APPENDIX L: PRELIMINARY STRUCTURES
I. Project: La Loma  
City of Austin

II. Problem: Calculate the factors of safety for CONTECH 2-flange liner plate for the worst case loading condition in accordance with the minimum requirements of AASHTO Section 16: "Steel Tunnel Liner Plates".

Recommended minimum factors of safety:
- Longitudinal Test Seam Strength: 3
- Pipe Wall Buckling: 2
- Installation Stiffness: 1

** Minimum stiffness for installation is selected based on job conditions and practical experience. Minimum handling stiffness is checked in these calculations but should be reviewed and approved for accuracy.

III. Material Reference Specifications:
- Liner plates are fabricated from steel conforming to ASTM A569.
- Plates with lapped seams have bolts not less than 5/8" diameter. Bolts shall conform to ASTM A449 for plate thickness equal to or greater than 0.209 inches and ASTM A307 for plate thickness less than 0.209 inches.
- Nuts shall conform to ASTM A307, Grade A.
- Steel plates are manufactured from Black Steel conforming to ASTM A569.
- Grout holes are one hole spaced every third ring (4.5’ o.c.).

IV. Given:
- Gage = 10
- Loading = E80 <--H20, HS25, or E80
- Diameter (inches) = 124
- Ht. of Cover (ft) = 10 Maximum
- Ht. of Cover (ft) = 6 Minimum
- Unit Weight of Soil (W) = 130 #/ft^3
- Soil Friction Angle (θ) = 0 degrees
- Thickness = 0.135 in
- Effective Area (Ae) = 0.174 in^2/in
- Moment of Inertia (I) = 2.088 in^4/ft
- Radius of Gyration (r) = 0.607 in/ft
- Modulus of Elasticity (E) = 29000000 #/in^2
- Soils Constant (k) = 0.44
- Tensile Strength (fu) = 42000 psi
- Yield Strength (fy) = 28000 psi
V. Solution:

A. Section 16.2 - Load determination: Calculate the worst case loading condition.

**Minimum Hc**

Load = E80

<table>
<thead>
<tr>
<th>Hc(min)</th>
<th>6 ft</th>
</tr>
</thead>
</table>

Dia. = 10.33 ft

Frict. < = 0

<table>
<thead>
<tr>
<th>Hc / D</th>
<th>6 ft / 10.333 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hc / D</td>
<td>0.58</td>
</tr>
</tbody>
</table>

Cd = 0.40 --- from figure 16.2.3A

\[
Pv = Pd + Pl
\]

\[
Pd = (W) (D) (Cd)
\]

\[
Pd = 130 \text{#/ft}^3 \cdot 10.333 \text{ ft} \cdot 0.4
\]

Pd = 537 #/ft^2

Pl = 2133 #/ft^2 --- Table 1.

Pv = 537 #/ft^2 + 2133 #/ft^2

**Pv** = 2670 #/ft^2

**Maximum Hc**

Hc(max) = 10 ft

Dia. = 10.33 ft

Frict. < = 0

<table>
<thead>
<tr>
<th>Hc / D</th>
<th>10 ft / 10.333 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hc / D</td>
<td>0.97</td>
</tr>
</tbody>
</table>

Cd = 0.80 --- from figure 16.2.3A

\[
Pv = Pd + Pl
\]

\[
Pd = (W) (D) (Cd)
\]

\[
Pd = 130 \text{#/ft}^3 \cdot 10.333 \text{ ft} \cdot 0.80
\]

Pd = 1075 #/ft^2

Pl = 1100 #/ft^2 --- Table 1.

Pv = 1075 #/ft^2 + 1100 #/ft^2

**Pv** = 2175 #/ft^2

**Pv (crit)** = 2670 #/ft^2
B. Section 16.3.2 - Joint Strength

Thrust (T) = Pv (D/2)

Pv = Load calculated in 16.2 (#/ft^2)
D = Diameter (ft)

\[ T = 2670.333333 \, \text{#/ft}^2 \times 5.1667 \, \text{ft} \]
\[ T = 13797 \, \text{#/ft} \]

Table 16.3.2.2 - Ultimate Seam Strength on Liner Plates

Gage = 10
Thickness = 0.135 in

Ult. SS = 47000 #/ft <-- Table 16.3.2.2

FS = Ultimate Seam Strength / Thrust
FS = 47000 #/ft / 13797 #/ft
FS = 3.4

C. Section 16.3.3 Minimum Stiffness for Installation

Stiffness = \( (E) (I) / (D^2) \)

\[ \text{Stiffness} = \frac{29000000 \, \text{#/in}^2 \times 0.064 \, \text{in}^4/\text{in}}{15376 \, \text{in}} \]
Stiffness = 120.71

Minimum Stiffness 2-flange = 50
FS = Actual Stiffness / Minimum Stiffness
FS = 120.71 / 50
FS = 2.4

D. Section 16.3.4 - Critical Buckling of Liner Plate Wall

Dc = Critical Pipe Diameter (in)

\[ Dc = \frac{(24 \, E \, \text{fu})^{1/2} \, (r/k)}{h} \]
\[ Dc = \frac{29000000 \, \text{#/in}^2 \times 24}{42000 \, \text{#/in}^2} \, h \]
\[ Dc = 177.59 \]
D. (cont)

If the specified diameter, \( D \), is greater than \( D_c \),
\[
f_c = \frac{12E}{(kD/r)^2}
\]
If the specified diameter, \( D \), is less than \( D_c \),
\[
f_c = f_u - \left(\frac{f_u^2}{48E}(kD/r)^2\right)
\]

\[
\begin{align*}
&f_u = 42000 \text{ #/in}^2 \\
&E = 29000000 \text{ #/in}^2 \\
&k = 0.44 \\
&D = 124 \text{ in} \\
&r = 0.607 \text{ in/ft}
\end{align*}
\]

\[
D < D_c
\]
Therefore...
\[
f_c = f_u - \left(\frac{f_u^2}{48E}(kD/r)^2\right)
\]
\[
f_c = 31762 \text{ #/in}^2
\]
Since \( f_c > f_y \), use \( f_y \)
therefore, \( f_c = 28000 \text{ #/in}^2 \)

\[
FS = \frac{f_c Ae}{T}
\]
\[
FS = \frac{28000 \text{ #/in}^2 \times 2.088 \text{ in}^2/\text{ft}}{13797 \text{ #/ft}} = 4.2
\]

VI. **Conclusion:**

10 Gage 2-flange liner plate provides the following Factors of Safety:

<table>
<thead>
<tr>
<th></th>
<th>Actual</th>
<th>Min. Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seam Strength:</td>
<td>3.4</td>
<td>3.0</td>
</tr>
<tr>
<td>Buckling:</td>
<td>4.2</td>
<td>3.0</td>
</tr>
<tr>
<td>Installation Stiffness</td>
<td>2.4</td>
<td>2.0</td>
</tr>
</tbody>
</table>
Steel Tunnel Liner Plate

Aluminum Tunnel Liner Plate
Contech® 2-Flange Tunnel Liner Plate provides optimum stability and protection when constructing new tunnels, relining structures under highways and railroads, and vertical shafts. It offers the highest continuous ring stiffness and high compression joint strength.

2-Flange Tunnel Liner Plate has effective stiffness that is more than twice that of the same gage (thickness) of 4-Flange Liner Plate.

**Applications**
- Tunnel Lining
- Relining (rehabilitation of failing structures)
- Both Vertical and Horizontal Shafts

**Features & Benefits**
- Minimizes installation expense
- Optimizes stability in both horizontal and vertical applications
- Unsurpassed in strength and safety

**Special shapes of Contech Liner Plate**

- Arch
- Horseshoe
- Pipe Arch
- Underpass
Contech 2-Flange Tunnel Liner Plate vs. 4-Flange Liner Plate

2-Flange Tunnel Liner Plate from Contech provides corrugations extending through the lapped longitudinal joint. When assembled, this liner functions as a corrugated pipe with continuous circumferential corrugations. The result is more effective corrugation performance for the highest stiffness and strength in the industry. It has the strength to handle the loads encountered during construction, providing a safer working environment.

4-Flange Liner Plate feature shallow, partial corrugations that do not extend fully to the joint. When assembled, ring stiffness is limited by both the joint strength and lack of a continuous corrugation. The result is less stiffness and a hinge action joint.

Key Performance Differences

- Bending strength of the deep, fully corrugated 2-Flange Tunnel Liner Plate is much greater than 4-Flange Liner Plate.
- AASHTO Design Specifications for Tunnel Liner Plate, Section 15, states that effective stiffness of 2-Flange Tunnel Liner Plate is 2.22 x stiffer than equal thickness 4-Flange Liner Plate (111/50 = 2.22 – see Table 1A).
- The overlapped joint of 2-Flange Tunnel Liner Plate provides greater effective stiffness, when assembled, than 4-Flange Liner Plate.
- AASHTO Design Specifications for Tunnel Liner Plate, Section 15, states that the seam strength of 2-Flange Tunnel Liner Plate is up to 30% greater than 4-Flange Liner Plate.

What is the practical meaning of all this?

During tunnel construction, slough-ins and other concentrated loads are unpredictable and can be catastrophic without adequate protection. A sufficiently stiff tunnel liner functions as a safety zone for workers and equipment. The required amount of liner stiffness depends upon soils, tunnel size and construction methods.

If minimum effective stiffness required for a project is related in terms of thickness of Contech 2-Flange Tunnel Liner Plate, an equally stiff 4-Flange Liner Plate must have more than twice the moment of inertia. Minimum installation stiffness often governs the plate thickness, and in the case of Contech 2-Flange Tunnel Liner Plate, provides the most economical Liner Plate option.

<table>
<thead>
<tr>
<th>Table 1A - Equal Stiffness of 2-Flange vs. 4-Flange</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Flange Tunnel Liner Plate Thickness</td>
</tr>
<tr>
<td>0.075</td>
</tr>
<tr>
<td>0.105</td>
</tr>
<tr>
<td>0.135</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 1B - Minimum Installation Stiffness</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Flange Tunnel Liner Plate</td>
</tr>
<tr>
<td>50</td>
</tr>
</tbody>
</table>

NOTE: Per AASHTO Design Specifications for Tunnel Liner Plates, Section 15.
**AASHTO Design**

**Loading Considerations**

The load carrying capacity of a non-rigid tunnel lining such as a steel Liner Plate results from its ability to deflect under load so that side restraint developed by the lateral resistance of the soil constrains further deflection. Deflection tends to equalize radial pressures resulting in ring compression.

The load carried by the tunnel liner plate is dependent on the type of soil. In granular soil, with little or no cohesion, the load is a function of the internal friction angle (\(\phi\)) of the soil and the diameter of the tunnel. In cohesive soils, such as clays and silty clays, the load carried by the tunnel liner is dependent on the shearing strength of the soil above the tunnel.

Before design, appropriate soil test should be performed at each installation site.

**Table 2**

<table>
<thead>
<tr>
<th>Height of Cover (ft.)</th>
<th>H 20 Load (lb. per ft.²)</th>
<th>Height of Cover (ft.)</th>
<th>E 80 Load (lb. per ft.²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>400</td>
<td>4</td>
<td>3,000</td>
</tr>
<tr>
<td>5</td>
<td>250</td>
<td>5</td>
<td>2,400</td>
</tr>
<tr>
<td>6</td>
<td>200</td>
<td>8</td>
<td>1,600</td>
</tr>
<tr>
<td>7</td>
<td>175</td>
<td>10</td>
<td>1,100</td>
</tr>
<tr>
<td>8</td>
<td>100</td>
<td>12</td>
<td>800</td>
</tr>
<tr>
<td>9</td>
<td>90</td>
<td>15</td>
<td>600</td>
</tr>
<tr>
<td>10</td>
<td>75</td>
<td>20</td>
<td>300</td>
</tr>
<tr>
<td>&gt; 10</td>
<td>0</td>
<td>30</td>
<td>100</td>
</tr>
</tbody>
</table>

1. Based on AASHTO Design Specifications
2. AREMA Manual for Railway Engineering, Section 1.4

**Loads per AASHTO Section 15.2.1**

External load on any circular tunnel liner may be predicted by various methods, including actual tests. In cases where more precise methods of analysis are not employed, the external load, \(P\), can be predicted by the following:

- If the grouting pressure is greater than the computed external load, the external load \(P\) on the tunnel liner shall be the grouting pressure.
- In general the external load can be computed by the formula:

\[
P = P_L + P_d
\]

Where:
- \(P\) = The external load on the tunnel liner.
- \(P_L\) = The vertical load at the level of the top of the tunnel liner due to live loads (see Table 2 for approximate values).
- \(P_d\) = The vertical load at the level of the top of the tunnel liner due to dead load.

Values of \(P_d\) may be calculated using Marston’s formula for load or any other suitable method.

\[
P_d = C_d \times W \times D
\]

Where:
- \(C_d\) = Coefficient for tunnel liner (see Chart I).
- \(W\) = Total (moist) unit weight of soil.
- \(D\) = Neutral axis diameter of span.*
- \(H\) = Height of soil over the top of the tunnel.

In addition to the loads described above, grouting pressures should be considered on the tunnel liner.

* \(D\) (diameter) as referenced in this brochure always represents a neutral axis dimension.

In the absence of adequate borings and soil tests, the full overburden height should be the basis for \(P_d\) in the Tunnel Liner Plate design: \(P_d = H \times W\).
AASHTO Design

Design Criteria
The following criteria must be considered in the design of Liner Plates:

- Joint strength
- Minimum stiffness for installation
- Critical buckling of the Liner Plate wall
- Deflection or flattening of tunnel section

The design criteria described is per AASHTO design. Other design methodologies and publications may allow different factors of safety and minimum stiffness values.

Note: Sizes shown in this brochure are to the neutral axis, not the inside diameter.

Joint Strength
Seam strength for Liner Plates should be sufficient to withstand the thrust developed from the total load supported by the Liner Plate. This thrust, T, in pounds per linear foot is:

\[ T = \frac{P \times D}{2} \]

Where:  
- P = Load as defined on Page 4.  
- D = Neutral axis diameter or span.

Thrust, T, multiplied by the factor of safety (FS) as required should not exceed the ultimate seam strength shown in Table 4 on Page 9.

Minimum Stiffness for Installation
The Liner Plate ring should have enough rigidity to resist the unbalanced loadings of normal construction, including grouting pressure, local slough-ins, and miscellaneous concentrated loads.

The minimum stiffness required for these loads can be expressed for convenience by the following formula.

It must be recognized, however, that the limiting values given here are only recommended minimums. Actual job conditions may require higher values (greater effective stiffness). Final determination on this factor of safety should be based on intimate knowledge of the project, soil conditions, and practical experience.

The minimum stiffness for installation is determined by the formula:

\[ \text{Minimum stiffness} = \frac{E I}{D^2} \]

Where:  
- D = Neutral axis diameter or span.  
- E = Modulus of elasticity, psi.  

For 2-Flange:  \( \frac{E I}{D^2} = 50 \) minimum

For 4-Flange:  \( \frac{E I}{D^2} = 111 \) minimum

Note: An appropriate factor of safety is recommended. The effect of such an increase in factor of safety on the installed cost of a tunnel is typically very small.
AASHTO Design

Critical Buckling

Wall buckling stresses are determined from the following formulas:

**Determine** $D_c$, the critical pipe diameter or span:

$$D_c = \frac{r}{k} \sqrt[4]{\frac{24E}{f_u}}$$

For diameters less than $D_c$:

$$f_y = f_u - \left(\frac{f_u^2}{48E} \times \left(\frac{D}{r}\right)^2\right) \text{ (psi)}$$

For diameters greater than $D_c$ then:

$$f_y = \frac{12E}{\left(\frac{D}{r}\right)^2} \text{ (psi)}$$

*Variables as defined by AASHTO Section 15.*

Where:

- $f_u =$ Minimum specified tensile strength, psi.
- $f_y =$ Buckling stress, psi, $F_{cr}$ cannot exceed $F_y$.
- $k =$ Soil stiffness factor, will vary from 0.22 for soils with $\phi > 15^\circ$ to 0.44 for soils $\phi < 15^\circ$.
- $D =$ Pipe diameter or max span, inches.
- $r =$ Radius of gyration of section, inches.
- $E =$ Modulus of elasticity, psi.
- $\phi =$ Internal friction angle of soil.

Design for buckling is accomplished by limiting the ring compression thrust, $T$, to the buckling stress multiplied by the effective cross-sectional area of the Liner Plate, $A$, divided by the factor of safety:

**Where:**

- $T =$ Thrust per linear foot.
- $A =$ Effective cross-sectional area of Liner Plate, $\text{in}^2/\text{ft}$.
- $FS =$ Factor of safety (2) for buckling.

Deflection and Grouting

Deflection of a tunnel depends significantly on the amount of over-excavation of the bore and is also affected by delay in grouting or inadequate grouting. The magnitude of deflection is not primarily a function of soil modulus or the Liner Plate properties, so it cannot be computed with usual deflection formulas. Where the tunnel clearances are important, the designer should oversize the structure to provide for normal deflection.

Minimum Cover

For tunneling, a minimum cover of four feet, depending upon soil material, should be considered to prevent loss of overhead material. However, actual minimum cover required for a specific tunnel application is highly dependent on various factors, including site conditions, tunnel diameter, soil characteristics, and live load conditions, and must be determined by a qualified engineer or tunneling contractor.
Design Example

2-Flange Tunnel Liner Plate is designed to provide effective continuous ring stiffness and high compression joint strength. Continuous ring stiffness in 2-Flange Tunnel Liner Plate prevents hinge action at longitudinal joints. This bending strength is useful to maintain structure shape during installation and grouting.

After installation and back grouting, the ring must possess sufficient compressive wall strength and buckling resistance to carry the final loading on the ring. These loads approach a pattern of symmetry and thus place the 2-Flange Tunnel Liner Plate ring primarily in compression.

Design Example (Steel)

Assumed

H = 20’ E80 Live Load
D = Dia. = 144” (see Marston’s theory for diameter, B)
W = 120 lb./CF (saturated clay)
K = 0.44
E = 29 x 10^6
f_y = 42,000 psi*
f_y = 28,000 psi*

*These values are prior to cold working and are conservative for 2-Flange Tunnel Liner Plate.

Stiffness is often the control for plate thickness, so the calculation for it will be done first.

I. Minimum Stiffness for Installation

Construction Load Design

The design engineer should use an appropriate factor of safety for stiffness. Final determination of this factor of safety should be based on intimate knowledge of the project soil conditions and the contractor’s experience. In this example a factor of safety of 1.5 was selected.

Stiffness = EI/D^2

To provide FS = 1.5, set minimum stiffness equal to 1.5 x 50 = 75. Find requirement of moment of inertia (I).

I = D^2 x (Minimum Stiffness) / E = (144)^2 (75) / 29 x 10^6 = 0.0536 in^4/in

Select 0.1345” 2-Flange Tunnel Liner Plate with I = 0.064 in^4/in (from Table 3 on Page 8).

II. Final Load Design

1. Find Load

Now use Chart I to find that C_d = 1.36
P_d = C_d x W x D
P_d = 1.36 x 120 x 12 = 1,596 lb/ft^2
From Table 2, P_l = 300 lb/ft^2
P = P_d + P_l = 1,958 + 300 = 2,258 lb/ft^2

2. Joint Strength

Actual thrust
T = P x D/2
T = 2,258 x 12/2
T = 13,548 lb./LF

Minimum factor of safety required (AASHTO) = 3

From Table 4, 0.1345 2-Flange Tunnel Liner Plate (ultimate seam strength is 47,000 lb./LF)

Check factor of safety 47,000/13,548 = 3.47
3.47 > 3.0, therefore the factor of safety for 2-Flange Tunnel Liner Plate is sufficient for the joint strength.
3. Critical Buckling

From Table 3, radius of gyration \( r \) for 0.1345 plate = 0.606

\[
\frac{r}{k} \sqrt{\frac{24E}{f_y}} = \frac{0.606}{0.44} \sqrt{\frac{(24)(29,000,000)}{42,000}} = 177
\]

Tunnel diameter (84”) is less than 177, therefore use

\[
f_y = 28,000 \text{ psi}
\]

This exceeds the yield point of the corrugated plate (28,000 psi), therefore use \( f_y = 28,000 \text{ psi} \). Check factor of safety for 0.1345 2-Flange Tunnel Liner Plate where \( A = 0.174 \text{ in}^2/\text{ft} \) (Table 3).

The resulting factor of safety is 4.32, which is greater than the required FS of 2.

### TABLE 3 - Properties and Dimensions of 2-Flange Tunnel Liner Plate

<table>
<thead>
<tr>
<th>Nominal Thickness (Inches)</th>
<th>Area (In² per Inch)</th>
<th>Section Modulus (In² per Inch)</th>
<th>Moment of Inertia (In⁴ per Inch)</th>
<th>Radius of Gyration (Inches)</th>
<th>( X^* ) (Inches)</th>
<th>Approx. Plate Weights including Bolts (Pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12 Pt. Plate</td>
</tr>
<tr>
<td>STEEL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>14 GA** / 0.0747</td>
<td>0.096</td>
<td>0.0323</td>
<td>0.034</td>
<td>0.595</td>
<td>0.757</td>
<td></td>
</tr>
<tr>
<td>12 GA / 0.1046</td>
<td>0.135</td>
<td>0.0457</td>
<td>0.049</td>
<td>0.602</td>
<td>0.779</td>
<td>33</td>
</tr>
<tr>
<td>10 GA / 0.1345</td>
<td>0.174</td>
<td>0.0590</td>
<td>0.064</td>
<td>0.606</td>
<td>0.799</td>
<td>41</td>
</tr>
<tr>
<td>8 GA / 0.1644</td>
<td>0.213</td>
<td>0.0726</td>
<td>0.079</td>
<td>0.609</td>
<td>0.819</td>
<td>49</td>
</tr>
<tr>
<td>7 GA / 0.1793</td>
<td>0.233</td>
<td>0.0798</td>
<td>0.087</td>
<td>0.611</td>
<td>0.831</td>
<td>53</td>
</tr>
<tr>
<td>5 GA / 0.2092</td>
<td>0.272</td>
<td>0.0928</td>
<td>0.103</td>
<td>0.615</td>
<td>0.848</td>
<td>61</td>
</tr>
<tr>
<td>3 GA / 0.2391</td>
<td>0.312</td>
<td>0.1065</td>
<td>0.118</td>
<td>0.615</td>
<td>0.869</td>
<td>70</td>
</tr>
<tr>
<td>0.125</td>
<td>0.160</td>
<td>0.0540</td>
<td>0.0583</td>
<td>0.603</td>
<td>0.782</td>
<td>15</td>
</tr>
<tr>
<td>0.150</td>
<td>0.191</td>
<td>0.0649</td>
<td>0.0711</td>
<td>0.610</td>
<td>0.799</td>
<td>17</td>
</tr>
<tr>
<td>0.175</td>
<td>0.227</td>
<td>0.0756</td>
<td>0.0842</td>
<td>0.610</td>
<td>0.827</td>
<td>19</td>
</tr>
<tr>
<td>0.200</td>
<td>0.260</td>
<td>0.0864</td>
<td>0.0972</td>
<td>0.611</td>
<td>0.842</td>
<td>21</td>
</tr>
<tr>
<td>0.225</td>
<td>0.292</td>
<td>0.0972</td>
<td>0.1108</td>
<td>0.615</td>
<td>0.851</td>
<td>24</td>
</tr>
<tr>
<td>0.250</td>
<td>0.325</td>
<td>0.1080</td>
<td>0.1230</td>
<td>0.615</td>
<td>0.874</td>
<td>26</td>
</tr>
</tbody>
</table>

* \( X = \text{Distance from outer face to neutral axis, in inches. See page 9, Section B-B.} \)

** 14 GA is available upon special request.

Refer to AASHTO Standard Specifications for Highway Bridges Section 15, and AASHTO LRFD Bridge Design Specifications Section 12.

Refer to Section 12.13 for \( t, A, I, \) and \( r \); and Table 12.13.3.1-1 for nominal thicknesses (uncoated). Aluminum values are determined by the same design method.
Additional Data for 2-Flange Tunnel Liner Plate

Full depth corrugation with offset end.

Full depth corrugation with standard end.

2-Flange Lap Joint

TABLE 4 - Ultimate Longitudinal Seam Strength for 2-Flange Tunnel Liner Plate (lb/LF)

<table>
<thead>
<tr>
<th>STEEL</th>
<th>Specified Thickness</th>
<th>Strength lb./ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0747</td>
<td>20,000</td>
</tr>
<tr>
<td></td>
<td>0.1046</td>
<td>30,000</td>
</tr>
<tr>
<td></td>
<td>0.1345</td>
<td>47,000</td>
</tr>
<tr>
<td></td>
<td>0.1644</td>
<td>55,000</td>
</tr>
<tr>
<td></td>
<td>0.1793</td>
<td>62,000</td>
</tr>
<tr>
<td></td>
<td>0.2092</td>
<td>87,000</td>
</tr>
<tr>
<td></td>
<td>0.2391</td>
<td>92,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ALUMINUM</th>
<th>Specified Thickness</th>
<th>Strength lb./ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.125</td>
<td>35,000</td>
</tr>
<tr>
<td></td>
<td>0.150</td>
<td>45,000</td>
</tr>
<tr>
<td></td>
<td>0.175</td>
<td>50,000</td>
</tr>
<tr>
<td></td>
<td>0.200</td>
<td>60,000</td>
</tr>
<tr>
<td></td>
<td>0.225</td>
<td>70,000</td>
</tr>
<tr>
<td></td>
<td>0.250</td>
<td>74,000</td>
</tr>
</tbody>
</table>

Note: In 0.0747 through 0.1793 thickness structures, longitudinal bolts are ASTM A307, Grade A, 5/8" diameter by 1 1/4" long. For a thickness greater than 0.1793", the bolts are ASTM A449 Type 1, 5/8" diameter by 1 1/2" long.

Section A-A

Section B-B

Section C-C

Inside Dimensions

Actual reduction from neutral axis to inside value is less than the theoretical dimensions in Section B-B. To determine inside dimension, average reduction of all gages is 1 1/8" on radii or 2 1/4" on diameter.

Minimum Curving Radius = 24” (neutral axis)
General Considerations

Construction and Design
Tunnel loads vary widely in magnitude and classification, depending on the soils encountered and construction practices. Loads encountered during the tunneling operation are entirely different from those on the finished and grouted tunnel.

Once construction is finished and the tunnel has been grouted, a relatively uniform load distribution develops around the structure. These final loads consist of dead and live loads, if applicable.

Since loads that develop during construction depend on the tunneling procedure and soil conditions, they are difficult to predict. The installing contractor often encounters slough-ins, hydrostatic soil pressures and other forms of point loading. Handling these temporary loads, prior to backgrouting, requires proper equipment and good techniques to maintain the correct shape of the tunnel liner.

The designer should be aware that construction loads typically control the design especially in soft ground or hand-mined tunnels.

Contractors and designers utilize effectively designed liner structures with high bending resistance (stiffness) to resist concentrated loads that are common during construction.

Material and Coating Considerations

Black Steel » Offers both the lowest cost and high strength. Good for temporary and sacrificial requirements.

Dip-Galvanized Steel » Longer Service life than that of black steel.

Dip-Galvanized & Asphalt Coated Steel » Additional corrosion resistance & abrasion resistance.

Aluminized Steel Type 2 (ALT2) » Provides longer service life in certain environmental conditions that would be detrimental to a zinc/galvanic coating. Only available in 10 and 12 gages.

Aluminum » Provides longer service life in certain environmental conditions that would be detrimental to a zinc/galvanic coating. It is a lighter material and is easily carried into the structure. Most often considered for relines, where steel or galvanized steel has deteriorated.
Grout Options

Grout Coupling with Plug
For pressure grouting, liner sections may be supplied with 2” standard pipe half couplings welded into a hole in the center corrugation. Couplings are fitted with threaded plugs. These couplings are used:

- For lighter gages
- When required by specification

Tapped Grout Holes
As an option, grout holes may be supplied as threaded holes on 12 GA steel and heavier plates for 2” standard pipe located in the side of the center corrugation, in the middle of the plate.

Base Channel for Arches
Base channels are used to support arch-shaped tunnel liners.
Specification Guidelines

Scope
This specification covers 2-Flange Tunnel Liner Plate, fabricated to permit field assembly of structure. The tunnel structure shall match the neutral axis diameter and/or shape and gage shown on the plans.

Material
Plates shall be accurately curved to suit the tunnel cross-section and shall be of uniform fabrication to allow plates of similar curvature to be interchanged. All plates shall be punched for bolting on both the longitudinal and circumferential seams and shall be fabricated as to permit complete erection from the inside of the tunnel. Circumferential bolt hole spacing will be a multiple of the plate length to allow staggering of the longitudinal seam. Circumferential bolt spacing shall be 6 1/4" unless otherwise specified. All materials shall be fabricated in the U.S.A.

Grout holes shall be two inches (2") in diameter and shall be provided as shown on the shop drawings to permit grouting as the assembly of the Liner Plate proceeds.

Bolts and Nuts
Bolts and nuts shall be 5/8" in diameter and length as recommended by the manufacturer. Galvanizing shall conform to ASTM B695, Class 50.

Design
Liner Plate shall be designed per the methodology of the AASHTO Standard Design Specification for Tunnel Liner Plates Section 15, AASHTO LRFD Section 12, or AREMA.

Installation and Grouting
Liner Plate shall be assembled in accordance with manufacturer’s recommendations. Longitudinal seams shall be staggered between rings. After rings have been installed, back grouting to fill any voids should be conducted in a manner to prevent buckling or shifting of the liner ring. The grouting crews should be scheduled as soon as practical behind the assembly operation. Staged grouting in proper lifts is important. Grouting material to be determined by the project specification.

Excavation
Care should be taken during excavation to eliminate voids and maintain maximum plate-to-ground contact. Efficient tunneling reduces the quantity and frequency of back grouting, helps maintain tunnel shape, and proper ring compression of the Liner Plate.

In unstable soils, it is important that tunnel headings be continuously protected against any loss of ground materials. Poling plates, breast boards, shields, and soil solidification have been successful in controlling tunnel headings under unstable conditions. Use of any one of a combination of these methods may be necessary for the proper and safe advancement of the tunnel. The contractor shall be responsible for the safety of his/her employees and agents. Adequate safety measure is the contractor’s responsibility and shall be given to all personnel employed by his/her firm.

Stiffness
Wherever the soil becomes unstable, the loads on the tunnel tend to increase. Maximum ring stiffness under these conditions becomes of prime importance.

Contech Tunnel Liner Plate is fabricated in the United States of America.
<table>
<thead>
<tr>
<th>Neutral Axis Diameter</th>
<th>Approx. Inside Diameter-Inches</th>
<th>Approx. Outside Diameter-Inches</th>
<th>Approx. Outside Diameter-Inches</th>
<th>Total Number Required</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Plates Per Ring Plate Lengths and Offsets*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12 Pi Plate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>N</td>
</tr>
<tr>
<td>48</td>
<td>45.25</td>
<td>49.25</td>
<td>13.2</td>
<td>4</td>
</tr>
<tr>
<td>50</td>
<td>47.25</td>
<td>51.25</td>
<td>14.3</td>
<td>4</td>
</tr>
<tr>
<td>52</td>
<td>49.25</td>
<td>53.25</td>
<td>15.5</td>
<td>4</td>
</tr>
<tr>
<td>54</td>
<td>51.25</td>
<td>55.25</td>
<td>16.6</td>
<td>4</td>
</tr>
<tr>
<td>56</td>
<td>53.25</td>
<td>57.25</td>
<td>17.9</td>
<td>4</td>
</tr>
<tr>
<td>58</td>
<td>55.25</td>
<td>59.25</td>
<td>19.1</td>
<td>4</td>
</tr>
<tr>
<td>60</td>
<td>57.25</td>
<td>61.25</td>
<td>20.4</td>
<td>4</td>
</tr>
<tr>
<td>62</td>
<td>59.25</td>
<td>63.25</td>
<td>21.8</td>
<td>4</td>
</tr>
<tr>
<td>64</td>
<td>61.25</td>
<td>65.25</td>
<td>23.2</td>
<td>4</td>
</tr>
<tr>
<td>66</td>
<td>63.25</td>
<td>67.25</td>
<td>24.6</td>
<td>5</td>
</tr>
<tr>
<td>68</td>
<td>65.25</td>
<td>69.25</td>
<td>26.1</td>
<td>5</td>
</tr>
<tr>
<td>70</td>
<td>67.25</td>
<td>71.25</td>
<td>27.7</td>
<td>5</td>
</tr>
<tr>
<td>72</td>
<td>69.25</td>
<td>73.25</td>
<td>29.2</td>
<td>5</td>
</tr>
<tr>
<td>74</td>
<td>71.25</td>
<td>75.25</td>
<td>30.8</td>
<td>5</td>
</tr>
<tr>
<td>76</td>
<td>73.25</td>
<td>77.25</td>
<td>32.5</td>
<td>5</td>
</tr>
<tr>
<td>78</td>
<td>75.25</td>
<td>79.25</td>
<td>34.2</td>
<td>5</td>
</tr>
<tr>
<td>80</td>
<td>77.25</td>
<td>81.25</td>
<td>36.0</td>
<td>5</td>
</tr>
<tr>
<td>82</td>
<td>79.25</td>
<td>83.25</td>
<td>37.8</td>
<td>6</td>
</tr>
<tr>
<td>84</td>
<td>81.25</td>
<td>85.25</td>
<td>39.7</td>
<td>6</td>
</tr>
<tr>
<td>86</td>
<td>83.25</td>
<td>87.25</td>
<td>41.6</td>
<td>6</td>
</tr>
<tr>
<td>88</td>
<td>85.25</td>
<td>89.25</td>
<td>43.5</td>
<td>6</td>
</tr>
<tr>
<td>90</td>
<td>87.25</td>
<td>91.25</td>
<td>45.4</td>
<td>6</td>
</tr>
<tr>
<td>92</td>
<td>89.25</td>
<td>93.25</td>
<td>47.4</td>
<td>6</td>
</tr>
<tr>
<td>94</td>
<td>91.25</td>
<td>95.25</td>
<td>49.4</td>
<td>6</td>
</tr>
<tr>
<td>96</td>
<td>93.25</td>
<td>97.25</td>
<td>51.5</td>
<td>6</td>
</tr>
<tr>
<td>98</td>
<td>95.25</td>
<td>99.25</td>
<td>53.6</td>
<td>7</td>
</tr>
<tr>
<td>100</td>
<td>97.25</td>
<td>101.25</td>
<td>55.8</td>
<td>7</td>
</tr>
<tr>
<td>102</td>
<td>99.25</td>
<td>103.25</td>
<td>58.1</td>
<td>7</td>
</tr>
<tr>
<td>104</td>
<td>101.25</td>
<td>105.25</td>
<td>60.3</td>
<td>7</td>
</tr>
<tr>
<td>106</td>
<td>103.25</td>
<td>107.25</td>
<td>62.6</td>
<td>7</td>
</tr>
<tr>
<td>108</td>
<td>105.25</td>
<td>109.25</td>
<td>65.0</td>
<td>7</td>
</tr>
<tr>
<td>110</td>
<td>107.25</td>
<td>111.25</td>
<td>67.5</td>
<td>7</td>
</tr>
<tr>
<td>112</td>
<td>109.25</td>
<td>113.25</td>
<td>70.0</td>
<td>7</td>
</tr>
<tr>
<td>114</td>
<td>111.25</td>
<td>115.25</td>
<td>72.5</td>
<td>8</td>
</tr>
</tbody>
</table>

Larger diameters, in 2" increments, are available on request.

Note: Where the tunnel clearances are important, the designer should size the structure to provide for normal deflection.

* Type of offset at ends of plate. N = No Offset; S = Single Offset, D = Double Offset; Diameters are available above those shown in the same pattern. Structures designed for 4 Pi (12.5") stagger in longitudinal seams in alternate rings.
Table 6
2-Flange Steel Tunnel Liner Plate - Weight by Diameter Based on Nominal Thickness

<table>
<thead>
<tr>
<th>Neutral Axis Diameter</th>
<th>14 GA</th>
<th>12 GA</th>
<th>10 GA</th>
<th>8 GA</th>
<th>7 GA</th>
<th>5 GA</th>
<th>3 GA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inches</td>
<td>LB/FT</td>
<td>KG/M</td>
<td>LB/FT</td>
<td>KG/M</td>
<td>LB/FT</td>
<td>KG/M</td>
<td>LB/FT</td>
</tr>
<tr>
<td>48</td>
<td>1.22</td>
<td>65</td>
<td>96</td>
<td>86</td>
<td>128</td>
<td>107</td>
<td>159</td>
</tr>
<tr>
<td>50</td>
<td>1.27</td>
<td>67</td>
<td>99</td>
<td>89</td>
<td>132</td>
<td>111</td>
<td>165</td>
</tr>
<tr>
<td>52</td>
<td>1.32</td>
<td>68</td>
<td>102</td>
<td>91</td>
<td>135</td>
<td>114</td>
<td>170</td>
</tr>
<tr>
<td>54</td>
<td>1.37</td>
<td>71</td>
<td>106</td>
<td>95</td>
<td>141</td>
<td>118</td>
<td>176</td>
</tr>
<tr>
<td>56</td>
<td>1.42</td>
<td>74</td>
<td>109</td>
<td>98</td>
<td>146</td>
<td>122</td>
<td>182</td>
</tr>
<tr>
<td>58</td>
<td>1.47</td>
<td>76</td>
<td>113</td>
<td>101</td>
<td>150</td>
<td>126</td>
<td>187</td>
</tr>
<tr>
<td>60</td>
<td>1.52</td>
<td>79</td>
<td>117</td>
<td>105</td>
<td>156</td>
<td>130</td>
<td>193</td>
</tr>
<tr>
<td>62</td>
<td>1.57</td>
<td>81</td>
<td>121</td>
<td>108</td>
<td>161</td>
<td>134</td>
<td>199</td>
</tr>
<tr>
<td>64</td>
<td>1.63</td>
<td>83</td>
<td>124</td>
<td>111</td>
<td>165</td>
<td>138</td>
<td>205</td>
</tr>
<tr>
<td>66</td>
<td>1.68</td>
<td>88</td>
<td>132</td>
<td>117</td>
<td>174</td>
<td>145</td>
<td>216</td>
</tr>
<tr>
<td>68</td>
<td>1.73</td>
<td>90</td>
<td>134</td>
<td>120</td>
<td>179</td>
<td>149</td>
<td>222</td>
</tr>
<tr>
<td>70</td>
<td>1.78</td>
<td>92</td>
<td>137</td>
<td>123</td>
<td>183</td>
<td>153</td>
<td>228</td>
</tr>
<tr>
<td>72</td>
<td>1.83</td>
<td>95</td>
<td>141</td>
<td>126</td>
<td>187</td>
<td>157</td>
<td>234</td>
</tr>
<tr>
<td>74</td>
<td>1.88</td>
<td>97</td>
<td>144</td>
<td>129</td>
<td>192</td>
<td>161</td>
<td>240</td>
</tr>
<tr>
<td>76</td>
<td>1.93</td>
<td>99</td>
<td>147</td>
<td>132</td>
<td>196</td>
<td>165</td>
<td>245</td>
</tr>
<tr>
<td>78</td>
<td>1.98</td>
<td>101</td>
<td>151</td>
<td>135</td>
<td>201</td>
<td>169</td>
<td>251</td>
</tr>
<tr>
<td>80</td>
<td>2.03</td>
<td>104</td>
<td>155</td>
<td>139</td>
<td>207</td>
<td>173</td>
<td>257</td>
</tr>
<tr>
<td>82</td>
<td>2.08</td>
<td>108</td>
<td>161</td>
<td>144</td>
<td>214</td>
<td>180</td>
<td>268</td>
</tr>
<tr>
<td>84</td>
<td>2.13</td>
<td>110</td>
<td>164</td>
<td>147</td>
<td>219</td>
<td>184</td>
<td>274</td>
</tr>
<tr>
<td>86</td>
<td>2.18</td>
<td>113</td>
<td>168</td>
<td>151</td>
<td>225</td>
<td>188</td>
<td>280</td>
</tr>
<tr>
<td>88</td>
<td>2.24</td>
<td>116</td>
<td>172</td>
<td>154</td>
<td>229</td>
<td>192</td>
<td>286</td>
</tr>
<tr>
<td>90</td>
<td>2.29</td>
<td>118</td>
<td>175</td>
<td>157</td>
<td>234</td>
<td>196</td>
<td>292</td>
</tr>
<tr>
<td>92</td>
<td>2.34</td>
<td>120</td>
<td>179</td>
<td>160</td>
<td>238</td>
<td>200</td>
<td>298</td>
</tr>
<tr>
<td>94</td>
<td>2.39</td>
<td>122</td>
<td>182</td>
<td>163</td>
<td>243</td>
<td>203</td>
<td>302</td>
</tr>
<tr>
<td>96</td>
<td>2.44</td>
<td>125</td>
<td>185</td>
<td>166</td>
<td>247</td>
<td>207</td>
<td>308</td>
</tr>
<tr>
<td>98</td>
<td>2.49</td>
<td>129</td>
<td>192</td>
<td>172</td>
<td>256</td>
<td>214</td>
<td>318</td>
</tr>
<tr>
<td>100</td>
<td>2.54</td>
<td>131</td>
<td>195</td>
<td>175</td>
<td>260</td>
<td>218</td>
<td>324</td>
</tr>
<tr>
<td>102</td>
<td>2.59</td>
<td>134</td>
<td>199</td>
<td>178</td>
<td>265</td>
<td>222</td>
<td>330</td>
</tr>
<tr>
<td>104</td>
<td>2.64</td>
<td>136</td>
<td>202</td>
<td>181</td>
<td>269</td>
<td>226</td>
<td>336</td>
</tr>
<tr>
<td>106</td>
<td>2.69</td>
<td>139</td>
<td>206</td>
<td>185</td>
<td>275</td>
<td>230</td>
<td>342</td>
</tr>
<tr>
<td>108</td>
<td>2.74</td>
<td>141</td>
<td>210</td>
<td>188</td>
<td>280</td>
<td>234</td>
<td>348</td>
</tr>
<tr>
<td>110</td>
<td>2.79</td>
<td>143</td>
<td>213</td>
<td>191</td>
<td>284</td>
<td>238</td>
<td>354</td>
</tr>
<tr>
<td>112</td>
<td>2.84</td>
<td>146</td>
<td>216</td>
<td>194</td>
<td>289</td>
<td>242</td>
<td>360</td>
</tr>
<tr>
<td>114</td>
<td>2.90</td>
<td>150</td>
<td>223</td>
<td>200</td>
<td>298</td>
<td>249</td>
<td>370</td>
</tr>
</tbody>
</table>

Notes:
- Approximate weights may be extrapolated for diameters greater than 180 inches.
- Call for aluminum tunnel liner plate weights.
- Nominal thicknesses are uncoated.
Table 6 (continued)

<table>
<thead>
<tr>
<th>Neutral Axis Diameter</th>
<th>14 GA</th>
<th>12 GA</th>
<th>10 GA</th>
<th>8 GA</th>
<th>7 GA</th>
<th>5 GA</th>
<th>3 GA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0747in/1.90mm</td>
<td>0.1046in/2.66mm</td>
<td>0.1345in/3.42mm</td>
<td>0.1644in/4.18mm</td>
<td>0.1793in/4.55mm</td>
<td>0.2092in/5.31mm</td>
<td>0.2391in/6.07mm</td>
</tr>
<tr>
<td>Inches</td>
<td>LB/FT</td>
<td>KG/M</td>
<td>LB/FT</td>
<td>KG/M</td>
<td>LB/FT</td>
<td>KG/M</td>
<td>LB/FT</td>
</tr>
<tr>
<td>116</td>
<td>2.95</td>
<td>152</td>
<td>227</td>
<td>203</td>
<td>302</td>
<td>253</td>
<td>376</td>
</tr>
<tr>
<td></td>
<td>0.1046in/2.66mm</td>
<td>0.1345in/3.42mm</td>
<td>0.1644in/4.18mm</td>
<td>0.1793in/4.55mm</td>
<td>0.2092in/5.31mm</td>
<td>0.2391in/6.07mm</td>
<td>0.269</td>
</tr>
<tr>
<td></td>
<td>0.1345in/3.42mm</td>
<td>0.1644in/4.18mm</td>
<td>0.1793in/4.55mm</td>
<td>0.2092in/5.31mm</td>
<td>0.2391in/6.07mm</td>
<td>0.269</td>
<td>451</td>
</tr>
<tr>
<td></td>
<td>0.1644in/4.18mm</td>
<td>0.1793in/4.55mm</td>
<td>0.2092in/5.31mm</td>
<td>0.2391in/6.07mm</td>
<td>0.269</td>
<td>451</td>
<td>328</td>
</tr>
<tr>
<td></td>
<td>0.1793in/4.55mm</td>
<td>0.2092in/5.31mm</td>
<td>0.2391in/6.07mm</td>
<td>0.269</td>
<td>451</td>
<td>328</td>
<td>378</td>
</tr>
<tr>
<td></td>
<td>0.2092in/5.31mm</td>
<td>0.2391in/6.07mm</td>
<td>0.269</td>
<td>451</td>
<td>328</td>
<td>378</td>
<td>446</td>
</tr>
<tr>
<td></td>
<td>0.2391in/6.07mm</td>
<td>0.269</td>
<td>451</td>
<td>328</td>
<td>378</td>
<td>446</td>
<td>664</td>
</tr>
</tbody>
</table>

Note: Approximate weights may be extrapolated for diameters greater than 180 inches.
Call for aluminum tunnel liner plate weights.
Nominal thicknesses are uncoated.
Steel Vertical Shafts

Vertical Shafts are often required as access means for horizontal tunneling and relines. These shafts may vary in diameter from 4 feet to over 70 and depths well over 100 feet.

Optimizing Shaft Design

In each case, maintaining shaft integrity requires a dependable support system. Various methods are used for vertical shaft lining: sheet piling, unbraced timber, ring beams and timber lagging, concrete, and stacked trench boxes.

Liner Plate Systems

2-Flange Tunnel Liner Plate is used in vertical shafts when the top-down installation is preferred. A net laying depth of 18” permits advancing the shaft in 1.5’ increments. Bolts and nuts for 2-Flange Tunnel Liner Plate are easily installed from within the structure and rings of Liner Plate can be quickly installed and backgrouted.

2-Flange Tunnel Liner Plate is the stiffest plate available and, unlike other shaft liner systems, often does not require the use of permanent ring-beam stiffeners.

The Contech Liner Plate system, available in black (uncoated) or galvanized steel, provides strength and safety. Often, the Liner Plate may be dismantled and reused.

2-Flange Tunnel Liner Plate is much stiffer, gage for gage, than 4-Flange Liner Plate. Commonly required diameters for 2-Flange Liner Plate will not require Ring-Beam bracing, whereas 4-Flange designs would more than likely require them.

If adjacent structures are sensitive to pile driving, a starter shaft using 2-Flange Tunnel Liner Plate can be used. Once the shaft reaches sufficient depth, pile driving can be commenced and disturbance to nearby foundations, railroads or other structures is minimized or eliminated.
Additional Contech Products Provide Versatility for Optimum Efficiency

**MULTI-PLATE Liner Systems**

MULTI-PLATE® can be preassembled on the surface in large diameters and long lengths, then lowered into a pre-excavated or drilled shaft. Once installed, the void between the MULTI-PLATE liner and excavated/drilled shaft is grouted. Soil conditions must allow the shaft walls to be left temporarily exposed until the liner is installed.

MULTI-PLATE shaft liners are also extremely stiff, creating a very safe shaft and, as with 2-Flange Tunnel Liner Plate, ring beam stiffeners are often not required.

**HEL-COR Lining Systems**

HEL-COR® corrugated steel pipe, with or without ring beam stiffeners, can be supplied in diameters up to 120” (larger diameters are available at some locations). It is installed in the same manner as MULTI-PLATE structures, and eliminates the need for field assembly of plates. Ring beams, if needed, are installed by the contractor.

**Applications**

These additional products offer alternative options for different site or construction conditions. Site restrictions will often not allow drilling shafts. When “hand-digging” or bucket excavation is required, 2-Flange Tunnel Liner Plate is the most effective. If drilling of the shaft is allowed and the site soil will remain stable, then larger diameter shafts can be lined with MULTI-PLATE or HEL-COR corrugated steel pipe.

2-Flange Tunnel Liner Plate and MULTI-PLATE structures can be supplied in round or elliptical shapes. Smaller shaft diameters can be lined with HEL-COR alone or with ring beam stiffeners if required.

Prompt backgrouting, to fill the void between the shaft walls and the liner, is essential to the support and performance of any shaft liner system. Such backgrouting must be done in a controlled and balanced manner. In all cases, use of temporary bracing may be required to provide added protection and stiffness prior to backgrouting.
Design Considerations for Vertical Shafts

Typical Required Design Information

- Shaft diameter
- Shaft depth
- Unit weight of soil around the shaft
- Lateral earth pressures due to site soil conditions
- Location of ground water table
- Live loads to include in the design

While the actual design of such shafts is the responsibility of the project engineer, a common procedure for this design process can be summarized as:

1. Determine Loads on Shaft Liner

   Loads exerted by lateral earth pressures should be determined throughout the depth of the shaft. Any hydrostatic loads due to groundwater should be established and included within the design. The possibility for localized soil instabilities and slough-ins should be assessed and considered. If such localized loads produce differential pressures, then allowances for such unbalanced loads must be considered in the design and detail of the shaft. If the presence of any nearby foundation systems will produce an increase in the ground pressures in the area where the shaft is to be constructed that exceed 100 pounds per square foot, they should be included in the design.

2. Check the Seam Strength of the Liner

   The design thrust in the plate should be computed in the same manner as was shown for tunneling applications. In tunneling applications, a minimum factor of safety of 3.0 on seam strength is common and is required per the AASHTO specifications. However, this does not necessarily apply and may in fact be overly conservative in the design of vertical shafts. The selection of an appropriate factor of safety is left to the discretion of the designer.

3. Check the Liner Stiffness

   Due to the inherent stiffness and the moment transfer that the lapped longitudinal seams of 2-Flange Tunnel Liner Plate provide, a large range of depth and diameter combinations of vertical shafts can be constructed without the need for any additional reinforcement. However, while the rings of some larger shafts may be capable of carrying the service loads required by the permanent structure, the shaft may require temporary reinforcement during construction to provide additional stiffness during the assembly and grouting phases of construction. This reinforcement is commonly in the form of curved ring beams that can be temporarily blocked into place during construction, but removed once the shaft is assembled and grouted into place.

Loads on Shaft Liner
If the gage of the structure is controlled by the need for ring stiffness rather than load carrying capacity, many designers choose to design the required plate gage based strictly on what is required to carry the service loads and specify the use of ring beams to provide the necessary stiffness during construction. Generally two or three sets of ring beams is all that is necessary for construction as the ring beams can be moved downward as the shaft construction progresses. This can lead to a substantial reduction in the cost of materials for a large diameter and/or deep tunnel.

4. Check the Critical Buckling Stress of the Shaft Liner

This check can be performed using the same buckling equations introduced earlier for Liner Plate tunnels. Due to the strength of 2-Flange Tunnel Liner Plate, many large diameter and deep shafts can be constructed without the need for permanent reinforcement. If the service loads induce stresses beyond the limits that 2-Flange Tunnel Liner Plate alone can carry, permanent reinforcement in the form of ring beams or other means can be used to carry the loads beyond what the plates can accommodate. The addition of these ring stiffeners should be considered in the buckling check and modifications to the buckling check procedure may be required.

5. Design Reinforcing for Any Openings Cut in the Shaft Liner Wall

Any openings that may be cut within the Liner Plate may also require permanent reinforcement. In this instance, structural members are generally attached to the Liner Plate around the cut opening in the form of a frame to carry the loads in the vicinity of the opening.

6. Grouting the Void Between the Liner Plate and the Shaft Walls

The void between the shaft liner and excavated shaft wall should be grouted in a controlled and balanced manner as soon as possible as the shaft liner construction is advanced. The quicker this void is grouted and the grout cured, the less exposed the shaft liner will be to localized slough-ins, potential unbalanced loads, and unknown load pressures. Selection of grout materials and methods should be discussed and coordinated with the contractor.

Note: Additional references include the current specifications of AASHTO, AISI, and the NCSPA.
Contech Engineered Solutions provides site solutions for the civil engineering industry. Contech’s portfolio includes bridges, drainage, retaining walls, sanitary sewer, stormwater, erosion control and soil stabilization products.

For more information, call one of Contech’s Regional Offices located in the following cities:

<table>
<thead>
<tr>
<th>State</th>
<th>City</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ohio</td>
<td>(Corporate Office)</td>
<td>513-645-7000</td>
</tr>
<tr>
<td>California</td>
<td>(Roseville)</td>
<td>800-548-4667</td>
</tr>
<tr>
<td>Colorado</td>
<td>(Denver)</td>
<td>720-587-2700</td>
</tr>
<tr>
<td>Florida</td>
<td>(Orlando)</td>
<td>321-348-3520</td>
</tr>
<tr>
<td>Maine</td>
<td>(Scarborough)</td>
<td>207-885-9830</td>
</tr>
<tr>
<td>Maryland</td>
<td>(Baltimore)</td>
<td>410-740-8490</td>
</tr>
<tr>
<td>Oregon</td>
<td>(Portland)</td>
<td>503-258-3180</td>
</tr>
<tr>
<td>Texas</td>
<td>(Dallas)</td>
<td>972-590-2000</td>
</tr>
</tbody>
</table>

800-338-1122 | www.ContechES.com

NOTHING IN THIS CATALOG SHOULD BE CONSTRUED AS A WARRANTY. APPLICATIONS SUGGESTED HEREIN ARE DESCRIBED ONLY TO HELP READERS MAKE THEIR OWN EVALUATIONS AND DECISIONS, AND ARE NEITHER GUARANTEES NOR WARRANTIES OF SUITABILITY FOR ANY APPLICATION. CONTECH MAKES NO WARRANTY WHATSOEVER, EXPRESS OR IMPLIED, RELATED TO THE APPLICATIONS, MATERIALS, COATINGS, OR PRODUCTS DISCUSSED HEREIN. ALL IMPLIED WARRANTIES OF MERCHANTABILITY AND ALL IMPLIED WARRANTIES OF FITNESS FOR ANY PARTICULAR PURPOSE ARE DISCLAIMED BY CONTECH. SEE CONTECH’S CONDITIONS OF SALE (AVAILABLE AT WWW.CONTECHES.COM/COS) FOR MORE INFORMATION.
60 FT SPAN PED. BRIDGE
REFERENCE ONLY
FEASIBILITY STUDY DRAWINGS ONLY. NOT FOR CONSTRUCTION OR PERMITTING.
TYPICAL ELEVATION AT 140'-0" MAX SPAN PEDESTRIAN BRIDGE
SCALE: 3/32"=1'-0"

GENERAL BRIDGE NOTES:
1. BRIDGE SIZES BASED ON 16'-0" WIDE x 60'-0" SPAN OR 140'-0" SPAN SHORTER AND/OR NARROWER BRIDGES WILL BE SIMILAR.
2. BRIDGE HAS BEEN SIZED TO SUPPORT PEDESTRIAN AND BICYCLE TRAFFIC. HEAVY TRAFFIC LOADING MAY RESULT IN LARGER MEMBER SIZES. TRAFFIC BOLLARDS SHOULD BE LOCATED TO PREVENT VEHICLES FROM DRIVING ON THE BRIDGE.
3. THE BRIDGE DECK HAS NOT BEEN SIZED FOR HYDRODYNAMIC FORCES DUE TO INUNDATION. THESE FORCES MAY RESULT IN LARGER MEMBER SIZES.
4. BRIDGE SIZING IS BASED ON AASHTO'S LRFD GUIDE SPECIFICATIONS FOR THE DESIGN OF PEDESTRIAN BRIDGES, DEC. 2009, AND ITS CURRENT REFERENCES.

DETAIL AT 140'-0" MAX SPAN PEDESTRIAN BRIDGE
SCALE: 3/32"=1'-0"
SCHEMATIC PLAN OF TURNBACKS AT ENDS OF RETAINING WALLS

PROVIDE TURNBACKS AT ENDS OF RETAINING WALLS ADJACENT TO LOCATIONS WHERE RETAINING WALLS ARE REQUIRED AT BOTH SIDES OF A 16'-0" WIDE TRAIL SEGMENT NEAR THE EDGE OF THE CREEK.

NOTE: DETAILS 2/3-3 AND 1/3-4 MAY BE COMBINED FOR LOCATIONS WHERE RETAINING WALLS ARE REQUIRED AT BOTH SIDES OF A 16'-0" WIDE TRAIL SEGMENT NEAR THE EDGE OF THE CREEK.

NOTE: TYPICAL BELL DIAMETERS AT RETAINING WALL PIERS AUTOMATED TO BE 15x SHAFT DIAMETER.

NOTE: RETAINING WALL DESIGN IS BASED ON CLAY BACKFILL MATERIAL EXCEPT WHERE SELECT STRUCTURAL FILL IS PLACED BEHIND THE WALL. UNDER TRAIL FLATWORK, THE ALLOWED LATERAL EARTH PRESSURE FOR THE EXISTING SOIL BACKFILL CONDITION IS EQUIVALENT TO A SOIL WEIGHT OF 120 PSC AND AN ACTIVE EQUIVALENT FLUID DENSITY OF 70 PSC. A SURCHARGE OF 100 PSC WITH AN ACTIVE PRESSURE COEFFICIENT OF 0.56 WERE ALSO ASSUMED.

NOTE: THE DESIGN OF THE WALLS IS BASED ON PROVIDING A DRAIN OR HEEL SIZED TO PREVENT THE BUILD UP OF HYDRAULIC PRESSURE BEHIND THE WALL DUE TO WATER ACCUMULATION. DRAINS SHOULD CONNECT TO STORM DRAINS AT LOWER ELEVATIONS OR LIFT STATIONS.

NOTE: ADDITIONAL GEOTECHNICAL INVESTIGATION IN THE VICINITY OF THE PROPOSED WALLS MAY RESULT IN LOWER DESIGN VALUES AND REDUCE THE COST OF THE WALLS.

NOTE: THE RETAINING WALLS ARE ASSUMED TO BEAR ON SELECT STRUCTURAL FILL. WHERE APPLICABLE, BACKFILL BEHIND THE RETAINING WALLS IS SELECT STRUCTURAL FILL. THE SELECT FILL IS ASSUMED TO HAVE A DENSITY OF 195 PSC, AN EQUIVALENT FLUID DENSITY OF 33 PSC, AN ACTIVE PRESSURE COEFFICIENT OF 0.24, AND AN ALLOWABLE BEARING PRESSURE OF 1500 PSF.
NOTE: THE FLATWORK IS ASSIGNED TO PROTECTED FROM INUNDATION DURING A FLOOD BY THE CONC WALL.

PLATWORK TRAIL SEE CIVIL.

WIDTH OF TRAIL SEE CIVIL

1/2" EL.

3'-0"

1 1/2'-0" SMOOTH

DONELLS 8 12" OC

AT VERT WALL

JOINT LOCUS

4000 PSI CONC RETAINING

WALL W/ 8 10" OC EH

EA FACE

ASSUMED WATER LEVEL

AT FLOODED CONDITION

T.O. WALL

B.O. PIER

30'-0" BELOW

EXIST GRADE

[RECOMMENDED]

LAY BACK EXCAVATION

WHERE APPLICABLE PER

OSHA REQUIREMENTS

AND GEOTECHNICAL

RECOMMENDATIONS

SELECT STRUCTURAL

FILL BELOW FLATWORK.

CLAY FILL ELSEWHERE.

PERFORATED

DRAIN SEE 2/5-3

OPTIONAL TEMP

RETENTION WHERE

CONDITIONS DICTATE

EXIST EARTH

TOP OF CREEK BLK

WATERSTOP AT WALL

DONELLS TO WALL ABOVE

30' 3000 PSI CONC PIER W/ (17-40)

VERT BARS, SPACE AT 9'-0" OC MAX.

NOTE: ADDITIONAL GEOTECHNICAL

INVESTIGATION MAY BE REQD TO

ACCOUNT FOR BELLED PIER SPACINGS

TYPICAL RETAINING WALL AT EDGE OF CREEK (TRAIL BEHIND)

SCALE 1/4"=1'-0"

NOTE: DETAILS 2/5-3 AND 1/2-4 MAY BE COMBINED FOR LOCATIONS WHERE

RETAINING WALLS ARE REQUIRED AT BOTH SIDES OF A 16'-0" WIDE TRAIL

SIDEwall NEAR THE EDGE OF THE CREEK.

NOTE: TYPICAL BELL DIAETERS AT RETAINING WALL PIERS ASSUMED TO

BE 15X SHAFT DIAMETER.

NOTE: SEE 5-3 FOR DESIGN ASSUMPTIONS AT RETAINING WALLS.

FEASIBILITY STUDY DRAWINGS ONLY. NOT FOR CONSTRUCTION OR PERMITTING.
SCHEMATIC FRAMING PLAN AT WOOD BOARDWALK

SCALE: 1/4"=1'-0"

NOTE: THE TYPICAL WIDTH OF BOARDWALK IS ASSUMED TO BE 12'-0" WITH LESS THAN 1'-0" DROP AT THE EDGES. NO GUARDRAIL IS PROVIDED WHERE THE DROP IS GREATER THAN 1'-0" AND A GUARDRAIL IS REQUIRED. THE BOARDWALK WIDTH IS ASSUMED TO INCREASE TO 14'-0" OR 16'-0" WIDE. THE CANTILEVER EDGE CONDITION APPLIES WHEN GUARDRAILS ARE REQUIRED.

NOTE: TWO OPTIONS ARE PROVIDED FOR BOARDWALK FOUNDATIONS. THE FOOTING SHOWN IN 2/5'-6" MAY BE USED, THOUGH MOVEMENT DUE TO THE EXPANSIVE CLAYS SHOULD BE EXPECTED. WHERE EXCESSIVE MOVEMENT IS NOT ACCEPTABLE, DRILLED PIERS MAY BE USED INSTEAD. IN EACH CASE, THE WOOD POST IS EMBEDDED IN THE FOUNDATION.

FEASIBILITY STUDY DRAWINGS ONLY. NOT FOR CONSTRUCTION OR PERMITTING.
SCHEMATIC FOUNDATION PAD
AT RELOCATED BUS SHELTERS

NOTE: THE FOUNDATION HAS BEEN DESIGNED USING THE MAXIMUM DIMENSIONS SHOWN. IT IS APPLICABLE FOR SMALLER PADS ALSO.

EXIST BUS SHELTER COLUMN BASE
CONGRADATIONS AND LOCATIONS VARY, FIELD VERIFY AT EACH LOC.

NEW CONC PIER UNDER RELOCATED BUS SHELTER COLUMN BASE

EXIST SHELTER COLUMN & BASE PL. VY
3000 PSI CONC PEDESTAL W/4 ANCHOR BOLTS, MATCH EXIST
T.O.PAD EL = SEE CIVIL
CONC SLAB, SEE PLAN
SELECT STRUCT FILL BELOW PAD AND PLATHORK

CONC SLAB, SEE PLAN
18"/36" BELL 3000 PSI CONP PIER W/ 60-106 VERT BARS

SCALE: 3/4"=1'-0"

S-7

FEASIBILITY STUDY DRAWINGS ONLY. NOT FOR CONSTRUCTION OR PERMITTING.