Agenda – Day 1

8:00 am – 8:15 am  Introductions and House Keeping
8:15 am – 8:45 am  Session 1: Load Rating Basics
8:45 am – 9:30 am  Session 2: Basic Load Rating Calculations
9:30 am – 9:45 am  Break
9:45 am – 11:45 am Session 3: Example – Load Rating Concrete Slab Bridge
11:45 am – 12:00 pm Questions
12:00 pm – 1:00 pm Lunch
1:00 pm – 2:30 pm  Session 4: Example – Load Rating Steel Beam Bridges
2:30 pm – 2:45 pm  Break
2:45 pm – 3:45 pm  Session 4: Example – Load Rating Steel Beam Bridges (Con’t)
3:45 pm – 4:00 pm  Questions
Session 2: Basic Load Rating Calculations

• Capacity Calculations (C)
• Dead Load Calculations (DL)
• Live Load Calculations (LL + I)
• Rating Factor (RF)

\[
\text{LFR: } \quad \text{RF} = \frac{\text{Capacity} - A_1 \, (DL)}{A_2 \, (LL + I)}
\]
Capacity Calculations

- Capacity (C) depends on material, shape, & Condition
- Generally for normal bridges, bending controls the load rating of the bridge.
- Section loss at beam ends may make shear or bearing control the bridge capacity
- Examples will show how to calculate C
Capacity Calculations

• What to do when you don’t know material properties
  • ODOT BDM Figures 904 and 905 give material properties based on year built.
    • Be careful during transition years.

• See Appendix A
Capacity Calculations

- What to do when you don’t know Section properties
  
  - Steel Members:
    
    - AISC Manual of Steel Construction give section properties
    - See Appendix B for section properties for shapes rolled between 1873 and 1952 (Thank you B&N)
    - Measure the beams in the field – beam depth, flange width, web thickness, flange thickness (be careful with I and S shapes – bottom flanges are sloped)
Capacity Calculations

• What to do when you don’t know Section properties

• Concrete Members:
  • **Need to know reinforcing steel in member.**
  • Reinforcing steel can come from bridge plans, design data sheet, or standard drawing.
  • If don’t know the reinforcing steel in member, then “engineering judgment” is acceptable.
Dead Load Calculations

• Many bridges – DL can be applied as a uniform load (w k/ft)
  • Cross frames
  • Steel guardrail

• Standard references are available for unit weights for example:
  • Concrete = 150 lb/cf
  • Steel = 490 lb/cf
  • Asphalt = 144 lb/cf
Dead Load Calculations

• Do not include Future Wearing Surface in this calculation. Only include the dead load that is currently on the bridge.

• Any superimposed dead load that is placed after deck is poured, may be distributed to all beams. An example would be railing.

• Moment (M) for uniform load:
  \[ M = \frac{wL^2}{8} \]
  \( w = \) uniform load (k/ft.) \quad \( L = \) length of beam (ft.)
Dead Load Calculations

• If Dead Load includes concentrated items calculate dead load moment via shear and moment diagrams.
  
  • Diaphragms on pre-stressed box beams
Dead Load Calculations

RF = \frac{\text{Capacity} - A_1 \times (DL)}{A_2 \times (LL + I)}

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Ref: AASHTO Manual for Condition Evaluation of Bridges 1994
Live Load Calculations

• Items to discuss
  • Shear and Moment diagrams
  • Live load moment equations
  • Live load distribution factors
    • Wheel vs. Axle
  • Impact factor
Live Load Calculations

• Shear and Moment Calculations
  • Sample set of calculations to determine maximum moment for a 4F1 truck
  • Moment from any truck configuration can be determined this way
Given: Beam Size: W30 x 132 spaced at 8'-0" c/c
Cross Frames: L3 x 3 x 3/16 spaced at 15'-0" c/c
Railing: Twin Steel Tube
Span: 50'-0" c/c Brgs.

Transverse Section

4F1 Truck (See Figure 907 of the Ohio Bridge Design Manual)
Calculate resultant force and center of gravity of 4F1 truck:

\[ P_1 = 12 k \quad P_2 = P_3 = P_4 = 14 k \]

Resultant Force: \[ R = P_1 + P_2 + P_3 + P_4 = 12 k + 14 k + 14 k + 14 k = 54 k \]

Center of gravity (C.G.) is located at a distance 'x' from point 'O'.

This dimension 'x' can be calculated by taking summation of moment about point 'O' divided by the resultant force (R):

\[ x = \frac{14 k \times 10'}{54 k} + \frac{14 k \times 14'}{54 k} + \frac{14 k \times 18'}{54 k} = 10.8889' \]

Maximum bending moment in a single-span loaded with wheel loads will occur at the load nearest to the C.G. when the C.G. is the same distance on one side of the centerline of mid-span as the load nearest to the C.G. is on the other side.

However, for 4F1 Truck, the maximum bending moment occurs at P3 as shown in following sheets. Therefore, place the centerline of mid-span at half a distance between C.G. and P3.
\[ a = \frac{0.8889'}{2} = 0.4445' \]

\[
Ra = \frac{(12 k)(35.4445') + (14 k)(25.4445') + (14 k)(21.4445') + (14 k)(17.4445')}{50'}
\]

\[= 26.520 \, k\]

\[RB = 27.480 \, k\]

We can now draw shear and moment diagrams.
The maximum bending moment occurs at the location of P3, not P2.

Therefore, we need to place the centerline of mid-span at half a distance between C.G. and P3.
Place & Mid-Span between C.G. and P3

\[ a = \frac{3.1111'}{2} = 1.5556' \]

\[ R_A = \frac{(12k)(37.4444') + (14k)(27.4444') + (14k)(19.4444')}{50'} \]

\[ = 28.680 \text{ k} \]

\[ R_B = 25.320 \text{ k} \]
Equation for $M_{\text{max}}$ in Simple Span Bridge:

$$M_{\text{max}} = 13.5 \cdot \ell + \frac{130.6667}{\ell} - 140$$
Live Load Calculations

• Live Load Moment Calculations

  • See Appendix C for live load moment equations for the Ohio load rating trucks.

  • These are axle (full truck) live load moments
Live Load Calculations

• Live Load Distribution Factors (LLDF)
  • How much truck is carried by each beam or strip of slab.
  • One Axle = 2 wheels
    • Be careful with wheel vs. axle
    • Be consistent with LLDF and Live load moment
• See Section 3.23 AASHTO Standard Specifications for Highway Bridges for wheel live load distribution factors.
Live Load Calculations

- Live Load Distribution Factors (LLDF) - Examples
  - Longitudinal interior steel or concrete beam w/ concrete deck and two or more lanes on bridge
    - LLDF (wheel) = $S / 5.5$
      - $S =$ average beam spacing in feet
  - Longitudinal interior steel or concrete beam w/ 4 in. thick wooden deck and two or more lanes on bridge
    - LLDF (wheel) = $S / 4.0$
      - $S =$ average beam spacing in feet
Live Load Calculations

• Live Load Distribution Factors (LLDF)
  • Exterior steel or concrete beams:
    • Place wheel load 2 ft. from face of guardrail
    • Assume deck acts as simple span (AASHTO 3.23.2.3.1.2)
    • Calculate the Reaction of the wheel load

• Exterior steel beams with concrete decks:
  • Check for Minimum LLDF (controls for small cantilevers)
  • AASHTO 3.23.2.3.1.5
  • \( S/(4 + 0.25 \times S) \)  \[ 6 \text{ ft.} < S < 14 \text{ ft.} \]  
    • \( S = \) distance between exterior beam and next adjacent beam
Live Load Distribution Factor – Exterior Beam

\[ 8R_A - 2.5P - 8.5P = 0 \]

\[ R_A = \frac{2.5}{8} P + \frac{8.5}{8} P = \frac{11}{8} P = 1.38P \]

LLDF for Exterior Beam = 1.38 Wheels
Live Load Distribution Factor – Exterior Beam

Check Minimum LLDF:
LLDF Min. = 8.0 / (4 + (.25 x 8.0))
LLDF Min. = 1.33 wheels (does not control)
\[ 4R_A - 4.5P = 0 \]
\[ R_A = \frac{4.5}{4} P = 1.13P \]

LLDF for Exterior Beam = 1.13 Wheels
Check Minimum LLDF:

LLDF Min. = \( S / (4 + (0.25 \times S)) \)

LLDF Min. = \( 4 / (4 + (0.25 \times 4)) = 0.80 \)

LLDF Min. does not control
Live Load Calculations

• Live Load Impact Factor (I)

\[
I = \frac{50}{L + 125}
\]

I  Maximum = 30 %
L = length of loaded span
L = span length for simple spans
Live Load Calculations

• Live Load Impact Factor (I) – Example

  Beam is 55 ft. long
  L= 55

  \[ I = \frac{50}{(125 + 55)} \]
  \[ I = 0.28 = 28\% \leq 30\% \]
  \[ I = 28\% \]

  Multiply the Live Load Moment by 1.28
Live Load Calculations

$$RF = \frac{\text{Capacity} - A_1 (DL)}{A_2 (LL + I)}$$

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Rating Factor Calculations

• Converting Rating Factor (RF) to:
  • Percent Legal Load (Legal Load Vehicles)
    • RF X 100 = % Legal Load
  • Tons (Legal Load Vehicles)
    • RF X # tons of Truck used (GVW in tons)
    • For 5C1 Truck (GVW = 40 tons) with a RF = 1.23
      • Load Rating Tons = 1.23 X 40 = 49 tons
  • HS Rating (HS 20 truck used)
    • RF X 20 = HS rating
    • RF = 1.56 then 1.56 X 20 = HS 31.2
Questions ? ? ? ?