Steel Buried Bridge Structure Options
Short Span Steel Bridge Workshop
West Virginia Local Technical Assistance Program
Charleston, West Virginia
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Presentation Outline

- Introduction to Buried Bridges
- Design Considerations & Inputs
- Case studies / applications
- eSPAN140
- Questions
Introduction

• Definition of Buried Bridges:
  • Any bridge that derives its support from both the structure and the surrounding soil through soil-structure interaction.
  • Generally 20 ft minimum span per AASHTO definitions or combination of smaller spans totaling at least 20 ft.
  • Structures consisting of corrugated metal are Flexible Buried Bridges.

• Flexible Buried Bridge Materials and Capabilities:

• Advantages of Flexible Buried Bridges vs. Rigid Bridges:

• Buried Bridge Applications:
Introduction

- Definition of Flexible Buried Bridges:
- Flexible Buried Bridge Materials and Capabilities:

<table>
<thead>
<tr>
<th>Property</th>
<th>Aluminum (ALSP)</th>
<th>Shallow Corrugated Steel</th>
<th>Deep Corrugated Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometry Types</td>
<td>Arch, box, closed shapes</td>
<td>Arches, closed shapes</td>
<td>Arch, box, pipe, multi-radius arches</td>
</tr>
<tr>
<td>Span Range</td>
<td>10 to ~30ft</td>
<td>5 to ~20 ft</td>
<td>10 - ~100 ft +</td>
</tr>
<tr>
<td>Corrugation Profile</td>
<td>9” x 2.5”</td>
<td>6” x 2”</td>
<td>15” x 5.5”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>19” x 9.5”</td>
</tr>
<tr>
<td>Design Yield Strength (ASTM A796)</td>
<td>24 ksi</td>
<td>33 ksi</td>
<td>44 ksi</td>
</tr>
<tr>
<td>Stiffness based on 0.25” thickness (3 gauge)</td>
<td>~1.5 x shallow</td>
<td>1 (baseline)</td>
<td>~9 x shallow</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>~6.25 x ALSP</td>
</tr>
</tbody>
</table>
Introduction

• Definition of Flexible Buried Bridges:

• Flexible Buried Bridge Types and Capabilities:

• Advantages of Flexible Buried Bridges vs. Rigid Bridges:
  • Lower foundation costs & no bump at the end of the bridge (if foundations properly designed)
  • No bridge deck or joints or bearings to maintain, repair, or replace (or keep from freezing)
  • ABC benefits - No heavy equipment or specialized labor skills needed for construction, Shorter design & material lead times than rigid bridges, Can be installed in days or weeks rather than months, easier & cheaper to transport.
  • Able to accommodate complex site geometries & road profiles, No need to narrow roadway (users often don’t even know when they are crossing them), Can be lengthened for future road widening
  • Structural redundancy, aesthetic flexibility, sustainability benefits

• Buried Bridge Applications:
Introduction

• Definition of Flexible Buried Bridges:

• Flexible Buried Bridge Types and Capabilities:

• Advantages of Flexible Buried Bridges vs. Rigid Bridges:

• Buried Bridge Applications:
  • Bridge replacement
  • Limited site access
  • Remote locations
  • Grade separation
  • Drainage structures
  • Spans 5 - 80 ft +
  • Wildlife / aquatic crossings
  • Environmentally sensitive crossings
  • Canal / utility crossings
  • Pedestrian access
  • Emergency / temp / detours
Design Considerations & Inputs

• Site Geometry Inputs:
  • Min/max clear span at xx elevation or xx ft below road
  • Inside clearance / end area
  • Hydraulic considerations – maximize span to reduce / eliminate multi-cell crossings
  • Alignment relative to road
  • Available distance from bottom of structure to top of road
  • Flexibility (raise road grade, lower foundations, encroach on clearance box, etc.)

• Geometry Type:

• Site Soil Conditions & Backfill Properties:

• Loading / Performance Requirements:

• Other Considerations:
Design Considerations & Inputs

• Site Geometry Inputs:

• Geometry Type (arch vs. box):
  • Defined by AASHTO based on ratio of crown radius to haunch/side radius: >5:1 is a box
  • 2 ft min cover for box (1.5 ft for spans ≤ 25 ft 4 in), 3 ft min cover for arch
  • Box designs governed by flexural capacity, arches by thrust capacity
  • Arch geometries are lighter / more efficient / lower structure cost
  • Not an issue for specifier or owner to be concerned with – a qualified manufacturer can determine most efficient geometry based on project requirements & site limitations

• Site Soil Conditions & Backfill Properties:

• Loading / Performance Requirements:

• Other Considerations:
Design Considerations & Inputs

• Site Geometry Inputs:

• Geometry Type (arch vs. box):

• Site Soil Conditions & Backfill Properties:
  • Boring logs & historical site data
  • Local geology & experience
  • Classification tests of representative materials
  • Scour depth & other hydraulic concerns
  • Identify backfill source prior to design & bidding
  • Consider site grading impacts

• Loading / Performance Requirements:

• Other Considerations:
Design Considerations & Inputs

- **Site Geometry Inputs:**
- **Geometry Type (arch vs. box):**
- **Site Soil Conditions & Backfill Properties:**
- **Loading / Performance Requirements:**
  - HL-93 is AASHTO LRFD standard – simplifies NBI load rating reporting requirements
  - U-80, mining vehicles, E-80 Cooper, heavy trucks (heavier than legal loads)
  - Special design loads require axle loads & spacing, tire size, vehicle specs (if available)
  - Design capacity is driven by axle loading rather than GVW – less impact on design than a traditional or rigid bridge. As a result, buried bridges can generally carry higher loads.
  - Consider design benefits to raising road / lowering foundations to increase cover & carry more load

- **Other Considerations:**
Design Considerations & Inputs

- **Site Geometry Inputs:**
- **Geometry Type (arch vs. box):**
- **Site Soil Conditions & Backfill Properties:**
- **Loading / Performance Requirements:**
- **Other Considerations:**
  - Custom geometries provide lowest cost solution – define project requirements & let designer find best geometry options
  - Foundation types – design foundations based on settlement tolerance, consider foundation soil improvement to save on costs & improve quality. Biggest project cost / time savings vs. traditional & rigid bridges can come from foundations.
  - Modest investment in geotechnical engineering can pay off – have geotech consult with designer to make sure appropriate recommendations are provided. FEA designs can be customized and optimized to site.
  - Look at project costs rather than only comparative structure costs. Construction time & labor, foundations, grading, site access, equipment, maintenance, inspection, and other costs can be very different between flexible buried bridge & rigid / traditional bridge options.
Case Studies / Applications

• Small Span Rural Crossings
• NC State Veterans Home – Black Mountain, NC
• Emergency Bridge Replacement – Cape Girardeau County, MO
• Heavy Loads – NM, AK, IN, NE
• GRS Arches
Lincoln County, Colorado
56'5" span x 15' rise box structure
Black Mountain, North Carolina
Design Requirements

- New road to access new facility
- ~15’ distance from creek invert to road
- 48’ min clear span at 6’ above creek invert
- Creek bed soils sensitive to scour (sands)
- Wide span to get beyond limits of disturbance
- Sloping transverse grade
- Considered traditional bridge early on – would have required ~100 ft + span based on creek banks.
As Detailed in Project Documents

48' WIDTH
MINIMUM CLEARANCE AT ELEVATION
2309.0

APPROX. GL 2304.5±

FOUNDATION AND SCOUR DESIGN ANALYSIS BY CONCRETE SPAN ENGINEER

PROPOSED CENTERLINE GRADE

EXISTING GRADE

APPROX. GL 2305.0±
Buried Flexible Steel Bridge Option

Road Grade 3-8% max

Engineered backfill zone

Modular block wall (by others)

Sheet pile cut off walls

Site geometry

Type of End: 120' 0" Inside Span

At Elevation 2309.00

Inside rise 15'-0"

Neutral axis Elevation = ~2315.68

Cover 2.36' to 3.87'

Creek invert Elevation = ~2303.00

Toe Elevation = ~2300.45

Boat Elevation = ~2297.95

56'-5" Inside Span
## Cost Comparison

<table>
<thead>
<tr>
<th>Item</th>
<th>Rigid Bridge Structure Cost</th>
<th>Buried Flexible Steel Bridge Structure Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design, Installation, and Structure</td>
<td>$213,650</td>
<td>$205,950</td>
</tr>
<tr>
<td>Footings / Pile Caps, Ftg Excavation &amp; Dewatering</td>
<td>$52,500</td>
<td>$101,780*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* Includes cost for fnd soil improvement. Ftg larger than pipe cap.</td>
</tr>
<tr>
<td>Sheet Pile Cutoff Walls</td>
<td>$39,250</td>
<td>$39,250</td>
</tr>
<tr>
<td>H-Pile Deep Foundations</td>
<td>$360,000</td>
<td>---------</td>
</tr>
<tr>
<td>Backfill Foundation Cut</td>
<td>$10,000</td>
<td>$15,000</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td><strong>$675,400</strong></td>
<td><strong>$361,980 (-45%)</strong></td>
</tr>
</tbody>
</table>
US61 Over Buckeye Creek
Cape Girardeau County, Missouri

Twin Custom Box Structures
30’8¼” span x 11’7½” rise
Design Requirements

- Part of Missouri Safe & Sound Program
- First design-build project in Cape Girardeau County
- Emergency replacement for old steel truss bridge - critical detour route for construction on nearby I-55
- Accelerated Bridge Construction
- Hydraulic requirements (flow area)
Original Concept: 80' Span Precast Bridge
Twin Box Buried Bridge Option
## Structure Comparison

<table>
<thead>
<tr>
<th>Conventional Precast Plank Bridge</th>
<th>Twin Span Buried Bridges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inverted trapezoidal flow area – limited by sloped abutments</td>
<td>Widened hydraulic flow area at channel elevation with comparable end area</td>
</tr>
<tr>
<td>Required site re-grading</td>
<td>Minimal site grading – mainly finish grading</td>
</tr>
<tr>
<td>Approx. 100 ft of asphalt pavement removal &amp; replacement beyond bridge</td>
<td>Less than 50 ft of asphalt pavement removal &amp; replacement</td>
</tr>
<tr>
<td>Bridge abutments or sloped banks required</td>
<td>No abutments required</td>
</tr>
<tr>
<td>Required deep foundations with pile caps</td>
<td>Shallow foundations</td>
</tr>
<tr>
<td>45 days for design &amp; fabrication of bridge elements only</td>
<td>30 days for design &amp; fabrication of twin box culverts and precast MSE headwalls. Includes design, submittal, approval, material acquisition, fabrication, galvanizing, curing, &amp; delivery.</td>
</tr>
</tbody>
</table>
eSPAN140

• Enter project info as you would for a bridge

Notice: Based on the span length you have entered, eSPAN140 will include designs for: Buried Soil Steel Bridge Solutions and Manufacturers’ Solutions. It will not include: Rolled Beam (standard designs), Homogeneous Plate Girders (standard designs), and Hybrid Plate Girders. If this is not your intention, please click the "back" button to correct the value for "bridge length".
eSPAN140

- Make best guess at hydraulic requirements, know AASHTO minimum cover requirements
eSPAN140

- Review inputs & wait for results

Success!

Thank you for providing your input values into eSPAN140. The system is currently working to develop your customized Solutions Book – it will appear on your screen in just a few moments. You will also automatically receive an email containing a link to view and share your Solutions Book.

If you would like to print the file, it is recommended that you use the 11” x 17” printer setting for optimum viewing (although 8 ½” x 11” paper will also work – but the print will be smaller).

eSPAN140 will automatically save the input values and Solutions Book into your profile. In the future, you can view, edit, and share the document directly from your profile in eSPAN140 simply by logging into your account utilizing the username (your email address) and password you created.

If you have Questions, please contact our Bridge Technology Center.

Your Project Results
Once available, you can view your project here:

Click here to download your pdf.

Start New Project  Return to Projects
SuperCor® Steel Structural Plate & Vehicular Modular Bridges

Super Cor® Steel Structural Plate

Structural plate bridges are low-maintenance and lend themselves to numerous aesthetic possibilities in end treatments. They are ideal for staged construction applications and can also be used to reline existing structures. Super Cor® combines the advantages of lightweight construction with the superior strength and durability of deep corrugated, galvanized steel to create some of the world’s largest corrugated metal structures. The larger, annual corrugations (15” pitch x 5.5” depth) in Super Cor® provide nine times the stiffness of conventional structural plate, allowing it to withstand the heaviest of loads. Not only is Super Cor® the most versatile and economical corrugation on the market, it is also the most internationally accepted and widely-used.

Vehicular Modular Bridges

As the name suggests, these bridges are manufactured and shipped in modular sections that allow for rapid installation. Using equipment on hand, local crews can typically place the superstructure in one day – reducing costs and road closure time. Superstructures can be fabricated with both square and skewed ends to suit any site conditions. We also offer Portable Detour Bridges.

- Strong: able to withstand heavy-duty loading
- 8’ wide modules are typical
- 4.25” corrugated steel deck (galvanized) is standard
- Decking options – poured or precast concrete, asphalt, grating, wood or gravel
- Weathering, galvanized or painted structural steel
- Curb or rail system
- Sidewalks and utility corridors can be added to enhance use
Heavy Loads
Grants, New Mexico
2.7m lbs. Mining Shovel, 47 ft span
Knox County, Indiana
E-80 Cooper Engine, 52.5 ft span
Fort Knox Gold Mine
Fairbanks, Alaska
1.8m lbs. Mining Shovel, 46 ft span
Randolph, Nebraska
E-80 Cooper Engine, 3.67 ft cover, ~50 ft span
LaCygne, Kansas
RR Grade Separation, ~53.5 ft span
County Road Over Dual Track Crossing
Thank You!

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