I-70 over SR 121
Accelerated Bridge Construction – Design Challenges

Tyler S. Wolf, P.E.

Project Overview

- Located east of Richmond, IN
- Replace Existing Deteriorated Structure
I-70 over SR 121

Project Overview

- At a Project Scoping Meeting – Items Noted
  - IHCP will only Allow Nightly Lane Closures
  - Two Additional Bridges within I-70 MOT Footprint

A TRADITION OF EXCELLENCE SINCE 1945

I-70 over SR 121

Project Overview

- At a Project Scoping Meeting – Items Noted
  - Landfill and Quarry East of Bridge
  - Open Field Immediately East of Bridge

A TRADITION OF EXCELLENCE SINCE 1945
Engineering Assessment

- Looked at Five Options
- Construction Cost
- Maintenance of Traffic
- Construction Timeframe
- Traffic Impacts
- Engineering Cost

Do Nothing – $0.00
Conventional – $7,723,000
SPMT – $8,061,000
Slide-In – $7,636,000
Hybrid Slide-In – $8,448,000
Moved Ahead with a Dual Design - SPMT Option and Slide Option
I-70 over SR 121 ABC Bridge Slide

Engineering Assessment

- Self Propelled Modular Transporters (SPMT)

UDOT 4500 South over I-215

Total Estimated Cost = $8,061,000

Less than One Construction Season

Two – Two week Single Lane Closures
Engineering Assessment

- Slide-In Superstructure Installation

**Total Estimated Cost** = $7,636,000

**One Construction Season**

**Two – Two week Single Lane Closures**
Final Design - Challenges

- “Design-Build”
- Foundation
- Substructure
- Superstructure
- Interstate Lane Closure Policy
- Expedited Construction
- Provisions
I-70 over SR 121

Foundation – Spread Footing

- Rock Fairly Shallow at Project Site
- Existing Bridge Piers on Spread Footings
- Low Quality Rock
- Limited Space
I-70 over SR 121

Foundation – Micropiles

- Good Fit for Site
- Able to work in Low Head Room
- But…..

Buy America Requirement – 106.01(c)

Geo-strata Magazine Article “Buy America’ Act Threatens U.S. Micropile Business” (September/October 2012)

Back to the Drawing Board – Drilled Shafts
I-70 over SR 121

Foundation – Drilled Shafts

Substructure - Design

- Full Face Abutment or Conventional Bent
Substructure - Design

- **Full Face Abutment**
  - **Advantages:**
    - Deeper Section
    - More Working Room
    - Shorter Span
  - **Disadvantages:**
    - More Overturning Forces
    - More Excavation under End Span
    - Soil Mitigation for Backfill

- **Conventional Bent**
  - **Advantages:**
    - Less Excavation
    - Less Overturning Forces
    - Less Soil Mitigation
  - **Disadvantages:**
    - Tighter Construction Area
    - Longer Span
    - Less Structural Depth
I-70 over SR 121

Substructure - Geometry

- Full Faced Abutment

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Substructure - Geometry

- Needed to Accommodate Individual Bridge Installation Systems
  - Slide System – Needs to be Continuous from Coping to Coping plus Outside
  - Due to Drilled Shaft Locations and Construction Speed, extending Outside Coping warranted for SPMT
Substructure - Design

- Full Face Abutment – Use MSE Fill Behind
I-70 over SR 121 ABC Bridge Slide

Substructure - Design

- Used Cellular Concrete in lower portion of MSE section
  - Lightweight
    - Concerns with Stability of Soil
  - Stable – Will not induce Horizontal Loading on Abutment

Substructure – Strut and Tie

- Strut and Tie Analysis
- Based on AASHTO LRFD 5.6.3 says SHOULD use Strut and Tie
- Based on AASHTO LRFD 5.8.1.1 & 5.8.1.2 says SHALL use Strut and Tie in Deep Beams
I-70 over SR 121

Substructure – Strut and Tie

- FHWA/TX-12/5-5253-01-1 – Very Good Example

- Separate B & D Regions
  - [AASHTO 5.5.1.2] - 1d from Load Application
  - [AASHTO C.5.6.3.2] – Discusses 2d to 2.5d
  - Designed Abutment both as B and D Region
I-70 over SR 121 ABC Bridge Slide

Substructure – Strut and Tie

- Define Load Case
  - Dead Loads from Beam Design
  - Live Load – Taking into account the Construction in the Median, Proposed Condition and Future Condition
- Three Live Loading Conditions – Ten Load Combinations (Min and Max LF)

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Substructure – Strut and Tie

- Loading Condition 1 - Proposed
I-70 over SR 121

Substructure – Strut and Tie

- Loading Condition 2 – During Construction/Future MOT

Substructure – Strut and Tie

- Loading Condition 3 – Three Lane Section
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Substructure – Strut and Tie

- Analyze Structural Component
  - Perform Conventional Analysis to determine Reactions from Drilled Shafts

- Size Structural Component
  - Not required by AASHTO, but a quick and easy check

\[ V_r = \left[ a \cdot f_c \right] \sqrt{A_e} \]  \hspace{1cm} (2.1)

where:
- \( a \) = shear span (in.)
- \( d \) = effective depth of the member (in.)
- \( f_c \) = specified compressive strength of concrete (psi)
- \( A_e \) = width of member’s web (in.)

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Substructure – Strut and Tie

- Develop Strut and Tie – [AASHTO 5.6.3.2]
  - Struts should be oriented in Compressive Direction – 25 Deg. Max Angle
  - Top Strut and Bottom Tie Defined by Reinforcement – this became iterative.
  - Dead Load of Abutment applied at Discrete Nodes
Substructure – Strut and Tie

- Proportion Tension Ties – [AASHTO 5.6.3.4]
  - Top and Bottom Chords

Proportion Tension Ties – [AASHTO 5.6.3.4]
- Top and Bottom Chords
## Check Drilled Shaft Bearing – [AASHTO 5.6.3.5.3]

### Substructure – Strut and Tie

*Check Drilled Shaft Bearing – [AASHTO 5.6.3.5.3]*

### Analysis

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## Check Beam Bearings – [AASHTO 5.6.3.5.3]

### Substructure – Strut and Tie

*Check Beam Bearings – [AASHTO 5.6.3.5.3]*

### Analysis

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<tr>
<th>Load Combinations</th>
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*Completed by: [Staff Name]*

*A Tradition of Excellence Since 1945*
Substructure – Strut and Tie

- Perform Nodal Strength Checks – [AASHTO 5.6.3.5.3]
  - Most Complicated and Time Consuming Portion of Design
  - Vector Elements
  - Partition Nodes

Substructure – Strut and Tie

- Perform Nodal Strength Checks – [AASHTO 5.6.3.5.3]
  - Recalculate Node Geometry

Geometry of Node Partitions:
- Propagation and yield by vertical force from left strut and right strut
  - Left: 33.73 in
  - Right: 14.32 in

- Place nodes 2AA and 2AB at new locations in center of left and right partition
  - Offset left: 18.75 in
  - Offset right: 55.89 in

- Determine new angles based on relocalized loads and offsets above

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<tr>
<th>Strut</th>
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*“t” is compression*
I-70 over SR 121

Substructure – Strut and Tie

- Perform Nodal Strength Checks – [AASHTO 5.6.3.5.3]
  - Check Back Face – [AASHTO 5.6.3.5.3a]

Substructure – Strut and Tie

- Perform Nodal Strength Checks – [AASHTO 5.6.3.5.3]
  - Check Node Face – [AASHTO 5.6.3.5.3a]
Substructure – Strut and Tie

- Perform Nodal Strength Checks – [AASHTO 5.6.3.5.3]
  - Check Anchorage – [AASHTO 5.6.3.4.2]
  - Each Check Varies Depending on Node Type – CCC, CCT, CTT

Proportion Crack Control Reinforcement – [AASHTO 5.6.3.6]
I-70 over SR 121 ABC Bridge Slide

Substructure – Strut and Tie

- Proportion Stirrups in High Shear Regions –
  [AASHTO 5.6.3.4.1]

<table>
<thead>
<tr>
<th>Member</th>
<th>Str 1 Width</th>
<th>Str 2 Width</th>
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<tr>
<td>5</td>
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</tr>
</tbody>
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Superstructure

- Mostly followed Typical Design
- End Diaphragms Unique
  - Slide Diaphragm – Accommodate Jacking Ports
Superstructure

- End Diaphragms Unique
  - Slide Diaphragm – Accommodate Jacking Ports

- SPMT – Not Enough Room to cast up to Bridge Seats
- Used Precast Bridge Seat Cap
Superstructure

- End Diaphragms Unique
  - SPMT – Not Enough Room to cast up to Bridge Seats
  - Used Precast Bridge Seat Cap

Superstructure

- End Diaphragms Unique
  - SPMT – End Diaphragm needed to Eliminate Joint but Minimize Dead Load
I-70 over SR 121

Superstructure

- SPMT – Needed to perform 3D Finite Element of Transportation

Speed of Construction

- Tried to incorporate Precast wherever possible
- Precast Sleeper Slab w/ Precompressed Foam Joint instead of Terminal Joint
- MSE Wall Wings
- Allowed to Open with Concrete Strength = 500 psi
A+B Contract Provisions

- As Part of the Bid, Contractor to bid Number of Hours of I-70 Lane Closure and Days of SR 121 Road Closure
- I-70: Bid, Incentive and Disincentive = $2,500/hour on Fridays and $2,000/Hour on other Days
- SR 121: Bid, Incentive and Disincentive = $4,000/day


- Requirements of Revisions to Contract Plans, Working Drawings, Contingency Plans, Installation Plans, Tolerances
- Installation Bid at $160,000 and Engineering Bid at $95,000
Contract Award

- Walsh was the Successful Bidder – Slide Option
- Construction Cost $5,630,000 (Original Estimate $6,921,000)
- B Component = $855,000
- 24 Days of I-70 Lane Closure
- 30 Days of SR 121 Full Closure

Actual Construction

- Two Eight Day Lane Closures
- Two Three SR 121 Road Closure Days for Bridge Demolition
- 14 Days of SR 121 Closure for Road Work on SR 121
- [https://www.youtube.com/watch?v=N4FrVGW0Upg&feature=youtu.be](https://www.youtube.com/watch?v=N4FrVGW0Upg&feature=youtu.be)
- [https://www.youtube.com/watch?v=6SBjNkCRmUg&feature=youtu.be](https://www.youtube.com/watch?v=6SBjNkCRmUg&feature=youtu.be)
THANK YOU