Bridge Economy and Life Cycle Costs of Steel & Concrete Bridges

Short Span Steel Bridge Alliance

NACE 2017 Short Span Steel Bridge Workshop
Cincinnati, OH
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Problem Statement
Preconception that Concrete is Always Less Expensive for Short Span Bridges

Today’s Presentation
Direct Cost Comparison Between Steel and Concrete Short Span Bridges
• Economical Comparison of two “Identical” Bridges
• Life Cycle Cost Comparison of Steel & Concrete
Economics Case Study

Steel vs. Concrete Costs
Audrain County, MO
Case Study Bridges: Side-by-Side Comparison

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>Steel</th>
<th>Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Bridge Costs</strong></td>
<td><strong>Total Bridge Costs</strong></td>
</tr>
<tr>
<td>Material</td>
<td>Material</td>
</tr>
<tr>
<td>$41,764</td>
<td>$67,450</td>
</tr>
<tr>
<td>Labor</td>
<td>Labor</td>
</tr>
<tr>
<td>$24,125</td>
<td>$26,110</td>
</tr>
<tr>
<td>Equipment</td>
<td>Equipment</td>
</tr>
<tr>
<td>$21,521</td>
<td>$24,966</td>
</tr>
<tr>
<td>Guard Rail</td>
<td>Guard Rail</td>
</tr>
<tr>
<td>$7,895</td>
<td>$6,603</td>
</tr>
<tr>
<td>Rock</td>
<td>Rock</td>
</tr>
<tr>
<td>$8,302</td>
<td>$7,571</td>
</tr>
<tr>
<td>Engineering</td>
<td>Engineering</td>
</tr>
<tr>
<td>$8,246</td>
<td>$21,335</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>TOTAL</strong></td>
</tr>
<tr>
<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: Side-by-Side Comparison

**Steel**

- Total Bridge Costs per ft\(^2\)
  - Total Cost = $97.48 / sq. ft.
  - Total Construction Cost = $90.29 / sq. ft. (no Engineering)
  - Adjusted Construction Cost = $83.05 / sq. ft. (no Engineering or Rock)

**Concrete**

- Total Bridge Costs per ft\(^2\)
  - Total Cost = $120.83 / sq. ft.
  - Total Construction Cost = $104.08 / sq. ft. (no Engineering)
  - Adjusted Construction Cost = $98.14 / sq. ft. (no Engineering or Rock)
Case Study Bridges: Superstructure Only Comparison
(Remove Site Prep, Abutment, Grading & Finishing, Guardrail, Engineering, Rock, Etc)

<table>
<thead>
<tr>
<th>Material</th>
<th>Superstructure Costs</th>
<th>Steel</th>
<th>Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girders</td>
<td>$21,463</td>
<td>$50,765</td>
<td></td>
</tr>
<tr>
<td>Deck Panels</td>
<td>$7,999</td>
<td>$0</td>
<td></td>
</tr>
<tr>
<td>Reinf Steel</td>
<td>$3,135</td>
<td>$724</td>
<td></td>
</tr>
<tr>
<td>Concrete</td>
<td>$4,180</td>
<td>$965</td>
<td></td>
</tr>
<tr>
<td>Labor</td>
<td>$5,522</td>
<td>$4,884</td>
<td></td>
</tr>
<tr>
<td>Equipment*</td>
<td>$500</td>
<td>$4,000</td>
<td></td>
</tr>
<tr>
<td><strong>SUPER TOTAL</strong></td>
<td><strong>$42,799</strong></td>
<td><strong>$61,338</strong></td>
<td></td>
</tr>
</tbody>
</table>

SUPER TOTAL = $37.54 / sq. ft.  
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
Steel Bridge - Advantages

Lighter Cranes Required (Owner Cranes Can Save Costs)
Steel Bridge - Advantages

Lighter Abutments Possible for Steel Bridges
Steel Bridge - Economy

Cast-in-Place Deck on Prestressed Concrete Deck Panels
Steel Bridge - Economy

Simple and Practical Details
Steel Bridge - Economy

Elastomeric Bearings & Integral Abutments
Steel Bridge - Economy

Weathering Steel
## Case Study Bridges: Other Bridges in MO

<table>
<thead>
<tr>
<th>Superstructure</th>
<th>Steel</th>
<th>Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bridge Number</strong></td>
<td>061 140 149 152 710 AVG 028 057 069 520 AVG</td>
<td>028 057 069 520 AVG</td>
</tr>
<tr>
<td><strong>Span Length</strong></td>
<td>50 50 40 62 64 53.2 36 36 38 40 37.5</td>
<td>36 36 38 40 37.5</td>
</tr>
<tr>
<td><strong>Skew</strong></td>
<td>0 0 0 30 35 13 0 15 20 30 16.25</td>
<td>0 15 20 30 16.25</td>
</tr>
</tbody>
</table>

### Cost Summary

- **Labor**
  - Steel: $14,568, $21,705, $15,853, $24,765, $31,949
  - Concrete: $21,768, $12,065, $15,379, $19,044, $15,291

- **Material**
  - Steel: $56,676, $53,593, $46,282, $92,821, $69,357
  - Concrete: $63,746, $51,589, $54,450, $50,576, $46,850

- **Rock**
  - Steel: $6,170, $6,216, $3,694, $8,235, $6,501
  - Concrete: $6,163, $5,135, $7,549, $5,378, $3,621

- **Equipment**
  - Steel: $7,487, $12,026, $7,017, $19,579, $15,266
  - Concrete: $12,275, $5,568, $10,952, $11,093, $14,742

- **Guardrail**
  - Steel: $4,715, $7,146, $3,961, $7,003, $7,003
  - Concrete: $5,966, $4,737, $4,663, $5,356, $3,323

### Construction Cost

- Steel: $89,616, $100,686, $76,807, $152,403, $130,076
- Concrete: $109,918, $79,094, $92,993, $87,077, $87,580

### Const. Cost per ft²

- Steel: $74.68, $83.91, $80.01, $102.42, $84.68
- Concrete: $86.09, $91.54, $107.63, $95.48, $91.23
The Bottom Line…

• Short span steel bridges compete and win!
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
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

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

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

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

Table 9: Average Deterioration Rates

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</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

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

\[
\text{Bridge Life} = 2014 + 25 - 1969 = 70 \text{ years}
\]
**Life Cycle Costs**

**Example Bridge Costs**

<table>
<thead>
<tr>
<th>Type</th>
<th>Year (Year of Work)</th>
<th>Cost (in $/ft²)</th>
<th>Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Cost</td>
<td>1969</td>
<td>$141,475 ($18.56/ft²)</td>
<td>Bridge Construction</td>
</tr>
<tr>
<td>External Contract</td>
<td>1988</td>
<td>$58,401 ($7.66/ft²)</td>
<td>Latex Overlay</td>
</tr>
<tr>
<td>Maintenance 1</td>
<td>2009</td>
<td>$1,891 ($0.25/ft²)</td>
<td>Repair Concrete Deck</td>
</tr>
<tr>
<td>Maintenance 2</td>
<td>2013</td>
<td>$2,510 ($0.33/ft²)</td>
<td>Repair Concrete Deck</td>
</tr>
</tbody>
</table>

**ENR Construction Cost Indices**

\[ 2014 \text{ Dollars} = \frac{CCI_{2014}}{CCI_{19XX}} \times 19XX \text{ Dollars} \]

**Transform the costs to constant 2014 dollars using Construction Cost**

<table>
<thead>
<tr>
<th>Type</th>
<th>Year (Year of Work)</th>
<th>Cost (in $/ft²)</th>
<th>2014 Cost (in $/ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Cost</td>
<td>0</td>
<td>$18.56 (9806/1269)</td>
<td>$143.45/ft²</td>
</tr>
<tr>
<td>External Contract</td>
<td>19</td>
<td>$7.66 (9806/4919)</td>
<td>$16.63/ft²</td>
</tr>
<tr>
<td>Maintenance 1</td>
<td>40</td>
<td>$0.25 (9806/8570)</td>
<td>$0.28/ft²</td>
</tr>
<tr>
<td>Maintenance 2</td>
<td>44</td>
<td>$0.33 (9806/9547)</td>
<td>$0.34/ft²</td>
</tr>
</tbody>
</table>
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

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

Perpetual Present Value Cost

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

With PPVC, Can Compare Bridges Directly
Life Cycle Cost Analyses

The Steel Plate Girder Bridge Data Base

<table>
<thead>
<tr>
<th>General Information</th>
<th>Maintenance &amp; Contract Work</th>
<th>Initial &amp; LCC</th>
</tr>
</thead>
</table>

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
Life Cycle Cost Analyses

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 Study

Analysis and Variables Examined in this Video

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

For Steel Bridges
  Curved vs. Straight
  Fracture-Critical
  Protection (Painted, Weathering, Galvanized)

For the entire report:
www.ShortSpanSteelBridges.org
## 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

Probability Bridge Lasts >75 yrs
- Steel Rolled: 73.0%
- Steel Plate: 62.7%
- Conc Box Adjacent: 45.6%
- Conc Box Spread: 65.6%
- Conc I Beam: 44.3%
### Perpetual Present Value Cost – All Bridges

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

<table>
<thead>
<tr>
<th>Bridges Type</th>
<th># Bridges</th>
<th>PPVC 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>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>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>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>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>212</td>
<td>2.43</td>
<td>1985</td>
<td>73</td>
</tr>
</tbody>
</table>

Precast I Beam
Steel Rolled

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
# Future Costs

## Future Costs Compared to Initial Costs

Table 22: Life Cycle Costs and PPVC/Initial Cost for Total Database

<table>
<thead>
<tr>
<th></th>
<th># Bridges</th>
<th>PPVC</th>
<th>Initial Cost</th>
<th>Future Cost</th>
<th>Avg Life</th>
<th>PPVC/Initial Cost</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>82</td>
<td>1.20</td>
</tr>
<tr>
<td>Steel I Girder</td>
<td>144</td>
<td>$273.71</td>
<td>$226.10</td>
<td>$0.21</td>
<td>80</td>
<td>1.21</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>74</td>
<td>1.24</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>79</td>
<td>1.22</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>73</td>
<td>1.25</td>
</tr>
</tbody>
</table>

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

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

Overall Weighted Average PPVC = $252.40/ft²

Bridge Type 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
Summary

The report examines the Initial Costs, Life Cycle Costs, and Future Costs of the Bridges in the PennDOT Database.

The database is limited to bridges that met the Criteria – It is Not as Comprehensive as Desired and Results must be Taken In Context of the Database and the Database Limitations.
PennDOT Database 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

Owners Should Consider Both Steel and Concrete Alternatives for Individual Bridge Projects
Closing

Typical Steel and Concrete Bridges are Competitive in the Short Span Range for Initial Costs and Life Cycle Costs

Preconception that Concrete is always Less Expensive is Incorrect

Preliminary Steel Bridge designs are now Easily Available

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

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Thank You