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

Corrosion on steel and spalls on bottom of concrete deck

Corroded abutment bearing
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)

End Span

Center Span
Completed CFRP P-T System

End Span (Exterior)

Center Span

End Span (Interior)
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**

- 4 kips
- 16 kips

**Interior Beam**
- 5672 in-kips
- 100 ft-kips

**Exterior Beam**
- 6064 in-kips
- 100 ft-kips

**Due to P-T**

- 42.2 kips
- 100 ft-kips

**Interior Beam**
- 416 in-kips
- 100 ft-kips

**Exterior Beam**
- 574 in-kips
- 100 ft-kips
Beam Analysis (LL Moment)

After P-T

5693 in-kips
(Exterior Beam)

5404 in-kips
(Interior Beam)
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
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