The Longest Integral Abutment Bridge (IAB) in Illinois

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Overview

- Design criteria for I-90 over Kishwaukee
- Integral Abutment Bridges (IAB) Design Criteria
- Design analysis, details and construction
- Lessons Learned during construction
- Instrumentation by Illinois Center for Transportation (ICT - Tollway)
Rebuilding and widening the 54-year-old Jane Addams Memorial Tollway into a state-of-the-art corridor linking Rockford to Elgin (three lanes) and Elgin to O’Hare (four lanes) plus a transit lane. Total cost $2.2 Billion.
Project Location
Existing Bridges

- Constructed in 1964
- Two-lane seven-span 48” PPC I-Beam bridges, six open joints
- 35 degree skew
Existing Bridges
Project Goals

- Improve capacity and accommodate for a bus dedicated lane
- Accommodate heavy truck traffic (120 Kips)
- Reduce long-term maintenance cost
- Reduce number of expansion joints and bearings
- Introduce innovative solutions
- Standardize design procedures and details to increase design efficiency
Project Constraints

• Environmental
  – No direct stormwater discharge
  – Endangered species
  – No work in the River from April 1\textsuperscript{st} to June 30\textsuperscript{th}
• Minimize loss of toll revenues
• Safety of MOT
## Bridge Type Study

<table>
<thead>
<tr>
<th>Option</th>
<th>MOT</th>
<th>Bridge Type</th>
<th>Total Length</th>
<th>No. of Spans</th>
<th>No of Pier (River)</th>
<th>No. of Exp Joints</th>
<th>Skew</th>
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<tbody>
<tr>
<td>0</td>
<td>Base Case Concrete, staging</td>
<td><strong>Staging</strong> Alternate 1</td>
<td>48” PPC I-Beam Stub Abutments</td>
<td>517’-6” 70'-0”</td>
<td>7</td>
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<tr>
<td>1</td>
<td>Option 1A Concrete</td>
<td><strong>EB Closed</strong> Alternate 2</td>
<td>72” PPC Bulb Tee Integral Abutments</td>
<td>545’-2” 110'-0”</td>
<td>5</td>
<td>4(3)</td>
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<tr>
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<td>Option 1A Concrete, staging</td>
<td><strong>Staging</strong> Alternate 1</td>
<td>72” PPC Bulb Tee Integral Abutments</td>
<td>545’-2” 110'-0”</td>
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<td>4(3)</td>
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<td><strong>Staging</strong> Alternate 3</td>
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<td>Option 1A Weathering Steel</td>
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<td>50” Plate Girder Integral Abutments</td>
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<td>Option 1B Concrete</td>
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<td>72” PPC Bulb Tee Integral Abutments</td>
<td>529’-6” 106'-0”</td>
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<td>50” Plate Girder Integral Abutments</td>
<td>529’-6” 106'-0”</td>
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<td>4(3)</td>
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<td>Option 2A Weathering Steel</td>
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<td>60” Plate Girder Integral Abutments</td>
<td>545’-0” 120'-0”</td>
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<td>60” Plate Girder Integral Abutments</td>
<td>529’-6” 115'-0”</td>
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<td>529’-6” 264'-9”</td>
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</table>
### Proposed IAB Layout

<table>
<thead>
<tr>
<th>Total Length</th>
<th>Span 1</th>
<th>Span 2</th>
<th>Span 3</th>
<th>Span 4</th>
<th>Width</th>
<th>Skew</th>
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<tr>
<td>545’-0”</td>
<td>125’-0”</td>
<td>152’-0”</td>
<td>152’-0”</td>
<td>116’-0”</td>
<td>69’-0”</td>
<td>30°</td>
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</table>

**ELEVATION**

**PIER SKETCH**

**CIORBA GROUP | Consulting Engineers**
Proposed IAB Layout
## Length and Skew Limits for IABs

<table>
<thead>
<tr>
<th>State</th>
<th>Length limit - no skew (ft)</th>
<th>Skew Limit (°)</th>
<th>Comments</th>
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<tbody>
<tr>
<td></td>
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<tr>
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<td>45</td>
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<tr>
<td>IN</td>
<td>500</td>
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<td>TN</td>
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<td>400</td>
<td>No Limit</td>
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<td>590</td>
<td>330</td>
<td>20</td>
</tr>
<tr>
<td>WI</td>
<td>300</td>
<td>150</td>
<td>15</td>
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</table>
Design Issues with IAB

- Limitation of total length and skew
- Different criteria for steel and concrete
- Use of symmetric longitudinal schemes
- Pile orientation
- Use of active or passive pressure at the abutments
- Compacting of backfill
- Orientation of wingwalls
Design Issues with IAB

- Soil properties and limitations with stiff soils
  - Prebored holes for piles, decrease stress in piles and downdrag
  - Pile confinement
- Pile cap to diaphragm connection
  - Cap width / Geometry
  - Beam connections
  - Approach slab connection
Design Issues with IAB

- Loss of uncompacted backfill
  - Settlement of approach slabs
- Double curvature of piles
- Increased loads in the acute corner piles for bridges on a skew
- “Ratcheting” of shrinkage contraction displacements
- Abutment-pile connection deterioration
Pre 2012 IDOT Practice

- Typical Abutment Detail
Integral Abutment Pile Selection Chart

Effective Expansion Length (ft.)

Bridge Skew (Degrees)

- HP 14x102, HP 14x117
- HP 12x84, HP 14x80
- HP 12x74, HP 14x73
- HP 10x57, HP 12x63
- HP 12x53
- HP 10x42
- MS 14
- HP 8x36
- MS 12
INDOT Integral Abutment Guidelines

- **HP Piles Only**
  - Elastic Dynamic Analysis required for structures of length over 500 ft located in Seismic Design Category B.

- **HP or Shells**
Preliminary Analysis

- IDOT’s draft integral abutment guidelines
  - The I-90 bridge was off the charts due to the length combined with the skew and the stiff soils
  - The thermal movement based on expansion length and the temperature range of +/-80° is 1.73” for the west and 1.67” for the east abutment
Bridge Modeling

Zoom 7.314X
Deformed Model - Temperature
Scale Factor: 64.

Fig. 6. Prebored hole concept
Additional Analysis

- We ran an L-Pile model for these displacements with a fixed top and the soil lateral resistance.
- The same approach with piles isolated from the soil and installed in a pre-drilled shaft with different lengths.
Pile Design for Strength

• The maximum moment was determined and input into the column interaction equation to verify the pile

• For $Pu/Pr \geq 0.2$:

$$\frac{Pu}{Pr} + \frac{8.0}{9.0} \left( \frac{M_{ux}}{M_{rx}} + \frac{M_{uy}}{M_{ry}} \right) \leq 1.0 \quad (6.9.2.2-2)$$

• Calculations showed the need for a 10’ pre-bore hole
Detail at Integral Abutment
Additional Design Checks

- Aggregate slope wall vs. concrete
- Additional axial stresses in girders
- Evaluate approach slab standards and pouring sequence
- Verify abutment diaphragm design
Weathering Steel Detailing

- Drip plates at piers and abutments
- Polyethylene sheeting over piers prior to erection of girders
Construction - Work in the River
Construction – Work in the River
Construction - Work in the River
Construction - Work in the River
Construction - Work in the River
Construction - Work in the River
Construction - Foundations
Construction - Foundations
Construction - Substructure
Construction - Steel Erection
Construction – Steel Erection
Lessons Learned - Utilities
Lessons Learned - Utilities
Lessons Learned - Utilities
Lessons Learned - Piles
Bridge Instrumentation

- Illinois Center for Transportation and Illinois Tollway joint research project
- Validation of new IDOT and Tollway standards and details
- Compare actual behavior with analysis results

ILLINOIS CENTER FOR TRANSPORTATION

Illinois Tollway
Instrumentation Goals

- Monitor movements at abutments and at girder-abutment interface
- Determine temperature related strain distribution in composite deck-girder cross-sections
- Monitor pile behavior and effects of skew
Instrumentation Plan

- Embedded girder-checking level of fixity via tiltmeters
- Monitoring bridge movement by measuring at various joints
- Monitoring behavior of approach slab and effects on the rest of the bridge
- Measuring strain in the deck and girders
- Checking for differential tilt at joint
- Measuring strain at pile-abutment interface
Approach Slab Strains Changes with Temperature

Temperature

\[\text{App8-2 Embedded Strain Gage}\]

\[\varepsilon \text{ (microstrain)}\]
Abutment Displacements

North

South

Change in Average Superstructure Temperature (°F)

Change in Length (in.)

Pier-Girder
Abutment-Approach
Approach-Transition
Theoretical Free Expansion (Girder)
Top Survey Point
Bottom Survey Point
Model Displacements vs. Field Data

North Displacement (Pure Thermal)

North AppTrans + AbutApp - AppFromFieldStrain
Model Displacements vs. Field Data

South Displacement (Pure Thermal)

South AppTrans + AbutApp - AppFromFieldStrain
Pile 2 Strain Gages Schematic
Pile Strain Changes with Temperature

![Graph showing pile strain changes with temperature](image)
Piles: Comparison with FEM Model

Pile 2 Strain (Model)
(Pure Thermal)

Pile 2 Strain (Field)
(Initialized from first collected data point)
Field Pile Strains

Pile 5 Strains (Top)

Pile 5 Strains (Bottom)

Bridge

$\Delta l$ (in/ft)

$\Delta T$ (°F)

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Gage Locations - Superstructure
Girder Stresses

8-5B (Model – Pure Thermal)

Girder 8-5B Stresses (September to December)
Summary of Current Findings

• Girder – abutment connection performed well
• Soil behavior including pile encasement detail close to FEM prediction
• North and south abutments show similar displacements
Summary of Current Findings (cont.)

- Pure weak axis bending at top of piles, strong axis bending lower in the piles.
- Good correlation between FEM and measurements for stress distribution in deck and girders.
- Data collection continues, final ICT Report in May 2016.
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  – Greg Stukel, PE
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  – Larry Fahnstock, PhD, PE, Associate Professor

• Illinois Department of Transportation
  – Mark Shaffer, PE, SE

• Lorig and William Charles Construction
Questions?

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