CREATIVE SOLUTIONS FOR CHALLANGING PROBLEMS IN STRUCTURAL ENGINEERING

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ACKNOWLEDGEMENT

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- Chicago Department of Transportation
- Illinois Department of Transportation
- Illinois Tollway
- Florida Department of Transportation
- PB/WSP
- AECOM
- UIC (Professor Mohsen A. Issa)
- HBM Engineering Group

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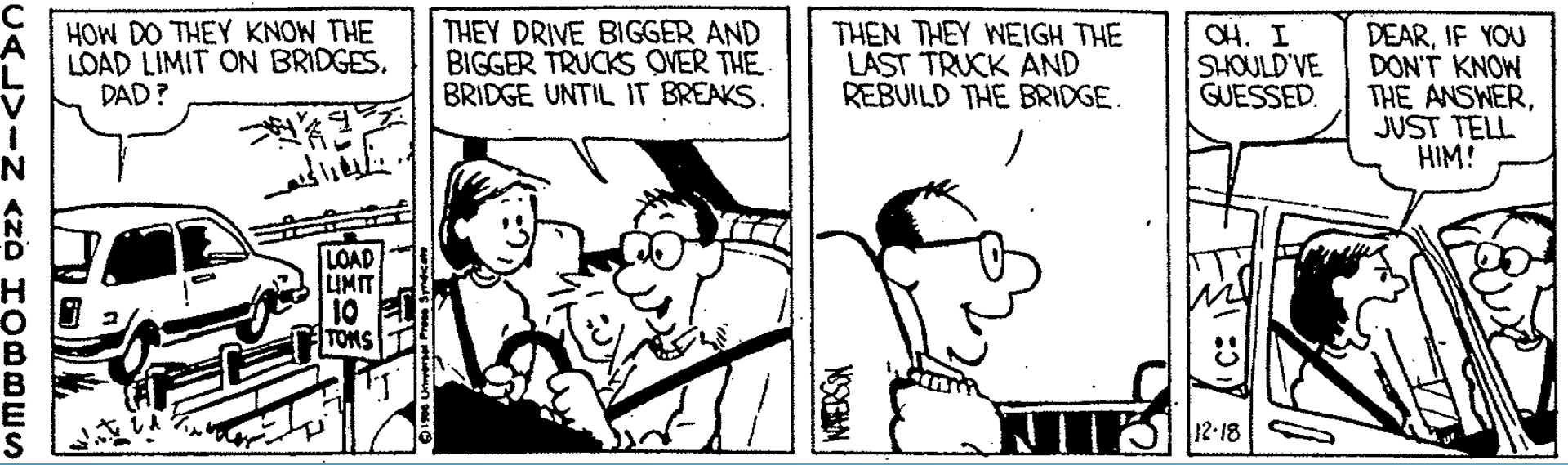
Presentation Outline

1. **Field Inspection, Rating and Testing of In-Service Bridges**
2. **Strengthening of In-Service Bridges by using CFRP**
3. **Approach Structures for 41st and 43rd Pedestrian Bridges**
4. **Demmolition of IL-89 Truss Bridge over the Illinois River**
5. **Field Investigation and Testing of Sign Structures for VMS/CMS System**



BRIDGE LOAD TESTING AND RATING

Associated Press

Bridge collapses in Manila

A 265-foot section of a bridge collapsed into the San Juan River in the Philippines on Tuesday, plunging at least 10 vehicles into the water and killing two people, police said. Officers said a loaded concrete carrier and several other vehicles were crossing the bridge linking Manila and the city of Mandaluyong when part of the span's eastbound lane collapsed.

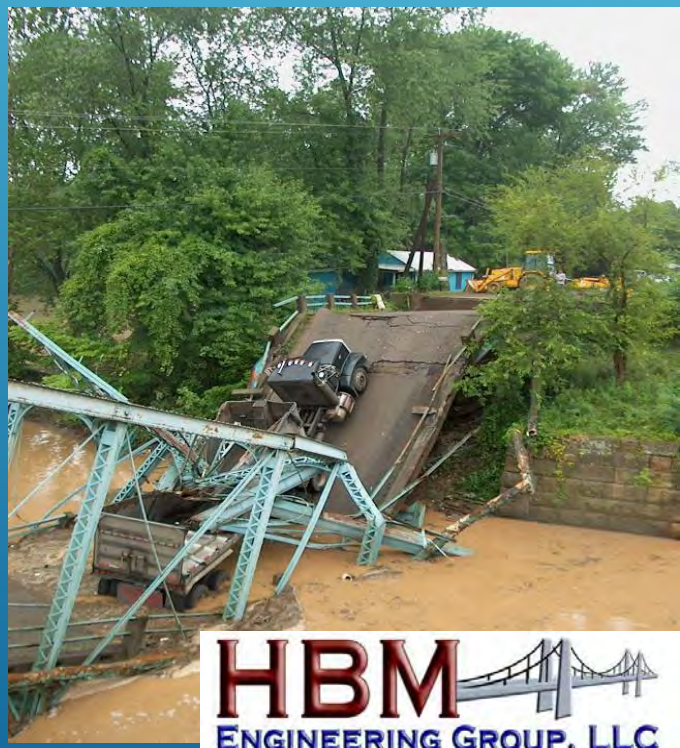


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PLATE GIRDER

SLAB BRIDGE

TRUSS

SUSPENSION

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Learning from failures!

- December 15, 1967 - collapse of the Silver Bridge
- 46 fatalities
- Eyebar/pin failure

Bridge Load Rating

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WHAT IS BRIDGE LOAD RATING?

The safe **live load** carrying capacity of a highway structure is called its load rating.

It is usually expressed as a (rating) factor (RF) of a defined vehicle **OR** as a gross tonnage for a defined vehicle axle configuration

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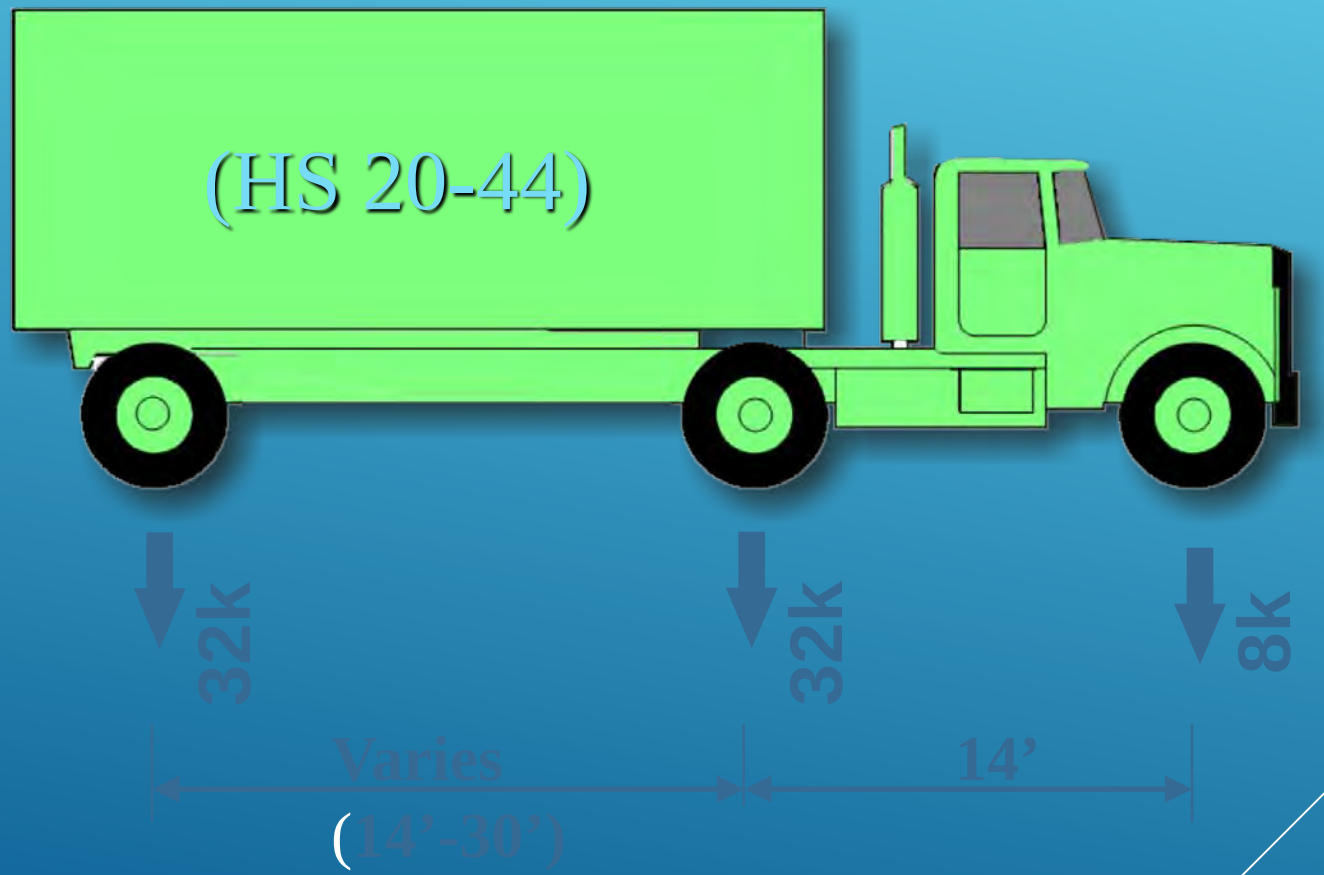
BASIC EQUATION FOR CALCULATING THE RATING FACTOR (RF)

How to calculate the Rating Factor (RF)

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

- RF = Rating factor for live load
- C = Capacity of member
- D = Dead load effect
- L = Live load effect
- I = Impact factor
- A1 = Factor for dead load
  - A1=1.0 for AS
  - A1=1.3 for LF
- A2 = Factor for live load
  - A2=1.0 for AS
  - A2=2.17 for LF (Inventory Rating)
  - A2=1.3 for LF (Operating Rating)

AASHTO HS 20-44 TRUCK



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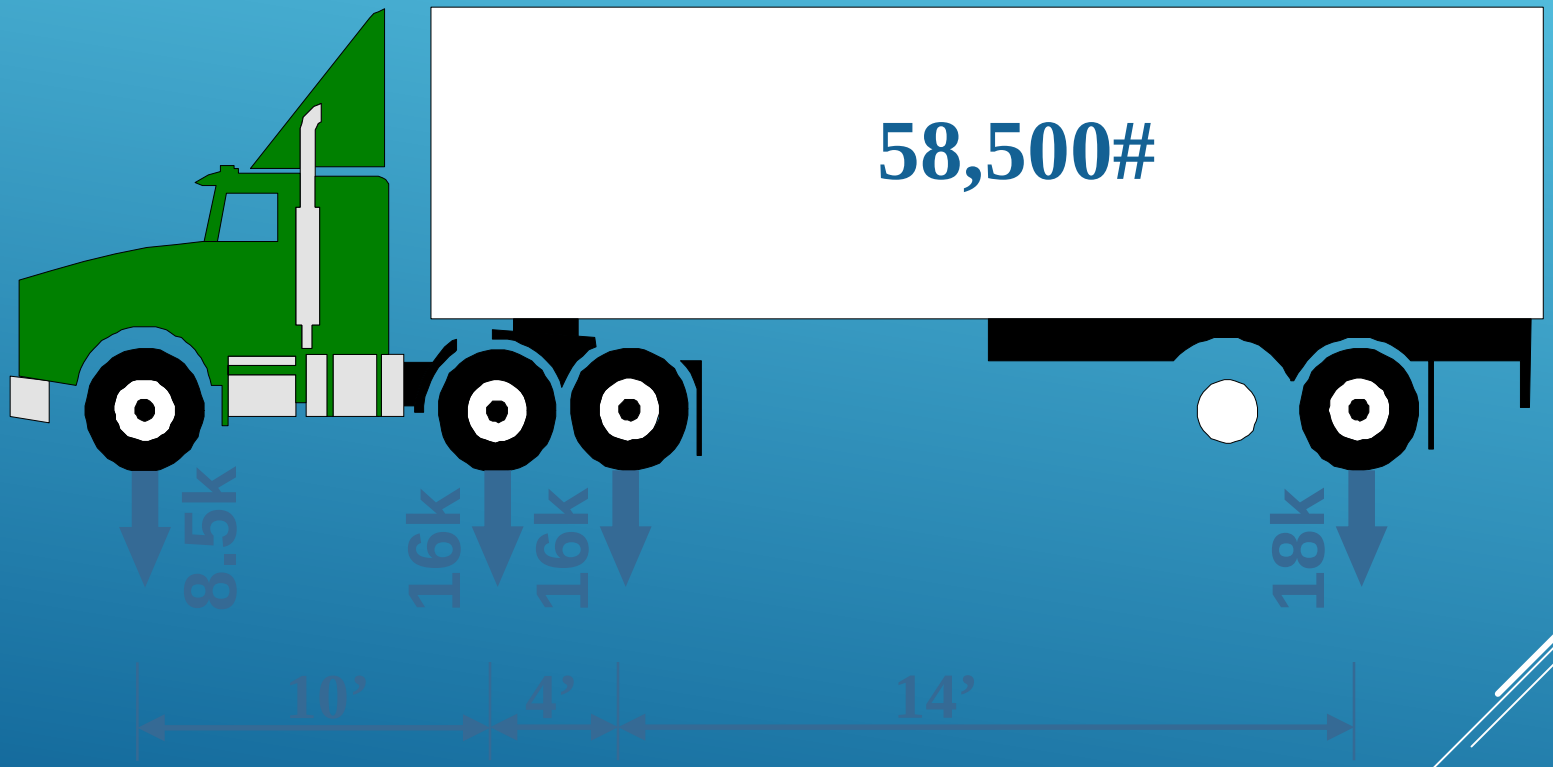
ILLINOIS LEGAL LOADS (TYPE 3-S1)



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BRIDGE LOAD RATING

AND

FIELD TESTING

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OBJECTIVES

- Diagnose Bridge Behavior.
- Rate Existing Bridges.
- Evaluate New Design Concepts.
- Evaluate Repairs of Damaged Bridges.

PROCEDURE FOR BRIDGE TESTING

- Inspection.
- Prediction and Planning.
- Instrumentation.
- Data Acquisition.
- Bridge Rating.

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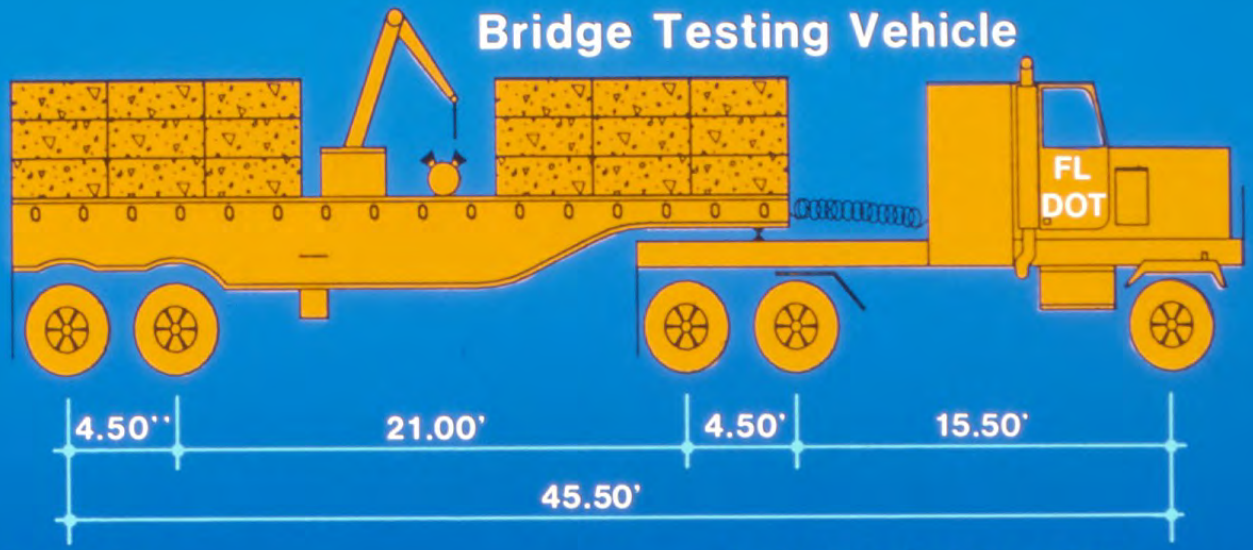
Bridge Testing Vehicle



WEIGHTS:		LOAD TRANSFER:	
72 Ballast blocks	154,800 lb.	5th wheel	82,350 lb.
Equipment	8,200 lb.	Steering axle	15,630 lb.
Trailer	24,000 lb.	Drive tandem	83,720 lb.
Tractor	17,000 lb.	Trailer tandem	104,650 lb.
Total	204,000 lb.		

Note: All weights and dimensions are approximate and for information only.

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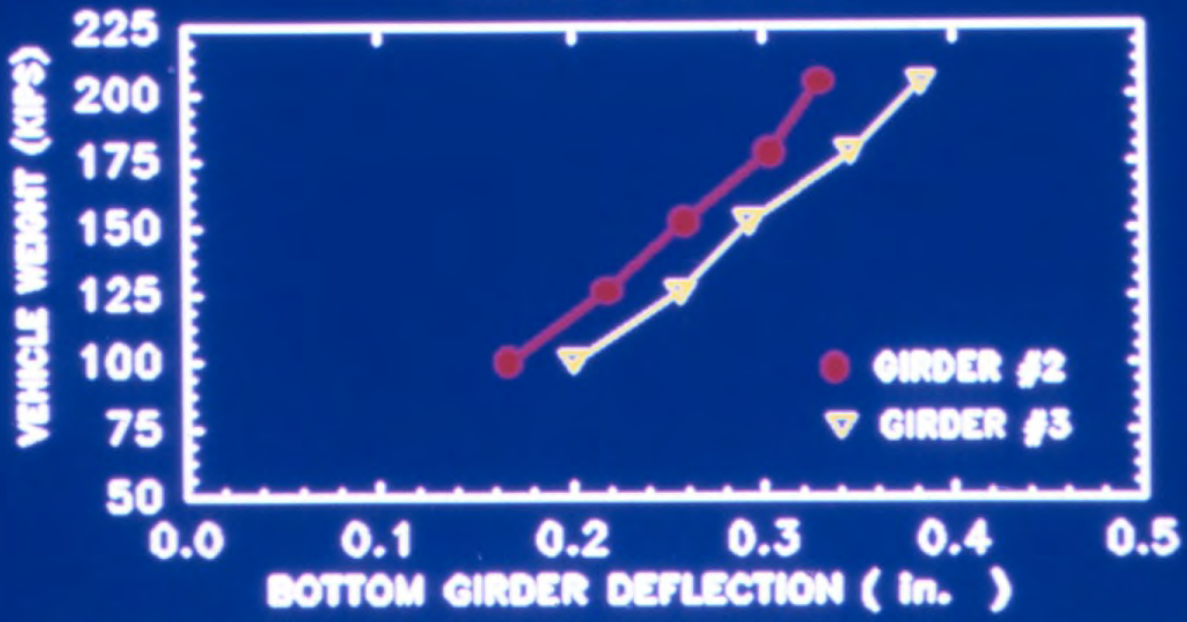
EXPERIMENTAL RESULTS FOR AASHTO TYPE III GIRDERS

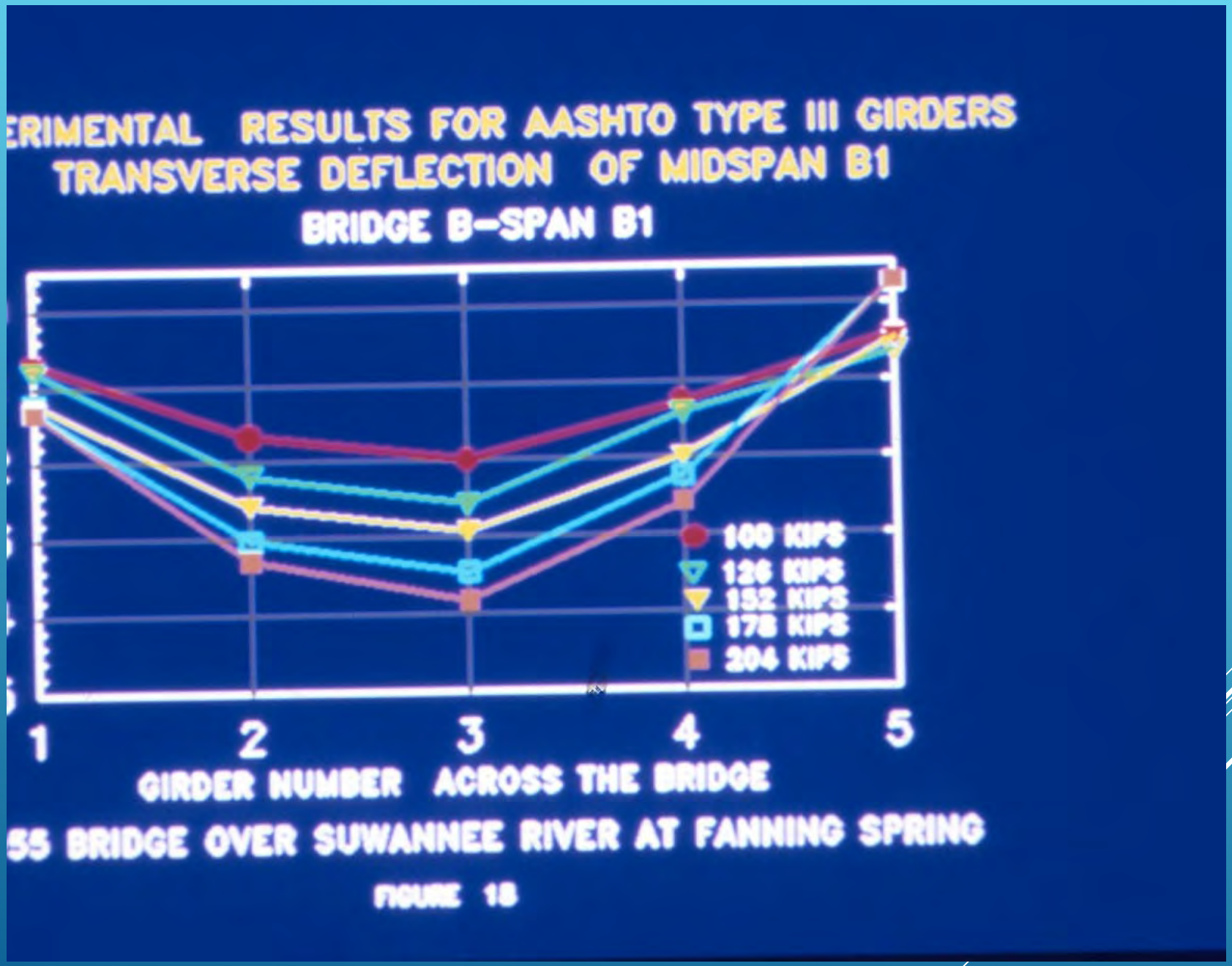
LOAD VS. GIRDER DEFLECTION AT MIDSPAN B1

BRIDGE B-SPAN B1



SR-55 BRIDGE OVER SUWANNEE RIVER AT FANNING SPRING

FIGURE 21



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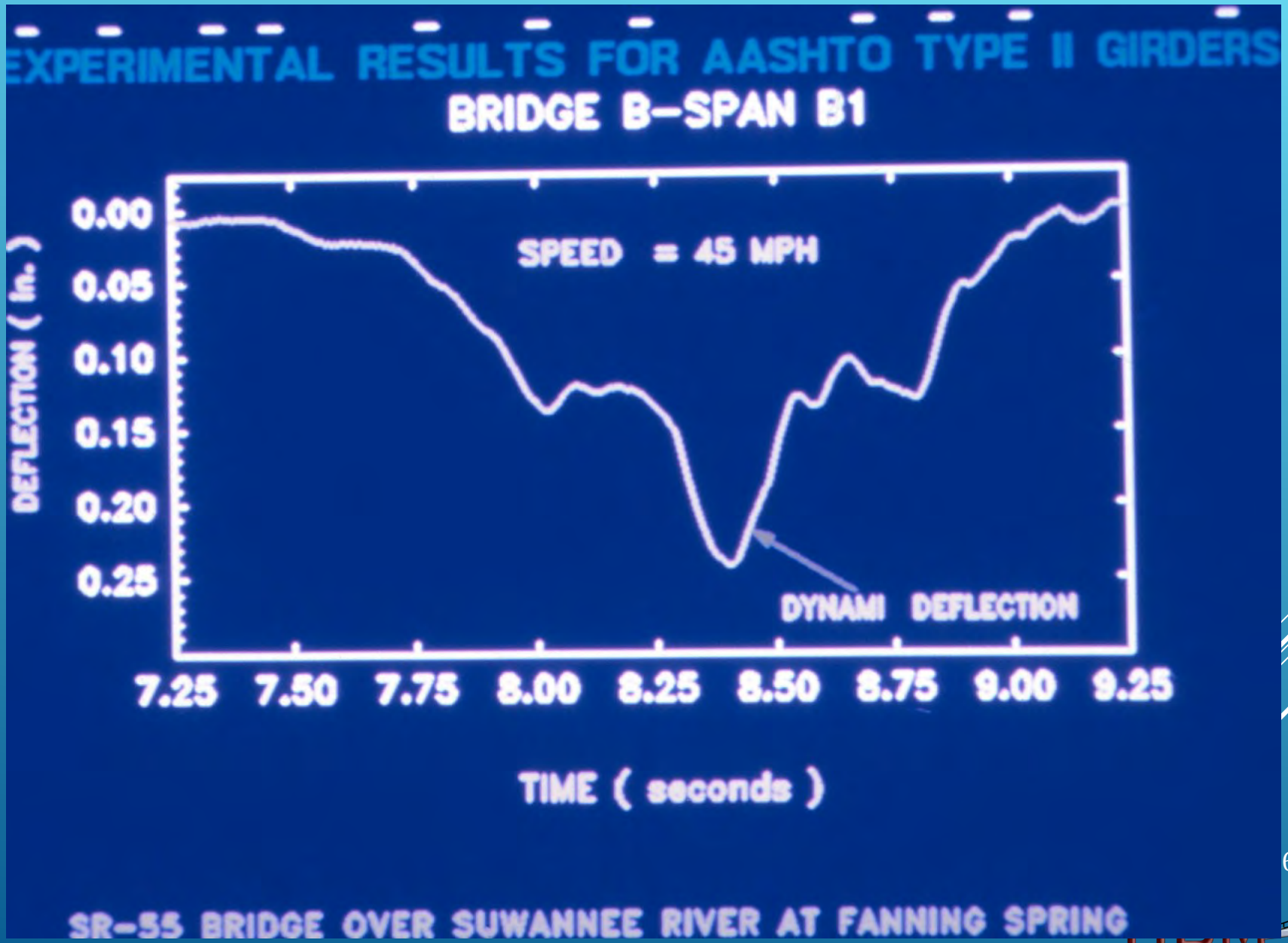

EXPERIMENTAL RESULTS FOR AASHTO TYPE II GIRDERS
BRIDGE B-SPAN B1
SPEED = 45 MPH
DYNAMI DEFLECTION
DEFLECTION (in.)
0.00
0.05
0.10
0.15
0.20
0.25
7.25
7.50
7.75
8.00
8.25
8.50
8.75
9.00
9.25
TIME (seconds)
SR-55 BRIDGE OVER SUWANNEE RIVER AT FANNING SPRING

CONCLUSIONS ON FIELD TESTING

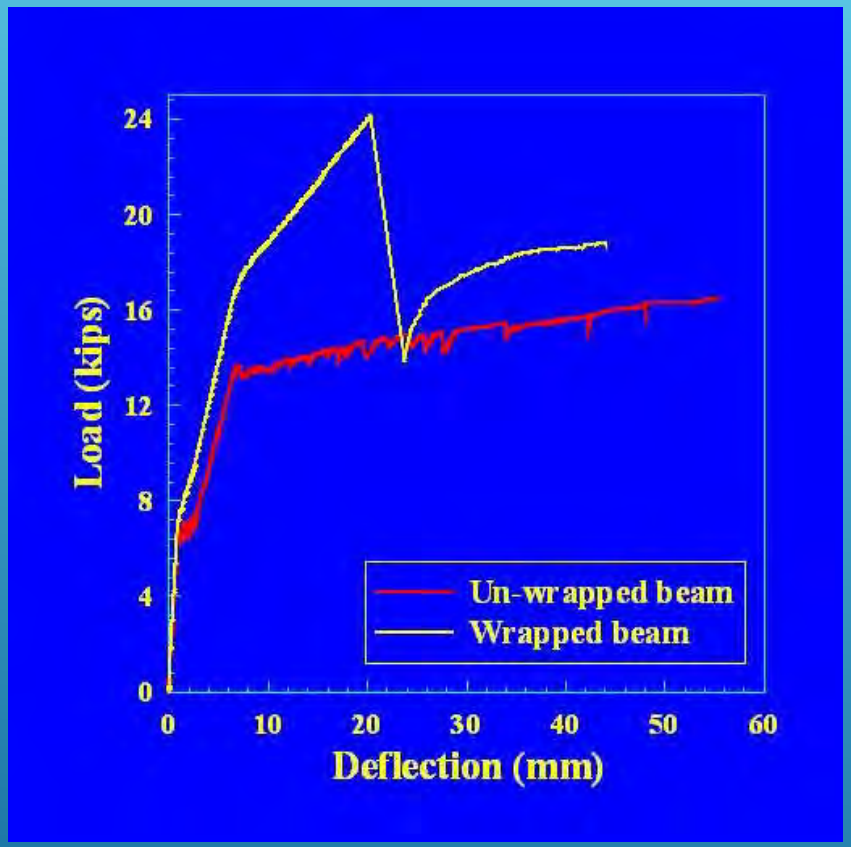
Remove Some Uncertainties

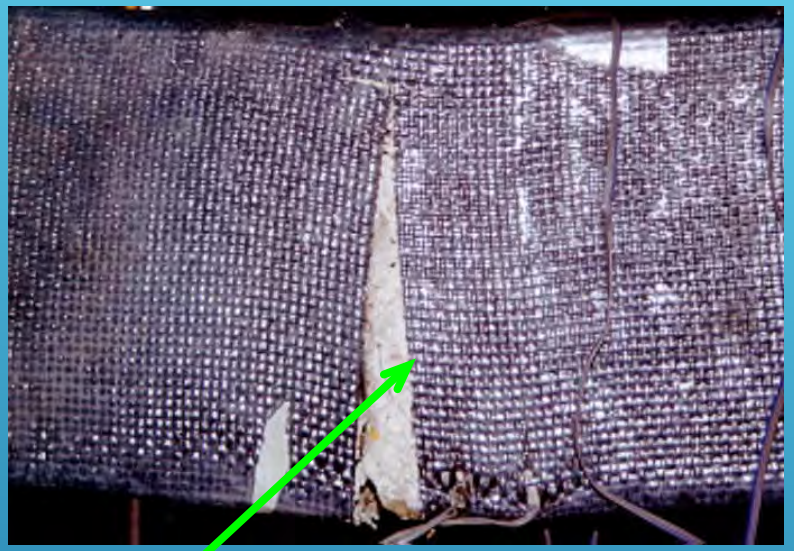
Reflect Bridge Behavior

Enhance Load Rating

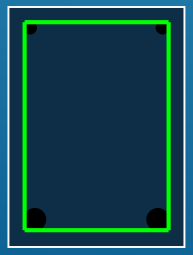
Avoid Unnecessary Retrofitting

CARBON FIBER REINFORCED POLYMER (CFRP)

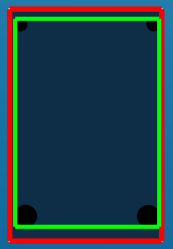




Rupture of CFRP



Unwrapped



1-Layer Fully Wrapped

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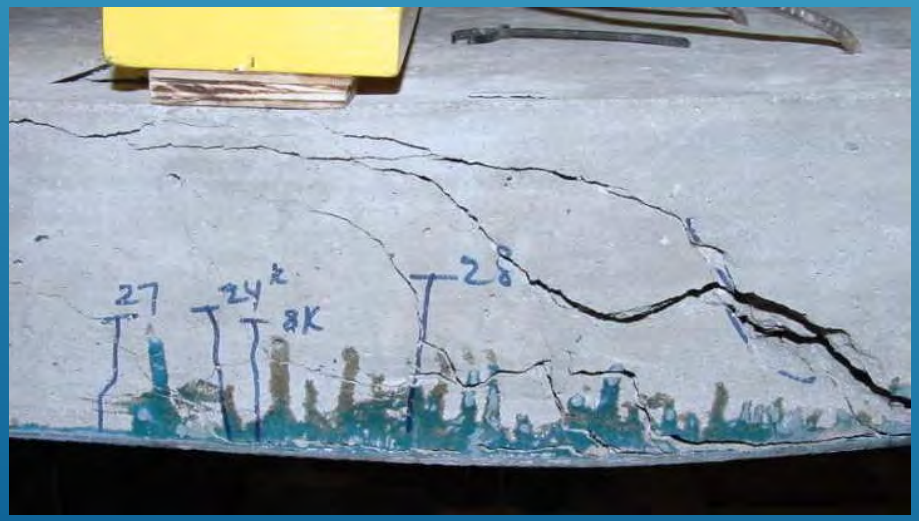
Mechanical properties of CFRP CF130 from Master Builders Inc.

Mbrace CF 130

Property	Amount
Ultimate strength	620 ksi (4275 MPa)
Design strength	550 ksi (3790 MPa)
Yielding modulus	33,000 ksi (228 GPa)
Ultimate strain	0.017 mm/mm

Modes of Failure



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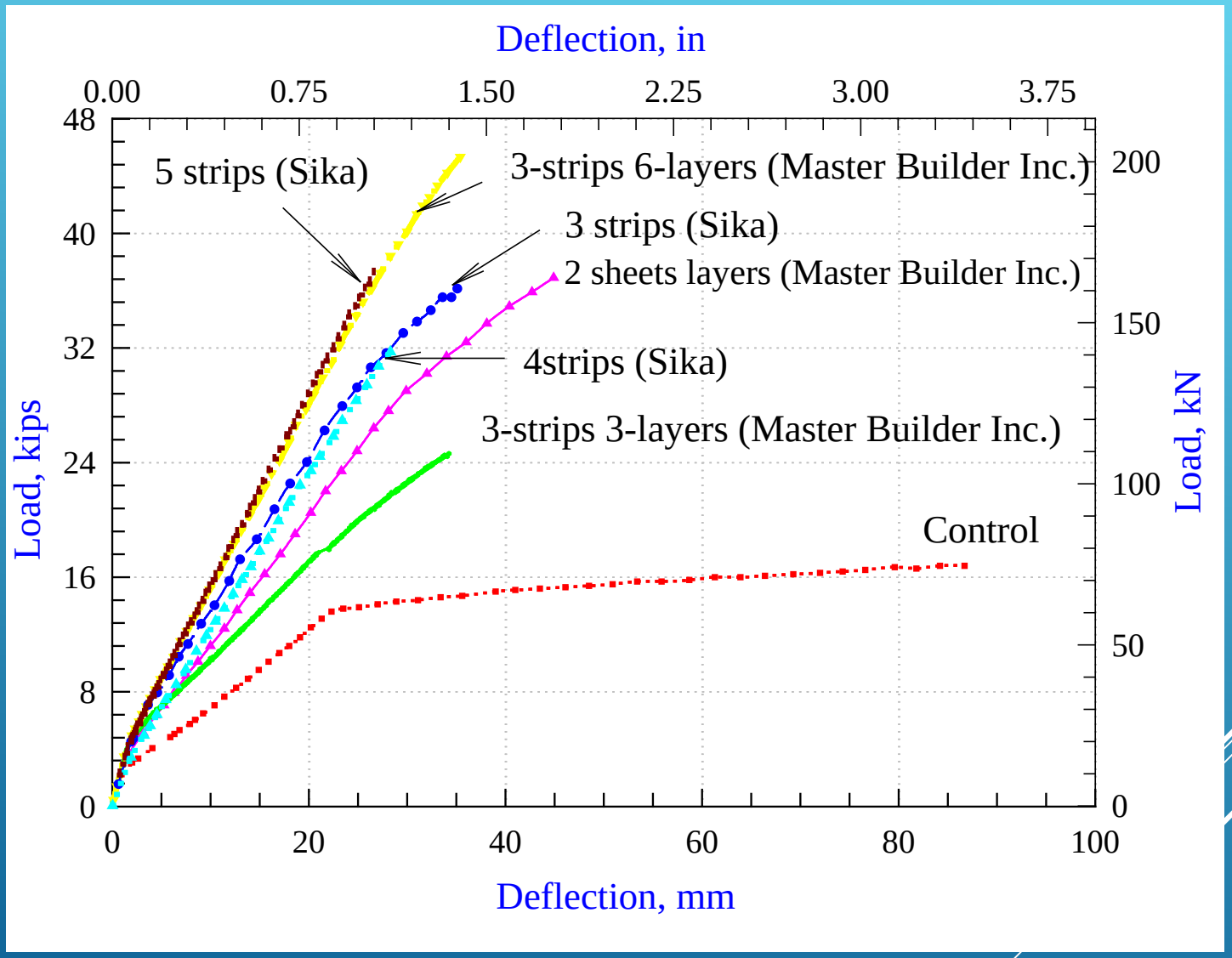
Load vs. Deflection Curves for all Slabs Master Builders and Sika CFRP



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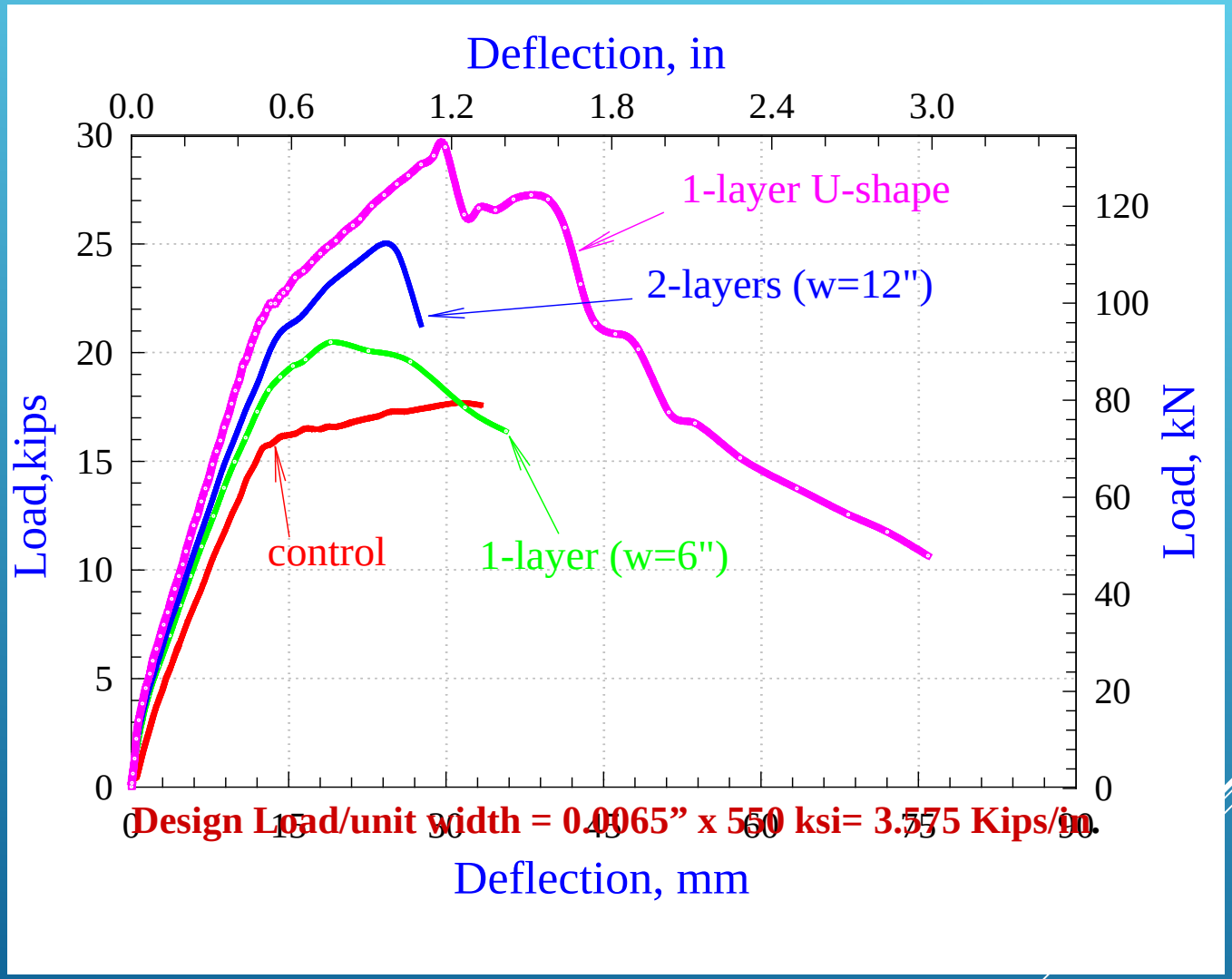
Load vs. Deflection Curves for 8 ft RC Beams Cured at Room Temperature



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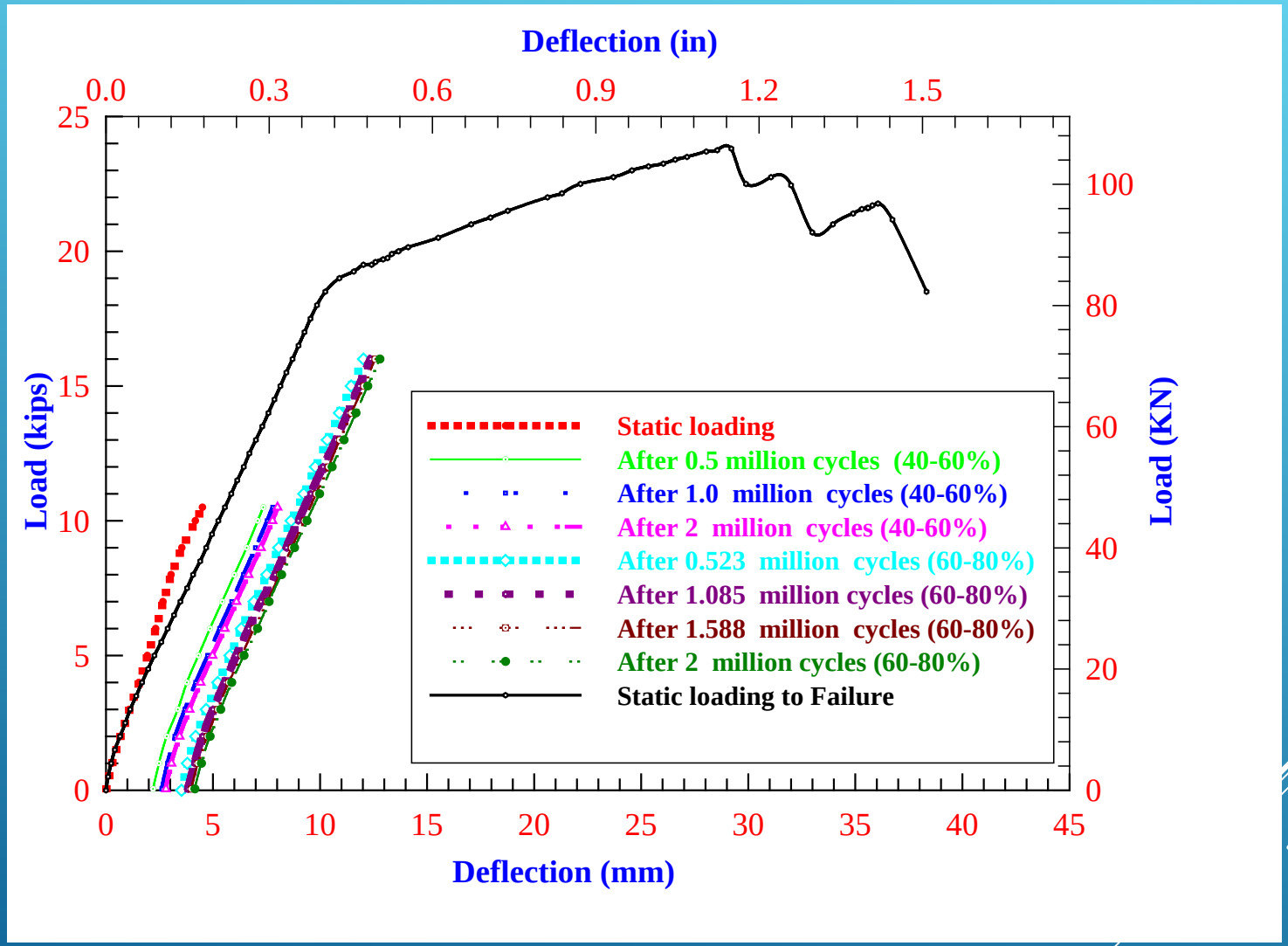
Load vs. Deflection Curves for Beam (B8F1L40-60, 60-80) Strengthened with 1-Layer of CFRP under Cyclic Loading



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Mode of Failure of RC Column (Control)

Mode of Failure of RC Column confined with CFRP

Test Results of all Circular 36 in. Long RC Columns

Specimen	Type of strengthening	Ultimate load kips	% Increase**
C36C0	Control (unconfined)	263 (264)*	---
C36S1	1- layer 4" strips @ 1" spacing	332 (334)*	26
C361T	1- layer in lateral direction	353 (347)*	34
C362T	2-layers in lateral direction	444 (422)*	69

Note: ( )* represents the ultimate load for the 30" long columns

** with respect to control specimens

FIELD APPLICATION

18”X48” VOIDED PRESTRESSED CONCRETE SLAB BRIDGE. THE BRIDGE CONSISTS OF FIFTEEN 39 FT. SPANS.

CORROSION OF PRESTRESSING STRANDS AND SPALLING OF CONCRETE

RESTORATION OF CONCRETE SECTION

APPLICATION OF CFRP

DAMAGED AASHTO TYPE II GIRDERS

FORMING AND RESTORING OF CONCRETE SECTIONS

APPLICATION OF CFRP

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I90 Toll Highway Bridge Over Burr Oak Ridge Road, Village of Roscoe

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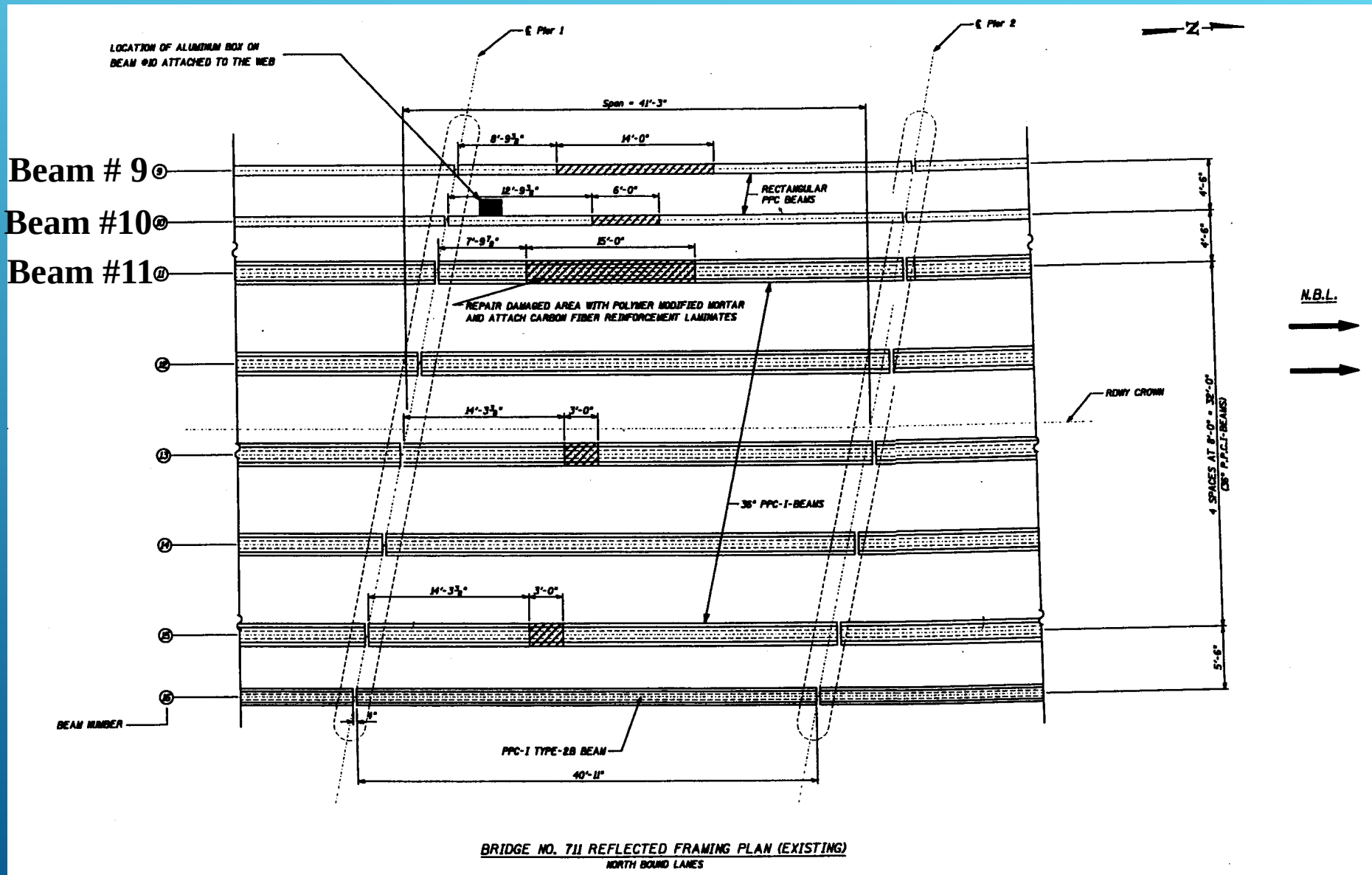
I90 Toll Highway Bridge Over Burr Oak Ridge Road, Village of Roscoe

Damaged Prestressed Concrete Beams

The existing plan for bridge No. 711



BRIDGE NO. 711 REFLECTED FRAMING PLAN (EXISTING)
NORTH BOUND LANES

Damaged Precast Prestressed Concrete Beam # 9 (Rectangular Section)

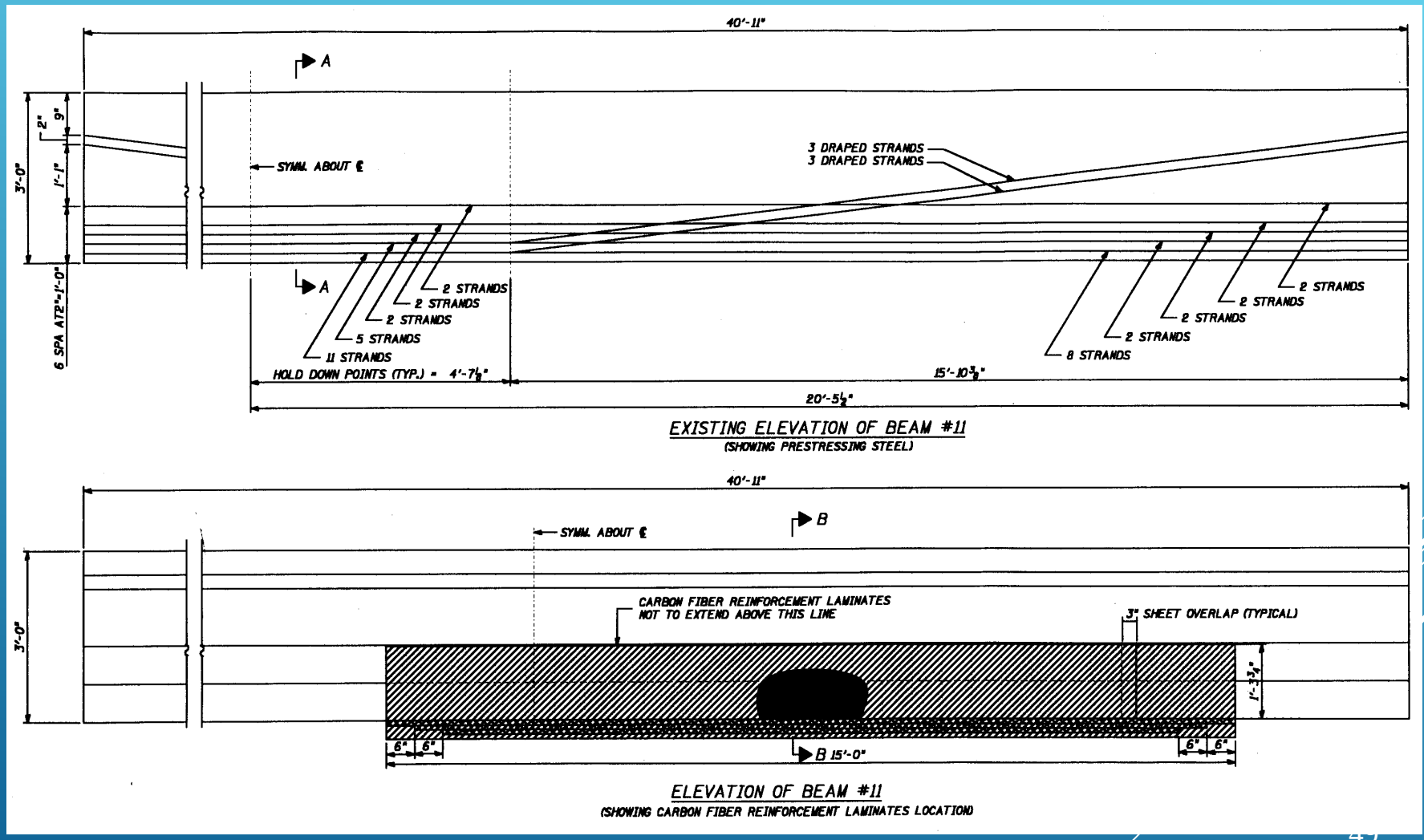
Bridge Condition:

Bridge hit and severely damaged, one strand cut, Two strands fully exposed with some damage.

Action:

Beam needs concrete repair and CFRP strengthening to counterbalance for the prestress force lost due to the damage. Beam also needs CFRP wrap to confine the beam at the damaged location.

Location of CFRP lamination and prestressing steel for beam #11



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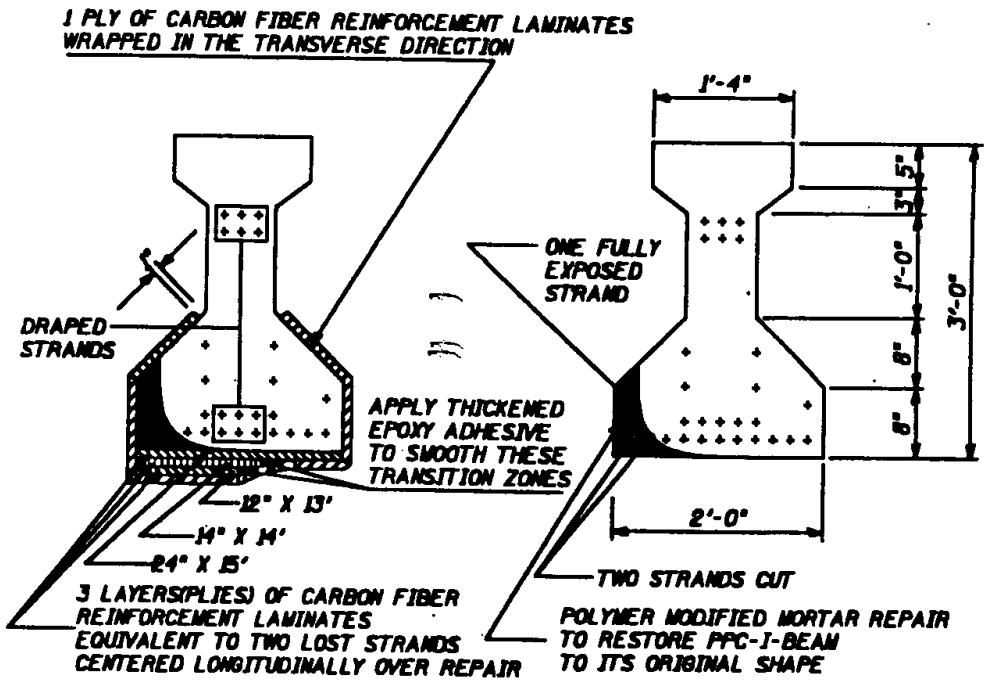
Damaged and repaired details of Beam #11



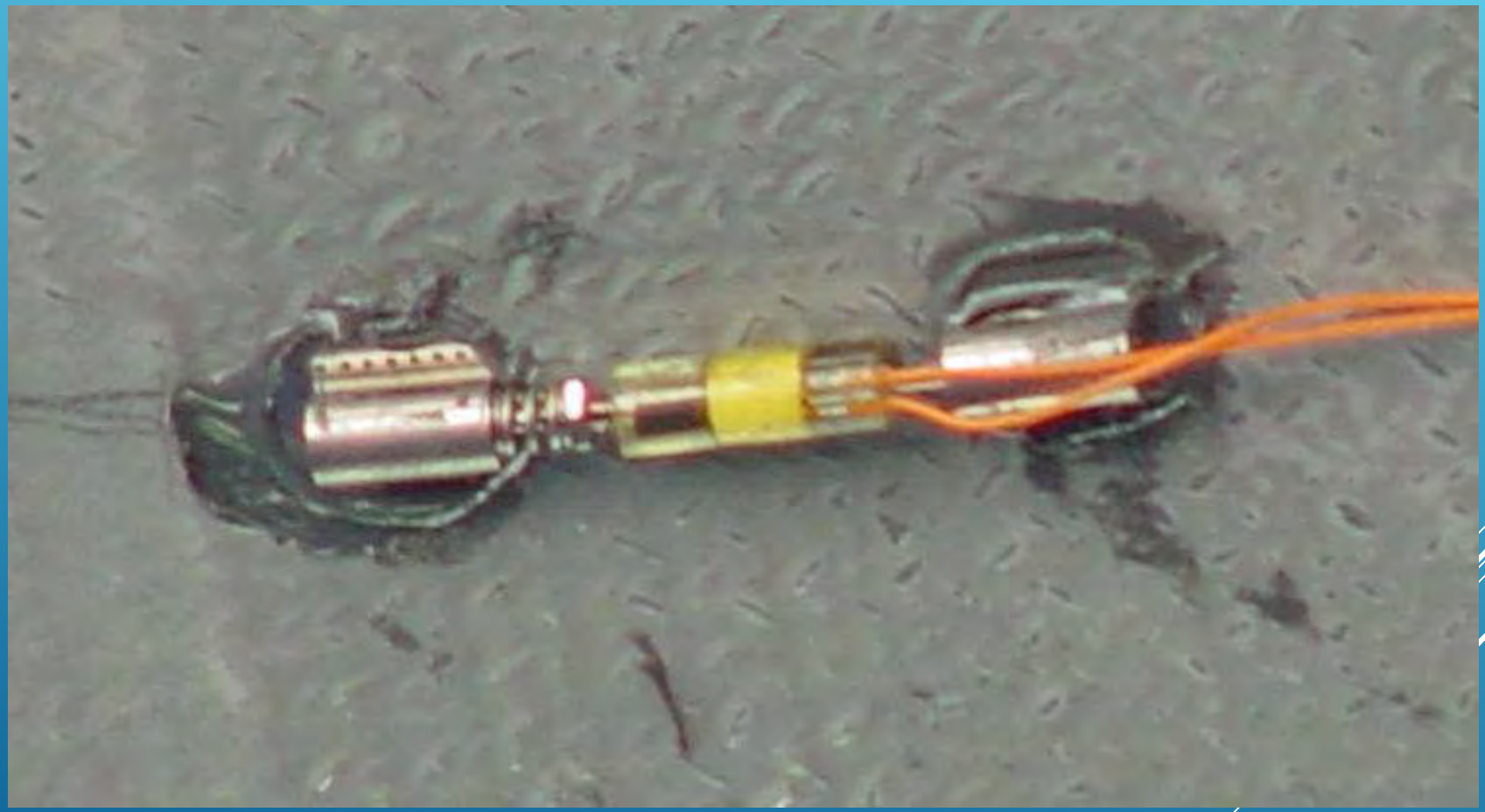
BEAM #11 (BRIDGE No. 711)

LEGEND:

- POLYMER MODIFIED MORTAR REPAIR
- CARBON FIBER REINFORCEMENT LAMINATES AT THE BOTTOM FLANGE CENTERED AND ORIENTED LONGITUDINALLY OVER THE REPAIR
- CARBON FIBER REINFORCEMENT LAMINATES WRAPPED UNIDIRECTIONAL IN THE TRANSVERSE DIRECTION

Application of CFRP to Fully Restored Damaged Girder

Instrumentation
Vibrating Wire Strain Gages



Repaired Damaged Areas and Installing the Monitoring System

Monitoring System Housed in Aluminum Box

Solar Panel

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Damaged AASHTO Beams on I88 Illinois Tollway Bridge

CFRP BEAM REPAIR NW TOLLWAY(I-90) OVER IL 173

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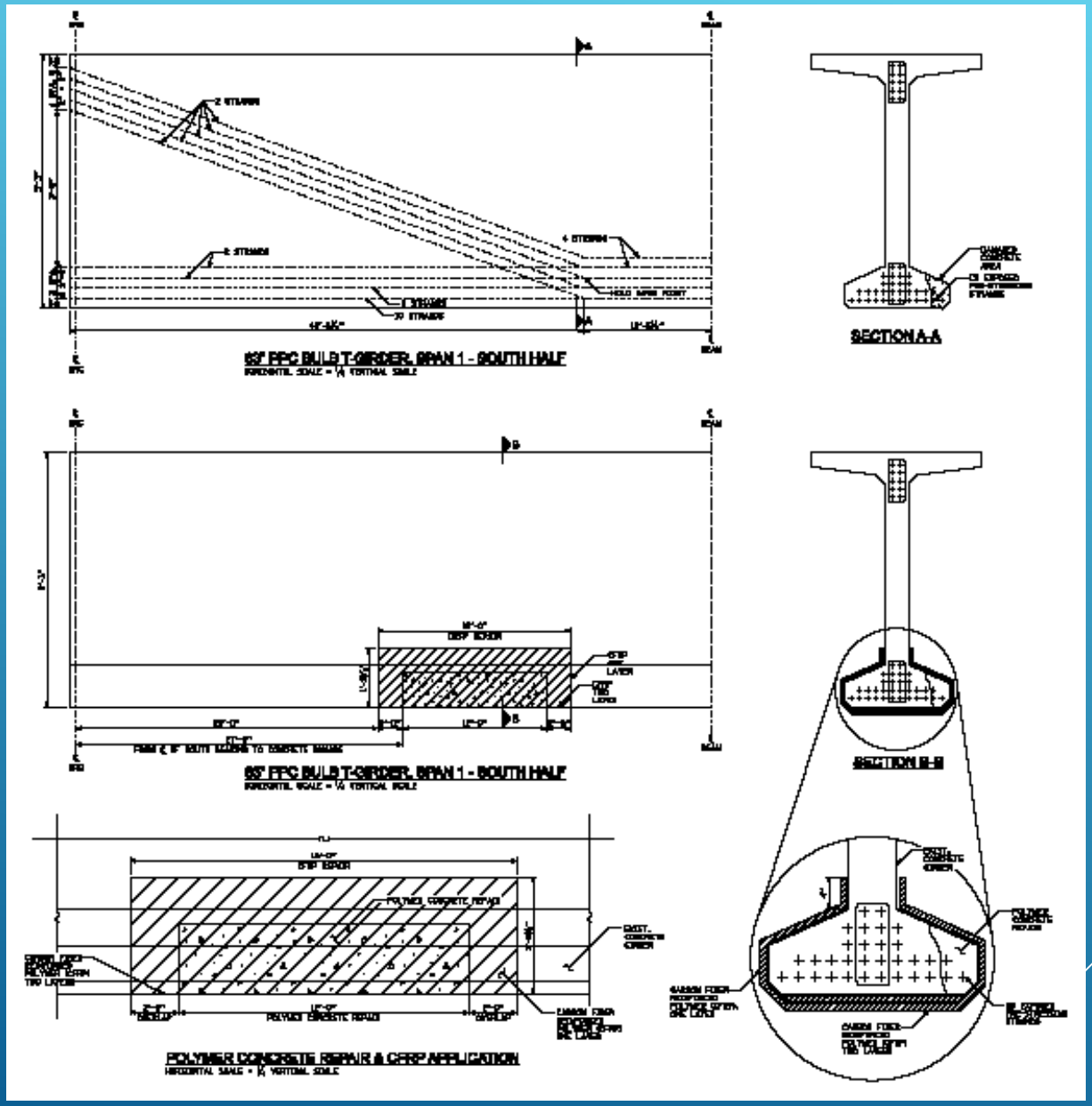
CFRP BEAM REPAIR NW TOLLWAY(I-90) OVER IL 173



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CFRP BEAM REPAIR NW TOLLWAY(I-90) OVER IL 173

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CFRP BEAM REPAIR NW TOLLWAY(I-90) OVER IL 173

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CFRP BEAM REPAIR NW TOLLWAY(I-90) OVER IL 173

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CFRP BEAM REPAIR NW TOLLWAY(I-90) OVER IL 173

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CFRP BEAM REPAIR NW TOLLWAY(I-90) OVER IL 173

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CFRP BEAM REPAIR NW TOLLWAY(I-90) OVER IL 173

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CFRP BEAM REPAIR NW TOLLWAY(I-90) OVER IL 173

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CFRP BEAM REPAIR NW TOLLWAY(I-90) OVER IL 173

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CFRP PIER REPAIR 18TH STREET – EAST OF THE RIVER

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CFRP PIER REPAIR 18TH STREET – EAST OF THE RIVER

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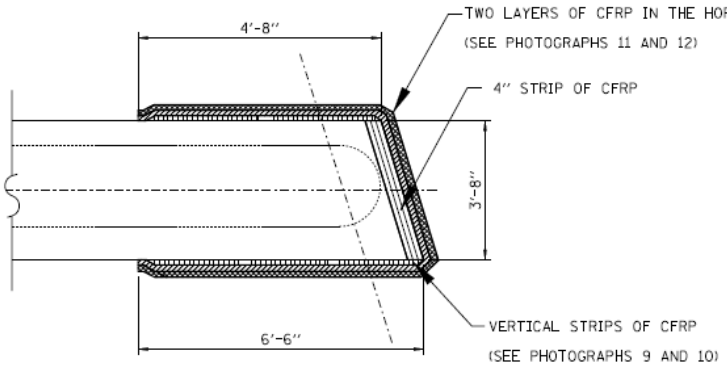
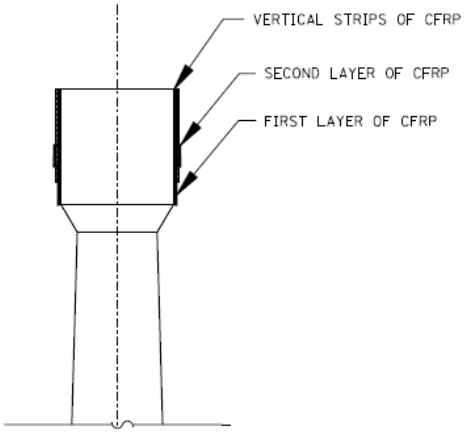
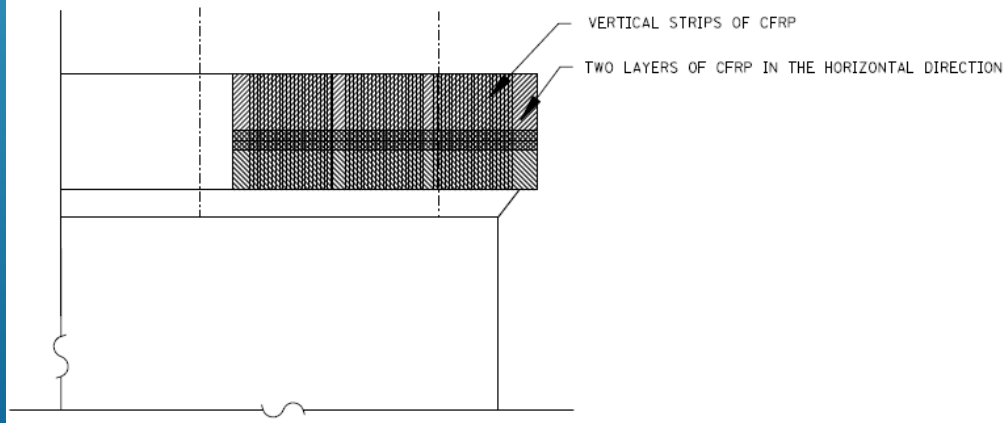
CFRP PIER REPAIR 18TH STREET – EAST OF THE RIVER



PIER 4 - PLAN VIEW



PIER 4 - SOUTH FACE



PIER 4 - WEST FACE

Typical Pier Repairs

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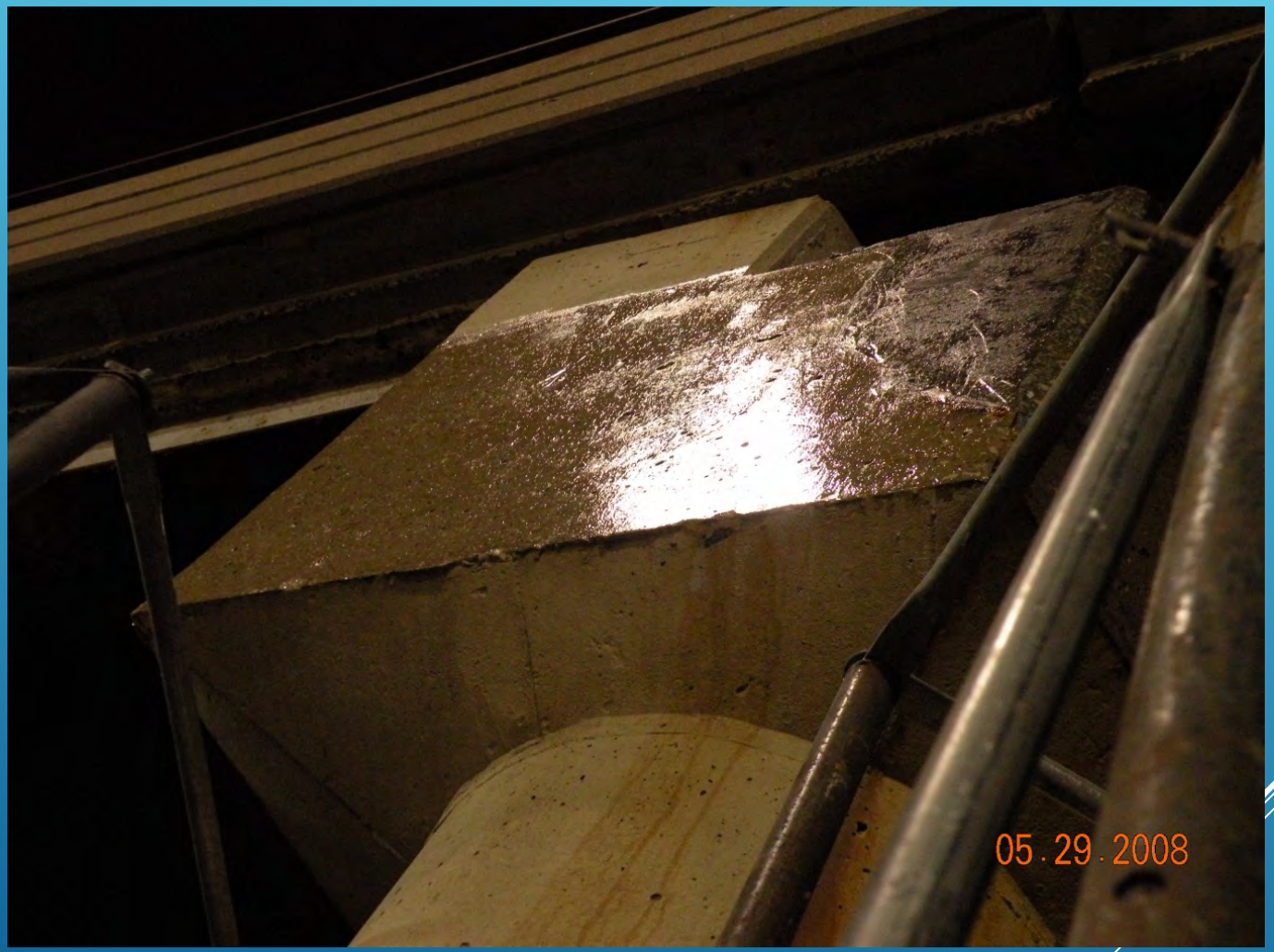
CFRP PIER REPAIR 18TH STREET – EAST OF THE RIVER



Application of Primer Material on Pier 1 Surface

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CFRP PIER REPAIR 18TH STREET – EAST OF THE RIVER

Application of First Horizontal Layer of CFRP on Pier 1

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CFRP PIER REPAIR 18TH STREET – EAST OF THE RIVER

Pier 4 with two coats of FRL in gray color

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CFRP PIER REPAIR 18TH STREET – EAST OF THE RIVER

Pull out Testing at Pier 4

Location #	Pullout Strength (PSI)
Pier 1	475
Pier 4	520
	Average = 497.5

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41ST & 43RD ST. PEDESTRIAN BRIDGES OVER IC/CN RAILROAD AND LSD, CHICAGO IL

APPROACH STRUCTURES

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41ST & 43RD STREET PEDESTRIAN BRIDGES DESIGN TEAM AND HISTORY

History

Double-curved, tilted arch mono tube concept was Winner of Chicago International Design Competition for updating and revitalizing Chicago's south side neighborhoods providing pedestrian access to Lake Shore Drive Lake Front Trail.

Original TS&L completed in 2007 by Earthtech (AECOM). Revisions made and resubmitted in 2014.

Design Team

- Cordogan Clark & Associates, Inc (Architect)
- AECOM (Structural, main spans, Civil and Construction Administrator).
- HBM Engineering Group, LLC (Structural, East and West Approaches).
- Singh and Associates (Lighting aesthetics).
- Ground Engineering Consultants, Inc (Geotechnical)
- RWDI (Wind tunnel and dynamic modeling)
- F.H Paschen (Contractor)

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41ST & 43RD STREET PEDESTRIAN BRIDGES

PROJECT LOCATION AND OVERVIEW

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41ST & 43RD STREET PEDESTRIAN BRIDGES ARCHICTURAL CONCEPT RENDERING

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41ST & 43RD STREET PEDESTRIAN BRIDGE

Design Challenges:

- **Complex Geometry**
  - Fabrication/Erection/Camber
    - 3-Dimensional Camber
  - Structural Stability
    - Fully welded saddle bearings for torsional restraint
  - Redundancy
    - Single circular carrier rib
- **Tight Radius of Curvature**
  - 120’-0” radius with 5% vertical profile (41st St. Approaches)
  - 60’-0” Radius with 8% vertical profile (43rd St. Approaches)
- **Uplift**
- **Thermal movements**
  - 3-Dimensional modeling considering foundation flexibility to determine location of thermal neutrality.
- **High Torsion**
- **Agency Coordination**

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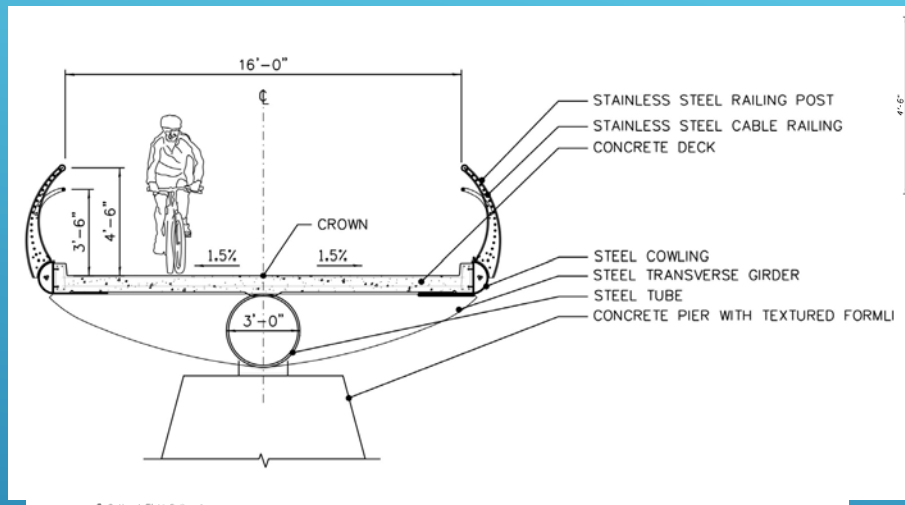
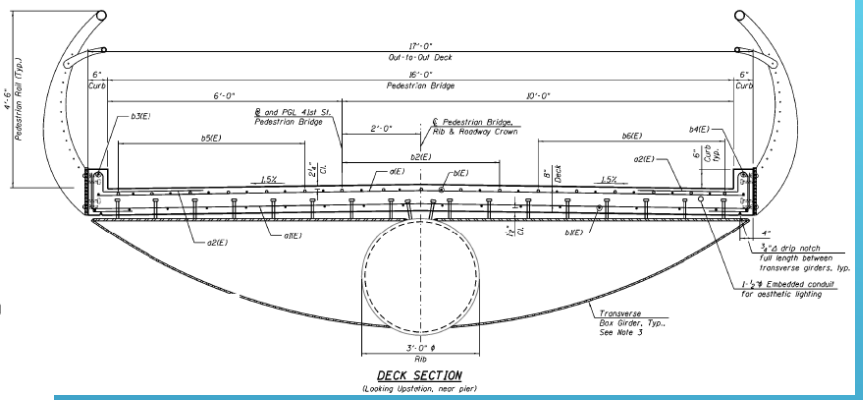
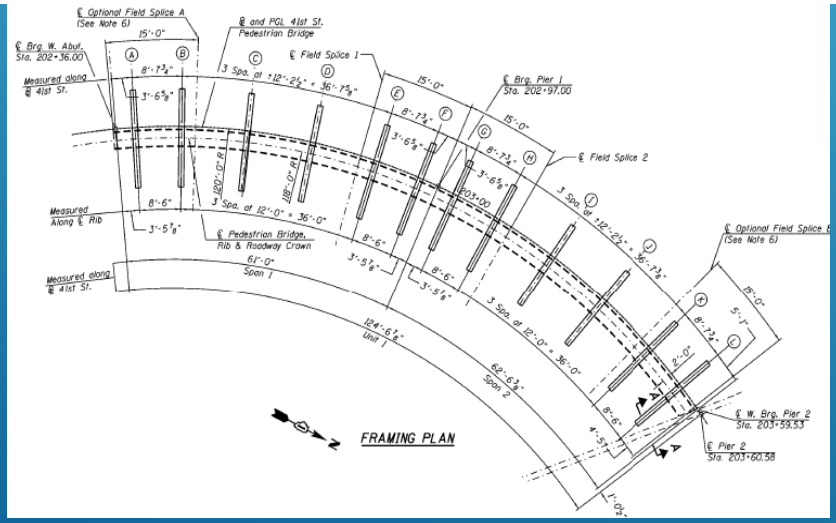
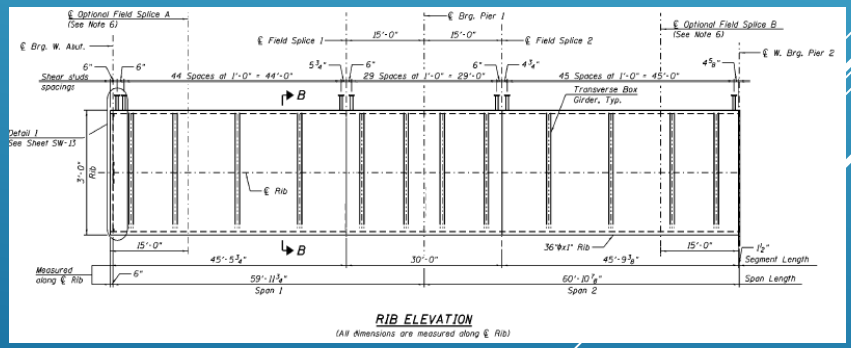
41ST STREET PEDESTRIAN BRIDGE

RAMP APPROACH SECTION









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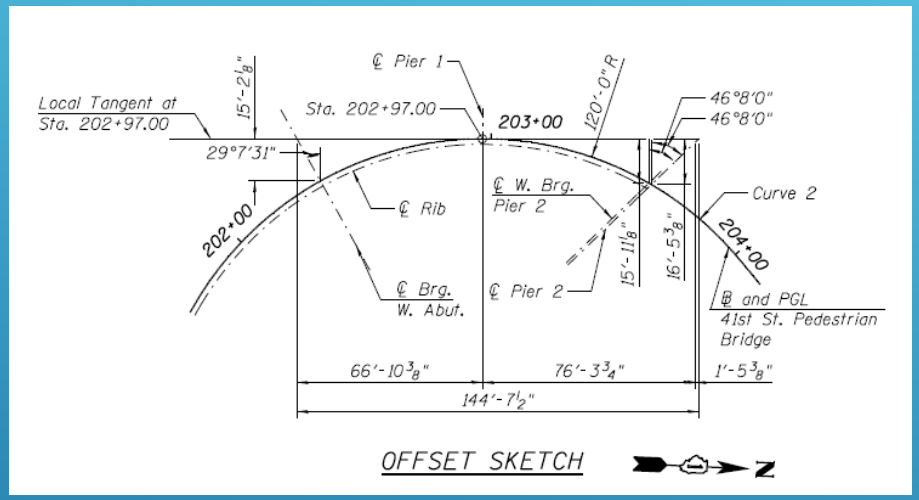
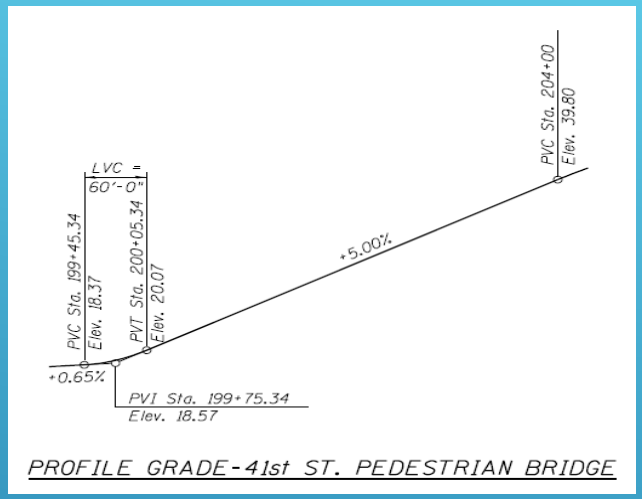
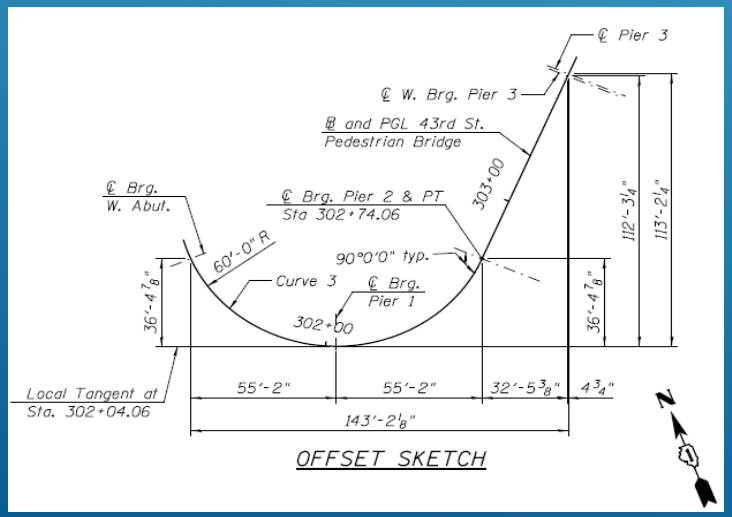
41ST & 43RD STREET PEDESTRIAN BRIDGE VERTICAL AND HORIZONTAL PROFILE

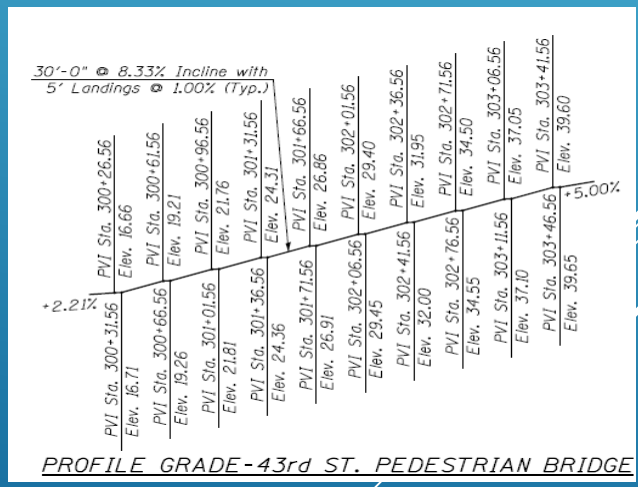
41st St. Bridge





43rd St. Bridge





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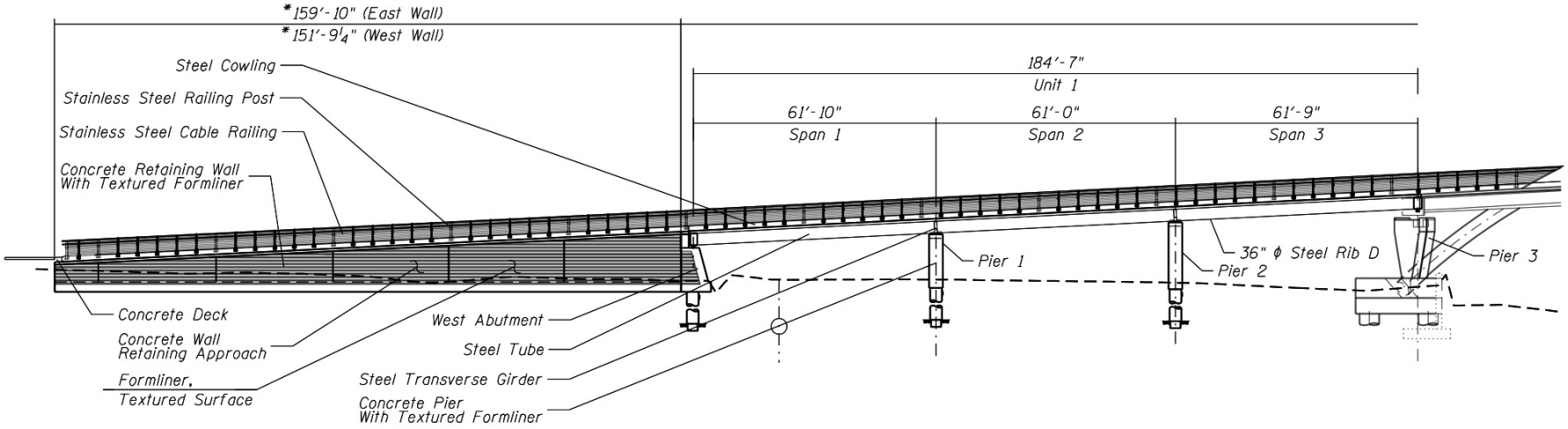
41ST STREET PEDESTRIAN BRIDGE
WEST APPROACH ELEVATION VIEW



41st ST WEST APPROACH ELEVATION

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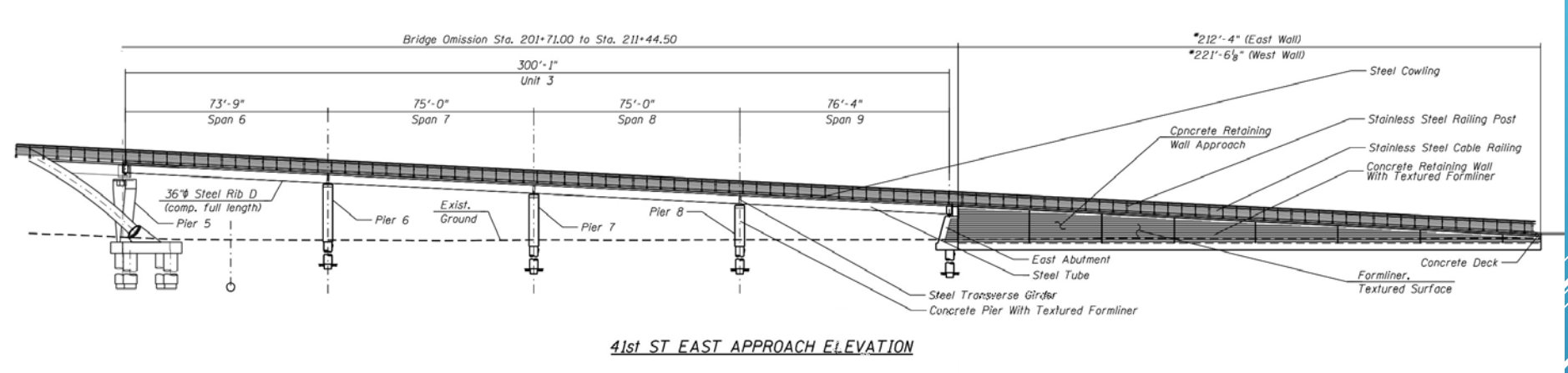
41ST STREET PEDESTRIAN BRIDGE
EAST APPROACH ELEVATION VIEW



41st ST EAST APPROACH ELEVATION

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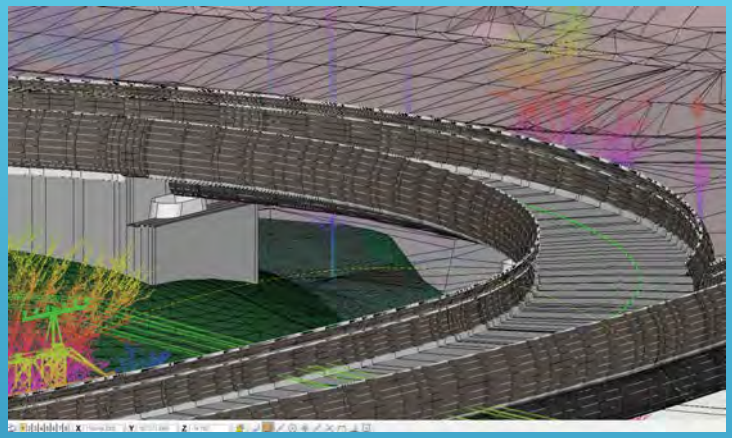
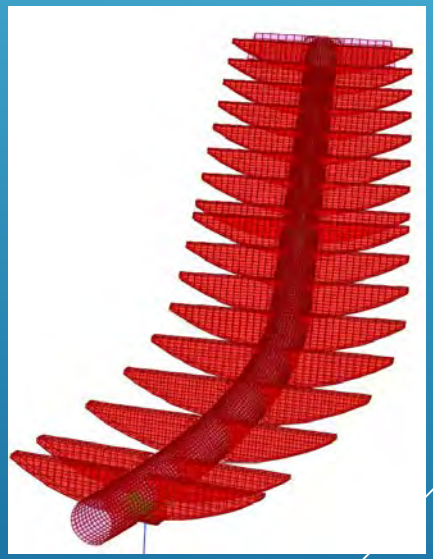
41ST STREET PEDESTRIAN BRIDGE

RAMP WEST APPROACH





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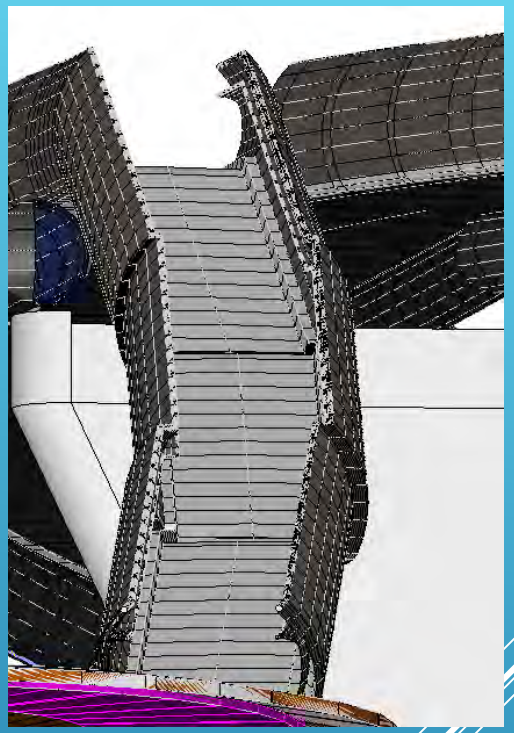
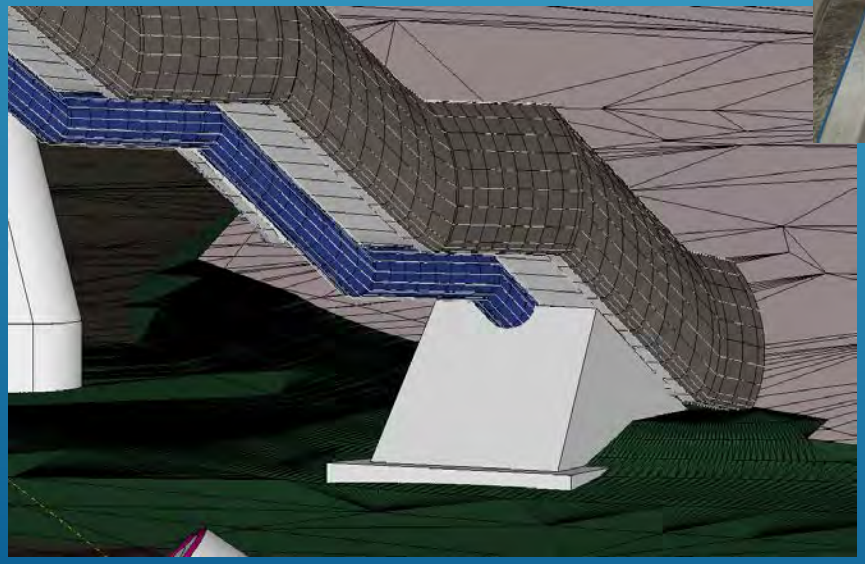
41ST STREET PEDESTRIAN BRIDGE

RAMP WEST APPROACH STAIRS





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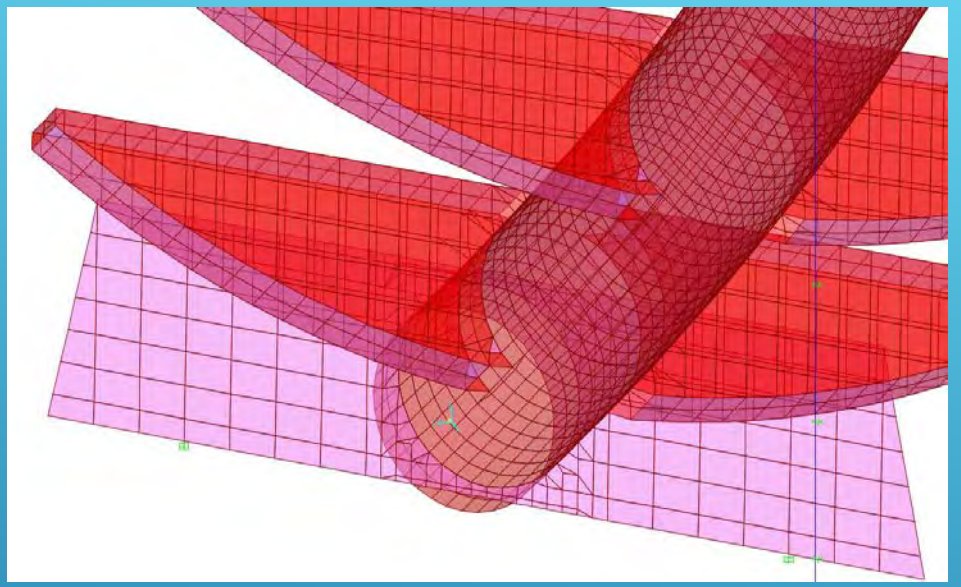
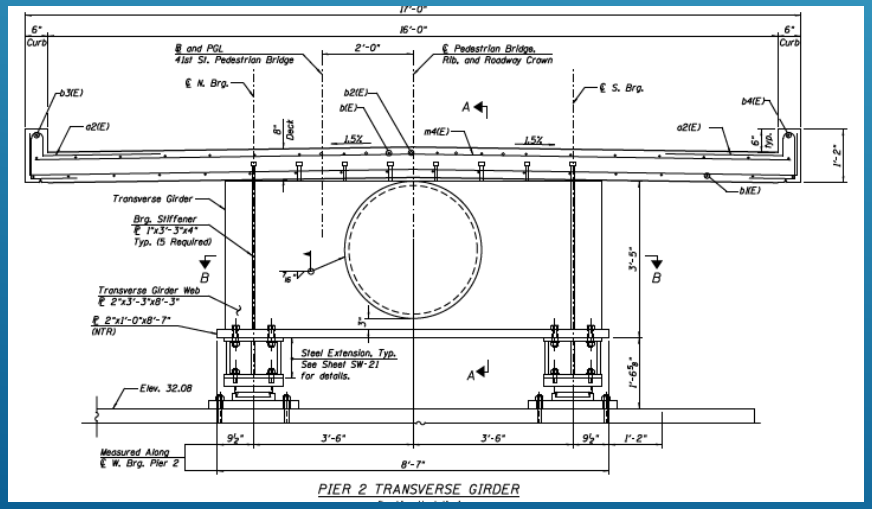
41ST STREET PEDESTRIAN BRIDGE

RAMP WEST APPROACH SHARED PIER





PIER 2 TRANSVERSE GIRDER

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41ST STREET PEDESTRIAN BRIDGE

RAMP WEST APPROACH

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DEMOLITION OF IL 89 TRUSS BRIDGE OVER THE ILLINOIS RIVER

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BACKGROUND

- 19-span bridge over the Illinois River in Spring Valley, IL
- Built in 1934
- 14 approach spans consisting of concrete slab on rolled steel stringers
- 5 truss spans
- (200 ft – 362 ft length)

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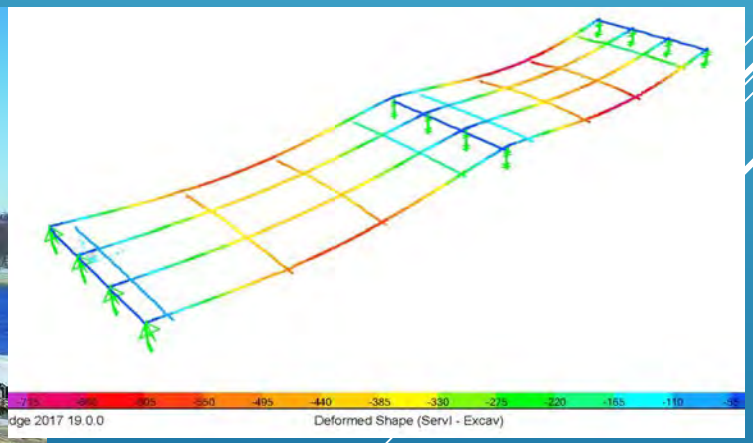
BRIDGE REMOVAL

- After the construction of the new bridge:
- Approach spans were wrecked to the ground
- Modeled in CSI Bridge with equipment loads for deck removal (including 50% impact)



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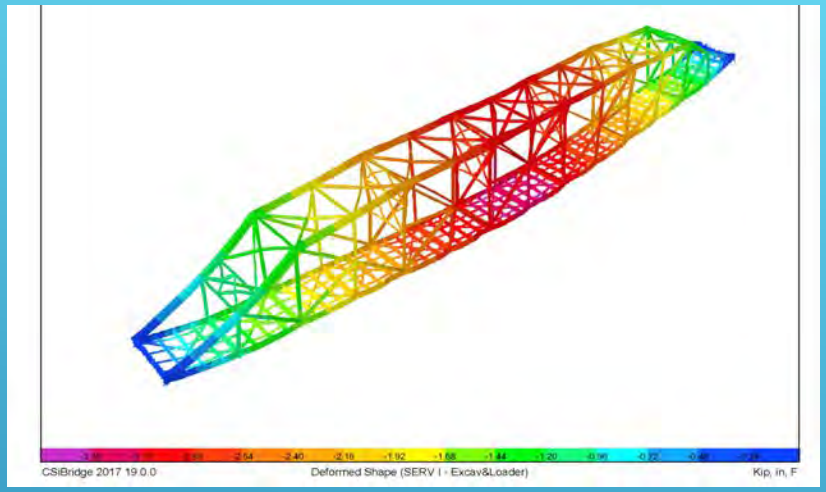
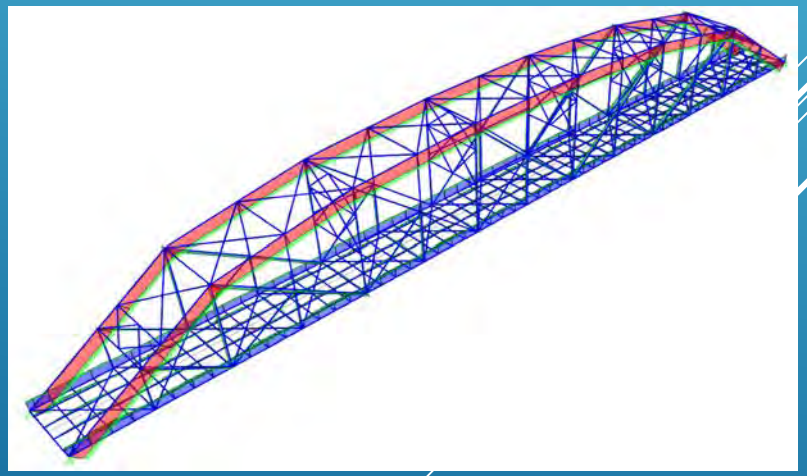
TRUSS SPANS

- Deck sawcut and removed
- Stringers removed
- Top and bottom lateral bracing members cut or removed
- Weakened to prepare for demolition by explosives, while still withstanding the wind load prior to blasting
- Shorter truss spans (200 ft) were weakened at the 4 corners to drop into the river
- Longer truss span (362 ft) was weakened at every truss panel (truss top chord, bottom chord & diagonal members)





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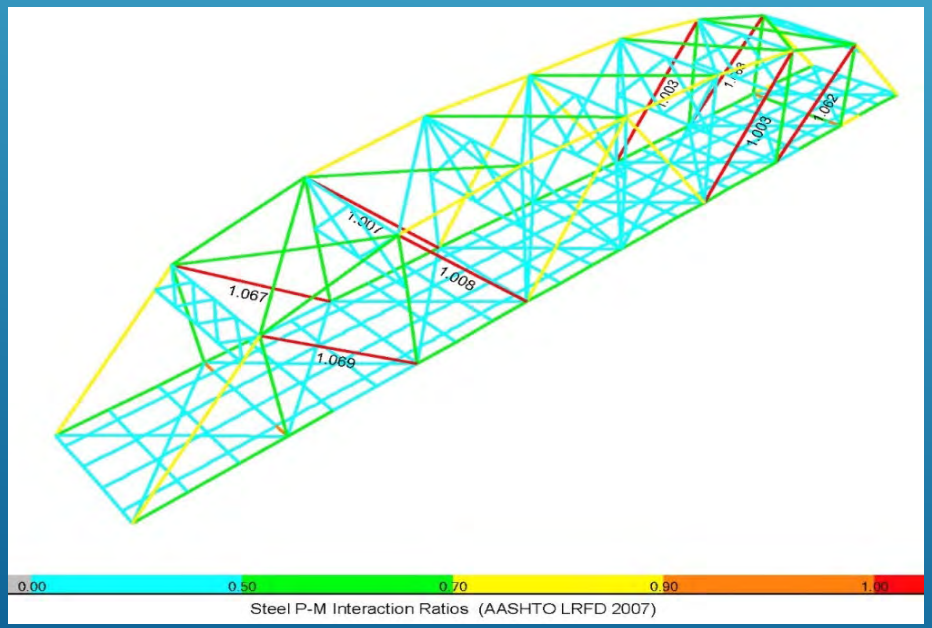
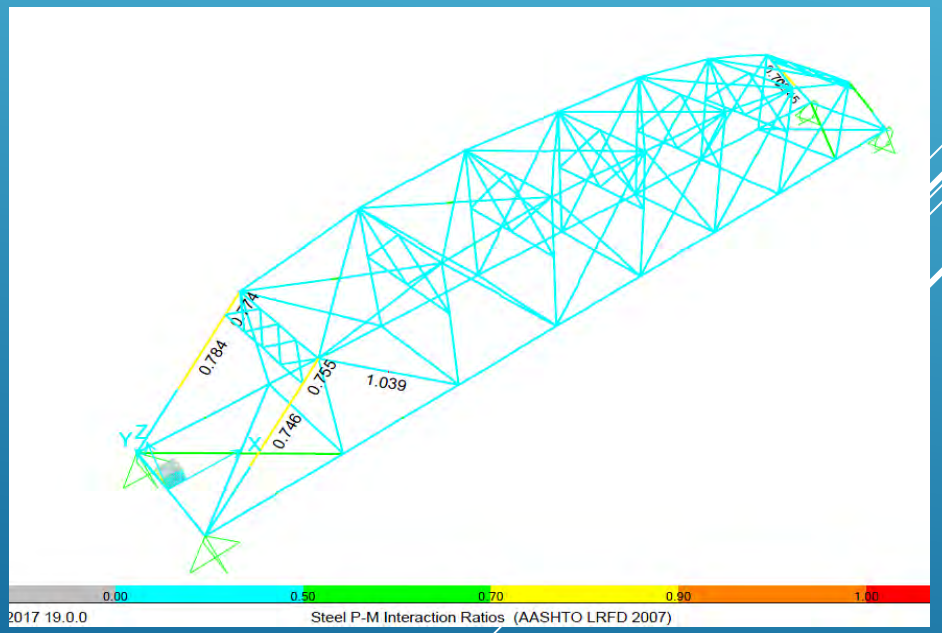
2 MODELS IN CSI BRIDGE FOR EACH TRUSS SPAN:

- Full truss model with equipment loads for deck removal (including 50% impact)
- Weakened truss without the deck: dead load and 50% wind





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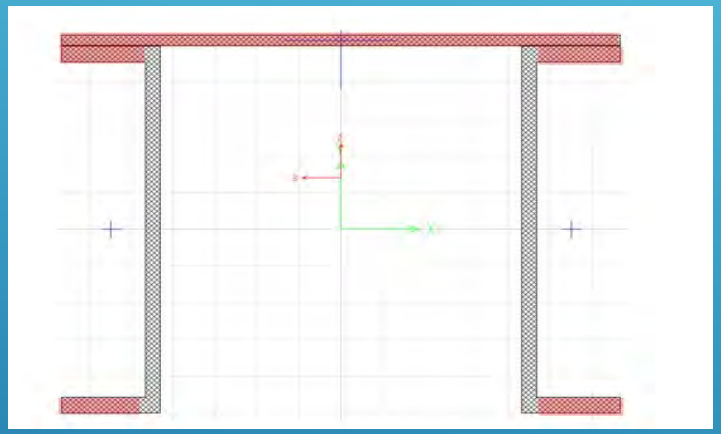
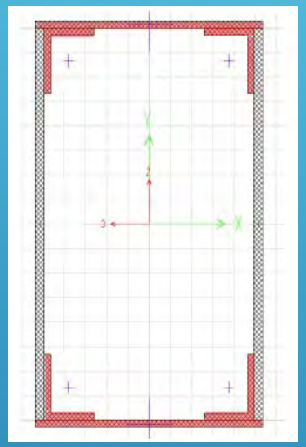
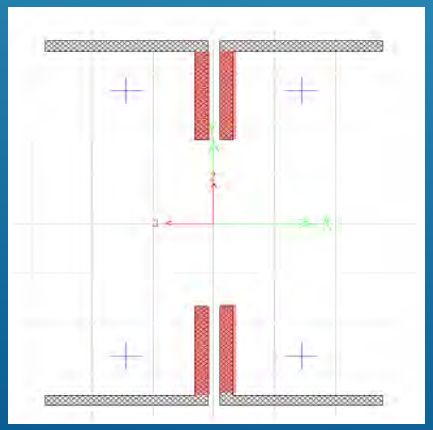
WEAKEN TRUSS MEMBERS

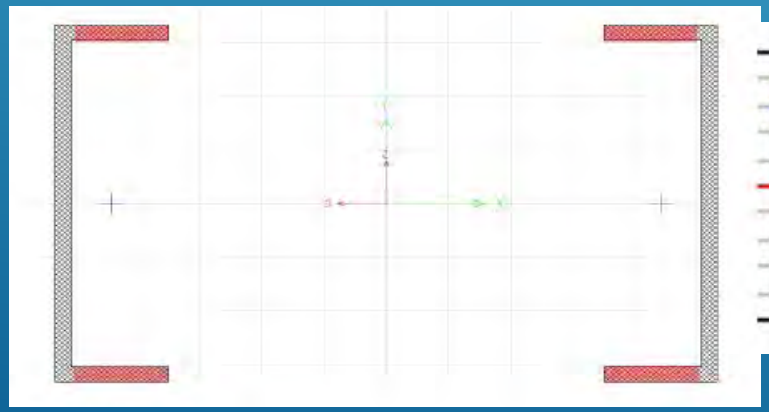
- Red areas removed by torch cutting: Top & Bottom Chords

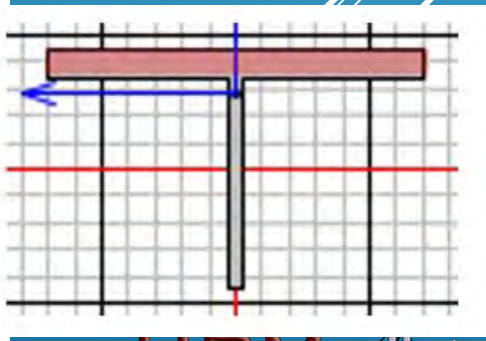




- Diagonals & Lateral Bracing







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DESIGN CHALLENGES & CONCLUSIONS

- Performance ratios slightly exceeding 1.0
  - Obtained conservatively using 50% impact for construction live load
  - Temporary condition (few days): not scheduled during weather of maximum design-force winds
- Specified load permitted to be carried by construction equipment & allowable travel lanes

- **Determined cuts for truss & lateral bracing members**
- **Project concluded with safe & successful demolition in August 2018**

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https://youtu.be/cLf9xhpwrIl

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Field Investigation & Testing of Sign Structures for VMS/CMS System

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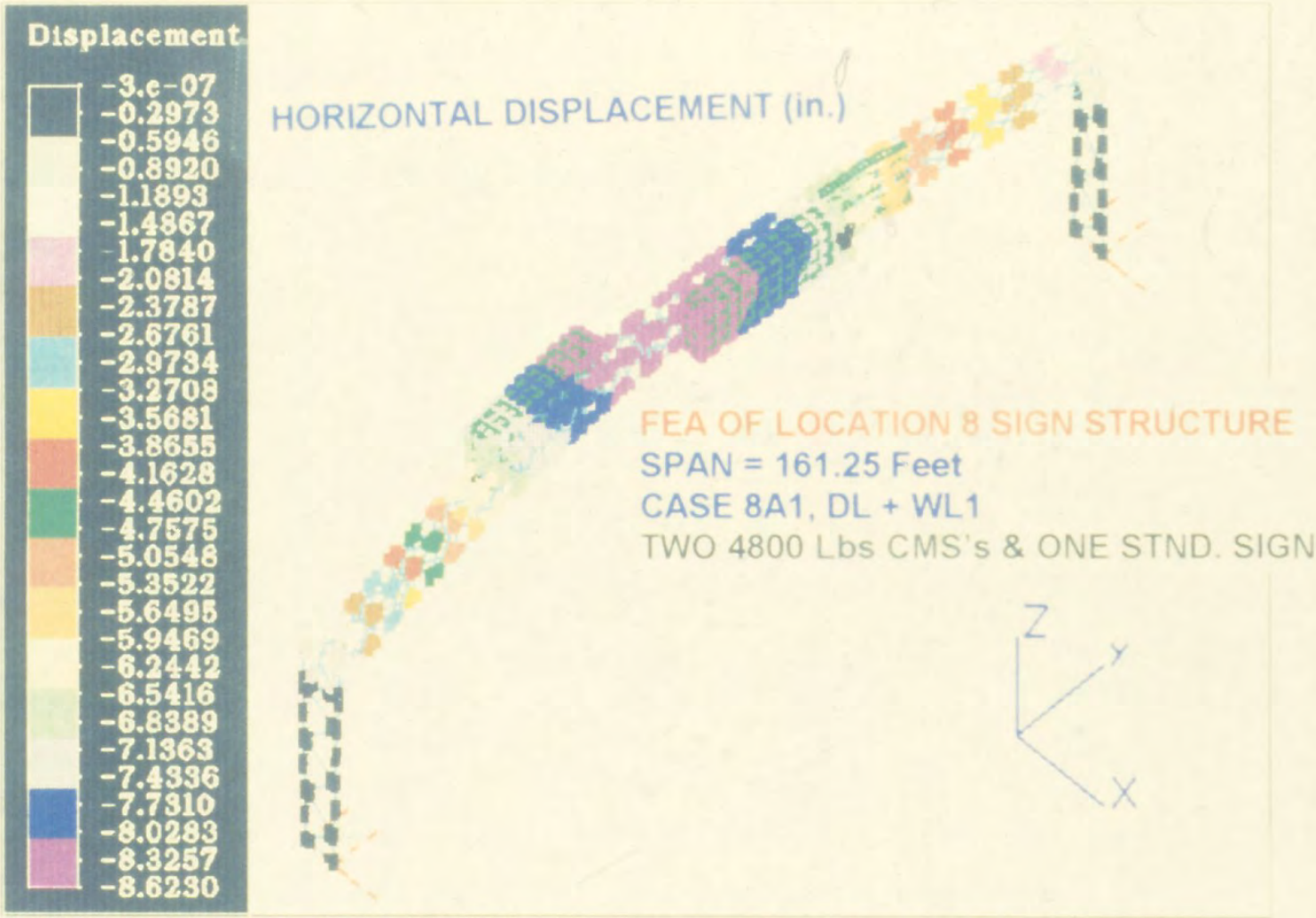
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-3.e-07
-0.2973
-0.5946
-0.8920
-1.1893
-1.4867
-1.7840
-2.0814
-2.3787
-2.6761
-2.9734
-3.2708
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-3.8655
-4.1628
-4.4602
-4.7575
-5.0548
-5.3522
-5.6495
-5.9469
-6.2442
-6.5416
-6.8389
-7.1363
-7.4336
-7.7310
-8.0283
-8.3257
-8.6230
HORIZONTAL DISPLACEMENT (in.)
FEA OF LOCATION 8 SIGN STRUCTURE
SPAN = 161.25 Feet
CASE 8A1, DL + WL1
TWO 4800 Lbs CMS's & ONE STND. SIGN
Z
Y
X
SVIEW 4.12 File:signstr 95/02/21 10:39 LC 1/ 1 Vu= 7 Lo= 45 La= 45 R= 0

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THANK YOU

QUESTIONS?

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