Design & Construction Considerations
When Lining CMP Pipe-Arches

Hugh B. Mickel, P.E.
Design Methods for Lining and Sliplining Round Pipes are Usually Straightforward
Construction Methods for Lining and Sliplining Round Pipes are Usually Straightforward
What About Pipe-Arches?
Today’s Focus Areas:

- Design Challenges
- Construction Challenges
- Pipe-Arch Case Studies
Fit/Geometry is the 1st Major Hurdle
Pipe-Arch Dimensions:
It’s much more than just span & rise
### TABLE 8-5 DETAILS OF CORRUGATED METAL PIPE-ARCHES

<table>
<thead>
<tr>
<th>Diam. of Pipe of Equal Periphery in Inches</th>
<th>Span* in Inches</th>
<th>Rise* in Inches</th>
<th>“B”* in Inches</th>
<th>Area in Sq Ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>18</td>
<td>11</td>
<td>4½</td>
<td>1.1</td>
</tr>
<tr>
<td>18</td>
<td>22</td>
<td>13</td>
<td>4¾</td>
<td>1.6</td>
</tr>
<tr>
<td>21</td>
<td>25</td>
<td>16</td>
<td>5¼</td>
<td>2.2</td>
</tr>
<tr>
<td>24</td>
<td>29</td>
<td>18</td>
<td>5½</td>
<td>2.8</td>
</tr>
<tr>
<td>30</td>
<td>36</td>
<td>22</td>
<td>6½</td>
<td>4.4</td>
</tr>
<tr>
<td>36</td>
<td>43</td>
<td>27</td>
<td>7</td>
<td>6.4</td>
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<tr>
<td>42</td>
<td>50</td>
<td>31</td>
<td>8</td>
<td>8.7</td>
</tr>
<tr>
<td>48</td>
<td>58</td>
<td>36</td>
<td>9¼</td>
<td>11.4</td>
</tr>
<tr>
<td>54</td>
<td>65</td>
<td>40</td>
<td>10½</td>
<td>14.3</td>
</tr>
<tr>
<td>60</td>
<td>72</td>
<td>44</td>
<td>11¾</td>
<td>17.6</td>
</tr>
</tbody>
</table>

*Manufacturing tolerance = plus or minus one inch.
For More Pipe-Arch History:

- Early dimensions and tolerances varied by manufacturer.
- AASHTO M-36 and present day equipment provides greater consistencies among manufacturers.
Structural Plate Pipe-Archs are in 2 Size Groupings:

- 18” Corner Radius (shown)
- 31” Corner Radius
**Standard Plate Detail**

3 3/8"

3" Spacing = 4 holes per foot standard,
6 or 8 holes per foot furnished on special
order in 1 gauge only

2 3/8"

Circumferential Seam
Holes in Crest

All Longitudinal Holes 7/8" Dia.
All Circumferential Holes 1"

1 3/8"

9.6" Spacing

3 3/8"

3 3/8"

2" ±

Inside Surface

Flow

Net Length = 10'-0" or 12'-0"
Over-all Length = 10'-4" 12'-4"
What size is this structural plate pipe-arch?

Count the spaces around the perimeter
The best method for determining available space: 3D Laser Scanning
Structural Design of Pipe-Arches is Different Compared to Round Pipe

**Figure 4.10** The pressure on a pipe-arch varies with location and radius, being greatest at the corners.
Soil Arching

How do you know it’s present?

Where is it occurring?

What can make it shift?

What can negate it?
Soil Arching

How do you know it’s present?

Where is it occurring?

What can make it shift?

What can negate it?
When Can a Reduced Load Be Used?

- **For Rigid Pipes**
  - Possibly when installation records show an induced, zero projecting or negative projecting trench installation

- **For Flexible Pipes**
  - Only if original soil arch is in place (recent movements negate it)
  - Installation records are detailed, including deflection at the time of acceptance
  - Current and full soils investigation shows backfill and prism properties are favorable, and there are no inconsistent areas indicating future consolidation or movements might occur
  - Groundwater migration isn’t possible
Crucial Factors when Determining Design Loads for Reline Applications

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1. ABSTRACT

An important yet sometimes bewildering question that occurs when an engineer, contractor or owner considers a reline option instead of a full open cut replacement is, "What loads should be used for the structural design?". Hydrostatic pressures are normally a factor. Live load pressures can be a factor, depending on the depth. Information about the original installation is critical. Perhaps the most challenging component is determination of the dead load still acting on a buried pipeline, culvert, bridge or storm/sanitary sewer. The American Association of State Highway and Transportation Officials (AASHTO) and the American Railway Engineering and Maintenance-of-way Association (AREMA) have long been leading technical authorities on buried pipe design and they are working toward establishing various rehabilitation standards for pipe, but the industry could use some commonsense guidelines now. Meanwhile those parties have been using well established principles for determining loads on buried pipes of all sizes for more than five decades. This paper reviews current methods available to help determine design loads for buried pipes in direct bury and reline situations. It discusses the applicability of these approaches and presents a number of considerations that can be important factors in determining design loads for reline applications.
- Designing Outside the Limits of AASHTO & ASTM Standards is Risky

- Examine the strength of freezing water left behind in the corrugations.
2017 ODOT Project in Brown County

BENCHMARK DATA

- SV #1: STA. 337+29.39, ELEV. 854.27, OFFSET 14.04 RIGHT
- SV #2: STA. 344+68.00, ELEV. 858.37, OFFSET 10.38 LEFT
- SV #3: STA. 347+85.38, ELEV. 862.07, OFFSET 8.36, LEFT

NOTES

- Earthwork limits shown are approximate, actual slopes shall conform to plan cross sections.

LEGEND

- #3: Rock channel protection
- Low strength mortar backfill

HYDRAULIC DATA

- Drainage Area: 1.0650 ACRES
- Normal Water: 685.38
- Flooded Water: 685.50
- Elevation: 847.40
- Outlet Elevation: 847.40
- 2'-0" MAX. COVER
- Full Height Headwall

EXISTING STRUCTURE

- Type: Existing corrugated metal plate arch with span 6'-6" and rise 6'-6"
- Loading: HS-20
- Approach: Slab: None
- Alignment: Horizontal curve 1905.65' LEFT
- Crown Varies
- Structural File Number: 0803683
- Date Built: 1964
- Disposition: Rehabilitation

PROPOSED STRUCTURE

- Type: 837 liner pipe (144” OD) MINIMUM SPAN 12'-6” AND MINIMUM RISE 7'-0”
- Coordinates: Latitude: 41.664250
- Longitude: -84.0097

PLAN VIEW OF EXISTING CULVERT
EXISTING STRUCTURE

TYPE: EXISTING CORRUGATED METAL PLATE ARCH
WITH SPAN +13'-5" AND RISE +8'-5"

ROADWAY: +59'-6", F/F GUARDRAIL
LOADING: HS-20
SKEW: 58°00'00" RIGHT FORWARD
APPROACH SLABS: NONE
ALIGNMENT: HORIZONTAL CURVE 19°05'55" LEFT
CROWN: VARIES
STRUCTURAL FILE NUMBER: 0803693
DATE BUILT: 1954
DISPOSITION: REHABILITATION

PROPOSED STRUCTURE

TYPE: 837 LINER PIPE (748.06) MINIMUM SPAN 12'-6"
AND MINIMUM RISE 7'-11"

COORDINATES: LATITUDE 38.864025
LONGITUDE -84.011977

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### Table 2.25 Structural Plate Pipe-Arch Size and Layout Details

**6 x 2 in. Corrugation—Bolted Seams**

**18-inch Corner Radius, $R_c$**

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Layout Dimensions</th>
<th>Periphery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Span, ft-in.</td>
<td>Waterway Area, ft²</td>
<td>$R_b$, ft</td>
</tr>
<tr>
<td>12-4</td>
<td>7-9</td>
<td>74</td>
</tr>
<tr>
<td>12-6</td>
<td>7-11</td>
<td>78</td>
</tr>
<tr>
<td>12-8</td>
<td>8-1</td>
<td>81</td>
</tr>
<tr>
<td>12-10</td>
<td>8-4</td>
<td>85</td>
</tr>
<tr>
<td>13-5</td>
<td>8-5</td>
<td>89</td>
</tr>
</tbody>
</table>

**Color Key:** Built / Attempted / Existing
Layover of Original & Attempted, Drawn to Design Shapes:

PROPOSED 12'-6" SPAN x 7'-11" RISE
MULTI-PLATE PIPE ARCH

111" FIELD MEASURED
111 3/4"
97 1/2" FIELD MEASURED
117 3/8"

BOLT SEAM

Ex. 13'-5" Span x 8'-5" Rise
Multi-Plate Pipe Arch
(DRAWN TO DESIGN DIMENSIONS)

1.5 PI (4.5"

BOLT SEAM
Resubmitted a 123 pi MPPA with an improved hydraulic inlet
New Structure with Improved Inlet and Paved Invert
Lessons Learned

1. Get a 3D Laser Profile if possible, or
2. Provide detailed field measurements in plans
3. Assess possibility of movements between Scoping and Construction
4. Engage us early (we have lots of knowledge)
2017 ODOT Project in Highland County
Tunnel Liner Plate with Paved Invert
1964 MPPA – 8’-10” Span x 6’-1” Rise
Under I-91 in Connecticut

- ADT: 57,000 vehicles per day
- Abrasion Level 3 site
- 22’ of fill
- Active movement
Corrosion and Invert Wall Buckling
Laser scan sections
Corrugations are 6 inches on center. No more than 4 corrugations or 24 inches removed at a time down the structure invert.

Remove no more invert then necessary and do not remove beyond the bolt seams as shown here. If more removal is required, call CBC first.

I-91 Aluminum Liner Plate Reline, Middletown, CT
Bracing the Host Structure
Aluminum Tunnel Liner Plate

- builds safe working environment as you go
- allows for partial & full tunneling with assembly done from the inside
• Inlet Control vs. Outlet Control - the governing mode is the one that produces the highest Headwater Depth (inlet end)

• HY8 v 7.50 software by FHWA

It’s a free download at: http://www.fhwa.dot.gov/engineering/hydraulics/software/hy8/
Questions?

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