Plastic vs Concrete Pipe

An Engineer's Responsibility

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Ohio PE Registration – 1985
35 Years in the Precast Industry
Architectural, Structural, Underground, Form MFG.

American Concrete Pipe Association

Assessment

Technical

Financial

Loads on Any Pipe

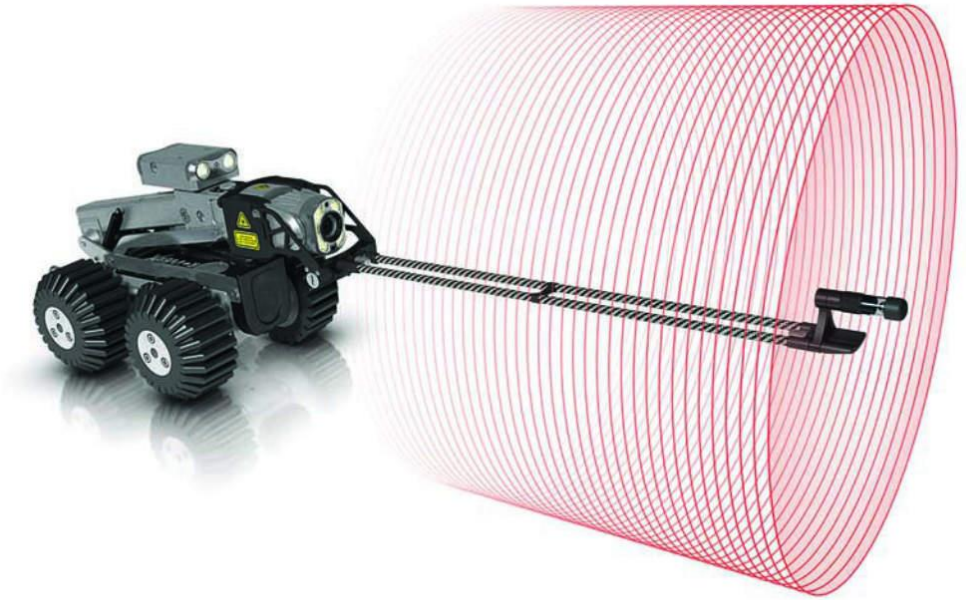
- Earth
- Live
- Construction
- Surcharge Loads

Concrete Pipe

An Engineered Product

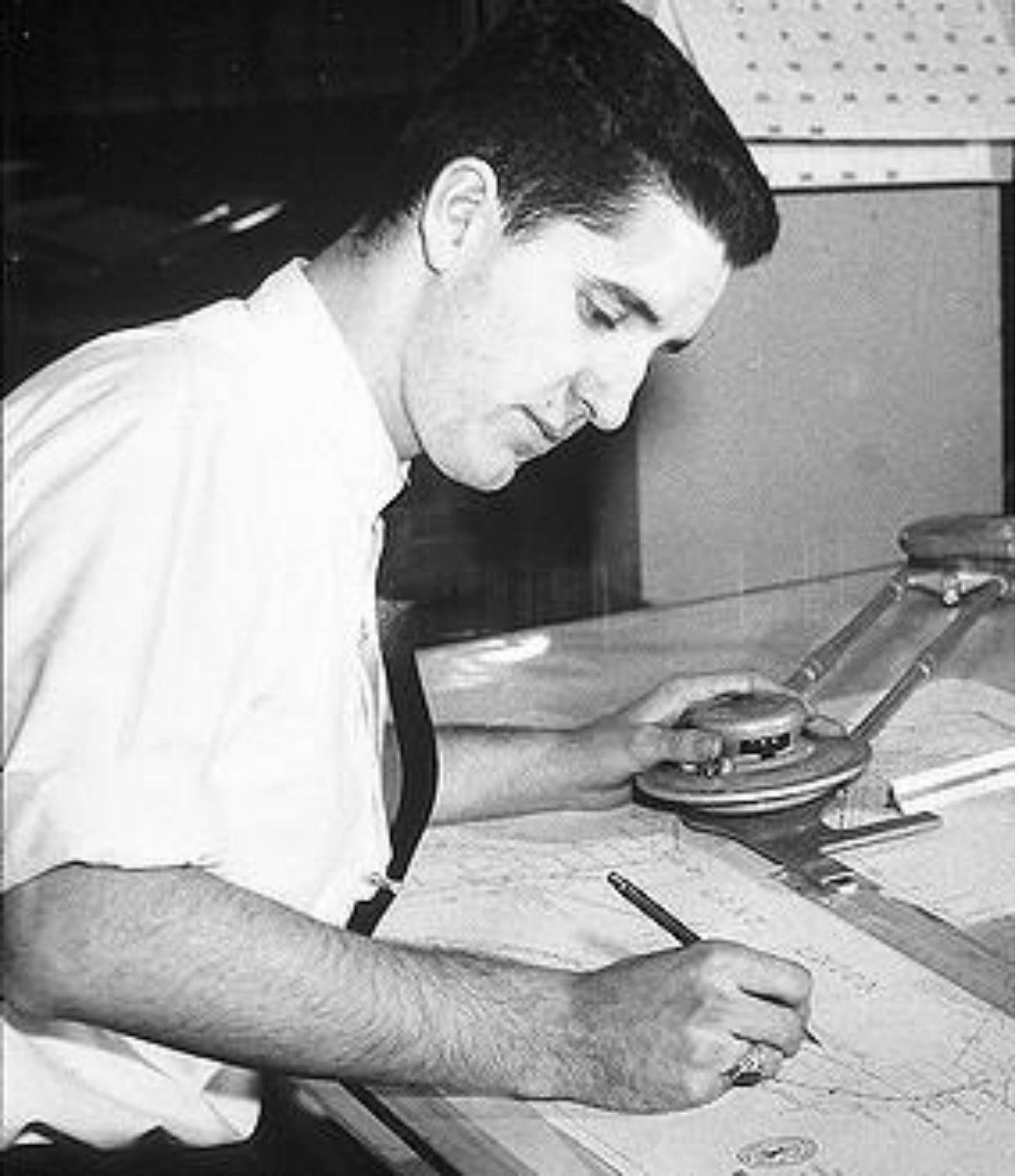
Plant Tested

Flexible Pipe



An Engineered Installation

Field Tested???



Designing Pipe for Drainage Systems

What does the FHWA Require

FHWA email to all districts - July 20, 2016

"…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

Section 23CFR625 refers to "AASHTO LRFD Bridge Design Specifications, 7th Edition, AASHTO 2014, with 2015 Interim Revisions"

Thomas D. Everett
Associate Administrator
FHWA Office of Infrastructure

FHWA email to all districts - July 20, 2016

"…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

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

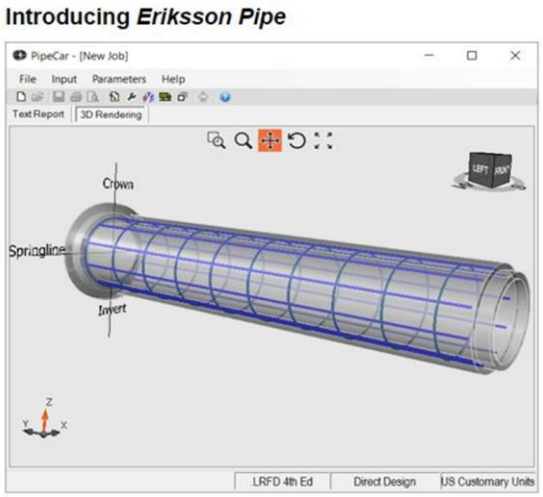
Direct Design:

Hand Calculations

Software

PIPECAR

Version 4.0 June, '05



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

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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. γs = 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.

D-Load (lb/ft/ft) for Type 1 Bedding

Class I
Class II
Class III
Class IV
Class V
Special Design

	Fill Height in Feet													
Pipe Size (in)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
12	1612	1399	888	695	633	620	635	661	544	603	662	721	780	839
15	1546	1344	856	673	614	602	617	644	532	589	646	704	761	818
18	1462	1307	836	660	604	593	608	634	526	583	639	696	752	809
21	1309	1281	823	653	598	588	604	630	525	581	637	693	749	805
24	1287	1262	814	648	595	587	603	629	527	583	638	694	750	805
27	1442	1264	815	653	599	591	608	634	530	586	642	697	753	809
30	1581	1272	819	660	605	598	615	640	535	591	646	702	758	814
33	1443	1222	798	651	599	596	615	641	541	597	653	709	765	821
36	1329	1187	780	643	595	595	616	643	547	603	660	716	772	829
42	1151	1099	745	627	587	591	613	641	553	609	665	721	778	834
48	1019	961	713	614	582	589	612	641	560	616	673	729	785	841
54	969	919	689	604	578	589	613	643	569	625	681	737	794	850
60	994	890	670	596	577	590	615	646	578	634	691	747	804	860
66	946	865	657	589	576	592	618	651	588	644	701	758	814	871

Concrete Pipe

Fill Height Tables are based on:
1. γs = 120 pcf
2. AASHTO HL-93 live load
3. Positive Projecting Embankment Condition - this gives conservative results in comparison to trench conditions

D-Load (lb/ft/ft) for Type 3 Bedding

Class I
Class II
Class III
Class IV
Class V
Special Design

Pipe i.d. (inches)	Fill Height (feet) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
12	1735	1100	875	800	800	850	900	975	1050	1125	1225	1300	1400	1475	1575
15	1600	1025	850	775	775	825	875	950	1025	1100	1200	1275	1375	1450	1525
18	1475	1000	825	775	775	825	875	925	1025	1100	1175	1250	1375	1425	1525
21	1250	950	800	750	750	825	875	925	1025	1075	1175	1250	1375	1425	1500
24	1075	925	775	750	750	825	850	925	1025	1075	1175	1250	1375	1425	1500
27	1000	900	775	750	750	825	875	925	1025	1100	1175	1250	1375	1425	1500
30	950	875	775	750	750	825	875	950	1025	1100	1175	1275	1375	1425	1525
33	925	825	750	750	750	825	875	950	1025	1100	1200	1275	1375	1450	1525
36	900	775	750	750	775	825	875	950	1025	1125	1200	1275	1375	1450	1550
42	850	700	750	750	775	825	900	975	1050	1125	1200	1300	1375	1475	1550
48	875	700	700	750	775	825	900	975	1050	1150	1225	1300	1400	1475	1575
54	850	725	700	750	800	850	925	1000	1075	1150	1250	1350	1400	1500	1575
60	875	750	700	750	800	850	925	1000	1100	1175	1250	1350	1425	1525	1600
66	875	775	700	750	800	875	950	1025	1100	1200	1275	1350	1450	1550	1625
72	850	800	700	750	825	900	975	1050	1125	1200	1300	1375	1475	1550	1650
78	800	775	750	775	825	900	975	1050	1125	1225	1300	1400	1475	1575	1650
84	750	750	775	775	850	900	975	1075	1150	1225	1325	1400	1500	1575	1675
90	725	750	775	800	850	925	1000	1075	1150	1250	1325	1425	1500	1600	1675
96	700	750	775	825	875	925	1000	1100	1175	1250	1350	1425	1525	1600	1700
102	725	750	775	825	875	950	1025	1100	1200	1275	1350	1450	1525	1625	1700
108	725	725	800	825	900	950	1050	1125	1200	1275	1375	1450	1550	1625	1725

Resource # 16-201 (Revised 07/09)

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Design Complete!

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

Fill Height Tables are based on:
1. γs = 120 pcf
2. AASHTO HL-93 live load
3. Positive Projecting Embankment Condition - this gives conservative results in comparison to trench conditions

D-Load (lb/ft/ft) for Type 3 Bedding

Class I, Class II, Class III, Class IV, Class V, Special Design

	Fill Height (feet)														
Pipe i.d. (inches)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
12	1735	1100	875	800	800	850	900	975	1050	1125	1225	1300	1400	1475	1575
15	1600	1025	850	775	775	825	875	950	1025	1100	1200	1275	1375	1450	1525
18	1475	1000	825	775	775	825	875	925	1025	1100	1175	1250	1375	1425	1525
21	1250	950	800	750	750	825	875	925	1025	1075	1175	1250	1375	1425	1500
24	1075	925	775	750	750	825	850	925	1025	1075	1175	1250	1375	1425	1500
27	1000	900	775	750	750	825	875	925	1025	1100	1175	1250	1375	1425	1500
30	950	875	775	750	750	825	875	950	1025	1100	1175	1275	1375	1425	1525
33	925	825	750	750	750	825	875	950	1025	1100	1200	1275	1375	1450	1525
36	900	775	750	750	775	825	875	950	1025	1125	1200	1275	1375	1450	1550
42	850	700	750	750	775	825	900	975	1050	1125	1200	1300	1375	1475	1550
48	875	700	700	750	775	825	900	975	1050	1150	1225	1300	1400	1475	1575
54	850	725	700	750	800	850	925	1000	1075	1150	1250	1350	1400	1500	1575
60	875	750	700	750	800	850	925	1000	1100	1175	1250	1350	1425	1525	1600
66	875	775	700	750	800	875	950	1025	1100	1200	1275	1350	1450	1550	1625
72	850	800	700	750	825	900	975	1050	1125	1200	1300	1375	1475	1550	1650
78	800	775	750	775	825	900	975	1050	1125	1225	1300	1400	1475	1575	1650
84	750	750	775	775	850	900	975	1075	1150	1225	1325	1400	1500	1575	1675
90	725	750	775	800	850	925	1000	1075	1150	1250	1325	1425	1500	1600	1675
96	700	750	775	825	875	925	1000	1100	1175	1250	1350	1425	1525	1600	1700
102	725	750	775	825	875	950	1025	1100	1200	1275	1350	1450	1525	1625	1700
108	725	725	800	825	900	950	1050	1125	1200	1275	1375	1450	1550	1625	1725

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Design Complete!

Flexible Pipe

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

Diameter in. (mm)	Class 1 Compacted		Class 1 Dumped		Class 2 95%		Class 2 90%		Class 2 85% [3]		Class 3 95%		Class 3 90% [3]	
4 (100)	37	(11.3)	18	(5.5)	25	(7.6)	18	(5.5)	12	(3.7)	18	(5.5)	13	(4.0)
6 (150)	44	(13.4)	20	(6.1)	29	(8.8)	20	(6.1)	14	(4.3)	21	(6.4)	15	(4.6)
8 (200)	32	(9.8)	15	(4.6)	22	(6.7)	15	(4.6)	10	(3.0)	16	(4.9)	11	(3.4)
10 (250)	38	(11.6)	18	(5.5)	26	(7.9)	18	(5.5)	12	(3.7)	18	(5.5)	13	(4.0)
12 (300)	35	(10.7)	17	(5.2)	24	(7.3)	17	(5.2)	8	(2.4)	17	(5.2)	11	(3.4)
15 (375)	38	(11.6)	17	(5.2)	25	(7.6)	17	(5.2)	8	(2.4)	18	(5.5)	11	(3.4)
18 (450)	36	(11.0)	17	(5.2)	24	(7.3)	17	(5.2)	8	(2.4)	17	(5.2)	11	(3.4)
24 (600)	28	(8.5)	13	(4.0)	20	(6.1)	13	(4.0)	7	(2.1)	14	(4.3)	10	(3.0)
30 (750)	28	(8.5)	13	(4.0)	20	(6.1)	13	(4.0)	7	(2.1)	14	(4.3)	9	(2.7)
36 (900)	26	(7.9)	12	(3.7)	18	(5.5)	12	(3.7)	7	(2.1)	13	(4.0)	9	(2.7)
42 (1050)	23	(7.0)	11	(3.4)	16	(4.9)	11	(3.4)	7	(2.1)	11	(3.4)	7	(2.1)
48 (1200)	25	(7.6)	11	(3.4)	17	(5.2)	11	(3.4)	7	(2.1)	12	(3.7)	7	(2.1)
54 (1350)	22	(6.7)	10	(3.0)	16	(4.9)	10	(3.0)	6	(1.8)	11	(3.4)	7	(2.1)
60 (1500)	25	(7.6)	11	(3.4)	17	(5.2)	11	(3.4)	6	(1.8)	12	(3.7)	7	(2.1)

Notes:

1. *Results based on calculations shown in the Structures section of the ADS Drainage Handbook (v20.7). Calculations assume no hydrostatic pressure and a density of 120 pcf (1926 kg/m^3) for overburden material.*
2. *Installation assumed to be in accordance with ASTM D2321 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 detail.*
5. *Material must be adequately "knifed" into haunch and in between corrugations. Compaction and backfill material is assumed uniform throughout entire backfill zone.*
6. *Compaction levels shown are for standard Proctor density.*
7. *For projects where cover exceeds the maximum values listed above, contact for specific design considerations.*

Flexible Pipe

TECHNICAL NOTE

Minimum and Maximum Burial Depth for Corrugated HDPE Pipe (per AASHTO)

TN 2.01
October 2016

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

Fill Height Tables are based on:
1. γs = 120 pcf
2. AASHTO HL-93 live load
3. Positive Projecting Embankment Condition - this gives conservative results in comparison to trench conditions

D-Load (lb/ft/ft) for Type 3 Bedding

Class I
Class II
Class III
Class IV
Class V
Special Design

Pipe i.d. (inches)	Fill Height (feet) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
12	1735	1100	875	800	800	850	900	975	1050	1125	1225	1300	1400	1475	1575
15	1600	1025	850	775	775	825	875	950	1025	1100	1200	1275	1375	1450	1525
18	1475	1000	825	775	775	825	875	925	1025	1100	1175	1250	1375	1425	1525
21	1250	950	800	750	750	825	875	925	1025	1075	1175	1250	1375	1425	1500
24	1075	925	775	750	750	825	850	925	1025	1075	1175	1250	1375	1425	1500
27	1000	900	775	750	750	825	875	925	1025	1100	1175	1250	1375	1425	1500
30	950	875	775	750	750	825	875	950	1025	1100	1175	1275	1375	1425	1525
33	925	825	750	750	750	825	875	950	1025	1100	1200	1275	1375	1450	1525
36	900	775	750	750	775	825	875	950	1025	1125	1200	1275	1375	1450	1550
42	850	700	750	750	775	825	900	975	1050	1125	1200	1300	1375	1475	1550
48	875	700	700	750	775	825	900	975	1050	1150	1225	1300	1400	1475	1575
54	850	725	700	750	800	850	925	1000	1075	1150	1250	1350	1400	1500	1575
60	875	750	700	750	800	850	925	1000	1100	1175	1250	1350	1425	1525	1600
66	875	775	700	750	800	875	950	1025	1100	1200	1275	1350	1450	1550	1625
72	850	800	700	750	825	900	975	1050	1125	1200	1300	1375	1475	1550	1650
78	800	775	750	775	825	900	975	1050	1125	1225	1300	1400	1475	1575	1650
84	750	750	775	775	850	900	975	1075	1150	1225	1325	1400	1500	1575	1675
90	725	750	775	800	850	925	1000	1075	1150	1250	1325	1425	1500	1600	1675
96	700	750	775	825	875	925	1000	1100	1175	1250	1350	1425	1525	1600	1700
102	725	750	775	825	875	950	1025	1100	1200	1275	1350	1450	1525	1625	1700
108	725	725	800	825	900	950	1050	1125	1200	1275	1375	1450	1550	1625	1725

Resource # 16-201 (Revised 07/09)

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Design Complete!

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 pipes 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

Fill Height Tables are based on:
1. γs = 120 pcf
2. AASHTO HL-93 live load
3. Positive Projecting Embankment Condition - this gives conservative results in comparison to trench conditions

D-Load (lb/ft/ft) for Type 3 Bedding

Class I
Class II
Class III
Class IV
Class V
Special Design

Pipe i.d. (inches)	Fill Height (feet)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
12	1735	1100	875	800	800	850	900	975	1050	1125	1225	1300	1400	1475	1575
15	1600	1025	850	775	775	825	875	950	1025	1100	1200	1275	1375	1450	1525
18	1475	1000	825	775	775	825	875	925	1025	1100	1175	1250	1375	1425	1525
21	1250	950	800	750	750	825	875	925	1025	1075	1175	1250	1375	1425	1500
24	1075	925	775	750	750	825	850	925	1025	1075	1175	1250	1375	1425	1500
27	1000	900	775	750	750	825	875	925	1025	1100	1175	1250	1375	1425	1500
30	950	875	775	750	750	825	875	950	1025	1100	1175	1275	1375	1425	1525
33	925	825	750	750	750	825	875	950	1025	1100	1200	1275	1375	1450	1525
36	900	775	750	750	775	825	875	950	1025	1125	1200	1275	1375	1450	1550
42	850	700	750	750	775	825	900	975	1050	1125	1200	1300	1375	1475	1550
48	875	700	700	750	775	825	900	975	1050	1150	1225	1300	1400	1475	1575
54	850	725	700	750	800	850	925	1000	1075	1150	1250	1350	1400	1500	1575
60	875	750	700	750	800	850	925	1000	1100	1175	1250	1350	1425	1525	1600
66	875	775	700	750	800	875	950	1025	1100	1200	1275	1350	1450	1550	1625
72	850	800	700	750	825	900	975	1050	1125	1200	1300	1375	1475	1550	1650
78	800	775	750	775	825	900	975	1050	1125	1225	1300	1400	1475	1575	1650
84	750	750	775	775	850	900	975	1075	1150	1225	1325	1400	1500	1575	1675
90	725	750	775	800	850	925	1000	1075	1150	1250	1325	1425	1500	1600	1675
96	700	750	775	825	875	925	1000	1100	1175	1250	1350	1425	1525	1600	1700
102	725	750	775	825	875	950	1025	1100	1200	1275	1350	1450	1525	1625	1700
108	725	725	800	825	900	950	1050	1125	1200	1275	1375	1450	1550	1625	1725

Resource # 16-201 (Revised 07/09)

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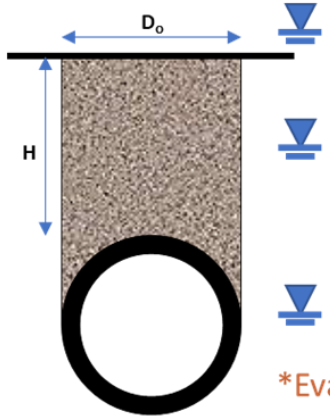
Design Complete!

Flexible Pipe

SOIL PRISM PRESSURE (P_{sp})

Also check for FLOTATION

P_{sp} is calculated for 3 possible conditions:



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

$$P_{sp} = \frac{\left(H + 0.11\frac{D_o}{12}\right)\gamma_b}{144}$$

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

$$P_{sp} = \frac{1}{144}\left[\left[\left(H_w - \frac{D_o}{24}\right) + 0.11\frac{D_o}{12}\right]\gamma_b + \left[H - \left(H_w - \frac{D_o}{24}\right)\right]\gamma_s\right]$$

3. Water table below top of pipe

$$P_{sp} = \frac{\left(H + 0.11\frac{D_o}{12}\right)\gamma_s}{144}$$

*Evaluate multiple conditions if water table fluctuates.

Concrete Pipe

Fill Height Tables are based on:
1. γs = 120 pcf
2. AASHTO HL-93 live load
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D-Load (lb/ft/ft) for Type 3 Bedding

Class I
Class II
Class III
Class IV
Class V
Special Design

Pipe i.d. (inches)	Fill Height (feet) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
12	1735	1100	875	800	800	850	900	975	1050	1125	1225	1300	1400	1475	1575
15	1600	1025	850	775	775	825	875	950	1025	1100	1200	1275	1375	1450	1525
18	1475	1000	825	775	775	825	875	925	1025	1100	1175	1250	1375	1425	1525
21	1250	950	800	750	750	825	875	925	1025	1075	1175	1250	1375	1425	1500
24	1075	925	775	750	750	825	850	925	1025	1075	1175	1250	1375	1425	1500
27	1000	900	775	750	750	825	875	925	1025	1100	1175	1250	1375	1425	1500
30	950	875	775	750	750	825	875	950	1025	1100	1175	1275	1375	1425	1525
33	925	825	750	750	750	825	875	950	1025	1100	1200	1275	1375	1450	1525
36	900	775	750	750	775	825	875	950	1025	1125	1200	1275	1375	1450	1550
42	850	700	750	750	775	825	900	975	1050	1125	1200	1300	1375	1475	1550
48	875	700	700	750	775	825	900	975	1050	1150	1225	1300	1400	1475	1575
54	850	725	700	750	800	850	925	1000	1075	1150	1250	1350	1400	1500	1575
60	875	750	700	750	800	850	925	1000	1100	1175	1250	1350	1425	1525	1600
66	875	775	700	750	800	875	950	1025	1100	1200	1275	1350	1450	1550	1625
72	850	800	700	750	825	900	975	1050	1125	1200	1300	1375	1475	1550	1650
78	800	775	750	775	825	900	975	1050	1125	1225	1300	1400	1475	1575	1650
84	750	750	775	775	850	900	975	1075	1150	1225	1325	1400	1500	1575	1675
90	725	750	775	800	850	925	1000	1075	1150	1250	1325	1425	1500	1600	1675
96	700	750	775	825	875	925	1000	1100	1175	1250	1350	1425	1525	1600	1700
102	725	750	775	825	875	950	1025	1100	1200	1275	1350	1450	1525	1625	1700
108	725	725	800	825	900	950	1050	1125	1200	1275	1375	1450	1550	1625	1725

Resource # 16-201 (Revised 07/09)

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Design Complete!

Flexible Pipe

THRUST

$$T_u = \left[\eta_{EV}\left(\gamma_{EV}K_{\gamma E}K_2VAFP_{sp} + \gamma_{WA}P_w\right) + \eta_{LL}\gamma_{LL}P_L\,C_LF_1F_2\right]\frac{D_o}{2} \quad (12.12.3.5\text{-}1)$$

Live Load
Soil Load (reduced by VAF)
Groundwater

$$\varepsilon_{uc} \le \Phi_T\varepsilon_{yc}$$

Factored compressive strain
Factored compressive strain limit

$$\varepsilon_{uc} = \frac{T_u}{1000\left(A_{eff}E_p\right)}$$

Factored thrust

- Check both **springline** & **crown** of pipe
- Total load contributes – **soil load**, **live load** & **hydrostatic load**
- Short & long-term material properties need to be evaluated due to time-dependent nature of plastic pipe

in which:

$$VAF = 0.76 - 0.71\left(\frac{S_H - 1.17}{S_H + 2.92}\right) \quad (12.12.3.5\text{-}3)$$

$$S_H = \frac{\phi_s M_s R}{E_p A_g} \quad (12.12.3.5\text{-}4)$$

$$C_L = \frac{L_w}{D_o} \le 1.0 \quad (12.12.3.5\text{-}5)$$

$$F_1 = \frac{0.75D_o}{L_w} \ge F_{min} \quad (12.12.3.5\text{-}6)$$

$$F_{min} = \frac{15}{D_i} \ge 1 \quad (12.12.3.5\text{-}7)$$

$$F_2 = \frac{0.95}{1 + 0.6S_H} \quad (12.12.3.5\text{-}8)$$

Concrete Pipe

Fill Height Tables are based on:
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D-Load (lb/ft/ft) for Type 3 Bedding

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Special Design

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15	1600	1025	850	775	775	825	875	950	1025	1100	1200	1275	1375	1450	1525
18	1475	1000	825	775	775	825	875	925	1025	1100	1175	1250	1375	1425	1525
21	1250	950	800	750	750	825	875	925	1025	1075	1175	1250	1375	1425	1500
24	1075	925	775	750	750	825	850	925	1025	1075	1175	1250	1375	1425	1500
27	1000	900	775	750	750	825	875	925	1025	1100	1175	1250	1375	1425	1500
30	950	875	775	750	750	825	875	950	1025	1100	1175	1275	1375	1425	1525
33	925	825	750	750	750	825	875	950	1025	1100	1200	1275	1375	1450	1525
36	900	775	750	750	775	825	875	950	1025	1125	1200	1275	1375	1450	1550
42	850	700	750	750	775	825	900	975	1050	1125	1200	1300	1375	1475	1550
48	875	700	700	750	775	825	900	975	1050	1150	1225	1300	1400	1475	1575
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60	875	750	700	750	800	850	925	1000	1100	1175	1250	1350	1425	1525	1600
66	875	775	700	750	800	875	950	1025	1100	1200	1275	1350	1450	1550	1625
72	850	800	700	750	825	900	975	1050	1125	1200	1300	1375	1475	1550	1650
78	800	775	750	775	825	900	975	1050	1125	1225	1300	1400	1475	1575	1650
84	750	750	775	775	850	900	975	1075	1150	1225	1325	1400	1500	1575	1675
90	725	750	775	800	850	925	1000	1075	1150	1250	1325	1425	1500	1600	1675
96	700	750	775	825	875	925	1000	1100	1175	1250	1350	1425	1525	1600	1700
102	725	750	775	825	875	950	1025	1100	1200	1275	1350	1450	1525	1625	1700
108	725	725	800	825	900	950	1050	1125	1200	1275	1375	1450	1550	1625	1725

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Design Complete!

Flexible Pipe

BUCKLING

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

Resistance factor = 0.7

$$\varepsilon_{uc} \le \Phi_{bck}\varepsilon_{bck}$$

Factored compressive strain

Buckling strain capacity of pipe

Poor soil support decreases pipe's ability to resist buckling

$$\varepsilon_{bck} = \frac{1.2C_n\left(E_pI_p\right)^{\frac{1}{3}}}{A_{eff}E_p}\left[\frac{\phi_s M_s\left(1-2\nu\right)}{\left(1-\nu\right)^2}\right]^{-\frac{2}{3}} R_h \qquad (12.12.3.10.1e\text{-}2)$$

in which:

$$R_h = \frac{11.4}{11+\frac{D}{12H}} \qquad (12.12.3.10.1e\text{-}3)$$

Concrete Pipe

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18	1475	1000	825	775	775	825	875	925	1025	1100	1175	1250	1375	1425	1525
21	1250	950	800	750	750	825	875	925	1025	1075	1175	1250	1375	1425	1500
24	1075	925	775	750	750	825	850	925	1025	1075	1175	1250	1375	1425	1500
27	1000	900	775	750	750	825	875	925	1025	1100	1175	1250	1375	1425	1500
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36	900	775	750	750	775	825	875	950	1025	1125	1200	1275	1375	1450	1550
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72	850	800	700	750	825	900	975	1050	1125	1200	1300	1375	1475	1550	1650
78	800	775	750	775	825	900	975	1050	1125	1225	1300	1400	1475	1575	1650
84	750	750	775	775	850	900	975	1075	1150	1225	1325	1400	1500	1575	1675
90	725	750	775	800	850	925	1000	1075	1150	1250	1325	1425	1500	1600	1675
96	700	750	775	825	875	925	1000	1100	1175	1250	1350	1425	1525	1600	1700
102	725	750	775	825	875	950	1025	1100	1200	1275	1350	1450	1525	1625	1700
108	725	725	800	825	900	950	1050	1125	1200	1275	1375	1450	1550	1625	1725

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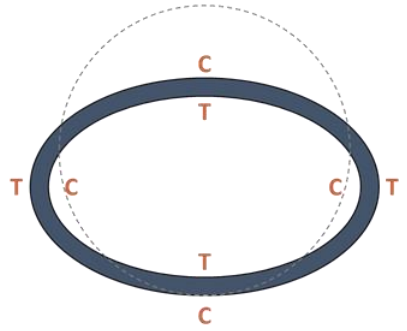
Design Complete!

Flexible Pipe

COMBINED STRAINS

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



12.12.3.10.2b—Combined Strain

If summation of axial strain, ε_{uc}, and bending strain, ε_f, produces tensile strain in the pipe wall, the combined strain at the extreme fiber where flexure causes tension shall satisfy:

$$\varepsilon_f - \varepsilon_{uc} < \phi_f \varepsilon_{yt} \qquad (12.12.3.10.2b\text{-}1)$$

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

$$\varepsilon_f + \varepsilon_{uc} < \phi_T \left(1.5\varepsilon_{yc}\right) \qquad (12.12.3.10.2b\text{-}2)$$

Concrete Pipe

Fill Height Tables are based on:
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D-Load (lb/ft/ft) for Type 3 Bedding

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18	1475	1000	825	775	775	825	875	925	1025	1100	1175	1250	1375	1425	1525
21	1250	950	800	750	750	825	875	925	1025	1075	1175	1250	1375	1425	1500
24	1075	925	775	750	750	825	850	925	1025	1075	1175	1250	1375	1425	1500
27	1000	900	775	750	750	825	875	925	1025	1100	1175	1250	1375	1425	1500
30	950	875	775	750	750	825	875	950	1025	1100	1175	1275	1375	1425	1525
33	925	825	750	750	750	825	875	950	1025	1100	1200	1275	1375	1450	1525
36	900	775	750	750	775	825	875	950	1025	1125	1200	1275	1375	1450	1550
42	850	700	750	750	775	825	900	975	1050	1125	1200	1300	1375	1475	1550
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54	850	725	700	750	800	850	925	1000	1075	1150	1250	1350	1400	1500	1575
60	875	750	700	750	800	850	925	1000	1100	1175	1250	1350	1425	1525	1600
66	875	775	700	750	800	875	950	1025	1100	1200	1275	1350	1450	1550	1625
72	850	800	700	750	825	900	975	1050	1125	1200	1300	1375	1475	1550	1650
78	800	775	750	775	825	900	975	1050	1125	1225	1300	1400	1475	1575	1650
84	750	750	775	775	850	900	975	1075	1150	1225	1325	1400	1500	1575	1675
90	725	750	775	800	850	925	1000	1075	1150	1250	1325	1425	1500	1600	1675
96	700	750	775	825	875	925	1000	1100	1175	1250	1350	1425	1525	1600	1700
102	725	750	775	825	875	950	1025	1100	1200	1275	1350	1450	1525	1625	1700
108	725	725	800	825	900	950	1050	1125	1200	1275	1375	1450	1550	1625	1725

Resource # 16-201 (Revised 07/09)

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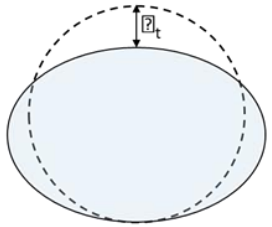
Design Complete!

Flexible Pipe

DEFLECTION



Soil Load | Live Load | Circumferential Shortening

$$\Delta_t = \frac{K_B\left(D_L P_{sp} + C_L P_L\right) D_o}{1000\left(\frac{E_p I_p}{R^3} + 0.061 M_s\right)} + \varepsilon_{sc} D$$

Pipe Properties | Soil Properties

- 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

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18	1475	1000	825	775	775	825	875	925	1025	1100	1175	1250	1375	1425	1525
21	1250	950	800	750	750	825	875	925	1025	1075	1175	1250	1375	1425	1500
24	1075	925	775	750	750	825	850	925	1025	1075	1175	1250	1375	1425	1500
27	1000	900	775	750	750	825	875	925	1025	1100	1175	1250	1375	1425	1500
30	950	875	775	750	750	825	875	950	1025	1100	1175	1275	1375	1425	1525
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Resource # 16-201 (Revised 07/09)

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Flexible Pipe

Modified Iowa Formula

$$\text{Deflection} = \frac{\text{Load}}{\text{Pipe Stiffness} + (\text{Constant})\,(\text{Soil Stiffness})}$$

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

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

Concrete Pipe

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18	1475	1000	825	775	775	825	875	925	1025	1100	1175	1250	1375	1425	1525
21	1250	950	800	750	750	825	875	925	1025	1075	1175	1250	1375	1425	1500
24	1075	925	775	750	750	825	850	925	1025	1075	1175	1250	1375	1425	1500
27	1000	900	775	750	750	825	875	925	1025	1100	1175	1250	1375	1425	1500
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Resource # 16-201 (Revised 07/09)

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Flexible Pipe

Modified Iowa Formula

$$\text{Deflection} = \frac{\text{Load}}{\text{Pipe Stiffness} + (\text{Constant})(\text{Soil Stiffness})}$$

$$\Delta y = \frac{1000K\,(D_L W_C + W_L)}{2.682 + 61.00}$$

4% **96%**

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

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18	1475	1000	825	775	775	825	875	925	1025	1100	1175	1250	1375	1425	1525
21	1250	950	800	750	750	825	875	925	1025	1075	1175	1250	1375	1425	1500
24	1075	925	775	750	750	825	850	925	1025	1075	1175	1250	1375	1425	1500
27	1000	900	775	750	750	825	875	925	1025	1100	1175	1250	1375	1425	1500
30	950	875	775	750	750	825	875	950	1025	1100	1175	1275	1375	1425	1525
33	925	825	750	750	750	825	875	950	1025	1100	1200	1275	1375	1450	1525
36	900	775	750	750	775	825	875	950	1025	1125	1200	1275	1375	1450	1550
42	850	700	750	750	775	825	900	975	1050	1125	1200	1300	1375	1475	1550
48	875	700	700	750	775	825	900	975	1050	1150	1225	1300	1400	1475	1575
54	850	725	700	750	800	850	925	1000	1075	1150	1250	1350	1400	1500	1575
60	875	750	700	750	800	850	925	1000	1100	1175	1250	1350	1425	1525	1600
66	875	775	700	750	800	875	950	1025	1100	1200	1275	1350	1450	1550	1625
72	850	800	700	750	825	900	975	1050	1125	1200	1300	1375	1475	1550	1650
78	800	775	750	775	825	900	975	1050	1125	1225	1300	1400	1475	1575	1650
84	750	750	775	775	850	900	975	1075	1150	1225	1325	1400	1500	1575	1675
90	725	750	775	800	850	925	1000	1075	1150	1250	1325	1425	1500	1600	1675
96	700	750	775	825	875	925	1000	1100	1175	1250	1350	1425	1525	1600	1700
102	725	750	775	825	875	950	1025	1100	1200	1275	1350	1450	1525	1625	1700
108	725	725	800	825	900	950	1050	1125	1200	1275	1375	1450	1550	1625	1725

Resource # 16-201 (Revised 07/09)

11

Design Complete!

Flexible Pipe

HDPE System Strength

Diameter	Pipe Stiffness	Pipe Contribution	Soil Contribution
12	50	11%	89%
15	42	10%	90%
18	40	9%	91%
24	34	8%	92%
30	28	6%	94%
36	22	5%	95%
42	20	5%	95%
48	18	4%	96%
54	16	4%	96%
60	14	3%	97%

QUICKPOLL

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

Thrust

Loading

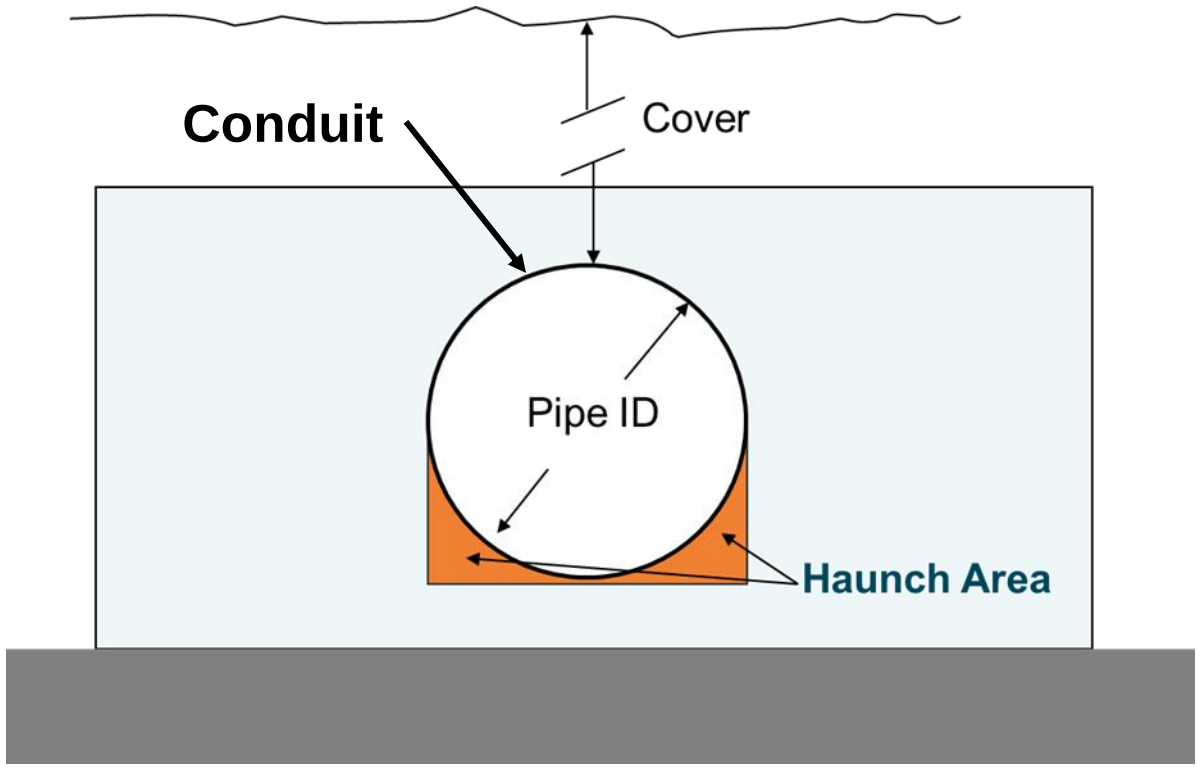
Deflection

Combined Strains

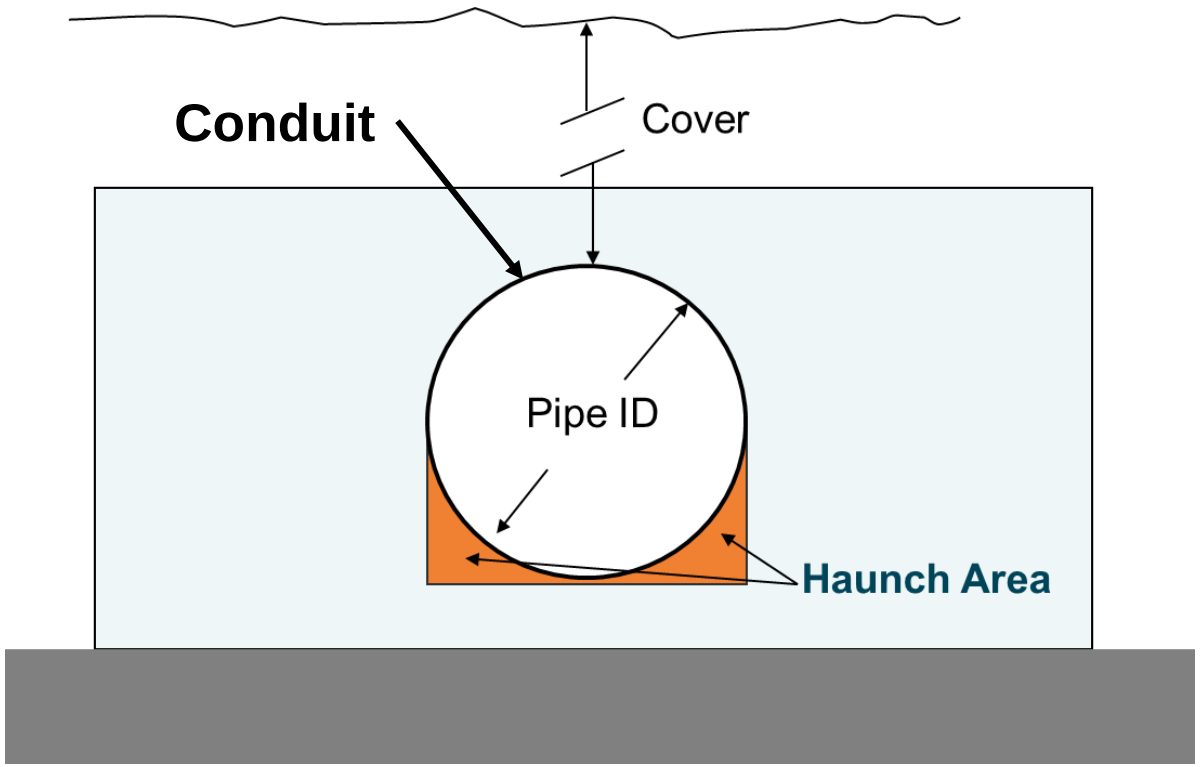
Pipe Installations

Key Differences

Concrete Pipe

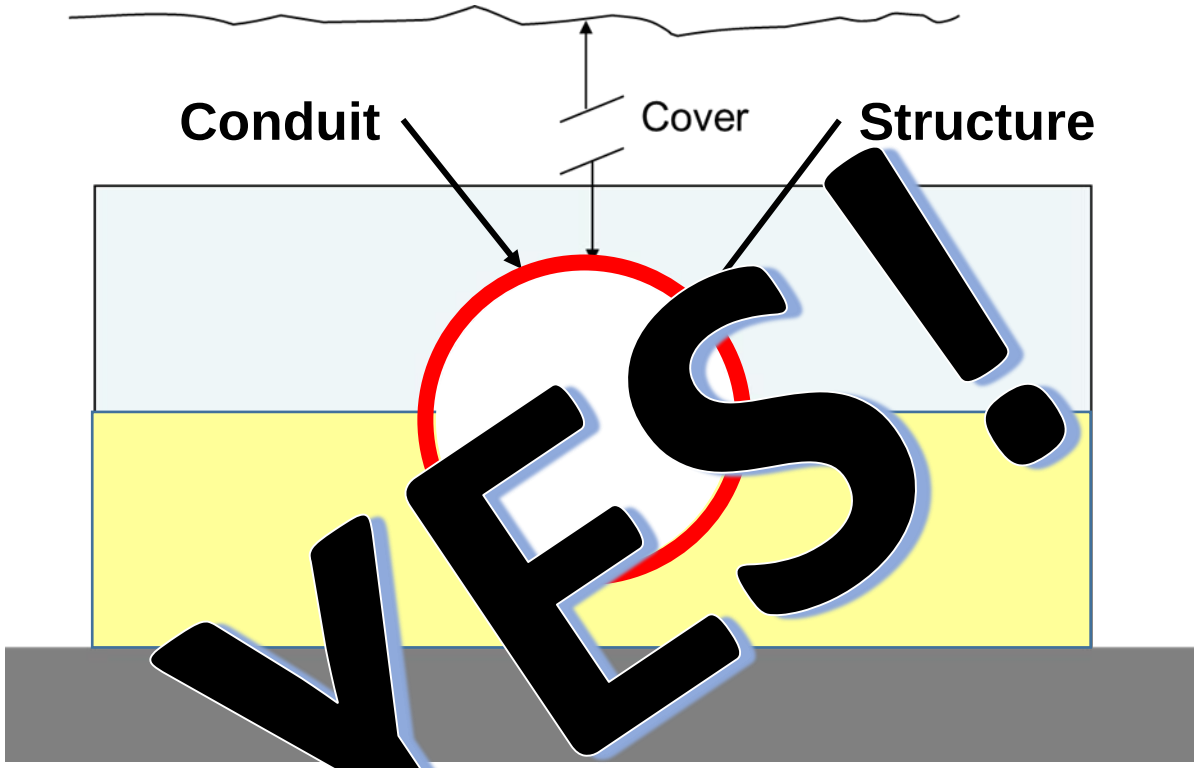


Flexible Pipe



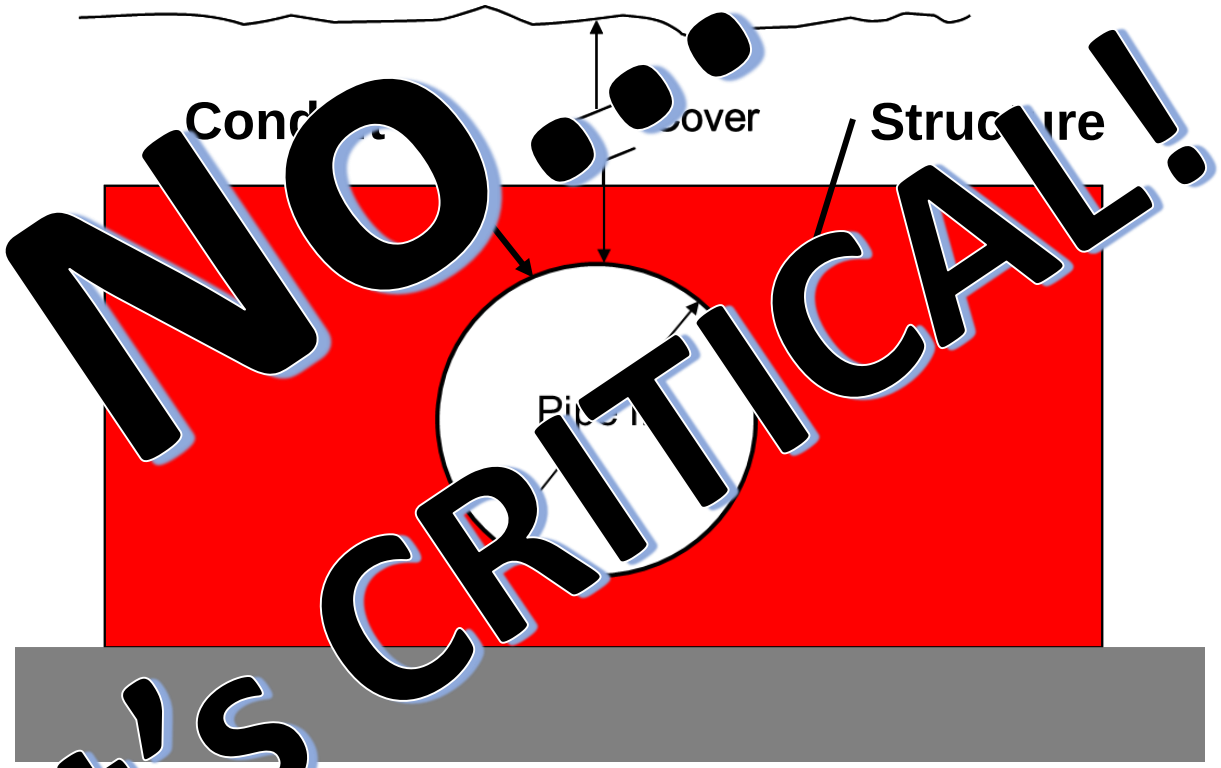
Concrete Pipe

Installation – Is It Important?



Flexible Pipe

Installation – Is It Important?




WHAT DIFFERENCE DOES IT MAKE???


IF YOU COULD JUST GO AHEAD AND EXPLAIN THAT
THAT'D BE GRRRREAT

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[1]

Flexible Pipe

Designation: D2321 – 18

Standard Practice for
Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications[1]


TIME TO TALK DIRTY

Concrete Pipe

Designation: C1479 – 16

TABLE 3 Equivalent USCS and AASHTO Soil Classifications for Soil Designations

Soil	Representative Soil Types	
	USCS ASTM Practice D2487	AASHTO M 145
Category I	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	A-1, A-3
Category II	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 Sandy or gravelly fine-grained soils: CL, ML, (or CL-ML, CL/ML, ML/CL) with 30 % or more retained on a #200 sieve	A-2-4, A-2-5, A-2-6, or A-4 or A-6 soils with 30 % or more retained on a #200 sieve
Category III	Fine-grained soils: CL, ML, (or CL-ML, CL/ML, ML/CL) with less than 30 % retained on a #200 sieve	A-2-7, or A-4 or A-6 with less than 30 % retained on a #200 sieve
Category IV but not allowed for haunch or bedding	MH, CH, OL, OH, PT	A-5, A–7

Flexible Pipe

Designation: D2321 – 18

TABLE 2 Soil Classes

Soil Group[A]	Soil Class	American Association of State Highway and Transportation Officials (AASHTO) Soil Groups[B]
Crushed rock, angular[C]: 100% passing 1-1/2in. sieve, </=15 % passing #4 sieve, </= 25 % passing 3/8in. sieve and </= 12 % passing #200 sieve	Class I	...
Clean, coarse grained soils: SW, SP, GW, GP or any soil beginning with one of these symbols with </=12 % passing #200 sieve[DE]	Class II	A1,A3
Coarse grained soils with fines: GM, GC, SM, SC, or any soil beginning with one of these symbols, containing > 12 % passing #200 sieve; Sandy or gravelly fine-grained soils: CL, ML, or any soil beginning with one of these symbols, with > 30 % retained on #200 sieve	Class III	A-2-4, A-2-5, A-2-6, or A-4 or A-6 soils with more than 30% retained on #200 sieve
Fine-grained soils: CL, ML, or any soil beginning with one of these symbols, with </=30 % retained on #200 sieve	Class IV	A-2-7, or A-4, or A-6 soils with 30% or less retained on #200 sieve
MH, CH, OL, OH, PT	Class V Not for use as embedment	A5, A7

Concrete Pipe

Designation: C1479 – 16

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Category III	Fine-grained soils: CL, ML, (or CL-ML, CL/ML, ML/CL) with less than 30 % retained on a #200 sieve	A-2-7, or A-4 or A-6 with less than 30 % retained on a #200 sieve
Category IV but not allowed for haunch or bedding	MH, CH, OL, OH, PT	A-5, A–7

Flexible Pipe

Designation: D2321 – 18

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Coarse grained soils with fines: GM, GC, SM, SC, or any soil beginning with one of these symbols, containing > 12 % passing #200 sieve; Sandy or gravelly fine-grained soils: CL, ML, or any soil beginning with one of these symbols, with > 30 % retained on #200 sieve	Class III	A-2-4, A-2-5, A-2-6, or A-4 or A-6 soils with more than 30% retained on #200 sieve
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MH, CH, OL, OH, PT	Class V Not for use as embedment	A5, A7

ADS/HancorPipe Youtube Video

Concrete Pipe

Designation: C1479 – 16

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

Designation: D2321 – 18

Concrete Pipe

Designation: C1479 – 16

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Flexible Pipe

Designation: D2321 – 18

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

Designation: C1479 – 16

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Flexible Pipe

Designation: D2321 – 18

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.

Concrete Pipe

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QUICKPOLL

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

Designation: C1479 – 16

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

Designation: D2321 – 18

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

Concrete Pipe

Designation: C1479 – 16

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.

Flexible Pipe

Designation: D2321 – 18

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.

Concrete Pipe

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Concrete Pipe

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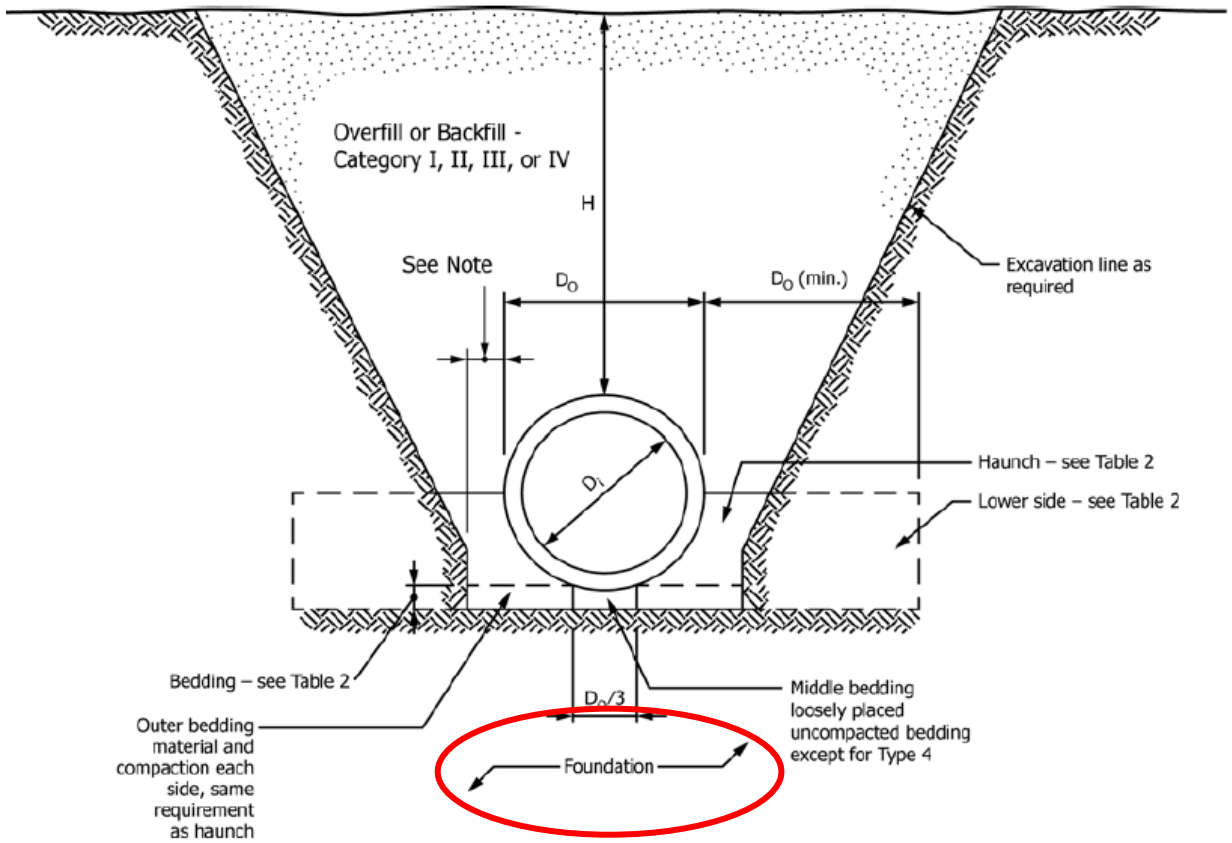
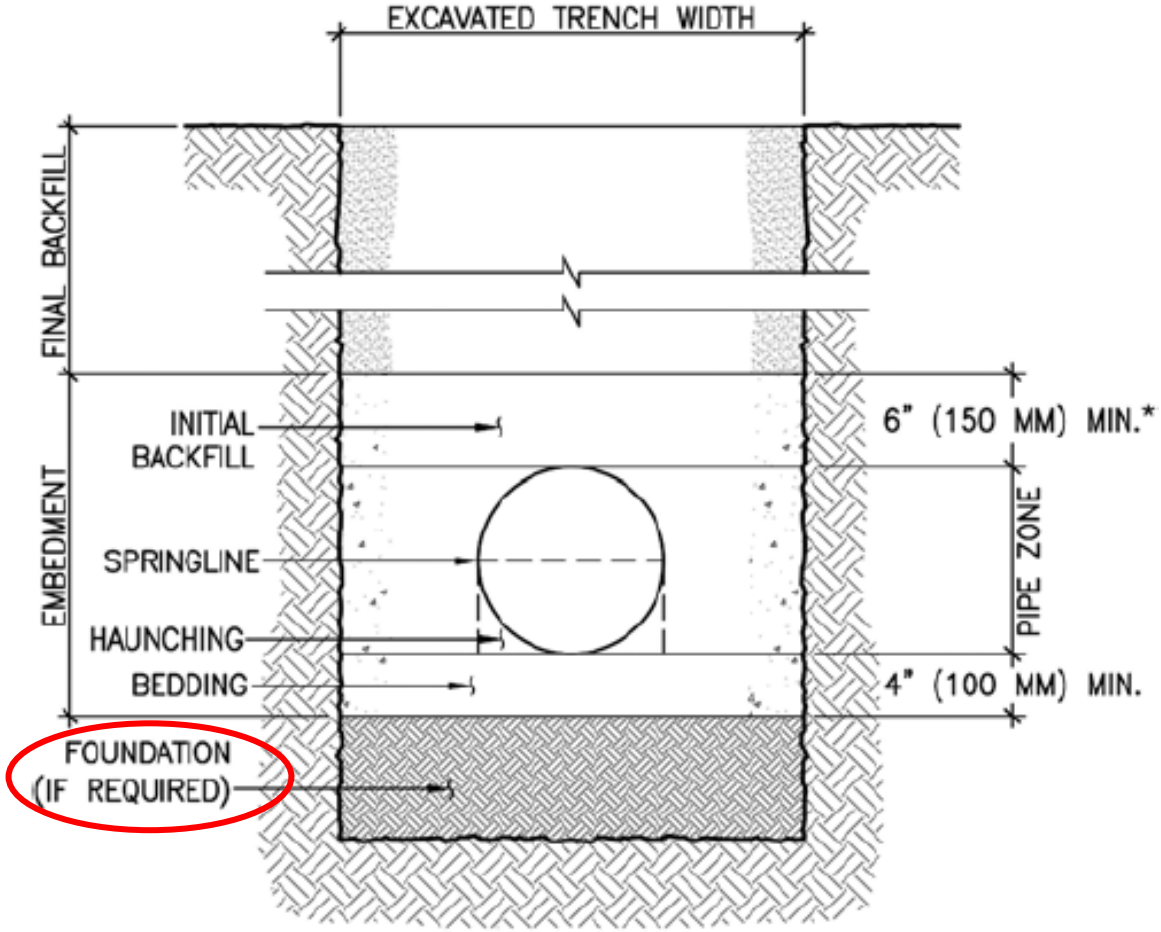
Concrete Pipe



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

FIG. 3 Standard Trench Installations

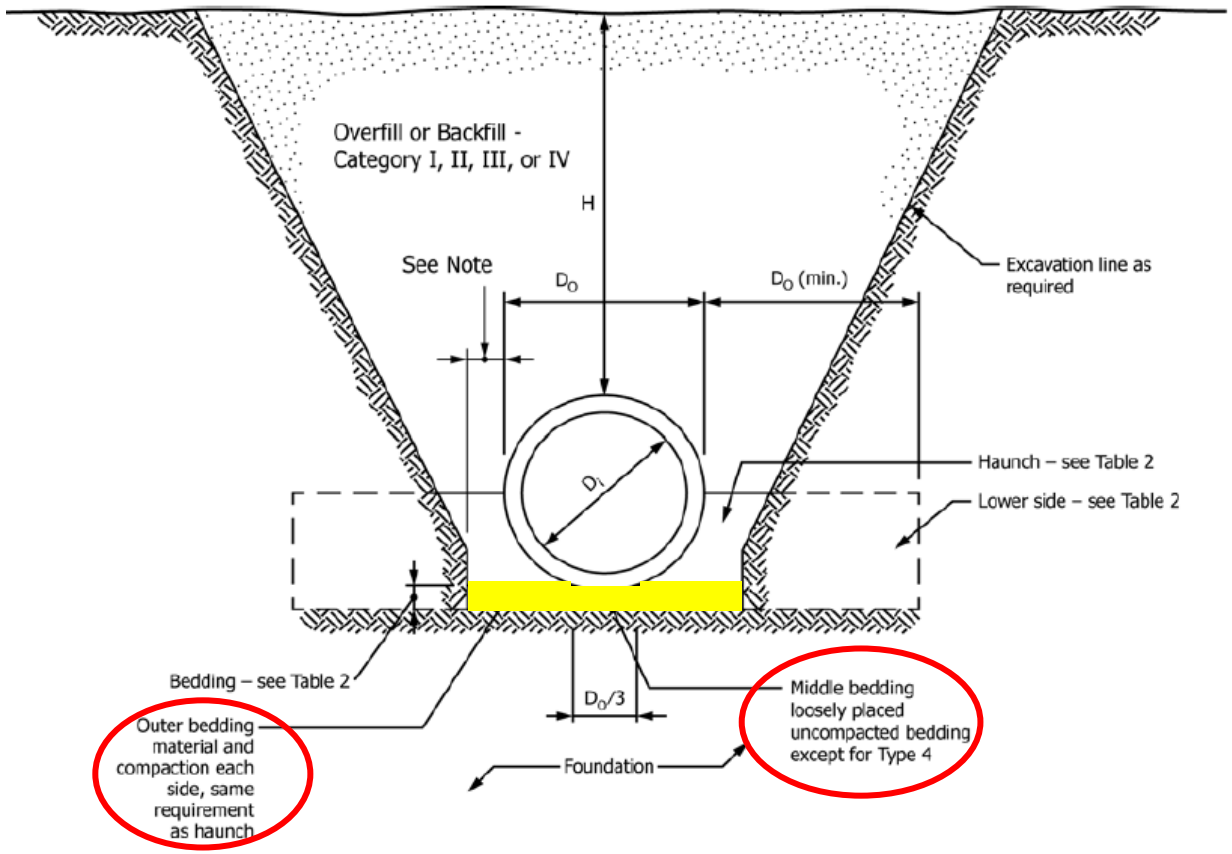
Flexible Pipe



* See 7.6 Minimum Cover

FIG. 1 Trench Cross Section

Concrete Pipe



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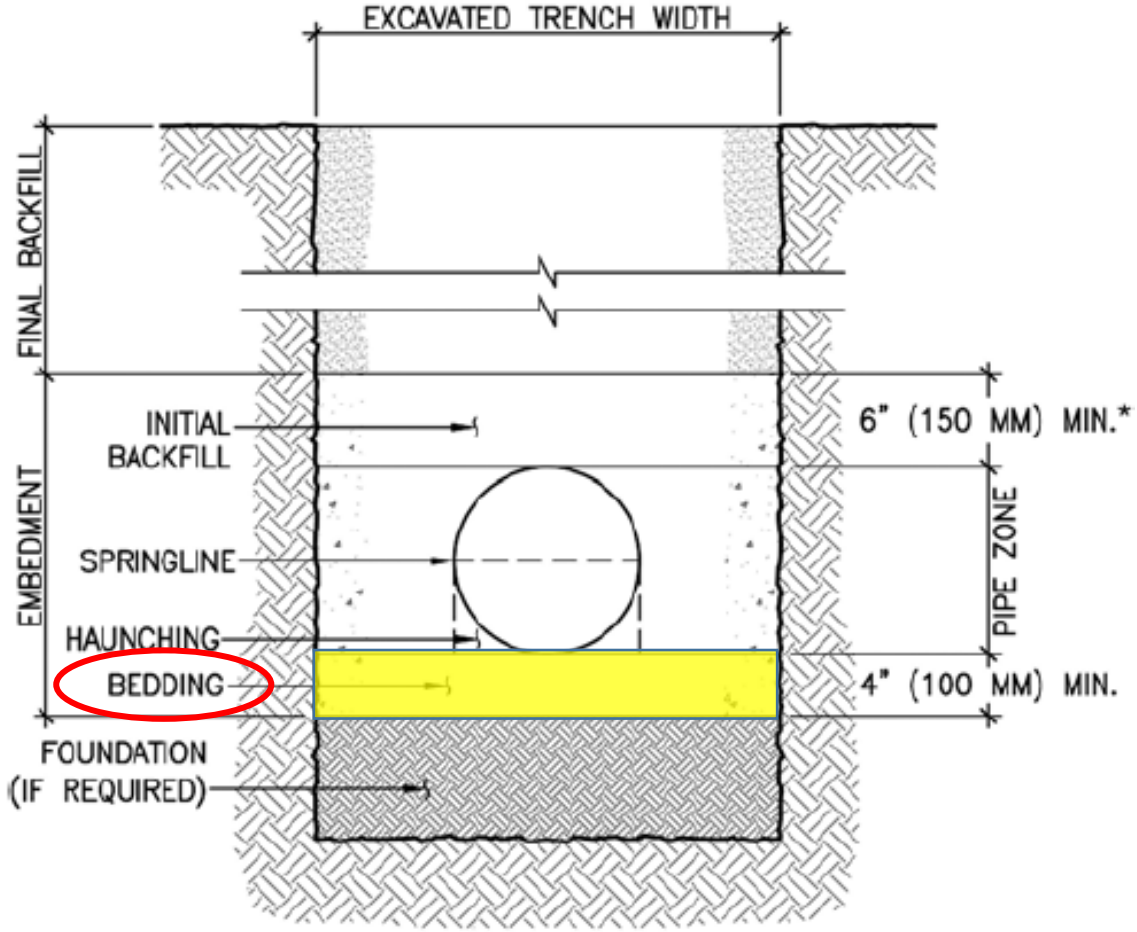

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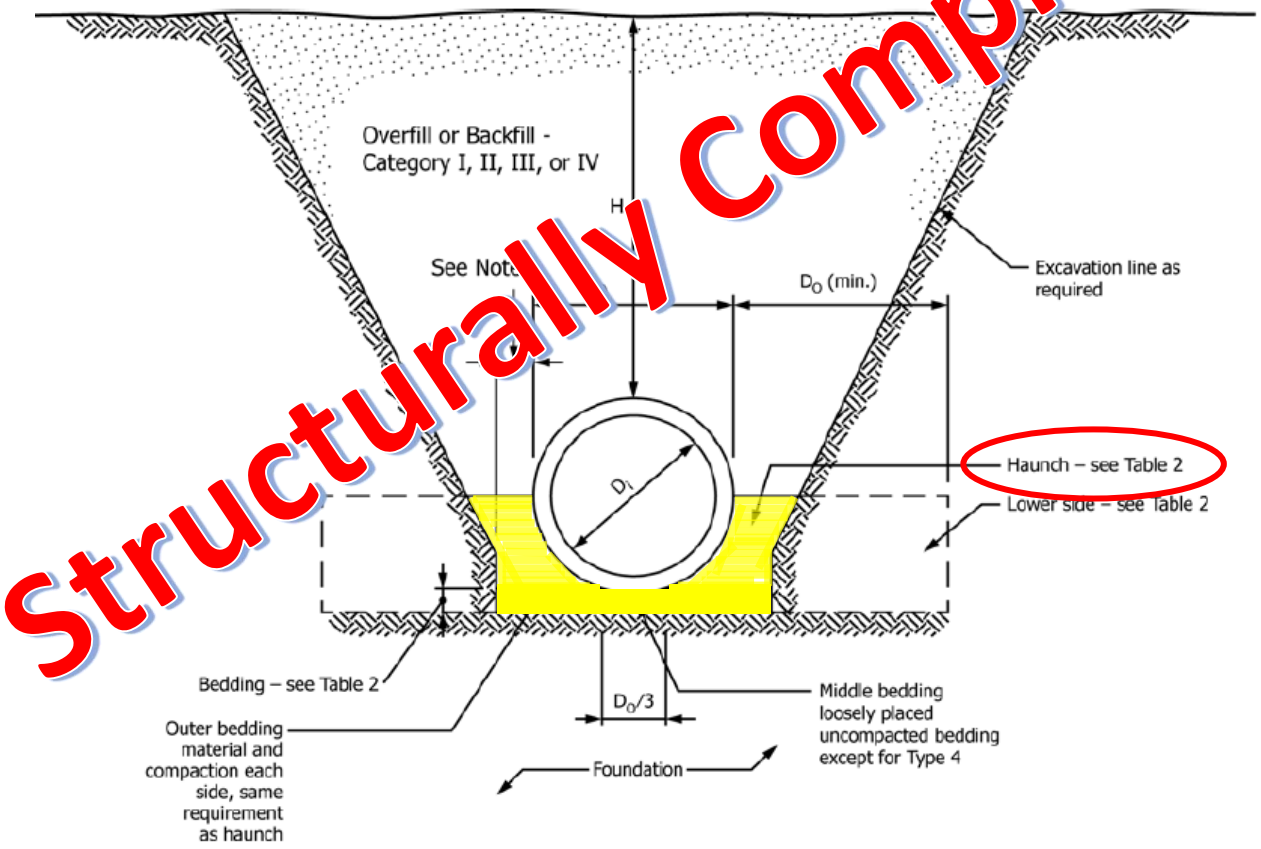
Concrete Pipe



Structurally Complete!

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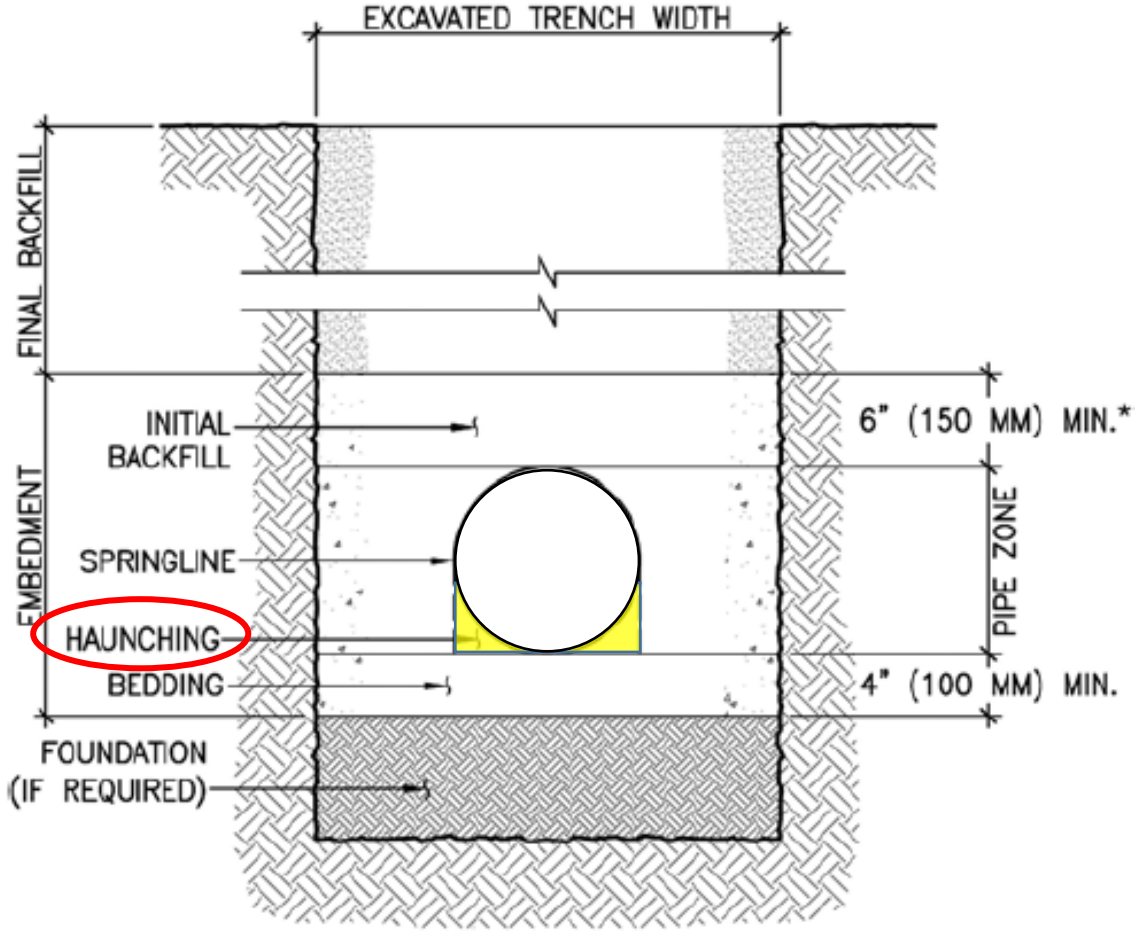
Flexible Pipe



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Concrete Pipe

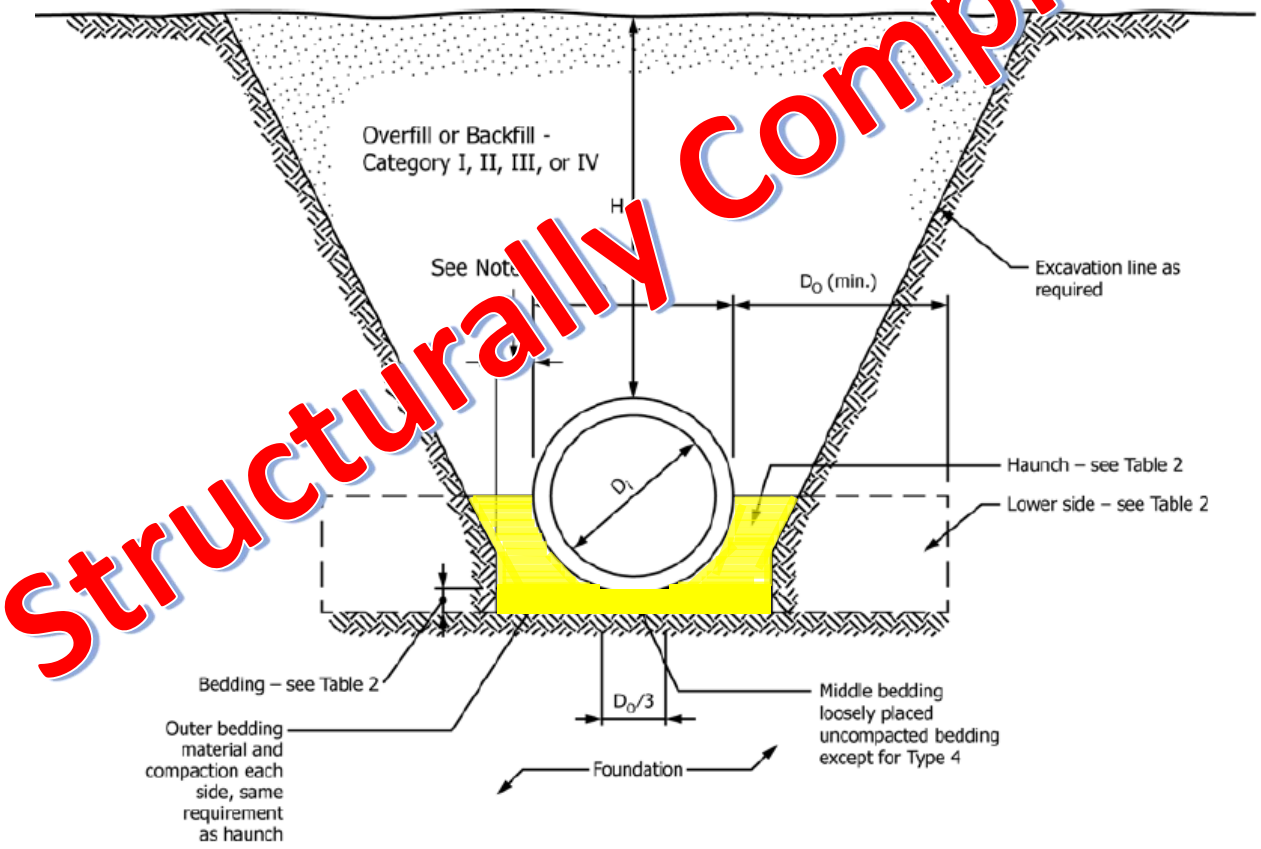

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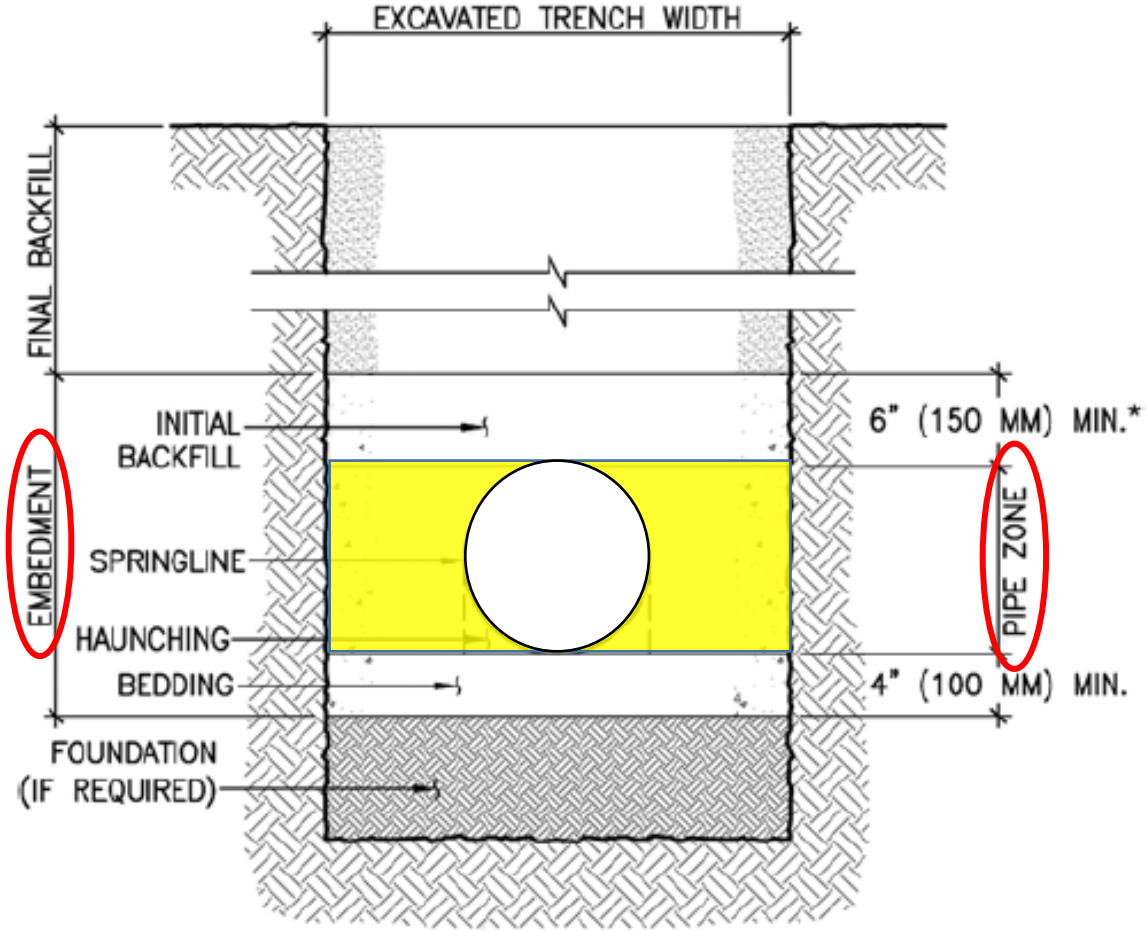
FIG. 3 Standard Trench Installations

Flexible Pipe



* See 7.6 Minimum Cover

FIG. 1 Trench Cross Section

Concrete Pipe

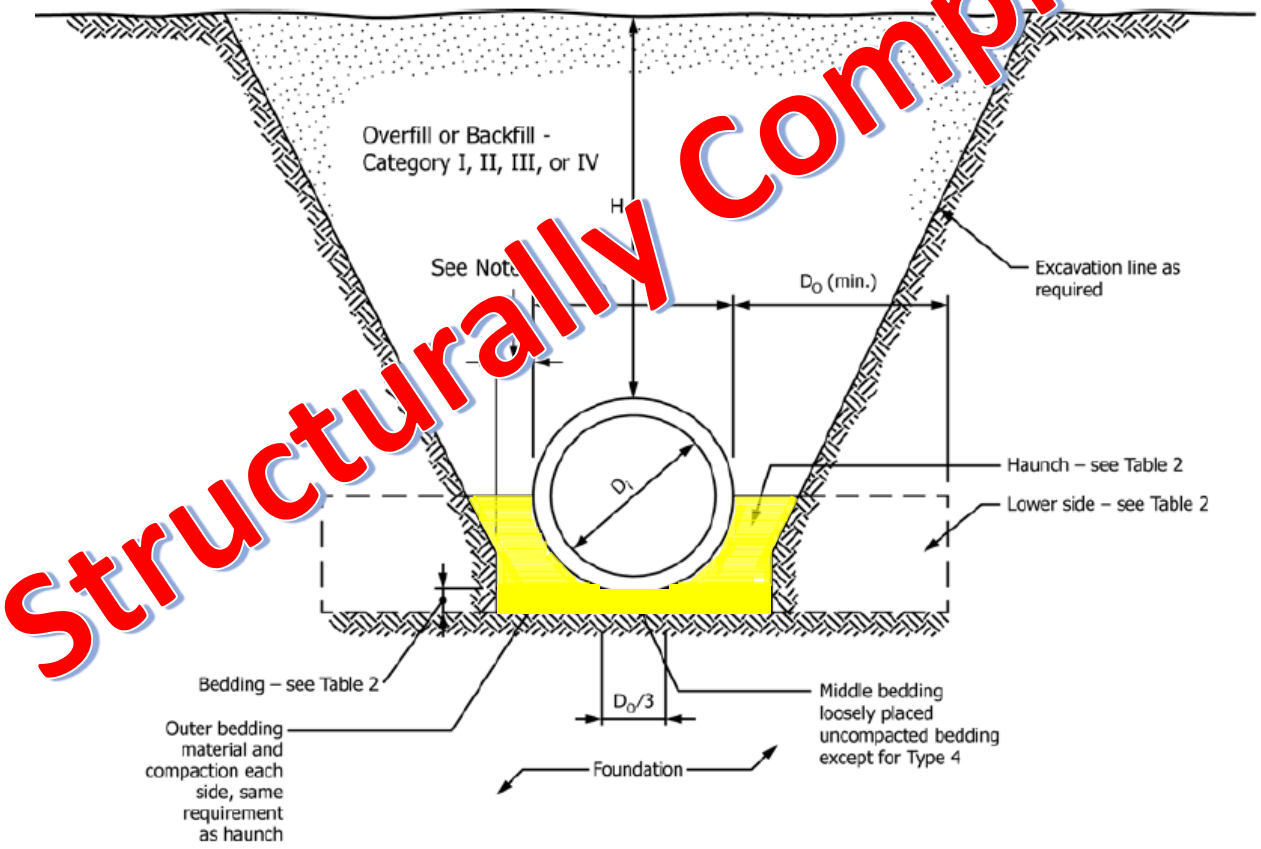


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FIG. 3 Standard Trench Installations

Flexible Pipe

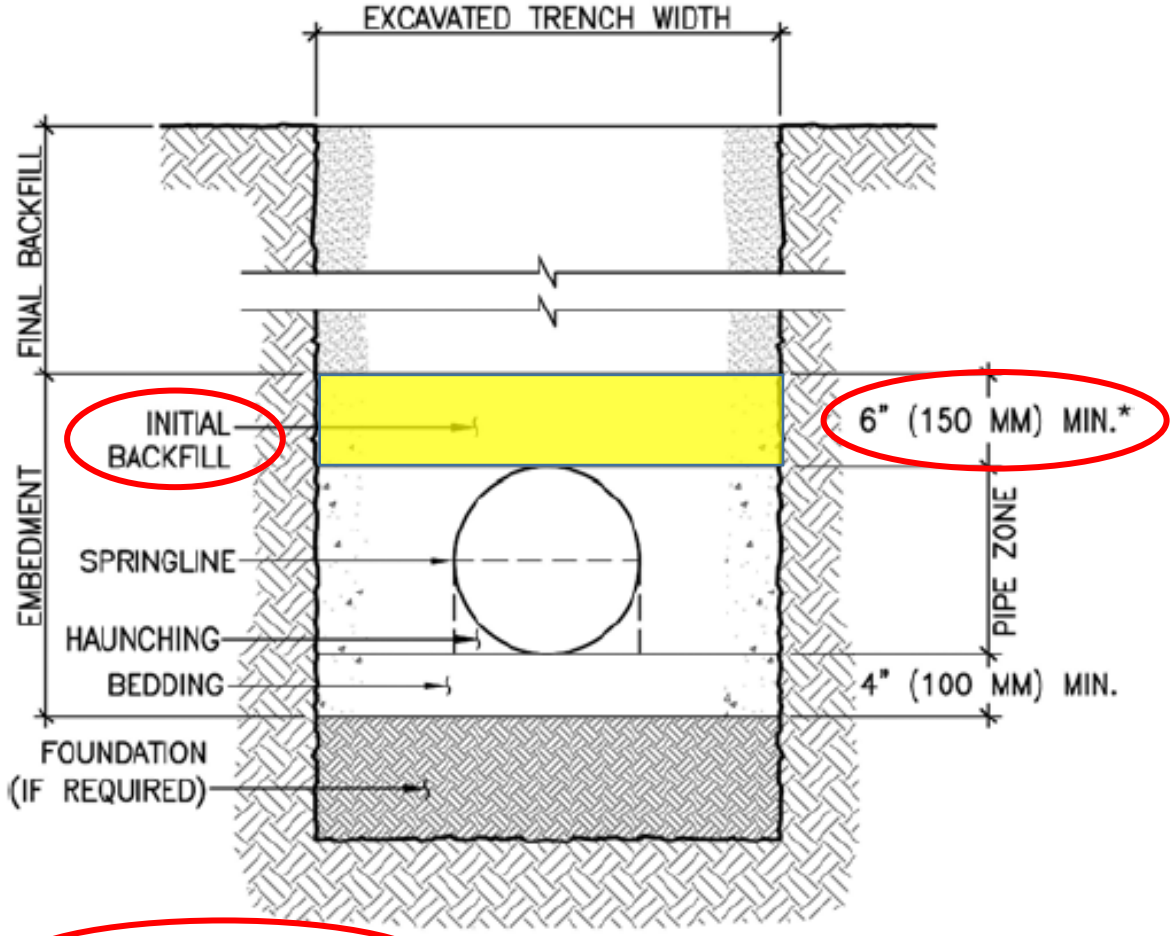

FIG. 1 Trench Cross Section

Designation: D2321 – 14ε1

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...

Size	Class I	Class II, III, IV	Hydrohammer
12”	24”	36”	48”
18”	24”	36”	48”
24”	24”	36”	48”
30”	30”	36”	48”
36”	36”	36”	48”
42”	42”	42”	48”
48”	48”	48”	48”
54”	54”	54”	48”
60”	60”	60”	48”

...Do not use hydrohammer-type compactors unless approved by the engineer.

Concrete Pipe

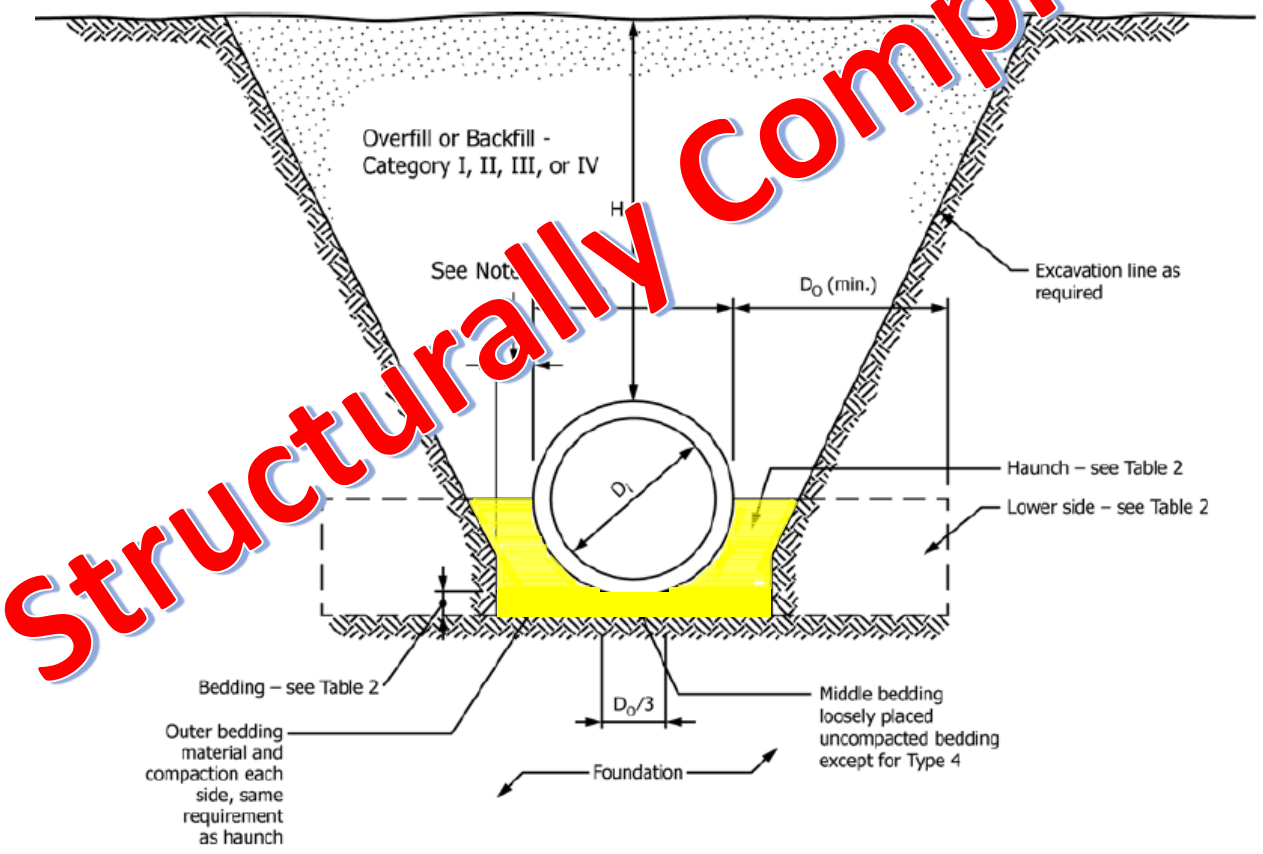

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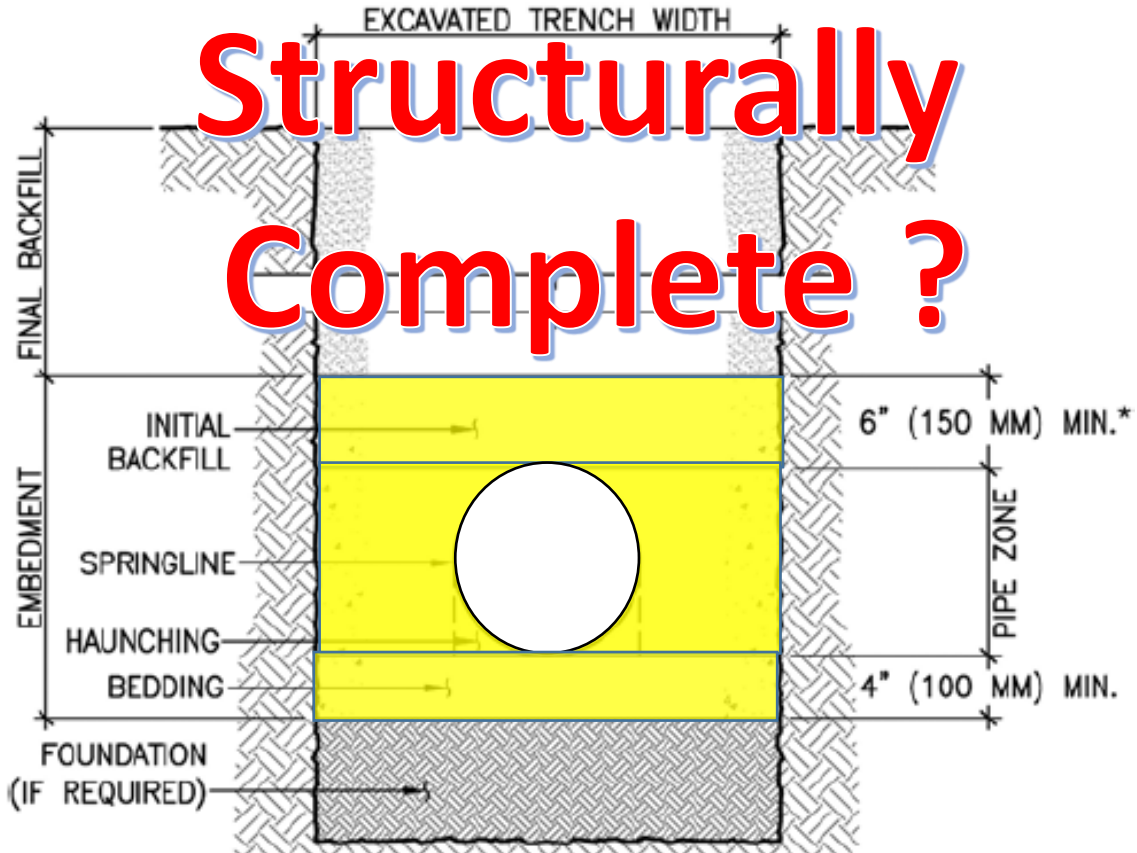
FIG. 3 Standard Trench Installations

Structurally Complete!

Flexible Pipe



* See 7.6 Minimum Cover

FIG. 1 Trench Cross Section

Structurally Complete ?

How Would You Know?

Concrete Pipe

Designation: C1479 – 16

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.

Flexible Pipe

Designation: D2321 – 18

4. Significance and Use

4.1 This practice is for use by designers and specifiers, installation contractors, regulatory agencies, owners, and inspection organizations who are involved in the construction of sewers and other gravity-flow applications that utilize flexible thermoplastic pipe. As with any standard practice, modifications may be required for specific job conditions or for special local or regional conditions. Recommendations for inclusion of this practice in contract documents for a specific project are given in Appendix X2.


BACK TO THE SOILS

Concrete Pipe

Designation: C1479 – 16

C1479 – 16

TABLE 2 Standard Trench Installation Soils and Minimum Compaction Requirements

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

Flexible Pipe

TABLE 3 Recommendations for Installation and Use of Soils and Aggregates for Foundation and Pipe-Zone Embedment

Soil Class[A]	Class I[B]	Class II	Class III	Class IV
General Recommendations and Restrictions	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).	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., 0.15 mm) behave like silts and should be treated as Class III soils.	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	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
Foundation	Suitable as foundation and for replacing over-excavated and unstable trench bottom as restricted above.	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	Suitable for replacing over-excavated trench bottom as restricted above. Install and compact in 6 in. (150 mm) maximum layers	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
Pipe Embedment	Suitable as restricted above. Work material under pipe to provide uniform haunch support.	Suitable as restricted above. Work material under pipe to provide uniform haunch support.	Suitable as restricted above. Difficult to place and compact in the haunch zone.	Suitable as restricted above. Difficult to place and compact in the haunch zone.
Minimum Recommended Percent Compaction, SPD[D]	See Note[C]	85 % (SW and SP soils) For GW and GP soils see Note[E]	90 %	95 %
Relative Compactive Effort Required to Achieve Minimum Percent Compaction	low	moderate	high	very high
Compaction Methods	vibration or impact	vibration or impact	impact	impact
Required Moisture Control	none	none	Maintain near optimum to minimize compactive effort	Maintain near optimum to minimize compactive effort

Designation: D2321 – 18

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 3 Recommendations for Installation and Use of Soils and Aggregates for Foundation and Pipe-Zone Embedment

Soil Class[A]	Class I[B]	Class II	Class III	Class IV
General Recommendations and Restrictions	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).	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., 0.15 mm) behave like silts and should be treated as Class III soils.	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	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
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Pipe Embedment	Suitable as restricted above. Work material under pipe to provide uniform haunch support.	Suitable as restricted above. Work material under pipe to provide uniform haunch support.	Suitable as restricted above. Difficult to place and compact in the haunch zone.	Suitable as restricted above. Difficult to place and compact in the haunch zone.
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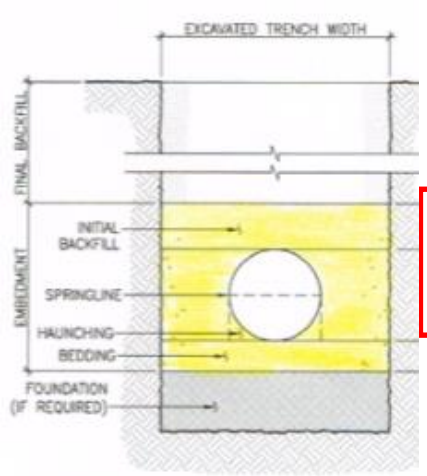

* See 7.6 Minimum Cover

FIG. 1 Trench Cross Section

TABLE 3 Recommendations for Installation and Use of Soils and Aggregates for Foundation and Pipe-Zone Embedment

Soil Class[A]	Class I[B]	Class II	Class III	Class IV
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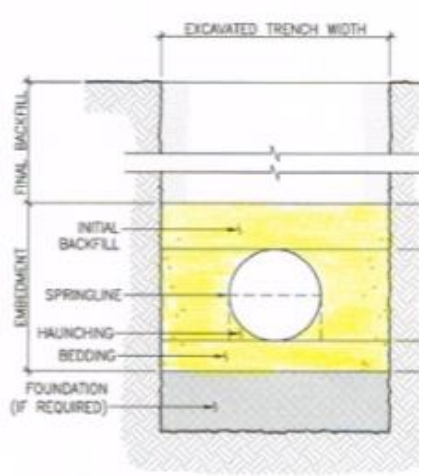

* See 7.6 Minimum Cover

FIG. 1 Trench Cross Section

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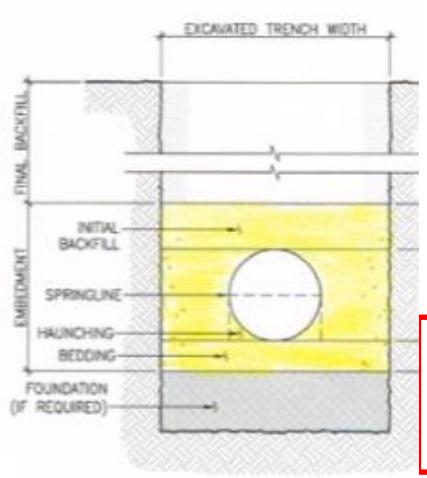

* See 7.6 Minimum Cover

FIG. 1 Trench Cross Section

		maximum layers		maintained, as approved by the engineer. Install and compact in 6-in (150 mm) maximum layers
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[A] Class V materials are unsuitable as embedment. They may be used as final backfill as permitted by the engineer.

[B] 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 (SPD95), 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 (SPD100). Even if placed uncompacted (that is, dumped), Class I materials should always be worked into the haunch zone to assure complete placement.

[C] Suitable compaction typically achieved by dumped placement (that is, uncompacted but worked into haunch zone to ensure complete placement).

[D] SPD is standard Proctor density as determined by Test Method D698.

[E] Place and compact GW and GP soils with at least two passes of compaction equipment.

Concrete Pipe

Fill Height Tables are based on:
1. γs = 120 pcf
2. AASHTO HL-93 live load
3. Positive Projecting Embankment Condition - this gives conservative results in comparison to trench conditions

D-Load (lb/ft/ft) for Type 3 Bedding

Class I, Class II, Class III, Class IV, Class V, Special Design

	Fill Height (feet)														
Pipe i.d. (inches)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
12	1735	1100	875	800	800	850	900	975	1050	1125	1225	1300	1400	1475	1575
15	1600	1025	850	775	775	825	875	950	1025	1100	1200	1275	1375	1450	1525
18	1475	1000	825	775	775	825	875	925	1025	1100	1175	1250	1375	1425	1525
21	1250	950	800	750	750	825	875	925	1025	1075	1175	1250	1375	1425	1500
24	1075	925	775	750	750	825	850	925	1025	1075	1175	1250	1375	1425	1500
27	1000	900	775	750	750	825	875	925	1025	1100	1175	1250	1375	1425	1500
30	950	875	775	750	750	825	875	950	1025	1100	1175	1275	1375	1425	1525
33	925	825	750	750	750	825	875	950	1025	1100	1200	1275	1375	1450	1525
36	900	775	750	750	775	825	875	950	1025	1125	1200	1275	1375	1450	1550
42	850	700	750	750	775	825	900	975	1050	1125	1200	1300	1375	1475	1550
48	875	700	700	750	775	825	900	975	1050	1150	1225	1300	1400	1475	1575
54	850	725	700	750	800	850	925	1000	1075	1150	1250	1350	1400	1500	1575
60	875	750	700	750	800	850	925	1000	1100	1175	1250	1350	1425	1525	1600
66	875	775	700	750	800	875	950	1025	1100	1200	1275	1350	1450	1550	1625
72	850	800	700	750	825	900	975	1050	1125	1200	1300	1375	1475	1550	1650
78	800	775	750	775	825	900	975	1050	1125	1225	1300	1400	1475	1575	1650
84	750	750	775	775	850	900	975	1075	1150	1225	1325	1400	1500	1575	1675
90	725	750	775	800	850	925	1000	1075	1150	1250	1325	1425	1500	1600	1675
96	700	750	775	825	875	925	1000	1100	1175	1250	1350	1425	1525	1600	1700
102	725	750	775	825	875	950	1025	1100	1200	1275	1350	1450	1525	1625	1700
108	725	725	800	825	900	950	1050	1125	1200	1275	1375	1450	1550	1625	1725

Resource # 16-201 (Revised 07/09)

11

Design Complete!

Flexible Pipe

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

Diameter in. (mm)	Class 1 Compacted	Class 1 Dumped	Class 2 95%	Class 2 90%	Class 2 85% [3]	Class 3 95%	Class 3 90% [3]
4 (100)	37 (11.3)	18 (5.5)	25 (7.6)	18 (5.5)	12 (3.7)	18 (5.5)	13 (4.0)
6 (150)	44 (13.4)	20 (6.1)	29 (8.8)	20 (6.1)	14 (4.3)	21 (6.4)	15 (4.6)
8 (200)	32 (9.8)	15 (4.6)	22 (6.7)	15 (4.6)	10 (3.0)	16 (4.9)	11 (3.4)
10 (250)	38 (11.6)	18 (5.5)	26 (7.9)	18 (5.5)	12 (3.7)	18 (5.5)	13 (4.0)
12 (300)	35 (10.7)	17 (5.2)	24 (7.3)	17 (5.2)	8 (2.4)	17 (5.2)	11 (3.4)
15 (375)	38 (11.6)	17 (5.2)	25 (7.6)	17 (5.2)	8 (2.4)	18 (5.5)	11 (3.4)
18 (450)	36 (11.0)	17 (5.2)	24 (7.3)	17 (5.2)	8 (2.4)	17 (5.2)	11 (3.4)
24 (600)	28 (8.5)	13 (4.0)	20 (6.1)	13 (4.0)	7 (2.1)	14 (4.3)	10 (3.0)
30 (750)	28 (8.5)	13 (4.0)	20 (6.1)	13 (4.0)	7 (2.1)	14 (4.3)	9 (2.7)
36 (900)	26 (7.9)	12 (3.7)	18 (5.5)	12 (3.7)	7 (2.1)	13 (4.0)	9 (2.7)
42 (1050)	23 (7.0)	11 (3.4)	16 (4.9)	11 (3.4)	7 (2.1)	11 (3.4)	7 (2.1)
48 (1200)	25 (7.6)	11 (3.4)	17 (5.2)	11 (3.4)	7 (2.1)	12 (3.7)	7 (2.1)
54 (1350)	22 (6.7)	10 (3.0)	16 (4.9)	10 (3.0)	6 (1.8)	11 (3.4)	7 (2.1)
60 (1500)	25 (7.6)	11 (3.4)	17 (5.2)	11 (3.4)	6 (1.8)	12 (3.7)	7 (2.1)

Notes:

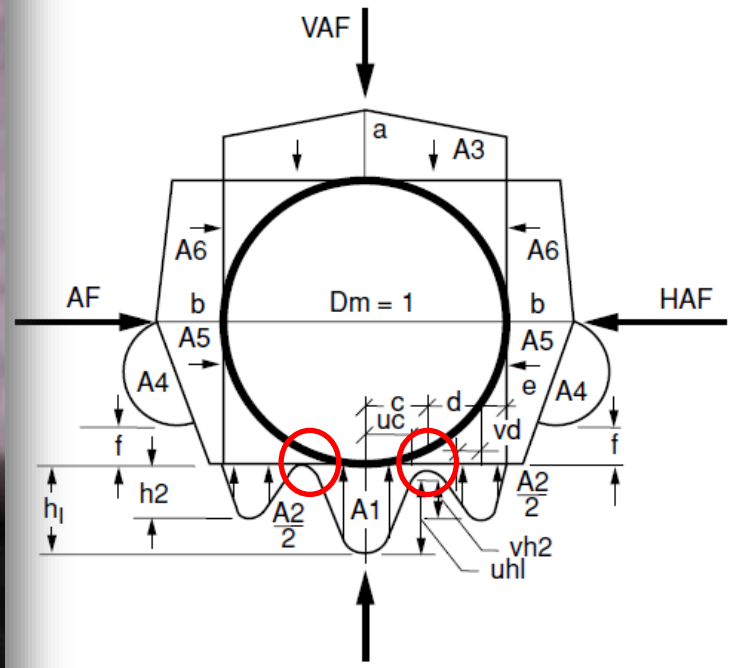
1. *Results based on calculations shown in the Structures section of the ADS Drainage Handbook (v20.7). Calculations assume no hydrostatic pressure and a density of 120 pcf (1926 kg/m^3) for overburden material.*
2. *Installation assumed to be in accordance with ASTM D2321 and the Installation section 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 detail.*
5. *Material must be adequately "knifed" into haunch and in between corrugations. Compaction and backfill material is assumed uniform throughout entire backfill zone.*
6. *Compaction levels shown are for standard Proctor density.*
7. *For projects where cover exceeds the maximum values listed above, contact for specific design considerations.*

QUICKPOLL

Which pipe material is MOST dependent on soil support in the haunches?

Concrete

Thermoplastic



National Clay Pipe Institute Youtube Video

Concrete Pipe

Designation: C1479 – 16

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

Designation: D2321 – 18

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

Designation: C1479 – 16

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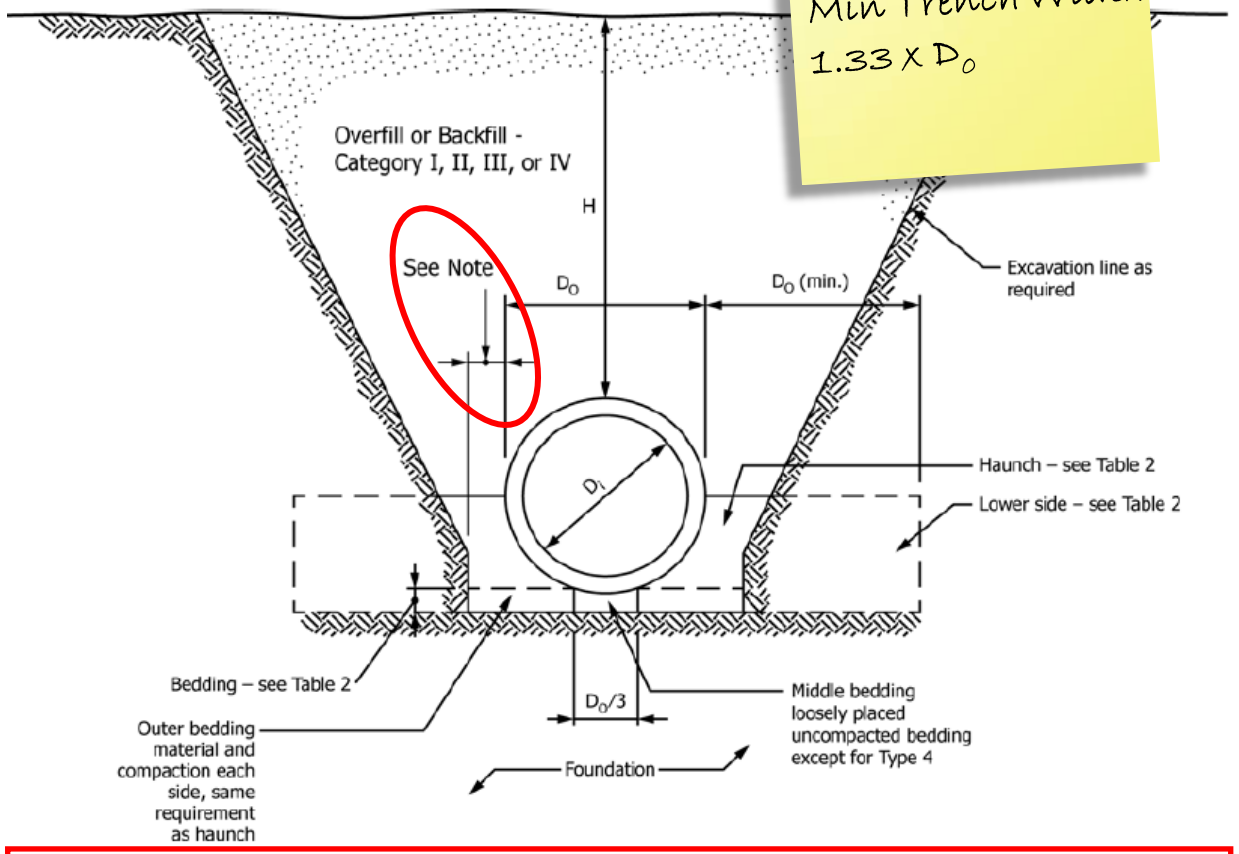
X1.9 ***Maximum Particle Size*** — Limiting particle size to 3⁄4 in. (20 mm) or less enhances placement of embedment material for nominal pipe sizes 8 in. (200 mm) through 15 in. (380 mm). For smaller pipe, a particle size of about 10 % of the nominal pipe diameter is recommended.

Concrete Pipe

Designation: C1479 – 16

Fig. 3
Min Trench Width
1.33 x D_o

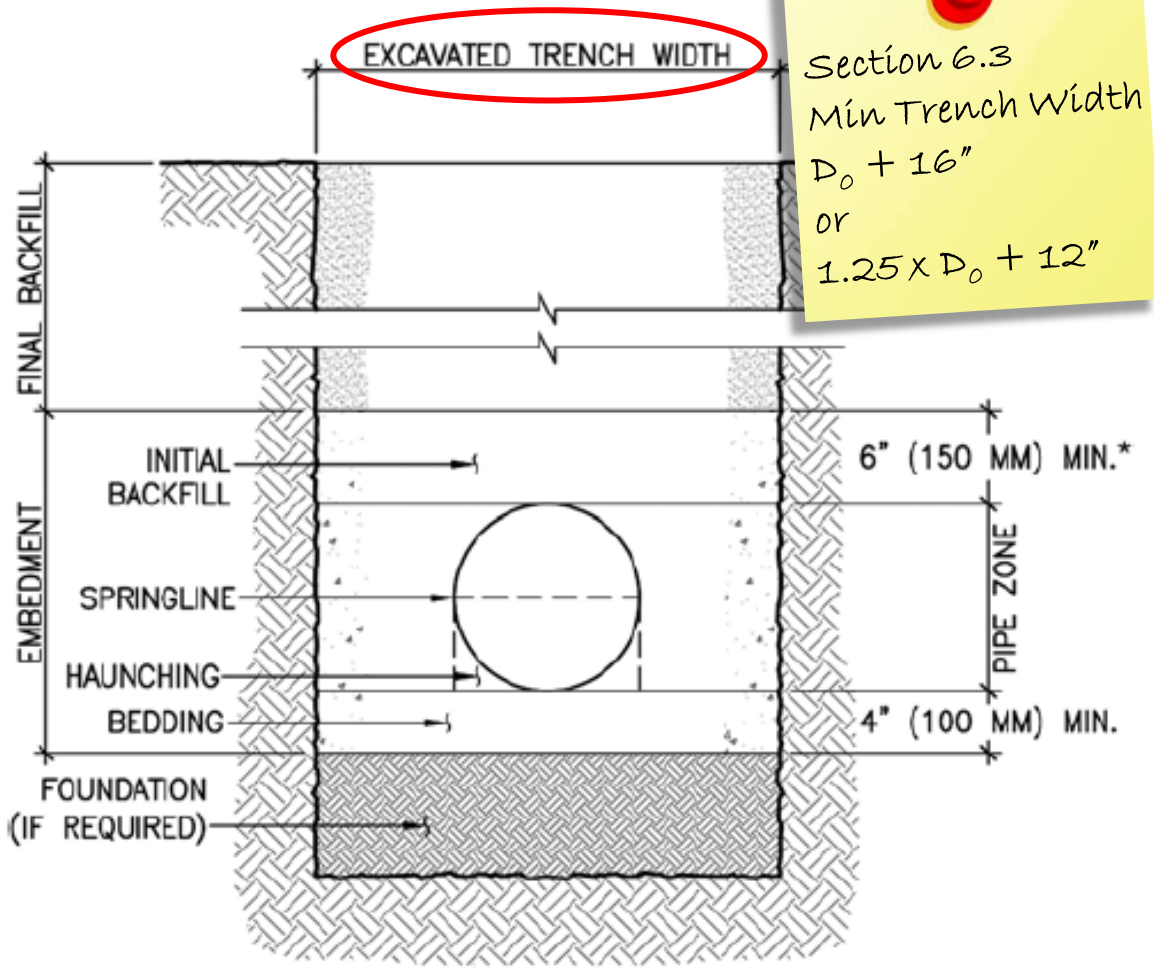


NOTE 1—Clearance between pipe and trench wall shall be adequate to enable specified compaction but not less than $D_o/6$

FIG. 3 Standard Trench Installations

Flexible Pipe

Section 6.3
Min Trench Width
D_o + 16"
or
1.25 x D_o + 12"



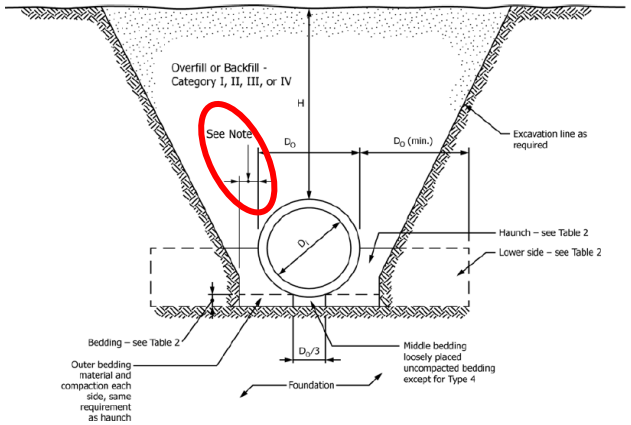
* See 7.6 Minimum Cover

FIG. 1 Trench Cross Section

Concrete Pipe

Designation: C1479 – 16

Trench Installation



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

FIG. 3 Standard Trench Installations

Pipe Size	O.D.*	1.33 x O.D.	Clear Each Side
12”	16”	21 ⅜”	2 ⅝”
15”	19-1/2”	26”	3 ¼”
18”	23”	30 ⅝”	3 ⅞”
24”	30”	40”	5”
30”	37”	49 ⅜”	6 ¼”
36”	44”	58 ¾”	7 ⅜”
42”	51”	68”	8 ½”
48”	58”	77 ⅜”	9 ⅝”
60”	67”	89 ⅜”	11 ⅜”

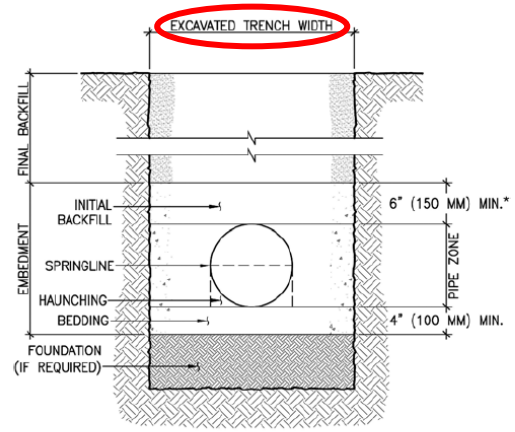
* B-Wall

Flexible Pipe

Designation: D2321 – 14$^{\varepsilon 1}$

6. Trench Excavation

6.3 *Minimum Trench Width* –



* See 7.6 Minimum Cover

FIG. 1 Trench Cross Section

Pipe Size	O.D.	O.D.+16”	1.25xO.D.+12”	Clear Each Side
12”	15”	31”	30”	8”
15”	18”	34”	35”	8 ½”
18”	21”	37”	38”	8 ½”
24”	28”	44”	47”	9 ½”
30”	36”	52”	57”	10 ½”
36”	42”	58”	65”	11 ½”
42”	48”	64”	72”	12”
48”	54”	70”	80”	13”
60”	67”	83”	96”	14 ½”

Flexible Pipe

Designation: D2321 – 14$^{\varepsilon 1}$

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

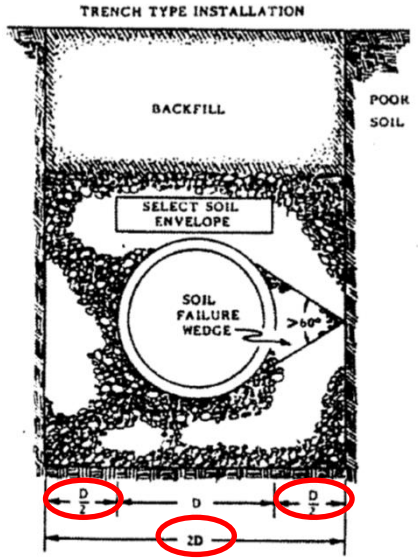
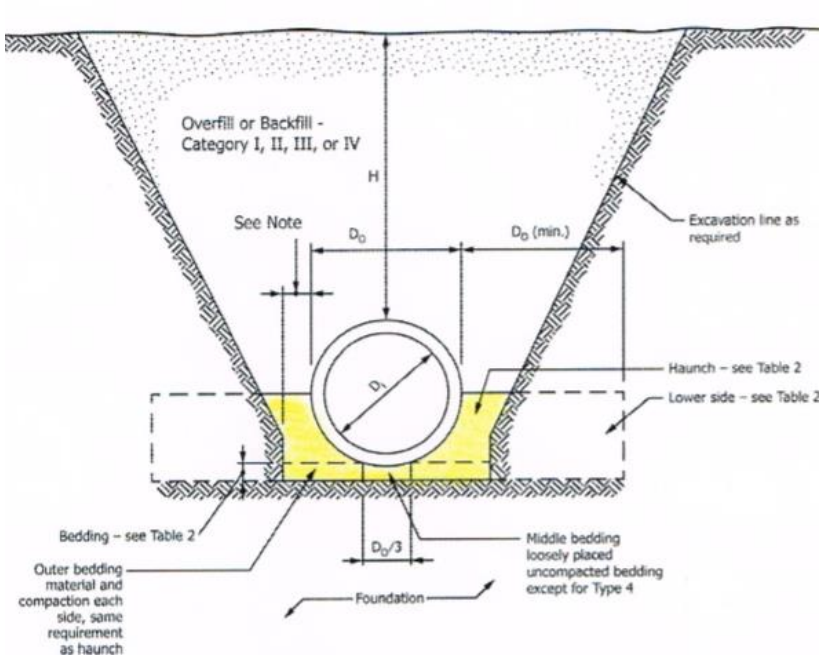


FIG. X1.1 Minimum Embedment Width When Trench and Native Soil Can Sustain a Vertical Cut

Pipe Size	O.D.	O.D. / 2	2 x O.D.
12”	15”	7 ½”	**30”**
15”	18”	9”	**36”**
18”	21”	10 ½”	**42”**
24”	28”	14”	**56”**
30”	36”	18”	**72”**
36”	42”	21”	**84”**
42”	48”	24”	**96”**
48”	54”	27”	**108”**
60”	67”	33 ½”	**134”**

Concrete Pipe

Trench Installation

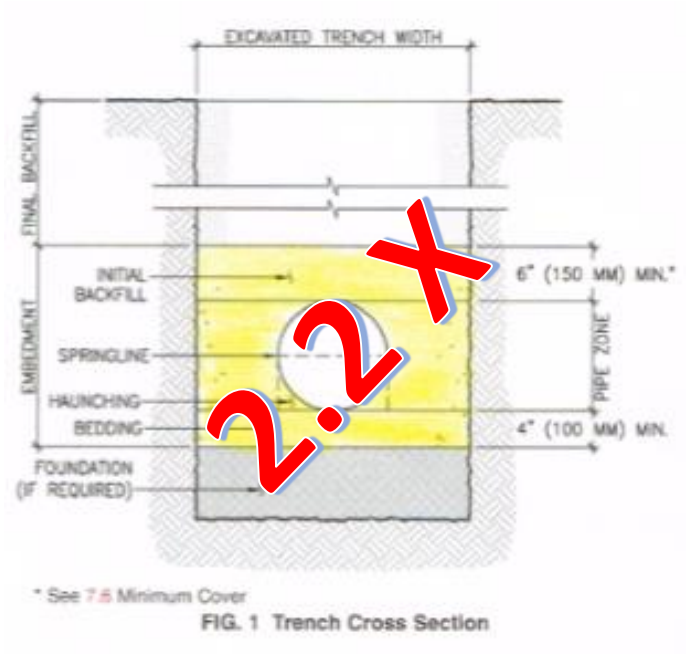


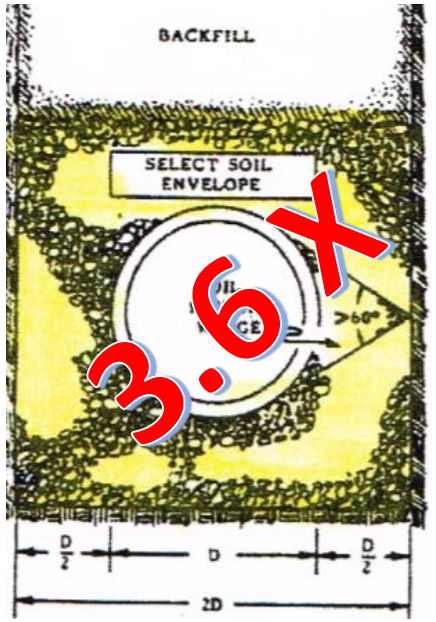
9.0 ft^3/ft Soil

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

Flexible Pipe

Trench Installation





20.0 ft^3/ft Soil

32.4 ft^3/ft Soil

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

Concrete Pipe

Designation: C1479 – 16

Embankment Installation

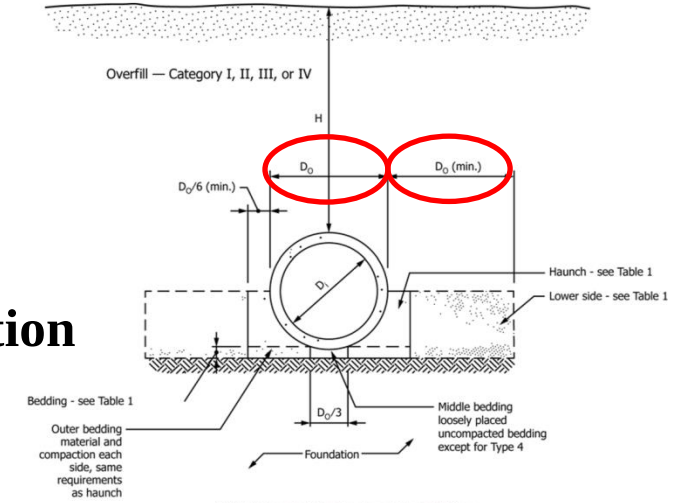


FIG. 2 Standard Embankment Installations

Pipe Size	O.D.	3 x O.D.
12”	16”	48”
15”	19 ½”	58 ½”
18”	23”	69”
24”	30”	90”
30”	37”	111”
36”	44”	132”
42”	51”	153”
48”	58”	174”
60”	67”	201”

Flexible Pipe

Designation: D2321 – 1

Embankment Installation Or Trench w/ Poor Soil

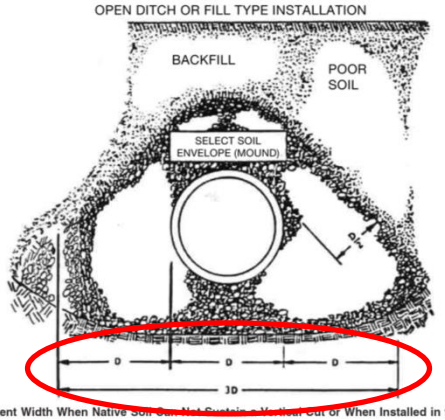
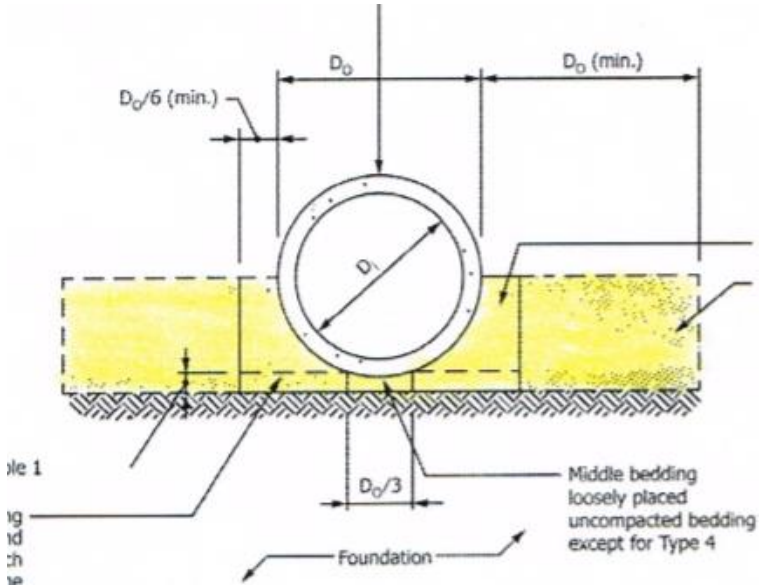


FIG. X1.2 Minimum Embedment Width When Native Soil Can Not Sustain a Vertical Cut or When Installed in the Embankment Condition

Pipe Size	O.D.	3 x O.D.
12”	15”	45”
15”	18”	54”
18”	21”	63”
24”	28”	84”
30”	36”	108”
36”	42”	126”
42”	48”	144”
48”	54”	162”
60”	67”	201”

Concrete Pipe

Embankment Installation

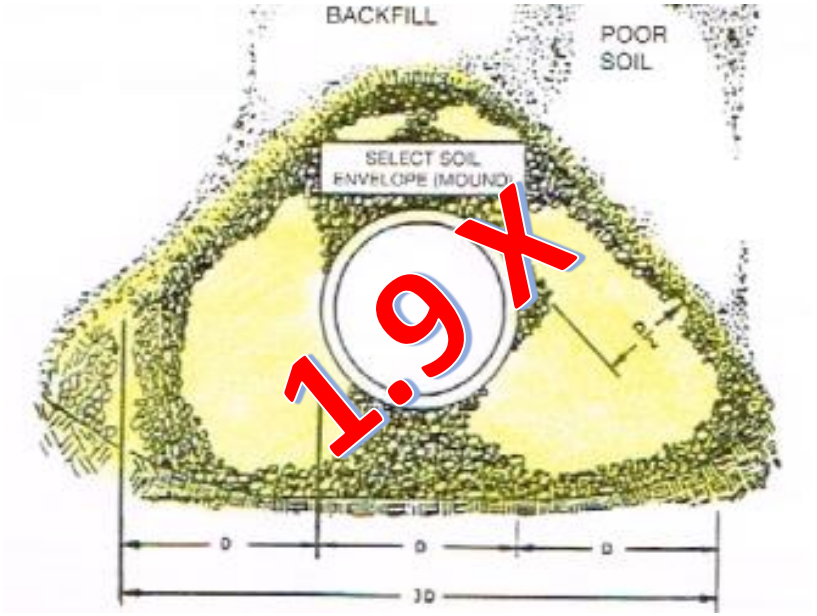


29.5 ft^3/ft Soil

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

Flexible Pipe

Embankment Installation



56.4 ft^3/ft Soil

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

Flexible Pipe

Designation: D2321 – 18

6. Trench Excavation

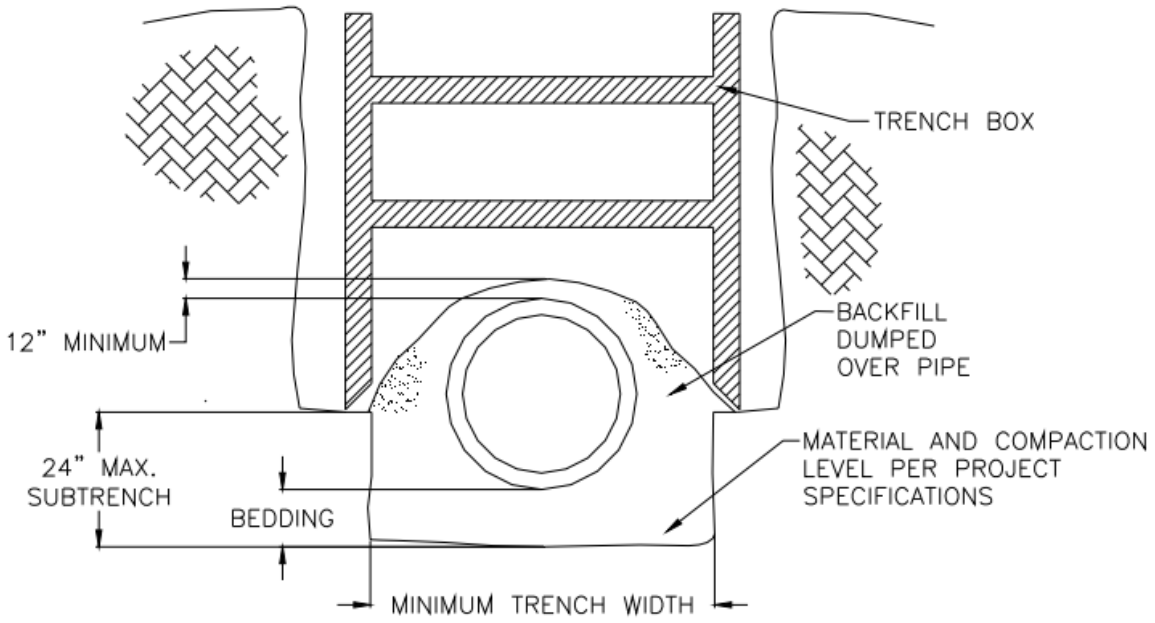
6.4.2 *Movable Trench Wall Supports* Do not disturb the installed pipe and its embedment when using movable trench boxes and shields. Movable supports should not be used below the top of the pipe zone unless approved methods are used for maintaining the integrity of embedment material. Before moving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

TECHNICAL NOTE

Recommended Use for Trench Boxes

TN 5.01
March 2009

Figure 1
Subtrench Installation



Flexible Pipe

Designation: D2321 – 18

6. Trench Excavation

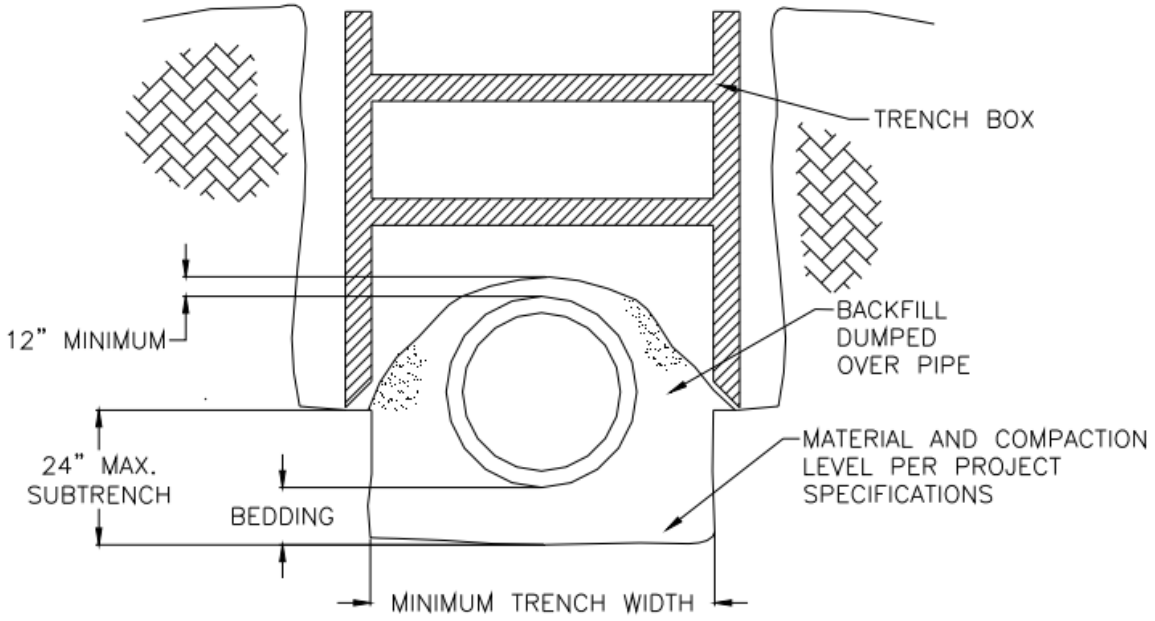
6.4.2 *Movable Trench Wall Supports* Do not disturb the installed pipe and its embedment when using movable trench boxes and shields. Movable supports should not be used below the top of the pipe zone unless approved methods are used for maintaining the integrity of embedment material. Before moving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

TECHNICAL NOTE

Recommended Use for Trench Boxes

TN 5.01
March 2009

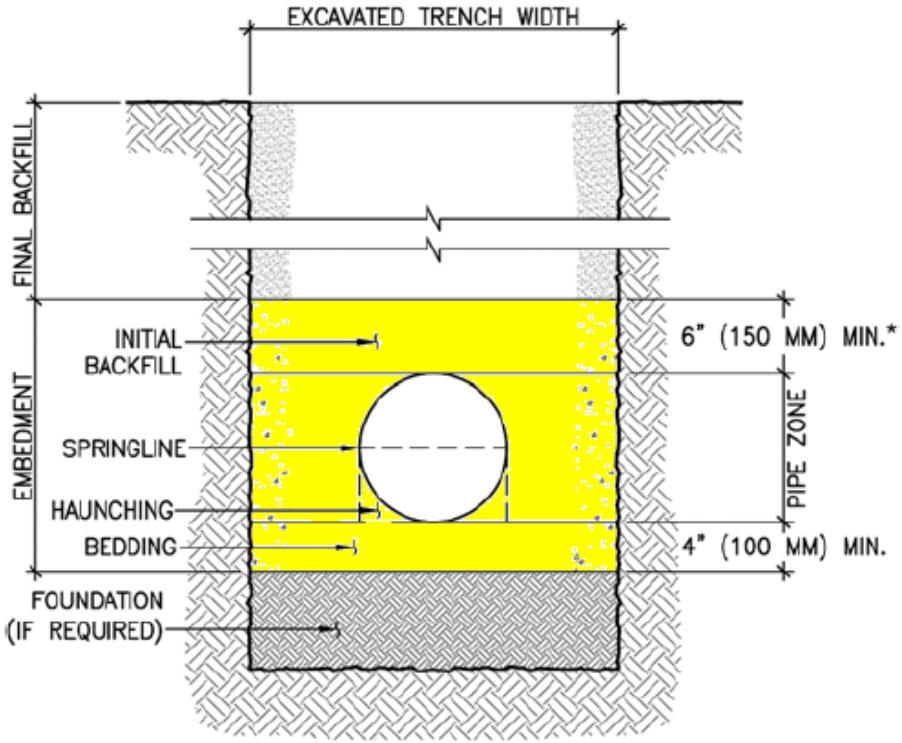
Figure 1
Subtrench Installation



Flexible Pipe

ASTM INTERNATIONAL

Designation: D2321 – 18



* See 7.6 Minimum Cover

FIG. 1 Trench Cross Section

TECHNICAL NOTE

Recommended Use for Trench Boxes

TN 5.01
March 2009

Regular Trench Installations

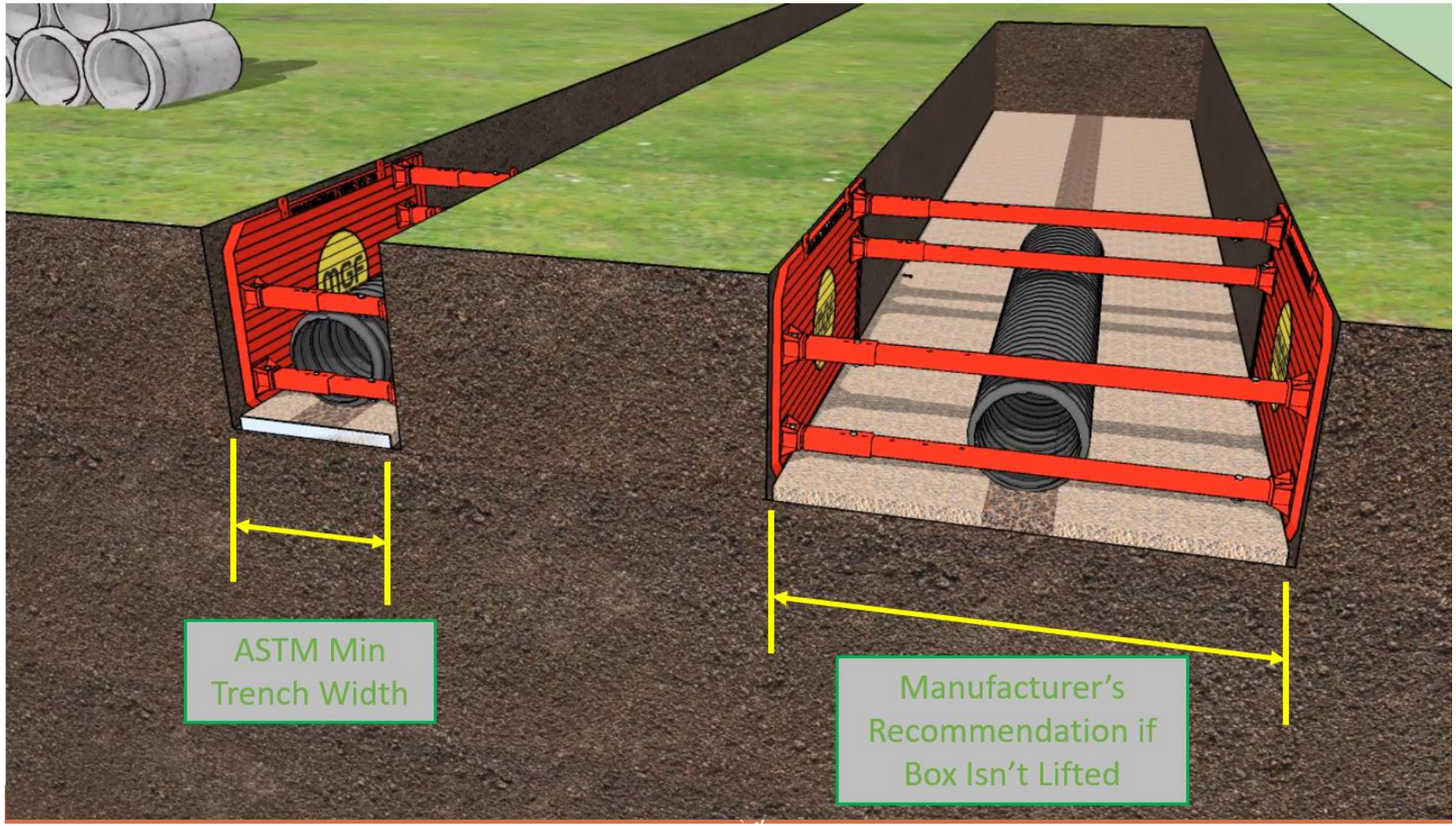
In installations not involving a subtrench situation, dragging a trench box should only be done if it does not damage the pipe or disrupt the backfill; otherwise, the box should be lifted vertically into its new position. If it is necessary for a trench box to be dragged through a trench, do not raise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

Trench Basics

Trench Boxes

American Concrete Pipe Association



Concrete Pipe

Designation: C1479 – 16

8. Foundation

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

Flexible Pipe

Designation: D2321 – 18

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.

Concrete Pipe

Designation: C1479 – 16

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.

Flexible Pipe

Designation: D2321 – 18

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

C1479 – 16

TABLE 2 Standard Trench Installation Soils and Minimum Compaction Requirements

NOTE 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.

NOTE 2—Type 1 installations require greater soil stiffness from the surrounding soils 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.

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

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

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

NOTE 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.

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

NOTE 8—"Dumped" material without additional compactive effort will not provide the design haunch support required for Type 1 and 2 installations.

Installation Type	Bedding Thickness	Haunch and Outer Bedding	Lower Side
Type 1	D_o/24 minimum; not less than 3 in. If rock foundation, use D_o/12 minimum; not less than 6 in.	95 % Category I	Undisturbed natural soil with firmness equivalent to the following placed soils: 90 % Category I, 95 % Category II, or embankment to the same requirements
Type 2	D_o/24 minimum; not less than 3 in. If rock foundation, use D_o/12 minimum; not less than 6 in.	90 % Category I or 95 % Category II	Undisturbed natural soil with firmness equivalent to the following placed soils: 85 % Category I, 90 % Category II, 95 % Category III, or embankment to the same requirements
Type 3	D_o/24 minimum; not less than 3 in. If rock foundation, use D_o/12 minimum; not less than 6 in.	85 % Category I, 90 % Category II, or 95 % Category III	Undisturbed natural soil with firmness equivalent to the following placed soils: 85 % Category I, 90 % Category II, 95 % Category III, or embankment to the same requirements
Type 4	No bedding required, except if rock foundation, use D_o/12 minimum; not less than 6 in.	No compaction required, except if Category III, use 85 % Category III	No compaction required, except if Category III, use 85 % Category III

Flexible Pipe

Designation: D2321 – 18

Concrete Pipe

C1479 – 16

TABLE 2 Standard Trench Installation Soils and Minimum Compaction Requirements

NOTE 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.

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

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Installation Type	Bedding Thickness	Haunch and Outer Bedding	Lower Side
Type 1	D_o/24 minimum; not less than 3 in. If rock foundation, use D_o/12 minimum; not less than 6 in.	95 % Category I	Undisturbed natural soil with firmness equivalent to the following placed soils: 90 % Category I, 95 % Category II, or embankment to the same requirements
Type 2	D_o/24 minimum; not less than 3 in. If rock foundation, use D_o/12 minimum; not less than 6 in.	90 % Category I or 95 % Category II	Undisturbed natural soil with firmness equivalent to the following placed soils: 85 % Category I, 90 % Category II, 95 % Category III, or embankment to the same requirements
Type 3	D_o/24 minimum; not less than 3 in. If rock foundation, use D_o/12 minimum; not less than 6 in.	85 % Category I, 90 % Category II, or 95 % Category III	Undisturbed natural soil with firmness equivalent to the following placed soils: 85 % Category I, 90 % Category II, 95 % Category III, or embankment to the same requirements
Type 4	No bedding required, except if rock foundation, use D_o/12 minimum; not less than 6 in.	No compaction required, except if Category III, use 85 % Category III	No compaction required, except if Category III, use 85 % Category III

Flexible Pipe

Designation: D2321 – 18

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).

Flexible Pipe

TABLE 3 Recommendations for Installation and Use of Soils and Aggregates for Foundation and Pipe-Zone Embedment

Soil Class[A]	Class I[B]	Class II	Class III	Class IV
General Recommendations and Restrictions	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).	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., 0.15 mm) behave like silts and should be treated as Class III soils.	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	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
Foundation	Suitable as foundation and for replacing over-excavated and unstable trench bottom as restricted above.	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	Suitable for replacing over-excavated trench bottom as restricted above. Install and compact in 6 in. (150 mm) maximum layers	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
Pipe Embedment	Suitable as restricted above. Work material under pipe to provide uniform haunch support.	Suitable as restricted above. Work material under pipe to provide uniform haunch support.	Suitable as restricted above. Difficult to place and compact in the haunch zone.	Suitable as restricted above. Difficult to place and compact in the haunch zone.
Minimum Recommended Percent Compaction, SPD[D]	See Note[C]	85 % (SW and SP soils) For GW and GP soils see Note[E]	90 %	95 %
Relative Compactive Effort Required to Achieve Minimum Percent Compaction	low	moderate	high	very high
Compaction Methods	vibration or impact	vibration or impact	impact	impact
Required Moisture Control	none	none	Maintain near optimum to minimize compactive effort	Maintain near optimum to minimize compactive effort

[A] Class V materials are unsuitable as embedment. They may be used as final backfill as permitted by the engineer.
[B] 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 (SPD95), 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 (SPD100). Even if placed uncompacted (that is, dumped), Class I materials should always be worked into the haunch zone to assure complete placement.
[C] Suitable compaction typically achieved by dumped placement (that is, uncompacted but worked into haunch zone to ensure complete placement).
[D] SPD is standard Proctor density as determined by Test Method D698.
[E] Place and compact GW and GP soils with at least two passes of compaction equipment.

Designation: D2321 – 18

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.

Flexible Pipe

TABLE 3 Recommendations for Installation and Use of Soils and Aggregates for Foundation and Pipe-Zone Embedment

Soil Class[A]	Class I[B]	Class II	Class III	Class IV
General Recommendations and Restrictions	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).	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., 0.15 mm) behave like silts and should be treated as Class III soils.	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	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
Foundation	Suitable as foundation and for replacing over-excavated and unstable trench bottom as restricted above.	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	Suitable for replacing over-excavated trench bottom as restricted above. Install and compact in 6 in. (150 mm) maximum layers	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
Pipe Embedment	Suitable as restricted above. Work material under pipe to provide uniform haunch support.	Suitable as restricted above. Work material under pipe to provide uniform haunch support.	Suitable as restricted above. Difficult to place and compact in the haunch zone.	Suitable as restricted above. Difficult to place and compact in the haunch zone.
Minimum Recommended Percent Compaction, SPD[D]	See Note[C]	85 % (SW and SP soils) For GW and GP soils see Note[E]	90 %	95 %
Relative Compactive Effort Required to Achieve Minimum Percent Compaction	low	moderate	high	very high
Compaction Methods	vibration or impact	vibration or impact	impact	impact
Required Moisture Control	none	none	Maintain near optimum to minimize compactive effort	Maintain near optimum to minimize compactive effort

[A] Class V materials are unsuitable as embedment. They may be used as final backfill as permitted by the engineer.
[B] 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 (SPD95), 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 (SPD100). Even if placed uncompacted (that is, dumped), Class I materials should always be worked into the haunch zone to assure complete placement.
[C] Suitable compaction typically achieved by dumped placement (that is, uncompacted but worked into haunch zone to ensure complete placement).
[D] SPD is standard Proctor density as determined by Test Method D698.
[E] Place and compact GW and GP soils with at least two passes of compaction equipment.

Designation: D2321 – 18

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.

Flexible Pipe

TABLE 3 Recommendations for Installation and Use of Soils and Aggregates for Foundation and Pipe-Zone Embedment

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Foundation	Suitable as foundation and for replacing over-excavated and unstable trench bottom as restricted above.	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	Suitable for replacing over-excavated trench bottom as restricted above. Install and compact in 6 in. (150 mm) maximum layers	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
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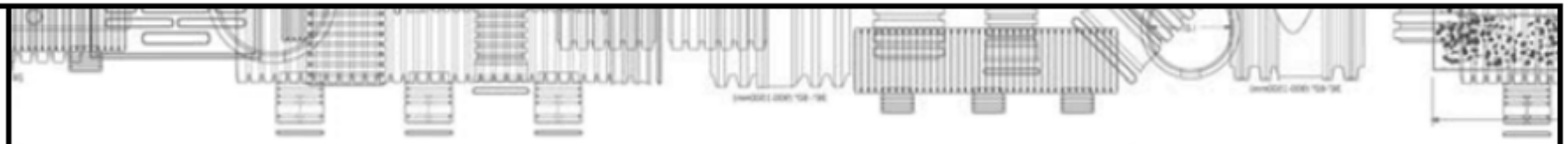
Minimum Recommended Percent Compaction, SPD[D]	See Note[C]	85 % (SW and SP soils) For GW and GP soils see Note[E]	90 %	95 %
Relative Compactive Effort Required to Achieve Minimum Percent Compaction	low	moderate	high	very high
Compaction Methods	vibration or impact	vibration or impact	impact	impact
Required Moisture Control	none	none	Maintain near optimum to minimize compactive effort	Maintain near optimum to minimize compactive effort

[A] Class V materials are unsuitable as embedment. They may be used as final backfill as permitted by the engineer.
[B] 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 (SPD95), 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 (SPD100). Even if placed uncompacted (that is, dumped), Class I materials should always be worked into the haunch zone to assure complete placement.
[C] Suitable compaction typically achieved by dumped placement (that is, uncompacted but worked into haunch zone to ensure complete placement).
[D] SPD is standard Proctor density as determined by Test Method D698.
[E] Place and compact GW and GP soils with at least two passes of compaction equipment.

Designation: D2321 – 18

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).



TECHNICAL NOTE

Pipe Flotation

TN 5.05
March 2016

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?

Designation: D2321 – 14$^{\varepsilon 1}$

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...

Size	Class I	Class II, III, IV	Hydrohammer
12”	24”	36”	48”
18”	24”	36”	48”
24”	24”	36”	48”
30”	30”	36”	48”
36”	36”	36”	48”
42”	42”	42”	48”
48”	48”	48”	48”
54”	54”	54”	48”
60”	60”	60”	48”

Concrete Pipe

Designation: C1479 – 16

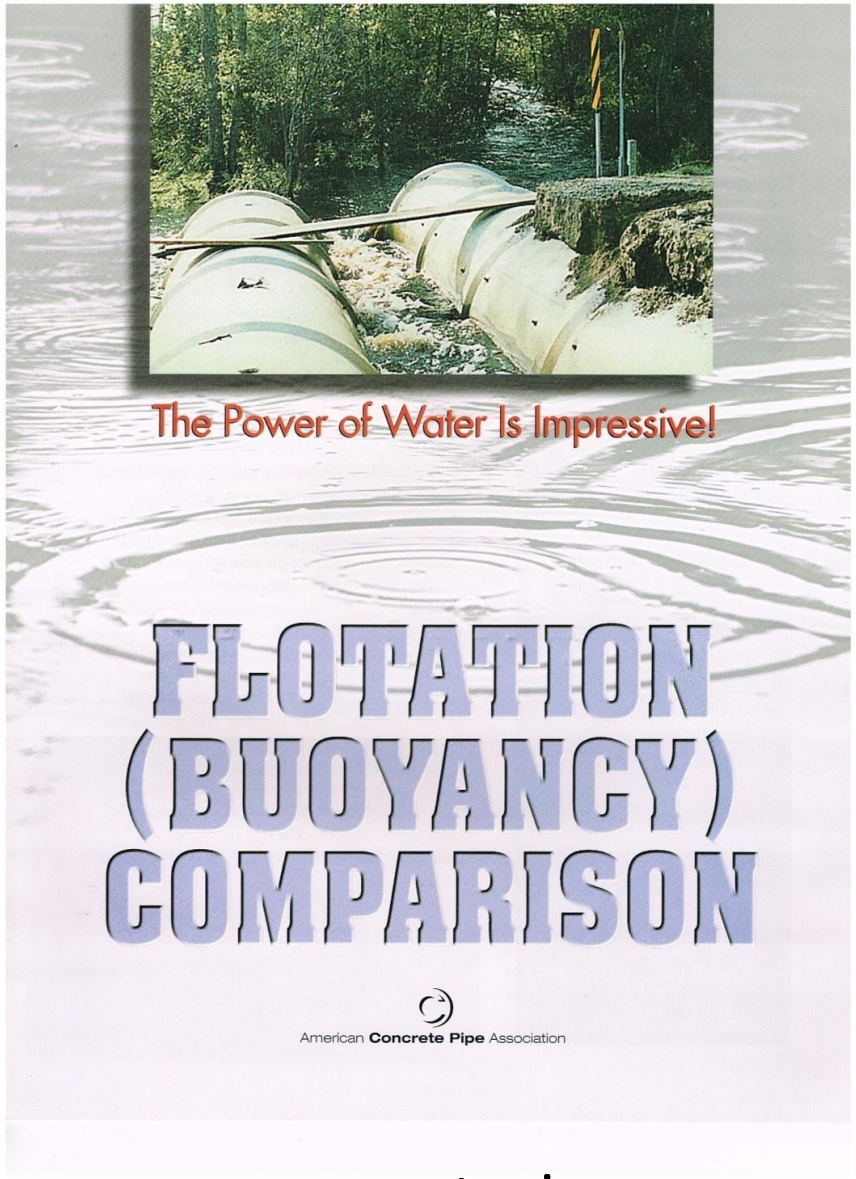
17. Safety

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.

Concrete Pipe

Designation: C1479 – 16



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Concrete Pipe

Designation: C1479 – 16

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 reminder of the pipeline to reduce the possibility of differential settlement between pipe and fittings.

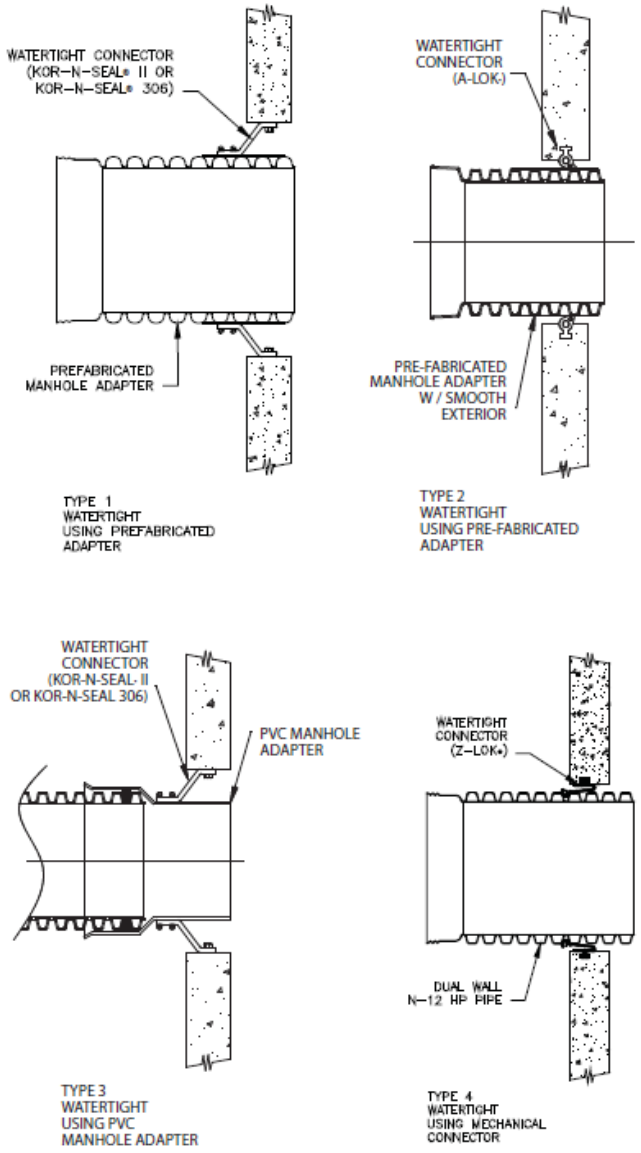
Flexible Pipe

Designation: D2321 – 18

Flexible Pipe

Figure 4:

Product Detail for Manhole Connections



Designation: D2321 – 18

Flexible Pipe

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.

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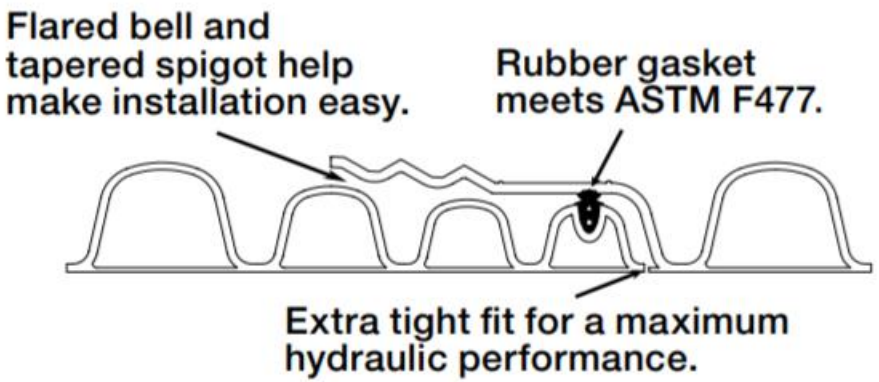

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Concrete Pipe

Designation: C1479 – 16

Flexible Pipe

Designation: D2321 – 18

The installation was completed successfully.

- Introduction
- Destination Select
- Installation Type
- Installation
- **Summary**

The installation was successful.

Pipeline Complete!!!

Go Back | Close

Field Inspection of Pipes

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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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Designation: D2321 – 18

Concrete Pipe

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Flexible Pipe

Designation: D2321 – 18

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!

Concrete Pipe

Designation: C1479 – 16

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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.

Concrete Pipe

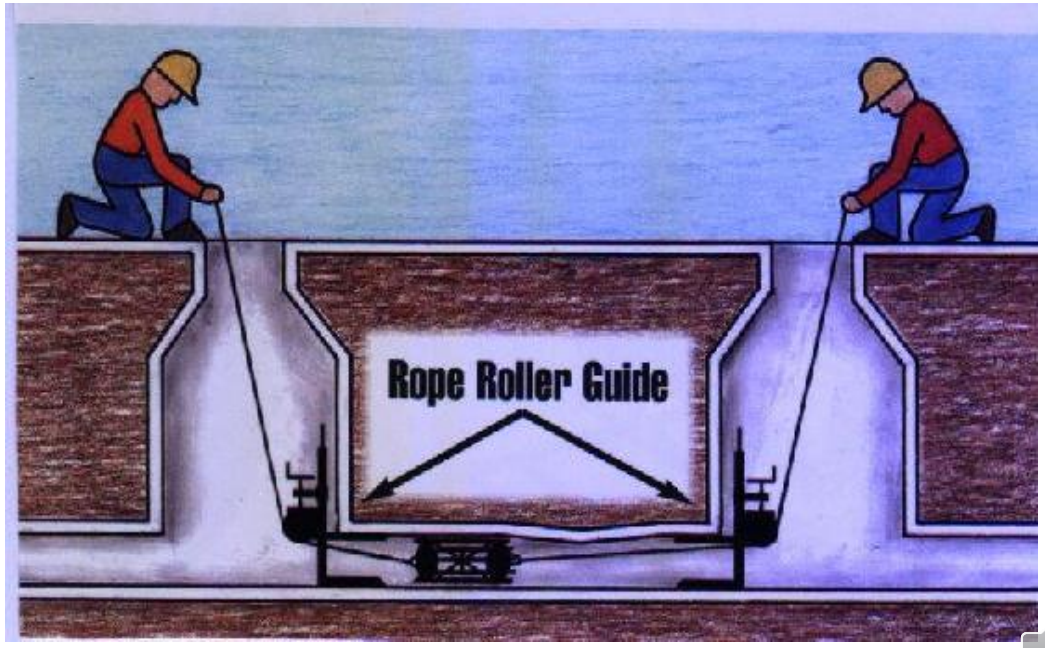
Designation: C1479 – 16

Deflection Testing – Not Relevant

Flexible Pipe

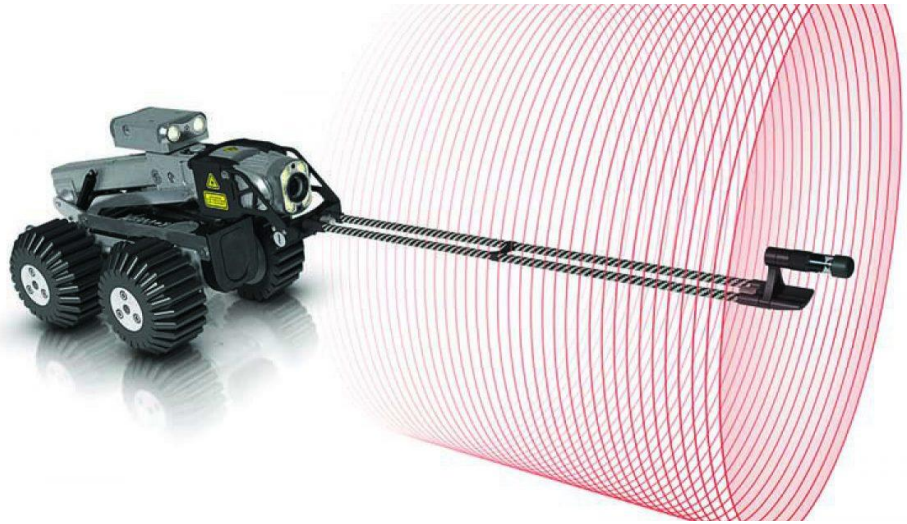
Designation: D2321 – 18

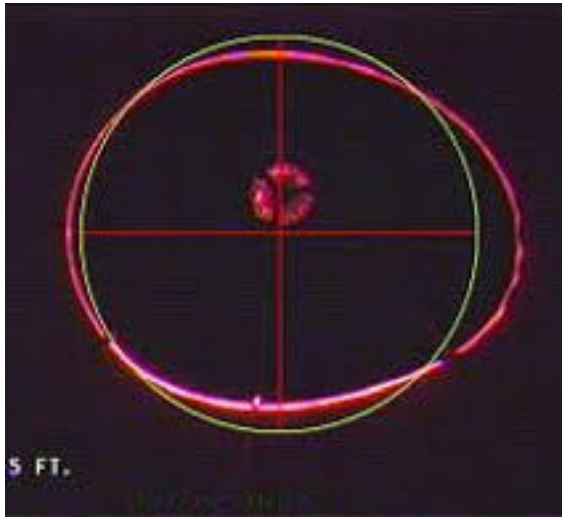
- Go-No-Go device
- 5% Deflection
- Stuck if deflection exceeded



Concrete Pipe

Flexible Pipe





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

Concrete Pipe

Designation: C1479 – 16

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.*

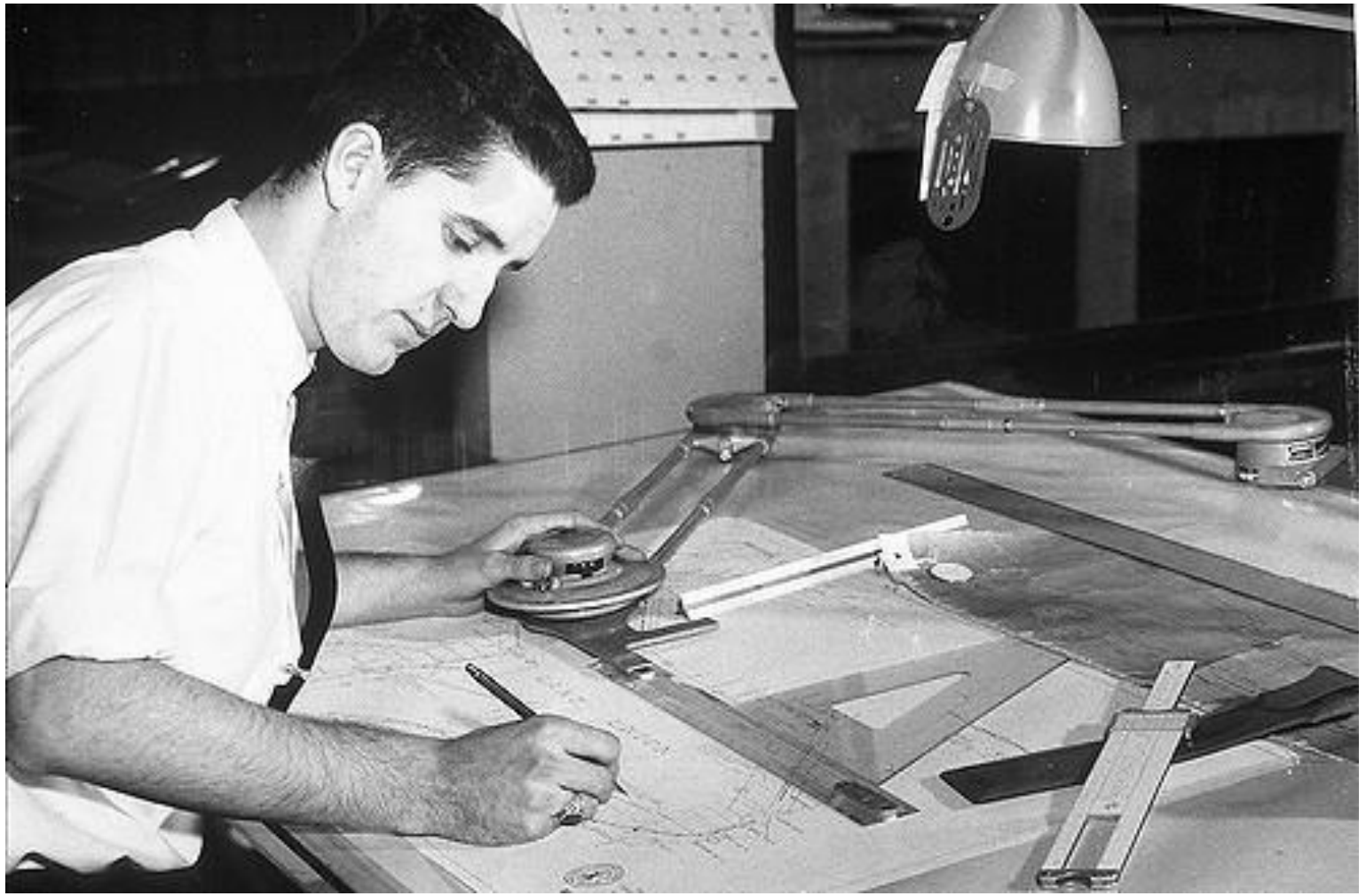
Flexible Pipe

Designation: D2321 – 18

1. Scope

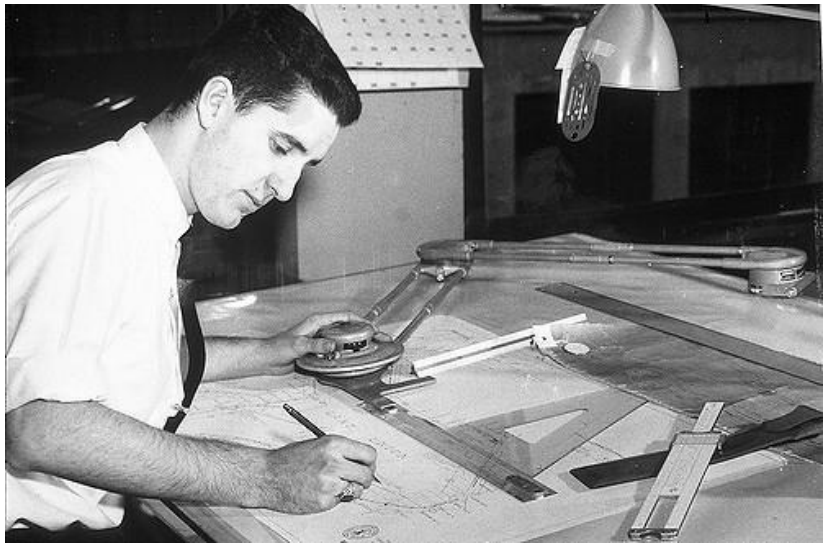
1.1 This practice provides recommendations for the installation of buried thermoplastic pipe used in sewers and other gravity-flow applications. These recommendations are intended to ensure a stable underground environment for thermoplastic pipe under a wide range of service conditions. However, because 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.**

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

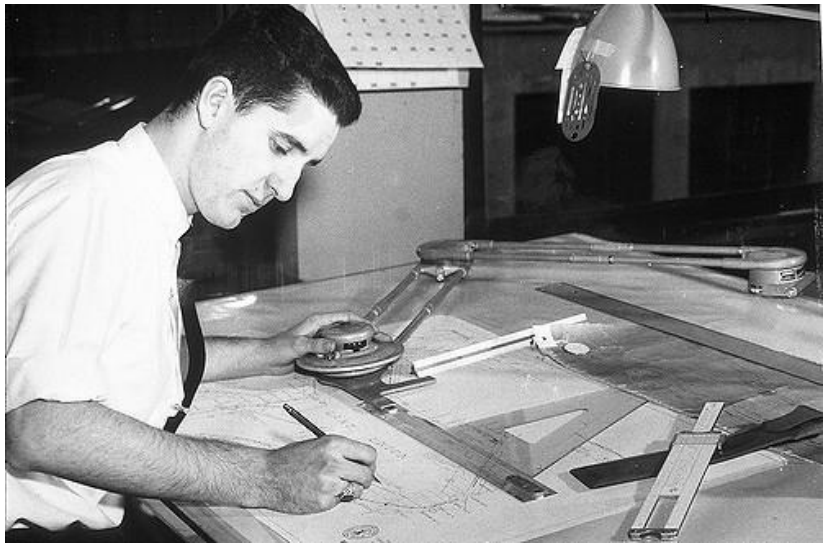
Determine In-Situ Soils

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

Specify Deflection Testing!!!

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

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.

Thank You!

American Concrete Pipe Association