Introduction to Buried Bridges

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Outline

• Introduction to Buried Bridges
• Case Studies / Applications
• Questions
Buried Bridge Overview

• Definition of Buried Bridges:
  • Buried Bridge is any bridge that derives its support from both the structure and the surrounding soil through soil-structure interaction. Structures consisting of corrugated metal are Flexible Buried Bridges.
  • AASHTO LRFD Bridge Design Specifications Section 12.8.9 (design).
  • AASHTO LRFD Bridge Construction Specifications Section 26 (construction).
  • AASHTO Materials Specifications – M167
  • AREMA Chapter 1, Section 4
## Buried Bridge Materials

**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>Small 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</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>
Buried Bridge Profiles

• Flexible Buried Bridge Materials and Capabilities:

Advantages of Flexible Buried Bridges vs. Traditional Bridges:

LVR Buried Bridge Applications:
Raw Materials – Steel Coil
Corrugating
Punching Bolt Holes
Forming – Computerized 3-Roll
Galvanizing
Shipping
Buried Bridge Design

- Shallow corrugated structures use empirical design methods – no consideration for site conditions
- AASHTO LRFD requires finite element analysis (FEA) for deep corrugated structures (corrugation profile depth > 5”). FHWA developed CANDE for FEA designs.
- Soil-structure interaction – backfill and structure work together to carry load
- FEA provides flexibility – possibly design heavier structure to be able to use lower quality backfill or optimize structure using high quality backfill
- Custom geometries provide the most economical & efficient designs
- Designs consider inputs based on site conditions – each design is customized to the site
Buried Bridge Advantages

• Advantages of Flexible Buried Bridges vs. Rigid Bridges:
  • No bridge deck or joints or bearings to maintain, repair, or replace
  • Lower foundation costs & no bump at the end of the bridge (if foundations properly designed)
  • Able to accommodate complex site geometries & road profiles, No need to minimize bridge width (allowing for pedestrian access, bike lanes, etc.), Can be lengthened for future road widening
  • Structural redundancy, resilient, aesthetic flexibility, sustainability, enhanced safety benefits
  • Often able to reuse bridge foundations
  • 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.

Eddyville, OR

Edwards, MS
Durability & Service Life

• Buried bridges typically have no invert
• Steel structures have 50% more galvanizing than CSP and are available in much higher steel thicknesses (currently ~1/3 inch)
• Backfill electrochemical requirements apply for soil & water in contact with the structure – not necessarily site soil conditions.
• Use same backfill electrochemical requirements as those in AASHTO LRFD Design Section 11.10.6.4.2 for MSE walls. Considers pH, resistivity, chlorides, sulfates, organics.
• Added features/detailing like splash walls can limit exposure.
• Secondary coatings (polyurea, epoxy, asphalt, polymer, etc.) can be used in harsh conditions.
• Barriers can be used to shed surface water to prevent leaking and protect from de-icing chemicals
• American Galvanizers Association (AGA) is a good resource for information on performance of galvanized structures www.galvanizeit.org

• Service life primarily depends on proper installation, maintenance, and what structure is exposed to. End user (owner) has greatest impact on service life.
Typical Applications

• Buried Bridge Applications:
  • Bridge replacement
  • Limited site access / remote locations
  • Grade separation
  • Staged construction
  • Drainage structures
  • Rehabilitation of existing bridges
  • Wildlife / aquatic crossings
  • Environmentally sensitive crossings
  • Pedestrian access
  • Emergency / temp / detours
  • Single span alternative for multi-cell hydraulic crossings
  • Any bridge project!

Dubois, WY

Vicksburg, MS

Gray, ME
Case Studies / Applications

- Phased Construction – Spokane, WA
- Emergency Bridge Replacement – Cape Girardeau County, MO
- ABC Temporary Bridge – Attleboro, MA
- Foundation Cost Savings – Black Mountain, NC
- Bridge Replacement – St. Johnsbury, VT
- Additional Projects
US 2 Lowering – Spokane, WA

- Part of US 2 / US 395 interchange reconstruction
- Replacement of smaller precast structure to allow fish passage
- 30’ span deep corrugated steel arch with ~40’ cover
- Staged construction with temporary MSE wall & lagging wall
US61 Over Buckeye Creek
Cape Girardeau County, Missouri
Twin Custom Box Structures
30’8¼” span x 11’7½” rise

• Emergency replacement for old steel truss bridge - critical detour route for construction on nearby I-55
• Accelerated Bridge Construction
• Incorporated MSE Headwalls.
Original Concept: 80’ Span Precast Box Beam Bridge
Twin Box Buried Bridge Option
<table>
<thead>
<tr>
<th>Conventional Precast Box Girder 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>
I-95 Temporary Bridge over North Ave
Attleboro, Massachusetts
56’6” span x 17’9” rise Box Structure

- Carrying I-95 traffic during replacement of twin bridges
- VE alternative to Bailey Bridge
- Saved 4mo on project & won job for contractor
- 100 plates assembled in one 16hr day by first time contractor
- Incorporated MSE Wire Headwalls.
56’5” span x 15’ rise box structure
Black Mountain, North Carolina

• ~15’ distance from creek invert to road
• 48’ min clear span at 6’ above creek invert
• Stream 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
- EXISTING GRADE
- PROPOSED CENTERLINE GRADE
- 8.00% down
- 2.00% up
Buried Flexible Steel Bridge Option

- **Engineered Backfill Zone**
- **Modular Block Wall (by Others)**
- **Sheet Pile Cut Off Walls**
- **Road Grade 3.8% Max.**
- **Cover 2.36' to 3.87'**
- **Neutral Axis El. = ~2315.68**
- **Creek Invert El. = ~2303.00**
- **Tof El. = ~2300.45**
- **Bof El. = ~2297.95**
- **49'-3" Inside Span @ ELEV 2309.00**
- **56'-5" Inside Span**
- **Site Geometry**
- **Inside Rise 15'-0"**
## 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>* Includes cost for fnd soil improvement. Ftg larger than pipe cap.</td>
<td></td>
<td></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>
Replacement for 139 ft 3-span steel & concrete bridge built in 1936
Sized for AREMA clearance
28 day max. trail closure / 50 day road closure for all work
1.5 days for assembly by first time contractor, open to public in 45 days
Incorporated MSE precast panel headwalls on curve.
Used precast footings – sized to match anticipated settlement of approach embankments.
Other Applications
Randolph, Nebraska
E-80 Cooper Engine, 3.67 ft cover, ~50 ft span
Grants, New Mexico
2.7m lbs. Mining Shovel, 47 ft span
LaCygne, Kansas
RR Grade Separation, ~53.5 ft span
County Road Over Dual Track Crossing
Topeka, Kansas
Reline of 40’ span x 200’ long concrete arch under I-70
Laguna Niguel, California
Twin 39.7’ span x 13.2’ rise Buried Bridges
Hydraulic Improvements & Signature Entrance to City Park
Houston, Texas
Phased Construction
Recycled Concrete Backfill
Architectural Requirements
Findlay, Ohio
I-75 Bridge Replacement
Phased Construction
Knox County, Indiana
E-80 Cooper Engine, 52.5 ft span
Coos Bay, Oregon
26’ span with 48’ cover
Banff, Alberta
Wildlife Crossing
Thank You!

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