Load Rating

For Two Steel Bridges

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Western Bridge Engineers' Seminar

Project Introduction

Outline

Load rating procedure:

- Determine load rating method
- Determine member condition
- General finite element analysis of demand
- Customized tool for code specified equation for capacity
- Customized tool for rating factors

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LFR Load Rating of the Steel Plate Girder Bridge

Location: SR167 and 15 St. SW, Auburn, WA

Owner: City of Auburn/WSDOT

Year built: 1995

Bridge inspection (Dec. 2010):

Superstructure in very good condition (index code: 8)

Substructure in good condition (index code: 7)

Load rating time: October 2011

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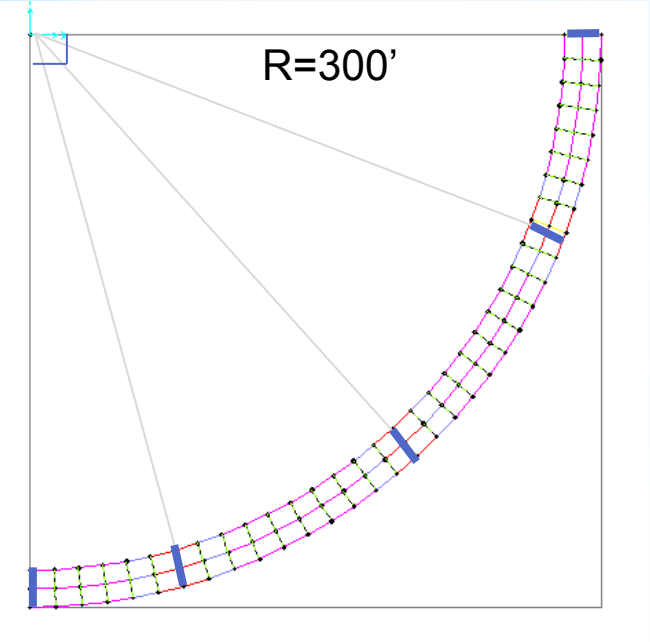
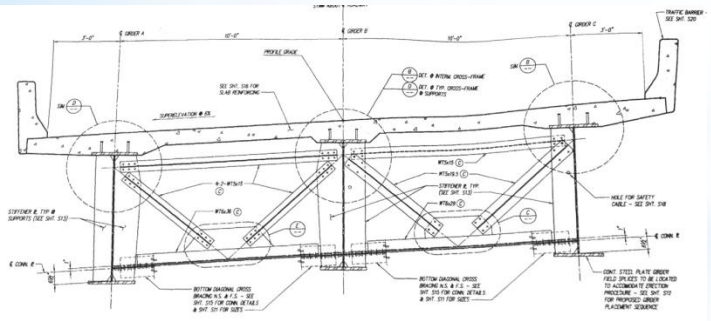
Steel Plate Girder Bridge (LFR)

Structural Details





Alignment:
90 degree turn, centerline radius 300 ft.

Each span has:
3 Curved girders, web depth: 5’-6”,
Flange width 2’-0”

Structural Material:
Deck and Cap Beam final cast-in-place concrete strength, f’c : 4 ksi
Structural steel: AASHTO M223 Grade 50, Fy=50 ksi
Steel reinforcement: ASTM A615 Grade 60, Fy=60 ksi

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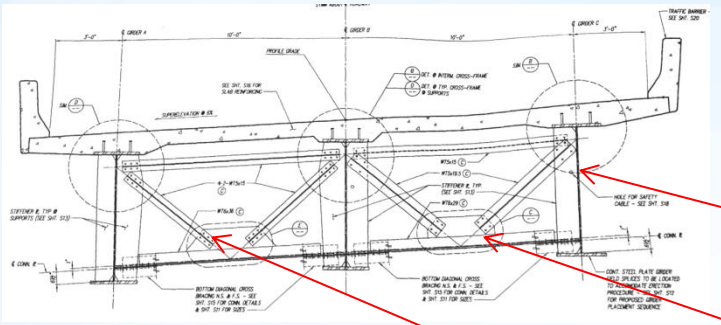
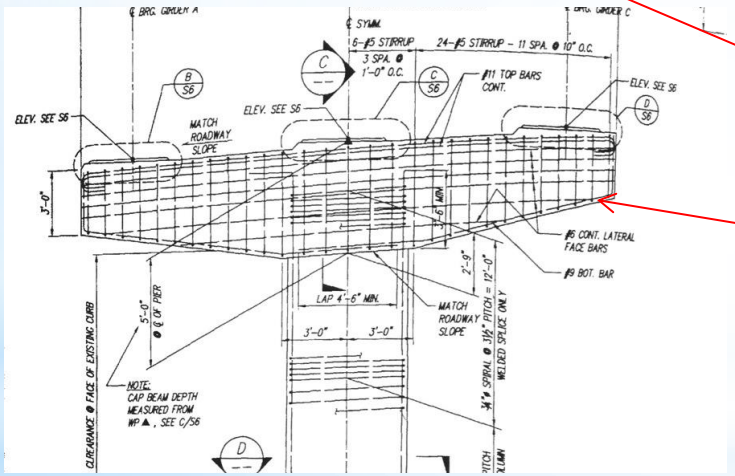
Steel Plate Girder Bridge (LFR)

Rating Components





Steel Plate Girder

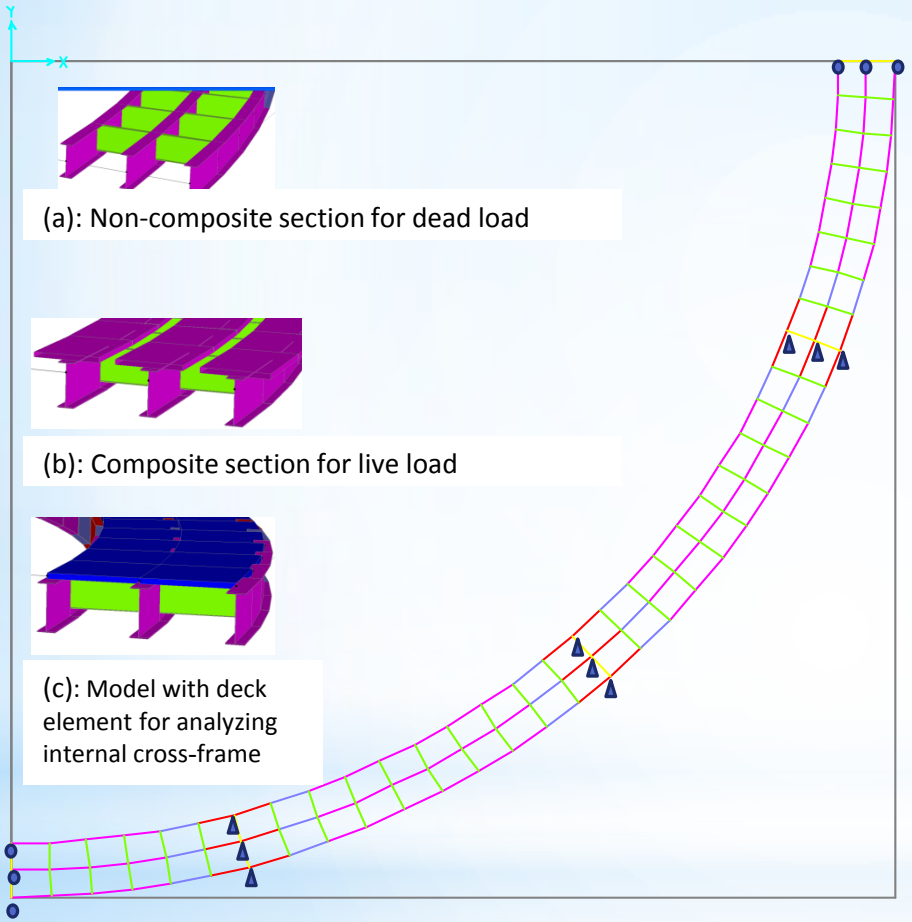
Intermediate crossbeam

Pier Crossbeam

Pier Cap beam

Steel Plate Girder Bridge (LFR)

Global Analysis of Demand



SAP2000 3D Analysis

Dead Load:

All existing components weight

Non-composite section

Live load:

Design Live Loads: HS-20

Legal Trucks: 25-40 short tons

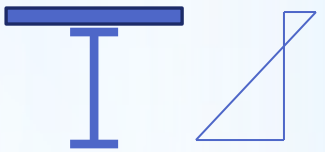
Permit Trucks: 103.5 short tons

Composite section

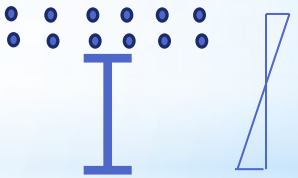
Determine Member Demand and Capacity

Component behavior:

- Plate girder positive flexure at middle span
  - Section is non-compact, use flange stress
  - Non-composite section under dead load
  - Uncracked composite section for live load
  - Bottom flange resistance: steel yielding



- Plate girder negative flexural at pier
  - Section is non-compact, use flange stress
  - Non-composite section for dead load
  - Cracked composite section for live load
  - Bottom flange compression stress:
    flange and web buckling control



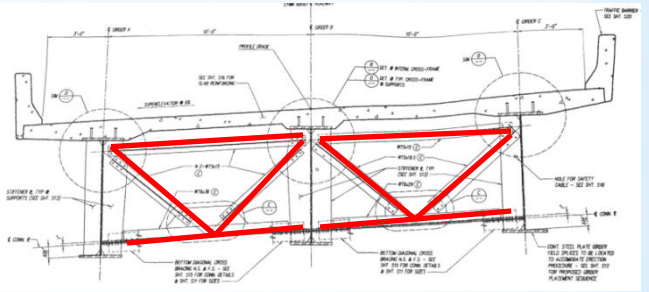
- Plate girder web shear: web buckling control

Determine Member Demand and Capacity

Component behavior:

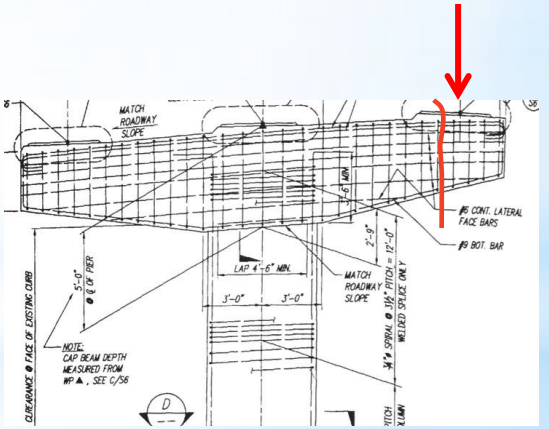
- Flange lateral bending

$$M_{lateral} = \frac{M \cdot l^2}{10 \cdot R \cdot D_{web}}$$



- Crossbeam: shear and moment

  Transformed from crossbeam bracing members axial tension or compression



- Pier cap: RC concrete shear at bearing and moment at column face

Steel Plate Girder Bridge (LFR)

LFR Rating Equation

$$RF = \frac{\phi \cdot C - \gamma_{DL} \cdot DL \pm S}{\gamma_{LL} \cdot LL(1+IM)}$$

RF: rating factor

Φ: Material resistance factor
Φ=1.0, for steel flexural and shear
Φ=0.9, for concrete flexural
Φ=0.85, for concrete shear

γ_{DL}, dead load factor: 1.3
DL: dead load effect on rating components

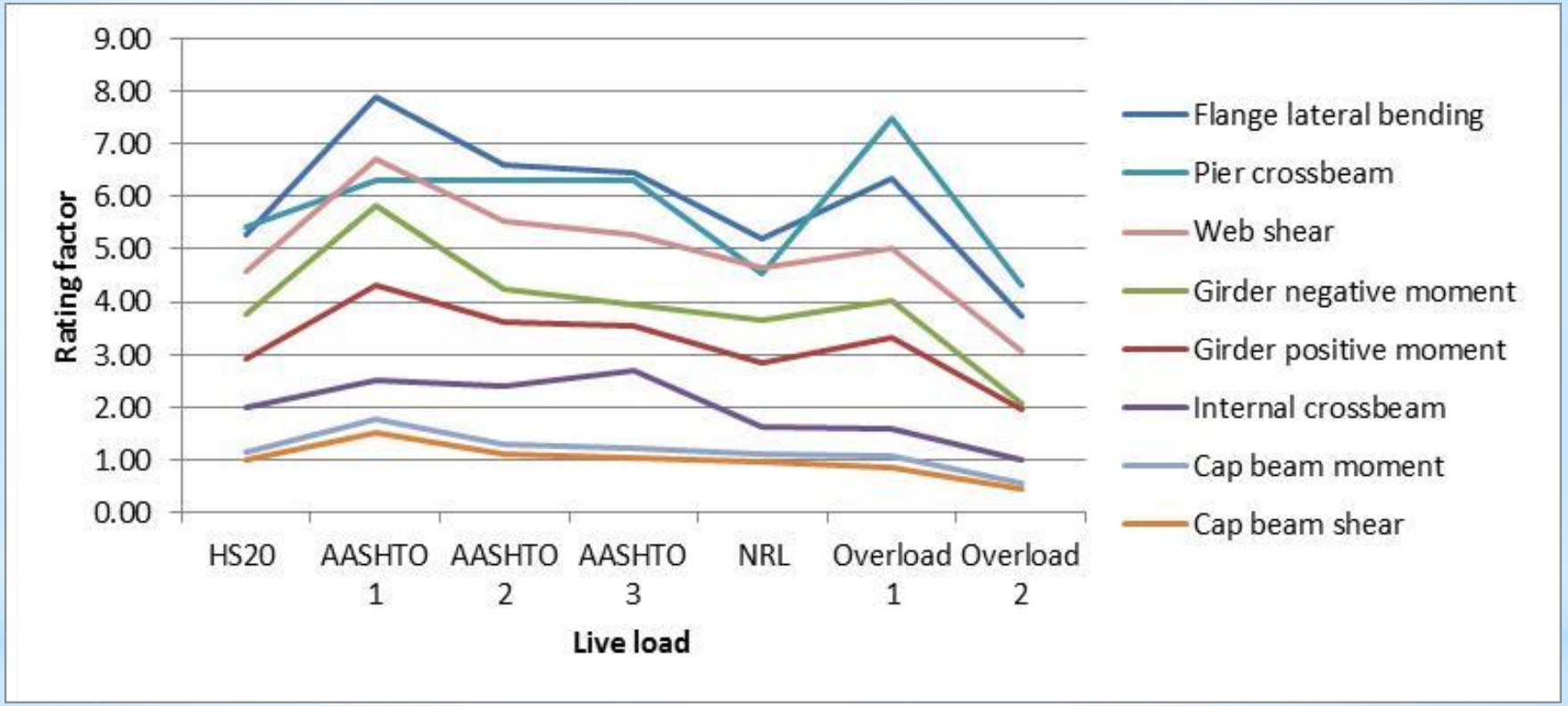
S=0 (no prestress effect)

γ_{LL}, live load factor: 2.17 or 1.3
LL(1+IM): live load plus impact

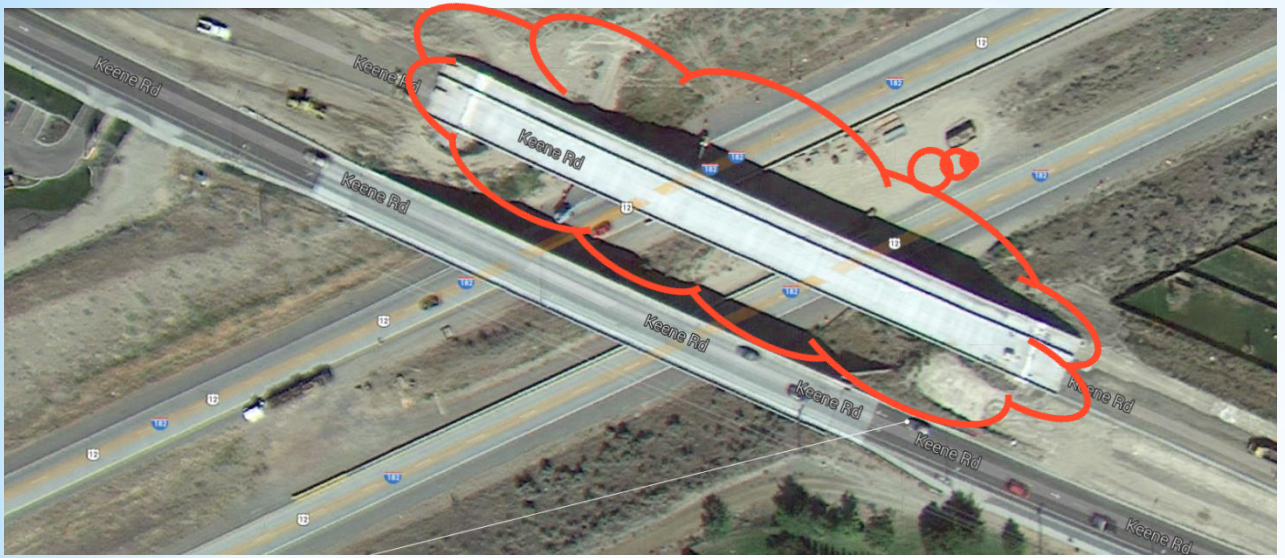
Member resistance according to AASHTO Standard Specifications for Highway Bridge, 17th edition

Steel Plate Girder Bridge (LFR)

Load Rating Results



LRFR Load Rating of the Steel Box Girder Bridge



Location: JCT S182 & Keene Road, Richland

Owner: City of Richland/WSDOT

Year built: 1982

Inspection: Dec. 2008

- Superstructure in very good condition (index code: 8)
- Substructure in very good condition (index code: 8)

Year widened: 2012

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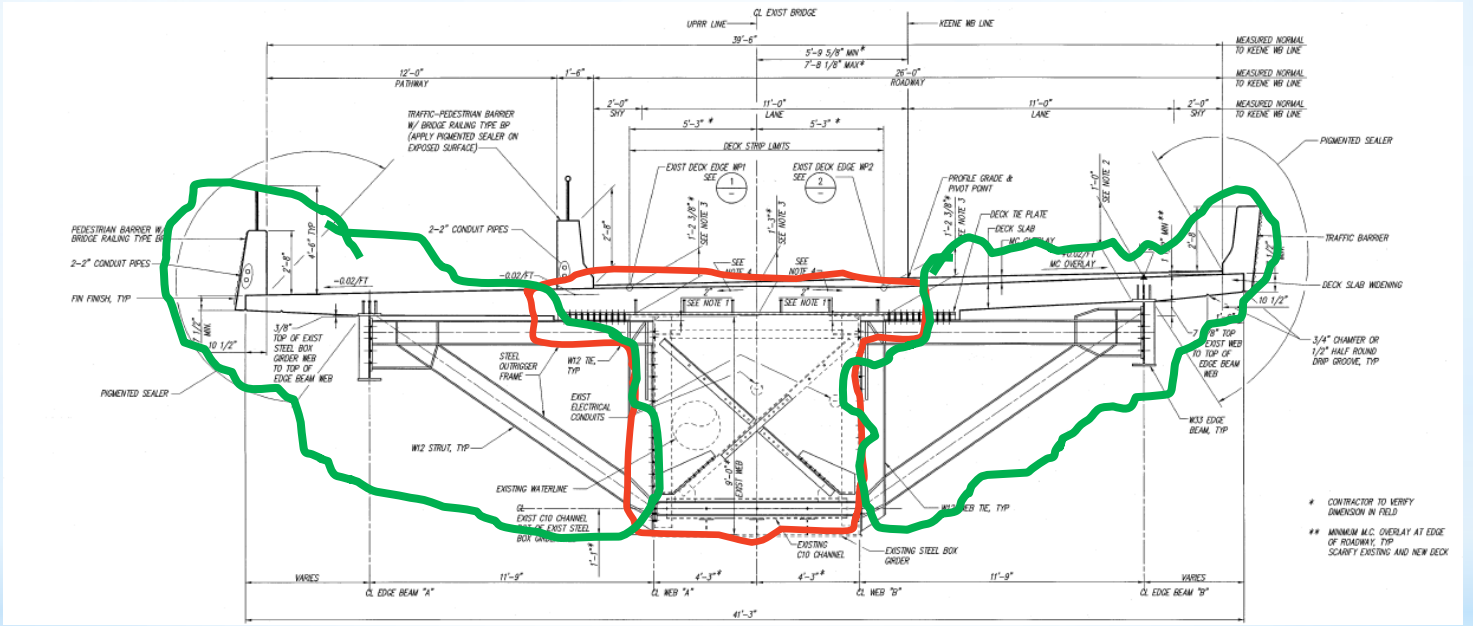
Steel Box Girder Bridge (LRFR)

Structural Introduction

Existing single steel box and deck, deck widening by bracings and edge beams



Structural Material:

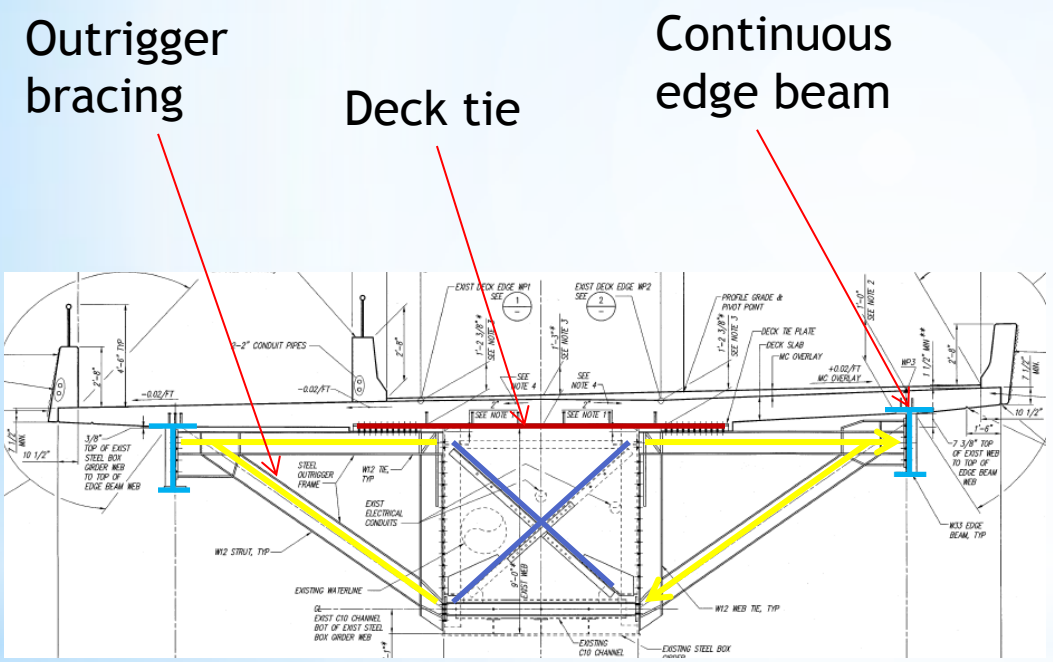
Concrete strength, f'c : 4 ksi

Structural steel: AASHTO M223 Grade 50, Fy=50 ksi

Steel reinforcement: ASTM A615 Grade 60, Fy=60 ksi

Steel Box Girder Bridge (LRFR)

Rating Components



Steel box girder: top and bottom flange normal stress, web shear stress

Splice Connections: flexural and shear

Crossbeam bracings: tension or compression

Deck tie: tension

Outrigger bracings: Axial and flexural

Edge beam: flexural

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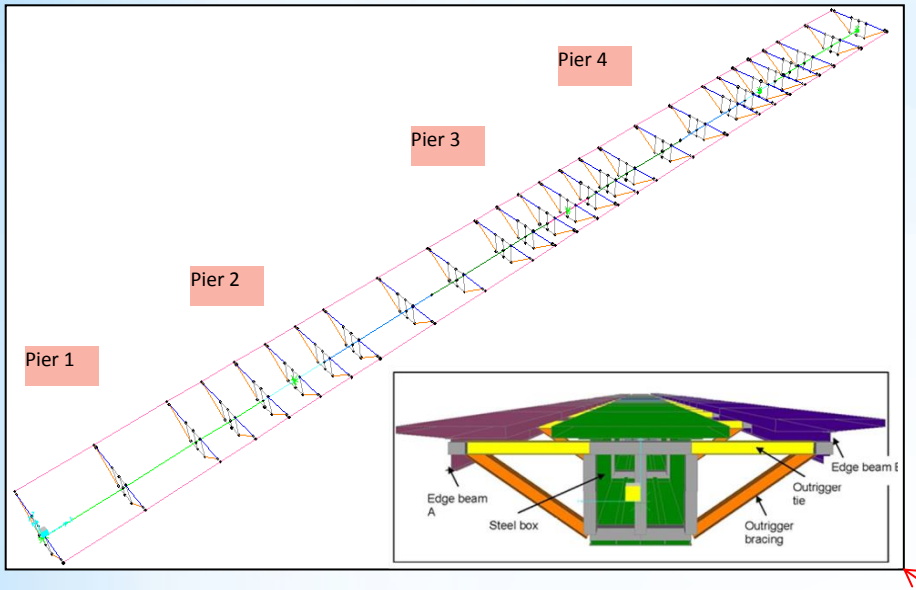
Steel Box Girder Bridge (LRFR)



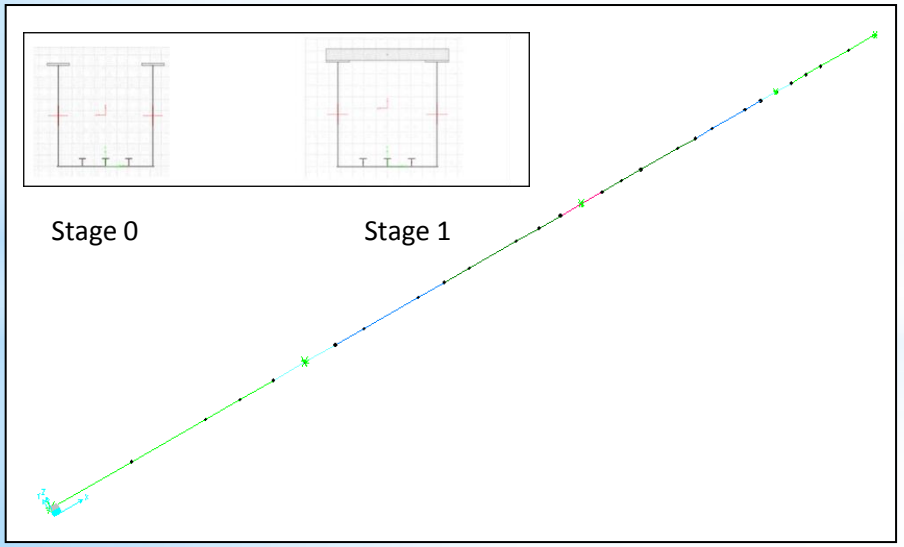
Component Demand

Demand:

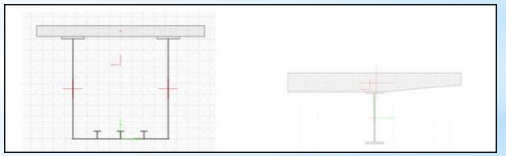
SAP2000 Stick Model

Capacity:

Excel and VBA



Stage 2



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Component resistance

Component behavior:

- Box girder top and bottom flange normal stress, web shear stress
- Box girder splices: shear and moment
- Outrigger bracing: axial and flexural
- Deck tie: axial tension
- Edge beam: flexural (non-composite section for dead load, composite section for live load)

Iteration on component resistance

Component behavior:

- Box girder top and bottom flange normal stress, shear stress

$$F_{nc} = R_b R_h F_{yc} \sqrt{1 - 3\left(\frac{f_v}{F_{yc}}\right)}$$

$$f_v = \frac{T}{2A_0 t_{fc}}$$

- Outrigger bracing: axial and flexural

$$If \ \frac{P_u}{P_r} \geq 0.2$$

$$\frac{P_u}{P_r} + \frac{8}{9}\left(\frac{M_{ux}}{M_{rx}} + \frac{M_{uy}}{M_{ry}}\right) \leq 1.0$$

$$If \ \frac{P_u}{P_r} < 0.2$$

$$\frac{P_u}{2.0P_r} + \left(\frac{M_{ux}}{M_{rx}} + \frac{M_{uy}}{M_{ry}}\right) \leq 1.0$$

Steel Box Girder Bridge (LRFR)

LRFR Rating Equation

$$RF = \frac{\phi \cdot C - \gamma_{DL} \cdot DL \pm S}{\gamma_{LL} \cdot LL(1+IM)}$$

Strength and service limit state

Φ: resistance factor
$\Phi=\Phi_c\Phi_s\Phi_n$

γ_{DL}: dead load factor
DL: dead load effect on rating components

Member resistance according AASHTO LRFD Bridge Design Specifications, 5th edition

S=0 (no prestress effect)

γ_{LL}: live load factor
LL(1+IM): live load plus impact

Steel Box Girder Bridge (LRFR)

Material resistance factors

Behavior		Φ_n
Strength limit state	flexure	1.0
	Shear	1.0
	Axial compression	0.9
	Axial tension, fracture	0.8
	Axial tension, yield	0.95
	For bolts shear	0.8
Service state		1.0

Φ: Capacity factor

$\Phi = \Phi_c \Phi_s \Phi_n$

Φ_c: Condition factor

Φ_s: System redundancy factor

Φ_n: Material resistance factor

Steel Box Girder Bridge (LRFR)

Load and Factors

Dead Load: All existing components weight

Live load:
Design Live Loads: HL-93
Legal Trucks: 25-40 short tons
Permit Trucks: 103.5 short tons

Load Factors

Limit State	γ_{DC}	γ_{DW}	HL-93 Inventory	HL-93 Operating	Legal and NRL	Permit
Strength	1.25	1.5	1.75	1.35	1.8	1.5
Service	1.0	1.0	1.30	1.0	1.30	1.0

Steel Box Girder Bridge (LRFR)

boxbot(box, stage, P, M22, M33)
Calculate box bottom flange stress

boxtop(box, stage, P, M22, M33)
Calculate box top flange stress

boxdeck(box, stage, P, M22, M33)
Calculate box deck top stress

Determine flange normal stress

Fcw(box, ftop, fbot)
Calculate web bend-buckling resistance

Fncbot(box, stage, Fvv)
Calculate bottom flange nominal compression resistance

Determine flange resistance at negative moment

Fvvt(box, stage, T)
Calculate St. venant shear stress

Fvvb(box, stage, T) 'St venant stress bottom flange
Calculate St. venant shear stress on bottom flange

Vst(box, stage, T)
Calculate St. venant shear stress on web

Fnctop(box, stage, Fvv)
Calculate top flange nominal compression resistance

Determine torsion shear stress

Fnt(box, stage, Fvv)
Calculate flange tension resistance

Determine flange resistance at positive moment

RFtop(box, stage, sigmadeadtop, sigmalivetop, Fvvdeadtop, Fvvlivetop, faif)
Calculate top flange load rating factor for strength limit state

RFBOT(box, stage, sigmadead, sigmalive, Fvvdeadbot, Fvvlivebot, faif)
Calculate bottom flange load rating factor for strength limit state

RFtopser(fa, box, sigmadeadtop, sigmalivetop, sigmadeadbot, sigmalivebot)
Calculate top flange load rating factor for service limit state

RFbotser(fa, box, sigmadeadtop, sigmalivetop, sigmadeadbot, sigmalivebot)
Calculate bottom flange load rating factor for service limit state

Calculating rating factors

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Steel Box Girder Bridge (LRFR)

Rating Results

Bridge Name: UPRR UXING
Bridge Number: 182/8
Span Types: FOUR SPANS CONTINUOUS STEEL BOX GIRDER WITH BRACINGS
Span Length: 81.5 FT + 124.5 FT + 124.5 FT + 81.5 FT
Design Load: HL-93.
Rated By: JJL
Checked By: COH/JX
Date: July 2011

Inspection Report Date: 12/10/2008
Rating Method: LRFR
Overlay Thickness: 1.5 in. minimum

Substructure Condition	8
Deck Condition	7
Superstructure Condition	8

Truck	RF	γ	Controlling Point
AASHTO 1	3.15	1.8	Cross-frame diagonal compression close to pier 1 and 5
AASHTO 2	3.11	1.8	Cross-frame diagonal compression close to pier 1 and 5
AASHTO 3	3.12	1.8	Edge beam bottom flange compressive stress at pier 3
NRL	1.97	1.8	Cross-frame diagonal compression close to pier 1 and 5
OL-1	2.51	1.5	Cross-frame diagonal compression close to pier 1 and 5
OL-2	2.10	1.5	Cross-frame diagonal compression at span 2 middle

NBI Rating	RF	γ	Controlling Point
Inventory (HL-93)	1.52	1.75	Cross-frame diagonal compression near pier 1 and 5
Operating (HL-93)	1.96	1.35	Cross-frame diagonal compression near pier 1 and 5

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SUMMARY

- 3D line models with moderate complexity to analyze member demand
  Construction staging
  Member resistance using Excel

- Steel plate girder bridge (LFR):
  Pier cap beam shear controls rating factor

- Steel box girder bridge (LRFR)
  Crossbeam diagonal compression controls rating factor

- Development of generalized rating tools combining commercial software and Excel spreadsheets.

QUESTIONS?

Thank you for your attention !

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