Strengthening of Steel Girder Bridges Using Fiber Reinforced Polymer (FRP)

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Background

- Need some level of strengthening due to
  - Increases in live loads
  - Loss of capacity (deterioration)
- Bridges not critical enough to warrant replacement
- Need to employ structurally efficient but cost-effective means of strengthening

Primary Objectives

- Investigate the effectiveness of FRP composite materials in strengthening of deteriorated steel girder bridges
- Identify changes in structural behavior due to addition of strengthening system

Two Strengthening Schemes

- Strengthening with Carbon Fiber Reinforced Polymer (CFRP) Post-Tensioning Rods
- Strengthening with CFRP Plates

Advantages

- Corrosion resistance
- Very light (one tenth of steel)
- Can be installed with minimal crews and scaffoldings
- Load capacity may be fully restored without exceeding original weight

Strengthening with CFRP Post-Tensioning Rods

Strengthening with CFRP Post-Tensioning (P-T) Rods

- Guthrie County, IA
- Constructed in 1956
- 210 ft x 26 ft Three-span continuous steel girder bridge
- Two 64 ft End spans & 82 ft Center span
- Two WF 30x116 exterior & two WF 33x141 interior I-beams

Strengthening with CFRP Post-Tensioning (P-T) Rods

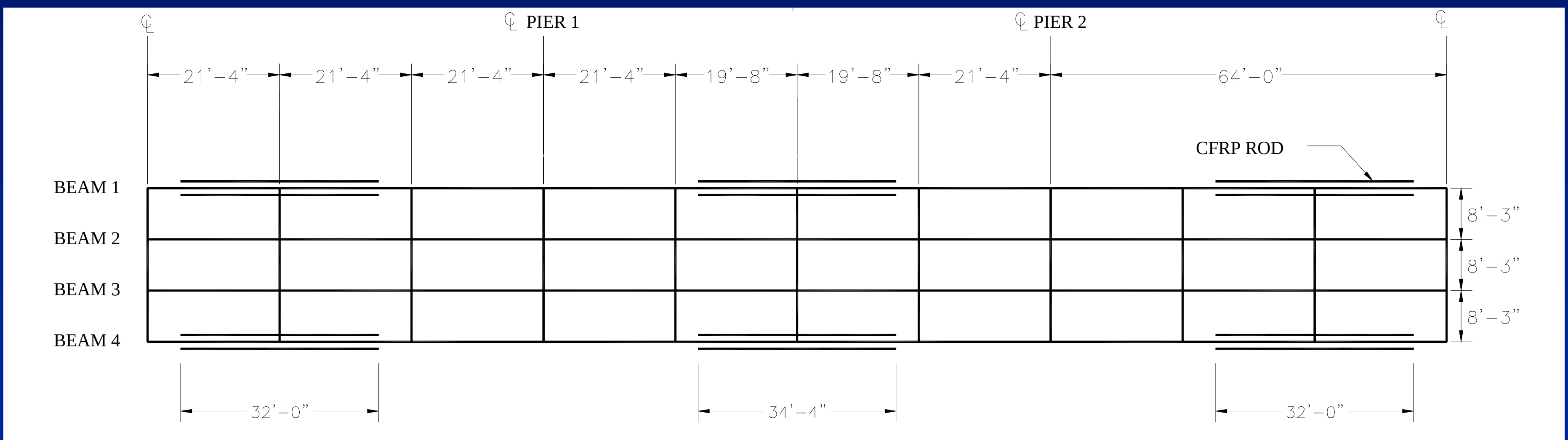
Strengthening with CFRP Post-Tensioning (P-T) Rods

Corroded abutment bearing

Corrosion on steel and spalls on bottom of concrete deck

Strengthening System

- Positive moment region of Exterior girders in all three spans
- Design force of 12 kips per rod, 48 kips per location (4 rods)



Strengthening System

- CFRP rods
  - Outstanding mechanical characteristics and non-corrosive nature
  - 3/8 inch in diameter
  - Fiber Content : 65 % by volume
  - Tensile Strength : 300 ksi
  - Tensile Modulus : 20,000 ksi
- Anchorage assemblies
  - 5 in. x 5 in. x ¾ in. stiffened angles
  - 1 in. couplers
  - Steel tube anchors

Installation Process (anchorage assembly)

Installation Process (Placing CFRP Rod)

Placement of CFRP Rod

Top rod placed

Installation Process (Application of P-T force)

Center Span

End Span

Completed CFRP P-T System

End Span (Exterior)

End Span (Interior)

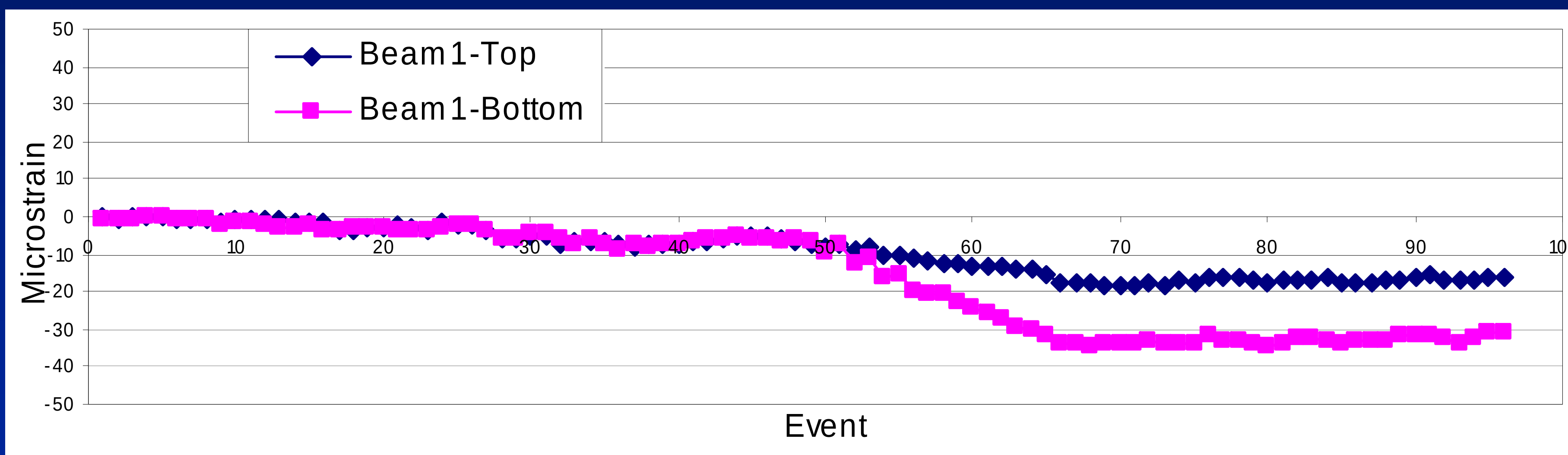
Center Span

Load Testing & Classic Analysis

- To assess changes in performance due to addition of P-T system and time
- Tested before & shortly after installation, and one & two years of service
- Standard 3-axle dump trucks used in Load Testing and HS-20 Truck utilized in Classic Beam Analysis

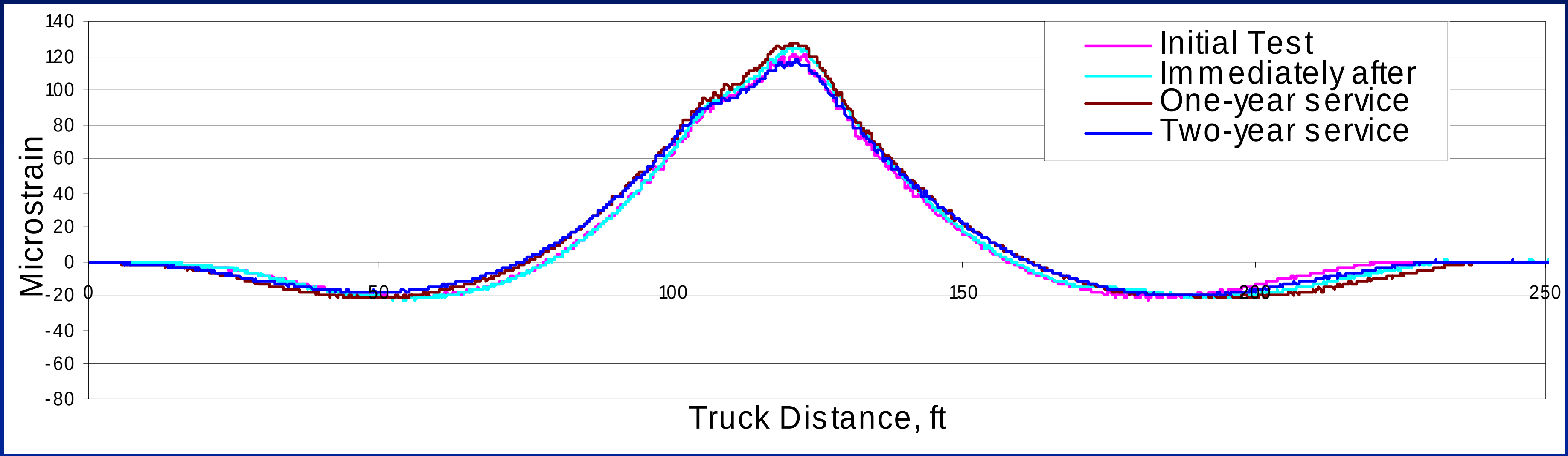
Monitoring (During P-T)

- P-T generates strain opposite in sign to those generated by dead and secondary load



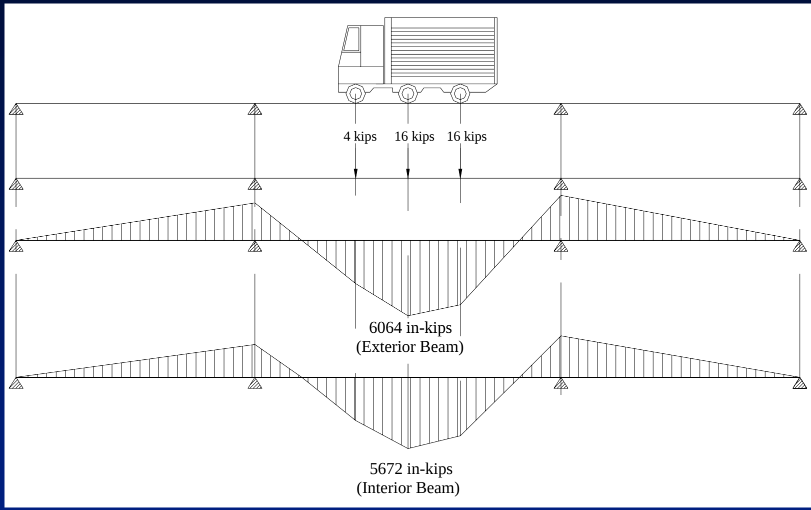
Monitoring (In service over two year period)

- Consistency in strain readings over two year period



Beam Analysis (LL Moment)

Before P-T



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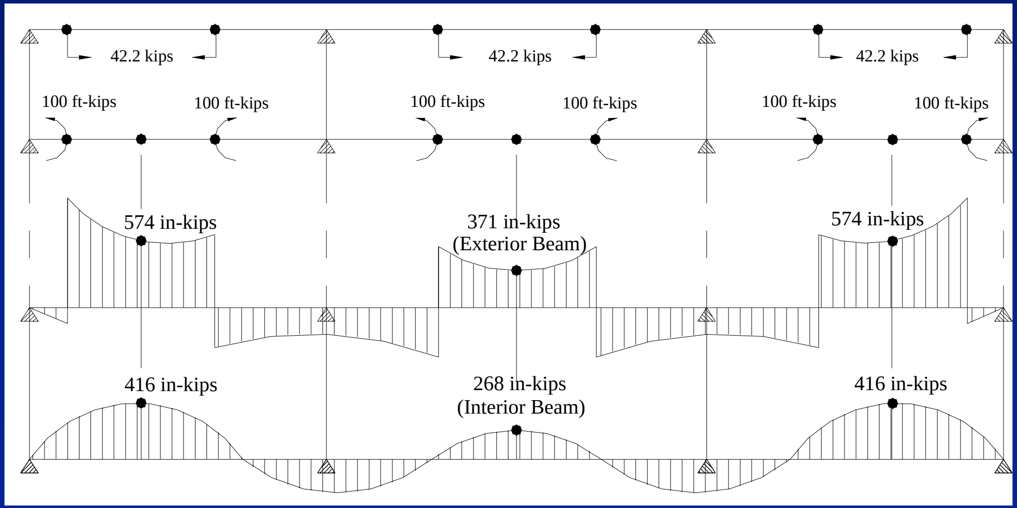
Due to P-T



Beam Analysis (LL Moment)

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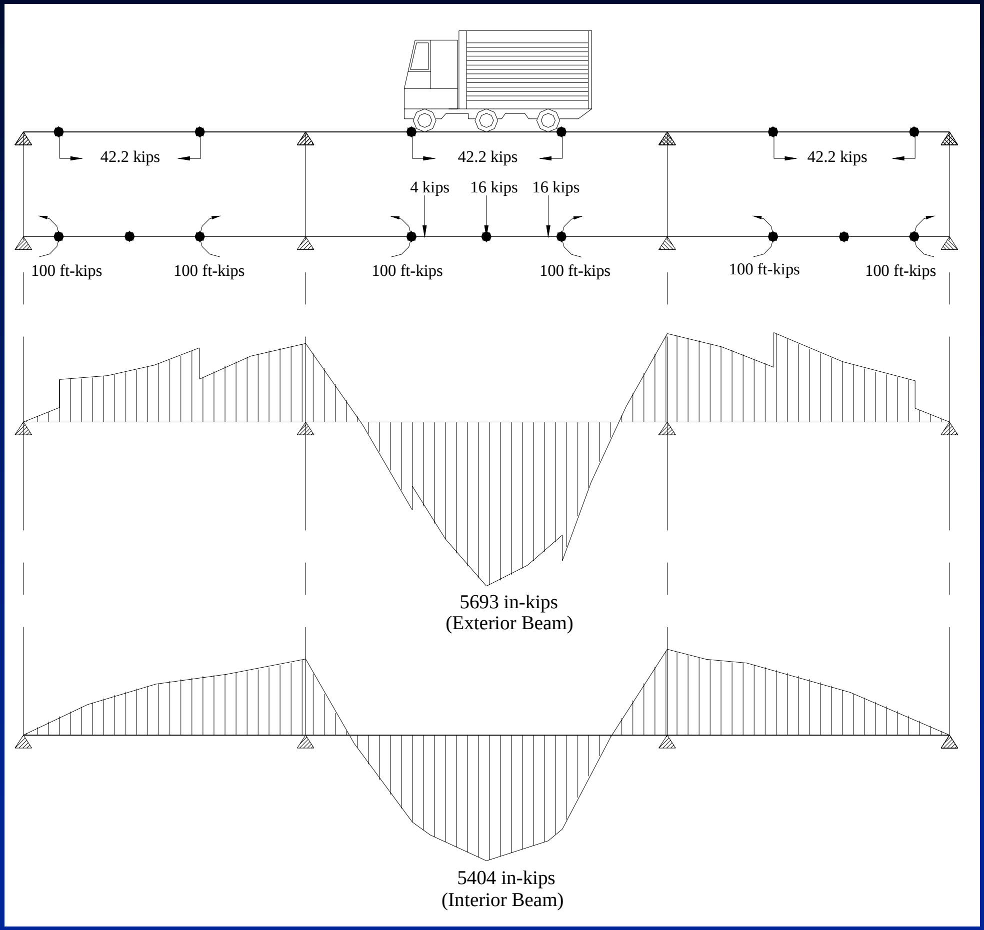
After P-T



Conclusion

- Consistency in strain readings
  - CFRP P-T system had negligible impact on changing stiffness of bridge
- 5 to 10 % of Live load moment carrying capacity enhanced

Acknowledgement

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