Research Update on Selected Buried Structures Topics

Jesse L. Beaver, PE
Chair, TRB AFF70

Matthew C. Richie, PE
Outline

1. NCHRP Project 14-26 Culvert and Storm Drain System Inspection Manual
2. Structural Steel Plate Seam Strength Testing – Project Status
3. TRB Committee AFF70 Culverts and Hydraulic Structures – Research Update
NCHRP Project 14-26
Culvert and Storm Drain System Inspection Manual

Jesse L. Beaver, PE
Matthew C. Richie, PE
NCHRP Project 14-26

• Completed: May 2016
• Objective: Develop an inspection manual for assessing the condition of in-service culvert and storm drain systems to ensure system safety and performance and the economical use of owner resources.
• Oversight Panel Representation: DOT, FHWA, Industry, Consultants, Academia
• Final Deliverable: Final Report with Culvert and Storm Drain System Inspection Manual
  – Manual is submitted to AASHTO for publication
CULVERT AND STORM DRAIN SYSTEM INSPECTION MANUAL

FINAL REPORT

Prepared for
NCHRP 14-26 Culvert and Storm Drain System Inspection Manual

Transportation Research Board
of
The National Academies

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES
PRIVILEGED DOCUMENT

This document, not released for publication, is furnished only for review to members of or participating in the work of CRP. This document is to be regarded as fully privileged, and dissemination of the information included herein must be approved by CRP.

Jesse L. Beaver
Matthew C. Richie
Simpson, Gumpertz & Heger, Inc.
Waltham, MA
May 2016
Inspection Manual Table of Contents

• Section 1 – Introduction
• Section 2 – Design and Performance Characteristics
• Section 3 – Inspection Procedure
• Section 4 – Condition Rating System
• Section 5 – Inventory Management
• Appendix A – Structural Shapes and Materials: Describes various culvert and storm-drain barrel shapes, components, and materials.
• Appendix B – Catalog of Distressed Conditions
Section 1 – Introduction

• Introduces culvert and storm drain system inspection
• Outlines need for standardized inspection program
• Provides the manual objectives
• Identifies the intended audience
• Instructs users on the manual organization and use for inspections.

Figure 1.2-3 – Roadway Collapse Due to Structural Failure of Culvert
(Photo courtesy of Iowa Department of Transportation)
Section 2 – Design and Performance Characteristics

- Introduces the general factors that affect structural and functional performance of culvert and storm drain barrels.
- Introduces structural shapes and materials for pipe, coatings, and linings.
- Introduces various culvert and storm drain system components.
- Refers to Appendix A for additional details.

**Debris Barriers** are grates or cribbing installed at the inlet to prevent large debris from entering the barrel and redirect smaller debris (align orientation of debris with barrel) so that it can easily pass through the culvert barrel.

*(Photo source: FHWA Debris Control Structures Evaluation and Countermeasures, Hydraulic Engineering Circular No. 9)*
Construction and Installation Requirements

Construction and installation practices play a critical role in the structural behavior of flexible and rigid culverts and storm drains. Critical items are discussed briefly in the following text.

Installation Conditions

Culverts and storm drains are installed in excavated (narrow) trench, or in embankments. Figures 2.2-11 and 2.2-12 depict typical trench and embankment cross-section with associated terminology. Governing design standards define the allowable geometry, soil types, and level of compaction for each of the installation types shown. Project drawings and specifications provide the site-specific installation details. In the structural design of culverts, the soil or embankment material surrounding the culvert plays an important role in supporting the pipe and maintaining joint integrity. If bedding or compaction is inadequate, rigid pipe sections may separate resulting in joint separation and offset. Flexible pipe may deflect, resulting in sags and heaves along the pipe length.
Section 3 – Inspection Procedure

• Covers inspection frequency
• Details preparation and planning inspections
• Provides types of inspections/entry with action sequence
• Recommends qualifications of the inspector and team and lists typical equipment
• Provides quality control and quality assurance practices
• Introduces inspection safety
# Recommended Inspection Frequency

<table>
<thead>
<tr>
<th>Barrel Size (S)</th>
<th>Inspection Frequency (Ratings ≤ 2)</th>
<th>Inspection Frequency (Ratings ≥ 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Installation (S &gt; 1 ft)</td>
<td>Inspect annually for the first 2 years after construction.</td>
<td>N/A</td>
</tr>
<tr>
<td>S ≤ 1 ft</td>
<td>No routine inspection required. Inspect during roadway maintenance activities.</td>
<td>No routine inspection required. Inspect during roadway maintenance activities.</td>
</tr>
<tr>
<td>1 ft &lt; S ≤ 4 ft</td>
<td>Every 10 years or prior to routine roadway maintenance activities, whichever is less.</td>
<td>At least every 5 years and with routine roadway maintenance activities.</td>
</tr>
<tr>
<td>4 ft &lt; S ≤ 10 ft</td>
<td>Every 5 years or prior to routine roadway maintenance activities, whichever is less.</td>
<td>At least every 2 years and with routine roadway maintenance activities.</td>
</tr>
<tr>
<td>S &gt; 10 ft</td>
<td>Every 2 years</td>
<td>At least every 2 years and with routine roadway maintenance activities.</td>
</tr>
</tbody>
</table>
Inspection Types

- **Initial (Inventory) Inspection**
  - First inspection after commissioning, used to verify the as-built structure meets the design, record the necessary data for the inventory and asset management system

- **Routine Inspection**
  - Conducted on a defined frequency using rating system described in the manual

- **Special Inspection**
  - Conducted outside of the routine inspection to monitor specific distress or to conduct an in-depth review
  - May be triggered by a critical or failed rating to determine corrective action
  - May also be used to inspect at more frequent intervals due to accelerated deterioration that may reach critical stage sooner than would be captured under the routine inspection schedule
  - Used to monitor new structural materials, types of structures, or system details being evaluated on a trial or research basis.

- **Damage Inspection**
  - Unscheduled, event-driven inspection, i.e. to assess damage after flooding, fires, appearance of roadway sinkholes, or traffic accidents
The Inspection Team and Qualifications

There are no specific federal guidelines for qualifications of culvert and storm drain system inspectors. The National Bridge Inspection Standards (NBIS) describe the minimum qualifications for three levels of bridge inspection personnel. A similar system is used for culvert and storm drain system inspection in this manual. The inspection team personnel include: the Program Manager, the Inspector, and the Assistant Inspector.

Program Manager

Role
The program manager is responsible for managing the agency culvert and storm drain system inspection program. This individual generally supervises the inspection teams and can provide guidance or assistance to the inspection teams when problems are encountered. The Program Manager is responsible for inspection quality assurance.

Qualifications
The program manager shall have a minimum of ten years of bridge or culvert inspection experience and be a registered Professional Engineer in the state in which they are conducting inspections. Program managers shall have completed agency inspection training and be thoroughly familiar with the provisions in this manual.

Inspector

Role
The inspector is in charge of the culvert or storm drain system inspection team and is responsible for the onsite supervision and direction of the inspection team, including all assistant inspectors. The inspector is responsible for inspection quality control by ensuring the quality, completeness, and consistency of the work produced by the inspection team. The inspector approves and signs all final inspection reports. For personnel safety, ease of inspection, measuring, and documenting, inspection teams should be composed of at least two people, including the inspector and at least one assistant inspector.

Qualifications
The inspector shall have a minimum of five years of bridge or culvert inspection experience or be a registered Professional Engineer in the state in which they are conducting inspections. Inspectors shall have completed agency inspection training and be thoroughly familiar with the provisions in this manual.

Assistant Inspector

Role
Assistant inspectors perform the day-to-day routine inspections under the direct supervision of an inspector, including assignment of component condition ratings using the tables in Section 4.

Qualifications
Assistant inspectors shall have completed agency inspection training and be thoroughly familiar with the provisions in this manual.
### Sample Inventory and Inspection Forms

#### CULVERT & STORM DRAIN INVENTORY FORM

<table>
<thead>
<tr>
<th>Structure ID</th>
<th>Date Last Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route &amp; Milepost</td>
<td>Inspection Frequency</td>
</tr>
<tr>
<td>AOP Plan</td>
<td>Date Last Maintenance</td>
</tr>
</tbody>
</table>

#### LOCATION, FEATURES, & ROADWAY

<table>
<thead>
<tr>
<th>County</th>
<th>Year Built</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance Unit</td>
<td>Year Reconstructed</td>
</tr>
<tr>
<td>City / Town</td>
<td>Barrel Material</td>
</tr>
<tr>
<td>Roadway Surface</td>
<td>Shape</td>
</tr>
<tr>
<td>Number of Lanes</td>
<td>Span (in.)</td>
</tr>
<tr>
<td>ADT (Yearly)</td>
<td>Rise (in.)</td>
</tr>
<tr>
<td>Truck ADT (Yearly)</td>
<td>Length (ft)</td>
</tr>
<tr>
<td>Features Crossed</td>
<td>Skew (deg)</td>
</tr>
<tr>
<td>Features Carried</td>
<td>Wall Gage/Thickness</td>
</tr>
</tbody>
</table>
Section 4 – Condition Rating System

• Provides quantitative criteria for rating the condition of culvert and storm drain system components
• Tables instruct assignment of a condition rating from 1 to 5 using specific criteria obtained by visual inspection or basic measurements
Quantitative Measures of Distress

Sedimentation and Debris
Accumulation of debris and sediment at the inlet or within the culvert barrel reduces both the size of the opening and the culvert's capacity to handle peak flows and may cause scour of the stream banks and roadway embankment, head cutting, or changes in the channel alignment. Debris and sediment accumulations at the culvert inlets or within the culvert barrel may result in roadway overtopping, excessive ponding, and the potential for damage due to buoyant forces. Deposits of debris or sediment that could block the culvert or cause local scour in the stream channel should be noted. Downstream obstructions which cause water to pond at the culvert's outlet may also reduce the culvert's capacity. The following guide should be used to evaluate severity of sedimentation and debris:

Fair – Depth of blockage less than 10% of pipe diameter
Poor – Depth of blockage between 10% and 30% of pipe diameter
Critical – Depth of blockage greater than 30% of pipe diameter

Figure 4.5-7 – Sedimentation: Fair (Left), Poor (Middle), Critical (Right)
(Photo courtesy of Simpson Gumpertz & Heger Inc.)
**Condition Rating System**

**Spalling**

Spalling is a fracture of the concrete parallel or inclined to the surface of the concrete. In precast concrete pipe, spalls often occur along the edges of either longitudinal or transverse cracks when the crack is due to overloading or poor support rather than normal tension or shrinkage cracking. Spalling may also be caused by corrosion of the steel rebar when water is able to reach the rebar through wide cracks or shallow cover. As the rebar corrodes, the oxidized steel expands, causing the concrete covering to spall. The severity of spalling can be evaluated as follows:

- **Fair** – spalls are not greater than 1/2 in. in depth and less than 6 in. in diameter or longest dimension. No exposed rebar.
- **Poor** – spalls are not greater than 3/4 in. in depth and larger than 6 in. in diameter or longest dimension. No exposed rebar.
- **Critical** – spalls are greater than 3/4 in. depth with exposed rebar.

Spalling may be detected by visual examination of the concrete along the edges of cracks. Tapping with a hammer should be performed along cracks to check for areas that have fractured but are not visibly debonded. For large arch or box-shaped culverts, this inspection will require a ladder or other safe means to access the culvert wall and top slab. Debonded areas will produce a hollow sound when tapped. These areas may be referred to as delaminations or incipient spalls. Figure 4.10-4 shows an example of spalling at a crack.

![Figure 4.10-4 - Small Spall Along Crack, Large Spall with Exposed/Corroded Rebar](Photo courtesy of American Concrete Pipe Association)
Numerical Rating System

• 5-point scale (1986 manual had 10-point scale)
• Component level ratings (similar to bridge element inspection).
• Rating descriptions based on consensus standards from a broad range of sources compiled during our literature review
  – industry research
  – manufacturer’s literature
  – design standards
  – experience of the research team
## Rating Scale and Action

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOOD</td>
<td>Like new, with little or no deterioration, structurally sound and functionally adequate.</td>
<td>Some deterioration, but structurally sound and functionally adequate.</td>
<td>Significant deterioration and/or functional inadequacy, requiring maintenance or repair.</td>
<td>Very poor conditions that indicate possible imminent failure which could threaten public safety.</td>
<td>Failed or non-functional condition.</td>
</tr>
<tr>
<td>FAIR</td>
<td>ACTION INDICATED</td>
<td>No action is recommended. Note in inspection report only.</td>
<td>No immediate action is recommended, but more frequent inspection may be warranted. Maintenance personnel should be informed.</td>
<td>Team Leader (Inspector) evaluates need for corrective action and makes recommendation in inspection report.</td>
<td>Corrective action is required and urgent. Engineering evaluation is required to specify appropriate repair.</td>
</tr>
<tr>
<td>POOR</td>
<td>CRITICAL</td>
<td>FAILED</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Condition Rating Table – Concrete Barrel

<table>
<thead>
<tr>
<th>CRACKING</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOOD</td>
<td>No measurable crack width greater than hairline (maximum 0.01 in.).</td>
<td>Longitudinal cracks 0.01 in. to 0.05 in. wide (thickness of dime) with spacing of 3.0 ft. or more. Some circumferential cracks with no infiltration. Efflorescence but no rust staining emanating from cracks.</td>
<td>Longitudinal cracks between 0.05 in. and 0.1 in. wide, no exposed rebar with spacing 1.0 - 3.0 ft. Water infiltration through circumferential cracks. Efflorescence and/or rust staining emanating from cracks. No cracks with vertical offset. No increase in cracking from previous inspection.</td>
<td>Longitudinal cracks greater than 0.1 in. wide, exposed rebar, significant water infiltration and/or soil migration. Cracks with vertical offset. Large areas of rust staining emanating from cracks.</td>
<td>Collapse (complete or partial) or imminent collapse of culvert barrel.</td>
</tr>
<tr>
<td>FAIR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POOR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRITICAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAILED</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SLABBING, SPALLING, DELAMINATION, PATCHES</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOOD</td>
<td>No spalling or slabling, as indicated by wall visual appearance. No delamination. No delaminations that are sound.</td>
<td>Localized spalls less than 1/2 in. depth and less than 6 in. in diameter. No exposed rebar. No slabbing. Small delaminations indicated by hollow sounds at patches but patch remains stable.</td>
<td>Spalling and/or delaminations from 1/2 in. to 3/4 in. in depth and larger than 6 in. in diameter. No exposed rebar. Some rust staining from spalled areas, structure stable. No slabbing. Patched areas that are delaminated or deteriorating.</td>
<td>Widespread spalling greater than 3/4 in. in depth or delamination with exposed rebar, structure unstable. Slabbing of concrete.</td>
</tr>
<tr>
<td>FAIR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POOR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRITICAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAILED</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DETERIORATION</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOOD</td>
<td>No scaling, abrasion, or other surface damage.</td>
<td>Light or moderate scaling (less than 0.25 in. exposed aggregate). Abrasion less than 0.25 in. deep over less than 20% of pipe surface. Localized superficial (less than 0.25 in.) impact damage No rebar exposed. Multiple plugged weep holes.</td>
<td>Moderate to severe scaling (aggregate clearly exposed). Abrasion between 0.25 in. and 0.5 in. deep over more than 30% of pipe surface. Impact damage with exposed rebar.</td>
<td>Extensive surface damage and aggregate pop-out. Includes exposed and/or corroded rebar. Complete invert deterioration and loss of pipe wall section.</td>
</tr>
<tr>
<td>FAIR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POOR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRITICAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAILED</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Section 5 – Inventory Management

- Presents tools for developing a culvert and storm drain inventory and asset management program
- Gives examples for culvert and storm drain asset management practices
- Provides references for further research into this significant topic

In response to growing emphasis and requirements for infrastructure asset management, AASHTO published the *AASHTO Transportation Asset Management Guide – A Focus on Implementation*. This guide is the recommended resource for development of a culvert and storm drain system asset management plan.

AASHTO’s Subcommittee on Asset Management defines Transportation Asset Management (TAM) as a strategic and systematic process of operating, maintaining, and upgrading physical assets effectively throughout their lifecycle. It focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision-making based upon quality information and well-defined objectives. The goal is to minimize the costs for managing and maintaining transportation assets, including roads, bridges (and bridge-length culverts), tunnels, rails, and roadside features.
Appendix A – Structural Shapes and Materials

- Augments Sections 2 and 4
- Describes culvert and storm drain barrel shapes
- Lists common culvert and storm drain barrel materials
- Describes culvert and storm drain system components
Appendix B – Distressed Conditions Catalog

• Provides inspectors with a visual comparator for assessing the condition of typical culvert and storm drain system component

• Organized to match the distress conditions listed in condition rating tables of Section 4

• Includes a range of distress advancement for specific components and specific distress modes
Distressed Conditions Photographs

- Contacted over 200 sources for photographs, representing all 50 States, plus international sources
- Collected over 3,500 photos
- Obtained copyright permissions for all photographs allowing publication by AASHTO
CONCRETE BARREL

Cracking

Critical: Longitudinal cracks greater than 0.1 in. wide, exposed rebar, significant water infiltration and/or soil migration. Cracks with vertical offset. Large areas of rust staining emanating from cracks.

Failed: Collapse (complete or partial) or imminent collapse of culvert barrel.
## CONCRETE BARREL

### Cracking

**Fair:** Longitudinal cracks 0.01 in. to 0.05 in. wide (thickness of dime) with spacing of 3.0 ft or more. Some circumferential cracks with no infiltration. Efflorescence but no rust staining emanating from cracks.

<table>
<thead>
<tr>
<th>Image</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.jpg" alt="Image" /></td>
<td>Longitudinal cracks less than 0.01 in. Some circumferential cracks with no infiltration. Courtesy of Delaware Department of Transportation.</td>
</tr>
<tr>
<td><img src="image2.jpg" alt="Image" /></td>
<td>Crack width less than 0.05 in. with spacing greater than 3.0 ft. Courtesy of Simpson Gumpertz &amp; Heger.</td>
</tr>
<tr>
<td><img src="image3.jpg" alt="Image" /></td>
<td>Efflorescence through cracks less than 0.05 in. Courtesy of Simpson Gumpertz &amp; Heger.</td>
</tr>
</tbody>
</table>

**Poor:** Longitudinal cracks between 0.05 in. and 0.1 in. wide, no exposed rebar with spacing 1.0 – 3.0 ft. Water infiltration through circumferential cracks. Efflorescence and/or rust staining emanating from cracks. No cracks with vertical offset. No increase in cracking from previous inspection.

<table>
<thead>
<tr>
<th>Image</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image4.jpg" alt="Image" /></td>
<td>Longitudinal cracks between 0.05 in. and 0.1 in., no exposed rebar. Minor water infiltration through cracks. Courtesy of Kentucky Transportation Center.</td>
</tr>
<tr>
<td><img src="image5.jpg" alt="Image" /></td>
<td>Longitudinal cracks at crown and springline up to 0.1 in. Courtesy of Kentucky Transportation Center.</td>
</tr>
<tr>
<td><img src="image6.jpg" alt="Image" /></td>
<td>Cracks up to 0.1 in. with efflorescence and rust staining. Courtesy of Kentucky Transportation Center.</td>
</tr>
</tbody>
</table>
Conclusions

• New manual is available for use by AASHTO with rights to all content available from NCHRP
• Manual is ready for immediate use for condition assessment of in-service culverts
• Inspectors will be able to easily transition to new criteria based on use and implementation of consensus industry standards
Structural Steel Plate
Longitudinal Seam Strength Testing

Project Status

Jesse L. Beaver, PE
Outline

• Develop a standard ASTM practice for testing seam strengths
• Evaluate ASTM A796 seam strengths for 15” x 5.5” corrugations with 45” panel widths
• Recommend seam strengths for larger thickness plates that are not in ASTM A796 (Tables 34 and 35)
• Conduct preliminary evaluation of alternatives to full-scale testing
Standard Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications

TABLE 34 Sectional Properties of Corrugated Steel Plates for Corrugation: 15 by 5 1/2 in. (Annular)

<table>
<thead>
<tr>
<th>Specified Thickness, in.</th>
<th>Ultimate Strength of Bolted Structural Plate Longitudinal Seams in Pounds per Foot of Seam 6 Bolts per Corrugation$^A$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.140</td>
<td>66 000</td>
</tr>
<tr>
<td>0.170</td>
<td>87 000</td>
</tr>
<tr>
<td>0.188</td>
<td>102 000</td>
</tr>
<tr>
<td>0.218</td>
<td>127 000</td>
</tr>
<tr>
<td>0.249</td>
<td>144 000</td>
</tr>
<tr>
<td>0.280</td>
<td>159 000</td>
</tr>
</tbody>
</table>

$^A$ The number of bolts per corrugation includes the bolts in the corrugation crest and in the corrugation valley; the number of bolts within one pitch. The ultimate seam strengths listed are based on tests of staggered seams in assemblies fabricated from panels with a nominal width of 30 in. and include the contribution of additional bolts at the stagger. The listed ultimate seam strengths are only applicable for panels with a nominal width of 30 in. and with staggered seams.
Panel Width and Test Specimens
New Draft ASTM Standard for Seam Strength Test

Standard Practice for Testing the Ultimate Strength of Bolted Longitudinal Seams in Deep Corrugated Structural Plate (Long Span) Structures

9.5 Calculate the Normalized Seam Strength, \( SS \) (lbs/ft), as follows:

\[
SS = \min \left( \frac{P_{\text{max}}}{L_{\text{eff}} * M_{\text{red}}} , \left( \frac{P_p}{L_{\text{eff}}} \right) , \left( \frac{V_{\text{bnt}}}{L_{\text{eff}}} \right) \right)
\]
ASTM Standard & Status

• Expected to ballot ASTM subcommittee in the Fall
• Will be further generalized to capture testing for most seam strengths in ASTM A796
• Includes failure modes assessment
  – Local buckling
  – Bolt Prying
  – Bolt Hole Bearing
  – Bolt Shear Failure
  – Block Shear Rupture
Seam Strengths for 15” x 5.5” @ 45”

- Physical Testing on full-scale specimens
  - Gages tested with 3/4” bolts – 8, 7, 5, 3, 1
  - Gages tested with 7/8” bolts – 0 (5/16”), 000 (3/8”)
- Physical Testing on small-scale specimens
  - 7 gage (0.188 in.)
- Finite element analysis of plate buckling
- Test results normalization
- Incorporation of failure modes into the draft standard

<table>
<thead>
<tr>
<th>Thickness (in.)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.170</td>
<td>8 GA</td>
</tr>
<tr>
<td>0.188</td>
<td>7 GA</td>
</tr>
<tr>
<td>0.218</td>
<td>5 GA</td>
</tr>
<tr>
<td>0.249</td>
<td>3 GA</td>
</tr>
<tr>
<td>0.280</td>
<td>1 GA</td>
</tr>
<tr>
<td>0.313</td>
<td>0 GA</td>
</tr>
<tr>
<td>0.375</td>
<td>000 GA</td>
</tr>
</tbody>
</table>
Full-Scale Test Specimen & Instruments

• Vertical displacement – min 3 locations
• Bolt rotation – min 3 locations
• Load
  – Min every 10 s
  – Accurate within 0.5% of ultimate load
• Three plate length
  – For 45” plate = 11 ft - 3 in.
  – For 30” plate = 7 ft - 6 in.
Load-Displacement Plots

- **Buckling Failure**

- **Bolt Shear Failure**
FEA Plate Buckling Modes
Results of testing

- All values in ASTM A796 are acceptable for 45” plate
- Missing values will be provided
- ASTM subcommittee ballot in the Fall will include 45” plate and new seam strengths
- After approval at ASTM, the values will come to AASHTO
TRB Committee AFF70
Culverts and Hydraulic Structures

Research Update

Jesse L. Beaver
TRB AFF70 Activities

• Active executive committee
• Triennial strategic plan (TSP) submitted this year
• Interacted with T-13 and AFS40 on research topics
• Technology transfer presentations at annual meeting
• Actively drafting research needs statements (RNS)
• Nominated a new emeritus member
• Sponsored webinar
• 2 new subcommittees
• Research underway
• Workshop for annual meeting
• Paper submissions are open in 1 month
# AFF70 Executive Committee

<table>
<thead>
<tr>
<th>Role</th>
<th>Name</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chair</td>
<td>Jesse L. Beaver</td>
<td><a href="mailto:jlbeaver@sgh.com">jlbeaver@sgh.com</a></td>
</tr>
<tr>
<td>Committee Research Coordinator</td>
<td>Kean Ashurst</td>
<td><a href="mailto:kashurst@engr.uky.edu">kashurst@engr.uky.edu</a></td>
</tr>
<tr>
<td>Committee Communications Coordinator</td>
<td>Michael Pluimer</td>
<td><a href="mailto:michael.pluimer@gmail.com">michael.pluimer@gmail.com</a></td>
</tr>
<tr>
<td>Secretary</td>
<td>Kim Spahn</td>
<td><a href="mailto:kspahn@concrete-pipe.org">kspahn@concrete-pipe.org</a></td>
</tr>
<tr>
<td>Chair, Subcommittee on Buried Bridges</td>
<td>Joel Hahm</td>
<td><a href="mailto:jhahm@bigrbridge.com">jhahm@bigrbridge.com</a></td>
</tr>
<tr>
<td>Chair, Subcommittee on Resilience and Sustainability</td>
<td>Kevin Williams</td>
<td><a href="mailto:kwilliams@ail.ca">kwilliams@ail.ca</a></td>
</tr>
<tr>
<td>Young Members Council, AFF70 Rep</td>
<td>Ashley Wilson</td>
<td><a href="mailto:ashley.wilson@lehighhanson.com">ashley.wilson@lehighhanson.com</a></td>
</tr>
</tbody>
</table>
Search Results

Record Type: RNS
Keywords: “AFF70”

Results 1 - 6 out of 6 [Page 1 of 1]

Marked projects: Print view Summary Print view E-mail
Select projects: This page Clear page Clear all

- Prevention of Soil Migration into Coarse Aggregate Pipe Trench Backfill
  Committee: AFF70, Culverts and Hydraulic Structures
  Date Posted: 3/14/2016
  Date Modified: 3/25/2016

- LRFD Calibration of Design Methods for Culverts and Buried Bridges
  Committee: AFF70, Culverts and Hydraulic Structures
  Date Posted: 3/14/2016
  Date Modified: 3/25/2016

- Structural Design Methods for Alternate Culvert Systems Based on Equivalent Risk Factors
  Committee: AFF70, Culverts and Hydraulic Structures
  Date Posted: 3/7/2013
  Date Modified: 2/15/2015

- Modulus-Based Quality Control in Culvert Backfill Installation
  Committee: AFF70, Culverts and Hydraulic Structures
  Date Posted: 3/7/2013
  Date Modified: 1/7/2015

- Bedding Design for Culverts and Underground Structures to Improve Performance and Reduce Cost
  Committee: AFF70, Culverts and Hydraulic Structures
  Date Posted: 3/7/2013
  Date Modified: 1/8/2015

- Trenchless Utility Pipe Installation and Replacement Under Highways to Minimize Traffic Disruption and Other
  Direct and Indirect Costs
  Committee: AFF70, Culverts and Hydraulic Structures
  Date Posted: 3/7/2013
  Date Modified: 5/14/2015
LRFD Calibration of Design Methods for Culverts and Buried Bridges - Objectives

• Development of load and resistance factors that properly allocate risk and provide a consistent level of safety in the designs of different culvert and buried bridge materials.

• Development of models to characterize variability of backfill soils as a material.

• Improved treatment of soil in design models to consider its contribution to both load and resistance through soil-structure interaction.

• Provide means to ensure consideration of quality control levels during the design phase.

• Improved design and construction specifications for use by engineers and contractors.
LRFD Calibration of Design Methods for Culverts and Buried Bridges -Tasks

• Literature review.
• Investigate existing models of culvert behavior used for design and evaluate their use for investigating culvert reliability.
• Develop a model for considering soil in the calibration process.
• Develop statistical data on variability of backfills used in culvert construction.
• Perform reliability analyses to establish consistent load and resistance factors.
• Propose changes to AASHTO specifications with commentary.
New RNS and Synthesis Topics

• RNS
  – How much deterioration is too much
  – Seismic design of buried bridges
  – Sustainable practices for culverts
  – Use of recycled material backfill (co-sponsor with AFS40)
  – Durability and soil-structure interaction design for a selected minimum service life
  – Updates and graphical user interface (GUI) for the culvert design software CANDE

• Synthesis
  – Identify culvert failures by characteristics and frequency
  – Summarize how DOTs spend agency dollars on culverts
  – Non-destructive msmt of flexible culvert deflections
Webinar presented 6/23/16

TRB Webinar: Introduction to Structural Design of Buried Bridges (Non-seismic)

TRB conducted a webinar on Thursday, June 23, 2016 from 2:00PM to 4:00PM ET that introduces attendees to the structural design of an alternative to traditional bridge systems when replacing or installing new bridge systems because of their reduced costs, accelerated band sustainability, and reduced maintenance. This webinar discussed sample designs and demonstrate the impacts of varying design i

This webinar was organized by the TRB Standing Committee on Culverts and Hydraulic Structures. A certificate for 2.0 Professional D and attend the webinar as an individual. Contact Reggie Gillum at RGillum@nas.edu for instructions on receiving a copy of the recorde

Here are the slides from the presentation.

Webinar Presenters

- Jesse Beaver, Simpson Gumpertz & Heger
- Joel Hahm, Big R Bridge
- Philip Creamer, CONTECH Engineered Solutions LLC

Moderated by: Jesse Beaver, Simpson Gumpertz & Heger

Webinar Outline

1. Description of buried bridges
2. Design of concrete buried bridges
3. Design of metal buried bridges
4. Advanced analysis
5. Question and answer session
Subcommittee AFF70-1
Buried Bridges

- Buried bridges are arch, three-sided, or box-shaped structures with unsupported spans (bridge lengths) greater than 20 ft that rely on soils for support.

- Subcommittee Scope
  - Concerned with the design, construction, applications, maintenance, and inspection of buried bridge systems.
  - Emphasis is placed on applications where buried bridges are used as alternative to traditional bridges.
  - Includes foundations, use of alternative construction materials, accelerated bridge construction, cost, and quality.
  - The primary goals are education and advancement in the use, applications, and capabilities of buried bridges.
## Buried Bridges

<table>
<thead>
<tr>
<th>SHAPE</th>
<th>RANGE OF SIZES</th>
<th>COMMON USES</th>
</tr>
</thead>
<tbody>
<tr>
<td>REINFORCED CONCRETE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RECTANGULAR (BOX)</td>
<td>Span 8 ft to 48 ft</td>
<td>Culverts and Short-span bridges</td>
</tr>
<tr>
<td>THREE-SIDED</td>
<td>Span 8 ft to 48 ft</td>
<td>Culverts and Short-span bridges</td>
</tr>
<tr>
<td>ARCH</td>
<td>Span 15 ft to 102 ft</td>
<td>Culverts and Short-span bridges For low, wide waterway enclosures, aesthetic bridges</td>
</tr>
<tr>
<td>CORRUGATED METAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARCH</td>
<td>Span x Rise 5 ft x 1 ft 9.5 in. to 82 ft x 42 ft</td>
<td>Culverts and Short-span bridges, Low clearance waterway, aesthetic bridges</td>
</tr>
<tr>
<td>HIGH PROFILE ARCH</td>
<td>Span 20 ft to 83 ft</td>
<td>Culverts and Short-span bridges, Grade separations, Ammunition magazines, earth covered storage</td>
</tr>
<tr>
<td>BOX</td>
<td>Span 10 ft to 53 ft</td>
<td>Culverts and Short-span bridges</td>
</tr>
</tbody>
</table>
Subcommittee AFF70-2
Resilient and Sustainable Buried Structures

• A sustainable buried structure performs its entire design life in a manner which is non-disruptive to society and the environment, minimizes life cycle cost and cradle to grave footprint, and enhances biodiversity.

• Resilience is the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events such as natural disasters and human-induced disasters.

• Subcommittee scope
  – Stimulate and communicate research related to resilience and sustainability of buried structures.
  – Integrate resilient and sustainable principles into transportation planning, decision-making, maintenance, and design of buried structures.
NCHRP Research Underway & Recently Completed

• 15-54 Culvert load rating (underway)
• 14-19 Culvert rehab methods (underway)
• 4-39 Use of recycled PE pipe (underway)
• 14-26 Culvert inspection manual (complete)
• 20-07/T347 Tests for joint watertightness (complete)
• 15-38 Structural design of culvert joints (complete)
2017 TRB Annual Meeting – AFF70

• Workshop
  – State of practice for concrete, metal, plastic pipe
  – Typical rehab methods
  – Design and installation of cementitious liner

• Technology transfer presentations

• Research paper sessions – Please encourage paper submissions from your agencies
Questions

Jesse L. Beaver, PE
Chair, TRB AFF70
781-907-9272, JLBeaver@sgh.com
Simpson Gumpertz & Heger, Waltham, MA