Workshop Agenda

VIII. Load Rating Example #2
- Simple Span Nail Laminated Timber Deck (without distress)

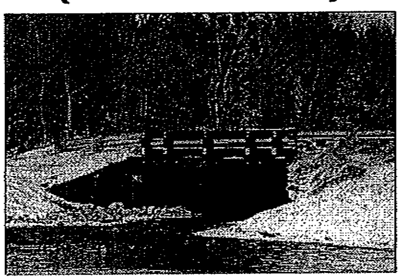
IX. Class Exercise
- Simple Span Nail Laminated Timber Deck (with distress)

X. Review of worked out examples

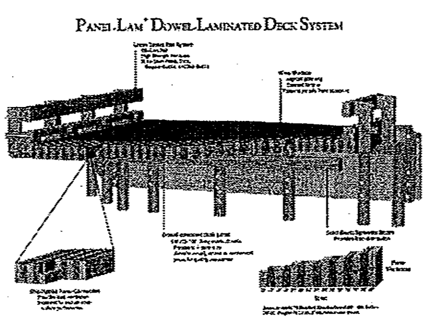
XI. Submittal to MN/DOT and Review of Process

XII. Common mistakes and questions

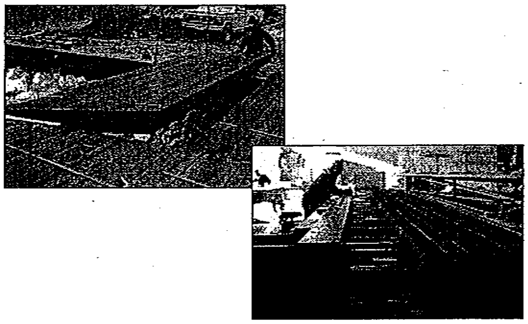
Simple Span Nail Laminated Timber Deck Example (without distress)



Nail Laminated Timber Deck



Nail Laminated Timber Deck



Simple Span Nail Laminated Timber Deck Example (without distress)

- A simple span nail laminated bridge, two lanes.
- 32'-1" roadway, Span length = 20'-10"
- Timber dimensions were field measured (actual)
- Good maintenance and inspection

Simple Span Nail Laminated Timber Deck Example (without distress)

- Deck in new condition
- Year built 1966
- Average wear course thickness of 3.5"
- 0 degree skew
- Timber species: Douglas fir-larch No. 2

MINNESOTA DEPARTMENT OF TRANSPORTATION

ASR TIMBER LONGITUDINAL NAIL LAMINATED DECK RATING WORKSHEET

Location: Rye Rd. over Bourbon Creek

Given information:
- A simple span nail laminated bridge, two lanes.
- Timber dimensions were field measured (actual)
- Good maintenance and inspection
- Deck in new condition
- Average wear course thickness of 3.5"
- 0 degree skew
- Timber species: Douglas fir-larch No. 2 (coastal region)

Unit Definitions

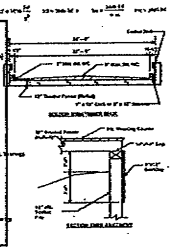
Input

Reference AASHTO Table 13.5.1A

Species: Douglas fir-larch (coastal region)

Commercial Grade: No. 2

Size Class: 2" and wider



Determine allowable unit stress for bending

$F_b' = F_b \times C_M \times C_D \times C_F \times C_r$

Timber Adjustment Factors

Allowable unit stress for bending

Determine allowable unit stress for shear

$F_v' = F_v \times C_M \times C_D$

Determine Effective Span Length (3.25.2.3)

Determine allowable unit stress for bending

$F_b' = F_b \times C_M \times C_D \times C_F \times C_r$

Timber Adjustment Factors

Allowable unit stress for bending

Determine allowable unit stress for shear

$F_v' = F_v \times C_M \times C_D$

Determine Effective Span Length (3.25.2.3)

Determine allowable unit stress for bending

Timber Adjustment Factors

Allowable unit stress for bending

Determine allowable unit stress for shear

Determine Effective Span Length

Compute Live Load Distribution Width per AASHTO

Dead Loads

Compute Dead Load Moment

Compute Live Load Moment

Compute Live Load Distribution Width per AASHTO

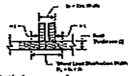
Dead Loads

Compute Dead Load Moment

Compute Live Load Moment

Compute Live Load Distribution Width per AASHTO 3.25.2.2

Normal to direction of the span, wheel load shall be distributed as follows. [illegible]



[illegible]

Dead Loads

[illegible]

Compute Dead Load Moment

[illegible]

Compute Live Load Moment

HS20 Truck Moment per AASHTO App. A (Note that Live load moments in App. A are based on one lane without impact)

For Span = [illegible] feet

For Span = [illegible] feet

Therefore for Span = [illegible] feet

[illegible]

Section Modulus of deck

Section Modulus: [illegible]

Calculate Inventory and Operating Ratings of deck based on flexure

Calculate Inventory Level Rating

[illegible] (Dead load bending stress) [illegible]

[illegible] (Live load bending stress) [illegible]

Calculate Operating Rating Factors for bending in deck

[illegible]

Inventory Rating [illegible]

Operating Rating [illegible]

Note: Rating for shear will not control over rating for flexure when rating nail laminated bridge decks

Section Modulus of deck

Section Modulus: [illegible]

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Calculate Inventory Level Rating

Calculate Operating Rating Factors for bending in deck

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Note: Rating for shear will not control over rating for flexure when rating nail laminated bridge decks

Section Modulus of deck

Calculate Inventory and Operating Ratings of deck based on flexure

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Calculate Operating Rating Factors for bending in deck

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Note: Rating for shear will not control over rating for flexure when rating nail laminated bridge decks

Simple Span Nail Laminated Timber Deck Example #2 (with distress)

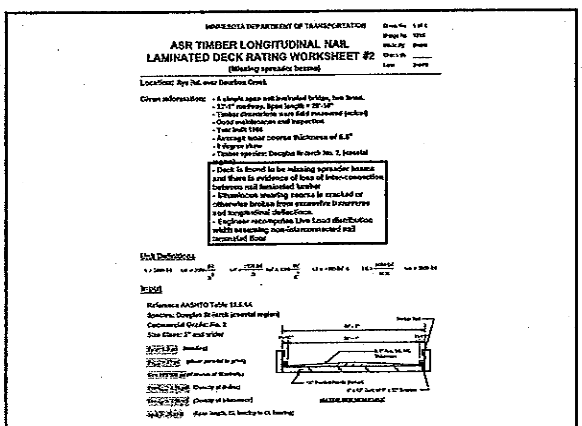
- A simple span nail laminated bridge, two lanes.
- 32'-1" roadway, Span length = 20'-10"
- Timber dimensions were field measured (actual)
- Good maintenance and inspection
- Year built 1966

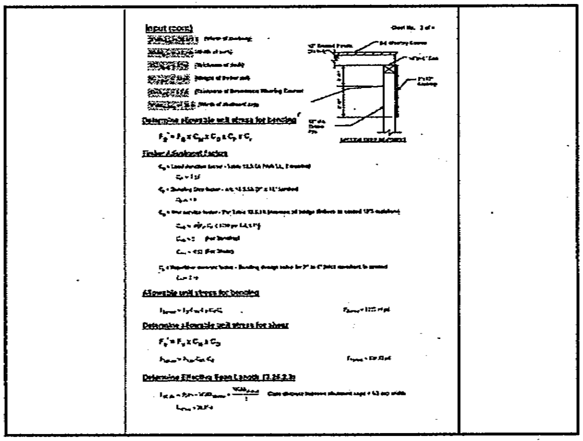
Simple Span Nail Laminated Timber Deck Example #2 (with distress)

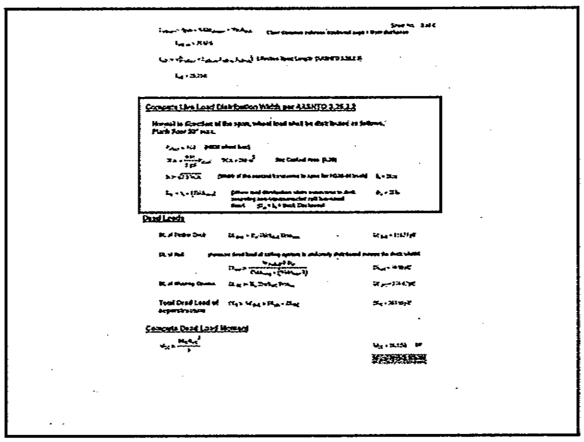
- Average wear course thickness of 6.5"
- 0 degree skew
- Timber species: Douglas fir-larch No. 2
- Deck is found to be missing spreader beams and there is evidence of loss of inter-connection between nail laminated lumber

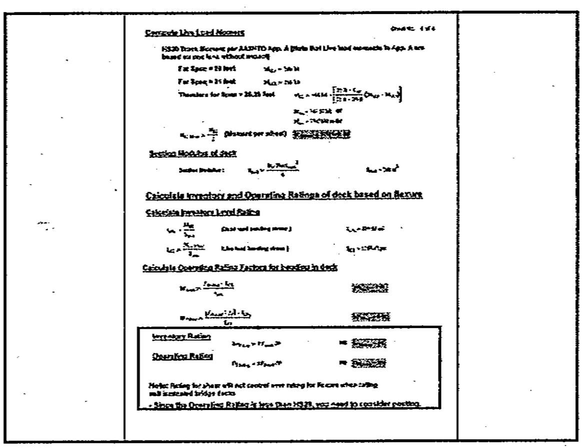
Simple Span Nail Laminated Timber Deck Example #2 (with distress)

- Bituminous wearing course is cracked or otherwise broken from excessive transverse and longitudinal deflections.
- Engineer must recompute Live Load distribution width assuming non-interconnected nail laminated floor


ASR TIMBER LONGITUDINAL NAIL
LAMINATED DECK RATING WORKSHEET #2


Input (cont)
Determine allowable unit stress for bending
Timber Adjustment Factors
Allowable unit stress for bending
Determine allowable unit stress for shear
Determine Effective Span Length (3.25.2.3)


Dead Loads
Compute Dead Load Moment


Compute Live Load Moments
Section Modulus of deck
Calculate Inventory and Operating Ratings of deck based on flexure
Calculate Inventory Level Rating
Inventory Rating
Operating Rating
- Since the Operating Rating is less than HS20, you need to consider posting.

2008 BRIDGE RATING CLASS 101

Timber Basics

Sawn Lumber Beams:

- Typically 4" to 8" wide, 12" to 18" deep with spans up to 25'; beams spaced 2' to 6' apart.

Glue Laminated Beams:

- Manufactured from 1-1/2" or 1-3/8" thick lumber laminations with waterproof adhesives.
- Beam widths from 3" to 14-1/4" with depths limited only by transportability. Spans range from 20' to 80'.

Longitudinal Deck Superstructures:

- Glulam Panels
    - Glue laminated longitudinally
    - Panels are 6-3/4" to 14-1/4" deep and 42" to 54" wide
- Nail or Spike laminated Panels
    - Uses 2" to 4" wide sawn lumber, 8"-16" deep, nailed or spiked together
- Clear spans for longitudinal decks up to 36'

Spreader Beams:

- Stiffener beams placed across the deck width to distribute live loads among the individual panels.
- Spreader beams are placed at midspan and at intermediate spacings not to exceed 10 feet.

Timber Substructures:

- Abutments:
    - Pile abutments (See Photo 1 below); superstructure is supported on timber piles (20 to 32 tons capacity) with average pile length from 30 to 65 feet.
    - The superstructure is connected to the piles by a continuous cap attached to the piles and superstructure.

- Piers:
    - Bents used for multiple-span crossings. Constructs of timber piles with bracing to provide stability and resist lateral loads. The superstructure is connected to the piles by a continuous cap attached to the piles and superstructure (See Photo 2 below).

Physical Properties:

- Density – 50 pcf used for design.
- Durability - Keep dry, with moisture content below approximately 20%
- Wood fully saturated with water does not decay
- Decay needs air, water, and temperature
- Chemicals used for preservative treatment have little or no effect on strength

Mechanical Properties:

- Directional Characteristics:
  - Compressive strength parallel to grain may be 5 to 10 times greater than that perpendicular to the grain.
  - Modulus of Elasticity (E) parallel to the grain is 10 to 25 times that perpendicular to the grain

- Resistance to Shear Loads:
  - Shear strength parallel to grain has a relative low value. Shear strength across the grain is never considered, since its value is high and failure will occur first in shear parallel to grain

- Resistance to Repeated Loads:
  - Fatigue strength of wood is often several times that of most metals. Repeated loads are generally of little concern. Fatigue is not normally a consideration in timber bridge design.

- Resistance to Rapidly Applied or Long-Continued loads:
  - The load that will cause failure in a member that must carry loads continuously for long periods of time is much less than the load that would cause failure in a few minutes
  - i.e. A member under continuous action of bending stress for 10 years will carry only about 60% of the load under which the same member would fail in a few minutes

Effects:

- Moisture - Higher properties at the lower moisture contents.
- Temperature - Properties increase with cooler temps, decrease with hotter temps. Temp effects are recoverable in short durations. Temps greater than 150 deg F for extended periods will result in permanent reduction in strength.
- Decay - Delay effects can be several times greater than usual observations. 50%-70% strength loss with corresponding weight loss of 3%.
- Ultraviolet - Degradation is very slow – ¼" per century – no serious effects on properties

Adjustments to Tabulated Design Values (standard conditions):

- When actual conditions vary from standard conditions, tabulated values must be adjusted by the appropriate factors.

"Factors": C_M – Moisture content (wet use factor)
C_D – Duration of load
C_F – Size factor
C_f – Form factor
C_L – Lateral stability of beams
C_P – Lateral stability of columns

Applicable Factors for Strength Properties:

- **Bending F_b:** C_D, C_M, C_F, C_f, C_L
- **Compression F_c:** C_D, C_M, C_P
- **Horizontal shear F_v:** C_D, C_M
- **Modulus of Elasticity E:** C_M

NOTE: Design values are for 10 year load and dry service conditions

(C_D) – When the load is applied for periods other than 10 yrs, tabulated stresses are multiplied by C_D in AASHTO Table 13.5.5A. For vehicle live load, $C_D = 1.15$

(C_M) - Use when moisture content is expected to exceed 19%, per AASHTO Art. 13.5.5.1.1, C_m values given in footnotes of Table 13.5.1A.

(C_F) - For rectangular sawn lumber, bending members 5 inches or thicker and greater than 12" in depth, reference AASHTO 13.6.4.2.2
$C_F = (12 / d)^{1/9}$
d = member depth in inches

(C_f) - Form factor, tabulated bending stresses are based on members with square and rectangular cross sections. For round sections, stresses must be modified by the form factor C_f per AASHTO 13.6.4.5.
$C_f = 1.18$

(C_L) - When members are not adequately braced, tabulated bending stress shall be modified by C_L. When there is no danger of lateral buckling, $C_L = 1.0$.
- Other cases use AASHTO 13.6.4.4.3

(C_P) - When a compression member is supported throughout its length to prevent displacement, $C_P = 1.0$ per AASHTO 13.7.3.3.2

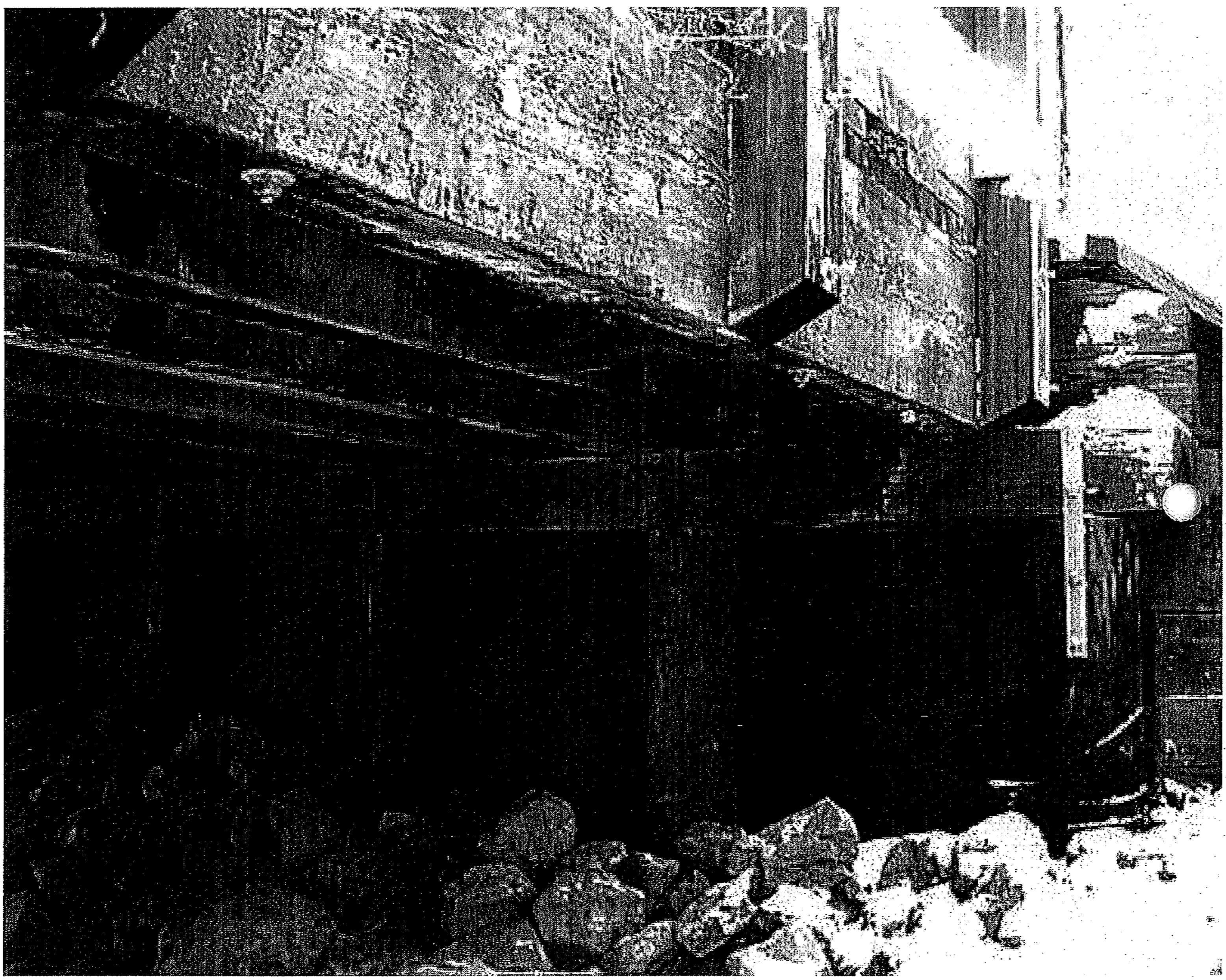


Photo 1

Photo 2

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2008 BRIDGE RATING CLASS 101

DESIGN OF TIMBER SUPERSTRUCTURE BASICS

LOADS

Dead Loads (permanent wt)

- Steel - 490 lb/ft
- Earth - 120 lb/ft
- Compacted gravel - 140 lb/ft
- Timber - 50 lb/ft
- Bit. - 150 lb/ft
- Conc. - 150 lb/ft

- Dead loads are commonly assumed to be uniformly distributed along the length of a structural member (beam, deck panel, etc).

Live Loads (vehicular)

Terms:
- Gross vehicle wt (GVW) – is the maximum total weight of vehicle
- Axle load – is the total weight transferred through one axle
- Axle spacing – is center-to-center distance between axles
- Wheel load – is one half the axle load
- Wheel line – is series of wheel loads measured along the vehicle length, one-half GVW
- Track width – is the center-to-center distance between wheel lines

Standard vehicle loads

- AASHTO specifications provide 2 systems of standard vehicle loads: H loads and HS loads. Each system consists of individual truck loads or lane loads.

H Truck loads:

H 15-44
H 20-44

- Represents a two axle truck designated by the letter H followed by the first number indicating the GVW in tons.

- The second number "44" indicates the year the load was adopted by AASHTO (1944). The weight of an H truck assumes 2/10th weight to front axle, 8/10th to rear axle. Axles are spaced at 14' with track width of 6'.

HS Truck loads:

HS – 15-44
HS – 20-44

- Represent a two axle truck with a one-axle semi-trailer. The configuration and weight of the HS truck is identical to the corresponding H load. The additional semi-trailer axle is equal in weight to the rear truck axle and is spaced at a variable distance of 14 to 30'.

Traffic Lanes:

- Vehicle live loads are applied in design traffic lanes that are 12' wide. The number of traffic lanes depends on the width of the bridge roadway. Fractional parts of design lanes are not permitted.

- Each traffic lane is loaded with one standard truck or one standard lane load, regardless of the bridge length or number of spans. The standard loads occupy a 10' width within the lane. Traffic lanes and vehicle loads in lanes are positioned laterally on the bridge to produce the maximum stress. Traffic lanes cannot overlap.

- The number of traffic lanes to be loaded should be in conformance with AASHTO and the following:

- Rdwy 18' to 20', should have two design lanes
- Rdwy less than 18' should carry one traffic lane

Reduction in Load Intensity

- When live load stress is based on a number of traffic lanes simultaneously loaded, the following percentages of live loads may be used in view of the improbability:

- One or two lanes – 100%
- Three lanes – 90%
- Four lanes or more – 75%

- AASHTO also specifies an alternate military loading. This hypothetical loading consists of two 24,000 lb axles spaced 4' apart. There is no lane load for military loading.

Lane Loads:

- Adopted by AASHTO to provide a simpler method of calculating moments and shears to simulate a train of trucks on the bridge.

- AASHTO specs include a lane load for HS20-44. The uniform load is 640 lbs per linear foot of load lane with concentrated loads for shear and moment.

Modification to Standard Loads

- There may be instances when the standard vehicle loads do not accurately represent the design loading required for a bridge.

- For example, in 1989 live loading for State Aid bridges was revised to HS25 from the previous HS20 loading. Since 1944, when HS20 was established, truck weights have continued to increase along with allowable legal loads in response to trucking industry requests. In fact, the legal load in Minnesota allows trucks which exceed the HS20 design load by up to 10%.

- FYI: Cost imports of revising to HS25 resulted in a weighted average cost increase of 4.0% for bridges.

Distribution of Live Loads

- The fraction of live load transferred to a single member should be per AASHTO design specs. See AASHTO table 3.23.1 Distribution of Wheel Loads.

- Ref. AASHTO art. 3.25.2 Live Load Distribution for plank and nail laminated longitudinal flooring.

Impact (Dynamic / Vibratory Effects)

- Impact should be added to the live load for rating per AASHTO 3.8.

- Note: Because timber's ability to absorb shock and loads of short duration, AASHTO does not require an impact factor for timber bridges (AASHTO standard specs only).

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MINNESOTA DEPARTMENT OF TRANSPORTATION

ASR TIMBER LONGITUDINAL NAIL LAMINATED DECK RATING WORKSHEET

Sheet No.	1 of 4
Bridge No.	1895
Made By	Beam
Check By	______
Date	3/4/08

Location: Rye Rd. over Bourbon Creek

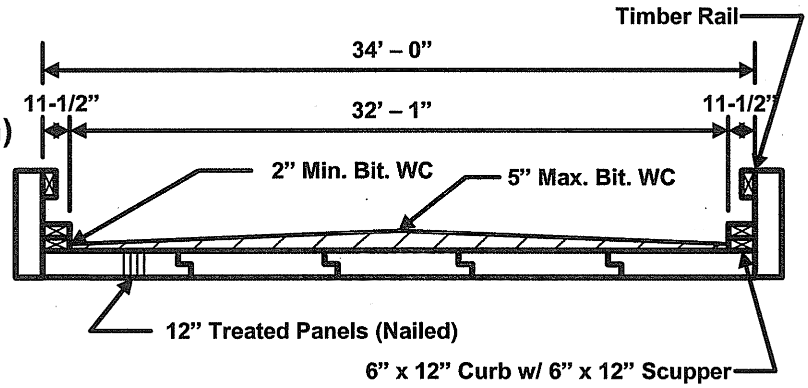
Given information:
- A simple span nail laminated bridge, two lanes.
- 32'-1" roadway, Span length = 20'-10"
- Timber dimensions were field measured (actual)
- Good maintenance and inspection
- Deck in new condition
- Year built 1966
- Average wear course thickness of 3.5"
- 0 degree skew
- Timber species: Douglas fir-larch No. 2, (coastal region)

Unit Definitions

$k \equiv 1000 \cdot lbf$ $ksf \equiv 1000 \cdot \frac{lbf}{ft^2}$ $klf \equiv \frac{1000 \cdot lbf}{ft}$ $kcf \equiv 1000 \cdot \frac{lbf}{ft^3}$ $kft \equiv 1000 \cdot lbf \cdot ft$ $ksi \equiv \frac{1000 \cdot lbf}{in \cdot in}$ $ton \equiv 2000 \cdot lbf$

Input

Reference AASHTO Table 13.5.1A
Species: Douglas fir-larch (coastal region)
Commercial Grade: No. 2
Size Class: 2" and wider



SECTION THRU TIMBER DECK

$F_B := 875 \cdot psi$ (bending)

$Fv_{par} := 95 \cdot psi$ (shear parallel to grain)

$E := 1600000 \cdot psi$ (Modulus of Elasticity)

$Dens_{timb} := 50 \cdot pcf$ (Density of timber)

$Dens_{bit} := 150 \cdot pcf$ (Density of bituminous)

$Span := 20.83 \cdot ft$ (Span length, CL bearing to CL bearing)

$Width_{rdwy} := 32.083 \cdot ft$ (Width of roadway)

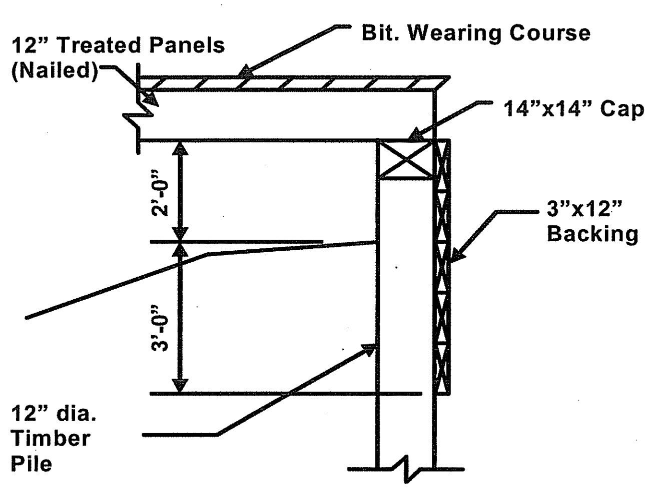
$Width_{rail} := 11.5 \cdot in$ (Width of curb)

$Thick_{deck} := 12 \cdot in$ (Thickness of deck)

$W_{TimRail} := 70 \cdot plf$ (Weight of timber rail)

$Thick_{WC} := 3.5 \cdot in$ (Thickness of Bituminous Wearing Course)

$Width_{abutcap} := 14 \cdot in$ (Width of abutment cap)



SECTION THRU ABUTMENT

Determine allowable unit stress for bending

$$F_B' = F_B \times C_M \times C_D \times C_F \times C_r$$

Timber Adjustment Factors

C_D = Load duration factor - Table 13.5.5A (Veh LL, 2 months)

$C_D := 1.15$

C_F = Bending Size factor - Art. 13.5.1A (4" x 14" lumber)

$C_F := 1.0$

C_M = Wet service factor - Per Table 13.5.1A (Assume all bridge timbers to exceed 19% moisture)

$C_{Mb} := \text{if}\left(F_B \cdot C_F \le 1150 \cdot \text{psi}, 1.0, 0.85\right)$

$C_{Mb} = 1$ **(For Bending)**

$C_{Mv} := 0.97$ **(For Shear)**

C_r = Repetitive member factor - Bending design value for 2" to 4" thick members in contact

$C_r := 1.15$

Allowable unit stress for bending

$F_{Bprime} := F_B \cdot C_{Mb} \cdot C_D \cdot C_F \cdot C_r$ $F_{Bprime} = 1157.19\ \text{psi}$

Determine allowable unit stress for shear

$$F_V' = F_V \times C_M \times C_D$$

$F_{Vprime} := F_{Vpar} \cdot C_{Mv} \cdot C_D$ $F_{Vprime} = 105.97\ \text{psi}$

Determine Effective Span Length (3.25.2.3)

$L_{effmin} := \text{Span} - \text{Width}_{abutcap} + \dfrac{\text{Width}_{abutcap}}{2}$ **Clear distance between abutment caps + 1/2 cap width**

$L_{effmin} = 20.25\ \text{ft}$

$L_{effmax} := \text{Span} - \text{Width}_{abutcap} + \text{Thick}_{deck}$ **Clear distance between abutment caps + floor thickness**

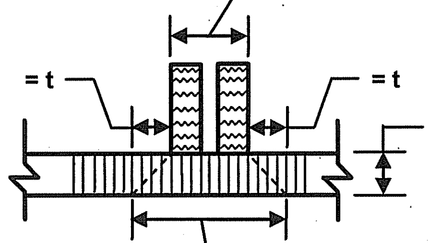
$L_{effmax} = 20.66\ \text{ft}$

$L_{eff} := \text{if}\left(L_{effmin} < L_{effmax}, L_{effmin}, L_{effmax}\right)$ **Effective Span Length (AASHTO 3.25.2.3)**

$L_{eff} = 20.25 \cdot \text{ft}$

Compute Live Load Distribution Width per AASHTO 3.25.2.2

Normal to direction of the span, wheel load shall be distributed as follows. Plank floor 20" max.



$P_{wheel} := 16000 \cdot lbf$ **(HS20 wheel load)**

$TCA := \frac{0.01}{1 \cdot psi} \cdot P_{wheel}$ $TCA = 160 \cdot in^2$ **Tire Contact Area (3.30)**

$b_t := \sqrt{2.5 \cdot TCA}$ **(Width of tire contact transverse to span for HS20-44 truck)** $b_t = 20\,in$

$D_w := b_t + (2 \cdot Thick_{deck})$ **(Wheel load distribution width transverse to deck)** $D_w = 44\,in$
($D_w = b_t$ + [2 x Deck Thickness])

Dead Loads

DL of Timber Deck $DL_{deck} := D_w \cdot Thick_{deck} \cdot Dens_{timb}$ $DL_{deck} = 183.33\,plf$

DL of Rail **(Assume dead load of railing system is uniformly distributed across the deck width)**

$$DL_{rail} := \frac{W_{TimRail} \cdot 2 \cdot D_w}{Width_{rdwy} + (Width_{rail} \cdot 2)}$$ $DL_{rail} = 15.1\,plf$

DL of Wearing Course $DL_{WC} := D_w \cdot Thick_{WC} \cdot Dens_{bit}$ $DL_{WC} = 160.42\,plf$

Total Dead Load of superstructure $DL_T := DL_{deck} + DL_{rail} + DL_{WC}$ $DL_T = 358.85\,plf$

Compute Dead Load Moment

$$M_{DL} := \frac{DL_T \cdot L_{eff}^2}{8}$$

$M_{DL} = 18.39\,ft\,k$ **or**

$M_{DL} = 220652.62\,in \cdot lbf$

Compute Live Load Moment

HS20 Truck Moment per AASHTO App. A (Note that Live load moments in App. A are based on one lane without impact)

For Span = 20 feet $M_{LL1} := 160 \cdot kft$

For Span = 21 feet $M_{LL2} := 168 \cdot kft$

Therefore for Span = 20.25 feet $$M_{LL} := 168 \cdot kft - \left[\frac{21 \cdot ft - L_{eff}}{21 \cdot ft - 20 \cdot ft} \cdot (M_{LL2} - M_{LL1})\right]$$

$M_{LL} = 161.97\,kft$ **or**

$M_{LL} = 1943680\,in \cdot lbf$

$M_{LLWheel} := \frac{M_{LL}}{2}$ **(Moment per wheel)** $M_{LLWheel} = 971840\,in \cdot lbf$

Section Modulus of deck

Section Modulus : $S_{deck} := \frac{D_w \cdot Thick_{deck}^2}{6}$ $S_{deck} = 1056\,in^3$

Calculate Inventory and Operating Ratings of deck based on flexure

Calculate Dead and Live Load bending stresses

$f_{bDL} := \frac{M_{DL}}{S_{deck}}$ **(Dead load bending stress)** $f_{bDL} = 208.95\,psi$

$f_{bLL} := \frac{M_{LLWheel}}{S_{deck}}$ **(Live load bending stress)** $f_{bLL} = 920.3\,psi$

Calculate Inventory and Operating Rating Factors for bending in deck

$RF_{Ideck} := \frac{F_{Bprime} - f_{bDL}}{f_{bLL}}$ $RF_{Ideck} = 1.03$

$RF_{Odeck} := \frac{(F_{Bprime} \cdot 1.33) - f_{bDL}}{f_{bLL}}$ $RF_{Odeck} = 1.45$

Inventory Rating

$Inv_{Rating} := RF_{Ideck} \cdot 20$ **HS** $Inv_{Rating} = 21$

Operating Rating

$Op_{Rating} := RF_{Odeck} \cdot 20$ **HS** $Op_{Rating} = 29$

Note: Rating for shear will not control over rating for flexure when rating nail laminated bridge decks

Sheet No.	1 of 4
Bridge No.	1895
Made By	Beam
Check By	______
Date	3/4/08

ASR TIMBER LONGITUDINAL NAIL LAMINATED DECK RATING WORKSHEET #2

(Missing spreader beams)

Location: Rye Rd. over Bourbon Creek

Given information:
- A simple span nail laminated bridge, two lanes.
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- Timber dimensions were field measured (actual)
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- Year built 1966
- Average wear course thickness of 6.5"
- 0 degree skew
- Timber species: Douglas fir-larch No. 2, (coastal region)
- Deck is found to be missing spreader beams and there is evidence of loss of inter-connection between nail laminated lumber
- Bituminous wearing course is cracked or otherwise broken from excessive transverse and longitudinal deflections.
- Engineer recomputes Live Load distribution width assuming non-interconnected nail laminated floor

Unit Definitions

$k \equiv 1000 \cdot lbf$ $\quad ksf \equiv 1000 \cdot \frac{lbf}{ft^2}$ $\quad klf \equiv \frac{1000 \cdot lbf}{ft}$ $\quad kcf \equiv 1000 \cdot \frac{lbf}{ft^3}$ $\quad kft \equiv 1000 \cdot lbf \cdot ft$ $\quad ksi \equiv \frac{1000 \cdot lbf}{in \cdot in}$ $\quad ton \equiv 2000 \cdot lbf$

Input

Reference AASHTO Table 13.5.1A

Species: Douglas fir-larch (coastal region)

Commercial Grade: No. 2

Size Class: 2" and wider

$F_B := 875 \cdot psi$ (bending)

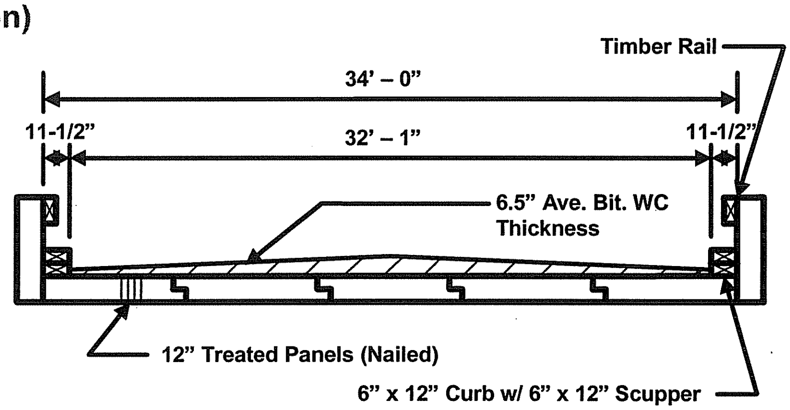
$F_{Vpar} := 95 \cdot psi$ (shear parallel to grain)

$E := 1600000 \cdot psi$ (Modulus of Elasticity)

$Dens_{timb} := 50 \cdot pcf$ (Density of timber)

$Dens_{bit} := 150 \cdot pcf$ (Density of bituminous)

$Span := 20.83 \cdot ft$ (Span length, CL bearing to CL bearing)



SECTION THRU TIMBER DECK

Input (cont)

$Width_{rdwy} := 32.083 \cdot ft$ **(Width of roadway)**

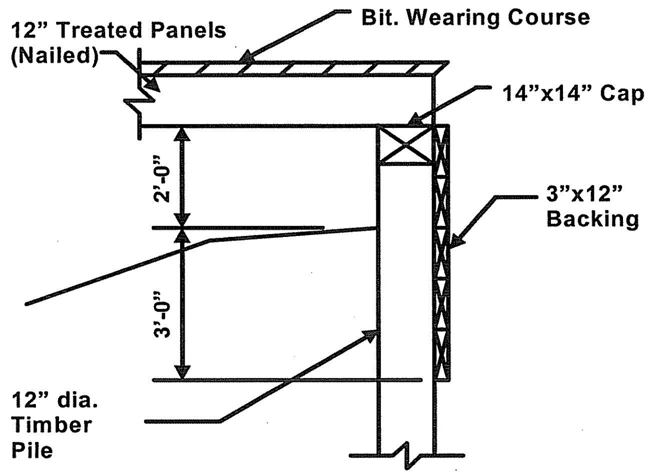
$Width_{rail} := 11.5 \cdot in$ **(Width of curb)**

$Thick_{deck} := 12 \cdot in$ **(Thickness of deck)**

$W_{TimRail} := 70 \cdot plf$ **(Weight of timber rail)**

$Thick_{WC} := 6.5 \cdot in$ **(Thickness of Bituminous Wearing Course)**

$Width_{abutcap} := 14 \cdot in$ **(Width of abutment cap)**



SECTION THRU ABUTMENT

Determine allowable unit stress for bending

$$F_B' = F_B \times C_M \times C_D \times C_F \times C_r$$

Timber Adjustment Factors

C_D = Load duration factor - Table 13.5.5A (Veh LL, 2 months)

$C_D := 1.15$

C_F = Bending Size factor - Art. 13.5.1A (4" x 14" lumber)

$C_F := 1.0$

C_M = Wet service factor - Per Table 13.5.1A (Assume all bridge timbers to exceed 19% moisture)

$C_{Mb} := if(F_B \cdot C_F \le 1150 \cdot psi, 1.0, 0.85)$

$C_{Mb} = 1$ **(For Bending)**

$C_{Mv} := 0.97$ **(For Shear)**

C_r = Repetitive member factor - Bending design value for 2" to 4" thick members in contact

$C_r := 1.15$

Allowable unit stress for bending

$F_{Bprime} := F_B \cdot C_{Mb} \cdot C_D \cdot C_F \cdot C_r$ $\qquad F_{Bprime} = 1157.19\,psi$

Determine allowable unit stress for shear

$$F_V' = F_V \times C_M \times C_D$$

$F_{Vprime} := F_{Vpar} \cdot C_{Mv} \cdot C_D$ $\qquad F_{Vprime} = 105.97\,psi$

Determine Effective Span Length (3.25.2.3)

$L_{effmin} := Span - Width_{abutcap} + \frac{Width_{abutcap}}{2}$ **Clear distance between abutment caps + 1/2 cap width**

$L_{effmin} = 20.25\,ft$

$L_{effmax} := Span - Width_{abutcap} + Thick_{deck}$ **Clear distance between abutment caps + floor thickness**

$L_{effmax} = 20.66\,ft$

$L_{eff} := if(L_{effmin} < L_{effmax}, L_{effmin}, L_{effmax})$ **Effective Span Length (AASHTO 3.25.2.3)**

$L_{eff} = 20.25 \cdot ft$

Compute Live Load Distribution Width per AASHTO 3.25.2.2

Normal to direction of the span, wheel load shall be distributed as follows. Plank floor 20" max.

$P_{wheel} := 16000 \cdot lbf$ **(HS20 wheel load)**

$TCA := \frac{0.01}{1 \cdot psi} \cdot P_{wheel}$ $TCA = 160 \cdot in^2$ **Tire Contact Area (3.30)**

$b_t := \sqrt{2.5 \cdot TCA}$ **(Width of tire contact transverse to span for HS20-44 truck)** $b_t = 20\,in$

$D_w := b_t + (Thick_{deck})$ **(Wheel load distribution width transverse to deck assuming non-interconnected nail laminated floor) ($D_w = b_t$ + Deck Thickness)** $D_w = 32\,in$

Dead Loads

DL of Timber Deck $DL_{deck} := D_w \cdot Thick_{deck} \cdot Dens_{timb}$ $DL_{deck} = 133.33\,plf$

DL of Rail **(Assume dead load of railing system is uniformly distributed across the deck width)**

$$DL_{rail} := \frac{W_{TimRail} \cdot 2 \cdot D_w}{Width_{rdwy} + (Width_{rail} \cdot 2)}$$ $DL_{rail} = 10.98\,plf$

DL of Wearing Course $DL_{WC} := D_w \cdot Thick_{WC} \cdot Dens_{bit}$ $DL_{WC} = 216.67\,plf$

Total Dead Load of superstructure $DL_T := DL_{deck} + DL_{rail} + DL_{WC}$ $DL_T = 360.98\,plf$

Compute Dead Load Moment

$$M_{DL} := \frac{DL_T \cdot L_{eff}^2}{8}$$

$M_{DL} = 18.5\,ft\,k$ **or**

$M_{DL} = 221963.76\,in \cdot lbf$

Compute Live Load Moment

HS20 Truck Moment per AASHTO App. A (Note that Live load moments in App. A are based on one lane without impact)

For Span = 20 feet $M_{LL1} := 160 \cdot kft$

For Span = 21 feet $M_{LL2} := 168 \cdot kft$

Therefore for Span = 20.25 feet $M_{LL} := 168 \cdot kft - \left[\frac{21 \cdot ft - L_{eff}}{21 \cdot ft - 20 \cdot ft} \cdot \left(M_{LL2} - M_{LL1} \right) \right]$

$M_{LL} = 161.97\,kft$ **or**

$M_{LL} = 1943680\,in \cdot lbf$

$M_{LLWheel} := \frac{M_{LL}}{2}$ **(Moment per wheel)** $M_{LLWheel} = 971840\,in \cdot lbf$

Section Modulus of deck

Section Modulus : $S_{deck} := \frac{D_w \cdot Thick_{deck}^{\,2}}{6}$ $S_{deck} = 768\,in^3$

Calculate Inventory and Operating Ratings of deck based on flexure

Calculate Dead and Live Load bending stresses

$f_{bDL} := \frac{M_{DL}}{S_{deck}}$ **(Dead load bending stress)** $f_{bDL} = 289.02\,psi$

$f_{bLL} := \frac{M_{LLWheel}}{S_{deck}}$ **(Live load bending stress)** $f_{bLL} = 1265.42\,psi$

Calculate Inventory and Operating Rating Factors for bending in deck

$RF_{Ideck} := \frac{F_{Bprime} - f_{bDL}}{f_{bLL}}$ $RF_{Ideck} = 0.69$

$RF_{Odeck} := \frac{\left(F_{Bprime} \cdot 1.33 \right) - f_{bDL}}{f_{bLL}}$ $RF_{Odeck} = 0.99$

Inventory Rating

$Inv_{Rating} := RF_{Ideck} \cdot 20$ **HS** $Inv_{Rating} = 14$

Operating Rating

$Op_{Rating} := RF_{Odeck} \cdot 20$ **HS** $Op_{Rating} = 20$

Note: Rating for shear will not control over rating for flexure when rating nail laminated bridge decks

- Since the Operating Rating is very close to HS20, you may need to consider posting