US 34 Over the Missouri River
Dusten Olds, PE - HDR
Project Information
Project Information

Project Information
Project Information
Bridge Information

Bridge Information – Unit 1
Bridge Information – Unit 2

Bridge Information – Units 3 & 4
Bridge Information – Unit 2

- 391'5" - 515' - 391' = 1297'
- 89'5" deck width
- 20'6" girder spacing
- 10" two course deck

Project Site Characteristics
Staging

Barge Work
Steel Storage

Steel Storage

Haunched Pier Section Storage
Temporary Supports

Preliminary Type Study
Options Investigated (July 2008)
1. Haunched Plate Girder
2. Haunched Plate Girder w/Substringers
3. Truss
4. Steel Box
5. Concrete Segmental
Preliminary Type Study

Steel Plate Girder Options

- Multi-girder vs. Substringer
- Weights based on prelim design and experience
- Fabricator discussions
- Review of existing structures

ADVANTAGE:

Substringer System

Preliminary Type Study

Truss Option

- Constant depth Warren Truss
- Weights based on prelim design and experience
- Fabricator discussions
- Review of existing structures
Preliminary Type Study

Steel Girder vs. Truss Comparison

Quantities (prelim member sizing)
+ Unit prices (fabricator & contractor input)
+ Life cycle costs

Prelim cost for comparison

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Preliminary Type Study

- Life Cycle Costs
  - Painting
    - Truss
    - Plate girder – fascia girder only
  - Similar Costs
    - Annual maintenance
    - Inspection
    - Overlay
    - Deck replacement
## Preliminary Type Study

### Life Cycle Costs

<table>
<thead>
<tr>
<th></th>
<th>Unit Rate for Structural Steel - Erected</th>
<th>Structural Steel - Erected Cost</th>
<th>Relative Grade Reduction Cost</th>
<th>Future Painting Cost</th>
<th>Comparative Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Plate Girder</td>
<td>$2.35 / Lb.</td>
<td>$26.1 MIL</td>
<td>$0</td>
<td>$0.56 MIL</td>
<td>$26.66 MIL</td>
</tr>
<tr>
<td>Steel Truss</td>
<td>$2.47 / Lb.</td>
<td>$25.9 MIL</td>
<td>-$0.5 MIL</td>
<td>$1.45 MIL</td>
<td>$26.85 MIL</td>
</tr>
</tbody>
</table>

### SLIGHT ADVANTAGE: Girder System

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## Preliminary Type Study

### Other Considerations

<table>
<thead>
<tr>
<th>Advantages</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Plate Girder</td>
<td>Truss</td>
</tr>
<tr>
<td>• Steel below deck</td>
<td>• Cantilever construction</td>
</tr>
<tr>
<td>• Fewer erection pieces</td>
<td>• Lighter pieces</td>
</tr>
<tr>
<td>• No fracture critical</td>
<td>• Shipping (no barges)</td>
</tr>
</tbody>
</table>

Preferred Alternative: **Substringer System**
Design Considerations
What is of interest to design engineers?
- Appropriate level of analysis?
- Reliable/accurate design forces
- Preliminary design vs. final design

Design Considerations
AASHTO LRFD Criteria
- Live load distribution – approximate equations

<table>
<thead>
<tr>
<th>AASHTO LRFD Approximate Equation Range of Applicability</th>
<th>Criteria Satisfied?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Girder Spacing, S ≤ 16.0ft</td>
<td>NO</td>
</tr>
<tr>
<td>2. Depth of Slab, t ≤ 12.0in</td>
<td>YES</td>
</tr>
<tr>
<td>3. Span of beam, L ≤ 240ft</td>
<td>NO</td>
</tr>
<tr>
<td>4. Number of beams, N ≥ 4</td>
<td>YES</td>
</tr>
<tr>
<td>5. Longitudinal Stiffness Parameter, K ≤ 7,000,000</td>
<td>NO</td>
</tr>
<tr>
<td>6. Horizontal distance from exterior beam to gutterline, d ≤ 5.5ft</td>
<td>YES</td>
</tr>
</tbody>
</table>
Design Considerations

- $d_e < 5.5\text{ft} \ (\text{OK})$
- $N_h \geq 4 \ (\text{OK})$
- $t_s < 12\text{in} \ (\text{OK})$
- $S \geq 16\text{ft} \ (\text{NG})$
- $K_e \geq 7,000,000 \ (\text{NG})$

Design Considerations

- $L \geq 240\text{ft} \ (\text{NG})$
Design Considerations
Final Design – Idealized 3D FE Model

- Plate Element (Deck)
- Plate Element (Web)
- Beam Element (Flange)
- Beam Element (Crossframe)
- Joint
- Beam Element (Rigid Link)

Design Considerations
Final Design – 3D FE Model

- Software
  - Analysis – LARSA 4D
  - Design - STLBRIDGE
Design Considerations

Is line girder accurate enough for prelim design?
  • Evaluate accuracy of AASHTO equations
  • Compare 3D FEM results to line girder
  • Investigated similar project

Results?
  • Line girder results were conservative
  • Exterior girder compared favorably

### Moment Comparison

<table>
<thead>
<tr>
<th>Girder</th>
<th>Analysis Type</th>
<th>Max Positive Moment End Span</th>
<th>Max Negative Moment Interior Pier</th>
<th>Max Positive Moment Middle Span</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (Exterior)</td>
<td>3D FEM (3D)</td>
<td>18397</td>
<td>-26608</td>
<td>19287</td>
</tr>
<tr>
<td></td>
<td>Line Girder (LG)</td>
<td>19741</td>
<td>-28665</td>
<td>20053</td>
</tr>
<tr>
<td></td>
<td>Delta (LG/3D)</td>
<td>+7.3%</td>
<td>+11.5%</td>
<td>+4.0%</td>
</tr>
</tbody>
</table>

### Shear Comparison

<table>
<thead>
<tr>
<th>Girder</th>
<th>Analysis Type</th>
<th>Max Shear End Support</th>
<th>Max Shear Interior Support End Span Side</th>
<th>Max Shear Interior Support Middle Span Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (Exterior)</td>
<td>3D FEM (3D)</td>
<td>207</td>
<td>297</td>
<td>297</td>
</tr>
<tr>
<td></td>
<td>Line Girder (LG)</td>
<td>210</td>
<td>297</td>
<td>299</td>
</tr>
<tr>
<td></td>
<td>Delta (LG/3D)</td>
<td>+6.3%</td>
<td>+11.5%</td>
<td>+4.0%</td>
</tr>
</tbody>
</table>
**Design Considerations**

Practical take away:

Approximate LRFD live load distribution equations can be reliably used for preliminary sizing of plates for a girder with substringer bridge.

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**Levee Implications**

[Map and Diagram of Levees]
Fabrication

- Veritas Steel
  - Palatka, FL
- Barge shipment
- Field Sections
  - 135' long
  - 24' deep
  - 150 Ton pieces

Fabrication

- Laser scanning (similar to LiDAR)
- CNC equipment
  - Field splices
  - Crossframe connections
Fabrication

- Scan of Girders

Fabrication

- Lay down of girders for field splice scan
Shipping
Challenges

- 24’ deep girders
- Height restrictions
- Deck v. hopper barges

Shipping Route

Routed Through
- Intracoastal Waterway
- Gulf of Mexico
- Mississippi/Missouri Rivers

Fabrication Shop

Project Location
**Shipping**

Additional Challenges
- 2012 drought v. 2011 floods
- Stranded barges?
- Maritime Law => Arrested Girders

**Construction/Erection Restrictions**

**Pallid Sturgeon**
- No Pile Driving
- No Cofferdam Installation
- Feb 1 – June 30

**Bald Eagles**
- No Clearing and Grubbing
- December 15 – February 20

**Spill Protection**
- Trained Personnel Onsite
Construction/Erection

Erection picks
- Office scale mode
Laser Scanning
- Field confirmation

Construction/Erection

Wing Struts
Falsework Towers
Construction/Erection

48” φ Pipe Piles

Pipe Pile Construction

Problem:
- Insufficient steel shell full penetration welds

Solution:
- Extend rebar cage below lower splice
- Extend concrete core 26’ below lower splice
- Load shedding from concrete core to steel shell
- Limit settlement in confined gravel core
Construction/Erection

Acknowledgements

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Iowa Dept. of Transportation
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Contractor
Jensen Construction Co.

Fabricator
Veritas Steel