Bridge Economy & Life Cycle Costs of Steel & Concrete Bridges

Missouri TEAM
March 14, 2019

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University of Wyoming & SSSBA Bridge Technology Center
Today’s Presentation

Initial Cost Case Studies & Life Cycle Cost Study of Typical Steel and Concrete Bridges
Problem Statement – Why This Presentation?

Preconception that Concrete is Less Expensive than Steel for Typical Bridges

Many Times Steel is Not Even Considered

Owners Paying More Than They Could for Bridges

Unwarranted Lack of Competition Not Good
Problem Statement – Why This Presentation?

Preconception that Concrete is Less Expensive than Steel for Typical Bridges

Today’s Presentation
Initial Costs – A Summary of Case Studies
Life Cycle Costs – A Look at Capital Costs

To Break That Preconception
First Costs: Steel & Concrete Bridges

Case Studies
Missouri County Bridges – Where the SSSBA Began

Steel

Audrain County, MO Bridge 411
Built 2012
Steel 4 Girders
47.5 ft. Span
24 ft. Roadway Width
2 ft. Structural Depth
No Skew

Concrete

Audrain County, MO Bridge 336
Built 2012
Precast 6 Hollowcore Slab Girders
50.5 ft. Span
24 ft. Roadway Width
2 ft. Structural Depth
20° Skew
## Case Study Bridges:
Side-by-Side Comparison Total Cost of Structure

<table>
<thead>
<tr>
<th>Material</th>
<th>Steel</th>
<th>Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Bridge Costs</td>
<td>$41,764</td>
<td>$67,450</td>
</tr>
<tr>
<td>Labor</td>
<td>$24,125</td>
<td>$26,110</td>
</tr>
<tr>
<td>Equipment</td>
<td>$21,521</td>
<td>$24,966</td>
</tr>
<tr>
<td>Guard Rail</td>
<td>$7,895</td>
<td>$6,603</td>
</tr>
<tr>
<td>Rock</td>
<td>$8,302</td>
<td>$7,571</td>
</tr>
<tr>
<td>Engineering</td>
<td>$8,246</td>
<td>$21,335</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$111,853 ($97.48 / sq. ft.)</td>
<td>$154,035 ($120.83 / sq. ft.)</td>
</tr>
</tbody>
</table>

19.3% Total Bridge Cost Savings with Steel
### Case Study Bridges: Superstructure Only Comparison
(Remove Site Prep, Abutment, Grading & Finishing, Guardrail, Engineering, Rock, Etc)

#### Steel

<table>
<thead>
<tr>
<th>Material</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Girders</td>
<td>$21,463</td>
</tr>
<tr>
<td>Deck Panels</td>
<td>$7,999</td>
</tr>
<tr>
<td>Reinf Steel</td>
<td>$3,135</td>
</tr>
<tr>
<td>Concrete</td>
<td>$4,180</td>
</tr>
<tr>
<td>Labor</td>
<td>$5,522</td>
</tr>
<tr>
<td>Equipment*</td>
<td>$500</td>
</tr>
<tr>
<td><strong>SUPER TOTAL</strong></td>
<td><strong>$42,799</strong></td>
</tr>
</tbody>
</table>

SUPER TOTAL = $37.54 / sq. ft.

---

#### Concrete

<table>
<thead>
<tr>
<th>Material</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slab Girders</td>
<td>$50,765</td>
</tr>
<tr>
<td>Deck Panels</td>
<td>$0</td>
</tr>
<tr>
<td>Reinf Steel</td>
<td>$724</td>
</tr>
<tr>
<td>Concrete</td>
<td>$965</td>
</tr>
<tr>
<td>Labor</td>
<td>$4,884</td>
</tr>
<tr>
<td>Equipment*</td>
<td>$4,000</td>
</tr>
<tr>
<td><strong>SUPER TOTAL</strong></td>
<td><strong>$61,338</strong></td>
</tr>
</tbody>
</table>

SUPER TOTAL = $50.61 / sq. ft.

---

*Added cost to use galvanized steel = $5,453.80 or $0.22 / lb. (includes est. 10% fabrication fee)
** Cost to use weathering steel is approximately $0.04 / lb. (already included in cost in example)

*County Crane (30 Ton) used for Steel, Larger Rented Crane (100 Ton) Required for Concrete  (Equivalent County Crane Cost is $1520, would result in Steel Cost of $38.88 / sq. ft.)
Case Study Bridges: Audrain County, MO

Steel: Superstructure $37.54 per sq. ft.
Concrete: Superstructure Cost $50.61 per sq. ft.

25.8% superstructure cost savings

Same bridge conditions:
• Structural Depth = 2 ft. (No Difference in Approaches)
• Roadway Width = 24 ft.
• Same Abutments for Both Can be Used (Steel Could Use Lighter)
• Same Guard Rail System
• Same Work Crew
### Case Study Bridges: Other Bridges in Audrain County

<table>
<thead>
<tr>
<th>Superstructure</th>
<th>Steel</th>
<th>Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridge Number</td>
<td>AVG</td>
<td>AVG</td>
</tr>
<tr>
<td>Year Built</td>
<td>AVG</td>
<td>AVG</td>
</tr>
<tr>
<td>Span Length</td>
<td>AVG</td>
<td>AVG</td>
</tr>
<tr>
<td>50 50 40 62 64</td>
<td>53.2</td>
<td>36 36 38 40 37.5</td>
</tr>
<tr>
<td>Skew</td>
<td>AVG</td>
<td>AVG</td>
</tr>
<tr>
<td>0 0 0 30 35 35</td>
<td>13</td>
<td>0 15 20 30 16.25</td>
</tr>
<tr>
<td>Cost Summary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Labor</td>
<td>$14,568 $21,705 $15,853 $24,765 $31,949</td>
<td>$21,768 $12,065 $15,379 $14,674 $19,044 $15,291</td>
</tr>
<tr>
<td>- Material</td>
<td>$56,676 $53,593 $46,282 $92,821 $69,357</td>
<td>$63,746 $51,589 $54,450 $50,576 $46,850 $50,866</td>
</tr>
<tr>
<td>- Rock</td>
<td>$6,170 $6,216 $3,694 $8,235 $6,501</td>
<td>$6,163 $5,135 $7,549 $5,378 $3,621 $5,421</td>
</tr>
<tr>
<td>- Equipment</td>
<td>$7,487 $12,026 $7,017 $19,579 $15,266</td>
<td>$12,275 $5,568 $10,952 $11,093 $14,742 $10,589</td>
</tr>
<tr>
<td>- Guardrail</td>
<td>$4,715 $7,146 $3,961 $7,003 $7,003</td>
<td>$5,966 $4,737 $4,663 $5,356 $3,323 $4,520</td>
</tr>
<tr>
<td>Construction Cost</td>
<td>$89,616 $100,686 $76,807 $152,403 $130,076</td>
<td>$109,918 $79,094 $92,993 $87,077 $87,580 $86,686</td>
</tr>
<tr>
<td>CONST. COST PER FT$^2$</td>
<td>$74.68 $83.91 $80.01 $102.42 $84.68</td>
<td>$86.09 $91.54 $107.63 $95.48 $91.23 $96.32</td>
</tr>
</tbody>
</table>
County Bridge (Designed by eSPAN140)

- Boone County, Missouri (Local)
  - High Point Lane Bridge
  - 102 feet (2 lane rural road plate girder bridge)
  - 44” weathering steel plate girders (4 lines)
  - Constructed in summer 2013
State Bridge (Designed by eSPAN140)

Kansas Department of Transportation
- Shawnee County
- 112 feet (5 plate girder bridge)
- Competitive bid process (steel vs. concrete)
- DOT used eSPAN140 for preliminary design
- Constructed in summer 2014

1 Steel Bridge Bid
3 Concrete Bridge Bids

Steel = $1.240 mil
Concrete = $1.243 – $1.425 mil
Two MoDOT State Bridges Crossing US 63 in Boone County

Concrete P/S: 92 ft – 92 ft
Route H (Columbia Airport)
Built 2011

Steel Plate Girder: 98 ft – 98 ft
Discovery Parkway (Columbia)
Built 2007
### Concrete P/S: 92 ft – 92 ft
Built 2011

<table>
<thead>
<tr>
<th>Letting Date</th>
<th>5/27/2011</th>
<th>Description</th>
<th>Volume</th>
<th>Unit</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1800</td>
<td>206-10.00</td>
<td>Class 1 Excavation</td>
<td>85 CUYD</td>
<td>$1,700.00</td>
<td></td>
</tr>
<tr>
<td>1810</td>
<td>702-10.12</td>
<td>Structural Steel Piles (12 in.)</td>
<td>737 LF</td>
<td>$33,533.50</td>
<td></td>
</tr>
<tr>
<td>1820</td>
<td>702-60.00</td>
<td>Pre-Bore for Piling</td>
<td>240 LF</td>
<td>$9,600.00</td>
<td></td>
</tr>
<tr>
<td>1830</td>
<td>702-70.00</td>
<td>Pile Point Reinforcement</td>
<td>22 EA</td>
<td>$2,420.00</td>
<td></td>
</tr>
<tr>
<td>1840</td>
<td>703-20.03</td>
<td>Class B Concrete (Substructure)</td>
<td>76.2 CUYD</td>
<td>$45,339.00</td>
<td></td>
</tr>
<tr>
<td>1850</td>
<td>703-42.13</td>
<td>Slab on Concrete I-Girder</td>
<td>630 SQYD</td>
<td>$160,650.00</td>
<td></td>
</tr>
<tr>
<td>1860</td>
<td>703-42.15</td>
<td>Safety Barrier Curb</td>
<td>438 LF</td>
<td>$27,156.00</td>
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</tr>
<tr>
<td>1870</td>
<td>705-60.03</td>
<td>Type 6 (54 in.), Prestressed Concrete I-Girder</td>
<td>731 LF</td>
<td>$120,615.00</td>
<td></td>
</tr>
<tr>
<td>1880</td>
<td>706-10.60</td>
<td>Reinforcing Steel (Bridges)</td>
<td>7860 LB</td>
<td>$9,039.00</td>
<td></td>
</tr>
</tbody>
</table>

**Total Bridge Cost = $440,632.50**

Cost/ft² = **$77.71**

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### Steel Plate Girder: 98 ft – 98 ft
Discovery Parkway (Columbia)
Built 2007

<table>
<thead>
<tr>
<th>Letting Date</th>
<th>9/28/2007</th>
<th>Description</th>
<th>Volume</th>
<th>Unit</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1560</td>
<td>206100</td>
<td>Class 1 Excavation</td>
<td>130 CUYD</td>
<td>$4,420.00</td>
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<tr>
<td>1580</td>
<td>7021012</td>
<td>Structural Steel Piles (12 in.)</td>
<td>1850 LF</td>
<td>$64,750.00</td>
<td></td>
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<tr>
<td>1570</td>
<td>6071066</td>
<td>Pedestrian Fence</td>
<td>470 LF</td>
<td>$33,940.00</td>
<td></td>
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<tr>
<td>1590</td>
<td>7027000</td>
<td>Pile Point Reinforcement</td>
<td>60 EA</td>
<td>$5,700.00</td>
<td></td>
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<tr>
<td>1600</td>
<td>7032003</td>
<td>Class B Concrete (Substructure)</td>
<td>171.7 CUYD</td>
<td>$60,095.00</td>
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<tr>
<td>1610</td>
<td>7034212</td>
<td>Slab on Steel</td>
<td>1835 SQYD</td>
<td>$308,280.00</td>
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<tr>
<td>1620</td>
<td>7034215</td>
<td>Safety Barrier Curb</td>
<td>387 LF</td>
<td>$17,415.00</td>
<td></td>
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<tr>
<td>1650</td>
<td>7121112</td>
<td>Fabricated Structural Low Alloy Steel (Plate G)</td>
<td>439610 LB</td>
<td>$518,739.80</td>
<td></td>
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<tr>
<td>1630</td>
<td>7061060</td>
<td>Reinforcing Steel (Bridges)</td>
<td>15820 LB</td>
<td>$15,029.00</td>
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</tr>
<tr>
<td>1640</td>
<td>7071000</td>
<td>Conduit System on Structure</td>
<td>L.S.</td>
<td>$7,000.00</td>
<td></td>
</tr>
<tr>
<td>1660</td>
<td>7123610</td>
<td>Slab Drains</td>
<td>12 EA</td>
<td>$2,400.00</td>
<td></td>
</tr>
<tr>
<td>1700</td>
<td>7151001</td>
<td>Vertical Drain at End Bents</td>
<td>2 EA</td>
<td>$4,000.00</td>
<td></td>
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<tr>
<td>1720</td>
<td>7162000</td>
<td>Laminated Neoprene Bearing Pad</td>
<td>9 EA</td>
<td>$10,800.00</td>
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<tr>
<td>1710</td>
<td>7161003</td>
<td>Laminated Neoprene Bearing Pad (Tapered)</td>
<td>18 EA</td>
<td>$6,750.00</td>
<td></td>
</tr>
<tr>
<td>1730</td>
<td>7251000</td>
<td>Corrugated Metal Pipe Pile Spacers</td>
<td>20 EA</td>
<td>$5,000.00</td>
<td></td>
</tr>
<tr>
<td>1670</td>
<td>7125365A</td>
<td>Intermediate Field Coat (System G)</td>
<td>22100 SQFT</td>
<td>$30,940.00</td>
<td></td>
</tr>
<tr>
<td>1680</td>
<td>7125370A</td>
<td>Finish Field Coat (System G)</td>
<td>2800 SQFT</td>
<td>$3,220.00</td>
<td></td>
</tr>
<tr>
<td>1690</td>
<td>7129911</td>
<td>Misc. Fab. Struc. Low Alloy Steel (Aesthetics)</td>
<td>24330 LB</td>
<td>$54,742.50</td>
<td></td>
</tr>
</tbody>
</table>

**Total Bridge Cost = $1,057,538.80**

Cost/ft² = **$64.04**

Cost/ft² with ENR CCI Adjustment of 1.139 = **$72.94**
Concrete P/S: 92 ft – 92 ft  
Route H (Columbia Airport) 
Built 2011

Steel Plate Girder: 98 ft – 98 ft  
Discovery Parkway (Columbia)  
Built 2007

Using ENR CCI Index Increase of 2.7%/yr  
For 2017

Cost/ft² = $91.18/ft²  
Concrete   =  $85.58/ft²  
Steel

Total Bridge Cost = $440,632.50  
Cost/ft² = $77.71

Cost/ft² with ENR CCI Adjustment of 1.139 = $72.94

Total Bridge Cost = $1,057,538.80
Summary on Initial Costs

Case Studies of County Bridges
Competitive Bids
Bridges over US 63
Others Not Shown Here

Two MoDOT Bridges Crossing US 63 in Boone County
Concrete P/S: 92 ft – 92 ft
Route H (Columbia Airport)
Steel Plate Girder: 98 ft – 98 ft
Discovery Parkway (Columbia)

Using ENR CCI Index Increase of 2.7%/yr
For 2017
Concrete = $91.18/ft²
Steel = $85.58/ft²

Total Bridge Cost = $297,711

Case Study Bridges: Audrain County, MO
Steel: Superstructure $32.84 per sq ft
Concrete: Superstructure Cost $50.81 per sq ft

Same bridge conditions:
• Structural Depth = 2 ft. (No Difference in Approaches)
• Roadway Width = 24 ft.
• Same Abutments for Both Can Be Used (Steel Could Use Lighter)
• Same Guard Rail System
• Same Work Crew

State Bridge (Designed by eSPAN140)
Kansas Department of Transportation
• Shawnee County
• 112 foot (5 lane girder bridge)
• Competitive bid process (steel vs. concrete)
• DOT used eSPAN140 for preliminary design
• Constructed in summer 2014
1 Steel Bridge Bid
3 Concrete Bridge Bids
Steel = $1.240 mil
Concrete = $1.243 – $1.425 mil

County Bridge (Designed by eSPAN140)
• Boone County, Missouri (Local)
• High Point Lane Bridge
• 102 foot (2 lane rural road plate girder bridge)
• 44” weathering steel plate girders (4 lines)
• Constructed in summer 2013
Steel Bridges Compete and Win!

Preconception is Wrong
Steel & Concrete Bridges Are Competitive
What About Life Cycle Costs?

*Historical Life Cycle Costs of Steel & Concrete Girder Bridges*

Report on ShortSpanSteelBridges.org

Thank You to PennDOT professionals for their participation. Thanks to SMDI, NSBA and AGA for supporting the work.
Why the Study?

As owners replace their bridge infrastructure, the question of Life Service and Life Cycle Costs routinely comes up between concrete and steel bridge options.

This is especially true for typical and short span bridge replacement projects.

The bridge industry does not have a good answer:

- Both steel and concrete bridge advocates claim an advantage.
- Anecdotal information is not convincing.
Study Objective

Examine Historical Life Service (Performance and Maintenance) and Agency Life Cycle Costs (True Agency Costs for a Bridge) of Steel and Concrete Bridges in Pennsylvania
Life Cycle Cost Data Collection

Start with a Comprehensive Inventory of Bridges

Initial Costs & Date Built
Maintenance Costs and Date Performed
End of Service Date – End of Life Model

Initial Cost
Contract
Maintenance
Maintenance
Replace with
Identical Bridge
Every 70 years
Life Cycle Cost Data Collection

Start with a Comprehensive Inventory of Bridges

Initial Costs & Date Built
Maintenance Costs and Date Performed
End of Service Date – End of Life Model

Issues: Availability of Historical Data
Large Amount of Time & Resources to Collect Data

PennDOT Stepped Up to Participate
PennDOT Database Development

Criteria to Develop LCC Bridge Database

Modern typical bridge structures
- Precast I-Beam, Box Adjacent, and Box Spread bridges
- Steel Rolled Shape and Welded Plate Girder bridges

Bridges built between 1960 and 2010

Bridges with complete and accurate department maintenance records
- Consider any maintenance cost that is equal to or greater than $0.25/ft²

Bridges with known initial costs

Bridges with complete and accurate external contractor maintenance and rehabilitation

Initial cost limitation to bridges with initial cost less than $500/ft² and greater than $100/ft²

Note: Total Recorded Initial and Maintenance Costs Used
PennDOT Database Development

All Bridges in PennDOT Inventory = 25,403
Number of Type Bridges in Inventory = 8,466
Number of Types Built 1960-2010 = 6,587

Bridges that Meet All Criteria

Table 8: Final LCC Database that Meets All Criteria

<table>
<thead>
<tr>
<th>Bridge Type</th>
<th>Number of Bridges that Meet All criteria</th>
<th>Percentage of 1960 – 2010 database</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel I Beam</td>
<td>82</td>
<td>14.9%</td>
</tr>
<tr>
<td>Steel I Girder</td>
<td>230</td>
<td>22.6%</td>
</tr>
<tr>
<td>P/S Box - Adjacent</td>
<td>400</td>
<td>27.8%</td>
</tr>
<tr>
<td>P/S Box - Spread</td>
<td>581</td>
<td>26.5%</td>
</tr>
<tr>
<td>P/S I Beam</td>
<td>412</td>
<td>29.8%</td>
</tr>
<tr>
<td>Total</td>
<td>1705</td>
<td>25.9%</td>
</tr>
</tbody>
</table>
NEEDED Notes on Limitations

Database Contains Only 25.9% of Eligible 1960 - 2010 Bridges

Large Percentage of Bridges Not Included

Bridges Removed Due To:

- Unknown Dates and/or Costs of Department Maintenance
- Unknown Dates and/or Costs of Contractor Maintenance

Therefore,

Database is “Skewed” Towards Bridges with Lower Amounts of Maintenance
NEEDED Notes on Limitations

The Systematic Nature of the Study Used

Total 1960-2010 PennDOT Database Average Deterioration Rates Based on Condition Ratings

The Study Does Not Predict Any Future Maintenance

Therefore,

Results, Comparisons & Conclusions Must Be Taken In Context to the Database and the Database Limitations
PennDOT Database Bridge Life Model

Bridge Life Model uses Average Deterioration Rates of Total PennDOT Inventory

Assume Bridge Replacement at Condition Rating = 3
Super Structure Condition Rating Used

Table 9: Average Deterioration Rates

<table>
<thead>
<tr>
<th>Bridge Type</th>
<th>Number of Bridges 1960 - 2010</th>
<th>Deterioration Rate (Condition Rating Loss/Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel I Beam</td>
<td>550</td>
<td>-0.07114</td>
</tr>
<tr>
<td>Steel I Girder</td>
<td>1017</td>
<td>-0.08144</td>
</tr>
<tr>
<td>P/S Box - Adjacent</td>
<td>1440</td>
<td>-0.08125</td>
</tr>
<tr>
<td>P/S Box - Spread</td>
<td>2196</td>
<td>-0.07988</td>
</tr>
<tr>
<td>P/S I Beam</td>
<td>1384</td>
<td>-0.08383</td>
</tr>
</tbody>
</table>

Deterioration Rate = \( \frac{(2014 \text{ Condition Rating}) - 9}{2014 - (\text{Year Built})} \)

Remaining Life = \( \frac{3 - (2014 \text{ Condition Rating})}{(\text{Average Deterioration Rate})} \)

Bridge Life = 2014 – (Year Built) + Remaining Life
PennDOT Database Bridge Life Model

Bridge Life Model uses Average Deterioration Rates of Total PennDOT Inventory

Assume Bridge Replacement at Condition Rating = 3
Super Structure Condition Rating Used

\[
Deterioration Rate = \frac{(2014 \text{ Condition Rating}) - 9}{2014 - (\text{Year Built})}
\]

\[
Remaining\ Life = \frac{3 - (2014 \text{ Condition Rating})}{(Average\ Deterioration\ Rate)}
\]

\[
Bridge\ Life = 2014 - (Year\ Built) + Remaining\ Life
\]

Table 9: Average Deterioration Rates

<table>
<thead>
<tr>
<th>Bridge Type</th>
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<tbody>
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<td>-0.07114</td>
</tr>
<tr>
<td>Steel I Girder</td>
<td>1017</td>
<td>-0.08144</td>
</tr>
<tr>
<td>P/S Box - Adjacent</td>
<td>1440</td>
<td>-0.08125</td>
</tr>
<tr>
<td>P/S Box - Spread</td>
<td>2196</td>
<td>-0.07988</td>
</tr>
<tr>
<td>P/S I Beam</td>
<td>1384</td>
<td>-0.08383</td>
</tr>
</tbody>
</table>

All are “similar” with None “Way Out” of Balance
Agency Life Cycle Costs – An Example

Precast Spread Box-Beam Bridge

- BrKey: 30570
- Bridge Type: P/S, Box Beam (Spread)
- County: Shuylkill
- Location: 0.75 mi. N of Exit 107(33)
- Year Built: 1969
- Spans: 3
- Length: 176 ft
- Deck Area: 7621 ft²
- Super Cond Rating: 5

Average Precast Box Beam – Spread bridge deterioration rate = -0.07988

\[
\text{Remaining Life} = \frac{(3 - 5)}{-0.07988} = 25 \text{ years}
\]

Bridge Life = 2014 + 25 – 1969 = 70 years
Life Cycle Costs

Example Bridge Costs

Initial Cost: Year = 1969 Cost = $141475 ($18.56/ft\(^2\)) Work: Bridge Construction

External Contract: Year = 1988 Cost = $58401 ($7.66/ft\(^2\)) Work: Latex Overlay

Maintenance 1: Year = 2009 Cost = $1891 ($0.25/ft\(^2\)) Work: Repair Concrete Deck

Maintenance 2: Year = 2013 Cost = $2510 ($0.33/ft\(^2\)) Work: Repair Concrete Deck

ENR Construction Cost Indices

\[
2014\; Dollars = \frac{CCI\; 2014}{CCI\; 19XX} \times 19XX\; Dollars
\]

Transform the costs to constant 2014 dollars using Construction Cost

Initial Cost: Year = 0 Cost = $18.56/ft\(^2\) (9806/1269) = $143.45/ft\(^2\)

External Contract: Year = 19 Cost = $7.66/ft\(^2\) (9806/4519) = $16.63/ft\(^2\)

Maintenance 1: Year = 40 Cost = $0.25/ft\(^2\) (9806/8570) = $0.28/ft\(^2\)

Maintenance 2: Year = 44 Cost = $0.33/ft\(^2\) (9806/9547) = $0.34/ft\(^2\)
Life Cycle Costs

Example Bridge Life Cycle

Present Value Cost for 1 Cycle

\[ PVC = 143.45 + 16.63(1.023)^{-19} + 0.28(1.023)^{-40} + 0.34(1.023)^{-44} = 154.49/ft^2 \]
**Life Cycle Costs**

Example Bridge Life Cycle

Present Value Cost for 1 Cycle

$$PVC = $143.45 + $16.63(1.023)^{-19} + $0.28(1.023)^{-40} + $0.34(1.023)^{-44} = $154.49/ft^2$$

Perpetual Present Value Cost = Capitalized Cost

$$PPVC = $154.49\left[\frac{(1 + 0.023)^{70}}{(1 + 0.023)^{70} - 1}\right] = 1.256($154.49) = $193.97/ft^2$$

With PPVC, Can Compare Bridges Directly
Life Cycle Cost Analyses

The Steel Plate Girder Bridge Data Base

General Information  Maintenance & Contract Work  Initial & LCC

The full history of the bridge
Location, year built, spans, length, area, geometry, materials
Department and contractor maintenance performed
Initial, perpetual present value, and future maintenance costs
Additional Bridges Removed Based on PPVC

To Consider “Typical” Bridges, Keep Bridges with PPVC within +/- 1 Standard Deviation of Overall Average

Bridges in the Life Cycle Cost Analyses

Table 13: Final Life Cycle Cost Database

<table>
<thead>
<tr>
<th>Bridge Type</th>
<th>Number of Bridges in Table 11 Database</th>
<th>Number of Bridges in LCC Study Database</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel I Beam</td>
<td>82</td>
<td>54</td>
</tr>
<tr>
<td>Steel I Girder</td>
<td>230</td>
<td>144</td>
</tr>
<tr>
<td>P/S Box - Adjacent</td>
<td>400</td>
<td>282</td>
</tr>
<tr>
<td>P/S Box - Spread</td>
<td>581</td>
<td>397</td>
</tr>
<tr>
<td>P/S I Beam</td>
<td>412</td>
<td>309</td>
</tr>
<tr>
<td></td>
<td>1705</td>
<td>1186</td>
</tr>
</tbody>
</table>
LCC Report

Analysis and Variables Examined in Report

- Bridge Life
- PPVC
  - Number of Spans
  - Bridge Length
  - PVC Future Costs
  - Department Maintenance
  - External Contracts

For the entire report: www.ShortSpanSteelBridges.org

Additional LCC report on Galvanizing: www.ShortSpanSteelBridges.org

For Steel Bridges

- Curved vs. Straight
- Fracture-Critical Protection (Painted, Weathering, Galvanized)
## Bridge Life

Table 10: Final LCC Database that Meets All Criteria

<table>
<thead>
<tr>
<th>Bridge Type</th>
<th>Number of Bridges in Final LCC Database</th>
<th>Average Year Built</th>
<th>Average Bridge Life (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel I Beam</td>
<td>82</td>
<td>1981</td>
<td>81.3</td>
</tr>
<tr>
<td>Steel I Girder</td>
<td>230</td>
<td>1977</td>
<td>79.2</td>
</tr>
<tr>
<td>P/S Box - Adjacent</td>
<td>400</td>
<td>1985</td>
<td>74.0</td>
</tr>
<tr>
<td>P/S Box - Spread</td>
<td>581</td>
<td>1984</td>
<td>79.9</td>
</tr>
<tr>
<td>P/S I Beam</td>
<td>412</td>
<td>1984</td>
<td>74.5</td>
</tr>
</tbody>
</table>

Steel Rolled Precast Box - Spread

All are “similar” with None “Way Out” of Balance
Bridge Life

CDF for Bridge Life

- Rolled: 73.0%
- Plate: 62.7%
- Box Adjacent: 45.6%
- Box Spread: 65.6%
- Conc I Beam: 44.3%

Probability Bridge Lasts >75 yrs
### Perpetual Present Value Cost – All Bridges

#### Table 14: Life Cycle Cost Results Using Total Database

<table>
<thead>
<tr>
<th></th>
<th># Bridges</th>
<th>PPVC</th>
<th>Initial Cost</th>
<th>Future Cost</th>
<th>Avg Length</th>
<th>Avg # Spans</th>
<th>Avg Year Built</th>
<th>Avg Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel I Beam</td>
<td>54</td>
<td>$232.78</td>
<td>$194.78</td>
<td>$0.42</td>
<td>166</td>
<td>2.19</td>
<td>1980</td>
<td>82</td>
</tr>
<tr>
<td>Steel I Girder</td>
<td>144</td>
<td>$273.71</td>
<td>$226.10</td>
<td>$0.21</td>
<td>406</td>
<td>4.07</td>
<td>1976</td>
<td>80</td>
</tr>
<tr>
<td>P/S Box - Adjacent</td>
<td>282</td>
<td>$278.30</td>
<td>$223.74</td>
<td>$0.96</td>
<td>89</td>
<td>1.31</td>
<td>1987</td>
<td>74</td>
</tr>
<tr>
<td>P/S Box - Spread</td>
<td>397</td>
<td>$256.11</td>
<td>$210.65</td>
<td>$2.06</td>
<td>89</td>
<td>1.56</td>
<td>1986</td>
<td>79</td>
</tr>
<tr>
<td>P/S I Beam</td>
<td>309</td>
<td>$217.50</td>
<td>$174.10</td>
<td>$0.20</td>
<td>212</td>
<td>2.43</td>
<td>1985</td>
<td>73</td>
</tr>
</tbody>
</table>

All are “similar” with None “Way Out” of Balance
Perpetual Present Value Cost – All Bridges

CDF for Bridge Cost

- Probability Bridge costs < $300
  - Steel Rolled: 88%
  - Steel Plate: 66%
  - Conc Box Adjacent: 67%
  - Conc Box Spread: 79%
  - Conc I Beam: 93%
Perpetual Present Value Cost – Length < 140 ft

Short Length Bridges

Table 20: Life Cycle Cost Results for Bridge Length Maximum = 140 ft

<table>
<thead>
<tr>
<th></th>
<th># Bridges</th>
<th>PPVC</th>
<th>Initial Cost</th>
<th>Future Cost</th>
<th>Avg Length</th>
<th>Avg # Spans</th>
<th>Avg Year Built</th>
<th>Avg Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel I Beam</td>
<td>27</td>
<td>$266.24</td>
<td>$222.08</td>
<td>$0.16</td>
<td>84</td>
<td>1.26</td>
<td>1978</td>
<td>82</td>
</tr>
<tr>
<td>Steel I Girder</td>
<td>18</td>
<td>$311.26</td>
<td>$257.19</td>
<td>$0.29</td>
<td>119</td>
<td>1.00</td>
<td>1977</td>
<td>81</td>
</tr>
<tr>
<td>P/S Box - Adjacent</td>
<td>240</td>
<td>$292.38</td>
<td>$235.03</td>
<td>$0.95</td>
<td>69</td>
<td>1.09</td>
<td>1987</td>
<td>74</td>
</tr>
<tr>
<td>P/S Box - Spread</td>
<td>325</td>
<td>$272.20</td>
<td>$225.14</td>
<td>$2.16</td>
<td>64</td>
<td>1.23</td>
<td>1986</td>
<td>81</td>
</tr>
<tr>
<td>P/S I Beam</td>
<td>98</td>
<td>$281.64</td>
<td>$231.20</td>
<td>$0.05</td>
<td>104</td>
<td>1.08</td>
<td>1987</td>
<td>77</td>
</tr>
</tbody>
</table>

Steel Rolled
Precast Box Spread

All are “similar” with None “Way Out” of Balance
Which Type of Bridge is Best?

- Steel Rolled Beam
- Precast Box Adjacent
- Steel Plate Girder
- Precast I Beam
- Precast Box Spread
Which Type of Bridge is Best?

All are “similar” with None “Way Out” of Balance
Which Type of Bridge is Best?

All are “similar” with None “Way Out” of Balance

Overall Weighted Average PPVC = $252.40/ft² – Capitalized Costs

Bridge Types within 14% of Weighted Average

Standard Deviation Range

$48.02/ft² - $65.60/ft²
[COV ≈ 20% - 25%]

Any One Type of Bridge May Be Most Economical for a Given Bridge Project

There is No One Type of Bridge That Clearly Beats the Others
Conclusions

Typical Concrete and Steel Bridges are Competitive on Initial Cost, Future Costs, Life Cycle Costs and Bridge Life.

For any Given Bridge Project, Concrete or Steel Bridge Types May Be the Most Economical.

Preconception that Concrete is Always Less Expensive is a Misconception.

Owners Should Consider Both Steel and Concrete Alternatives for Individual Bridge Projects.
Need More Information?

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Thank You