Plastic vs Concrete Pipe
An Engineer’s Responsibility

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BS Civil Engineering – University of Cincinnati – 1981
Ohio PE Registration – 1985
35 Years in the Precast Industry
    Architectural, Structural, Underground, Form MFG.
Assessment

Technical

Financial
Loads on Any Pipe

• Earth
• Live
• Construction
• Surcharge Loads
Concrete Pipe

An Engineered Product
Plant Tested

Flexible Pipe

An Engineered Installation
Field Tested???
Designing Pipe for Drainage Systems

What does the FHWA Require
“...While these requirements are routinely and rigorously applied to bridges and bridge-sized culverts, I wanted to remind you that they also extend to other applications such as smaller culverts, structural supports for signs, luminaries, traffic signals and buried pipes...”

Thomas D. Everett
Associate Administrator
FHWA Office of Infrastructure
FHWA email to all districts - July 20, 2016

Design requirements refer to Federal Regulation 23CFR625


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Concrete Pipe

AASHTO 12.10-Reinforced Concrete Pipe

12.10.1-General

The provisions herein shall apply to the structural design of buried precast reinforced concrete pipes of circular, elliptical and arch shapes. The structural design of the types of pipes indicated above may proceed by either of two methods:

• The **direct design method** at the strength limit state as specified in article 12.10.4.2, or

• The **indirect design method** at the service limit state as specified in article 12.10.4.3

Flexible Pipe

AASHTO 12.12-Thermoplastic Pipes

12.12.1-General

The provisions herein shall apply to the structural design of buried thermoplastic pipe with solid, corrugated, or profile wall, manufactured of PE, PP, or PVC.
Concrete Pipe

Direct Design:
Hand Calculations
Software

Indirect Design:
3 - Edge Bearing
In Situ

Flexible Pipe

AASHTO 12.12-Thermoplastic Pipes

12.12.1-General

The provisions herein shall apply to the structural design of buried thermoplastic pipe with solid, corrugated, or profile wall, manufactured of PE, PP, or PVC.
Concrete Pipe

The following Fill Height Tables have been developed by the American Concrete Pipe Association (ACPA) using the indirect design method in accordance with Section 12.10.4.3 of the AASHTO LRFD Bridge Design Specification, 7th Edition, 2014.

Fill Height Tables are based on:
1. ys = 120 pcf
2. AASHTO HL-93 live load
3. Positive Projecting Embankment Condition - this gives conservative results in comparison to trench conditions
4. A Type 1 installation requires greater soil stiffness from the surrounding soils than the Type 2, 3, and 4 installations, and is thus harder to achieve. Therefore, field verification of soil properties and compaction levels should be performed.

<table>
<thead>
<tr>
<th>Fill Height in Feet</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<th>11</th>
<th>12</th>
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<th>14</th>
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<tbody>
<tr>
<td>Pipe Size (in)</td>
<td>12</td>
<td>1612</td>
<td>1399</td>
<td>888</td>
<td>695</td>
<td>633</td>
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<td>635</td>
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<td>1262</td>
<td>814</td>
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<td>595</td>
<td>587</td>
<td>603</td>
<td>629</td>
<td>527</td>
<td>583</td>
<td>638</td>
<td>694</td>
<td>750</td>
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<td>586</td>
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<td>535</td>
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<td>641</td>
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<td>597</td>
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<td>709</td>
<td>765</td>
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<tr>
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<td>36</td>
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<td>1187</td>
<td>780</td>
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<td>595</td>
<td>595</td>
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<td>643</td>
<td>547</td>
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<td>961</td>
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<td>618</td>
<td>651</td>
<td>588</td>
<td>644</td>
<td>701</td>
<td>758</td>
<td>814</td>
</tr>
</tbody>
</table>
AASHTO 12.12-Thermoplastic Pipes

12.12.1-General

The provisions herein shall apply to the structural design of buried thermoplastic pipe with solid, corrugated, or profile wall, manufactured of PE, PP, or PVC.
Concrete Pipe

Flexible Pipe

D-Load (lb/ft²) for Type 3 Bedding

Design Complete!

Table 3
Maximum Cover for ADS N-12, N-12 ST, and N-12 WT Pipe (per AASHTO), ft (m)

<table>
<thead>
<tr>
<th>Diameter (in.)</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Compacted</td>
<td>Dumped</td>
<td>95%</td>
</tr>
<tr>
<td>4 (105)</td>
<td>37</td>
<td>35</td>
<td>29.5</td>
</tr>
<tr>
<td>6 (155)</td>
<td>44 (13.4)</td>
<td>40 (12)</td>
<td>31 (9.5)</td>
</tr>
<tr>
<td>8 (200)</td>
<td>48 (14)</td>
<td>44 (12)</td>
<td>35 (10)</td>
</tr>
<tr>
<td>10 (250)</td>
<td>50 (15)</td>
<td>46 (13)</td>
<td>33.5 (10)</td>
</tr>
<tr>
<td>12 (300)</td>
<td>52 (16)</td>
<td>48 (14)</td>
<td>32 (10)</td>
</tr>
<tr>
<td>15 (375)</td>
<td>56 (18)</td>
<td>52 (15)</td>
<td>30 (10)</td>
</tr>
<tr>
<td>18 (450)</td>
<td>58 (19)</td>
<td>54 (16)</td>
<td>28.5 (8.5)</td>
</tr>
<tr>
<td>24 (600)</td>
<td>64 (22)</td>
<td>60 (18)</td>
<td>23 (7)</td>
</tr>
<tr>
<td>30 (750)</td>
<td>66 (24)</td>
<td>62 (19)</td>
<td>21 (6.7)</td>
</tr>
<tr>
<td>36 (900)</td>
<td>68 (25)</td>
<td>64 (20)</td>
<td>20 (6)</td>
</tr>
<tr>
<td>48 (1200)</td>
<td>76 (29)</td>
<td>72 (23)</td>
<td>16 (4.9)</td>
</tr>
<tr>
<td>60 (1500)</td>
<td>78 (31)</td>
<td>74 (25)</td>
<td>15 (4.9)</td>
</tr>
</tbody>
</table>

Notes:
1. Results based on calculations shown in the Structures section of the ADS Drainage Handbook (V20.7). Calculations require an infiltration factor, which is a density of 120 lb/ft³ (200 kg/m³) for examination of pipe installation.
2. Installation assumed to be in accordance with ASTM D2291 and the installation section of the Drainage Handbook.
3. For installations using lower quality backfill materials or lower compaction efforts, pipe deflection may exceed the 5% design limit; however controlled deflection may not be a structurally limiting factor for the pipe. For installations where deflection is critical, pipe placement techniques or periodic deflection measurements may be required to ensure satisfactory pipe installation.
4. Backfill materials and compaction levels not shown in the table may also be acceptable. Contact for further details.
5. Material must be adequately “knifed” into haunch and in between corrugations. Compaction and backfill material is assumed uniform throughout the entire backfill zone.
6. Compaction values are for minimum proper density.
7. For projects where cover exceeds the maximum values listed above, contact specific design considerations.
Introduction

The information in this document is designed to provide answers to general cover height questions; the data provided is not intended to be used for project design. The design procedure described in the Structures section (Section 2) of the Drainage Handbook provides detailed information for analyzing most common installation conditions. This procedure should be utilized for project specific designs.

The two common cover height concerns are minimum cover in areas exposed to vehicular traffic and maximum cover heights. Either may be considered "worst case" scenario from a loading perspective, depending on the project conditions.
Concrete Pipe

Flexible Pipe

**2-2 INTRODUCTION**

Pipe behavior can be broadly classified as flexible or rigid, depending on how it performs when installed. Flexible pipe must move, or deflect, to transfer the overburden load to the surrounding soil. ADS N-12, HP Storm, SanItite, SanItite HP and Singlewall pipe are all examples of flexible pipe. Flexible pipe, therefore, is not designed to carry overburden loads directly. Rigid pipe is commonly defined as a pipe that does not deflect more than 2% without structural distress, and as such, it must be designed to carry the majority of the load directly. Reinforced and non-reinforced concrete pipe are both examples of rigid pipe.

Both flexible and rigid pipe depend on proper backfill. In the case of flexible pipe, deflection allows loads to be transferred to and carried by the backfill. Rigid pipe transmits most of the load through the pipe wall into the bedding. In both cases, proper backfill is very important in allowing this load transfer to occur.

Many research projects have investigated the behavior of flexible pipe. Thermoplastic pipe performance has been investigated through use of actual field installations, post-installation inspections, load cell tests, and finite element computer analyses. Now, three decades after its introduction, the behavior of thermoplastic pipe, including corrugated polyethylene and corrugated polypropylene pipes, has probably been analyzed more than any other conventional drainage pipe.

The information in subsequent areas of this section provides a step-by-step guide for the structural design of nonpressure corrugated polyethylene and polypropylene pipe. The methodology is based on the AASHTO design procedure, and has been proven through test installations and actual projects to be highly conservative. More discussion on actual installations is included in Section 2-5.
Concrete Pipe

D-Load (lb/ft²/ft) for Type 3 Bedding

Design Complete!

Flexible Pipe

SOIL PRISM PRESSURE ($P_{sp}$)

$P_{sp}$ is calculated for 3 possible conditions:

1. Water table above top of pipe and at or above the ground surface

2. Water table above top of pipe and below the ground surface

3. Water table below top of pipe

*Evaluate multiple conditions if water table fluctuates.

Also check for FLOTATION
Concrete Pipe

Flexible Pipe

Design Complete!
Concrete Pipe

Design Complete!

Flexible Pipe

BUCKLING

- Pipe wall must have sufficient stiffness to remain stable under compression loads.

\[
\varepsilon_{uc} = \frac{1.2 \cdot A_p \cdot E_p}{A_p \cdot (1 - v)} \leq \Phi \cdot \varepsilon_{pck}
\]

in which:

\[
R_b = \frac{114}{12 + H}
\]

Poor soil support decreases pipe's ability to resist buckling.
Concrete Pipe

Flexible Pipe

D-Load (lb/ft²) for Type 3 Bedding

COMBINED STRAINS

- Must check combined strains at extreme fibers since bending strain from deflection creates tension (T) and compression (C) zones

\[
\varepsilon_f = \varepsilon_{c, f} < \Phi_f \varepsilon_f \quad (12.12.3.10.b-1)
\]

The combined strain at the extreme fiber where flexure causes compression shall satisfy:

\[
\varepsilon_f + \varepsilon_{c, f} < \Phi_c (1.5\varepsilon_{c, f}) \quad (12.12.3.10.b-2)
\]

Design Complete!
Flexible Pipe

**DEFLECTION**

\[
\Delta_l = \frac{K_B(D_L P_{S_L} + C_L P_L)D_o}{1000 \left(\frac{E_p I_p}{R^3} + 0.061M_s\right)} + \epsilon_{SC} D
\]

- Caused by bending deformation plus circumferential shortening due to thrust
- Controlled by proper soil support and must be verified with a deflection test
- Maximum allowable deflection = 5.0%

Concrete Pipe

**Design Complete!**

D-Load (lb/ft^2) for Type 3 Bedding
**Concrete Pipe**

D-Load (lb/ft²) for Type 3 Bedding

**Flexible Pipe**

**Modified Iowa Formula**

\[
\Delta y = \frac{1000K (D_L W_C + W_L)}{0.149 (18) + 0.061 (1000)}
\]

For 48" HDPE, 12 ft. cover, HL-93 Live Load with PS=18 psi and \(E' = 1,000\) psi

Design Complete!
**Concrete Pipe**

**Flexible Pipe**

**Modified Iowa Formula**

\[
\Delta y = \frac{1000K (D_L W_C + W_L)}{\text{Pipe Stiffness} + (\text{Constant}) \times (\text{Soil Stiffness})}
\]

For 48" HDPE, 12 ft. cover, HL-93 Live Load

\[
\Delta y = \frac{1000 \times (2.682 + 61.00)}{2.682 + 61.00} \times 96\% + 4\%
\]

with PS=18 psi and \(E' = 1,000\) psi

*Design Complete!*
### Flexible Pipe

#### HDPE System Strength

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Pipe Stiffness</th>
<th>Pipe Contribution</th>
<th>Soil Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>50</td>
<td>11%</td>
<td>89%</td>
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<tr>
<td>15</td>
<td>42</td>
<td>10%</td>
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<td>91%</td>
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<td>24</td>
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<td>8%</td>
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<td>54</td>
<td>16</td>
<td>4%</td>
<td>96%</td>
</tr>
<tr>
<td>60</td>
<td>14</td>
<td>3%</td>
<td>97%</td>
</tr>
</tbody>
</table>

Design Complete!
Which calculation for thermoplastic pipe design can be verified in the field?

- Thrust
- Loading
- Deflection
- Combined Strains
Pipe Installations

Key Differences
Concrete Pipe

Flexible Pipe

Conduit

Cover

Pipe ID

Haunch Area
Concrete Pipe
Installation – Is It Important?

Flexible Pipe
Installation – Is It Important?

Conduit
Cover
Structure

NO...
It’s CRITICAL!

YES!
WHAT DIFFERENCE DOES IT MAKE???
IF YOU COULD JUST GO AHEAD AND EXPLAIN THAT

THAT’D BE GRRRRREAT
Concrete Pipe

Engineer
Manufacture per ASTM C76
Install per ASTM C1479

Manufacturer
C76 - OKAY

Installer
C1479 - OKAY

Flexible Pipe

Engineer
“as per manufacturer’s recommendations”

Manufacturer
“As per ASTM D2321”

ASTM D2321
Engineer referenced 24 times
WHAT DO THE STANDARDS REALLY SAY?
Concrete Pipe

Designation: C1479 – 16

Standard Practice for
Installation of Precast Concrete Sewer, Storm Drain, and Culvert Pipe Using Standard Installations

Flexible Pipe

Designation: D2321 – 18

Standard Practice for
Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications
TIME TO TALK DIRTY
### Concrete Pipe

**Designation:** C1479 – 16

**TABLE 3 Equivalent USCS and AASHTO Soil Classifications for Soil Designations**

<table>
<thead>
<tr>
<th>Soil Classification</th>
<th>USCS</th>
<th>Representative Soil Types</th>
<th>AASHTO M 145</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category I</td>
<td>Clean, coarse grained soils: SW, SP, GW, GP, or any soil beginning with one of these symbols, with 12 % or less passing a #200 sieve</td>
<td>A-1, A-3</td>
<td></td>
</tr>
<tr>
<td>Category II</td>
<td>Coarse grained soils with fines: GM, SC, SM, SC, or any soil beginning with one of these symbols, containing more than 12 % passing a #200 sieve</td>
<td>A-2-4, A-2-5, A-4-4 or A-6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sandy or gravely fine-grained soils: CL, ML, (or CL-ML, CL/ML, ML/CL) with 30 % or more retained on a #200 sieve</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Category III</td>
<td>Fine-grained soils: CL, ML, (or CL-ML, CL/ML, ML/CL) with less than 30 % retained on a #200 sieve</td>
<td>A-2-7, or A-4 or A-6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MH, CH, OL, OH, PT</td>
<td>A-6, A-7</td>
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</tr>
</tbody>
</table>

### Flexible Pipe

**Designation:** D2321 – 18

**TABLE 2 Soil Classes**

<table>
<thead>
<tr>
<th>Soil Group*</th>
<th>Soil Class</th>
<th>American Association of State Highway and Transportation Officials (AASHTO) Soil Groups†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushed rock, angular</td>
<td>Class I</td>
<td>…</td>
</tr>
<tr>
<td>100% passing 1-1/2 in. sieve, &lt;= 15 % passing #4 sieve, &lt;= 25 % passing 3/8 in. sieve and &lt;= 12 % passing #200 sieve</td>
<td>Class II</td>
<td>A-1, A-3</td>
</tr>
<tr>
<td>GM, GC, SM, SC, or any soil beginning with one of these symbols, containing more than 12 % passing a #200 sieve</td>
<td>Class III</td>
<td>A-2-4, A-2-5, A-2-6, or A-4, A-3, A-6, A-6 or A-6 soils with more than 30% retained on #200 sieve</td>
</tr>
<tr>
<td>Coarse grained soils with fines: GM, GC, SM, SC, or any soil beginning with one of these symbols, containing more than 12 % passing a #200 sieve</td>
<td>Class IV</td>
<td>A-2-7, A-4, or A-6 soils with 30% or less retained on #200 sieve</td>
</tr>
<tr>
<td>Sandy or gravelly fine-grained soils: CL, ML, or any soil beginning with one of these symbols, with &gt; 30 % retained</td>
<td>Class V</td>
<td>A-5, A-7</td>
</tr>
<tr>
<td>CL, ML, (or CL-ML, CL/ML, ML/CL) with 30 % or more retained on a #200 sieve</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Soil Group is based on USCS soil classification.
† AASHTO Soil Groups are based on AASHTO M 145.
### TABLE 3 Equivalent USCS and AASHTO Soil Classifications for Soil Designations

<table>
<thead>
<tr>
<th>Category</th>
<th>USCS</th>
<th>AASHTO M 145</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category I</td>
<td>Clean, coarse grained soils; SW, SP, GW, GP, or any soil beginning with one of these symbols, with 12 % or less passing a #200 sieve</td>
<td>A-1, A-3</td>
</tr>
<tr>
<td>Category II</td>
<td>Coarse grained soils with fines: GM, GC, SM, SC, or any soil beginning with one of these symbols, containing more than 12 % passing a #200 sieve</td>
<td>A-2-4, A-2-3, A-2-6, or A-4-4 or A-4-6 soils with 30 % or more retained on a #200 sieve</td>
</tr>
<tr>
<td>Category III</td>
<td>Sandy or gravelly fine-grained soils: CL, ML, (or CL-ML, CL/ML, ML/CL) with 30 % or more retained on a #200 sieve</td>
<td></td>
</tr>
<tr>
<td>Category IV</td>
<td>Fine-grained soils: CL, ML, (or CL-ML, CL/ML, ML/CL) with less than 30 % retained on a #200 sieve</td>
<td>A-2-7, or A-4 of A-6 with less than 30 % retained on a #200 sieve</td>
</tr>
<tr>
<td>Category IV</td>
<td>but not allowed for haunch or bedding</td>
<td>A-6, A-7</td>
</tr>
</tbody>
</table>

### TABLE 2 Soil Classes

<table>
<thead>
<tr>
<th>Soil Group</th>
<th>Soil Class</th>
<th>American Association of State Highway and Transportation Officials (AASHTO) Soil Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushed rock, angular: 100% passing 1-1/2 in sieve, &lt;=15 % passing #8 sieve, &lt;=25 % passing #300 sieve and &lt;=12 % passing #200 sieve</td>
<td>Class I</td>
<td>…</td>
</tr>
<tr>
<td>Coarse grained soils: SW, SP, GW, GP or any soil beginning with one of these symbols with &lt;=12 % passing #200 sieve</td>
<td>Class II</td>
<td>A-1, A-3</td>
</tr>
<tr>
<td>Coarse grained soils with fines: GM, GC, SM, SC, or any soil beginning with one of these symbols, containing &gt;12 % passing #200 sieve; Sandy or gravelly fine-grained soils: CL, ML, or any soil beginning with one of these symbols, with &gt;30 % retained on #200 sieve</td>
<td>Class III</td>
<td>A-2-4, A-2-5, A-2-6, or A-4 or A-6 soils with more than 30 % retained on #200 sieve</td>
</tr>
<tr>
<td>Fine-grained soils: CL, ML, or any soil beginning with one of these symbols, with &lt;=30 % retained on #200 sieve</td>
<td>Class IV</td>
<td>A-2-7, or A-4, or A-6 soils with 30 % or less retained on #200 sieve</td>
</tr>
<tr>
<td>MH, CH, OL, OH, PT</td>
<td>Class V</td>
<td>Not for use as embedment</td>
</tr>
<tr>
<td>MH, CH, OL, OH, PT</td>
<td>Class V</td>
<td>A-5, A-7</td>
</tr>
</tbody>
</table>
1. Scope

1.1 This practice covers the installation of precast concrete pipe intended to be used for the conveyance of sewage, industrial wastes, and storm water for the construction of culverts.

1.2 This practice is the inch-pound companion to practice C1479; therefore, no SI equivalents are presented in this practice.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of the standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
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---

1. Scope

1.1 This practice provides recommendations for the installation of buried thermoplastic pipe used in sewers and other gravity-flow applications. These recommendations are intended to ensure a stable underground environment for thermoplastic pipe under a wide range of service conditions. However, because of the numerous flexible plastic pipe products available and the inherent variability of natural ground conditions, achieving satisfactory performance of any one product may require modification to provisions contained herein to meet specific project requirements.
Concrete Pipe

1. Scope

1.1 This practice covers the installation of precast concrete pipe intended to be used for the conveyance of sewage, industrial wastes, and storm water for the construction of culverts.

1.2 This practice is the inch-pound companion to practice C1479; therefore, no SI equivalents are presented in this practice.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of the standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Flexible Pipe

1. Scope

1.2 The scope of this practice necessarily excludes product performance criteria such as minimum pipe stiffness, maximum service deflection, or long term strength. Thus, it is incumbent upon the product manufacturer, specifier, or project engineer to verify and assure that the pipe specified for an intended application, when installed according to procedures outlined in this practice, will provide a long term, satisfactory performance according to criteria established for that application. A commentary on factors important in achieving a satisfactory installation is included in Appendix X1.
1. Scope

1.1 This practice covers the installation of precast concrete pipe intended to be used for the conveyance of sewage, industrial wastes, and storm water for the construction of culverts.

1.2 This practice is the inch-pound companion to practice C1479; therefore, no SI equivalents are presented in this practice.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of the standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1. Scope

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At what point is the structural backfill complete for reinforced concrete pipe installations?

- Middle 1/3 of the bedding
- Springline
- 6” over top of the pipe
- Top of trench
Concrete Pipe

2. Referenced Documents

2.1 ASTM Standards: (7 Total)
   - Terminology
   - Manufacture of pipe
   - Soil description, classification & identification
   - Soil compaction

2.2 AASHTO Standards: (4 Total)
   - Soil classification, density & moisture

2.3 ASCE Standards: (1 Total)
   - ASCE 15 Standard practice for the Direct Design of Buried Precast Reinforced Concrete Pipe Using Standard Installations (SIDD)

Flexible Pipe

2. Referenced Documents

2.1 ASTM Standards: (23 Total)
   - Terminology
   - Site characterization for Engineering Design
   - Test Methods for density, unit weight, moisture
   - External loading – parallel plate loading
   - Soils classification
   - Solvent cements for PVC
   - Safe solvent handling
   - Guide for construction procedures

2.2 AASHTO Standards: (1 Total)
   - Soil classification
3. Terminology

3.1 For definitions of terms relating to concrete pipe, see Terminology C822

3.2 For terminology related to soil classifications, see Practice D2487 and Practice D2488

3.3 For terminology and definitions of terms relating to structural design, see ASCE 15

3.4 Fig. 1 illustrates the definitions and limits of the terms: foundation, subgrade, bedding, outer bedding, middle bedding, haunch, lower side, backfill or overfill, invert, crown, springline, top of pipe, and bottom of pipe as used in this practice.

3. Terminology

3.3.3 engineer – the engineer in responsible charge of the work or his duly recognized or authorized representative.

3.3.4 foundation, bedding, haunching, initial backfill, pipe zone, excavated trench width – See Fig. 1 for meaning and limits, and trench terminology.

3.3.6 modulus of soil reaction (E’) – an empirical value used in the Iowa deflection formula that defines the stiffness of the soil embedment around a buried pipe.
3. Terminology

3.1 For definitions of terms relating to concrete pipe, see Terminology C822

3.2 For terminology related to soil classifications, see Practice D2487 and Practice D2488

3.3 For terminology and definitions of terms relating to structural design, see ASCE 15

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Concrete Pipe

Flexible Pipe

FIG. 1 Trench Cross Section

* See 7.6 Minimum Cover

FIG. 3 Standard Trench Installations

Note 1—Clearance between pipe and trench wall shall be adequate to enable specified compaction but not less than $D_o/6$. 

CONCRETEPIPE.ORG
Concrete Pipe

Flexible Pipe

NOTES:
1. Clearance between pipe and trench wall shall be adequate to enable specified compaction but not less than D/6.

FIG. 3 Standard Trench Installations

FIG. 1 Trench Cross Section

* See 7.6 Minimum Cover
Concrete Pipe

Flexible Pipe

FIG. 1 Trench Cross Section

* See 7.6 Minimum Cover

FIG. 3 Standard Trench Installations

Note 1—Clearance between pipe and trench wall shall be adequate to enable specified compaction but not less than D_0/6.

CONCRETEPIPE.ORG
7.6 Minimum Cover — The minimum depth of cover should be established by the engineer based on evaluation of specific project conditions. In the absence of an engineering evaluation, the following minimum cover requirements should be used...

<table>
<thead>
<tr>
<th>Size</th>
<th>Class I</th>
<th>Class II, III, IV</th>
<th>Hydrohammer</th>
</tr>
</thead>
<tbody>
<tr>
<td>12&quot;</td>
<td>24&quot;</td>
<td>36&quot;</td>
<td>48&quot;</td>
</tr>
<tr>
<td>18&quot;</td>
<td>24&quot;</td>
<td>36&quot;</td>
<td>48&quot;</td>
</tr>
<tr>
<td>24&quot;</td>
<td>24&quot;</td>
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<td>54&quot;</td>
<td>54&quot;</td>
<td>54&quot;</td>
<td>48&quot;</td>
</tr>
<tr>
<td>60&quot;</td>
<td>60&quot;</td>
<td>60&quot;</td>
<td>48&quot;</td>
</tr>
</tbody>
</table>

...Do not use hydrohammer-type compactors unless approved by the engineer.
4. Significance and Use

4.1 This practice is useful as a reference by an owner and the owner’s engineer in preparing project specifications.
BACK TO THE SOILS
## TABLE 2 Standard Trench Installation Soils and Minimum Compaction Requirements

<table>
<thead>
<tr>
<th>Installation Type</th>
<th>Bedding Thickness</th>
<th>Haunch and Outer Bedding</th>
<th>Lower Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>$D_o/24$ minimum; not less than 3 in. If rock foundation, use $D_o/12$ minimum; not less than 6 in.</td>
<td>95 % Category I</td>
<td>90 % Category I, 95 % Category II</td>
</tr>
<tr>
<td>Type 2</td>
<td>$D_o/24$ minimum; not less than 3 in. If rock foundation, use $D_o/12$ minimum; not less than 6 in.</td>
<td>90 % Category I or 95 % Category II</td>
<td>85 % Category I, 90 % Category II, or 95 % Category III</td>
</tr>
<tr>
<td>Type 3</td>
<td>$D_o/24$ minimum; not less than 3 in. If rock foundation, use $D_o/12$ minimum; not less than 6 in.</td>
<td>85 % Category I, 90 % Category II, or 95 % Category III</td>
<td>85 % Category I, 90 % Category II, or 95 % Category III</td>
</tr>
<tr>
<td>Type 4</td>
<td>No bedding required, except if rock foundation, use $D_o/12$ minimum; not less than 6 in.</td>
<td>No compaction required, except if Category III, use 85 % Category III</td>
<td>No compaction required, except if Category III, use 85 % Category III</td>
</tr>
</tbody>
</table>
5. Materials

5.2 Installation and Use — Table 3 provides recommendations on installation and use on soil classifications and location in the trench. Soil classes I to IV should be used as recommended in Table 3. Soil Class V, including clays and silts with liquid limits greater than 50, organic soils, and frozen soils, shall be excluded from the pipe-zone embedment.
<table>
<thead>
<tr>
<th>Soil Class</th>
<th>Class II</th>
<th>Class III</th>
<th>Class IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Recommendations and Restrictions</td>
<td>Acceptable and common where no migration is probable or when combined with a geotextile filter media. Suitable for use as a drainage blanket and under drain where adjacent material is suitably graded or when used with a geotextile filter fabric (see Table 2).</td>
<td>Where hydraulic gradient exists check gradation to minimize migration. Clean groups are suitable for use as a drainage blanket and under drain (see Table 2). Uniform fine sands (SP) with more than 50% passing a No. 100 sieve (0.066 in., 0.16 mm) behave like silts and should be treated as Class III soils.</td>
<td>Do not use where water conditions in trench prevent proper placement and compaction. Not recommended for use with pipes with stiffness of 9 psi or less.</td>
</tr>
<tr>
<td>Foundation</td>
<td>Suitable as foundation and for replacing over-excavated and unstable trench bottom as restricted above.</td>
<td>Suitable for replacing over-excavated and unstable trench bottom as restricted above. Install and compact in 12 in. (300 mm) maximum layers.</td>
<td>Suitable for replacing over-excavated trench bottom for depths up to 12 in. (300 mm) as restricted above. Use only where uniform longitudinal support of the pipe can be maintained, as approved by the engineer. Install and compact in 6 in. (150 mm) maximum layers.</td>
</tr>
<tr>
<td>Pipe Embedment</td>
<td>Suitable as restricted above. Work material under pipe to provide uniform launch support.</td>
<td>Suitable as restricted above. Work material under pipe to provide uniform launch support.</td>
<td>Suitable as restricted above.</td>
</tr>
<tr>
<td>Minimum Recommended Percent Compaction, SP</td>
<td>See Note D</td>
<td>85% (SW and SP soils) For GW and GP soils see Note D</td>
<td>90% 95%</td>
</tr>
<tr>
<td>Relative Compactive Effort Required to Achieve Minimum Percent Compaction</td>
<td>low</td>
<td>moderate</td>
<td>high</td>
</tr>
<tr>
<td>Compaction Methods</td>
<td>vibration or impact</td>
<td>vibration or impact</td>
<td>impact</td>
</tr>
<tr>
<td>Required Moisture Control</td>
<td>none</td>
<td>none</td>
<td>Maintain near optimum to minimize compactive effort</td>
</tr>
<tr>
<td>Soil Class</td>
<td>Class I</td>
<td>Class II</td>
<td>Class III</td>
</tr>
<tr>
<td>------------</td>
<td>---------</td>
<td>----------</td>
<td>-----------</td>
</tr>
<tr>
<td>General Recommendations and Restrictions</td>
<td>Acceptable and common where no migration is probable or when combined with a geotextile filter media. Suitable for use as a drainage blanket and under drain where adjacent material is suitably graded or when used with a geotextile filter fabric (see X1.8).</td>
<td>Where hydraulic gradient exists check gradation to minimize migration. Clean groups are suitable for use as a drainage blanket and under drain (see Table 2). Uniform fine sands (SP) with more than 50% passing a #100 sieve (0.006 in., 0.16 mm) behave like silts and should be treated as Class III soils.</td>
<td>Do not use where water conditions in trench prevent proper placement and compaction. Not recommended for use with pipes with stiffness of 9 psi or less</td>
</tr>
<tr>
<td>Foundation</td>
<td>Suitable as foundation and for replacing over-excavated and unstable trench bottom as restricted above.</td>
<td>Suitable as foundation and for replacing over-excavated and unstable trench bottom as restricted above. Install and compact in 12 in. (300 mm) maximum layers</td>
<td>Suitable for replacing over-excavated trench bottom as restricted above. Install and compact in 5 in. (150 mm) maximum layers</td>
</tr>
<tr>
<td>Pipe Embedment</td>
<td>Suitable as restricted above. Work material under pipe to provide uniformlaunch support.</td>
<td>Suitable as restricted above. Work material under pipe to provide uniform launch support.</td>
<td>Suitable as restricted above. Difficult to place and compact in the launch zone.</td>
</tr>
<tr>
<td>Minimum Recommended Percent Compaction, (SPD)</td>
<td>See Note 2</td>
<td>85% (SW and SP soils) For GW and GP soils see Note 2</td>
<td>90%</td>
</tr>
<tr>
<td>Relative Compactive Effort Required to Achieve Minimum Percent Compaction</td>
<td>low</td>
<td>moderate</td>
<td>high</td>
</tr>
<tr>
<td>Compaction Methods</td>
<td>vibration or impact</td>
<td>vibration or impact</td>
<td>impact</td>
</tr>
<tr>
<td>Required Moisture Control</td>
<td>none</td>
<td>none</td>
<td>Maintain near optimum to minimize compactive effort</td>
</tr>
<tr>
<td>Soil Class&lt;sup&gt;a&lt;/sup&gt;</td>
<td>General Recommendations and Restrictions</td>
<td>Class I&lt;sup&gt;2&lt;/sup&gt;</td>
<td>Class II</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------------------------------------</td>
<td>-------------------</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td>Acceptable and common where no migration is probable or when combined with a geotextile filter media. Suitable for use as a drainage blanket and under drain where adjacent material is suitably graded or when used with a geotextile filter fabric (see X1.8).</td>
<td>Where hydraulic gradient exists check gradation to minimize migration. Clean groups are suitable for use as a drainage blanket and under drain (see Table 2). Uniform fine sands (SP) with more than 50% passing a #100 sieve (0.006 in., 0.16 mm) behave like silts and should be treated as Class III soils.</td>
<td>Do not use where water conditions in trench prevent proper placement and compaction. Not recommended for use with pipes with stiffness of 9 psi or less.</td>
</tr>
<tr>
<td></td>
<td>Foundation</td>
<td>Suitable as foundation and for replacing over-excavated and unstable trench bottom as restricted above.</td>
<td>Suitable as foundation and for replacing over-excavated and unstable trench bottom as restricted above. Install and compact in 12 in. (300 mm) maximum layers.</td>
</tr>
<tr>
<td></td>
<td>Pipe Embedment</td>
<td>Suitable as restricted above. Work material under pipe to provide uniform load support.</td>
<td>Suitable as restricted above. Work material under pipe to provide uniform load support.</td>
</tr>
<tr>
<td></td>
<td>Minimum Recommended Percent Compaction, SP&lt;sup&gt;d&lt;/sup&gt;</td>
<td>See Note&lt;sup&gt;f&lt;/sup&gt;</td>
<td>85% (SW and SP soils) For GW and GP soils see Note&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Relative Compactive Effort Required to Achieve Minimum Percent Compaction</td>
<td>low</td>
<td>moderate</td>
</tr>
<tr>
<td></td>
<td>Compaction Methods</td>
<td>vibration or impact</td>
<td>vibration or impact</td>
</tr>
<tr>
<td></td>
<td>Required Moisture Control</td>
<td>none</td>
<td>none</td>
</tr>
</tbody>
</table>

<sup>a</sup> See Note<sup>j</sup> Minimum Cover.
<sup>b</sup> Trench Cross Section.
<sup>c</sup> See Note<sup>f</sup>.
<sup>d</sup> See Note<sup>i</sup>.
<table>
<thead>
<tr>
<th>Soil Class&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Class I&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Class II</th>
<th>Class III</th>
<th>Class IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Recommendations and Restrictions</td>
<td>Acceptable and common where no migration is probable or when combined with a geotextile filter media. Suitable for use as a drainage blanket and underdrain (see Table 2). Uniform fine sands (SP) with more than 50% passing a #100 sieve (0.006 in., 0.16 mm) behave like silts and should be treated as Class III soils.</td>
<td>Where hydraulic gradient exists check gradation to minimize migration. Clean groups are suitable for use as a drainage blanket and underdrain (see Table 2). Uniform fine sands (SP) with more than 50% passing a #100 sieve (0.006 in., 0.16 mm) behave like silts and should be treated as Class III soils.</td>
<td>Do not use where water conditions in trench prevent proper placement and compaction. Not recommended for use with pipes with stiffness of 9 psi or less.</td>
<td>Difficult to achieve high soil stiffness. Do not use where water conditions in trench prevent proper placement and compaction. Not recommended for use with pipes with stiffness of 9 psi or less.</td>
</tr>
<tr>
<td>Foundation</td>
<td>Suitable as foundation and for replacing over-excavated and unstable trench bottom as restricted above.</td>
<td>Suitable as foundation and for replacing over-excavated and unstable trench bottom as restricted above. Install and compact in 12 in. (300 mm) maximum layers.</td>
<td>Suitable for replacing over-excavated trench bottom as restricted above. Install and compact in 6 in. (150 mm) maximum layers.</td>
<td>Suitable for replacing over-excavated trench bottom for depths up to 12 in. (300 mm) as restricted above. Use only where uniform longitudinal support of the pipe can be maintained, as approved by the engineer. Install and compact in 6 in. (150 mm) maximum layers.</td>
</tr>
<tr>
<td>Pipe Embedment</td>
<td>Suitable as restricted above. Work material under pipe to provide uniform haunch support.</td>
<td>Suitable as restricted above. Work material under pipe to provide uniform haunch support.</td>
<td>Suitable as restricted above.</td>
<td>Suitable as restricted above.</td>
</tr>
<tr>
<td>Minimum Recommended Percent Compaction, (SP)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>See Note&lt;sup&gt;d&lt;/sup&gt;</td>
<td>85% (SW and SP soils) For GW and GP soils see Note&lt;sup&gt;e&lt;/sup&gt;</td>
<td>90%</td>
<td>95%</td>
</tr>
<tr>
<td>Relative Compactive Effort Required to Achieve Minimum Percent Compaction</td>
<td>low</td>
<td>moderate</td>
<td>high</td>
<td>very high</td>
</tr>
<tr>
<td>Compaction Methods</td>
<td>vibration or impact</td>
<td>vibration or impact</td>
<td>impact</td>
<td>impact</td>
</tr>
<tr>
<td>Required Moisture Control</td>
<td>none</td>
<td>none</td>
<td>Maintain near optimum to minimize compactive effort</td>
<td>Maintain near optimum to minimize compactive effort</td>
</tr>
<tr>
<td>Pipe Embedment</td>
<td>Suitable as restricted above. Work material under pipe to provide uniform haunch support.</td>
<td>Suitable as restricted above. Work material under pipe to provide uniform haunch support.</td>
<td>Suitable as restricted above. Difficult to place and compact in the haunch zone.</td>
<td>Suitable as restricted above. Difficult to place and compact in the haunch zone.</td>
</tr>
<tr>
<td>---------------</td>
<td>------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Minimum Recommended Percent Compaction, SPD&lt;sup&gt;D&lt;/sup&gt;</td>
<td>See Note&lt;sup&gt;C&lt;/sup&gt; 85% (SW and SP soils) For GW and GP soils see Note&lt;sup&gt;E&lt;/sup&gt;</td>
<td>90%</td>
<td>95%</td>
<td></td>
</tr>
<tr>
<td>Relative Compactive Effort Required to Achieve Minimum Percent Compaction</td>
<td>low</td>
<td>moderate</td>
<td>high</td>
<td>very high</td>
</tr>
<tr>
<td>Compaction Methods</td>
<td>vibration or impact</td>
<td>vibration or impact</td>
<td>impact</td>
<td>impact</td>
</tr>
<tr>
<td>Required Moisture Control</td>
<td>none</td>
<td>none</td>
<td>Maintain near optimum to minimize compactive effort</td>
<td>Maintain near optimum to minimize compactive effort</td>
</tr>
</tbody>
</table>

---

<sup>A</sup> Class V materials are unsuitable as embedment. They may be used as final backfill as permitted by the engineer.

<sup>B</sup> Class I materials have higher stiffness than Class II materials, but data on specific soil stiffness values are not available at the current time. Until such data are available the soil stiffness of placed, uncompacted Class I materials can be taken equivalent to Class II materials compacted to 95% of maximum standard Proctor density (SPD<sub>95</sub>), and the soil stiffness of compacted Class I materials can be taken equivalent to Class II materials compacted to 100% of maximum standard Proctor density (SPD<sub>100</sub>). Even if placed uncompacted (that is, dumped), Class I materials should always be worked into the haunch zone to assure complete placement.

<sup>C</sup> Suitable compaction typically achieved by dumped placement (that is, uncompacted but worked into haunch zone to ensure complete placement).

<sup>D</sup> SPD is standard Proctor density as determined by Test Method D<sub>698</sub>.

<sup>E</sup> Place and compact GW and GP soils with at least two passes of compaction equipment.
Concrete Pipe

Design Complete!

Flexible Pipe

Table 3

Maximum Cover for ADS N-12, N-12 ST, and N-12 WT Pipe (per AASHTO), ft (m)

<table>
<thead>
<tr>
<th>Diameter (in.)</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Compacted</td>
<td>Dumped</td>
<td>95%</td>
</tr>
<tr>
<td>4.00 (100)</td>
<td>29 (8.5)</td>
<td>27 (8.2)</td>
<td>25 (7.6)</td>
</tr>
<tr>
<td>5.00 (125)</td>
<td>38 (9.7)</td>
<td>36 (9.3)</td>
<td>34 (8.7)</td>
</tr>
<tr>
<td>6.00 (150)</td>
<td>46 (11.6)</td>
<td>43 (11.2)</td>
<td>41 (10.7)</td>
</tr>
<tr>
<td>7.00 (175)</td>
<td>55 (14.1)</td>
<td>51 (13.6)</td>
<td>48 (13.1)</td>
</tr>
<tr>
<td>8.00 (200)</td>
<td>64 (16.1)</td>
<td>60 (15.7)</td>
<td>56 (15.2)</td>
</tr>
<tr>
<td>9.00 (225)</td>
<td>73 (18.7)</td>
<td>69 (18.3)</td>
<td>65 (17.9)</td>
</tr>
<tr>
<td>10.00 (250)</td>
<td>82 (20.7)</td>
<td>78 (20.3)</td>
<td>74 (19.9)</td>
</tr>
<tr>
<td>11.00 (275)</td>
<td>91 (22.7)</td>
<td>87 (22.3)</td>
<td>83 (22.0)</td>
</tr>
<tr>
<td>12.00 (300)</td>
<td>100 (24.7)</td>
<td>96 (24.3)</td>
<td>92 (24.0)</td>
</tr>
</tbody>
</table>

Notes:
1. Results based on calculations shown in the Structures section of the ADS Drainage Handbook (t20.7). Calculations assume an hydraulic diameter of 1,500 mm and a density of 154 gal/ft³ (1290 kg/m³) for examination characteristics.
2. Installation assumed to be in accordance with AASHTO T201 and the installation section of the Drainage Handbook.
3. For installations using lower quality backfill materials or lower compaction efforts, pipe deflection may exceed the 5% design limit, however controlled deflection may not be a structurally limiting factor for the pipe. For installations where deflection is critical, pipe placement techniques or periodic deflection measurements may be required to ensure satisfactory pipe installation.
4. Backfill materials and compaction levels not shown in the table may also be acceptable. Contact the manufacturer for further details.
5. Material must be adequately “torned” into place in and between corrugations. Compaction and backfill material is assumed uniform throughout entire backfill zone.
6. Compaction zone should be the same for standard backfill density.
7. For projects where cover exceeds the maximum values listed above, contact the manufacturer for specific design considerations.
Which pipe material is MOST dependent on soil support in the haunches?

- Concrete
- Thermoplastic
Concrete Pipe

9. Bedding

9.3 The maximum aggregate size shall be 1 in. when the bedding thickness is less than 6 in. and 1-1/2 in. when the bedding thickness is 6 in. or greater except as noted in 9.4

Flexible Pipe

5. Materials

5.4 Maximum Particle Size — Maximum particle size for embedment is limited to material passing a 1-1/2-in. (37.5-mm) sieve (see Table 2). To enhance placement around small diameter pipe and to prevent damage to the pipe wall, a smaller maximum size may be required (see X1.9). When final backfill contains rocks, cobbles, etc., the engineer may require greater initial backfill cover levels (see Fig. 1).
Concrete Pipe

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Flexible Pipe

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X1.9 Maximum Particle Size — Limiting particle size to 3/4 in. (20 mm) or less enhances placement of embedment material for nominal pipe sizes 8 in. (200 mm) through 15 in. (380 mm). For smaller pipe, a particle size of about 10 % of the nominal pipe diameter is recommended.
Concrete Pipe

Section 6.3
Min Trench Width
D₀ + 16"
or
1.25 × D₀ + 12"

Flexible Pipe

Fig. 3
Min Trench Width
1.33 × D₀

Notes:
1. Clearance between pipe and trench wall shall be adequate to enable specified compaction but not less than D₀/6
2. See 7.6 Minimum Cover

Fig. 1 Trench Cross Section
### Concrete Pipe

#### Trench Installation

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>O.D.*</th>
<th>1.33 x O.D.</th>
<th>Clear Each Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>12&quot;</td>
<td>16&quot;</td>
<td>21 ⅜&quot;</td>
<td>2 ⅜&quot;</td>
</tr>
<tr>
<td>15&quot;</td>
<td>19-1/2&quot;</td>
<td>26&quot;</td>
<td>3 ⅛&quot;</td>
</tr>
<tr>
<td>18&quot;</td>
<td>23&quot;</td>
<td>30 ⅝&quot;</td>
<td>3 ⅜&quot;</td>
</tr>
<tr>
<td>24&quot;</td>
<td>30&quot;</td>
<td>40&quot;</td>
<td>5&quot;</td>
</tr>
<tr>
<td>30&quot;</td>
<td>37&quot;</td>
<td>49 ⅝&quot;</td>
<td>6 ⅛&quot;</td>
</tr>
<tr>
<td>36&quot;</td>
<td>44&quot;</td>
<td>58 ⅝&quot;</td>
<td>7 ⅝&quot;</td>
</tr>
<tr>
<td>42&quot;</td>
<td>51&quot;</td>
<td>68&quot;</td>
<td>8 ⅛&quot;</td>
</tr>
<tr>
<td>48&quot;</td>
<td>58&quot;</td>
<td>77 ⅜&quot;</td>
<td>9 ⅜&quot;</td>
</tr>
<tr>
<td>60&quot;</td>
<td>67&quot;</td>
<td>89 ⅝&quot;</td>
<td>11 ⅝&quot;</td>
</tr>
</tbody>
</table>

* B-Wall

### Flexible Pipe

#### 6. Trench Excavation

**6.3 Minimum Trench Width**

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>O.D.</th>
<th>O.D.+16&quot;</th>
<th>1.25xO.D.+12&quot;</th>
<th>Clear Each Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>12&quot;</td>
<td>15&quot;</td>
<td>31&quot;</td>
<td>30&quot;</td>
<td>8&quot;</td>
</tr>
<tr>
<td>15&quot;</td>
<td>18&quot;</td>
<td>34&quot;</td>
<td>35&quot;</td>
<td>8 ½&quot;</td>
</tr>
<tr>
<td>18&quot;</td>
<td>21&quot;</td>
<td>37&quot;</td>
<td>38&quot;</td>
<td>8 ½&quot;</td>
</tr>
<tr>
<td>24&quot;</td>
<td>28&quot;</td>
<td>44&quot;</td>
<td>47&quot;</td>
<td>9 ½&quot;</td>
</tr>
<tr>
<td>30&quot;</td>
<td>36&quot;</td>
<td>52&quot;</td>
<td>57&quot;</td>
<td>10 ½&quot;</td>
</tr>
<tr>
<td>36&quot;</td>
<td>42&quot;</td>
<td>58&quot;</td>
<td>65&quot;</td>
<td>11 ½&quot;</td>
</tr>
<tr>
<td>42&quot;</td>
<td>48&quot;</td>
<td>64&quot;</td>
<td>72&quot;</td>
<td>12&quot;</td>
</tr>
<tr>
<td>48&quot;</td>
<td>54&quot;</td>
<td>70&quot;</td>
<td>80&quot;</td>
<td>13&quot;</td>
</tr>
<tr>
<td>60&quot;</td>
<td>67&quot;</td>
<td>83&quot;</td>
<td>96&quot;</td>
<td>14 ½&quot;</td>
</tr>
</tbody>
</table>
**Flexible Pipe**

**X1.10 Embedment Width for Adequate Support** – In certain conditions, a minimum width of embedment material is required to ensure that adequate embedment stiffness is developed to support the pipe. These conditions arise where in-situ lateral soil resistance is negligible, such as in very poor native soils or along highway embankments. Examples of poor native soils include poorly compacted soils and blow counts of five or less, peat, muck, or highly expansive soils. Under these conditions, if the native soil is able to sustain a vertical cut, the minimum embedment width shall be 0.5 pipe diameters on either side of the pipe as shown in Fig. X1.1

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>O.D.</th>
<th>O.D. / 2</th>
<th>2 x O.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>12”</td>
<td>15”</td>
<td>7 ½”</td>
<td>30”</td>
</tr>
<tr>
<td>15”</td>
<td>18”</td>
<td>9”</td>
<td>36”</td>
</tr>
<tr>
<td>18”</td>
<td>21”</td>
<td>10 ½”</td>
<td>42”</td>
</tr>
<tr>
<td>24”</td>
<td>28”</td>
<td>14”</td>
<td>56”</td>
</tr>
<tr>
<td>30”</td>
<td>36”</td>
<td>18”</td>
<td>72”</td>
</tr>
<tr>
<td>36”</td>
<td>42”</td>
<td>21”</td>
<td>84”</td>
</tr>
<tr>
<td>42”</td>
<td>48”</td>
<td>24”</td>
<td>96”</td>
</tr>
<tr>
<td>48”</td>
<td>54”</td>
<td>27”</td>
<td>108”</td>
</tr>
<tr>
<td>60”</td>
<td>67”</td>
<td>33 ½”</td>
<td>134”</td>
</tr>
</tbody>
</table>
Concrete Pipe

Trench Installation

Category I – 85% Compaction
Category II – 90% Compaction
Category III – 95% Compaction

Flexible Pipe

Trench Installation

Class I – Compacted
Class II – 85% Compaction
Class III – 90% Compaction
Class IV – 95% Compaction

9.0 ft³/ft Soil

20.0 ft³/ft Soil

32.4 ft³/ft Soil
## Concrete Pipe

**Embankment Installation**

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>O.D.</th>
<th>3 x O.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>12”</td>
<td>16”</td>
<td>48”</td>
</tr>
<tr>
<td>15”</td>
<td>19 ½”</td>
<td>58 ½”</td>
</tr>
<tr>
<td>18”</td>
<td>23”</td>
<td>69”</td>
</tr>
<tr>
<td>24”</td>
<td>30”</td>
<td>90”</td>
</tr>
<tr>
<td>30”</td>
<td>37”</td>
<td>111”</td>
</tr>
<tr>
<td>36”</td>
<td>44”</td>
<td>132”</td>
</tr>
<tr>
<td>42”</td>
<td>51”</td>
<td>153”</td>
</tr>
<tr>
<td>48”</td>
<td>58”</td>
<td>174”</td>
</tr>
<tr>
<td>60”</td>
<td>67”</td>
<td>201”</td>
</tr>
</tbody>
</table>

## Flexible Pipe

**Embankment Installation Or Trench w/ Poor Soil**

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>O.D.</th>
<th>3 x O.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>12”</td>
<td>15”</td>
<td>45”</td>
</tr>
<tr>
<td>15”</td>
<td>18”</td>
<td>54”</td>
</tr>
<tr>
<td>18”</td>
<td>21”</td>
<td>63”</td>
</tr>
<tr>
<td>24”</td>
<td>28”</td>
<td>84”</td>
</tr>
<tr>
<td>30”</td>
<td>36”</td>
<td>108”</td>
</tr>
<tr>
<td>36”</td>
<td>42”</td>
<td>126”</td>
</tr>
<tr>
<td>42”</td>
<td>48”</td>
<td>144”</td>
</tr>
<tr>
<td>48”</td>
<td>54”</td>
<td>162”</td>
</tr>
<tr>
<td>60”</td>
<td>67”</td>
<td>201”</td>
</tr>
</tbody>
</table>
Concrete Pipe
Embankment Installation

Flexible Pipe
Embankment Installation

29.5 ft^3/ft Soil
Category I – 85% Compaction
Category II – 90% Compaction
Category III – 95% Compaction

56.4 ft^3/ft Soil
Class I – Compacted
Class II – 85% Compaction
Class III – 90% Compaction
Class IV – 95% Compaction
6. Trench Excavation

6.4.2 Movable Trench Wall Supports  Do not disturb the installed pipe and its embedment when using movable trench boxes and shields. Movable supports should not be used below the top of the pipe zone unless approved methods are used for maintaining the integrity of embedment material. Before moving supports, place and compact embedment to sufficient depths to ensure protection of the pipe. As supports are moved, finish placing and compacting embedment.
6. Trench Excavation

6.4.2 Movable Trench Wall Supports  Do not disturb the installed pipe and its embedment when using movable trench boxes and shields. Movable supports should not be used below the top of the pipe zone unless approved methods are used for maintaining the integrity of embedment material. Before moving supports, place and compact embedment to sufficient depths to ensure protection of the pipe. As supports are moved, finish placing and compacting embedment.
Figure 1
Subtrench Installation

- Trench Box
- Backfill Dumped Over Pipe
- Material and Compaction Level Per Project Specifications
- Minimum Trench Width
- 12” Minimum
- 24” Max. Subtrench
- Bedding

Designation: D2321 – 18

EXCAVATED TRENCH WIDTH

FINAL BACKFILL

INITIAL BACKFILL

SPRINGLINE

HAUNCHING

BEDDING

FOUNDATION (IF REQUIRED)

4” (100 mm) MIN.

6” (150 mm) MIN.*

PIPE ZONE

* See 7.6 Minimum Cover

FIG. 1 Trench Cross Section
Regular Trench Installations

In installations not involving a subtrench situation, dragging a trench box should only be done if it does not damage the pipe or disrupt the backfill; otherwise, the box should be lifted vertically into its new position. If it is necessary for a trench box to be dragged through a trench, do not raise the box more than 24” above the work surface.

Another alternative for when the box will be dragged is to use a well-graded granular backfill material at least two diameters on either side of the pipe and compact it to a minimum of 90% standard Proctor density before moving the box. After the trench box is moved, immediately fill the area between the pipe/backfill structure and the trench wall with a granular material.
Concrete Pipe

8. Foundation

8.1 The foundation shall be moderately firm to hard in situ soil, stabilized soil, or compacted fill material.

Flexible Pipe

7. Installation

7.2 Trench Bottom — Install foundation and bedding as required by the engineer according to conditions in the trench bottom. Provide a firm, stable, and uniform bedding for the pipe barrel and any protruding features of its joint. Provide a minimum of 4 in. (100 mm) of bedding unless otherwise specified.
8. Foundation

8.1 the foundation shall be moderately firm to hard in situ soil, stabilized soil, or compacted fill material.

8.2 When unsuitable or unstable material is encountered, the foundation shall be stabilized.

7. Installation

7.2 Trench Bottom — Install foundation and bedding as required by the engineer according to conditions in the trench bottom. Provide a firm, stable, and uniform bedding for the pipe barrel and any protruding features of its joint. Provide a minimum of 4 in. (100 mm) of bedding unless otherwise specified.

7.2.2 Unstable Trench Bottom — Where the trench bottom is unstable or shows a “quick” tendency, excavate to a depth as required by the engineer and replace with a foundation of Class I or Class II material. Use a suitably graded material where conditions may cause migration of fines and loss of pipe support…
Concrete Pipe

Flexible Pipe

**TABLE 2 Standard Trench Installation Soils and Minimum Compaction Requirements**

<table>
<thead>
<tr>
<th>Installation Type</th>
<th>Bedding Thickness</th>
<th>Sub Base</th>
<th>Load Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type 1</strong></td>
<td>D_{r1}/24 minimum, not less than 3 in. If rock foundation, use D_{r1}/12 minimum, not less than 6 in.</td>
<td>95% Category I</td>
<td>Undisturbed soil with firmness equivalent to the following placed soils: 90% Category I, 90% Category II, or embankment to the same requirements</td>
</tr>
<tr>
<td><strong>Type 2</strong></td>
<td>D_{r1}/24 minimum, not less than 3 in. If rock foundation, use D_{r1}/12 minimum, not less than 6 in.</td>
<td>95% Category I or 90% Category II</td>
<td>Undisturbed soil with firmness equivalent to the following placed soils: 90% Category I, 90% Category II, 95% Category III, or embankment to the same requirements</td>
</tr>
<tr>
<td><strong>Type 3</strong></td>
<td>D_{r1}/24 minimum, not less than 3 in. If rock foundation, use D_{r1}/12 minimum, not less than 6 in.</td>
<td>95% Category I, 90% Category II, or 95% Category III</td>
<td>Undisturbed soil with firmness equivalent to the following placed soils: 85% Category I, 90% Category II, 95% Category III, or embankment to the same requirements</td>
</tr>
<tr>
<td><strong>Type 4</strong></td>
<td>No bedding required, except if rock foundation, use D_{r1}/12 minimum, not less than 6 in.</td>
<td>No compaction required, except if Category III, use 85% Category III</td>
<td>No compaction required, except if Category III, use 85% Category III</td>
</tr>
</tbody>
</table>

**Notes:**

1. Compaction and soil symbols (that is, 95% Category I) refer to a soil material category with a minimum standard proctor density. See Table 3 for equivalent modified proctor values and soil types.

2. Type 1 installations require greater soil stiffness than the Type 2, 3, and 4 installations. Proper field verification of soil properties and compaction levels must be performed to ensure compliance with the design requirements. See Appendix X2 for more information and guidance.

3. For Type 1 installation, crushed rock is not an appropriate material for bedding under the pipe. As uncompacted, non-crushed material must be used under the middle third of the pipe outside diameter. While crushed rock meets the requirements of this specification may self compact vertically, it will not flow laterally to provide support for the branches of the pipe. To achieve a 90 to 95% compaction with crushed rock, work material under the branch and compact it to achieve the specified density. Otherwise, the specified installation is not achieved.

4. When the trench width specified must be exceeded, the owner shall be notified.

5. The trench width shall be wider than shown (Fig. 3) if required for adequate space to attain the specified compaction in the branch and bedding zones.

6. Embankment loading shall be used when trench walls consist of embankment unless a geotechnical analysis is made and the soil in the trench walls is compacted to a higher level than the soil in the backfill zone.

7. Required bedding thickness is the thickness of the bedding prior to placement of the pipe.

8. “Dammed” material without additional compactive effort will not provide the design branch support required for Type 1 and 2 installations.

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**INTERNATIONAL**
7. Installation

7.5.1 Percent Compaction of Embedment — The Soil Class (from Table 2) and the required percent compaction of the embedment should be established by the engineer based on an evaluation of specific project conditions (see X1.6.2). The information in Table 3 will provide satisfactory embedment stiffness and is based on achieving an average modulus of soil reaction, \( E' \), of 1000 psi (or an appropriate equivalent constrained modulus, \( M_s \)).
7. Installation

X1.6.2 Embedment Compaction - Embedment compaction requirements should be determined by the engineer based on deflection limits established for the pipe, pipe stiffness, and installation quality control, as well as the characteristics of the in-situ soil and compactibility characteristics of the embedment materials used. The compaction requirements given in Table 3 are based on attaining an average modulus of soil reaction (E') of 1000 psi (or an appropriate equivalent constrained modulus, Ms), which relates soil stiffness to soil type and degree of compaction. For particular installations, the project engineer should verify that the percent compaction specified meets performance requirements.
7. Installation

X1.6.2 Embedment Compaction - Embedment compaction requirements should be determined by the engineer based on deflection limits established for the pipe, pipe stiffness, and installation quality control, as well as the characteristics of the in-situ soil and compactibility characteristics of the embedment materials used. The compaction requirements given in Table 3 are based on attaining an average modulus of soil reaction ($E'$) of 1000 psi (or an appropriate equivalent constrained modulus, $M_s$), which relates soil stiffness to soil type and degree of compaction. For particular installations, the project engineer should verify that the percent compaction specified meets performance requirements.
### 7. Installation

#### 7.5.1 Percent Compaction of Embedment

The Soil Class (from Table 2) and the required percent compaction of the embedment should be established by the engineer based on an evaluation of specific project conditions (see X1.6.2). The information in Table 3 will provide satisfactory embedment stiffness and is based on achieving an average modulus of soil reaction, $E'$, of 1000 psi (or an appropriate equivalent constrained modulus, $M_s$).

<table>
<thead>
<tr>
<th>Soil Class*</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Class IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Recommendations and Restrictions</td>
<td>Where hydraulic gradient exists check gradient to minimize migration. Clean groups are suitable for use as a drainage blanket and underdrain (see Table 2). Uniform fine sands (SP) with more than 50% passing a #100 sieve (0.150 mm) behave like silts and should be treated as Class III soils.</td>
<td>Do not use where water conditions in trench prevent proper placement and compaction. Not recommended for use with pipes with stiffness of 9 psi or less</td>
<td>Difficult to achieve high soil stiffness. Do not use where water conditions in trench prevent proper placement and compaction. Not recommended for use with pipes with stiffness of 9 psi or less</td>
<td></td>
</tr>
<tr>
<td>Foundation</td>
<td>Suitable as foundation and for replacing over-excavated and unstable trench bottom as restricted above.</td>
<td>Suitable as foundation and for replacing over-excavated and unstable trench bottom as restricted above. Install and compact in 6 in. (150 mm) maximum layers</td>
<td>Suitable for replacing over-excavated trench bottom for depths up to 12 in. (300 mm) as restricted above. Use only where uniform longitudinal support of the pipe can be maintained, as approved by the engineer. Install and compact in 6 in. (150 mm) maximum layers</td>
<td></td>
</tr>
<tr>
<td>Pipe Embedment</td>
<td>Suitable as restricted above. Work material under pipe to provide uniform launch support.</td>
<td>Suitable as restricted above. Work material under pipe to provide uniform launch support.</td>
<td>Suitable as restricted above. Difficult to place and compact in the launch zone. Suitable as restricted above. Difficult to place and compact in the launch zone.</td>
<td></td>
</tr>
<tr>
<td>Minimum Recommended Percent Compaction, GPD*</td>
<td>See Note1</td>
<td>65% (GW and GP soils) For GW and GP soils see Note1</td>
<td>90%</td>
<td>85%</td>
</tr>
<tr>
<td>Relative Compactive Effort Required to Achieve Minimum Percent Compaction</td>
<td>low</td>
<td>moderate</td>
<td>high</td>
<td>very high</td>
</tr>
<tr>
<td>Compaction Methods</td>
<td>vibration or impact</td>
<td>vibration or impact</td>
<td>impact</td>
<td>impact</td>
</tr>
<tr>
<td>Required Moisture Correction</td>
<td>none</td>
<td>none</td>
<td>Maintain near optimum to minimize compactive effort</td>
<td>Maintain near optimum to minimize compactive effort</td>
</tr>
</tbody>
</table>

*Class V materials are unsuitable as embedment. They may be used as final backfill as permitted by the engineer.
*Class II materials have higher stiffness than Class II materials, but data on specific soil stiffness values are not available at the current time. Until such data are available the soil stiffness of placed, uncompacted Class II materials can be taken equivalent to Class II materials compacted to 95% of maximum standard Proctor density (SPD50), and the soil stiffness of compacted Class II materials can be taken equivalent to Class II materials compacted to 100% of maximum standard Proctor density (SPD100). Even if placed uncompacted (that is, dumped), Class II materials should always be worked into the launch zone to ensure complete placement.
*Suitable compaction typically achieved by dumped placement (that is, uncompacted but worked into launch zone to ensure complete placement).
*SPD is standard Proctor density as determined by Test Method D1557.
*Place and compact GW and GP soils with at least two passes of compaction equipment.

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**Flexible Pipe**

Designation: D2321 - 18

CONCRETEPIPE.ORG
Introduction

The light weight of high density polyethylene (HDPE) and polypropylene (PP) pipe make it desirable because of the ease of handling and installation but this same benefit also makes these thermoplastic pipes prone to flotation. All pipe products, such as concrete and corrugated metal, are prone to flotation under the right circumstances. In fact, all pipe materials and other buried structures are subject to flotation. When the uplift on the pipe or structure exceeds the downward force of the weight and load it carries, the pipe (or structure) will rise or heave. Where flotation is a possibility, proper installation and/or anchoring of the pipe is critical. This document provides an analysis on minimum cover heights required to prevent pipe flotation for thermoplastic pipe sizes 12”-60”. Buoyant force due to flowable fill is also discussed.
Was Floatation Considered?
7.6 Minimum Cover — The minimum depth of cover should be established by the engineer based on evaluation of specific project conditions. In the absence of an engineering evaluation, the following minimum cover requirements should be used...

<table>
<thead>
<tr>
<th>Size</th>
<th>Class I</th>
<th>Class II, III, IV</th>
<th>Hydrohammer</th>
</tr>
</thead>
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<td>12”</td>
<td>24”</td>
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<td>48”</td>
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<tr>
<td>60”</td>
<td>60”</td>
<td>60”</td>
<td>48”</td>
</tr>
</tbody>
</table>
17. Safety

17.1 Safety requirements for construction shall be in accordance with applicable federal, state, and local regulations.

17.2 Open ends of installed pipe shall be covered during overnight or longer periods of suspended work to prevent access by animals, personnel, and accumulation of soil and debris. Covers shall be braced or fastened to prevent movement. It is not required that these covers be watertight.

Note 3 – (Advisory) If the pipe is plugged watertight when empty, the possibility of pipe floatation should be investigated, and, if necessary, appropriate measures shall be taken to prevent floatation.
Concrete Pipe

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15. Concrete Appurtenances

15.1 Manholes shall be installed in a manner that will minimize differential settlement between pipe and manhole.

15.2 Precast concrete fittings, such as tees and wyes, shall be bedded, installed, and overfilled with the same material and in the same manner as the remainder of the pipeline to reduce the possibility of differential settlement between pipe and fittings.
7. Installation

7.10 Manhole Connections

Use flexible water stops, resilient connectors, or other flexible systems approved by the engineer to make watertight connections to manholes and other structures.
Flexible Pipe

Figure 4:
Product Detail for Manhole Connections

Designation: D2321 – 18
7. Installation

7.11 Field Monitoring — Compliance with contract documents with respect to pipe installation, including trench depth, grade, water conditions, foundation, embedment and backfill materials, joints, density of materials in place, and safety, should be monitored by the engineer at a frequency appropriate to project requirements. Leakage testing specifications, while not within the scope of this practice, should be made part of the specifications for plastic pipe installations, when applicable.
Flexible Pipe

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Flexible Pipe

Designation: D2321 – 18

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Field Inspection of Pipes
X3. Lower Side, Inspection, and Overfill

X3.2 Inspection – The owner is advised to provide for or require adequate inspection of the pipe installation at the construction site.
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X1. Commentary

X1.13 Deflection Testing — To ensure specified deflection limits are not exceeded, the engineer may require deflection testing of the pipe using specified measuring devices. To allow for stabilization of the pipe soil system, deflection tests should be performed at least 30 days after installation. However, as a quality control measure, periodic checks of deflection may be made during installation.
I DON’T ALWAYS TEST PIPE INSTALLATIONS

BUT WHEN I DO, I DO IT RIGHT!
X3. Lower Side, Inspection, and Overfill

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Flexible Pipe

X1. Commentary

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X1.13.1 Optional devices for deflection testing include electronic deflectometers, calibrated television or video cameras, or a properly sized “go, no-go” mandrel. Deflection measurements can be made directly with extension rulers or tape measures in lines that permit safe entry. To ensure accurate measurements, clean the lines before testing.
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Deflection Testing – Not Relevant

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- Go-No-Go device
- 5% Deflection
- Stuck if deflection exceeded
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QUICKPOLL

Who is most at risk if no post installation inspection is required?

Contractor
Engineer
Owner
Pipe Manufacturer
Inspect ALL Pipes to Know What You Own
1. Scope

1.1 This practice covers the installation of precast concrete pipe intended to be used for the conveyance of sewage, industrial wastes, and storm water for the construction of culverts.

1.2 This practice is the inch-pound companion to practice C1479; therefore, no SI equivalents are presented in this practice.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of the standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
So, What is an Engineer to Do?
Concrete Pipe
An Engineered Product

Determine In-Situ Soils
Select Installation Type
Determine Strength Class Req’d
Specify Pipe Class & Installation Type
Specify Post Installation Inspection
**Concrete Pipe**
An Engineered Product

- Determine In-Situ Soils
- Select Installation Type
- Determine Strength Class Req’d
- Specify Pipe Class & Installation Type
- Specify Post Installation Inspection

Specify Manhole Connectors

Conduct Field Monitoring
- Trench Depth
- Grade
- Water Conditions
- Correct Materials
- Density of Materials in Place
- Joints
- Safety

**Flexible Pipe**
An Engineered Installation

Determine In-Situ Soils

Design Flexible Pipe Based on In-Situ Soils or Borrowed Soils

Determine Compaction Required for Structural Capacity

Calculate Deflection

Determine Bedding Requirements Based on Field Conditions

Determine Trench Width Based on Surrounding In-Situ Soils

Verify Depth of Cover is Acceptable for Flotation

Specify Deflection Testing!!!
Plastic vs Concrete Pipe
An Engineer’s Responsibility

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Ohio PE Registration – 1985
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   Architectural, Structural, Underground, Form MFG.

Thank You!