FDOT TRANSPORTATION SYMPOSIUM 2019

Structures Research Update

Will Potter

Outline

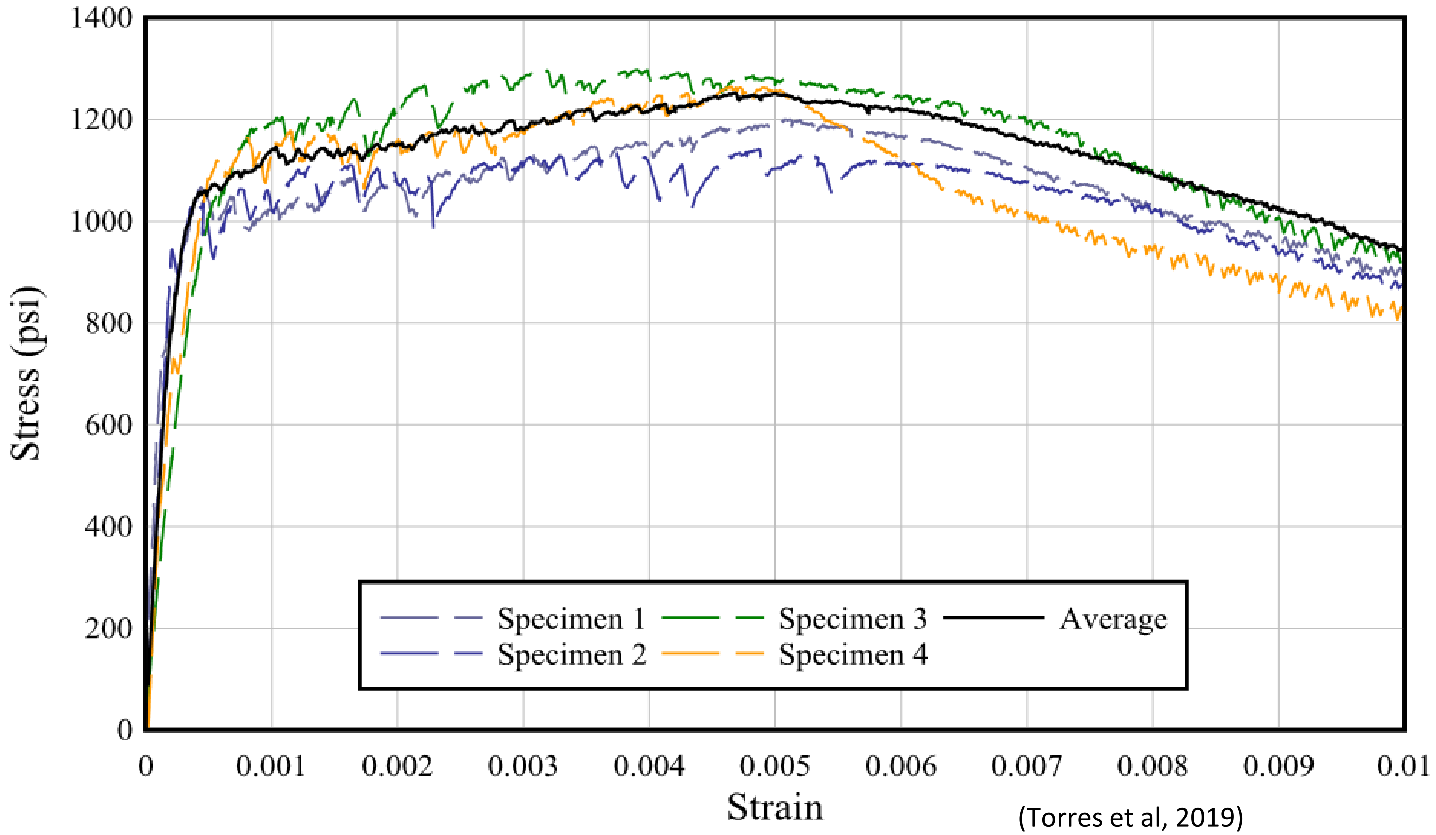
- SRC Overview
- UHPC Precast Members
- Large Bars Spliced in UHPC
- Stainless Steel Strands for Pretensioned Girders
- Shear Behavior of Voided Webs (PT)
- Effective Width Recommendations for Concrete Slab Bridges
- Mid-Bay Repair Monitoring
- Bridge Load Testing
- Additional Research Topics

Structures Research Center

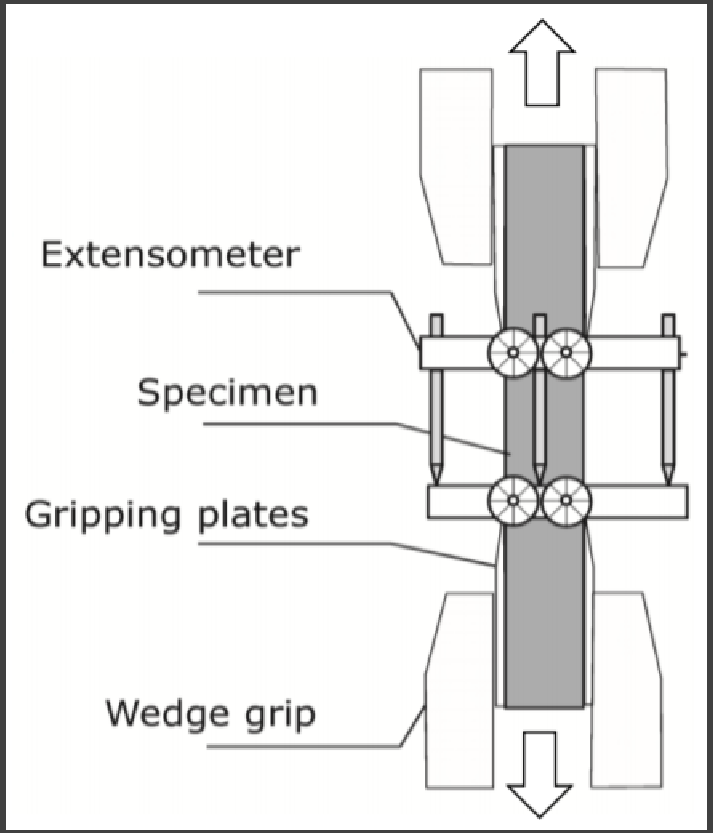
- Large Scale Structural Research
  - In-house
  - University/Consultant
- Bridge Load Testing/Rating and Monitoring

Ultra-High Performance Concrete

- Basic Background
  - Fiber Reinforced (2%)
  - Portland Cement Product
  - w/cm ratio < 0.25
  - Sustained Tensile Strength > 0.72 ksi
  - Enhanced Durability
  - Flowable



(Torres et al, 2019)



(FHWA, 2017)

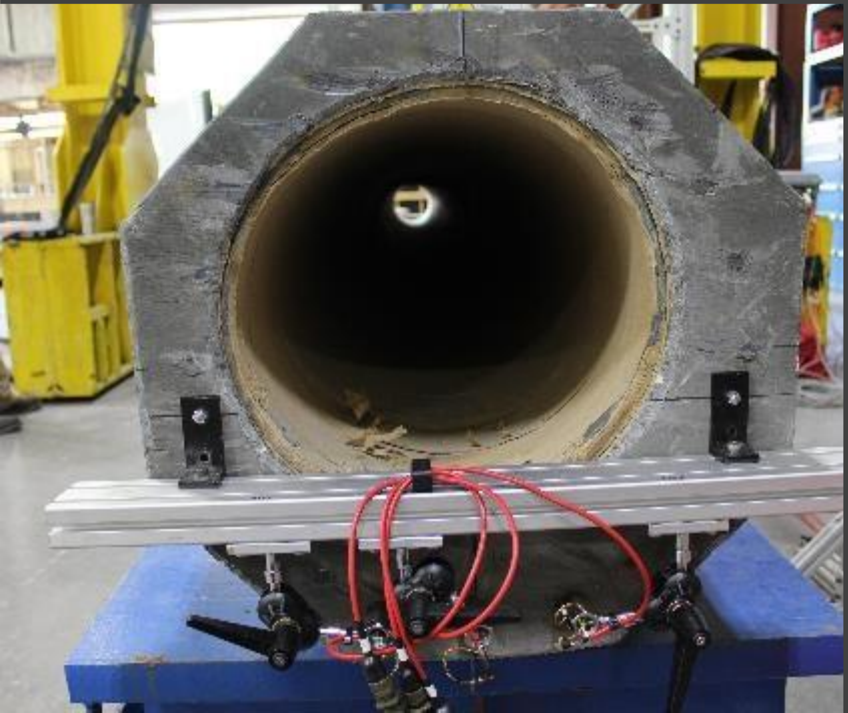
Direct Tension Test

UHPC Precast Members

DURA-STRESS Inc.

SCP STANDARD CONCRETE PRODUCTS

FDOT



SCP Piling

- 24-inch Octagonal Pile
- Compressive Strength (f’c) – 19 ksi
- ASTM 1609 Strength (tension) – 2.4 ksi

Dura-Stress Piling

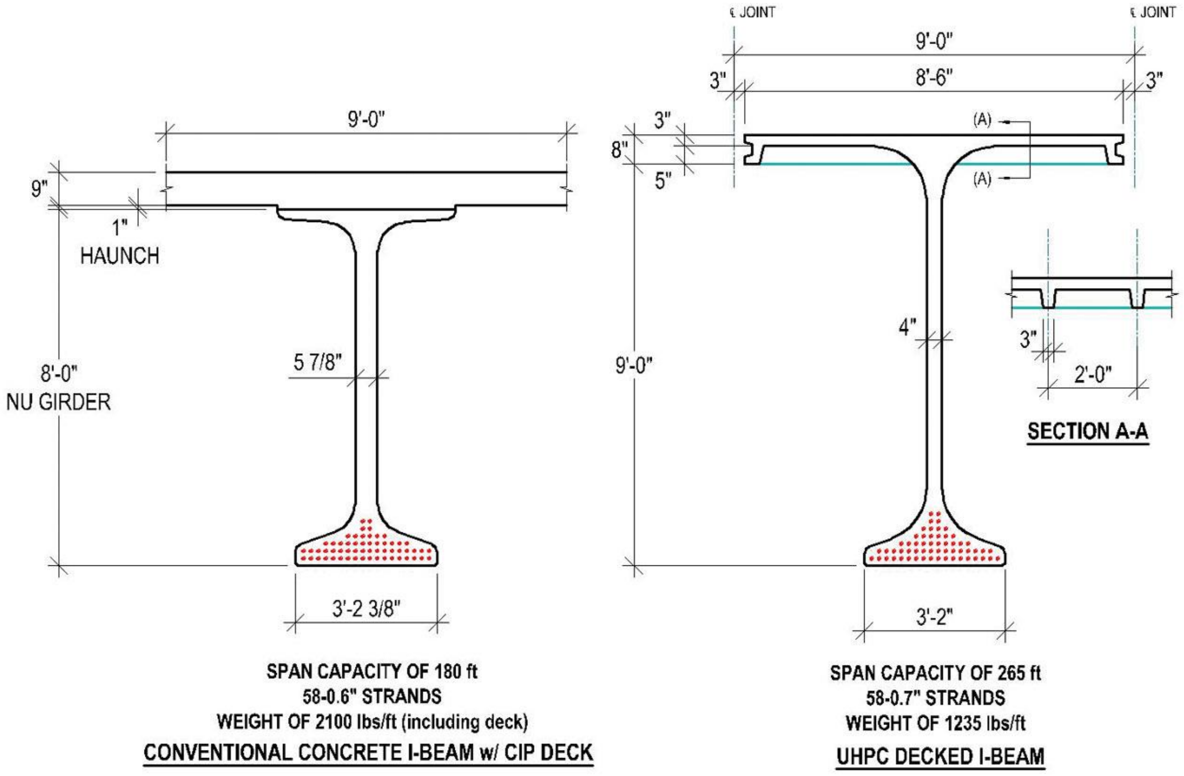
- 18-inch Square Pile
- Compr. Strength (f'c) – 23-24 ksi
- Direct Tension Test – 1.2 ksi


25:44.5
Running Time
-132.0
Load (kips)
4.024
D6 (inches)
4.024
D7 (inches)
-3868
S4 (ue)
-2602
S5 (ue)
-2602
S6 (ue)

UHPC Precast Members

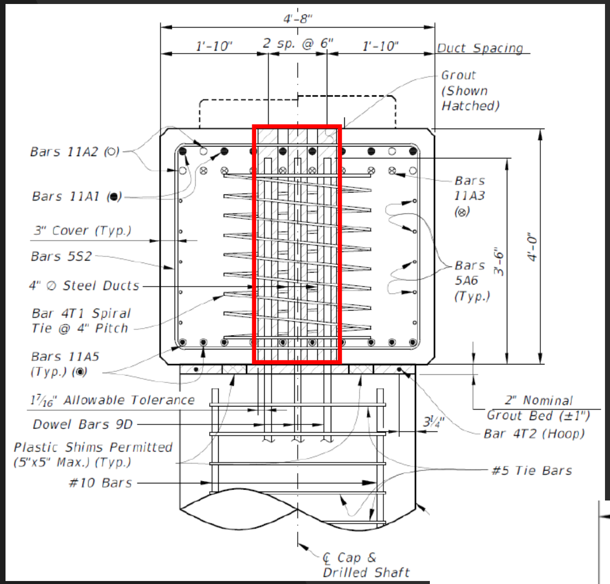
- Collaboration with Precaster's
- Developmental Specification (Dev 349 – Proprietary UHPC)
- State Materials Office – Developing Non-Proprietary Specification

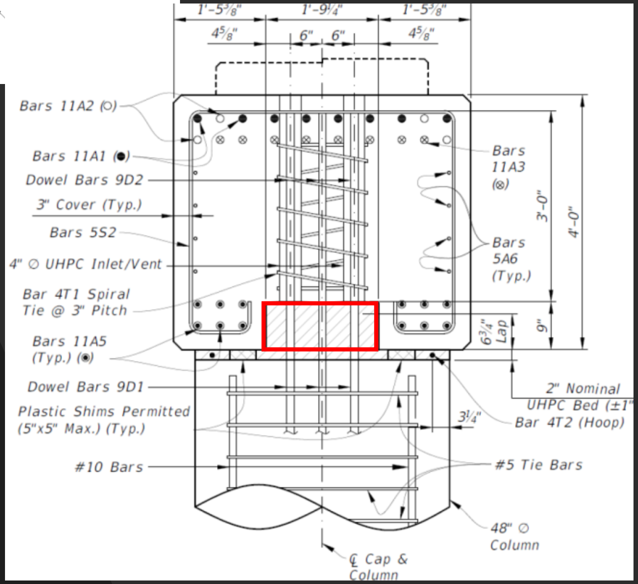
- National Level
  - PCI Research
  - FHWA Research

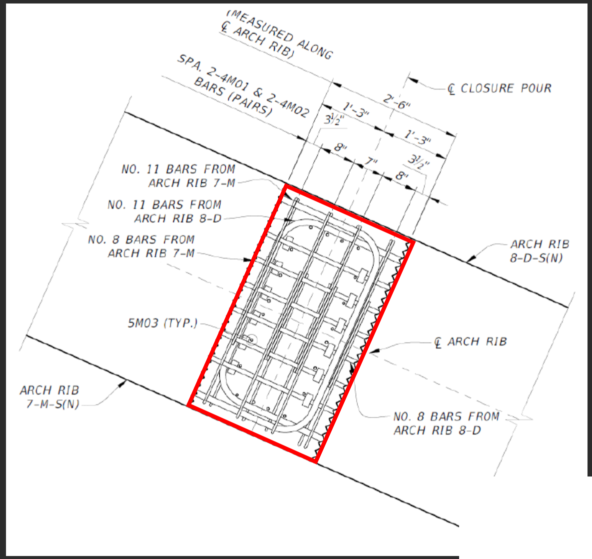


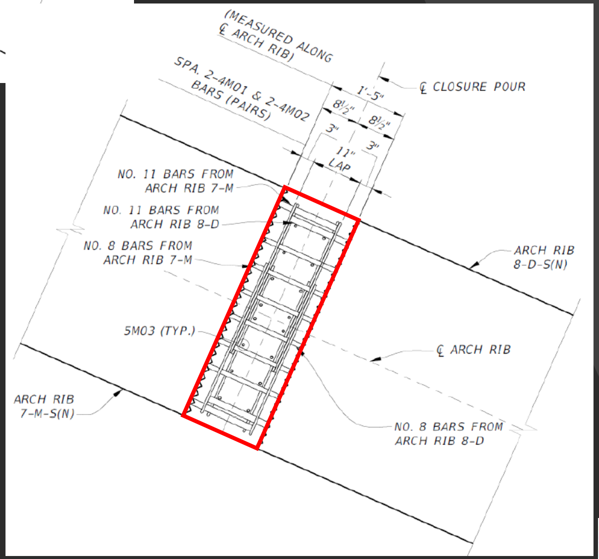
(Tadros, 2019)

Large Bars Spliced in UHPC



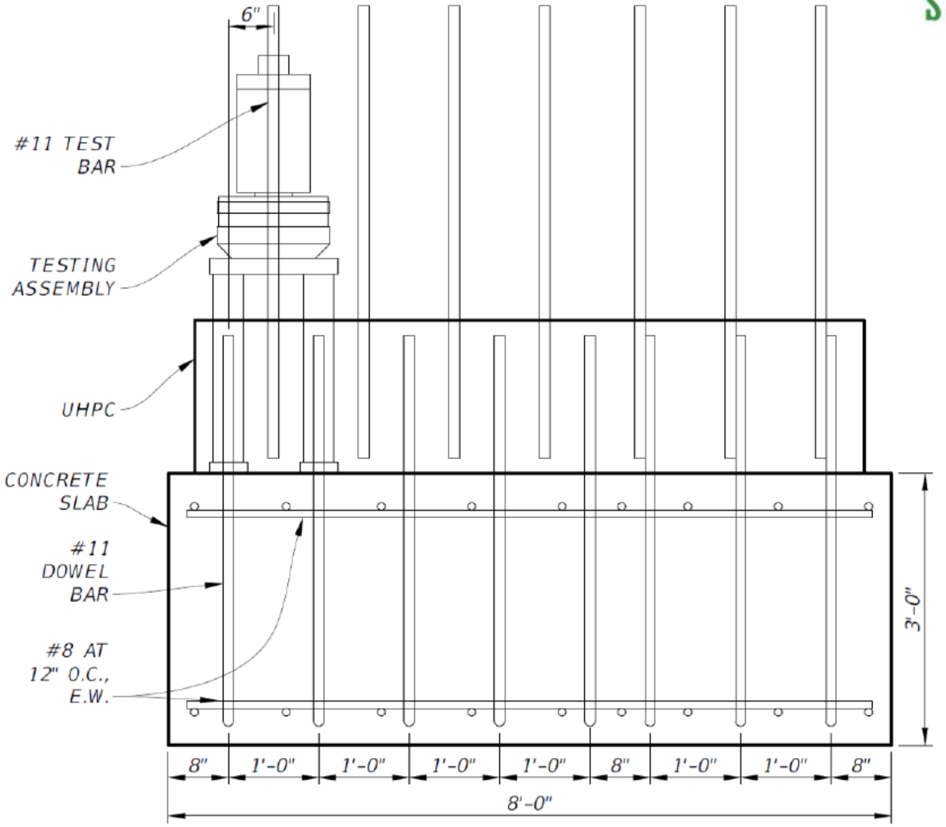






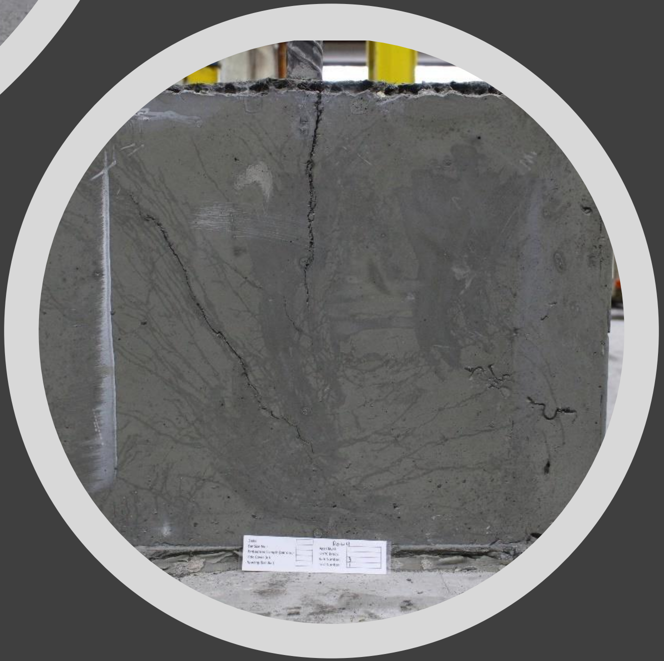
Test Parameters

- Bar Size: #8, #9, #10, #11
- Bar Strength: 60 ksi
- UHPC Strength: Less than 14 ksi target
- UHPC Fiber Content: 2% by volume
- 1.75” and 3.75” cover
- Various Bar Spacings


6"
#11 TEST BAR
TESTING ASSEMBLY
UHPC
CONCRETE SLAB
#11 DOWEL BAR
#8 AT 12" O.C., E.W.
3'-0"
8"
1'-0"
1'-0"
1'-0"
1'-0"
8"
1'-0"
1'-0"
8"
8'-0"

Test Setup

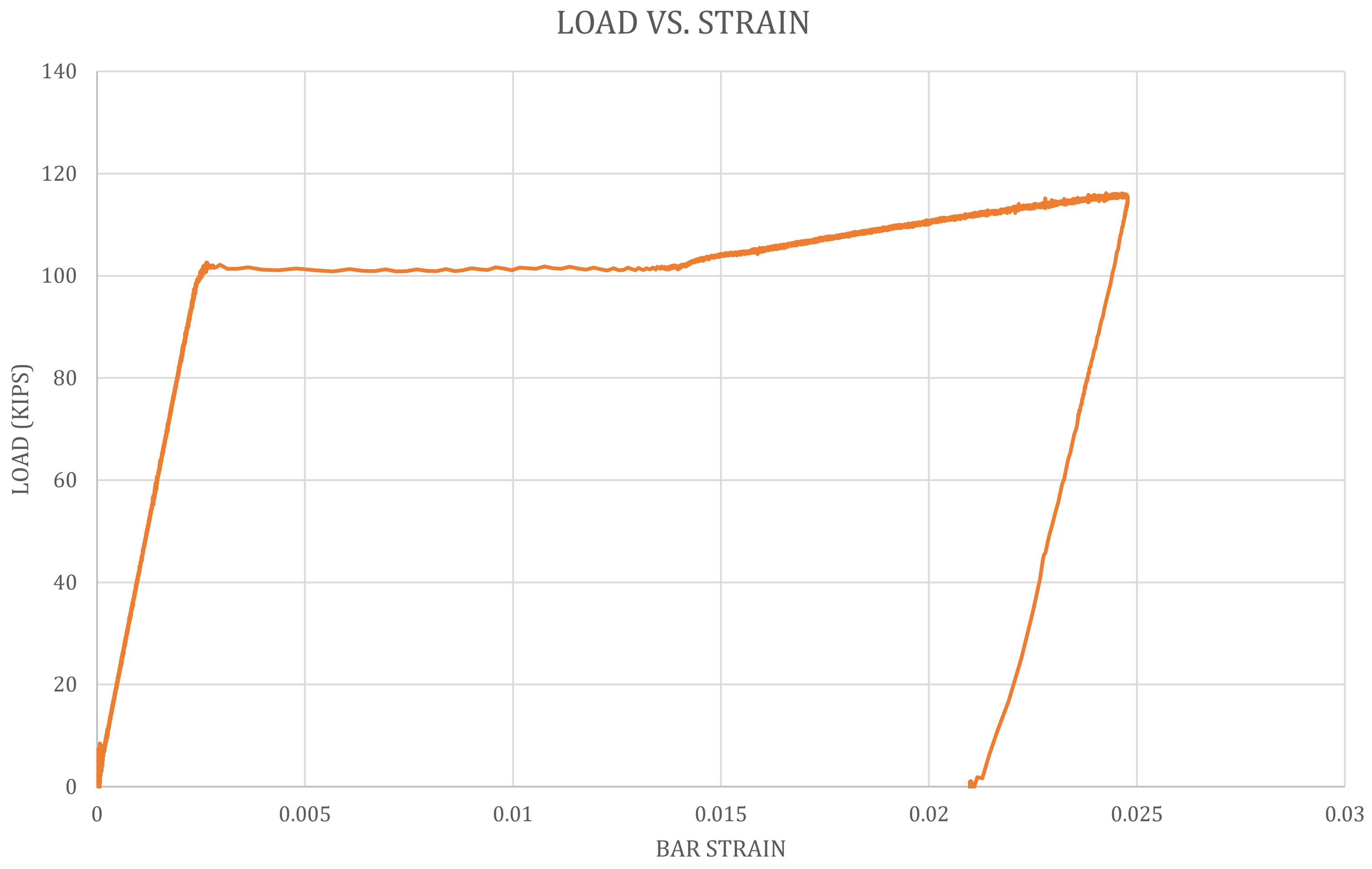
Break Modes

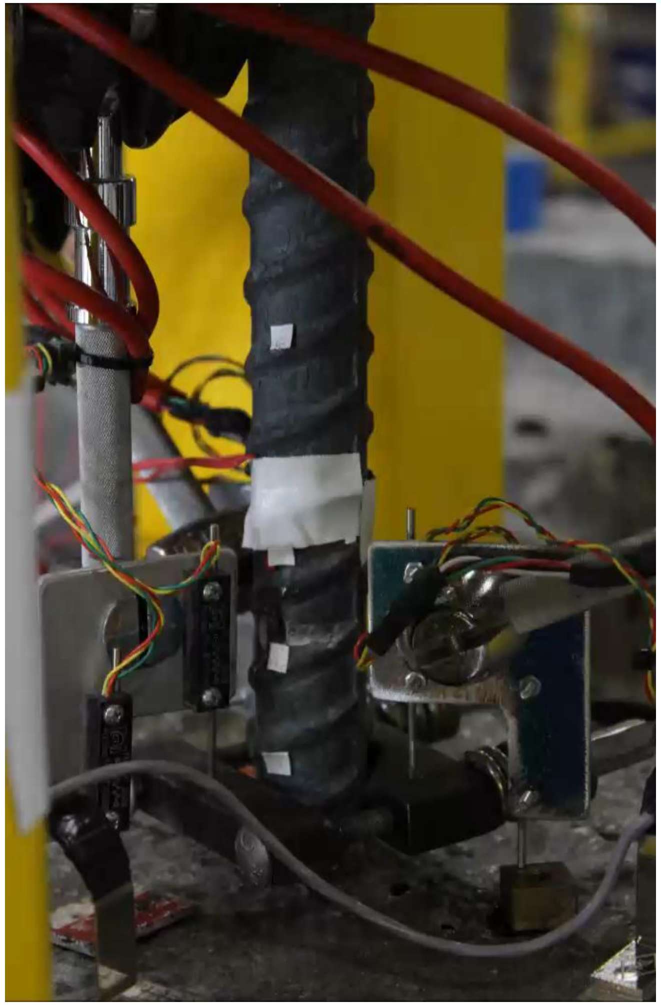


- 4 Different Modes
  - Side Splitting
  - UHPC Failure
  - Bar Yielding/Fracture
  - Side Splitting to Adjacent Bar

Completed Tests

Bar Size	Target Embedment Length in Bar Diameters	Target Splice Length in Bar Diameters	UHPC Clear Cover (in)	Number of Individual Bar Tests
#8	8	6	3.75	4
	8	6	1.75	14
#9	8	6	3.75	6
	8	6	1.75	5
	10	7.5	1.75	7
#10	10	8.8	1.75	6
	12	10	1.75	13
	8	6	3.75	12
#11	10	8	3.75	4
	11.5	10	3.75	5
	11.5	10	1.75	4
	13	11	1.75	7



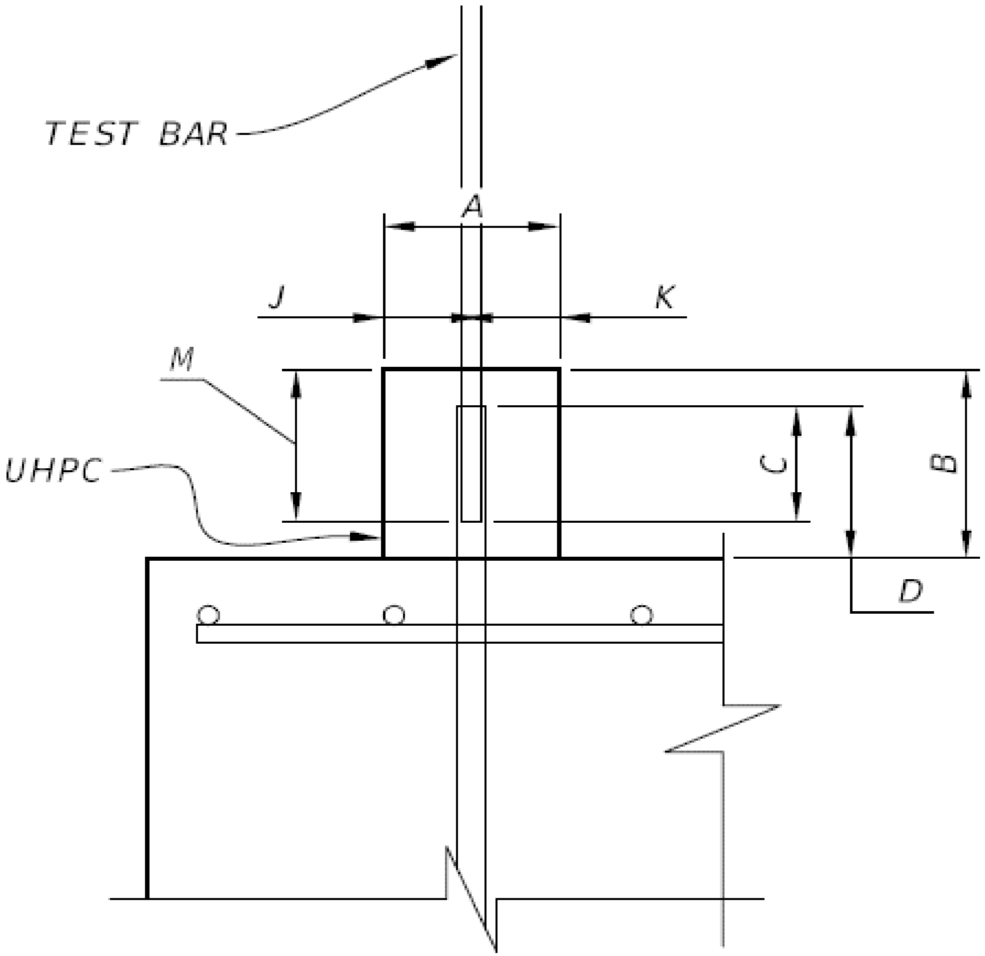


Results Processing

Preliminary Results

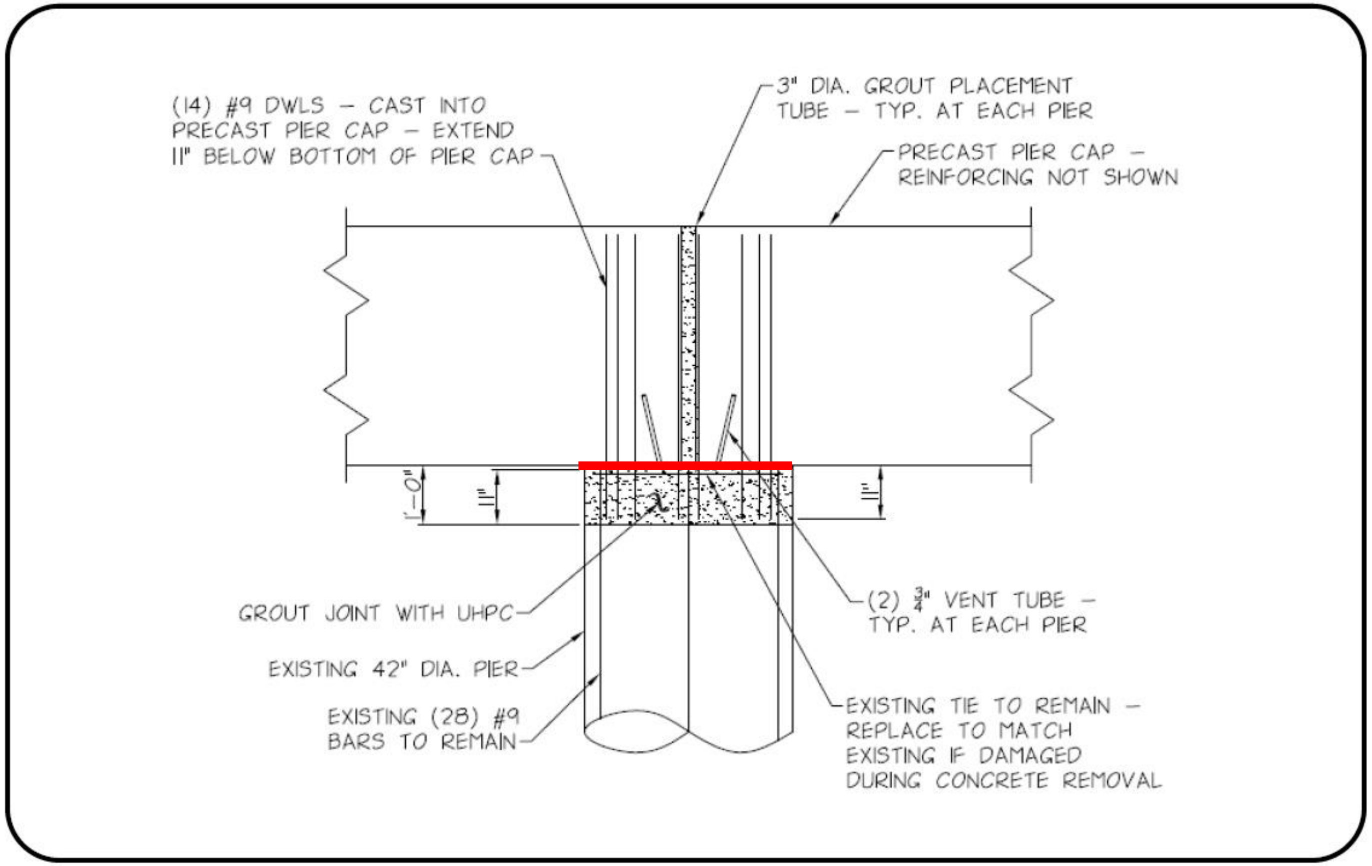
Required Embedment Length (M, D) in Terms of Bar Diameters					
		Bar Size			
		No. 8 (Per FHWA)	No. 9	No. 10	No. 11
Cover	1.75 in	8	10	12	13
	3.75 in	8	8	8.6	10

Required Splice Length (C) in Terms of Bar Diameters					
		Bar Size			
		No. 8 (Per FHWA)	No. 9	No. 10	No. 11
Cover	1.75 in	6	7.5	10	11
	3.75 in	6	6	6.6	8



Future Testing

- Blind Pour (Bond Behavior)
- Beam Bending (Comparison to Direct Pull-out)
- Vary the Bar Spacing (8” and 2”)
- Full Scale Testing



Hooper Road over US 17C in Union, New York

(Graybeal/FHWA)

FAMU-FSU Engineering

Stainless-Steel Prestressing Strand – Flexural Design

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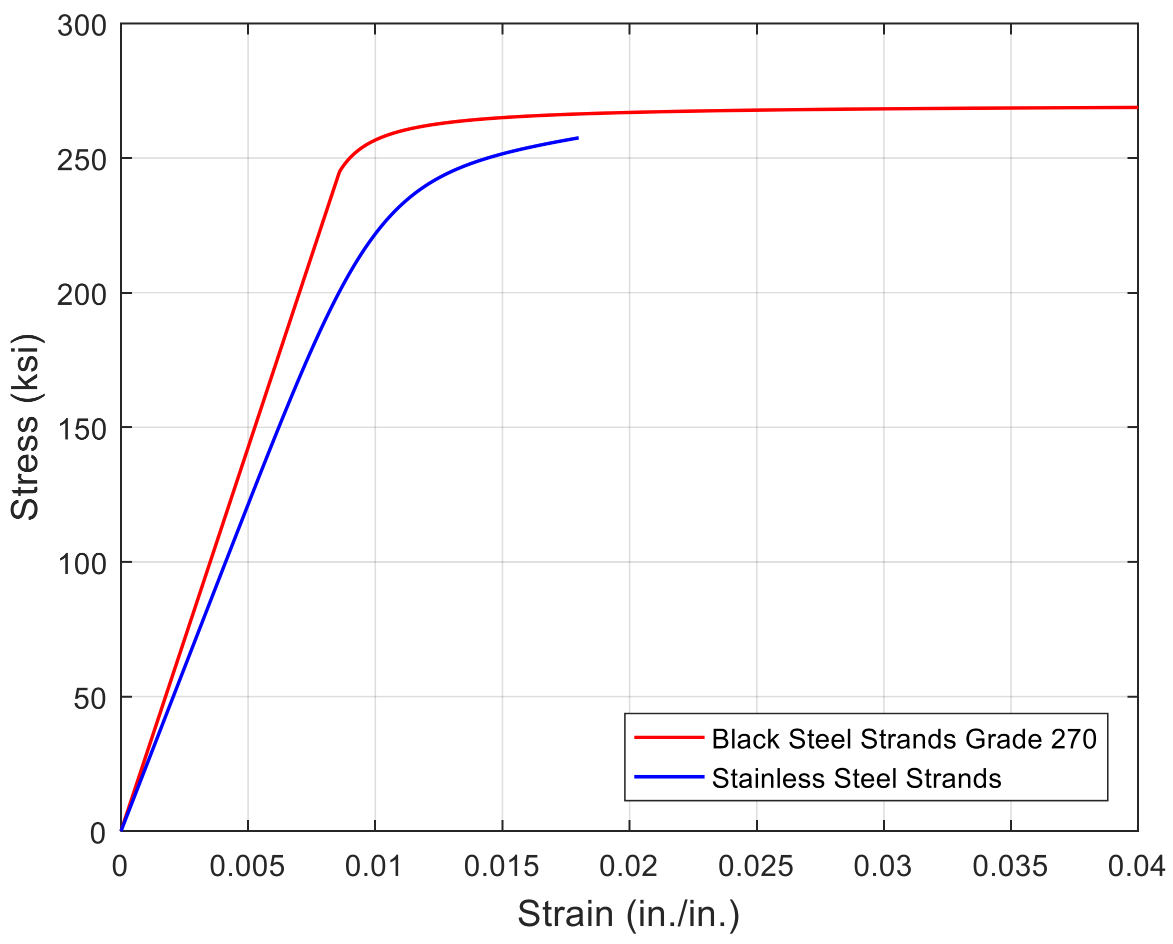
Background

- Corrosion Resistant – Duplex 2205
- Improve Durability of Pretensioned Girders
- Develop Flexural Design Criteria

SS-Strand Mechanical Properties

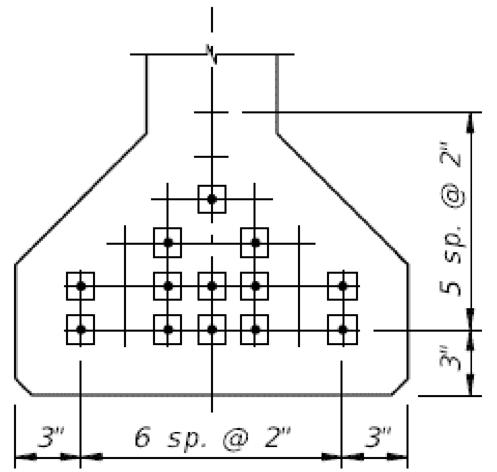
- Elongation – 1.2-1.9%
- Tensile Strength – 240 ksi
- Sizes – 0.5” & 0.6”
- 0.6” Area – 0.23 in^2
- Elastic Modulus - 24,400 ksi



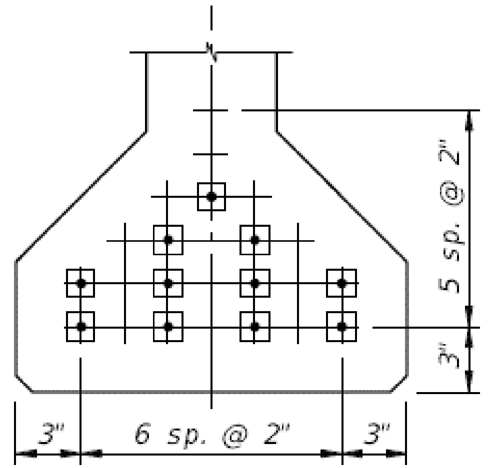
Experimental Testing

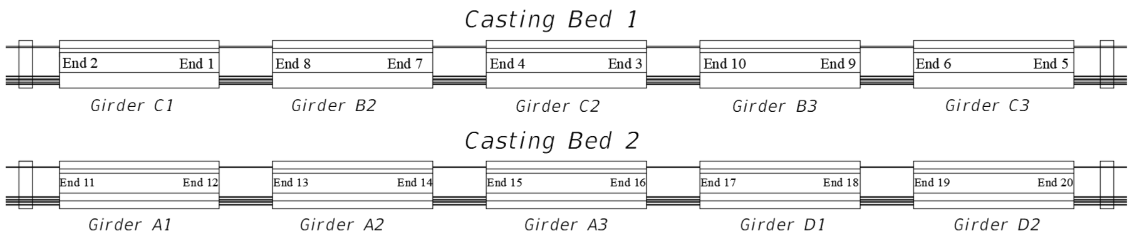
- 8 – AASHTO Type II Girders
  - Length – 42-ft
- Prestress Force
  - SS Girders – 64% of ultimate
  - Carbon Steel – 75% of ultimate
- A & B Girders – 11 strands (same area)
- C Girders – 13 strands (same force)

C Girders



A&B Girders





FAMU-FSU Engineering

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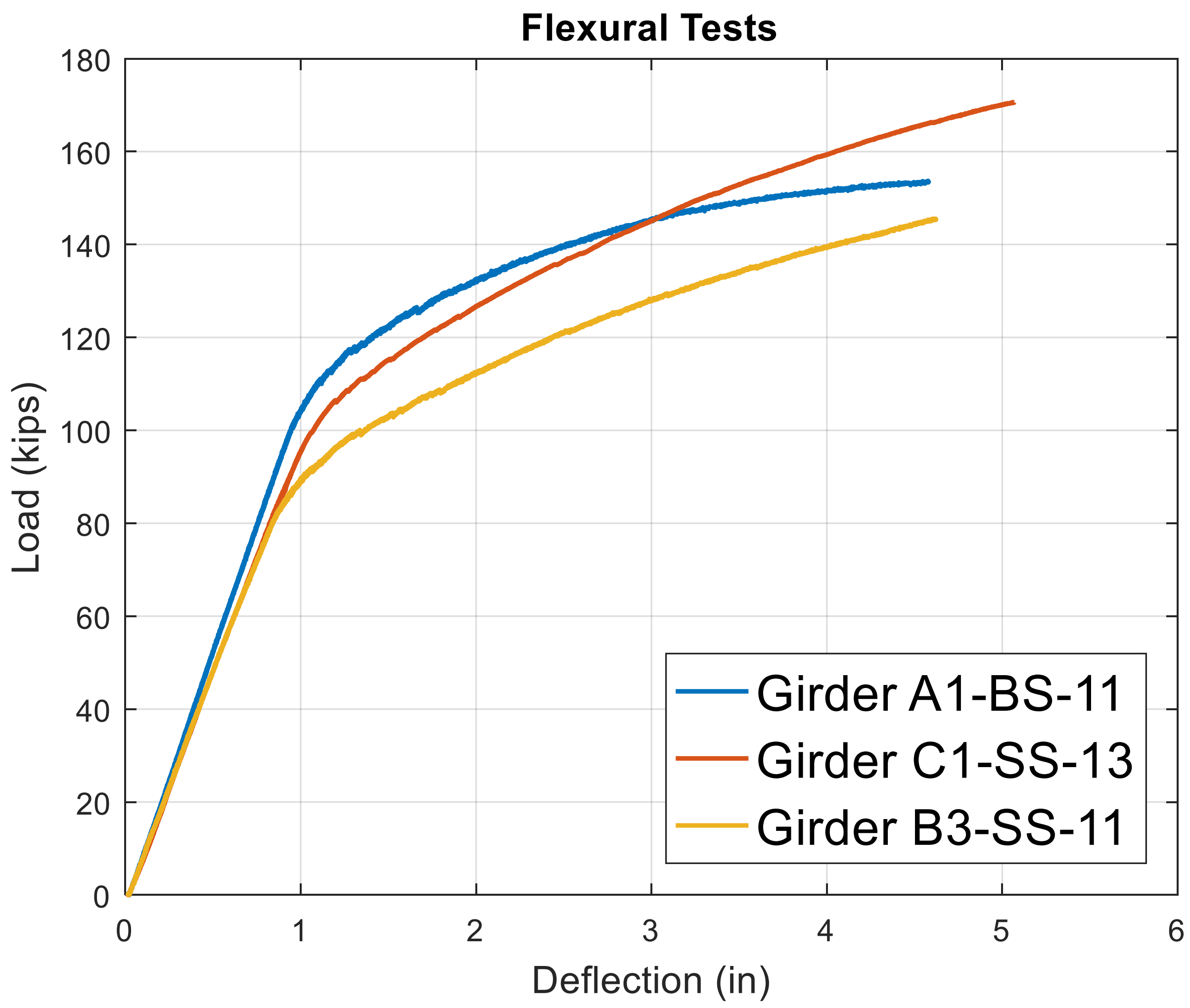
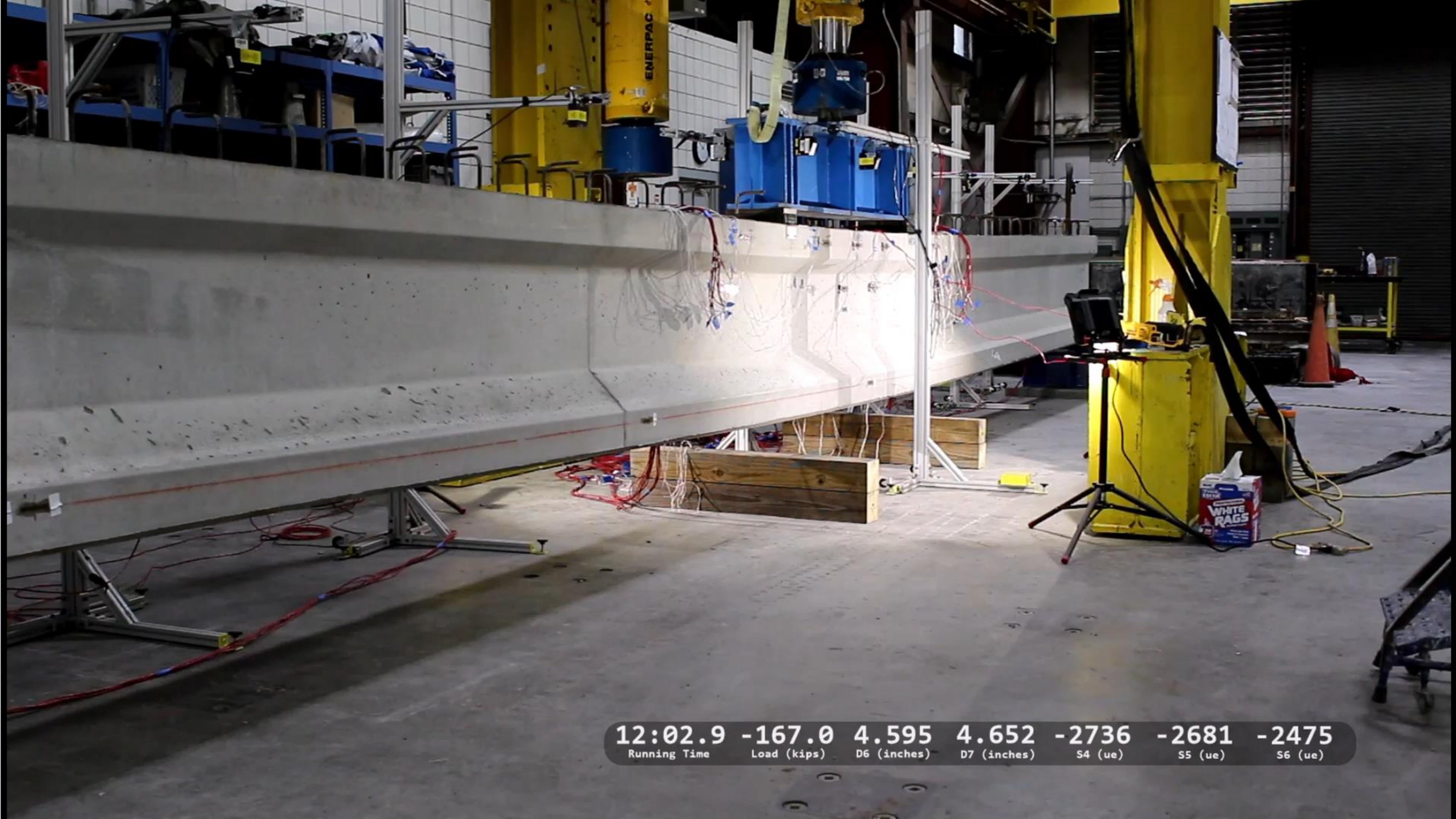
Initial Flexure Tests (No Deck)

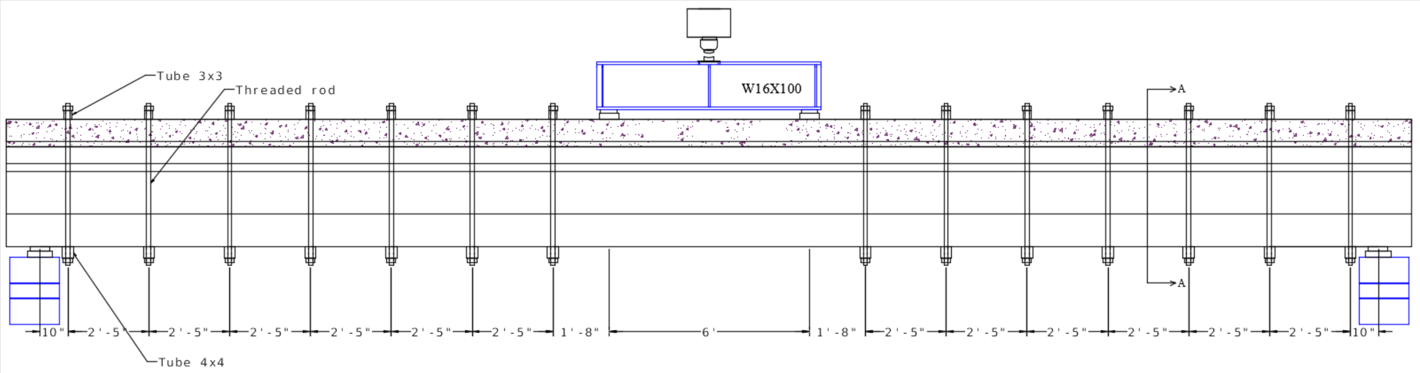


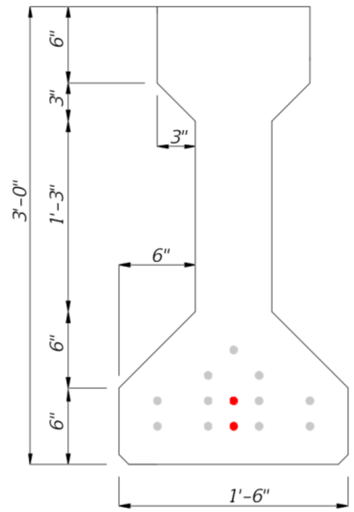
- 4-pt bending
- Compression failure reached in all 3 Girders
- B3 and C2 bottom layer tensile strain, 0.0158 & 0.0138

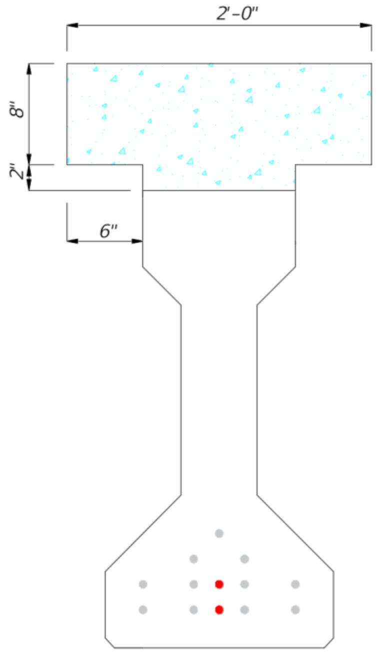

12:02.9 Running Time
-167.0 Load (kips)
4.595 D6 (inches)
4.652 D7 (inches)
-2736 S4 (ue)
-2681 S5 (ue)
-2475 S6 (ue)
ENERPAC
WHITE RAGS

Decked Flexural Tests

- Achieve strand rupture
- Specimen B2 and C2 has GFRP shear reinforcement
- Added external clamps to prevent possibility of shear failure





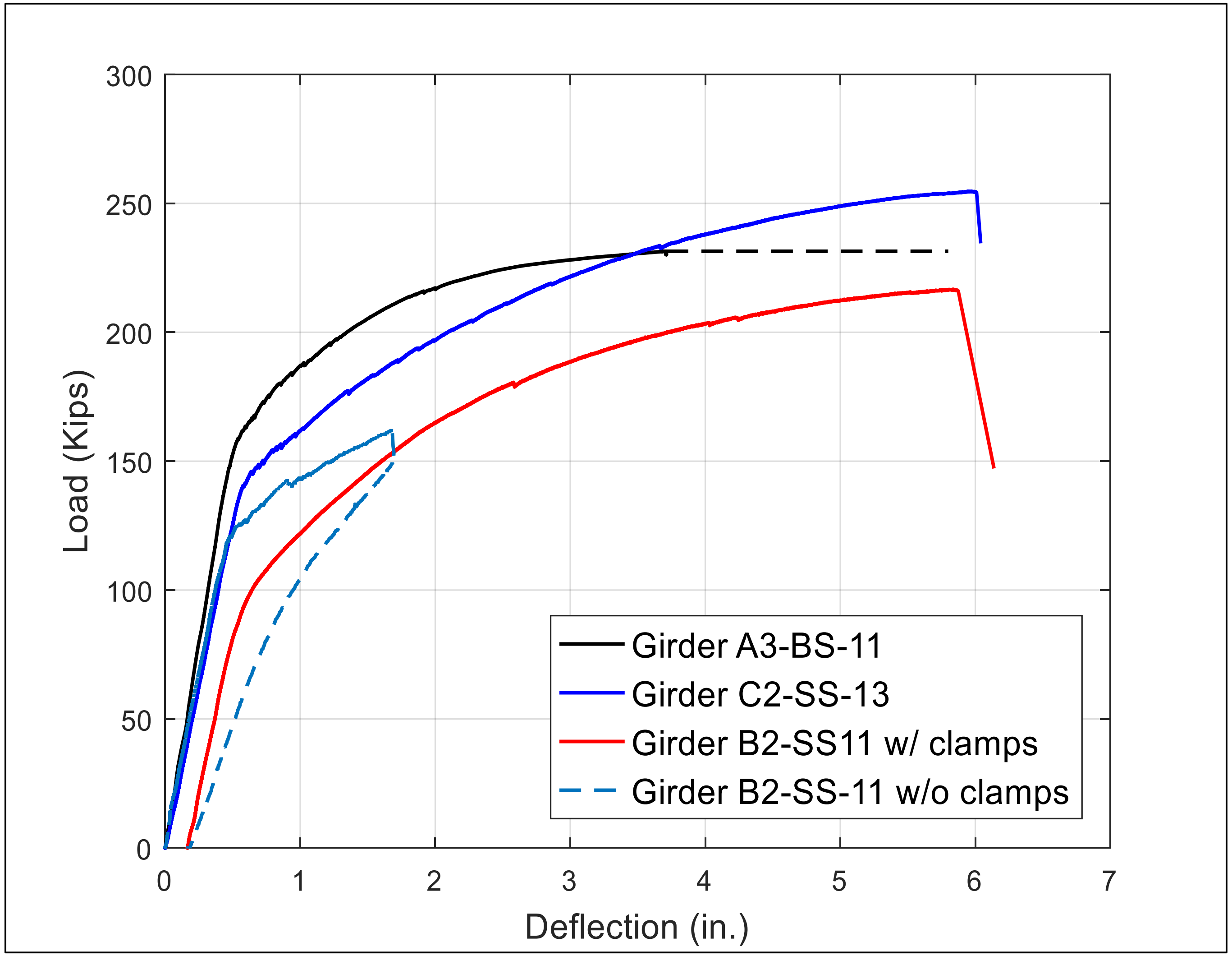



B1789
Lw9
B2
9-18-18
FAMU-FSU Engineering
FDOT
20:21.7 Running Time
-215.5 Load (kips)
5.229 D6 (inches)
5.205 D7 (inches)
-2210 S4 (ue)
-2076 S5 (ue)
-2530 S6 (ue)

B2 Failure

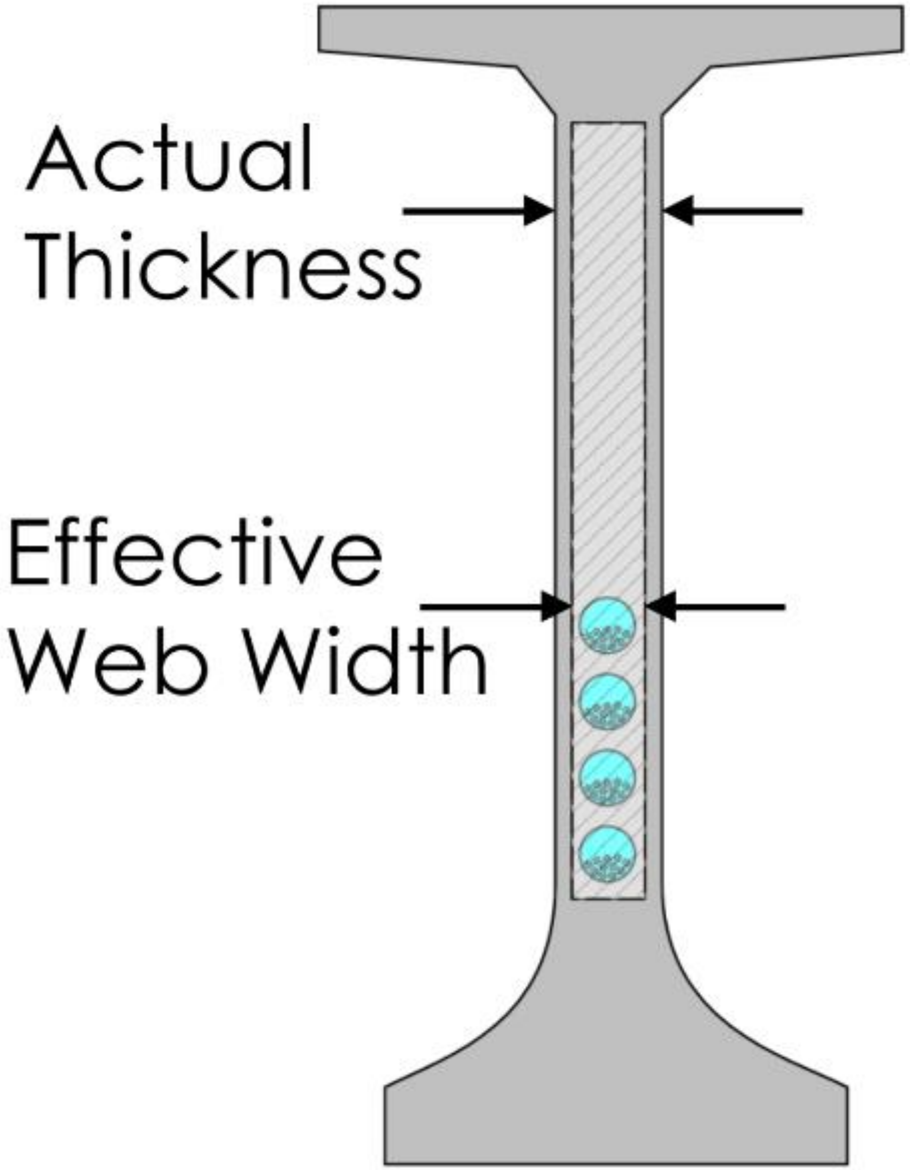
- Rupture of all 11 strands
- Max Load = 216 kips
- Max Deflection = 5.7 in.
- Max Top Strain = 0.00276

Flexural Tests (Decked)



- B2 & C2 both failed with strand rupture
- A3 was stopped just prior to failure (compression)

Shear Behavior of Voided Webs



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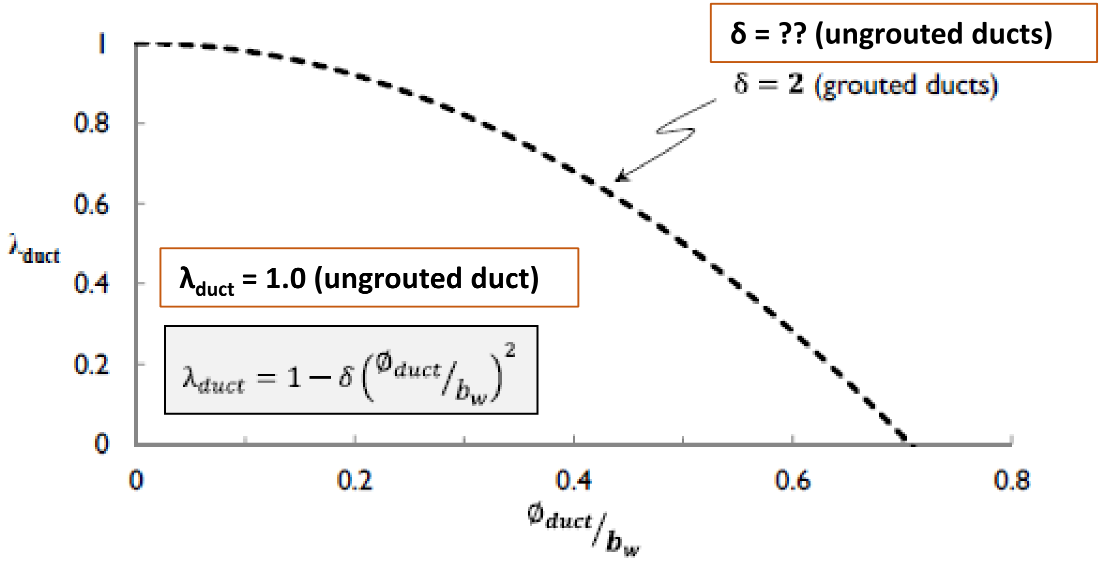


$$\lambda_{duct} = 1 - \delta\left(\frac{\phi_{duct}}{b_w}\right)^2$$

V_c / V_s

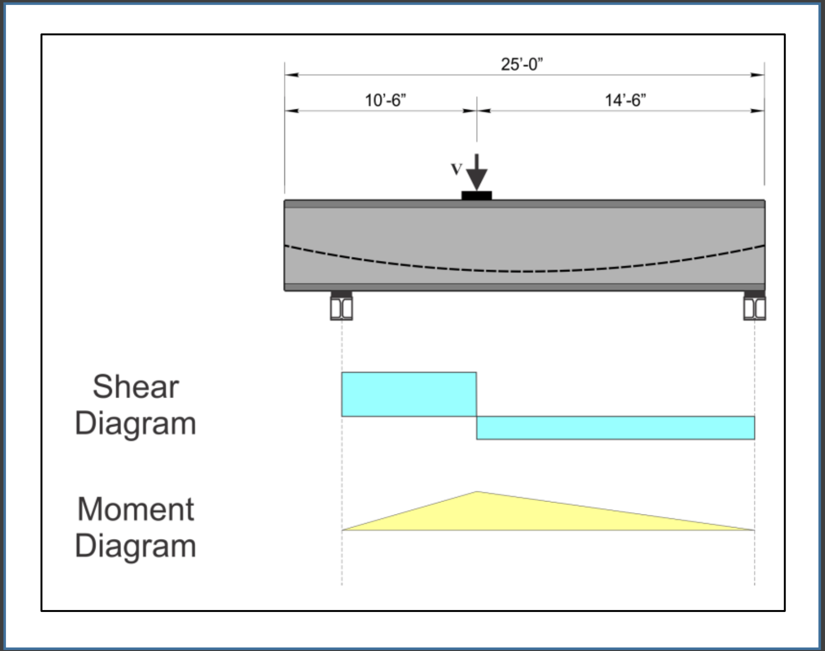
$$V_n = min\left\{\begin{matrix}\beta\sqrt{f'_c}\mathbf{b_w}d_v + \frac{A_s f_y}{s} d_v \boldsymbol{\lambda_{duct}} \cot\theta \\ 0.25 f'_c \mathbf{b_w} d_v\end{matrix}\right\} + V_p$$

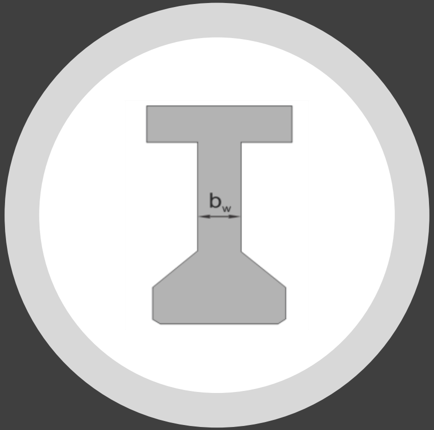
Reduce b_w to account for ungrouted duct

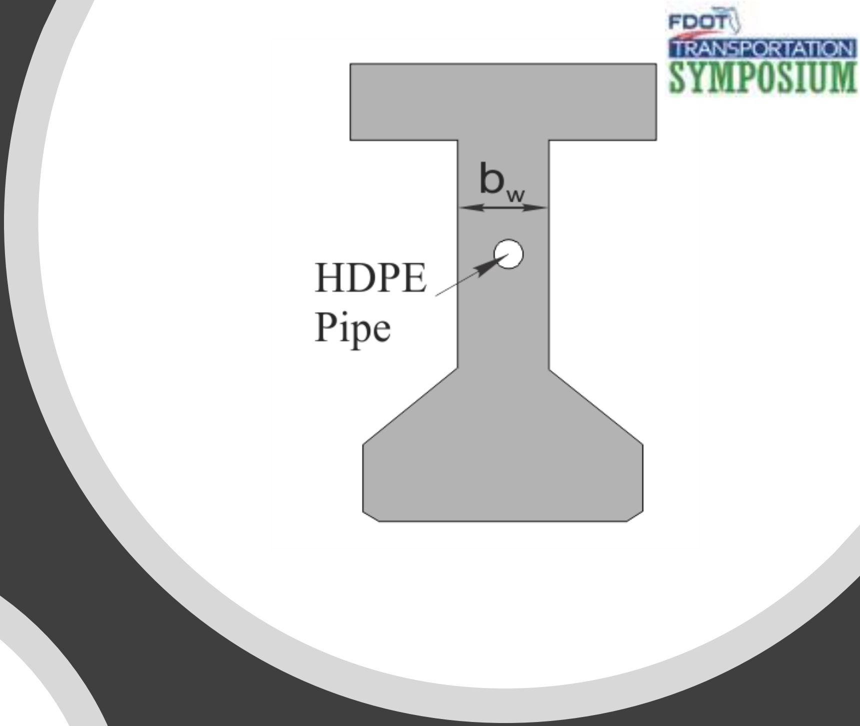
TxDOT Research – AASHTO Adopted

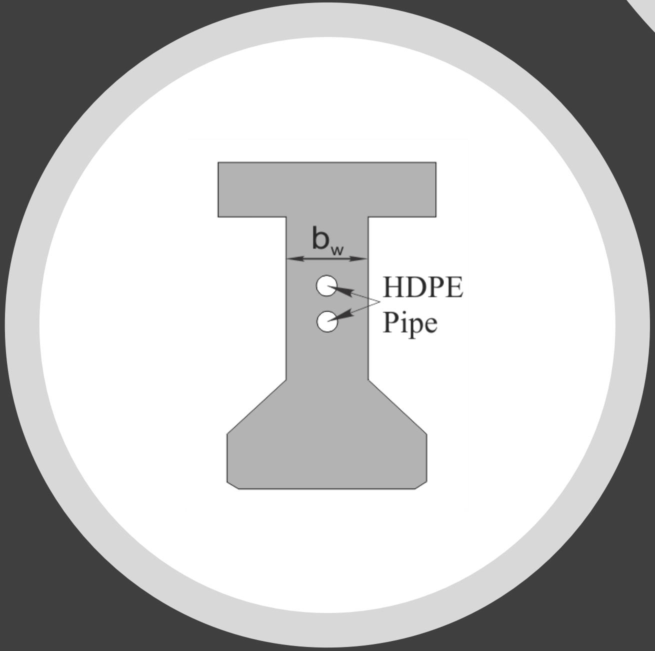
Initial Testing Phase

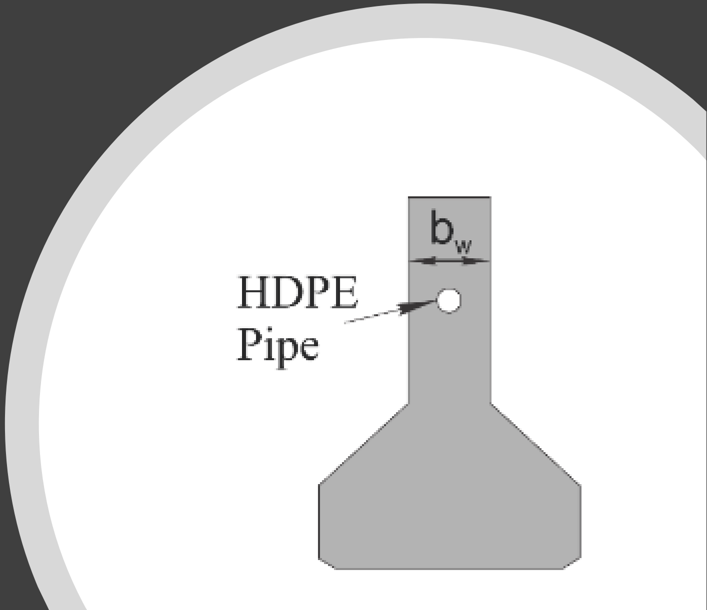
- Evaluation of Variables
  - Flange Boundary Conditions
  - Duct Diameter/Web Width Ratio
    - AASHTO increased to 0.54
    - 0.3-0.6 tested
  - Number of Ducts



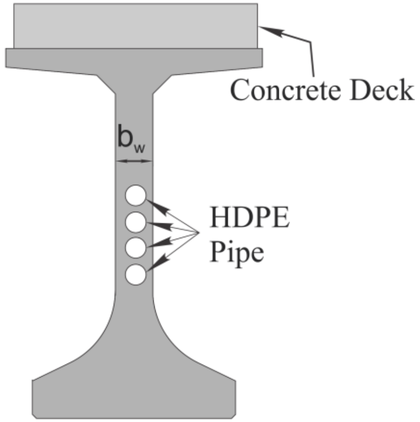


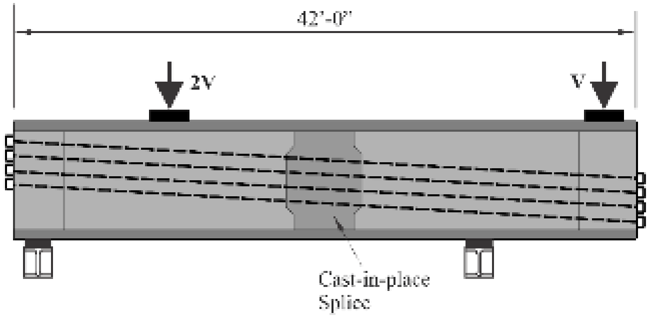


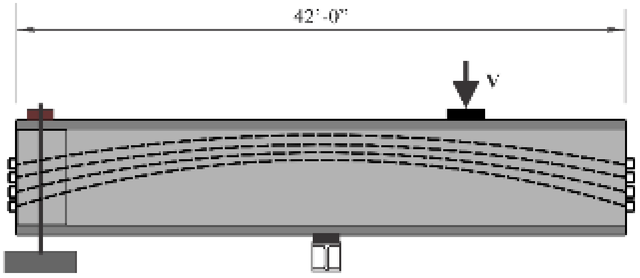




Initial Testing Phase







- Full-Scale Specimens
- Multiple Tendons
- Grouted vs. Empty
- Splice Region
- Negative Bending

Phase 2 in Planning

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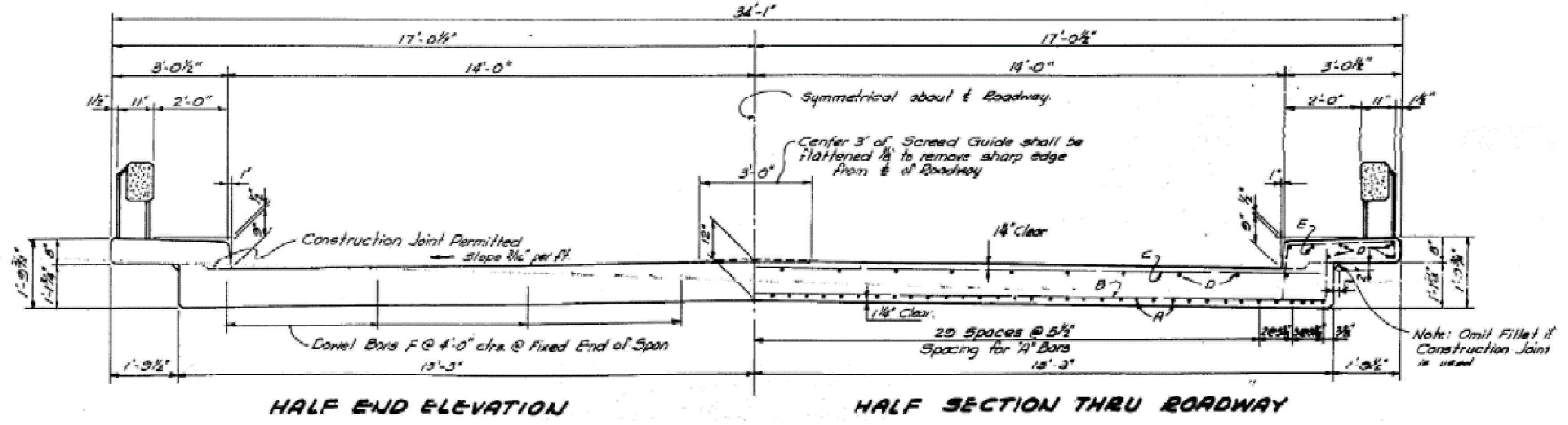
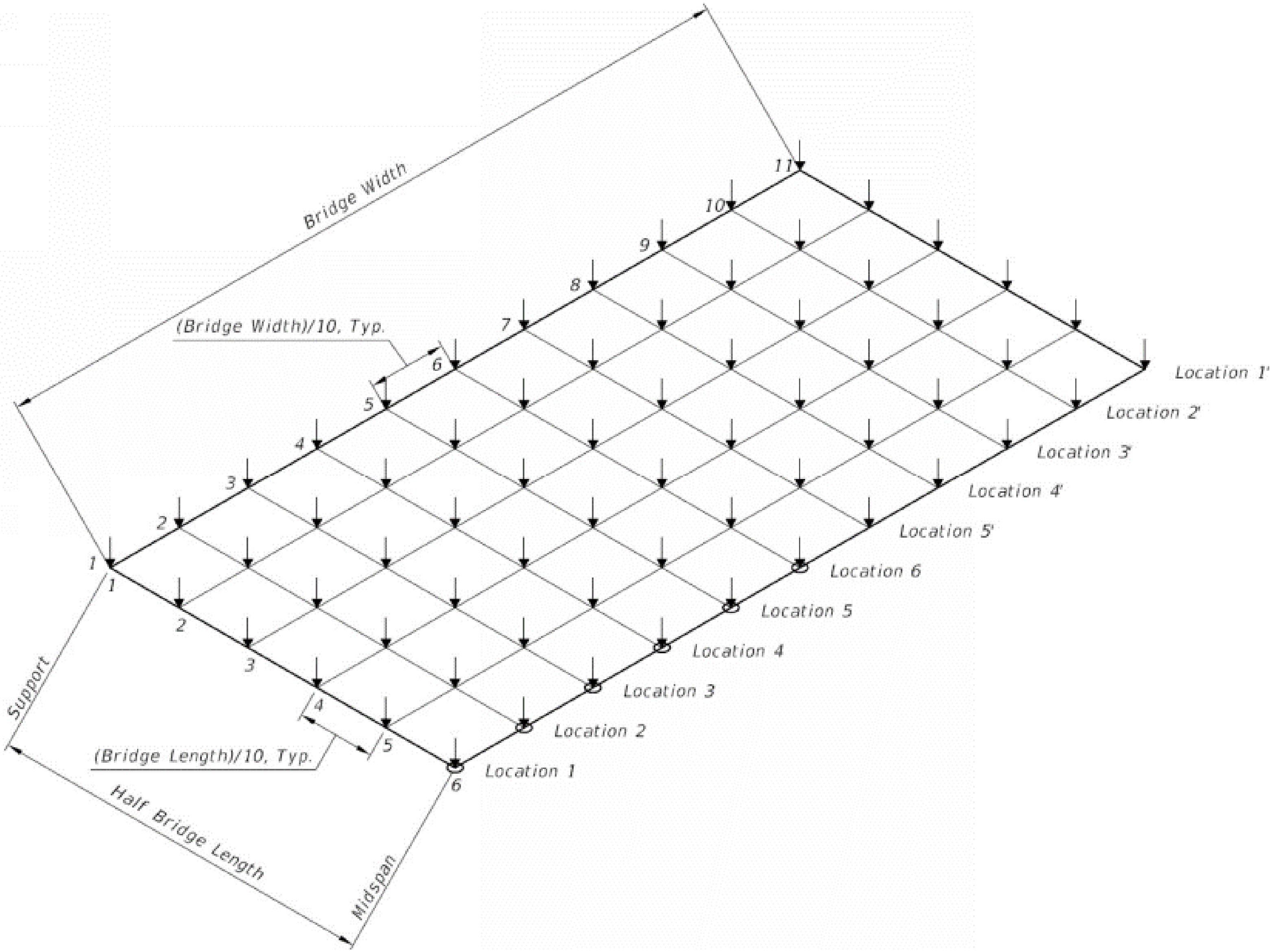
Effective Width for Concrete Slab Bridges



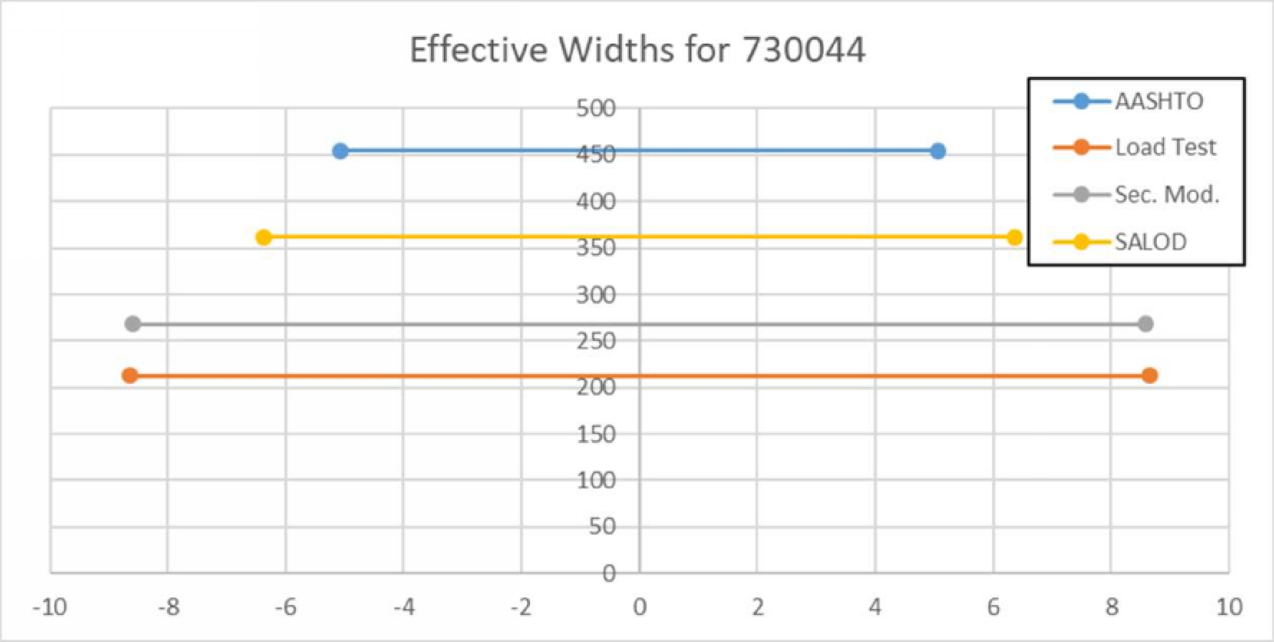
- ~980 Bridges (2016)
- ~170 Load Posted
- Varying aspect ratios
- Varying railing configurations

SALOD

- Based on 7 FEA models
- Aspect Ratio – 0.5 to 3.0
- Interpolation – Influence Surfaces
- Computes Effective Width
- Traditionally a “Black Box”



Results



- SALOD is generally less conservative than AASHTO
- Only practical within the formulated aspect ratios
- Using SALOD methodology is the most effective way to improve load ratings
- Conservative when compared to load test results

Conclusions/Mathcad Program

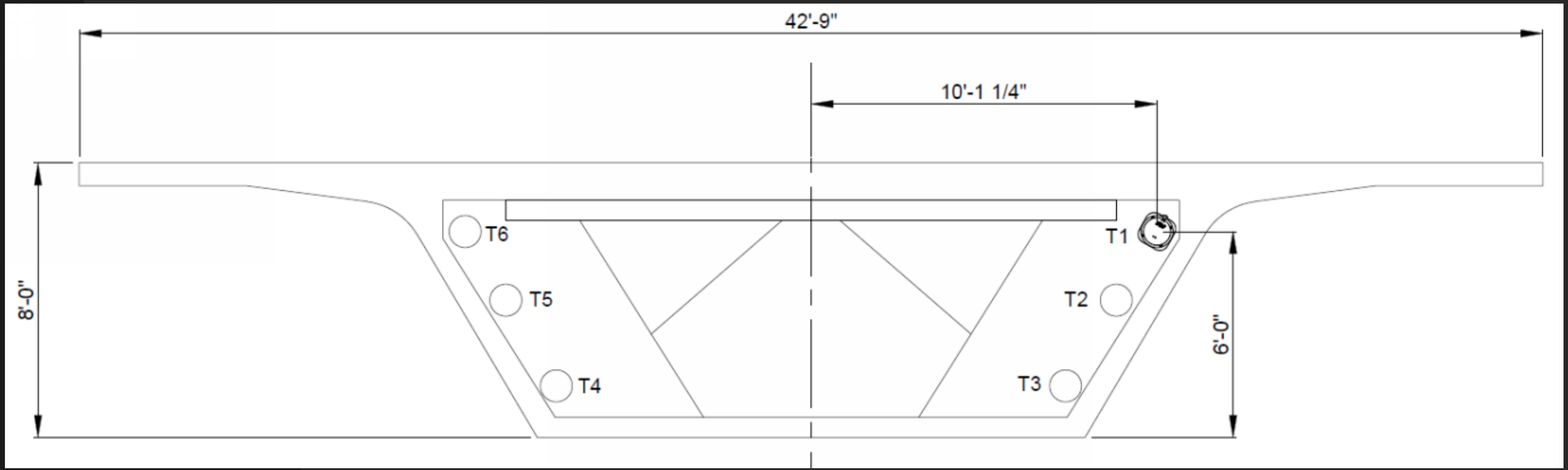
- SALOD methodology into Mathcad worksheet
- “Black Box” is removed
- Updated to current design practice and code changes
- Low cost “Refined Analysis” approach

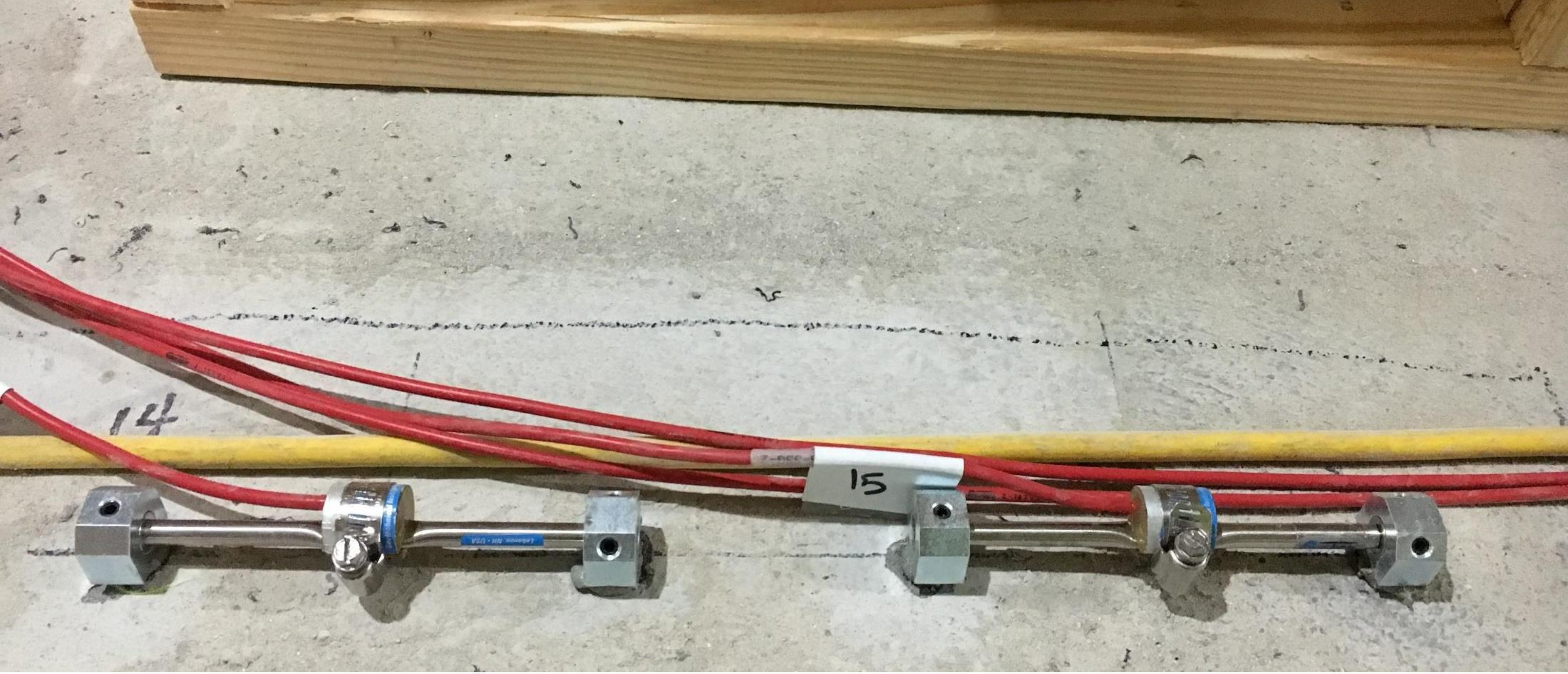
Mid-Bay Repair Monitoring

- Vibration Testing performed by Corven Engineering, Inc.

Span Number	Tendon Number	Tendon Force (kips)	
		Down-station	Up-station
39	1	702.5	243.8
40	6	218.4	783.4

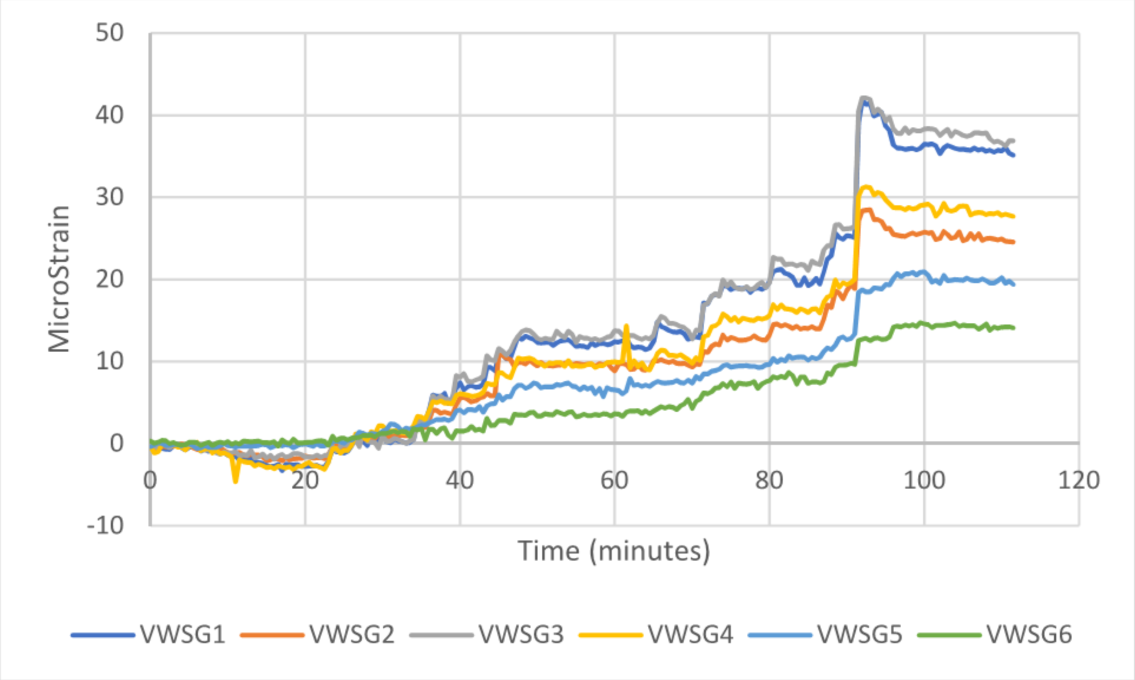
- Monitored spans 39 and 40 during tendon cut-down
- Performed Load Test after tendon cut-down





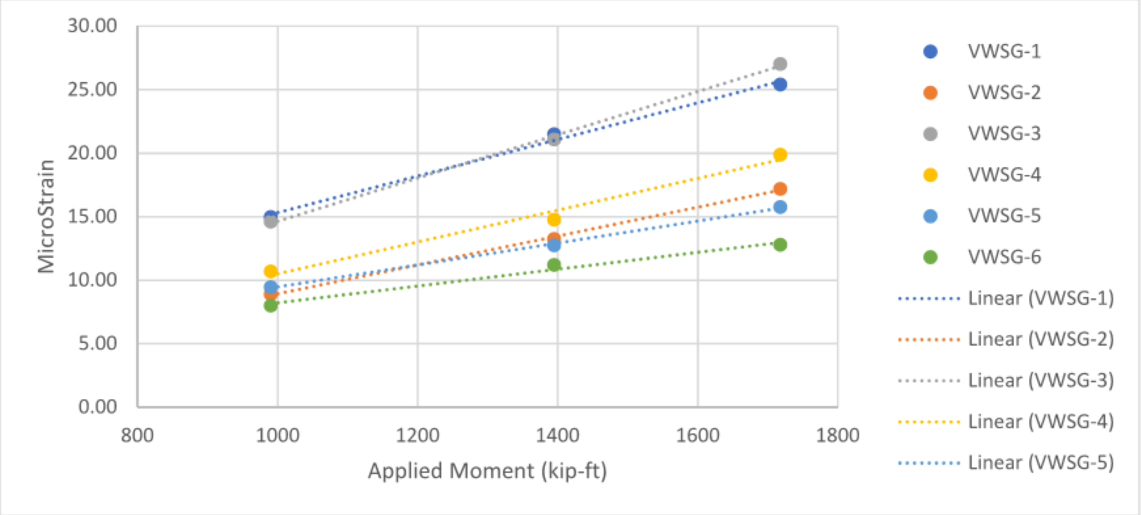
Instrumentation

Mid-Bay Repair Monitoring



	Force (kip)	
	Based on Maximum Individual Gage	Based on Overall Average Across Width
After Step 1	-33.1	-12.0
After Step 13	140.7	90.0
All Strands Cut	411.2	267.9

Mid-Bay Repair Monitoring



Truck Load Case	Applied Moment (kip-ft)	Predicted MicroStrain
Empty	990.2	14.3
Half Load (4 Blocks)	1394.9	20.1
Full Load (7 Blocks)	1717.8	24.8

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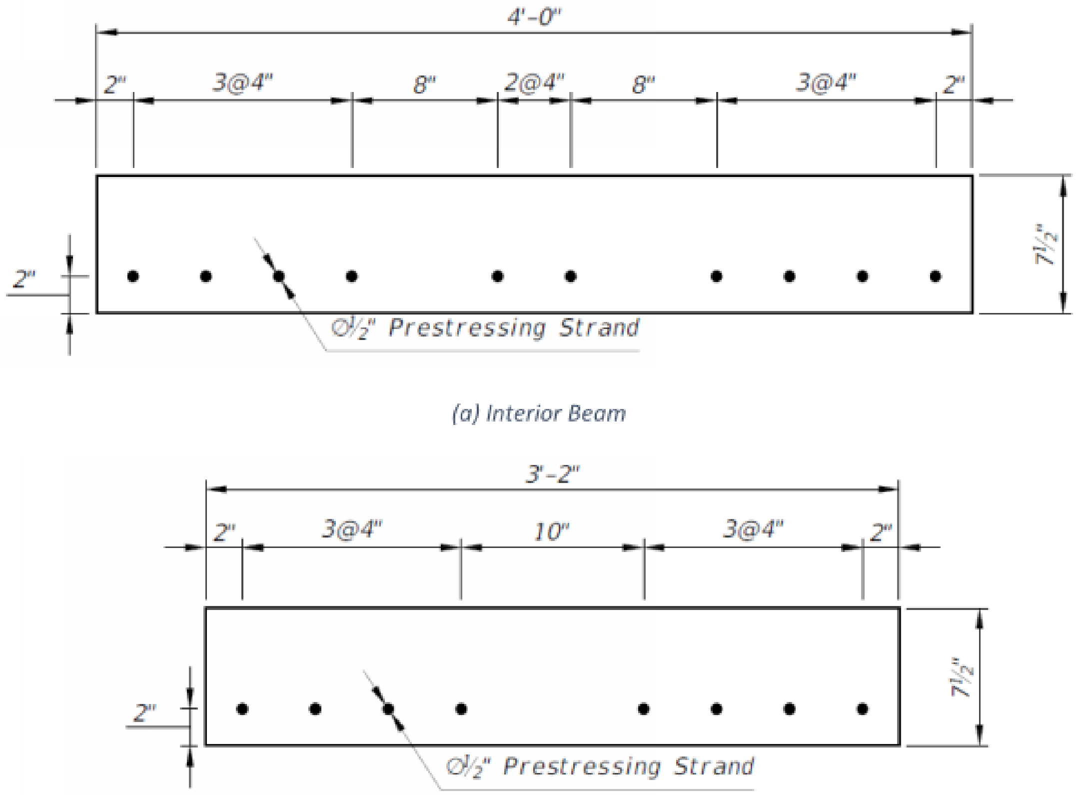
Bridge Load Testing

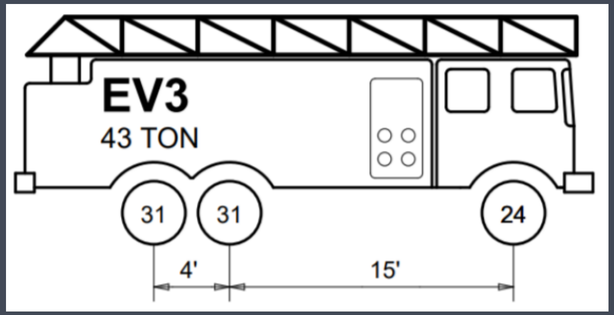
- Precast Pretensioned Panel Bridge (constructed 1977)
- Continuous for Live Load (??)
- 8 Spans (26-ft each)
- 46’-3” Width (2-12’ Lanes)
- Depth - 11.75” (7.5” precast panel – 4.25” topping)
- Crutch Bents added in 2003
- Condition is Good
- Emergency Vehicle Load Rating (EV3)



(a) Interior Beam

(b) Exterior Beam

Instrumentation

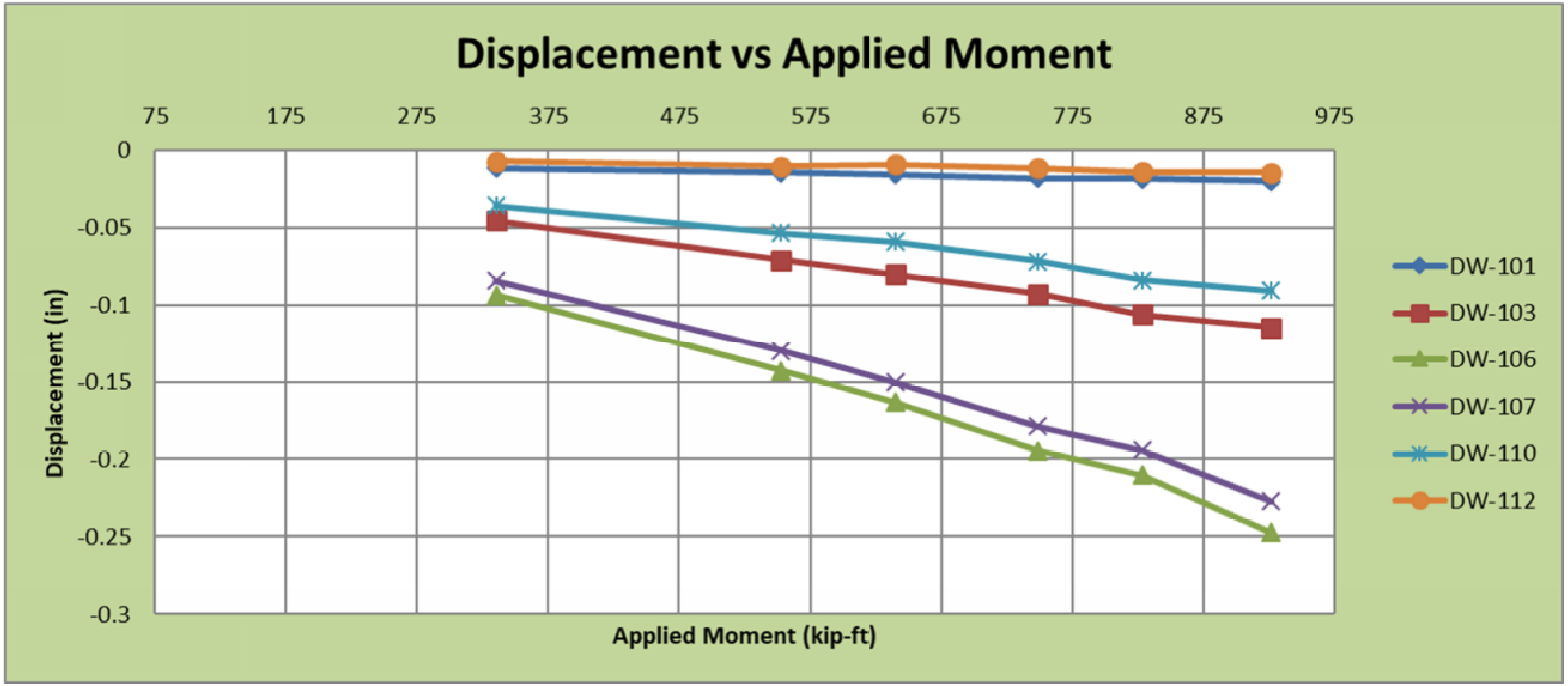


Proof Load Test

- Section 8 - Manual for Bridge Evaluation (MBE)
- Limited Bridge Information
- $L_T = X_{pA} L_R (1 + IM)$
  - $X_{pA} = 1.3 \text{ } to \text{ } 2.2$ (1.4)
  - $L_R = Unfact. LL \text{ } of \text{ } vehicle$
- Target $L_T = 463 \text{ } kip - ft$
- Test Truck $L_p = 463 \text{ } kip - ft$

Linearity Check

Linear response (strain and displacement) for both monitored spans



FDOT TRANSPORTATION SYMPOSIUM

Additional Research Topics

- Shear Friction Capacity of Corrugated Pipe Connections in Precast Footing
- Fiber-Reinforced Concrete Traffic Railings
- Hybrid Prestressed Concrete Girders using UHPC
- Evaluation of Concrete Pile to Footing Connections
- Evaluation of Tapered Bearing Pads
- Evaluation of GFRP Spirals in Piling
- Florida-Slab Beam (FSB) with UHPC Joints

Questions

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