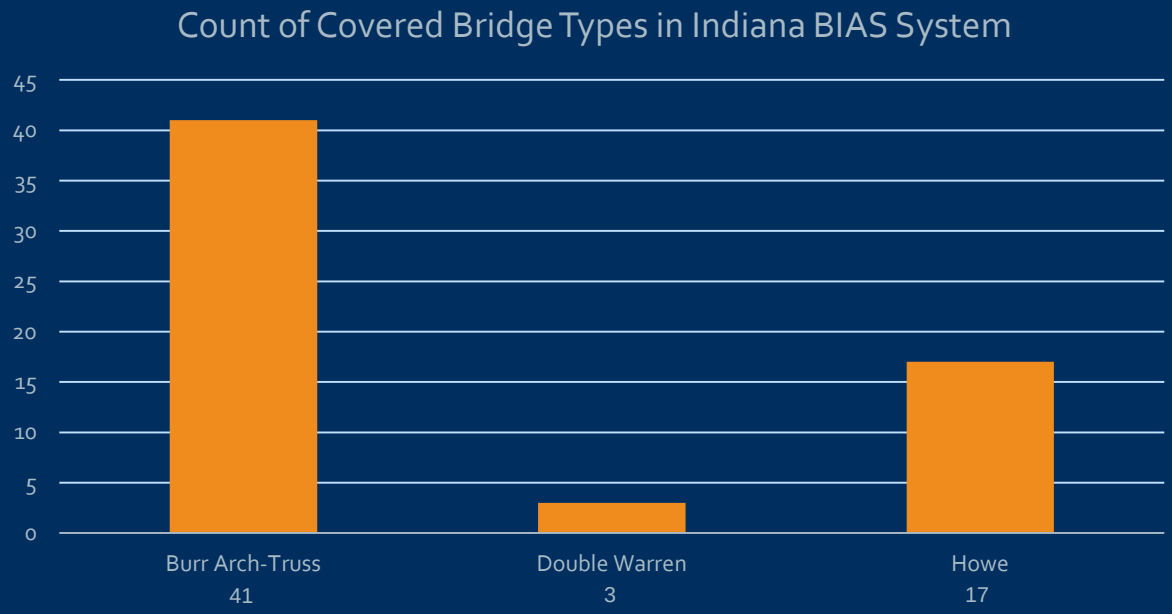
from *FHWA Bridge Inspector's Reference Manual* (BIRM), Figure 8.1.6

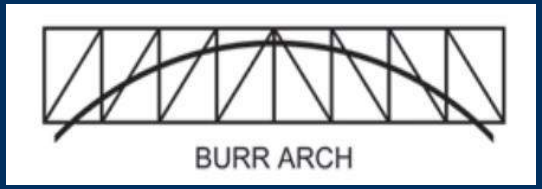


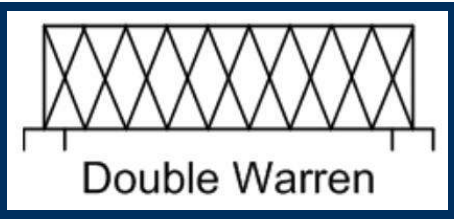
from *Covered Bridges and the Birth of American Engineering*, Christianson, J. et. al., 2015, Figure 0.2

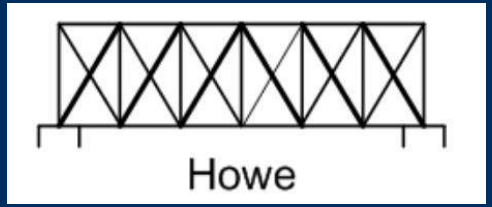
Additional Truss Types In Other Regions of the US

Covered Bridge Structure Types in Indiana



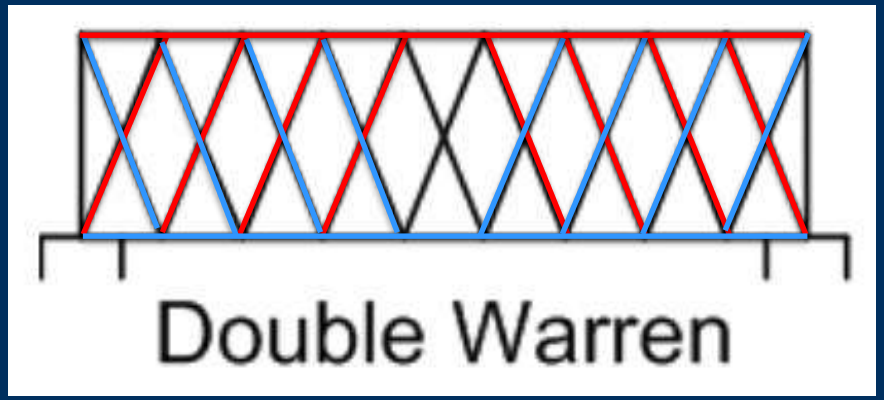


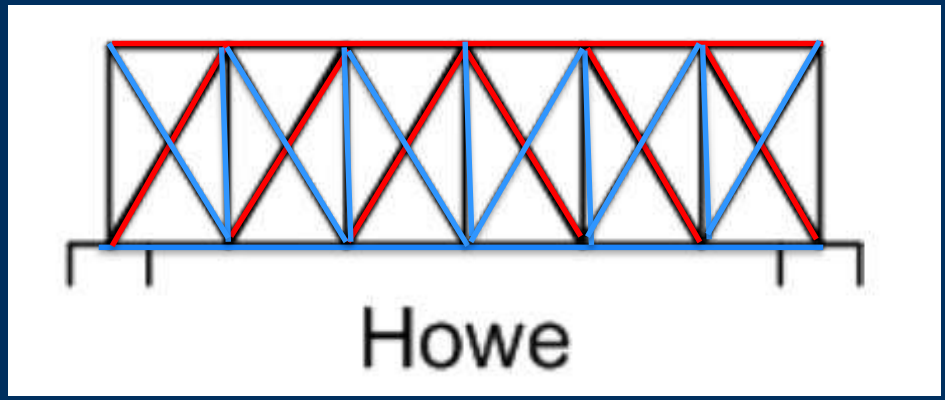




From BIAS database entries with:
NBI field 043A (Superstructure Type, Material) = '7' (Wood or Timber)
NBI field 043B (Superstructure Type, Design) = '10' (Truss – Thru)

Understanding the Load Path



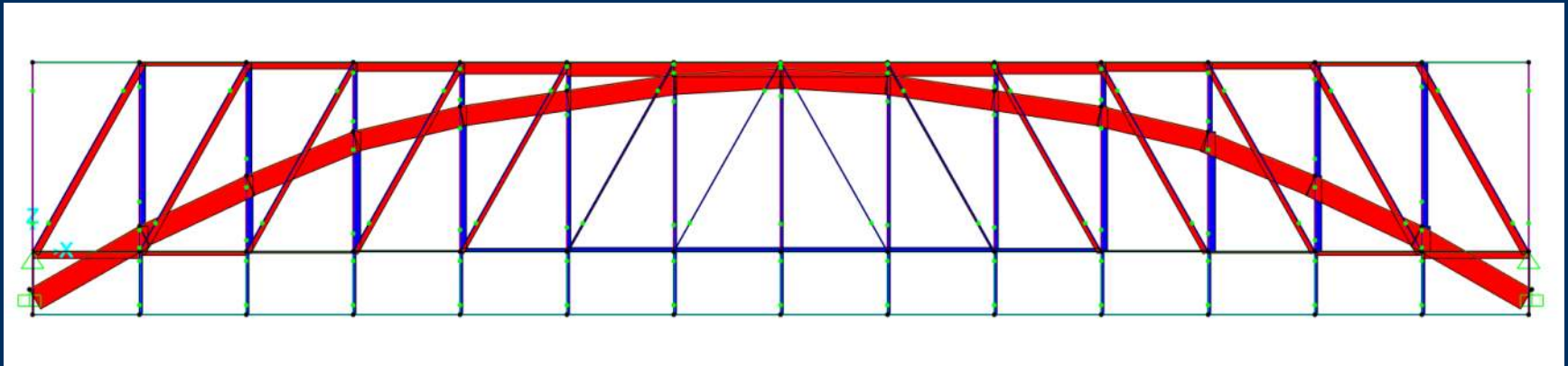


Primary Compression Member

Primary Tension Member

Reversal or Secondary Member

Understanding the Load Path



BURR ARCH

Compression Member

Tension Member

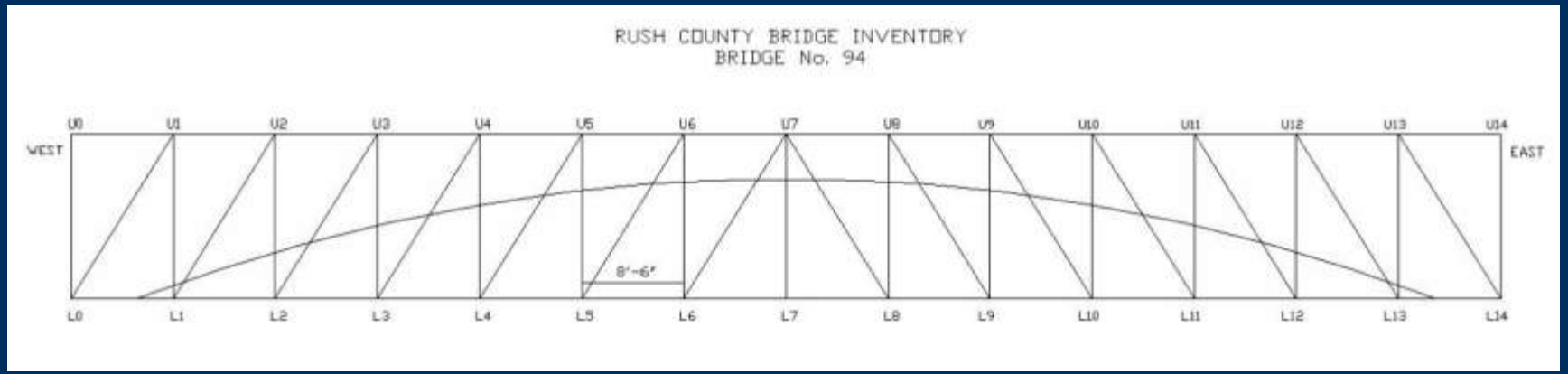
Many Burr Arch-Truss bridges remain today due to the greater relative strength of the stiffening arch (BIRM). 41/61 covered bridges in Indiana are Burr Arch-Trusses

- Maximum tensile load in the bottom chord ~33% that of similar span Howe/ Double Warren Trusses
- Maximum compressive load in each member ~60% that of similar span Howe/ Double Warren Trusses

Indiana Bridge 70-00094B

Components Inspected

- Siding, Roofing, and Roof Framing Members
- Deck and Wearing Surface
- Floor System
- Truss Members
- Arch Members
- Stone Masonry Abutments

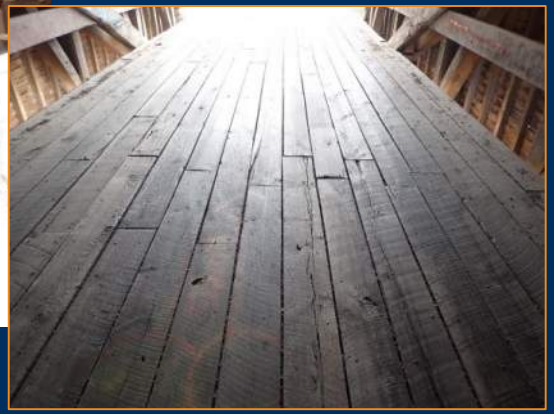


Siding, Roofing, and Roof Framing Members

- Multiple small holes in siding and roofing
- Siding typically missing over bottom-most segments of arch
- Evidence of previous repairs with straight boards

Deck, Wearing Surface, and Floor System

- Only minor deterioration
- Floor system appears to have been replaced since original construction



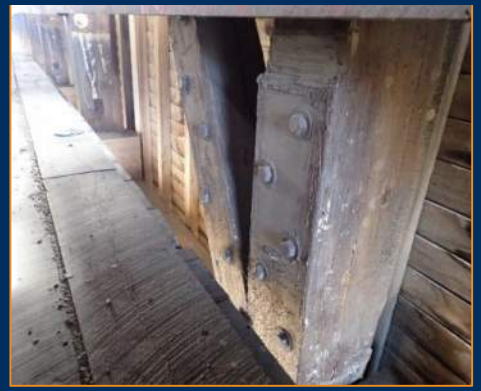
Truss and Arch Members

Age of the Bridge

- Minor Wear
- Carving marks
- Nails/ holes from various signs
- Previous probe marks
- Previous fire damage?
- Animal damage?

Truss and Arch Members

Bolted Steel Plate and Epoxy Repairs



Truss and Arch Members

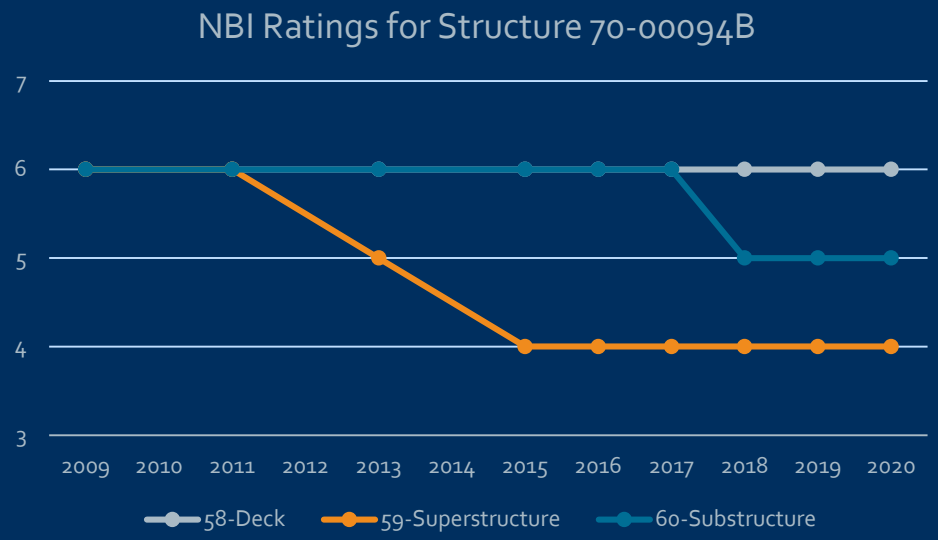
- Minor Distress. Some Severe Decay
- Most Decay at End Panels and Bearings

Arch Member Bearings

Stone Masonry Abutments

- Delamination type cracking in stone
- Bond line separations in mortar joints
- Some delaminations have progressed to spalls

Condition Assessment Ratings



- NBI 058 – Deck

  6 – Satisfactory

  Minor deterioration of planks

- NBI 059 – Superstructure

  4 – Poor

  Moderate to severe decay of truss members and arch, particularly at bearings

- NBI 060 – Substructure

  5 – Fair

  Deterioration of stone abutments. No significant loss of capacity.

Recommendations

- Repairs needed for some members, especially at arch bearings. Repairs should consider long term durability of the remaining wood in repaired areas
  - Arch Bearings
  - End Segments of Bottom Chords
- Evaluate suitability for local masonry repairs at abutments, and implement
- Repair holes in siding and roof. Segments need a compatible lapped board system or replacement
- Monitor decay at other repair locations

References

- *FHWA Bridge Inspector's Reference Manual* (BIRM), Chapter 8 – Inspection and Evaluation of Timber Structures
- *Covered Bridges and the Birth of American Engineering*, Christianson, J. et. al., Historic American Engineering Record, National Park Service and FHWA (2015)
- *Guidelines for Rehabilitating Historic Covered Bridges*, Marston, C.H. and Vitanza, T. A., Historic American Engineering Record, National Park Service and FHWA (2019)

WJE

Thank You!