Structural Design, Construction and Evaluation of a Prestressed Concrete Bridge Using UHPC Pi Girders

Buchanan County

Jakway Park Bridge
What is UHPC?

- Compressive strength = 16-30+ ksi.
- Flexural strength = 4-7 ksi.
- Highly ductile with low (zero) permeability.

Ductal®
Project Objectives

- Advance the state-of-the-art in concrete bridge construction technology.
- Develop and build on experience in Iowa in the design and construction of bridges utilizing advanced materials.
- Evaluate the long-term performance of the nation’s first Pi Shape UHPC bridge.
First Generation Pi-Girder

- Developed by MIT/FHWA
- Optimized section for shear and flexural capacity
- Prestressed
- No mild steel reinforcement
- Integral Deck
- Tested by FHWA
Testing Results by FHWA

24 ft. Span; Two mid-deck wheel loads

- Longitudinal flexural and shear capacity OK
- Low transverse flexural capacity in deck
- Low live load distribution between girders
- Low lateral stiffness of webs

70 ft. Span; Two Pi Girders
Revising the Section

- FEM analysis by ISU Bridge Engineering Center and FHWA (complemented Iowa DOT conventional evaluation)
- Analyzed girder unit and complete bridge
- Limit service stress levels below cracking for durability
Second Generation Pi Girder

SECTION A-A

<table>
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<tr>
<th>BOTTOM STRAND DEBONDING</th>
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<tbody>
<tr>
<td>SYMBOL</td>
<td>DEBONDED LENGTH FROM EACH END OF BEAM</td>
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<td>3'-0</td>
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\[ A = 860.8 \text{ in}^2 \]
\[ y_b = 22.5 \text{ in} \]
\[ I = 105,730 \text{ in}^4 \]
\[ w_t/ft = 0.932 \text{ k/ft} \]
First vs. Second Generation Pi Girder

Prototype Pi-Girder

2nd Generation Pi-Girder

2540 mm (100 inch)

2426 mm (95.5 inch)

838 mm (33 inch)
Cross-Section View of Pi Girders
Bridge Description

- **24’-6” wide x 112’-4” long**
- 3 simple spans (32’-2”, 52’-0”, 30’-2”)
  - End spans: 18 in, CIP concrete slab
  - Center span: 3 PI girders
Girder Casting

- Cast by Lafarge, Winnipeg, Manitoba, Canada
- 11.3 cu. yd. per beam
- Premixed bags of Ductal mixed in two ready-mix trucks
- Water added as ice cubes
- Total mixing time ~ 6-7 hours

25 ft lab specimen
Girder Connection Detail

Plan View Showing Dowel Pockets

Typical Longitudinal Section Thru Joint Detail at Pocket Locations
Field Evaluation

- 1st live load test performed immediately after construction
- 61,000 lb. truck, 28 passes over bridge
- 32 strain transducers monitoring
  - Longitudinal bulb strains
  - Transverse and longitudinal deck strains
  - Bending strains in webs
- 6 deflection gages at mid-span
Results of First Load Test

- Much improved Live Load Distribution compared to First Generation Pi Girder
- Measured strains matched FEM predictions closely
- All measured strain levels below cracking strain
- Highest tensile strains measured in webs
- Design was conservative, bridge performing well
Field Evaluation

- 2nd live load test performed approx. 1 yr. later
- 61,000 lb. truck, repeated passes from 1st test
- Also performed higher speed passes (~20-25 mph)
- 32 strain transducers with similar layout as 1st test
  - Additional web strain measurements made
- Performed crack survey of underside of girders
Results of Second Load Test

- Strains generally 10-15% higher than in first test
- All measured strain levels still below cracking strain
- Highest tensile strains measured in webs
- Minimal cracking observed
- Bridge performing well
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Elevation View