Restraining Thrust Forces

Forces Causing Thrust
- Static forces (Internal pressure)
- Dynamic forces (Fluid velocity)

Thrust Force
- Straight Run

Thrust Force
- Bend

Resultant Thrust: 90° Bend

<table>
<thead>
<tr>
<th>Nominal Pipe Size (in)</th>
<th>Thrust Force (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>7,932</td>
</tr>
<tr>
<td>12</td>
<td>29,030</td>
</tr>
<tr>
<td>24</td>
<td>110,901</td>
</tr>
<tr>
<td>36</td>
<td>244,396</td>
</tr>
<tr>
<td>48</td>
<td>429,956</td>
</tr>
<tr>
<td>64</td>
<td>718,506</td>
</tr>
</tbody>
</table>
Restraining Techniques

- Thrust blocks
- Restrained joint system
- Tie rods
- Combined systems

Types of Thrust Blocks

- Bearing
- Gravity

Bearing Thrust Block

\[ A = h b = \frac{T}{S_B} (S_f) \]

Safety Factor • Thrust Force (lbs)

Bearing Area (ft^2) = Safety Factor • Thrust Force (lbs)

Bearing Capacity of Undisturbed Soil (lbs/ft^2)

Soil Bearing Strength \( S_B \)

<table>
<thead>
<tr>
<th>Soil</th>
<th>( S_B ) (lb/ft^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muck</td>
<td>0</td>
</tr>
<tr>
<td>Soft clay</td>
<td>1,000</td>
</tr>
<tr>
<td>Silt</td>
<td>1,500</td>
</tr>
<tr>
<td>Sandy silt</td>
<td>3,000</td>
</tr>
<tr>
<td>Sand</td>
<td>4,000</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>6,000</td>
</tr>
<tr>
<td>Hard clay</td>
<td>9,000</td>
</tr>
</tbody>
</table>

Bearing Thrust Block

Bearing Block Construction

Right

Wrong
Gravity Block Size ($ft^3$) = Safety Factor \times \text{Thrust Force (lb)} \div \text{Density of Block Material (lb/ft^3)}
Restrained Joint Force System

\[ L = \frac{PA \tan(\theta/2)}{F_r + \frac{1}{2} R_s} \]

\[ \theta \]

\[ \frac{[F_r + \frac{1}{2} R_s] L \cos(\theta/2)}{PA \sin(\theta/2)} \]

Mechanical Joint Retainer Glands

- Set-Screw
- Mechanical Joint Retainer Gland
- Wedge-action
- Mechanical Joint Retainer Gland

Restrained Joints
**Designing Thrust Systems**

**Thrust Restraint Brochure**

A brochure outlining design theory and a design aid of restrained joint systems for ductile iron pipe.

**Restrained Joint Force System**

\[
L = \frac{PA \tan(\theta/2)}{F_f + \frac{1}{2} R_s} - \frac{PA \sin(\theta/2)}{R_s}\]

**Restrained Length Dependant Upon**

- Pipe size
- Type of fitting
- Internal pressure
- Depth of cover
- Soil characteristics
- Laying conditions

**Suggested Values for Soil Properties and Reduction Constant**

<table>
<thead>
<tr>
<th>Soil Designation</th>
<th>Soil Description</th>
<th>( \phi ) (deg)</th>
<th>( C_s ) (psf)</th>
<th>( L ) (deg)</th>
<th>( R_s )</th>
<th>( K_n )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay 1</td>
<td>Clay of medium to low plasticity, LL&lt;50, &lt;25% coarse particles (CL &amp; CH)</td>
<td>0</td>
<td>0</td>
<td>300</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Clay 2</td>
<td>Clay of high plasticity, LL&lt;20, &gt;75% coarse particles (CH)</td>
<td>0</td>
<td>0</td>
<td>300</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Cohesion</td>
<td>Cohesion only, ( \phi &gt; 40 )</td>
<td>0</td>
<td>0</td>
<td>300</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Cohesion &amp; Sand</td>
<td>Cohesion and sand, ( \phi &gt; 30 )</td>
<td>0</td>
<td>0</td>
<td>300</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Sand</td>
<td>Sand only, ( \phi &gt; 20 )</td>
<td>0</td>
<td>0</td>
<td>300</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Good Sand</td>
<td>Good sand, ( \phi &gt; 15 )</td>
<td>0</td>
<td>0</td>
<td>300</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

Consult Table 3 of thrust brochure for pertinent notes.

**Laying Conditions**

- Type 1
- Type 2
- Type 3
- Type 4
- Type 5

**Thrust Restraint - Research**

12" MJ Pipe and fittings with DI retainer glands.
Designing Thrust Systems

Thrust Restraint Computer Program

A computer program to aid in the design of restrained joint systems for ductile iron pipe.

Table B-5

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Coh - gran</th>
<th>A21.50 - Laying Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>θ</td>
<td>Tan(θ/2)</td>
<td>2PA Sin(θ/2)</td>
</tr>
<tr>
<td>90°</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>45°</td>
<td>0.414</td>
<td></td>
</tr>
<tr>
<td>22½°</td>
<td>0.199</td>
<td></td>
</tr>
<tr>
<td>11½°</td>
<td>0.098</td>
<td></td>
</tr>
</tbody>
</table>

Extend Restrained Joints at:

- Casings
- Bridge crossings
- Aboveground applications
- Poor soil conditions
- Closely located fittings
**Combined Horizontal Bends**

\[ L_1 = L_2 = \frac{2PA \sin(\theta/2)}{F_1 + \frac{1}{2}R_n} - L \]

**Vertical Offset**

\[ L_2 = \frac{2PA \tan(\theta/2)}{F_1 + \frac{1}{2}R_n} + L \]

**Combined Vertical Equal Angle Offsets**

\[ L_1 = L_2 = \frac{2PA \tan(\theta/2)}{F_1} - L \]
Thrust Restraint – Deflected Joints

Second unrestrained joint begin deflect

First unrestrained joint do not deflect

Horizontal Bend / Vertical Up Bend

\[ L = S_i \left( \frac{F_T + \frac{1}{2} R_s}{PA \tan(\theta/2)} \right) \]

\[ [F_T + \frac{1}{2} R_s] \cos(\theta/2) \]

Tie Rods
Calculating Number of Tie Rods

\[ F = S A \]

\[ N = \frac{S_f T_{(X \text{ or } Y)}}{F} \]

Where:
- \( F \) = Force Developed per Rod (lbs.)
- \( S \) = Tensile Strength of Rod Material (psi)
- \( A \) = Cross Sectional Area of Rod (in.\(^2\))
- \( N \) = Number of Rods Required
- \( T_{(X \text{ or } Y)} \) = Thrust Force Component (lbs.)
- \( S_f \) = Safety Factor (usually 1.5)

Combined Systems

DUCTILE IRON PIPE
THE RIGHT DECISION