INDOT Bridge Evaluation

Jennifer L. Hart, P.E.

1

Who We Are Today

- INDOT Bridge Evaluation Team
- INDOT Bridge Design Engineers – Provide added support
- 3 On-Call Load Rating Consultant Teams (~30 Engineers)
- 21 Indiana LPA Consultants performing load ratings on behalf of the State of Indiana

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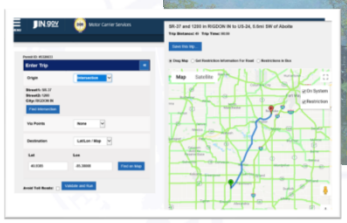
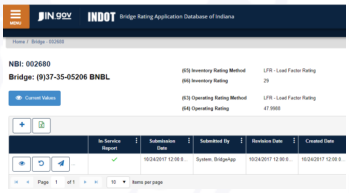
To Serve and Protect



- Maintain Indiana Policies Regarding Load Rating
- Owners of Load Rating Data
- Business Owners Load Rating ITAP Applications
  - BRADIN – Authoritative Source for All Load Rating Data
  - Load Rating Request Application (LRRA)
- Provide Oversight for County Load Ratings
- Maintain State BrR Models for Integration with Oversize Overweight Permitting System
- Manual Review of all Permits > 200,000 lbs
- Provide Departmental Support
  - Bridge Asset Management
  - Bridge Design
  - Bridge Inspection



NextLevel INDIANA

3

Bridge Evaluation Team Support

- INDOT Asset Engineers Project Scoping Review **~ 150 per year**
- Routine Load Rating Review **~ 600 per year**
  - ~250 Design project development load rating review
  - ~200 Updates in response to construction completion
  - ~150 Production model review in support of OSOWPS
- Updates to load rating models in response to INDOT Bridge Inspection notification **~ 25 per year**
- Overweight (>200,000 lb) Permit Evaluation **~ 1,000 per year**

NextLevel INDIANA

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US 136 over Wabash River - Collaborative Effort

NextLevel INDIANA

5

US 136 over Wabash River

Load Rating, Refined Capacity Analysis and Special Inspection of an Existing Segmental Post-Tensioned Bridge

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Indiana Department of Transportation

Amy Huebschman, PE
Structures Services Lead
EMCS, Inc.

Douglas Crampton, PE, SE
Principal
Wiss, Janney, Elstner Associates, Inc.

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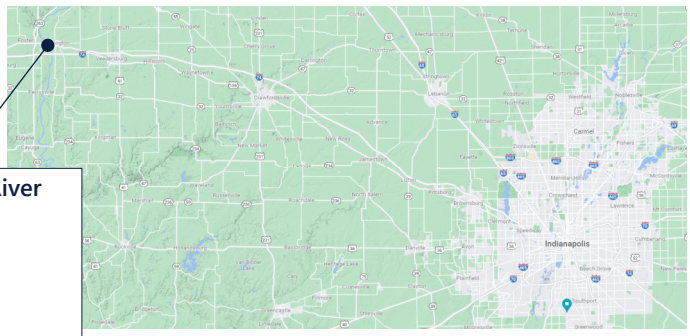
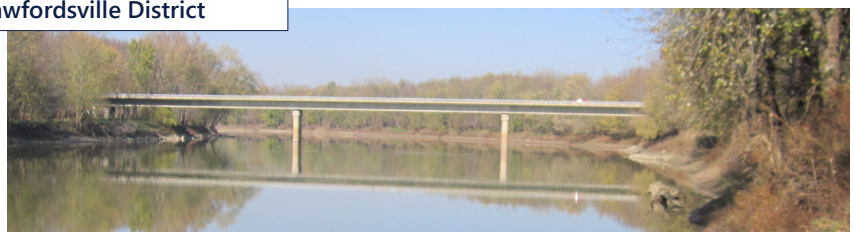
US 136 over Wabash River

PROJECT OVERVIEW



US 136 over Wabash River
136-86-06086 C
NBI. 026790

Covington, IN
Crawfordsville District



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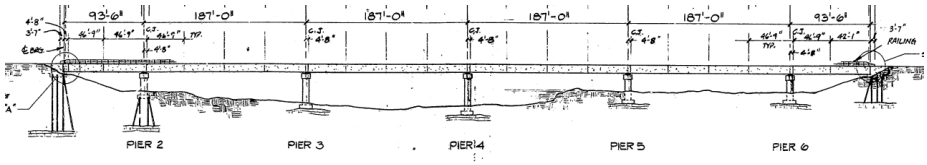
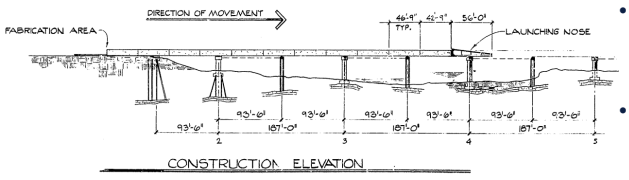
US 136 over Wabash River

PROJECT OVERVIEW

Six Span Continuous Segmental Concrete Bridge, **Constructed in 1975**



Originally Designed with 6'-6" Long Segments, Modified to Span Launching Method with 46'-9" long segments.



- Stage I Prestressing (PT) = Tensioned during Staged Construction
- Stage II Prestressing (PT) = Tensioned after Final Position from Inside Box

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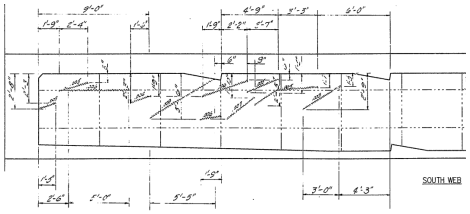
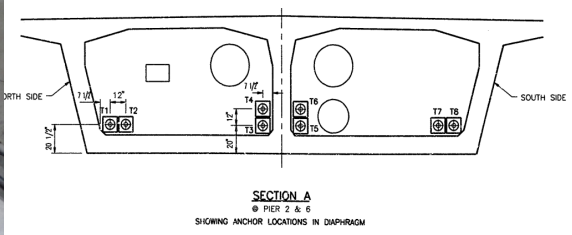
PROJECT OVERVIEW

1. Rehab A (1992) – Web Cracking Repair & Wearing Surface
   - Epoxy Crack Injection
   - Additional PT Tendons
2. Rehab B (2009) – Polymeric Deck Overlay
3. Rehab C (2020) – Rigid Deck Overlay





SECTION A
@ PIER 2 & 6
SHOWING ANCHOR LOCATIONS IN DIAPHRAGM

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Introduction to Load Rating (LRFR)

Load rating is the process in determining the safe load carrying capacity of bridges.

- INDOT Bridge Inspection Manual, PART 3: LOAD RATING (July 2021)
- AASHTO, Manual for Bridge Evaluation 3rd Ed. Section 6
- AASHTO Bridge Design Specifications, 8th Edition

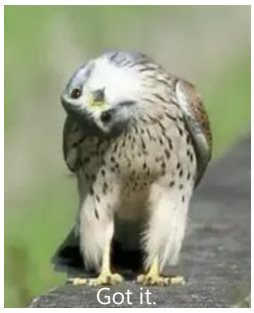
$$C = \varphi_c \varphi_s \varphi R_n$$

System, Condition, LRFD Resistance Factor

$$C \geq (\gamma_{DC})(DC) + (\gamma_{DW})(DW) + (\gamma_P)(P) + (\gamma_{LL})(LL)$$

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

(6A.4.2.1-1)



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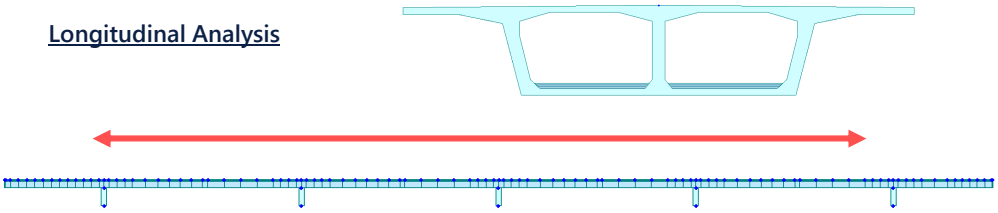
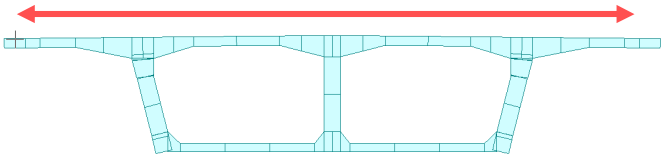
US 136 over Wabash River

FEM Analysis

Longitudinal Analysis



Transverse Analysis



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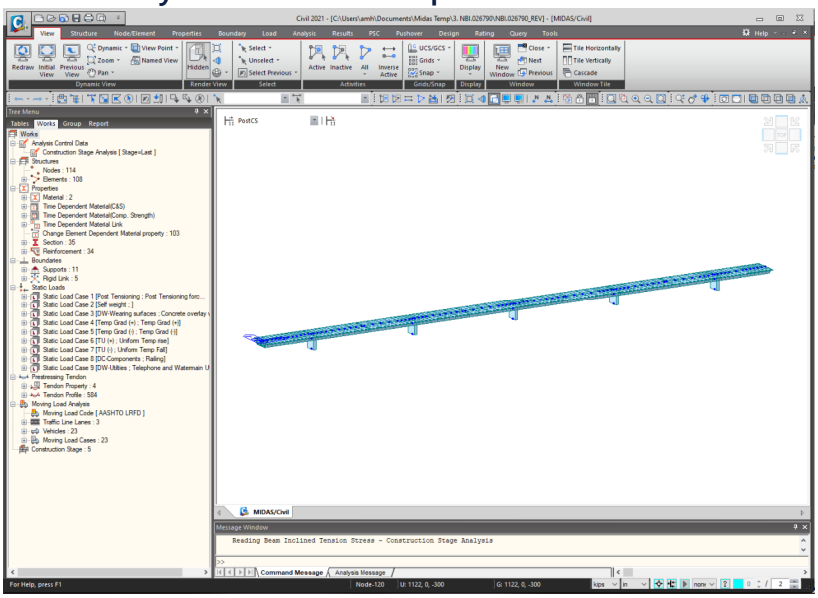
FEM Analysis – General Setup MIDAS



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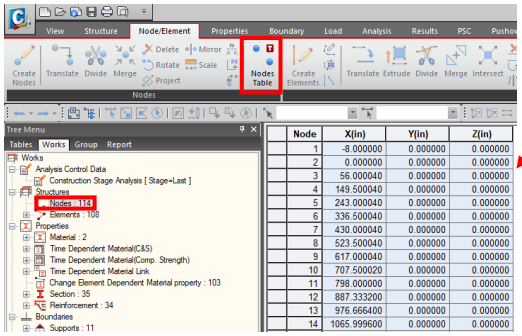
US 136 over Wabash River

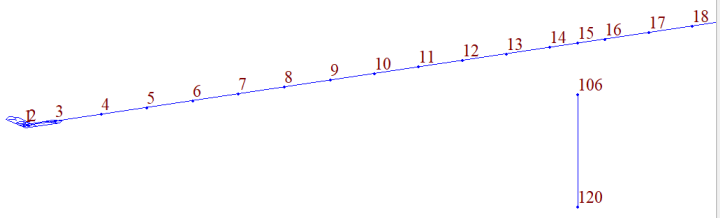
FEM Longitudinal Analysis

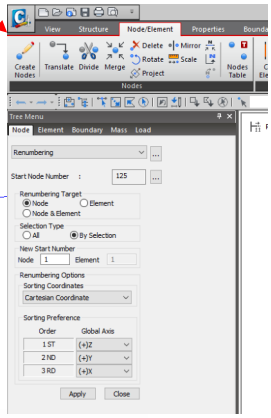
NODES –

- Copy for Excel – Suggested
- Place Graphically
- RE-ORDER



Node	X(in)	Y(in)	Z(in)
1	-8.000000	0.000000	0.000000
2	0.000000	0.000000	0.000000
3	56.000040	0.000000	0.000000
4	149.500040	0.000000	0.000000
5	243.000040	0.000000	0.000000
6	336.500040	0.000000	0.000000
7	430.000040	0.000000	0.000000
8	523.500040	0.000000	0.000000
9	617.000040	0.000000	0.000000
10	707.500020	0.000000	0.000000
11	798.000000	0.000000	0.000000
12	887.333200	0.000000	0.000000
13	976.666400	0.000000	0.000000
14	1065.999600	0.000000	0.000000





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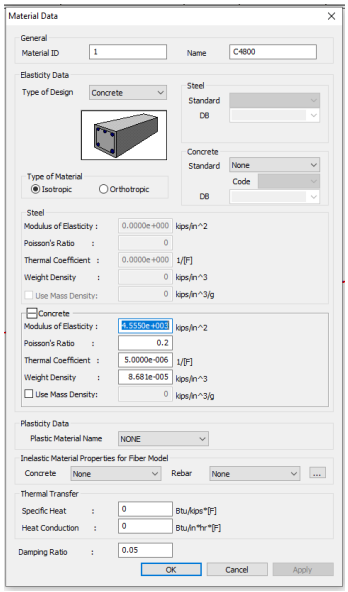
FEM Longitudinal Analysis

Material Data –

- Concrete Strength (4.8 ksi)
- Tendons (270 ksi)
- Time Dependent Materials (CR & SH)
- Time Dependent (Comp. Strength)

After Sections Created

- Link Dependent Material Property (to Section)
- Change Element Dependent Property – Program Calculates the h and V/S for sections



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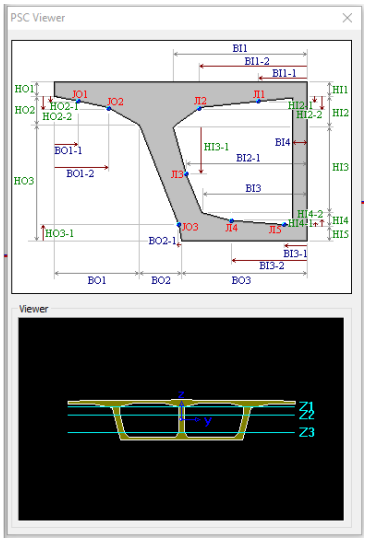
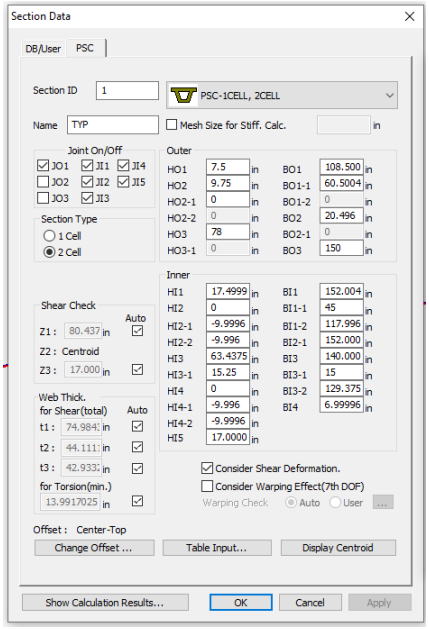
FEM Longitudinal Analysis

Section Input –





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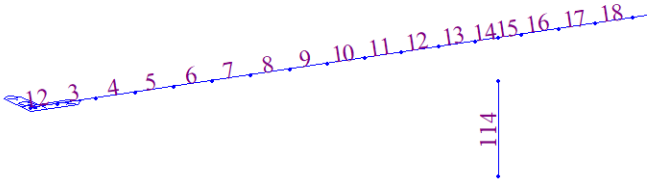
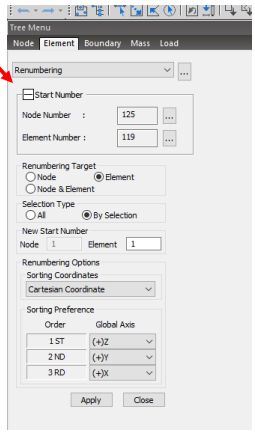
FEM Longitudinal Analysis

	Element	Type	Sub Type	Material	Property	B-Angle ([deg])	Node1	Node2	Node3	Nod
	70	BEAM		1	26	0.00	70	71	0	
	71	BEAM		1	2	0.00	71	72	0	
	72	BEAM		1	2	0.00	72	73	0	
	73	BEAM		1	27	0.00	73	74	0	
	74	BEAM		1	28	0.00	74	75	0	
	75	BEAM		1	29	0.00	75	76	0	
	76	BEAM		1	1	0.00	76	77	0	
	77	BEAM		1	1	0.00	77	78	0	
	78	BEAM		1	1	0.00	78	79	0	
	79	BEAM		1	1	0.00	79	80	0	
	80	BEAM		1	1	0.00	80	81	0	

ELEMENTS –

- Copy for Excel – Suggested
- Place Graphically
- RE-ORDER w/ NODES





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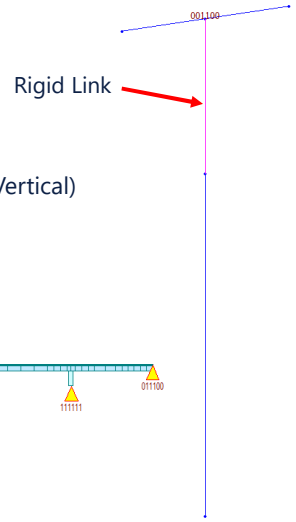
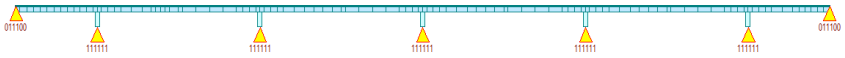
FEM Longitudinal Analysis



Boundaries –

- Supports – Fixed at Base of Piers, Roller at Abutments
- Rigid Links Between Piers and Supports Restrained in DZ (Vertical)
- All supports restrained in RX (Torsion)



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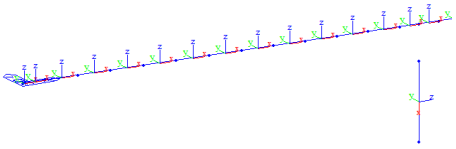
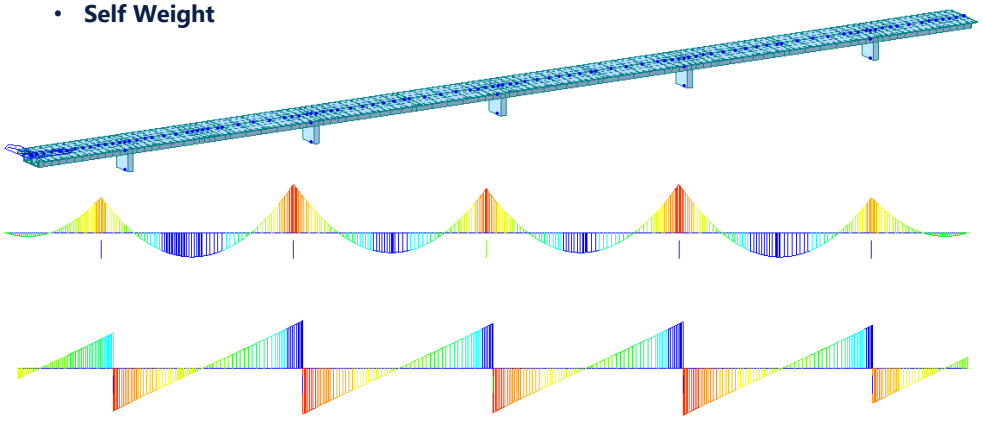
FEM Longitudinal Analysis



STOP CHECK –

- **Node, Element Order**
- **Local Axis**
- **Self Weight**



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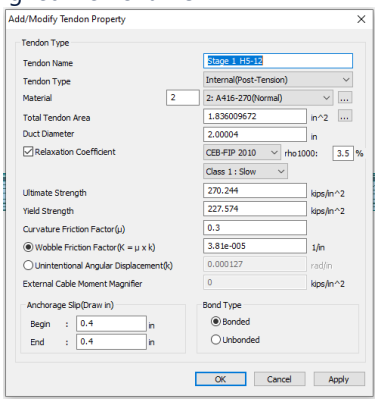
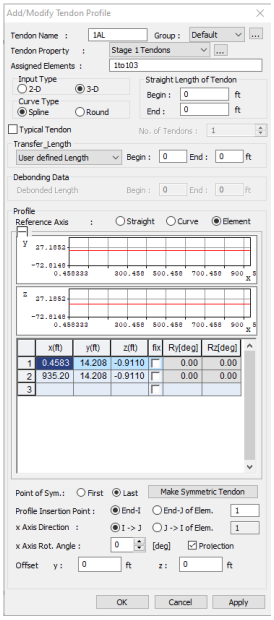
FEM Longitudinal Analysis

Prestressing Tendons –

- Tendon Material Properties
- Tendon Profiles entered for each Tendon – **EXCEL**
- Tendon profile geometry specific to the starting Assigned Element – ORDER





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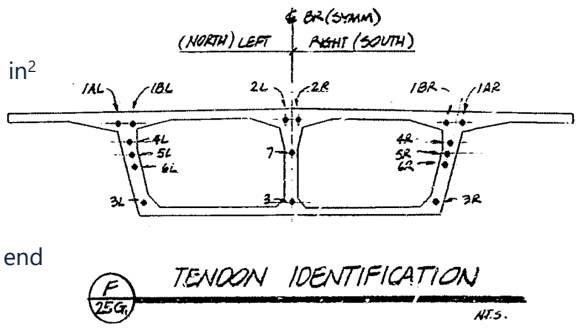
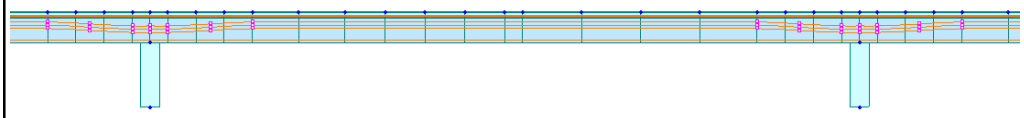
FEM Longitudinal Analysis

Tendons –

- Stage 1 Tendons – **16**
  - E5-12, 12 Strands, A = 0.153 in^2
  - A416-270 Stress Relieved
  - Strand geometry in Excel
  - Strands mirrored about the centerline of section
  - Strands were modeled from end to end





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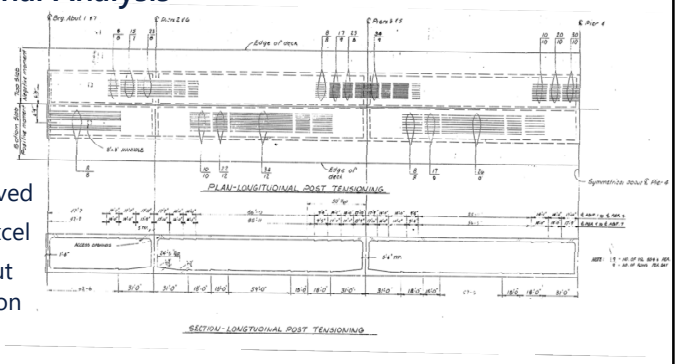
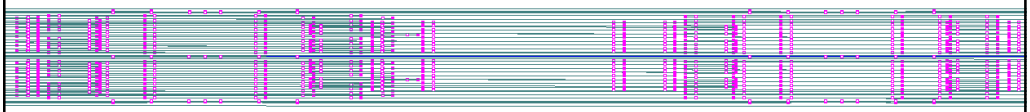
FEM Longitudinal Analysis

Tendons –

- Stage 2 Tendons – **560**
  - "SG4" 4 Strands, A = 0.153 in^2
  - A416-270 Stress Relieved
  - Strand geometry in Excel
  - Strands mirrored about the centerline of section
  - Repetitive





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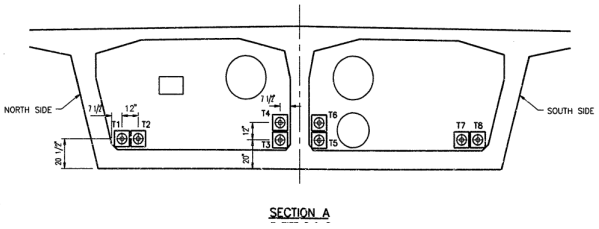
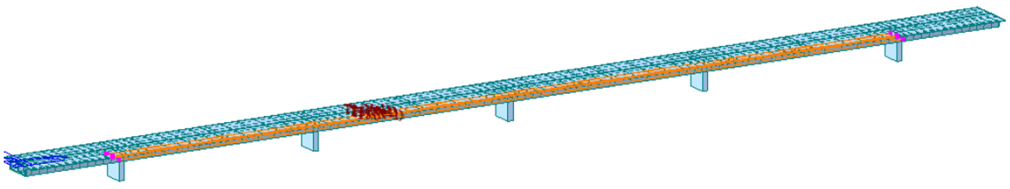
FEM Longitudinal Analysis

Tendons –

- 1992 Rehab B Tendons – **8**
  - 6-7 Strands, A = 0.217 in^2
  - A416-270 Stress Relieved
  - Strand geometry in Excel
  - Strands mirrored about the centerline of section



SECTION A



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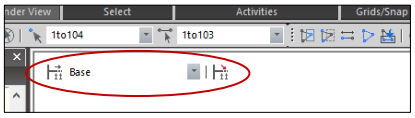
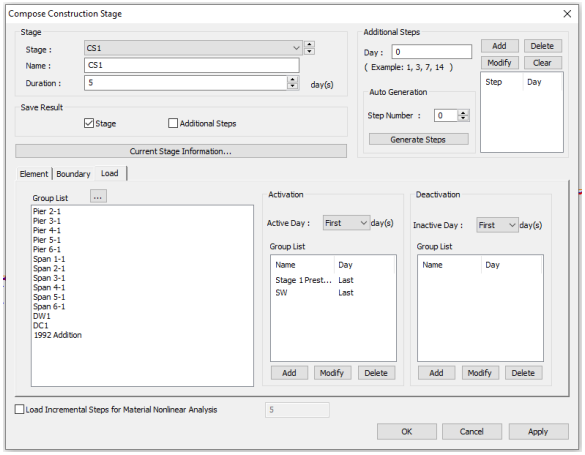
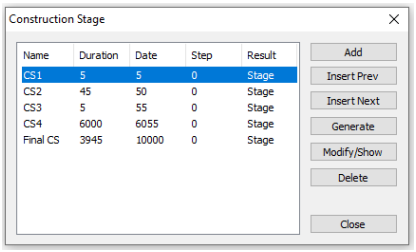
FEM Longitudinal Analysis

Construction Analysis –

- Use GROUP for Elements, Boundaries, and Loads







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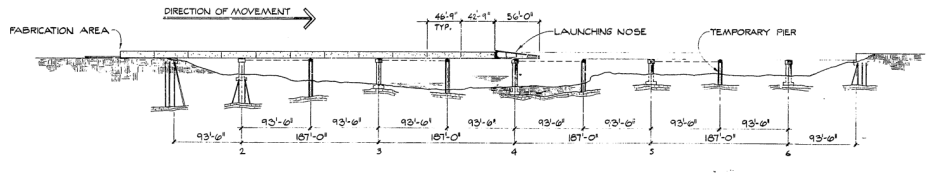
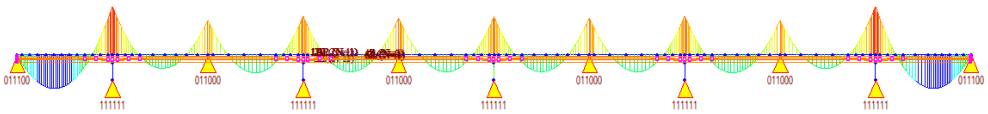
FEM Longitudinal Analysis

Construction Analysis –

- CS 1 = Cast All Segments, Construct Piers, Temporary Piers, Stress Stage 1 Tendons, SW





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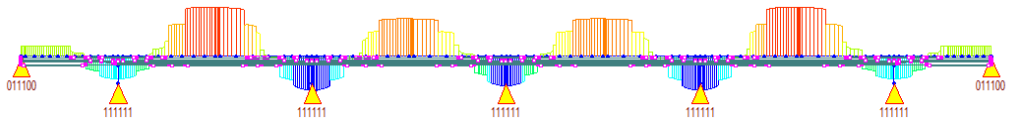
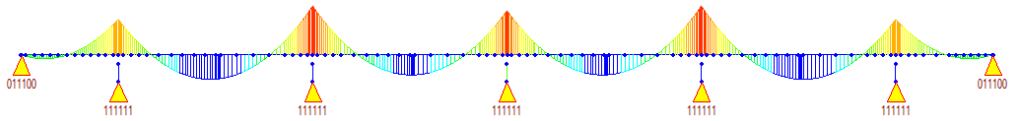
FEM Longitudinal Analysis

Construction Analysis –

- CS 2 = Stress Stage 2 Tendons, Remove Temporary Piers



- CS 3 = Add DC 2 and DW (End of Original Construction)



- CS 4 = Rehab A, Stress Rehab Tendons (Day 6000) – (1992-1975) x 365 ~ 6000 days
- **Final CS = Current Conditions**

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FEM Longitudinal Analysis

Static Loads

- Load Tables, Copy Excel
  - DC – Self Weight, DC Components
  - DW – Utilities (Watermain), Wearing Surface

	Eleme	BM LD Type	Load Case	Load Type	Dist-I(ft)	Dist-J(ft)	Direction	Proje	D1	D2	D3	D4	P1	P2	P3	P4	Unit	Group
	1	Beam Load	DC-Compo	Distributed	22.50	22.50	Global Z	No	0.00	1.00	0.00	0.00	-140.00	-140.00	0.00	0.00	lbf/ft	DC1
	1	Beam Load	DC-Compo	Distributed	-22.50	-22.50	Global Z	No	0.00	1.00	0.00	0.00	-140.00	-140.00	0.00	0.00	lbf/ft	DC1
	2	Beam Load	DC-Compo	Distributed	22.50	22.50	Global Z	No	0.00	1.00	0.00	0.00	-140.00	-140.00	0.00	0.00	lbf/ft	DC1
	2	Beam Load	DC-Compo	Distributed	-22.50	-22.50	Global Z	No	0.00	1.00	0.00	0.00	-140.00	-140.00	0.00	0.00	lbf/ft	DC1
	3	Beam Load	DC-Compo	Distributed	22.50	22.50	Global Z	No	0.00	1.00	0.00	0.00	-140.00	-140.00	0.00	0.00	lbf/ft	DC1
	3	Beam Load	DC-Compo	Distributed	-22.50	-22.50	Global Z	No	0.00	1.00	0.00	0.00	-140.00	-140.00	0.00	0.00	lbf/ft	DC1
	4	Beam Load	DC-Compo	Distributed	22.50	22.50	Global Z	No	0.00	1.00	0.00	0.00	-140.00	-140.00	0.00	0.00	lbf/ft	DC1
	4	Beam Load	DC-Compo	Distributed	-22.50	-22.50	Global Z	No	0.00	1.00	0.00	0.00	-140.00	-140.00	0.00	0.00	lbf/ft	DC1
	5	Beam Load	DC-Compo	Distributed	22.50	22.50	Global Z	No	0.00	1.00	0.00	0.00	-140.00	-140.00	0.00	0.00	lbf/ft	DC1
	5	Beam Load	DC-Compo	Distributed	-22.50	-22.50	Global Z	No	0.00	1.00	0.00	0.00	-140.00	-140.00	0.00	0.00	lbf/ft	DC1

- Temperature Gradient – Beam Section Temp Loads
- Uniform Temperature

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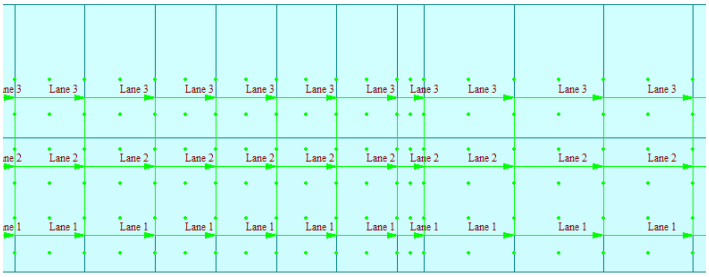
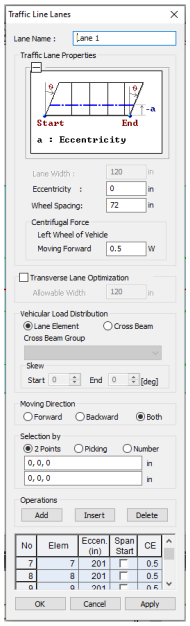
US 136 over Wabash River

FEM Longitudinal Analysis

Live Load Trucks & Lanes–

- Live Load Lanes for Load Rating – Worst Case Modeled for Max Torsion and Optimized
- Per AASHTO MBE 6A.5.11.4,5 "the number of live load lanes may be taken as the number of striped lanes. However, load shall be positioned so as to create maximum effects,"





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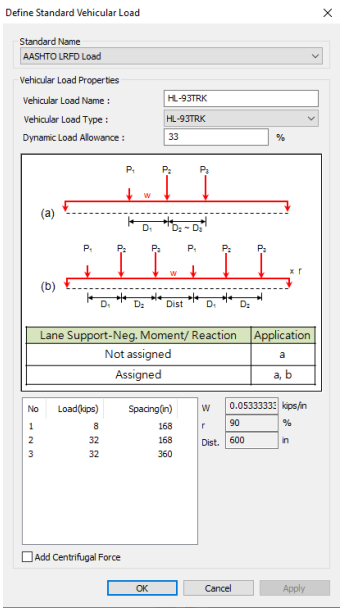
US 136 over Wabash River

FEM Longitudinal Analysis

Live Load Trucks & Lanes –

- Design Loads (Inventory and Operating)
  - HL-93, HS20, H20
- Emergency Vehicles
  - EV2, EV3
- Legal Vehicles
  - H-20, HS-20
  - AASHTO Type 3, 3-3, 3S2
  - Lane – Type, NRL
  - SU4, SU5, SU6, SU7
  - Alt. Military
- Permits (Superload)
  - 11 Axle
  - 13 Axle
  - 14 Axle
  - 19 Axle (305k & 481k)



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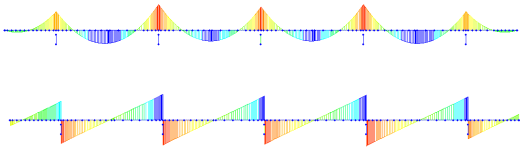
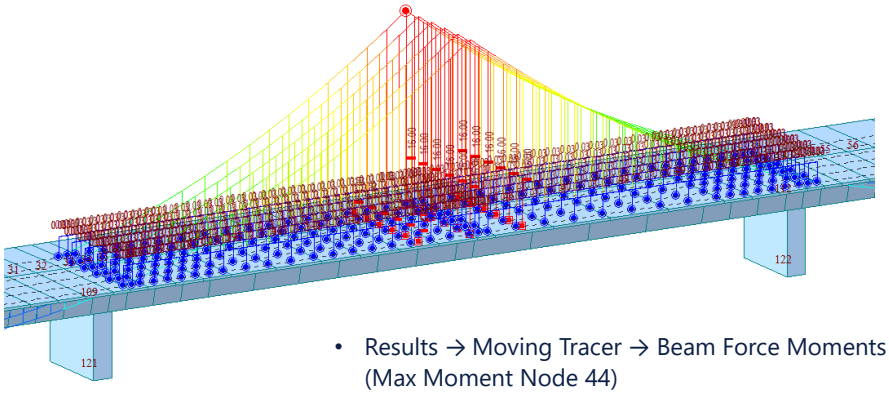
US 136 over Wabash River

FEM Longitudinal Analysis

Typical FE Analysis Results

- My, Moments – DC, DW, PS, TG, TU, LL
- Fz, Shears – DC, DW, PS, TG, TU, LL
- Mx, Torsions – DC, DW, PS, TG, TU, LL





- Results → Moving Tracer → Beam Force Moments (Max Moment Node 44)

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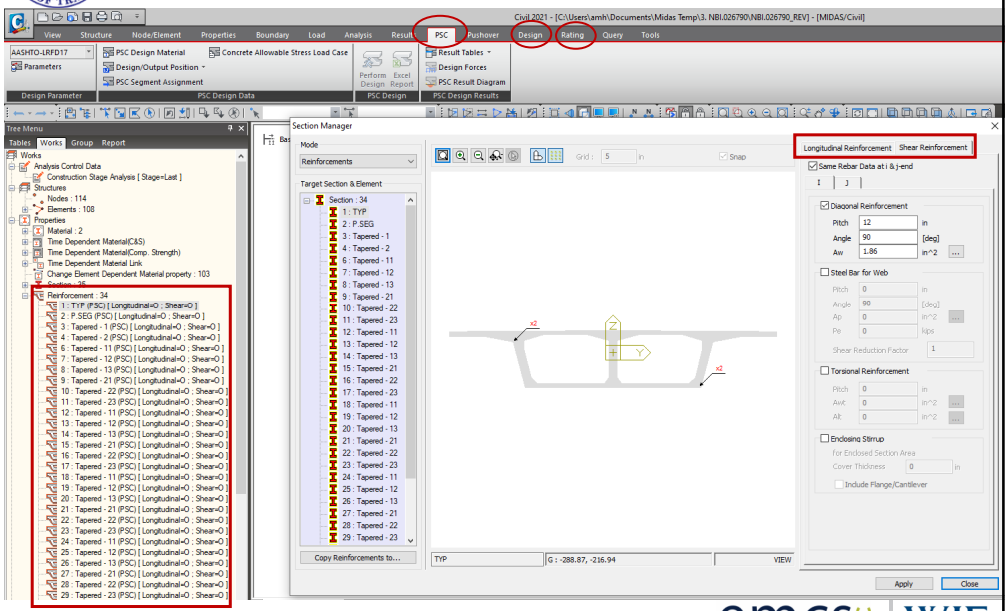
US 136 over Wabash River

FEM Longitudinal Analysis

PSC Box Bridge Design



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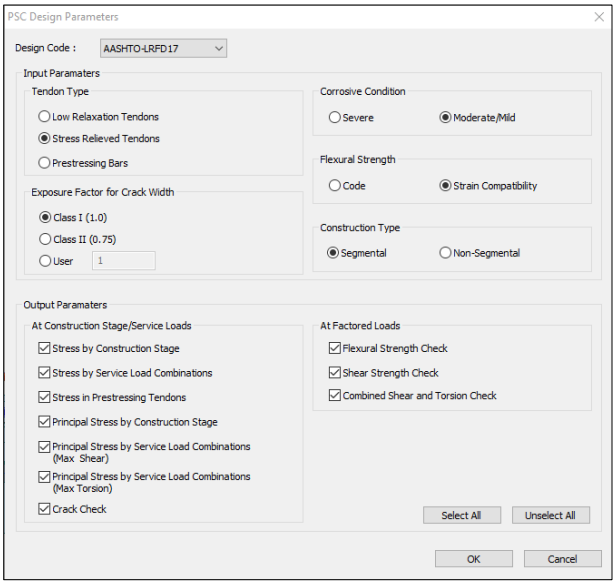
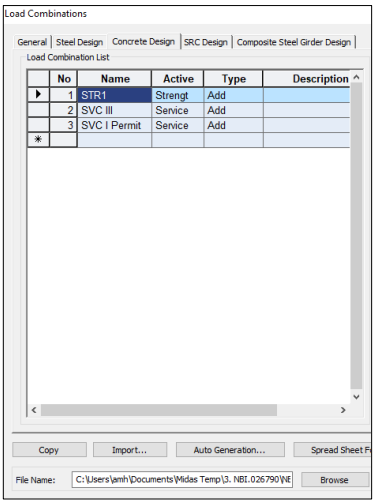
US 136 over Wabash River

FEM Longitudinal Analysis

PSC Box Bridge Design





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US 136 over Wabash River

FEM Design and Rating

PSC DESIGN Results

- Verified MIDAS Moment Capacity – Design Report, Separate Structure Positive and Negative M
- Verified Calculated Stresses – Section Properties
- Partially Verified Shear and Torsion Capacity – Spacing Definition Issues

Design Excel Report

1. Design Condition

Design Code	Element	Node(I/J)
AASHTO-LRFD2017	53	J

■ Section Properties

- Gross section

H	97.975 (in)	A_g	1.270E+04 (in²)	S_t	4.144E+05 (in³)
B	557.993 (in)	I_g	1.814E+07 (in⁴)	S_b	3.348E+05 (in³)
C_{gt}	43.782 (in)				
C_{gb}	54.193 (in)				

- Transformed section

H	97.975 (in)	A_g	1.323E+04 (in²)	S_t	4.388E+05 (in³)
B	557.993 (in)	I_t	1.886E+07 (in⁴)	S_b	3.428E+05 (in³)
C_{gt}	42.971 (in)				
C_{gb}	55.004 (in)				

■ Materials

- Concrete

f'_c (ksi)	E_c (ksi)	$f_r=0.20\sqrt{f'_c}$ (ksi)	β_1
4.800	3991.963	0.438	0.810

* β_1 : 0.85 if f'c is lower than 4ksi, the others are 0.85-0.05(fc-4.0)≥0.65

- Prestressing steel information

Result Tables

	Elem	Part	Positive/ Negative	LCom Name	Type	CHK	Muy (in*kips)	Mcr (in*kips)	Mny (in*kips)	PhiMny (in*kips)	Ratio (Muy/PhiMny)	PhiMny/ min(1.33Muy,Mcr)	E_p (ksi)
	4	J[5]	Negative	STR1	MY-MIN	OK	0.0000	349898.9770	581093.8247	581093.8247	0.0000	larger than 100	500.000
	5	J[6]	Negative	STR1	MY-MIN	OK	0.0000	350760.5375	581479.9742	581479.9742	0.0000	larger than 100	500.000
	6	J[7]	Negative	STR1	MY-MIN	OK	0.0000	352011.1230	581985.5608	581985.5608	0.0000	larger than 100	500.000
	7	J[8]	Negative	STR1	MY-MIN	OK	-34891.6130	353568.5316	582580.7576	582580.7576	0.0599	12.5540	500.000
	8	J[9]	Negative	STR1	MY-MIN	OK	-83390.9436	452209.3022	790702.6918	790702.6918	0.1055	7.1292	500.000
	9	J[10]	Negative	STR1	MY-MIN	OK	-142745.3564	457244.3272	792419.4143	792419.4143	0.1801	4.1739	
	10	J[11]	Negative	STR1	MY-MIN	OK	-214425.0330	569971.2069	952940.4582	952940.4582	0.2250	3.3415	
	11	J[12]	Negative	STR1	MY-MIN	OK	-297254.3136	585399.2183	934037.6870	934037.6870	0.3182	2.3626	
	12	J[13]	Negative	STR1	MY-MIN	OK	-392869.6024	670759.1661	1122646.4890	1122646.4890	0.3499	2.1485	
	13	J[14]	Negative	STR1	MY-MIN	OK	-506893.8699	678448.4430	1123315.4284	1123315.4284	0.4512	1.6662	
	14	J[15]	Negative	STR1	MY-MIN	OK	-588035.9786	642023.7290	1182298.2238	1064068.4014	0.5526	1.6574	

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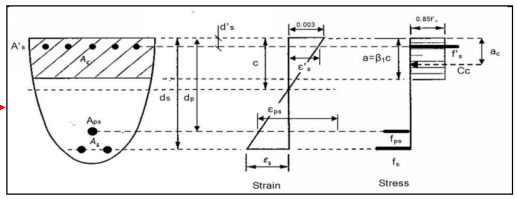
US 136 over Wabash River

FEM Design - Capacities

1. ϕMn, Strain Compatibility
   - AASHTO 5.6.2
2. Tn, Torsion – Investigation Not Required
   - AASHTO 5.7.2.1 $T_u > 0.25\phi T_{cr}$
3. ϕVn, Shear, Segmental
   - AASHTO 5.12.5.3.8



$$V_c = 0.0632K\lambda\sqrt{f_c'}\ b_v d$$

$$V_n = V_c + V_s$$

$$V_s = \frac{A_v f_y d}{s}$$

$$V_n = 0.379\lambda\sqrt{f_c'}\ b_v d$$

$$K = \sqrt{1 + \frac{f_{pc}}{0.0632\lambda\sqrt{f_c'}}} \le 2.0$$

b_v = effective web width taken as the total minimum width of all webs within the depth d

d = 0.8h or the distance from the extreme compression fiber to the centroid of he prestressing reinforcement, whichever is greater (in)

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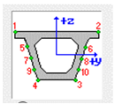
FEM Design - Capacities

1. Flexural Stress – Mc/I, M/S
2. Principal Stress – Stress at the Neutral Axis of the section for tension evaluated
   - Principal Stresses are NEVER ADDITIVE
   - Determine the Center of the Mohr's Circle for Permanent Loads from MIDAS (Node 7 & 8)

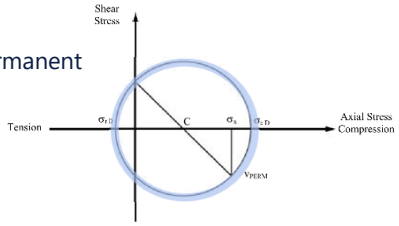


$$c = \frac{(\sigma_x + \sigma_y)}{2}$$

σ_y = Vertical Compressive Stress = 0 in most cases

   - Determine Radius of Mohr's Circle under Permanent Loads

$$r_P = \sqrt{\left[(c - \sigma_Y)^2 + (v_{PERM})^2\right]}$$



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FEM Design - Capacities

- Determine Allowable Principal Tensile Stress = $3.5*(f'c)^{0.5}$ and Max Allowed Mohr's Circle Radius

$$R_{MAX} = (c + \sigma_{TMAX}) = \left(\left(\frac{\sigma_x + \sigma_y}{2}\right)\right) + \left(\phi_{SERVICE} \cdot n\sqrt{f'_c}\right)$$

- Determine the Max Shear Capacity available for resisting loads

$$v_{CAP} = v_{LLMAX} + v_{PERM} = \sqrt{\left(R_{MAX}^{\ 2} - (\sigma_x - c)^2\right)}$$

- Determine Rating Factor

$$RF = \frac{(v_{CAP} - v_{PERM})}{v_{1LL}}$$

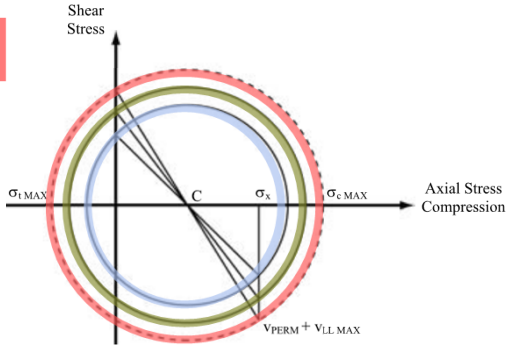

Figure B.3 – Mohr's Circle for All Permanent Loads + Max Live Load (for $\sigma_y = 0$)

Ref. Florida Post Tensioned Bridges, FINAL Report, Vol. 10 A, Appendix B

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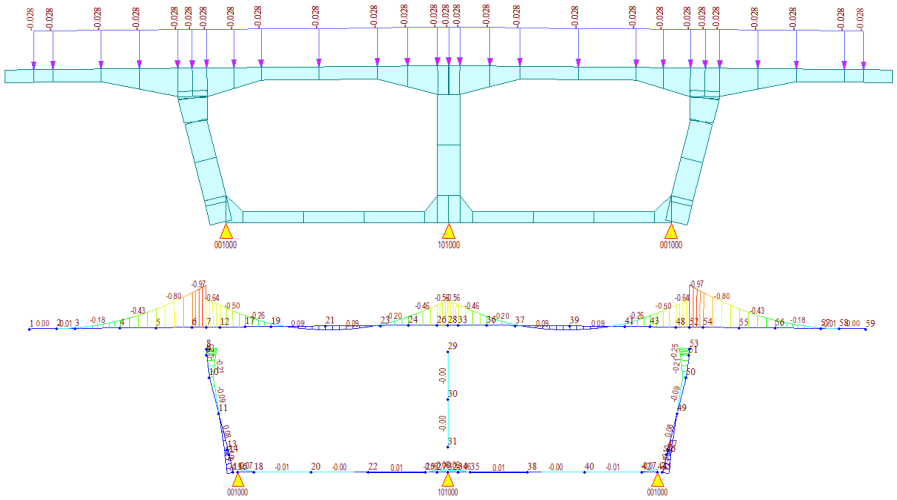
FEM Transverse Analysis

Transverse DC Analysis

- 1 ft thick Elements, DC & DW Applied



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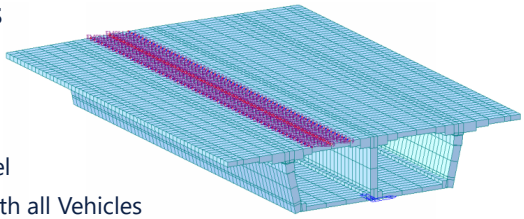
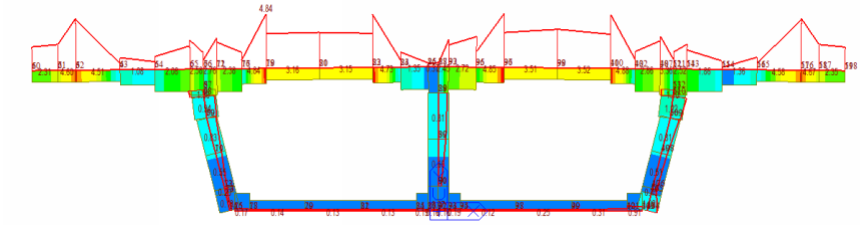
FEM Transverse Analysis



Transverse DC Analysis

- Plate Element Extruded x 100
- Fixed supports at faces of 3D Model
- Multiple Surface Lanes modeled with all Vehicles
- Section Cut at Center to get LL Envelopes

Lane 1 Max M, HL-93



Section Results Max M, HL-93

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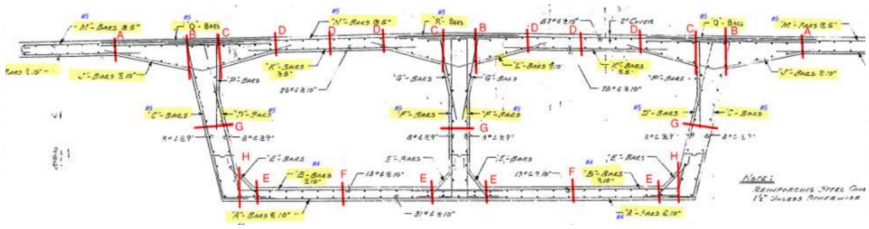
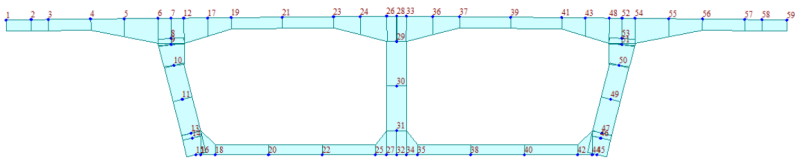
FEM Transverse Analysis

- Section Capacity, Hand Calculations. RC Strain Compatibility, Section A through H
- No Post Tensioning





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Load Rating Calculations

- MIDAS Resulting Rating Factors were Inconsistent
- Rating Calculated Outside of Program Excel – Independent check in Mathcad

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_{LL})(LL + IM)} \qquad (6A.4.2.1\text{-}1)$$

$$C = \varphi_c \varphi_s \varphi R_n$$

φ_s = 1.15 System Factor, more than 4 Tendons per web
AASHTO MBE 6.A.5.11.6-1

φ_c = 0.95 Inspection Report, Fair Condition
AASHTO MBE 6.A.4.2.3-1

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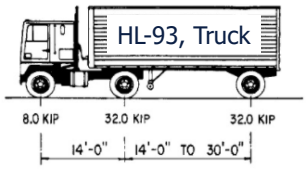
Load Rating Combinations

Design Load Rating; Inventory, HL-93, HS20, H20

1. Strength I, γ_{DC} = 1.25, γ_{DW} = 1.25, γ_P = 1.0, γ_{LL} = 1.75, Flexure - ϕMn
2. Strength I, γ_{DC} = 1.25, γ_{DW} = 1.25, γ_P = 1.0, γ_{LL} =1.75, Shear / Torsion - ϕVn
3. Service III, γ_{DC} = 1.0, γ_{DW} = 1.0, γ_P = 1.0, γ_{LL} =1.0, Flexural Tensile Stress = -100 psi, $3*(f'c)^{0.5}$
4. Service III, γ_{DC} = 1.0, γ_{DW} = 1.0, γ_P = 1.0, γ_{LL} = 1.0, γ_{LL} = 1.0, Flexural Compressive Stress = 0.6f'c
5. Service III, γ_{LL} = 1.0, Principal Stress = $3.5*(f'c)^{0.5}$

- Bridge Cast in 46'-9" Segments, with a segmental "Type B Joint", having no continuous reinforcement or epoxy. Utilized more conservative allowable stress per AASHTO Guide Specification for Segmental Bridges and previous practice. AASHTO Table 5.9.2.3.2b-1 utilized for locations within CIP segments, $3*(f'c)^{0.5} = 0.0948*(f'c)^{0.5}$
- Principal Stress, per AASHTO 5.9.2.3.3, $3.5*(f'c)^{0.5} = 0.110*(f'c)^{0.5}$
- Wearing Surface assumed Field Measured



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Load Rating Combinations

Design Load Rating; Operating, HL-93, HS20, H20

1.Strength I, γ_{DC} = 1.25, γ_{DW} = 1.25, γ_P = 1.0, γ_{LL} = 1.35, Flexure - ϕMn

2.Strength I, γ_{DC} = 1.25, γ_{DW} = 1.25, γ_P = 1.0, γ_{LL} = 1.35, Shear / Torsion - ϕVn

3.Service III, γ_{DC} = 1.0, γ_{DW} = 1.0, γ_P = 1.0, γ_{LL} = 1.0, Flexural Tensile Stress = 0 psi, $6*(f'c)^{0.5}$

4.Service III, γ_{DC} = 1.0, γ_{DW} =1.0, γ_P = 1.0, γ_{LL} = 1.0, γ_{LL} = 1.0, Flexural Compressive Stress = 0.6f'c

5.Service III, γ_{LL} = 1.0, Principal Stress = $3.5*(f'c)^{0.5}$

- Bridge Cast in 46'-9" Segments, with a segmental "Type B Joint", having no continuous reinforcement or epoxy. Utilized more conservative allowable stress per AASHTO Guide Specification for Segmental Bridges and previous practice. AASHTO Table 5.9.2.3.2b-1 utilized for locations within CIP segments, $6*(f'c)^{0.5} = 0.19*(f'c)^{0.5}$
- Principal Stress, per AASHTO 5.9.2.3.3, $3.5*(f'c)^{0.5} = 0.110*(f'c)^{0.5}$
- Wearing Surface assumed Field Measured

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US 136 over Wabash River

Load Rating Combinations

Legal Load Rating (Both Routine Commercial and Specialized Hauling) –

H-20, HS-20, EV2, EV3 AASHTO Type 3, 3-3, 3S2, NRL, Lane Type, SU4, SU5, SU6, SU7, Alt. Milt.

1. Strength I, γ_{DC} = 1.25, γ_{DW} = 1.25, γ_P = 1.0, γ_{LL} = 1.45, (1.3 EV) Flexure - ϕMn
2. Strength I, γ_{DC} = 1.25, γ_{DW} = 1.25, γ_P = 1.0, γ_{LL} = 1.45, (1.3 EV) Shear / Torsion - ϕVn
3. Service III, γ_{DC} = 1.0, γ_{DW} = 1.0, γ_P = 1.0, γ_{LL} = 1.0, Flexural Tensile Stress = 0 psi, $6*(f'c)^{0.5}$
4. Service III, γ_{DC} = 1.0, γ_{DW} = 1.0, γ_P = 1.0, γ_{LL} = 1.0, Flexural Compressive Stress = 0.6f'c
5. Service III, γ_{DC} = 1.0, γ_{DW} = 1.0, γ_P = 1.0, γ_{LL} = 1.0, Principal Stress = $3.5*(f'c)^{0.5}$

- Bridge Cast in 46'-9" Segments, with a segmental "Type B Joint", having no continuous reinforcement or epoxy. Utilized more conservative allowable stress per AASHTO Guide Specification for Segmental Bridges and previous practice. AASHTO Table 5.9.2.3.2b-1 utilized for locations within CIP segments, $6*(f'c)^{0.5} = 0.19*(f'c)^{0.5}$
- Principal Stress, per AASHTO 5.9.2.3.3, $3.5*(f'c)^{0.5} = 0.110*(f'c)^{0.5}$
- Wearing Surface assumed Field Measured

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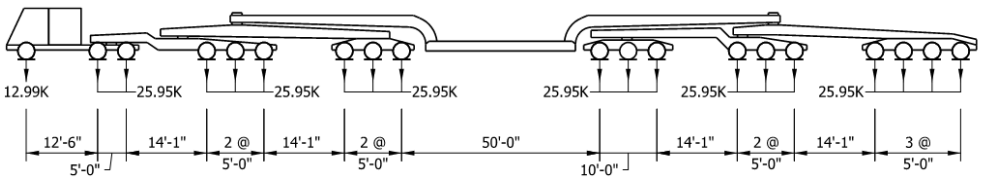
US 136 over Wabash River

Load Rating Combinations

Permit Load Rating ("Special", Single Trip, Mixed with Traffic) –

Superload 11 Axle, 13 Axle, 14 Axle, 19 Axle (305k & 481k)

1. Strength I, γ_{DC} = 1.25, γ_{DW} = 1.25, γ_P = 1.0, γ_{LL} = 1.35, Flexure - ϕMn
2. Strength I, γ_{DC} = 1.25, γ_{DW} = 1.25, γ_P = 1.0, γ_{LL} = 1.35, Shear / Torsion - ϕVn
3. Service III, γ_{DC} = 1.0, γ_{DW} = 1.0, γ_P = 1.0, γ_L = 1.0, Flexural Tensile Stress = 0 psi, $6*(f'c)^{0.5}$
4. Service III, γ_{DC} = 1.0, γ_{DW} = 1.0, γ_P = 1.0, γ_{LL} = 1.0, Flexural Compressive Stress = 0.6f'c
5. Service III, γ_{DC} = 1.0, γ_{DW} = 1.0, γ_P = 1.0, γ_{LL} = 1.0, Principal Stress = $3.5*(f'c)^{0.5}$



SUPERLOAD - 19 AXLES LOADING
(W = 480.09K)

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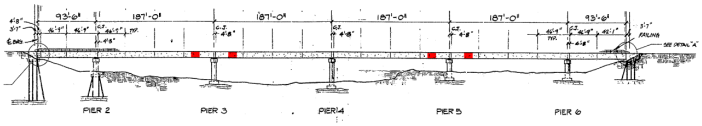
US 136 over Wabash River

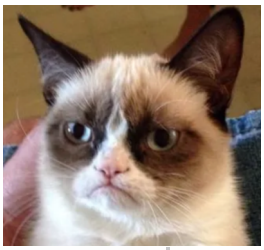
Initial Load Rating Results

Legal Load Rating (Both Routine Commercial and Specialized Hauling) –

H-20, HS-20, EV2, EV3 AASHTO Type 3, 3-3, 3S2, NRL, Lane Type, SU4, SU5, SU6, SU7, Alt. Milt.

1. Strength I, Flexure – ϕMn	
a. Longitudinal	1a. RF_{min} = 7.69 OK
b. Transverse	1b. RF_{min} = 1.01 OK
2. Strength I, Shear – ϕVn	2. RF_{min} = 0.66 NG ←
3. Service III, Flexural Tensile Stress	3. RF_{min} = 2.99 OK
4. Service III, Flexural Compressive Stress	4. RF_{min} = 3.14 OK
5. Service III, Principal Stress	5. RF_{min} = 0.99 NG ←





NEXT STEPS:

- **Check Again**
- **Refine Model**
- **Narrow Rating Results Location**
- **Collaborate Data / Direction**

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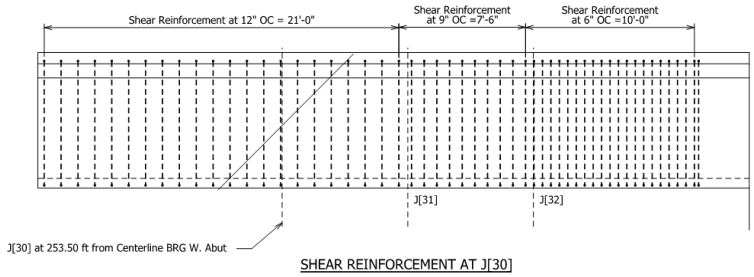
Initial Load Rating Results

Find all Locations NOT Rating and Narrow Down the Problem

- Shear Controlled, Approximately 27ft off either side of Piers 3 and 5
- At this location, the shear stirrups transition from 9 in to 12 in
- Addition nodes, suggestion that including counting all bars along the inclined crack path will not fix.



→ **Collaborate Data / Direction**

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What's Next?

1. Load Posting?

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What's Next?

1. Load Posting?

2. Repair / Retrofits?

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What's Next?

1. Load Posting?

2. Repair / Retrofits?

3. More Refinements?
   - Material Properties
   - Field Verification

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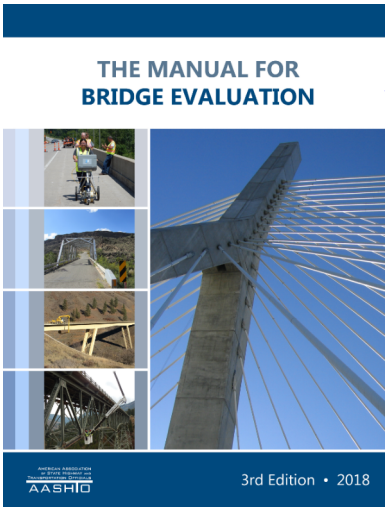
Material Property Refinements

6.A.5.2.1 Concrete

Where the quality of the concrete is uncertain, cores should be taken for mechanical property testing.

Cores may also be taken where the initial load capacity based on design concrete strength is considered inadequate.



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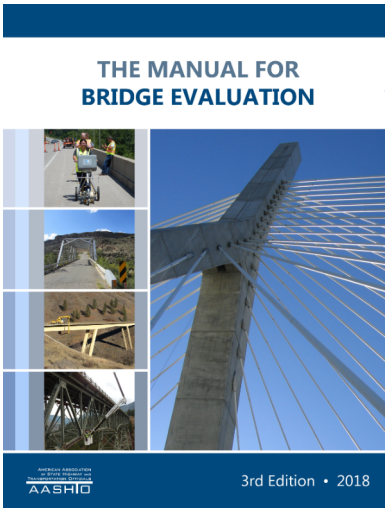
Material Property Refinements

6.A.6.2.1 Structural Steels

In cases where the initial evaluation suggests load capacity inadequacies, or there is doubt about the nature and quality of a particular material, the mechanical properties can be verified by testing. Mechanical properties of the material should be determined based on coupon tests.



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Field Verification Examples

Material Sampling

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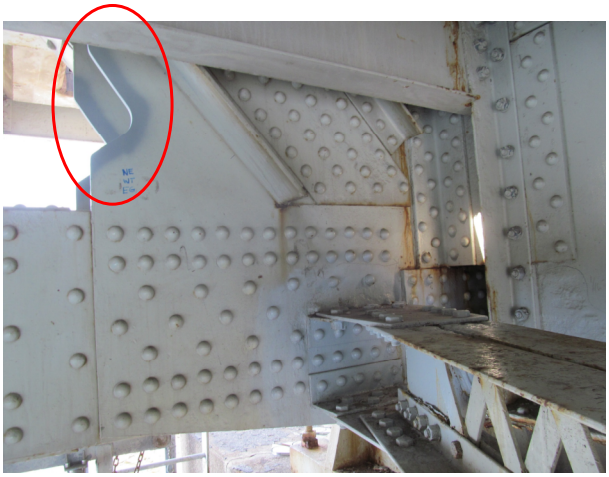
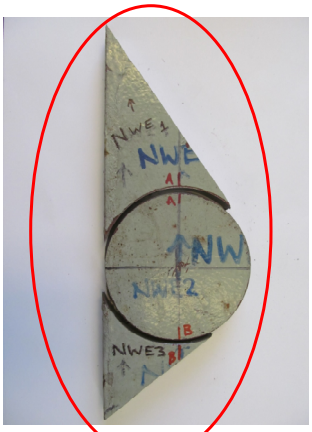
Field Verification Examples

Material Sampling





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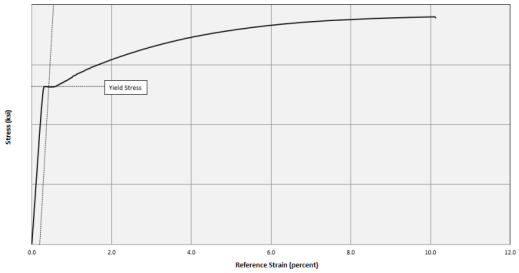
Field Verification Examples

Material Sampling

Tensile Testing

Tensile Orientation	Longitudinal	Transverse	Longitudinal
Tensile Strength, psi	63,500	63,000	61,000
Yield Strength, psi (Yield Point) (.2% Offset)	 37,200 33,800	 41,500 36,000	 - - 33,900



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Field Verification Examples

Ground Penetrating Radar (GPR)

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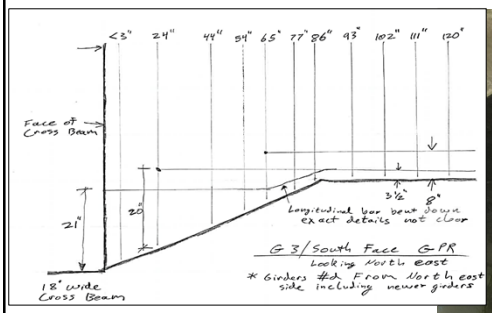
Field Verification Examples

Ground Penetrating Radar (GPR)



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Field Verification Examples

Inspection Openings

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Field Verification Examples

Reinforcing Bar Samples

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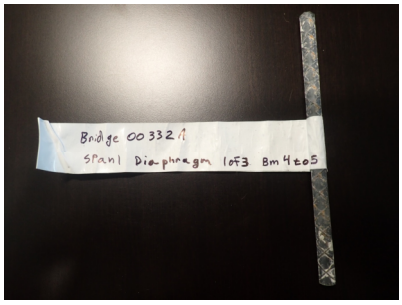
Field Verification Examples

Reinforcing Bar Testing



TENSILE TESTING

	East Wall North End	West Wall South End	West Wall North End
Specimen Orientation	Longitudinal	Longitudinal	Longitudinal
Specimen Type	.250	.250	.250
Tensile Strength, psi	71,500	70,500	72,000
Yield Strength, psi (Yield Point)[1] (.2% Offset)	 47,300 45,500	 44,100 43,100	 49,400 45,700

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Field Verification Examples

Condition Factors

Table 6A.4.2.3-1—Condition Factor: φ_c

Structural Condition of Member	φ_c
Good or Satisfactory	1.00
Fair	0.95
Poor	0.85

If section properties are obtained accurately, by actual field measurement of losses rather than by an estimated percentage of losses, the values specified for φ_c in Table 6A.4.2.3-1 may be increased by 0.05 ($\varphi_c \leq 1.0$).

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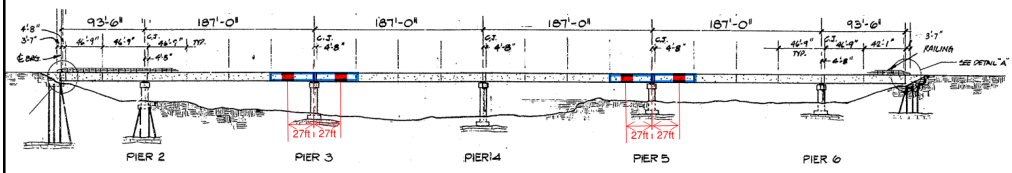
US 136 Field Verification



- Visual Inspection
- Ground Penetrating Radar
- Concrete Core Samples
- Concrete Strength Testing

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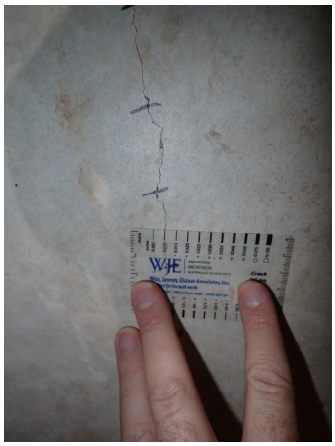
US 136 Field Verification



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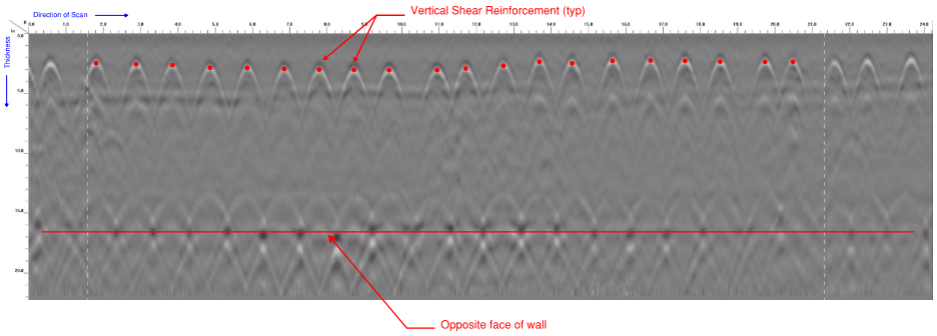
US 136 Field Verification

FILE_004 - Point 4 (Span E, Segment 6) - North Cell, North Web



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US 136 Field Verification

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US 136 Material Sampling

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US 136 Material Sampling

Sample ID	Corrected Compressive Strength (psi)	Section	Web
CORE 1	7,360	Point 4 (Span E)	Center
CORE 2	8,250	Point 4 (Span E)	North
CORE 3	7,920	Point 4 (Span E)	North
CORE 4	9,580	Point 3 (Span D)	North
CORE 5	7,910	Point 3 (Span D)	North
CORE 6	8,260	Point 3 (Span D)	Center
CORE 7	6,440	Point 2 (Span C)	Center
CORE 8	7,080	Point 2 (Span C)	North
CORE 9	8,610	Point 1 (Span B)	North
CORE 10	9,210	Point 1 (Span B)	South
CORE 11	8,060	Point 1 (Span B)	South
CORE 12	8,270	Point 1 (Span B)	Center
CORE 13	8,070	Point 2 (Span C)	South
CORE 14	8,250	Point 2 (Span C)	South
CORE 15	8,570	Point 3 (Span D)	South
CORE 16	8,610	Point 4 (Span E)	South
CORE 17	8,630	Point 4 (Span E)	South

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US 136 Material Sampling

Group	Concrete Compressive Strength (psi)		
	Mean (μ)	Standard Deviation (σ)	AASHTO MBE (μ - 1.65σ)
All Samples	8,181	744	6,954
Above Construction Joint	7,995	886	6,533
Below Construction Joint	8,347	595	7,366
Point 1 (Span B)	8,538	502	7,709
Point 2 (Span C)	7,460	853	6,053
Point 3 (Span D)	8,580	719	7,393
Point 4 (Span E)	8,154	531	7,277

$\mu - 1.65\sigma$ = 6,053 psi (Material Testing)
f'_c = 4,800 psi (Design Drawings)

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Updated Load Rating Results

Legal Load Rating – Strength I, Shear – ϕV_n

Previous: RF_{min} = 0.66 NG

Update
Concrete Strength

Updated: RF_{min} = 1.008 OK

Posting Consideration

No Longer Necessary

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Questions?

If you ask me anything I don't know,
I'm not going to answer.

-Yogi Berra

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