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)

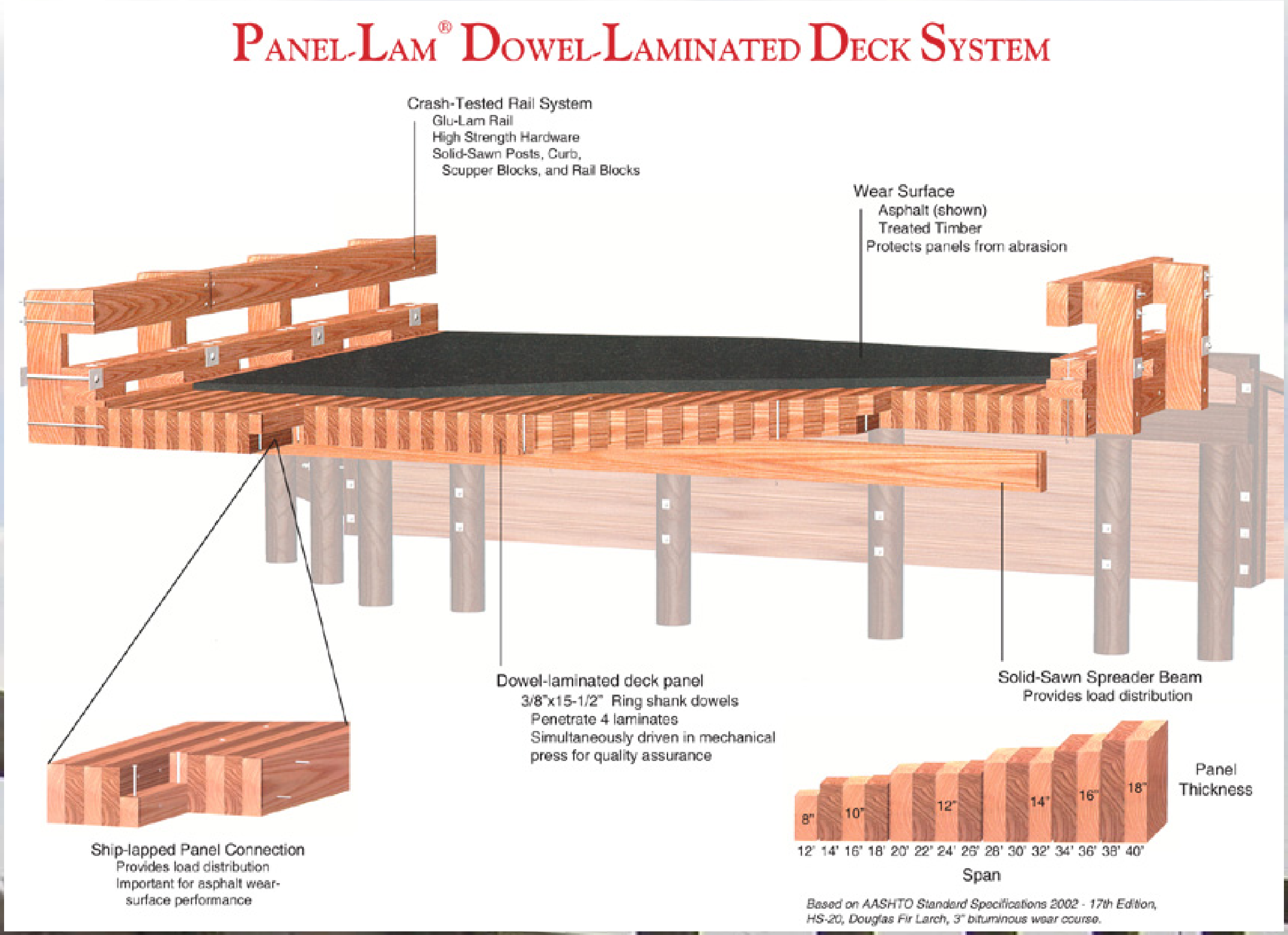
X. Review of worked out examples

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

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

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

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)

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

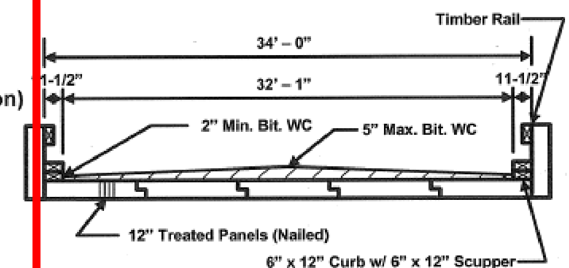
$Width_{curb} := 11.5 \cdot in$ (Width of curb)

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

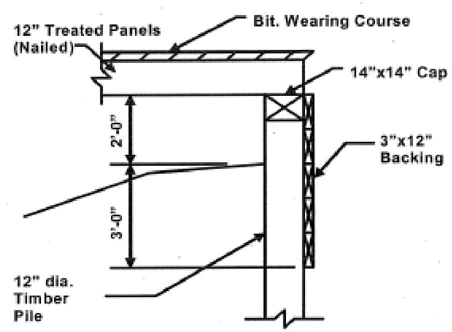
$W_{TimRail} := 70 \cdot plf$ (Weight of timber rail)

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

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



SECTION THRU TIMBER DECK



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 (3" x 12" lumber)

$C_F := 1.0$

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

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

$C_{Mb} = 1$ (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

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

Determine allowable unit stress for shear

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

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

Determine Effective Span Length (3.25.2.3)

$L_{effmin} := \text{Span} - \text{Width}_{abutcap} + \frac{\text{Width}_{abutcap}}{2}$ 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

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

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

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

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 (3" x 12" lumber)

$C_F := 1.0$

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

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

$C_{Mb} = 1$ (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

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

Determine allowable unit stress for shear

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

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

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

$L_{effmax} = 20.66\ ft$

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

$L_{eff} = 20.25 \cdot ft$

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 (3" x 12" lumber)

$C_F := 1.0$

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

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

$C_{Mb} = 1$ (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

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

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)

$L_{effmin} := \text{Span} - \text{Width}_{abutcap} + \frac{\text{Width}_{abutcap}}{2}$ 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

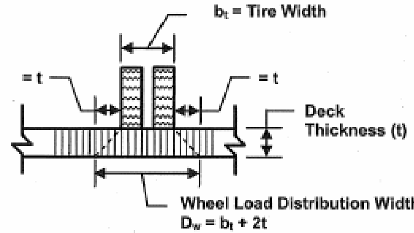
$L_{effmax} = 20.66\ \text{ft}$

$L_{eff} := \text{if}(L_{effmin} < L_{effmax}, L_{effmin}, L_{effmax})$ 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.



$P_{wheel} := 16 \cdot k$ **(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)**

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

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

$$M_{DL} := \frac{DL_T \cdot L_{eff}^2}{8} \qquad M_{DL} = 18.39\,ft\,k \quad \textbf{or}$$

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

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

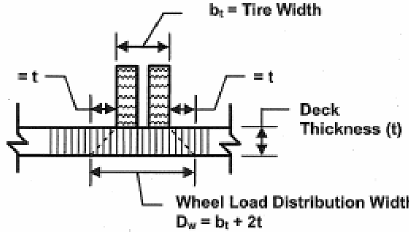
$M_{LL} = 161.97\,kft$ **or**

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

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

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.



$P_{wheel} := 16 \cdot k$ (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)

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

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

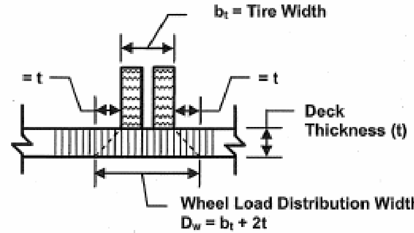
$M_{LL} = 161.97\,kft$ or

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

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

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.



$P_{wheel} := 16 \cdot k$ **(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)** **($D_w = b_t$ + [2 x Deck Thickness])** $D_w = 44\,in$

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)**

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

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

Calculate Inventory and Operating Ratings of deck based on flexure

Calculate Inventory Level Rating

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

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

Calculate Operating Rating Factors for bending in deck

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

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

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**

Section Modulus of deck

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

Calculate Inventory and Operating Ratings of deck based on flexure

Calculate Inventory Level Rating

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

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

Calculate Operating Rating Factors for bending in deck

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

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

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

Section Modulus of deck

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

Calculate Inventory and Operating Ratings of deck based on flexure

Calculate Inventory Level Rating

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

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

Calculate Operating Rating Factors for bending in deck

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

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

Inventory Rating

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

Operating Rating

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

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

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 Inventory Level Rating

$f_{bDL} := \frac{M_{DL}}{S_{deck}}$ **(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 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

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

(Missing spreader beams)

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
- 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

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

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)

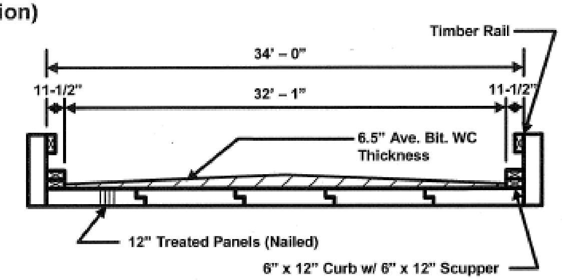
$F_{Vpar} := 95 \cdot psi$ (shear parallel to grain)

$E := 1600000 \cdot psi$ (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)

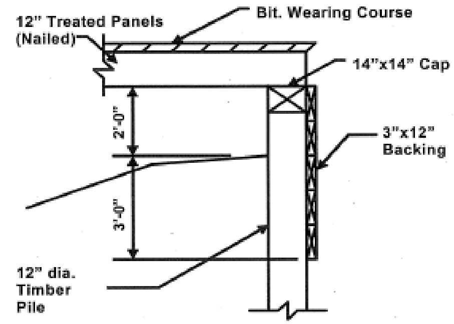
$Width_{curb} := 11.5 \cdot in$ (Width of curb)

$Thick_{deck} := 12 \cdot in$ (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 (3" x 12" lumber)

$C_F := 1.0$

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

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

$C_{Mb} = 1$ (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

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

Determine allowable unit stress for shear

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

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

Determine Effective Span Length (3.25.2.3)

$L_{effmin} := Span - Width_{abutcap} + \dfrac{Width_{abutcap}}{2}$ 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.**

$P_{wheel} := 16 \cdot k$ **(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)**

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

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

$M_{LL} = 161.97\,kft$ **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 : $S_{deck} := \frac{D_w \cdot Thick_{deck}^{\ 2}}{6}$ $S_{deck} = 768\,in^3$

Calculate Inventory and Operating Ratings of deck based on flexure

Calculate Inventory Level Rating

$f_{bDL} := \frac{M_{DL}}{S_{deck}}$ **(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 Operating Rating Factors for bending in deck

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

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

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 less than HS28, you need to consider posting.