BRIDGE LOAD RATING WORKSHOP

Hand Calculation Examples

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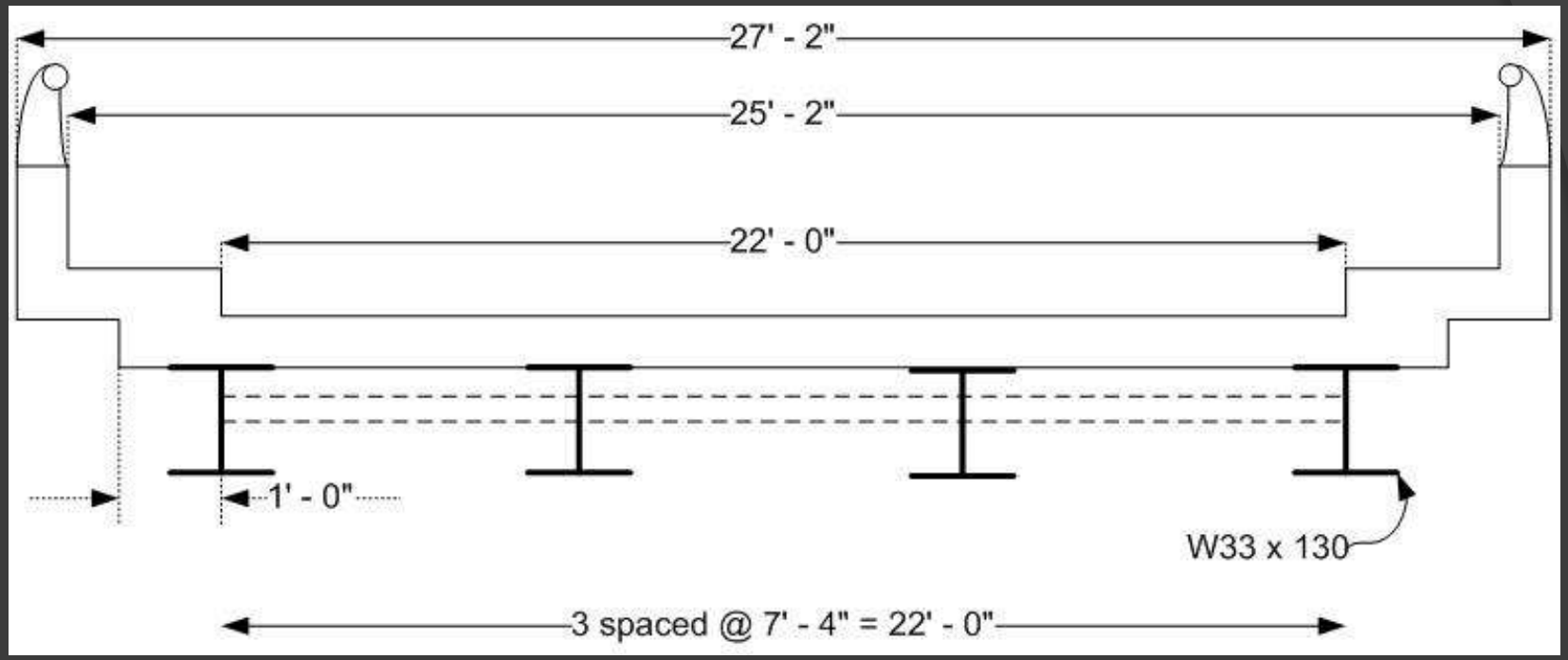
March 22nd, 2011

Example 1: LFR – Steel Superstructure



- Built in 1965
- 65 foot span
- No distress

General Properties

- Moment capacity: 2,910 ft*k
- Shear capacity: 380 k
- Combined dead load effect
  - moment: 573 ft*k
  - shear: 35.3 k
- Live load effect: to be determined as required for each component of the load rating
- Impact factor: 0.26
- Girder distribution factor (GDF): 0.667

General Load Rating Equation

$$RF = \frac{C - A_1 D}{A_2 (L)(GDF)(1 + I)}$$

RF = rating factor
C = capacity
D = dead load effect
L = live load effect
GDF = girder distribution factor
I = impact factor
A_1 = dead load effect factor
A_2 = live load effect factor

Federal Inventory Rating

Moment:

$$RF_m = \frac{2{,}910 - 1.3\,(573.6)}{2.17\,(896)\,(0.667)\,(1 + 0.26)} = 1.32$$

Shear:

$$RF_v = \frac{380 - 1.3\,(35.3)}{2.17\,(61.7)\,(0.667)\,(1 + 0.26)} = 2.96$$

Federal Operating Rating

Moment:

$$RF_m = \frac{2{,}910 - 1.3\,(573.4)}{1.3\,(896)\,(0.667)\,(1 + 0.26)} = 2.20$$

Shear:

$$RF_v = \frac{380 - 1.3\,(35.3)}{1.3\,(61.7)\,(0.667)\,(1 + 0.26)} = 4.96$$

Michigan Operating Rating

Moment (max effect caused by 2-unit truck #17):

$$RF_{m\ (2\ unit\ )} = \frac{2{,}910 - 1.3\ (573.4)}{1.3\ (1550)\ (0.667)\ (1 + 0.26)} = 1.27$$

Shear (max effect caused by 2-unit truck #17):

$$RF_{v\ (2\ unit\ )} = \frac{380 - 1.3\ (35.3)}{1.3\ (104)\ (0.667)\ (1 + 0.26)} = 2.93$$

No posting is required!

MDOT Overload Class

Moment (max effect caused by Class A Truck #10 &12)

$$RF_{m_{(A)}} = \frac{2{,}910 - 1.3\,(573.4)}{1.3\,(2{,}000)\,(0.667)\,(1 + 0.26)} = 0.99$$

Shear (max effect caused by Class A Truck #12):

$$RF_v = \frac{380 - 1.3\,(35.3)}{1.3\,(144)\,(0.667)\,(1 + 0.26)} = 2.12$$

Check Class B trucks

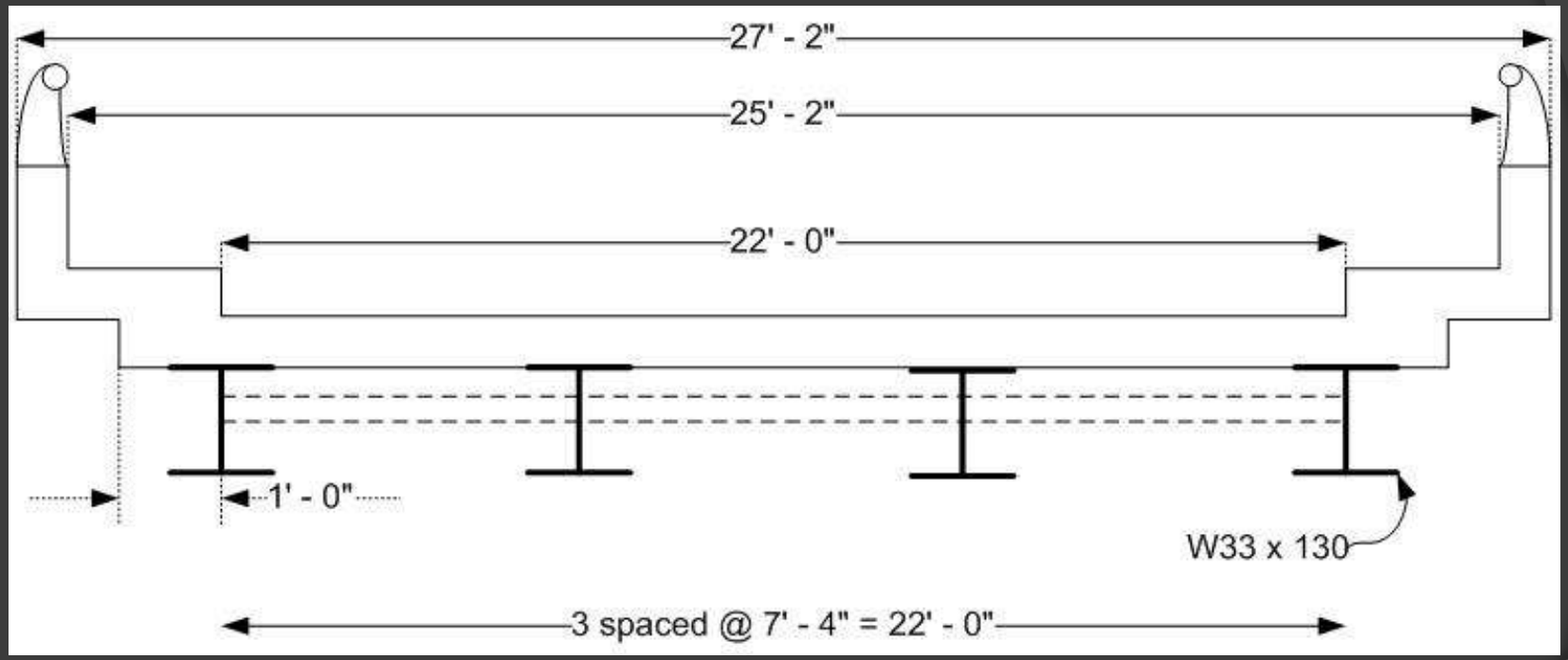
MDOT Overload Class

Moment (max effect caused by Class B Truck #12):

$$RF_{m_{(B)}} = \frac{2{,}910 - 1.3\,(573.4)}{1.3\,(1{,}680)\,(0.667)\,(1 + 0.26)} = 1.18$$

OVERLOAD CLASS B!

Example 2: LFR – Steel Superstructure with Distress



- Built in 1965
- 65 foot span
- Distress resulting in loss of section

General Properties

- Moment capacity: 2,066 ft*k
- Shear capacity: 164 k
- Combined dead load effect
  - moment: 573 ft*k
  - shear: 35.3 k
- Live load effect: to be determined as required for each component of the load rating
- Impact factor: 0.26
- Girder distribution factor (GDF): 0.667

General Load Rating Equation

$$RF = \frac{C - A_1 D}{A_2 (L)(GDF)(1 + I)}$$

RF = rating factor
C = capacity
D = dead load effect
L = live load effect
GDF = girder distribution factor
I = impact factor
A_1 = dead load effect factor
A_2 = live load effect factor

Federal Inventory Rating

Moment:

$$RF_m = \frac{2{,}066 - 1.3\,(573.6)}{2.17\,(896)\,(0.667)\,(1 + 0.26)} = 0.81$$

Shear:

$$RF_v = \frac{164 - 1.3\,(35.3)}{2.17\,(61.7)\,(0.667)\,(1 + 0.26)} = 1.05$$

Federal Operating Rating

Moment:

$$RF_m = \frac{2{,}066 - 1.3\,(573.4)}{1.3\,(896)\,(0.667)\,(1 + 0.26)} = 1.35$$

Shear:

$$RF_v = \frac{164 - 1.3\,(35.3)}{1.3\,(61.7)\,(0.667)\,(1 + 0.26)} = 1.75$$

Michigan Operating Rating

Moment (max effect caused by 2-unit truck #17):

$$RF_{m\ (2\ unit\ )} = \frac{2{,}066 - 1.3\ (573.4)}{1.3\ (1550)\ (0.667)\ (1 + 0.26)} = 0.78$$

Shear (max effect caused by 2-unit truck #17):

$$RF_{v\ (2\ unit\ )} = \frac{164 - 1.3\ (35.3)}{1.3\ (104)\ (0.667)\ (1 + 0.26)} = 1.04$$

Posting or repairs must be considered!

Michigan Operating Rating

Calculate Live Load Capacity:

$$L_{Allowed} = \frac{C - 1.3\,(D)}{1.3\,(RF)\,(GDF)\,(1 + I)}$$

$$= \frac{2{,}066 - 1.3(573.4)}{1.3\,(104)\,(0.667)\,(1 + 0.26)}$$

Live load moment effect is limited to 1,209 ft*k

Posting Procedure:

- 1-unit trucks
  - All these trucks produce a moment effect less than the max. The maximum weight of 42 tons is OK.
- 2-unit trucks
  - List trucks that have a moment effect greater than max allowable (#12, #13, #14, #15, #16, #17, #18)
  - The truck with highest moment/weight ratio will produce the greatest effect and must be used to restrict the loads applied to the bridge
  - Restrict 2-unit trucks to 57 tons

Posting Procedure, Cont.

- 3-unit trucks
  - List trucks that have a moment effect greater than max allowable (#21, #22, #23, #25)
  - The truck with highest moment/weight ratio will produce the greatest effect and must be used to restrict the loads applied to the bridge
  - Restrict 3-unit trucks to 65 tons

MDOT Overload Class

Moment (max effect caused by Class A Truck #10 &12)

$$RF_{m_{(A)}} = \frac{2{,}066 - 1.3\,(573.4)}{1.3\,(2{,}000)\,(0.667)\,(1 + 0.26)} = 0.60$$

Shear (max effect caused by Class A Truck #12):

$$RF_v = \frac{164 - 1.3\,(35.3)}{1.3\,(144)\,(0.667)\,(1 + 0.26)} = 0.74$$

Live Load Capacity (from previous calc) = 1,209 ft*k

MDOT Overload Class, Cont.

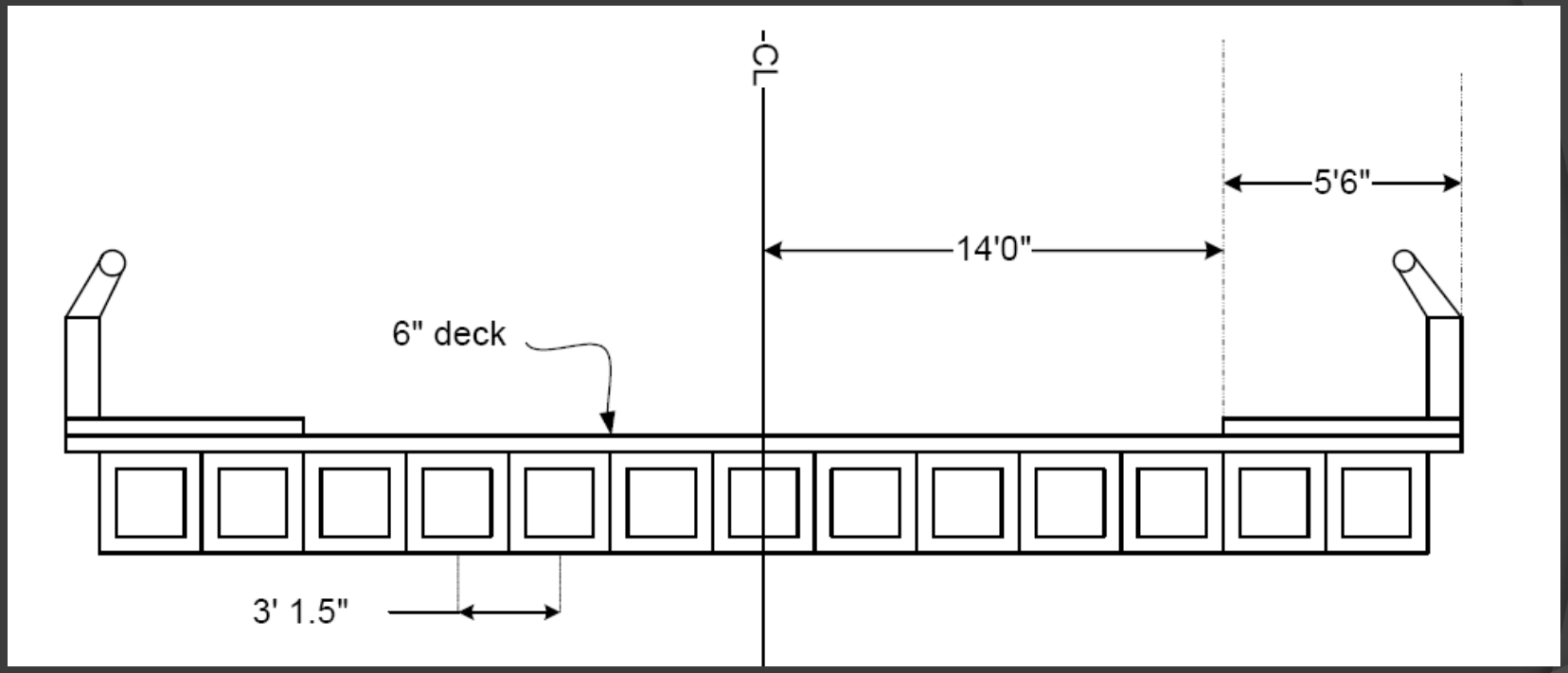
- Check Class B for load effects in excess of max
  - Max effect is exceeded
- Check Class C for load effects in excess of max
  - Max effect is exceeded
- Bridge is Class D
  - Calculate allowable axle loads
  - Use moment effects from Class A trucks and the corresponding axle loads

$$\text{Allowable Axle Load} = \frac{Allowable\ \ Effect}{Load\ \ Effect}\ Axle\ Load$$

MDOT Overload Class, Cont.

Axle Load Limits for Class D Overload			
Truck	**Axle Load (k) from Figure 8.1**	**Moment Effect for Class A Overload (ft*k) from Table 10.10**	**Calculated Allowable Axle Load (k) for Class D**
1	60	1150	60
2	60	1270	57
3	57	1400	49
4	49	1550	38
5	44	1630	32
6	30	1710	21
7	31	1820	20
8	24	1860	15
9	22	1920	13
10	20	2000	12
11	46	1830	30
12	31	2000	18
13	34	1820	22
14	24	1760	16

Example 3: LRFR – Prestressed Box Beam Bridge



- 27 x 36 inch side by side prestressed box-beams
- 50 foot span
- No deterioration

General Properties

- Moment Capacity: 991 ft*k
- Shear Capacity: 95.6 k
- c_b = 18.5 in (composite shape)
- I = 92,640 in^4 (composite shape)
- Combined Dead Load Effect
  - Moment: 293 ft*k
  - Shear: 22.1 k
- Live Load Effect: To be determined as required for each component of the load rating.
- IM: 0.26
- Girder Distribution Factor (GDF): 0.26
- ADTT: 5000

General Load Rating Equation

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_{LL})(LL + IM)}$$

RF = rating factor
C = capacity
γ_{DC} = LRFD load factor for structural components and attachments
DC = dead load effect due to structural components and attachments
γ_{DW} = LRFD load factor for wearing surfaces and utilities
DW = dead load effect due to wearing surfaces and utilities
γ_P = LRFD load factor for permanent loads other than dead loads = 1.0
P = permanent loads other than dead loads
γ_{LL} = evaluation live load factor
LL = live load effect
IM = dynamic load allowance

Limit States:

Prestressed Concrete:	**Design Load (HL-93)**	**Other Loads**
Strength I	Federal Inventory and Operating	MI Operating (Legal Loads)
Strength II		Permit Loads (Check Shear)
Service III	Federal Inventory	MI Operating (Legal Loads)
Service I		Permit Loads (Check Shear)

Federal Inventory Rating

Strength I: Flexure at midspan

$$RF = \frac{(1.0)(1.0)(1.0)(991\ ft \cdot k) - (1.25)(293\ ft \cdot k)}{(1.75)(1{,}034\ ft \cdot k)(0.26)}$$

$$RF = 1.33$$

Note: Shear need not be checked for HL-93 if bridge does not show signs of shear distress

Federal Inventory Rating

Service III: Tensile stress in concrete

$$RF = \frac{f_R - (\gamma_D)(f_D)}{(\gamma_{LL})(f_{(LL+IM)})}$$

$$RF = \frac{1.845\ ksi - (1.0)(0.952\ ksi)}{(0.80)(0.644\ ksi)}$$

$$RF = 1.73$$

Federal Operating Rating

Strength I: Flexure at midspan

$$RF = \frac{(1.0)(1.0)(1.0)(991\ ft \cdot k) - (1.25)(293\ ft \cdot k)}{(1.35)(1{,}034\ ft \cdot k)(0.26)}$$

$$RF = 1.72$$

Note: Shear need not be checked for HL-93 if bridge does not show signs of shear distress

Michigan Operating Rating

Note: Live load factor is a function of axle loads and configurations. Generate a table for factored load effects from BAG

Strength I: Flexure at midspan

$$RF = \frac{(1.0)(1.0)(1.0)(991\ ft \cdot k) - (1.25)(293\ ft \cdot k)}{(1{,}634\ ft \cdot k)(0.26)}$$

$$RF = 1.47$$

Michigan Operating Rating

Service III: Tensile stress in concrete

$$RF = \frac{1.845\ ksi - (1.0)(0.952\ ksi)}{(1.0)(0.837\ ksi)}$$

$$RF = 1.06$$

MDOT Overload Class

Note: Live load factor is a function of axle loads and configurations. Generate a table for factored load effects from BAG

Strength II: Flexure at midspan

$$RF = \frac{(1.0)(1.0)(1.0)(991\ ft \cdot k) - (1.25)(293\ ft \cdot k)}{(1{,}841\ ft \cdot k)(0.26)}$$

$$RF = 1.30$$

OK for routine permit Class A vehicles

MDOT Overload Class, Cont.

- Permit trucks should be checked for shear incrementally along the length of the member (not shown here)

References:

- Bridge Analysis Guide, 2005 Edition with 2009 Interim Update. MDOT Construction and Technology Support Area
- The Manual for Bridge Evaluation, Second Edition, AASHTO, Washington DC. (2011)