Know Your Specs
“A Tale of 2 Pipes”

ASTM C1479 vs D2321

- **Alec Parliament, P.E.** – Technical Resource Engineer for Foley Products Company in AL/FL Panhandle territories.

Designing Pipe for Drainage Systems

What is Required for Design?

Concrete Pipe

AASHTO 12.10-Reinforced Concrete Pipe

12.10.1-General

The provisions herein shall apply to the structural design of buried precast reinforced concrete pipes of circular, elliptical and arch shapes.

The structural design of the types of pipes indicated above may proceed by either of two methods:

- **The direct design method at the strength limit state as specified in article 12.10.4.2, or**
- **The indirect design method at the service limit state as specified in article 12.10.4.3**

Flexible Pipe

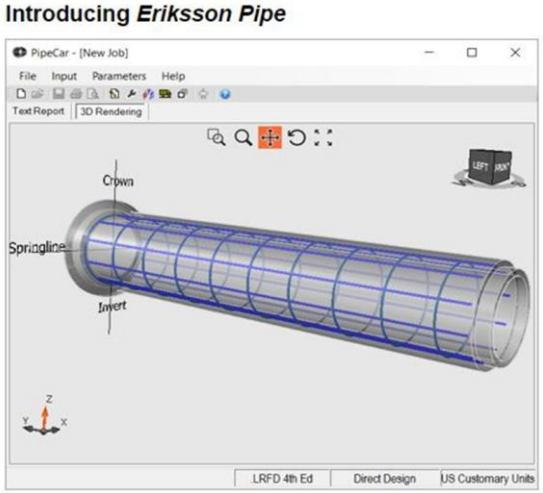
AASHTO 12.12-Thermoplastic Pipes

12.12.1-General

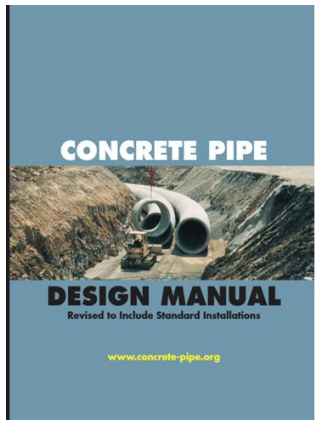
The provisions herein shall apply to the structural design of buried thermoplastic pipe with solid, corrugated, or profile wall, manufactured of PE, PP, or PVC.

Concrete Pipe

Direct Design:
Hand Calculations
Software



Indirect Design:



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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

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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

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

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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

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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

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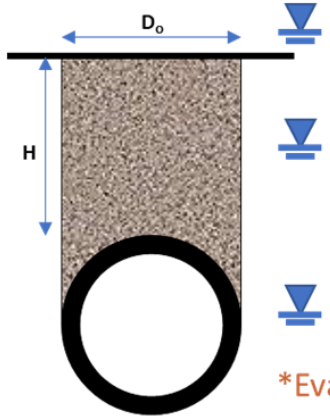
Design Complete!

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
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

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

Factored compressive strain

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

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:

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

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

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

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

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

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

Concrete Pipe

Fill Height Tables are based on:
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

BUCKLING

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

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:

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

Resistance factor = 0.7

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

Factored compressive strain

Buckling strain capacity of pipe

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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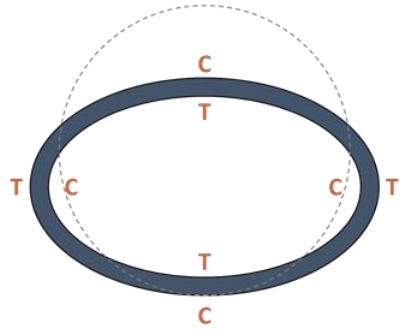
Design Complete!

Flexible Pipe

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:
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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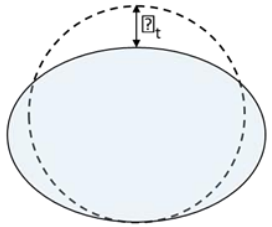
Design Complete!

Flexible Pipe

DEFLECTION



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

Soil Load
Live Load
Circumferential Shortening
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

Fill Height Tables are based on:
1. γs = 120 pcf
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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

Modified Iowa Formula

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

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

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

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

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

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
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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)

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Design Complete!

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

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)

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%

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	77												
33	925	825	75												
36	900	775	75												
42	850	700	75												
48	875	700	70												
54	850	725	70												
60	875	750	70												
66	875	775	70												
72	850	800	70												
78	800	775	75												
84	750	750	77												
90	725	750	77												
96	700	750	77												
102	725	750	77												
108	725	725	80												

Do we know what the Modulus of Soil Reaction is onsite?

11

Design Complete!

Flexible Pipe

SCIENCE!

Designing with Steel – fy = 36 ksi

Mill Certification

Designing with Concrete – f'_c = 4000 psi

Compression Test Cylinders

Designing with Soil – E' = 1000 psi

(Should be Science But Often Magic)

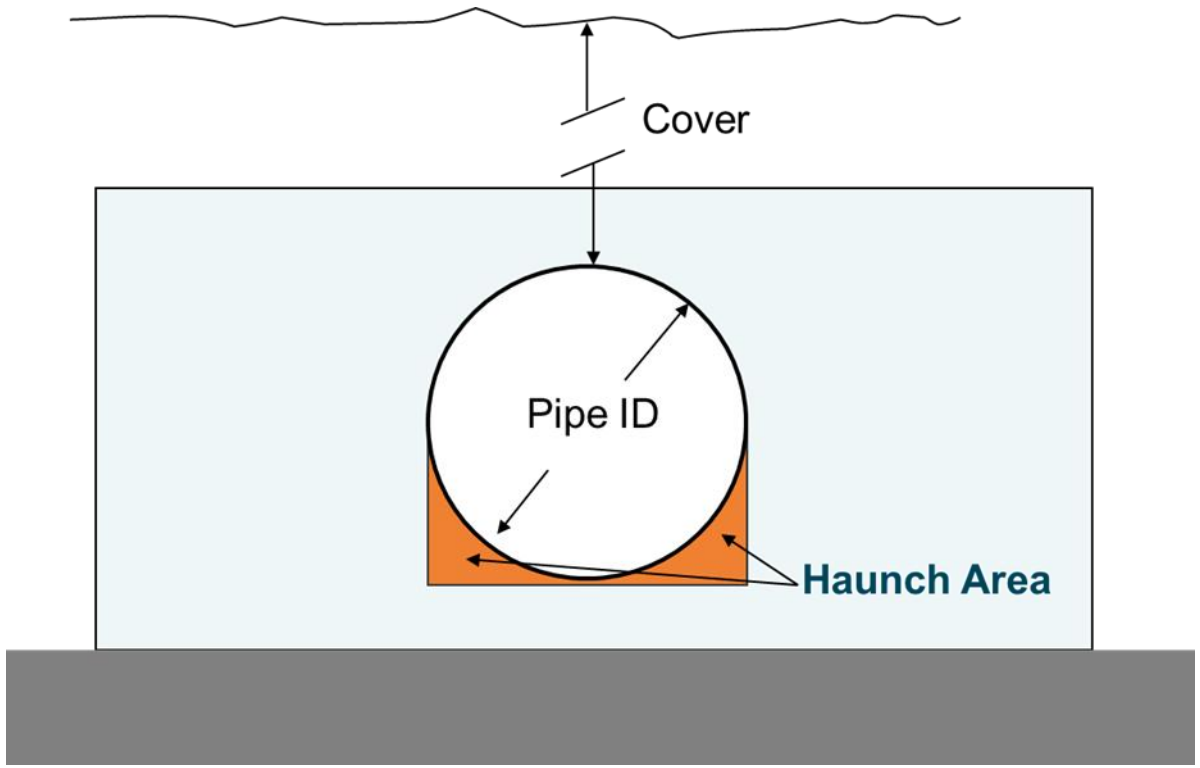
The soil was tested = Science

No test report = Magic!

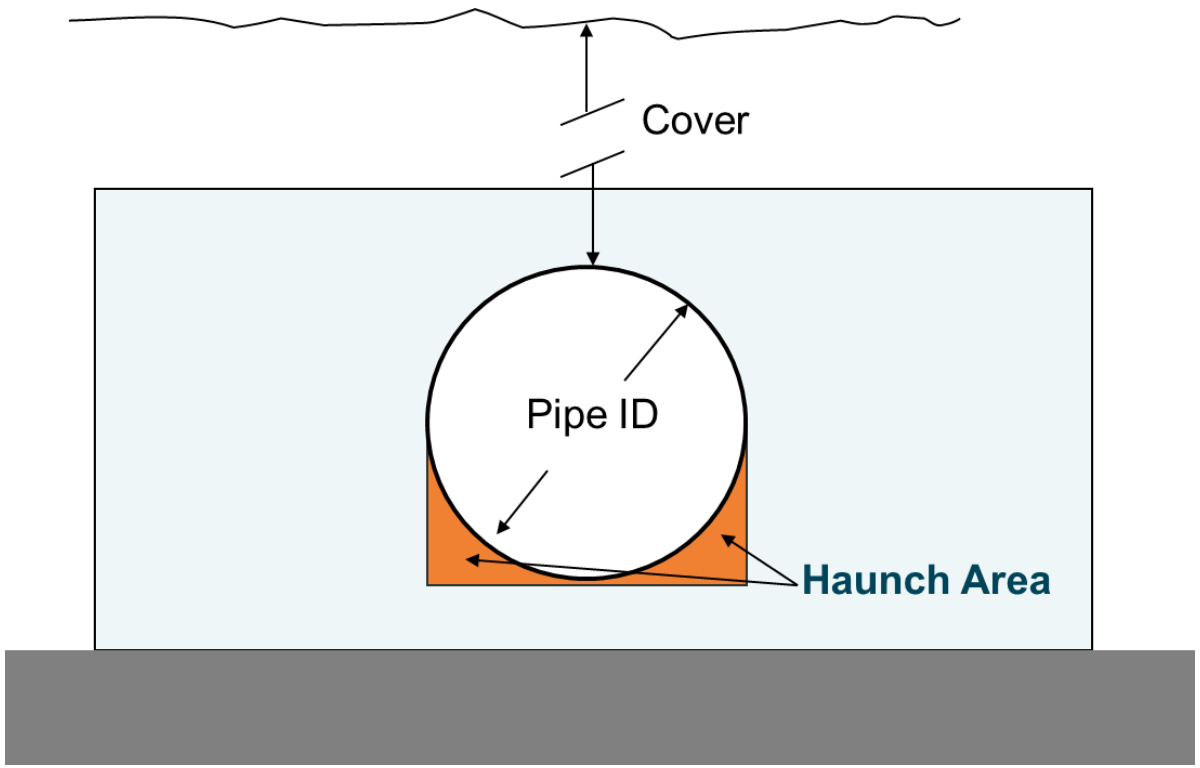
Pipe Installations

Similarities & Differences

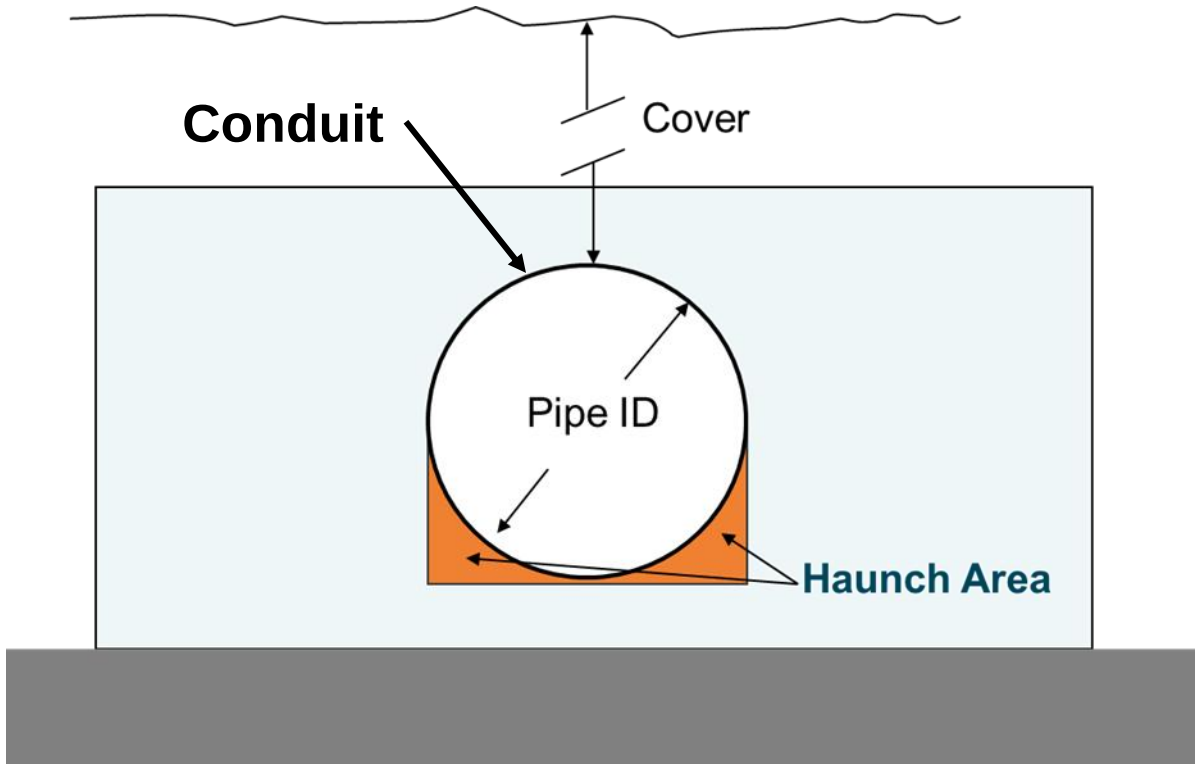
Concrete Pipe



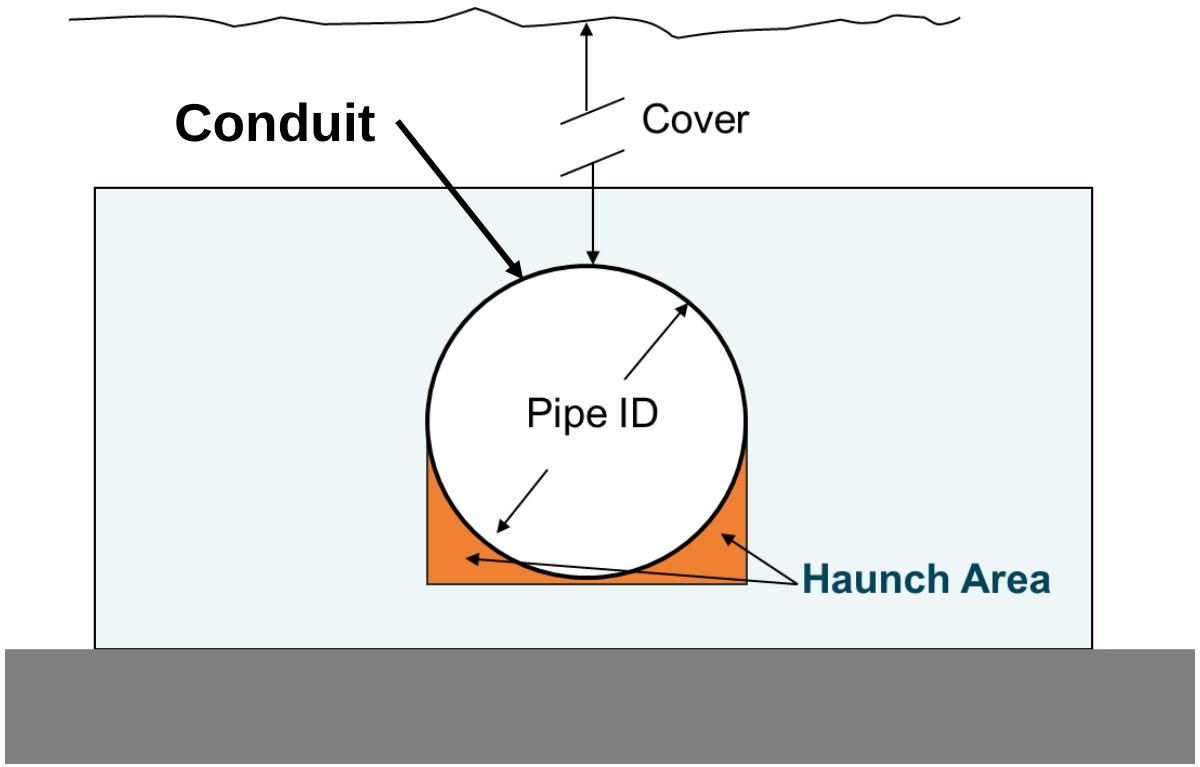
Flexible Pipe



Concrete Pipe

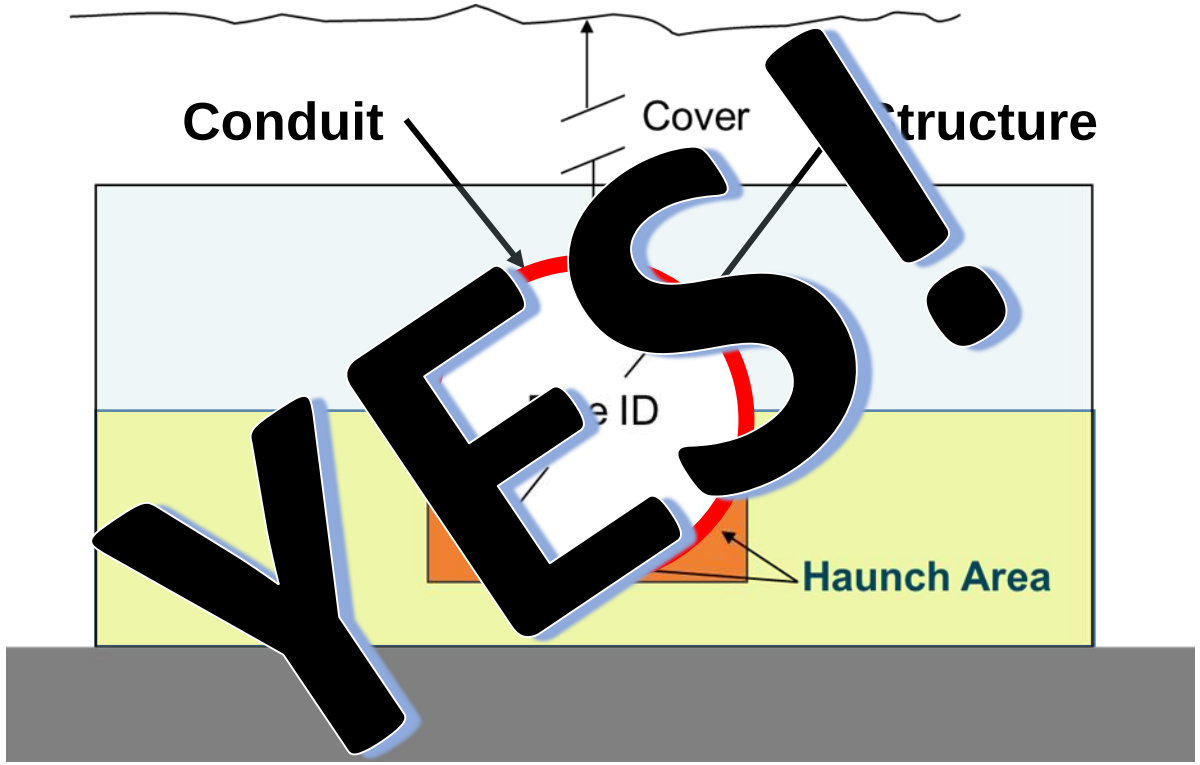


Flexible Pipe



Concrete Pipe

Installation – Is It Important?



Flexible Pipe

Installation – Is It Important?


WHAT DIFFERENCE DOES IT MAKE???


It’s Really
Really Youge!!!


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

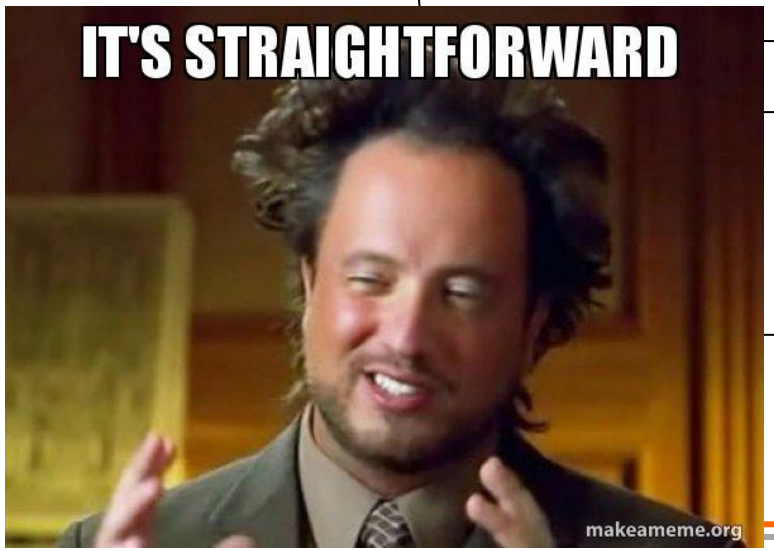
Concrete Pipe

Engineer

Manufacture per ASTM C76
Install per ASTM C1479

Manufacturer

C76 - OKAY



Installer

C1479 - OKAY

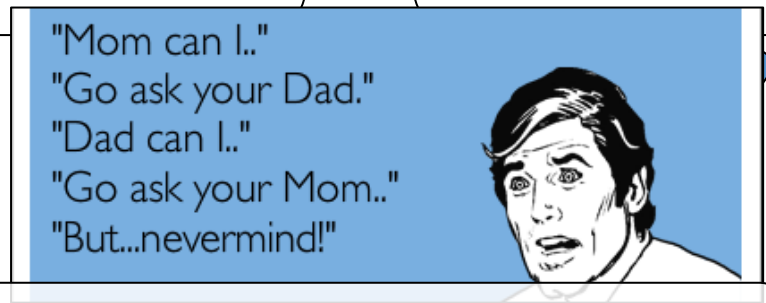
Flexible Pipe

Engineer

“as per manufacturer’s recommendations”

Manufacturer

“As per ASTM D2321”



ASTM D2321

Engineer referenced 24 times

A Closer Look at ASTM C1479 and D2321

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

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

Designation: C1479 – 16

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Concrete Pipe

Designation: C1479 – 16

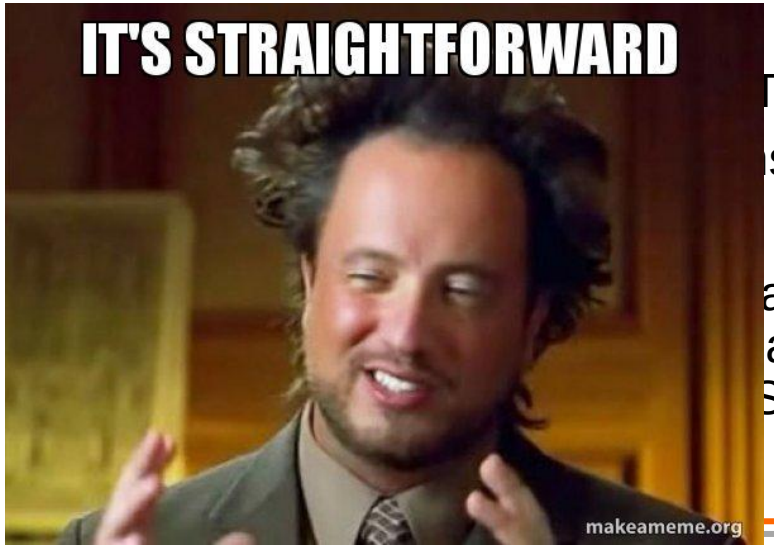
2. Referenced Documents

2.1 *ASTM Standards:* (7 Total)

Terminology

Manufacture of pipe

Soil description, classification & identification



Total)

sity & moisture

actice for the Direct
ast Reinforced
Standard Installations

Flexible Pipe

Designation: D2321 – 18

2. Referenced Documents

2.1 *ASTM Standards:* (23 Total)

Terminology

ng

ht,

ading

Soils classification.

Solvent cements for PVC

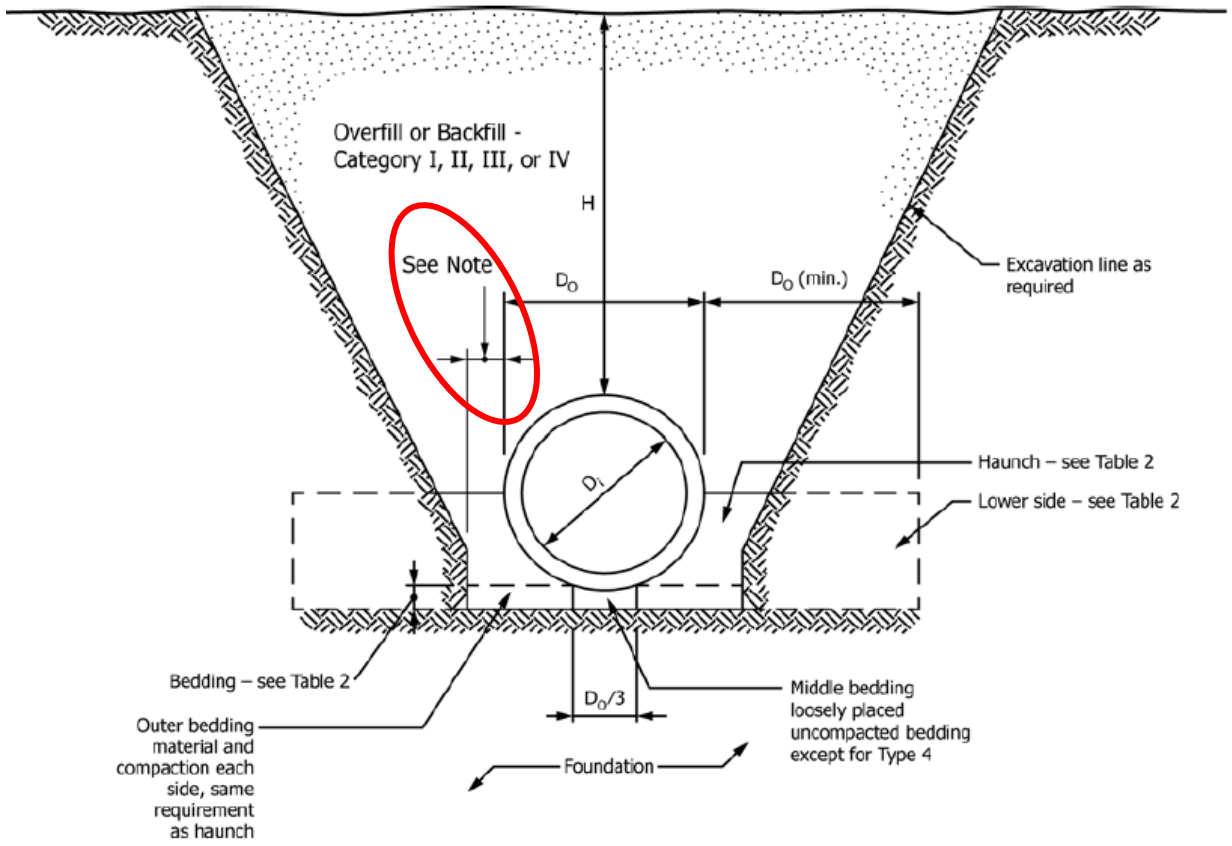
Safe solvent handling

Guide for construction procedures

2.2 *AASHTO Standards:* (1 Total)

Soil classification

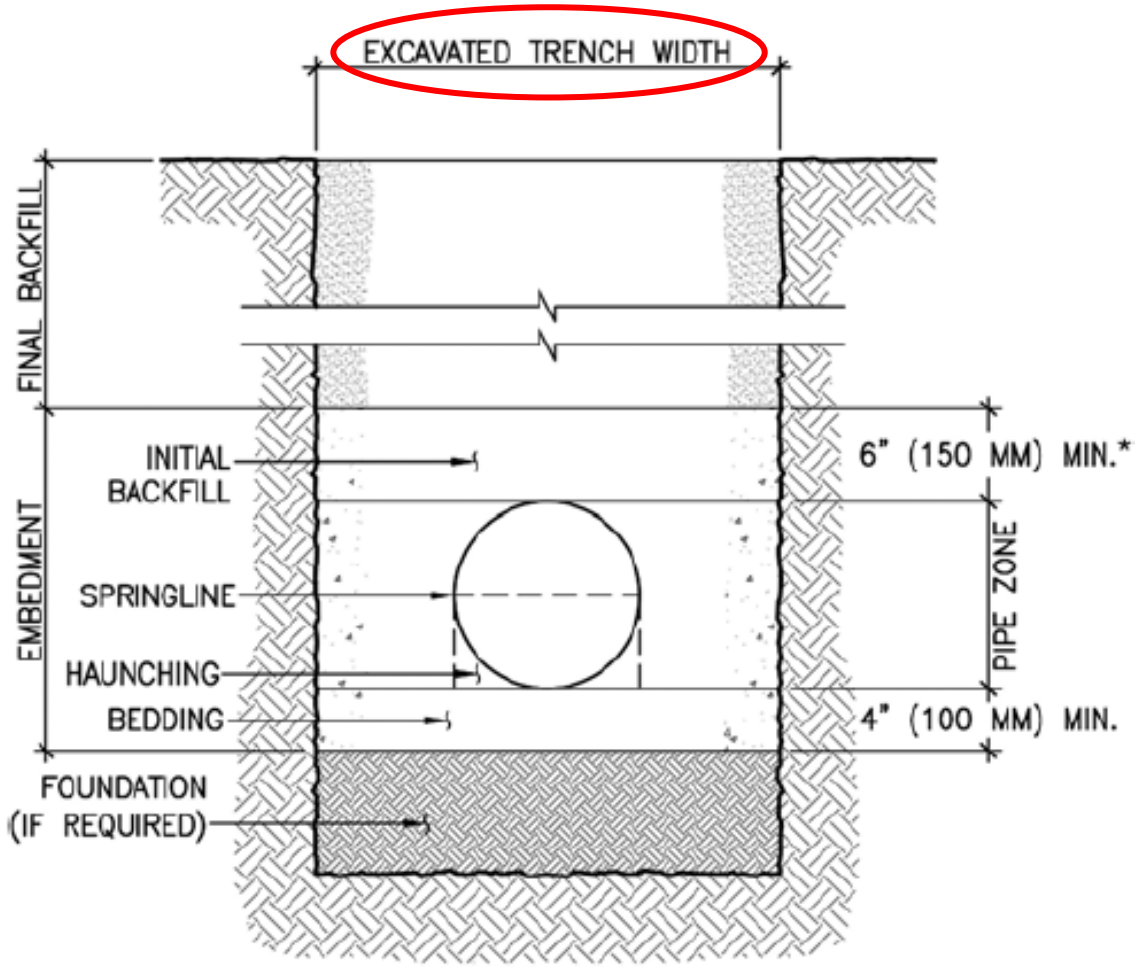
Concrete Pipe



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

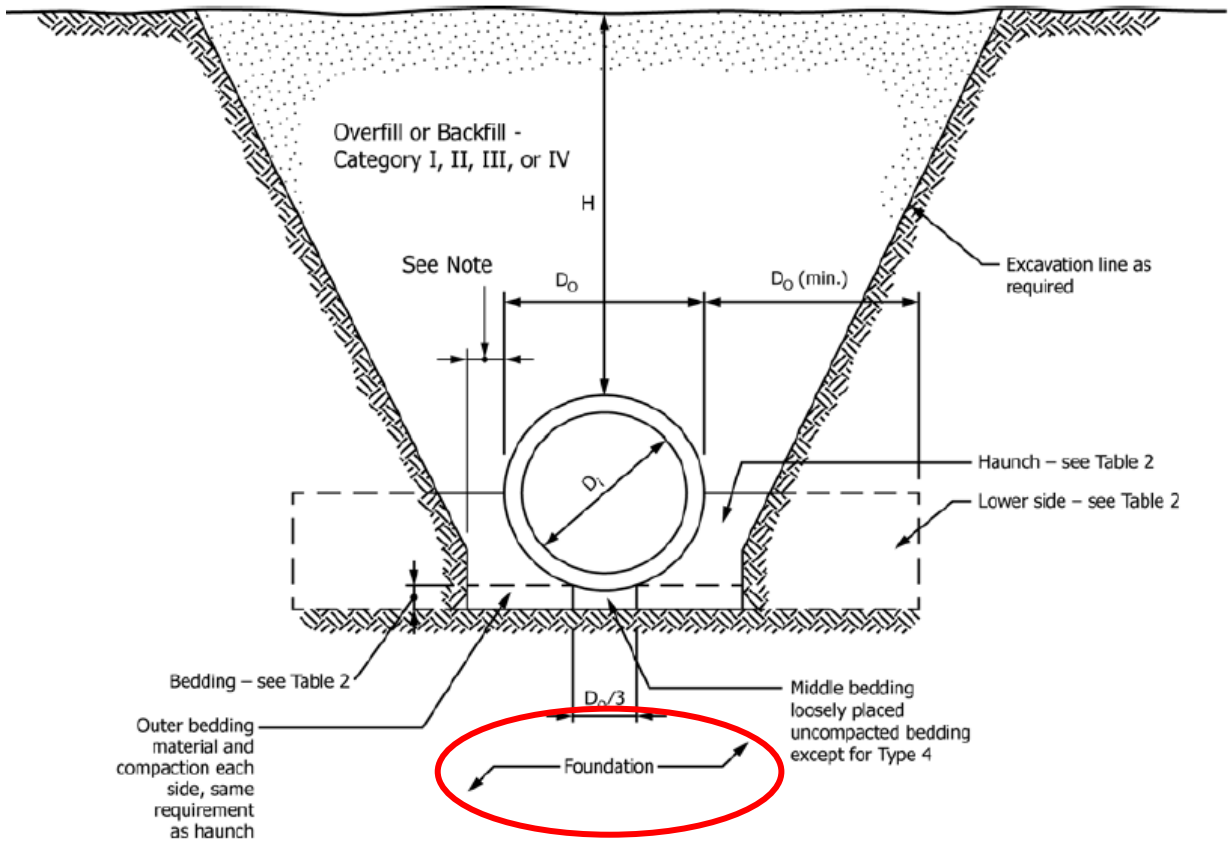


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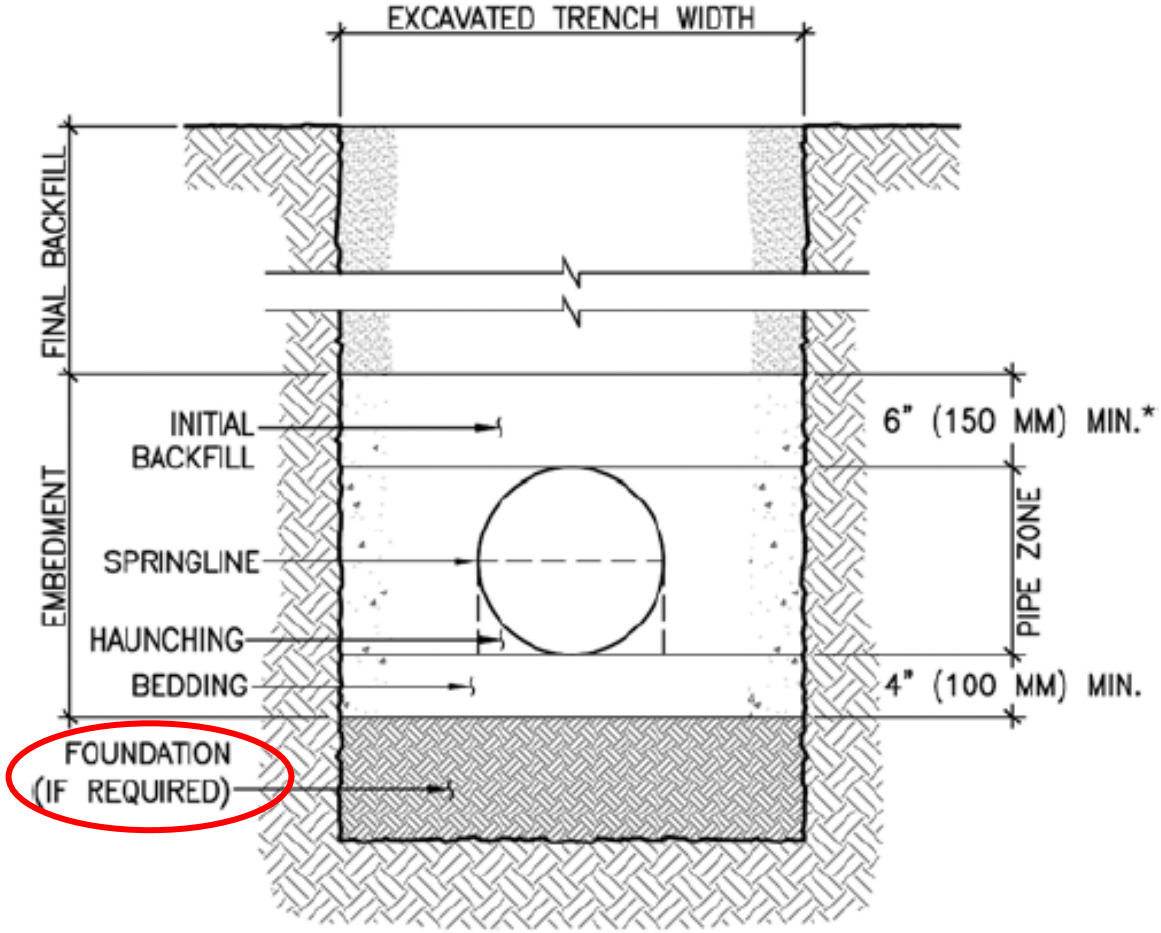
FIG. 3 Standard Trench Installations

Flexible Pipe



* See 7.6 Minimum Cover

FIG. 1 Trench Cross Section

Concrete Pipe

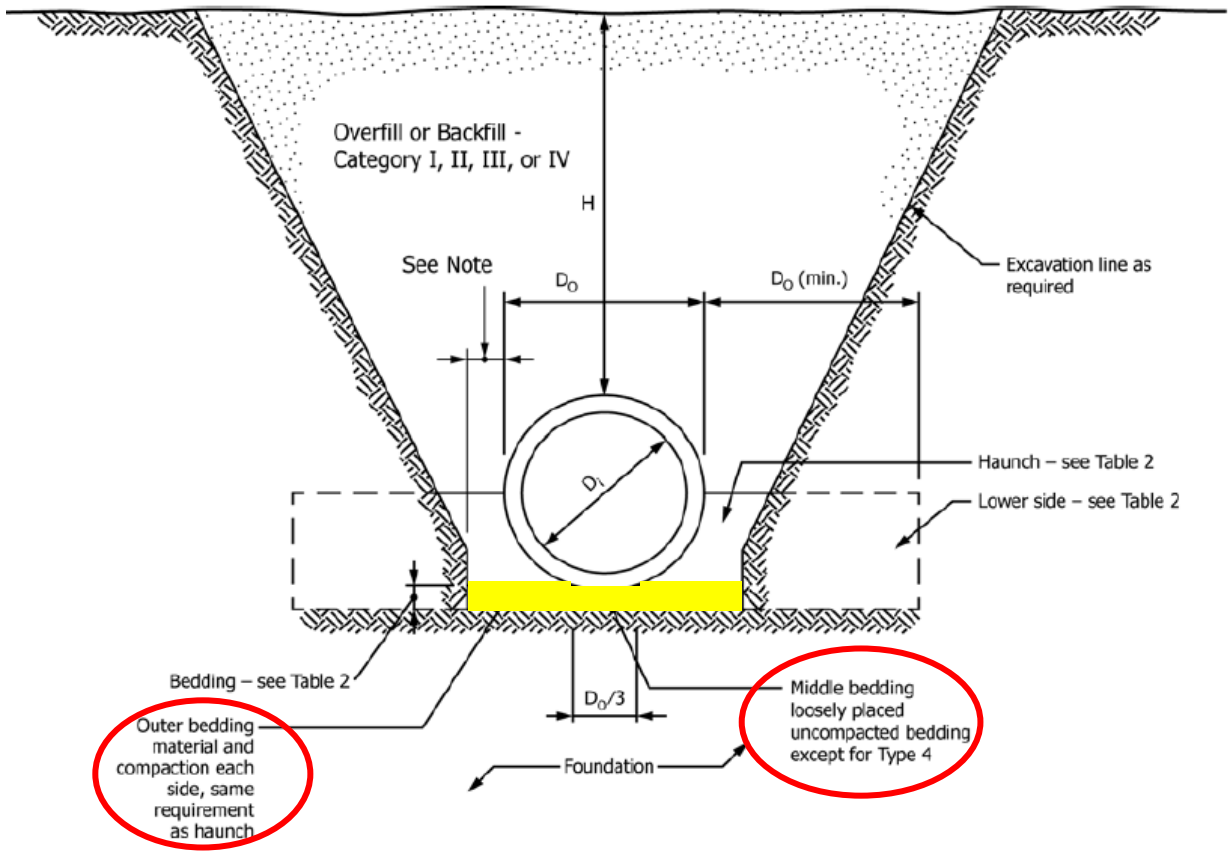


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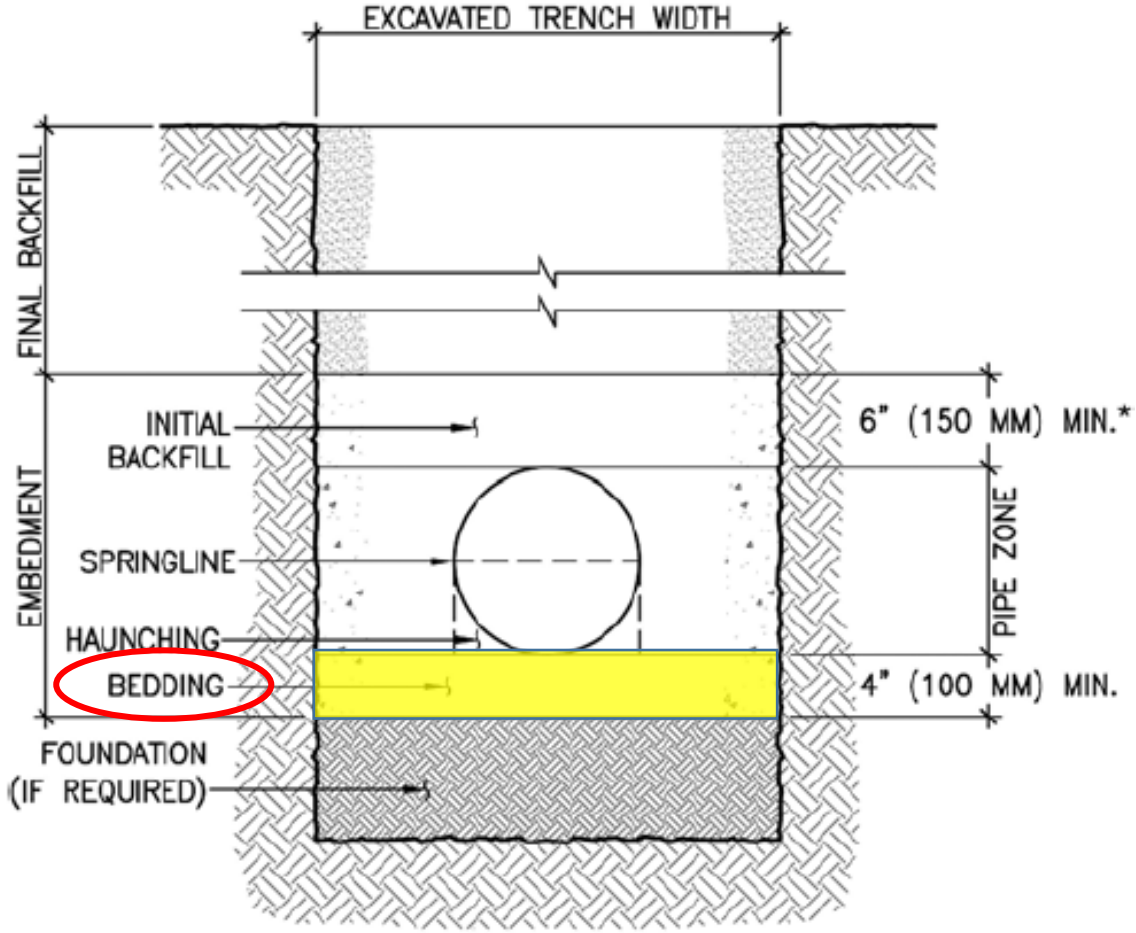
FIG. 3 Standard Trench Installations

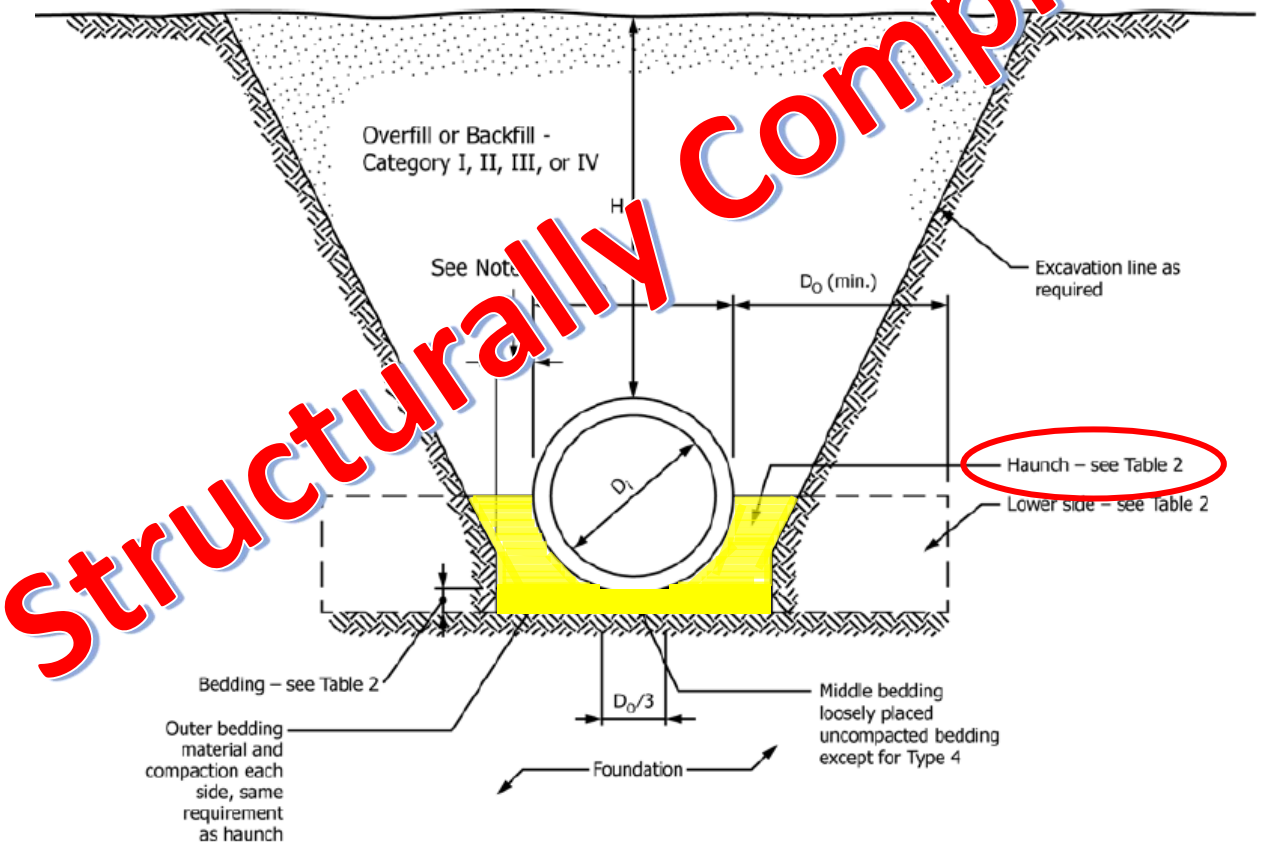
Flexible Pipe



* See 7.6 Minimum Cover

FIG. 1 Trench Cross Section

Concrete Pipe

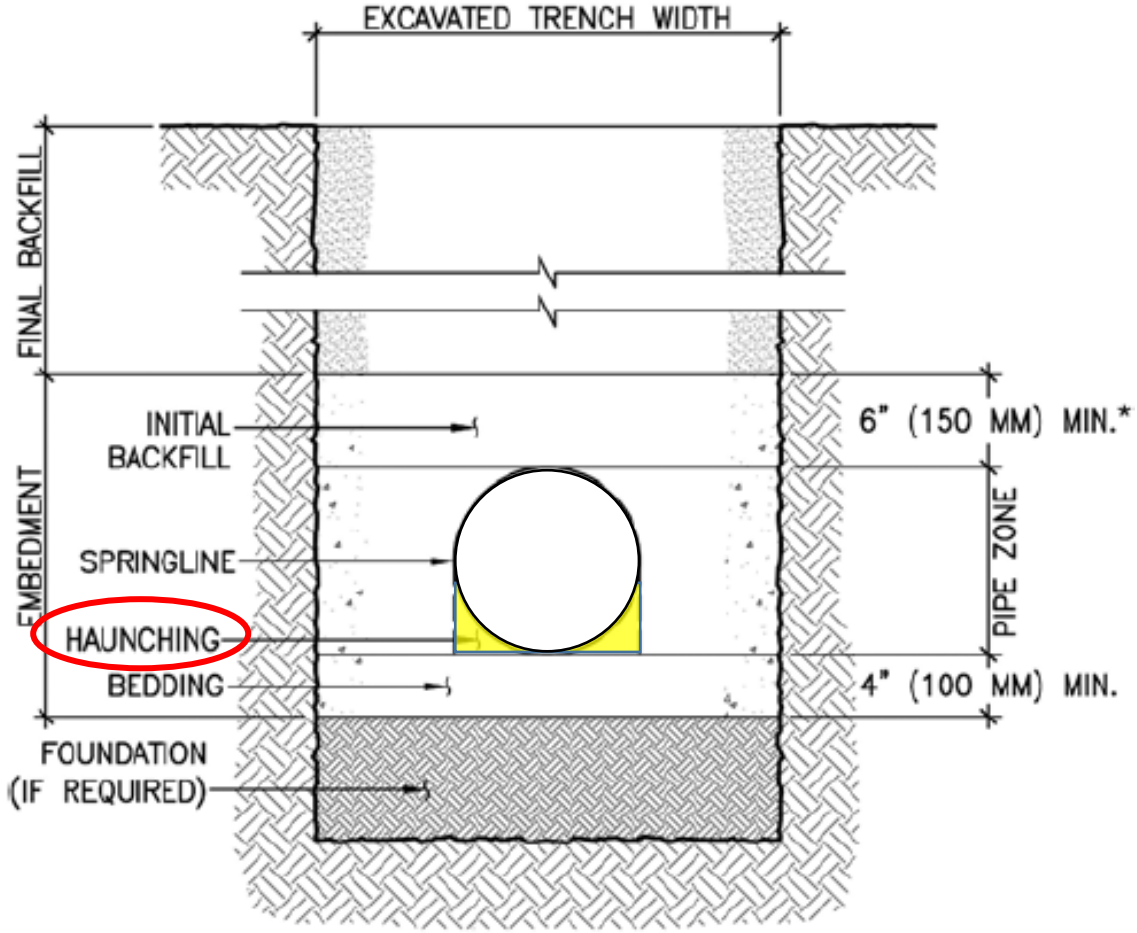


Structurally Complete!

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

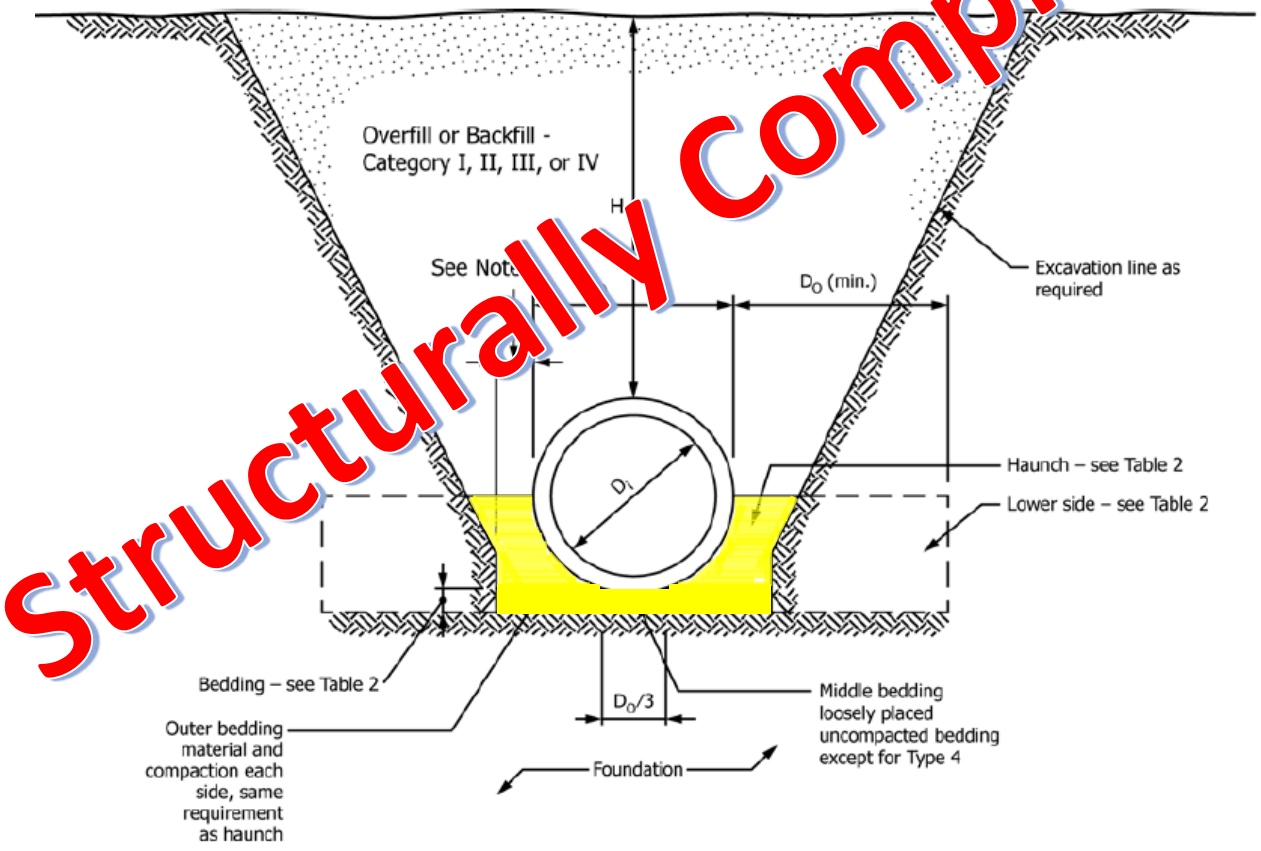


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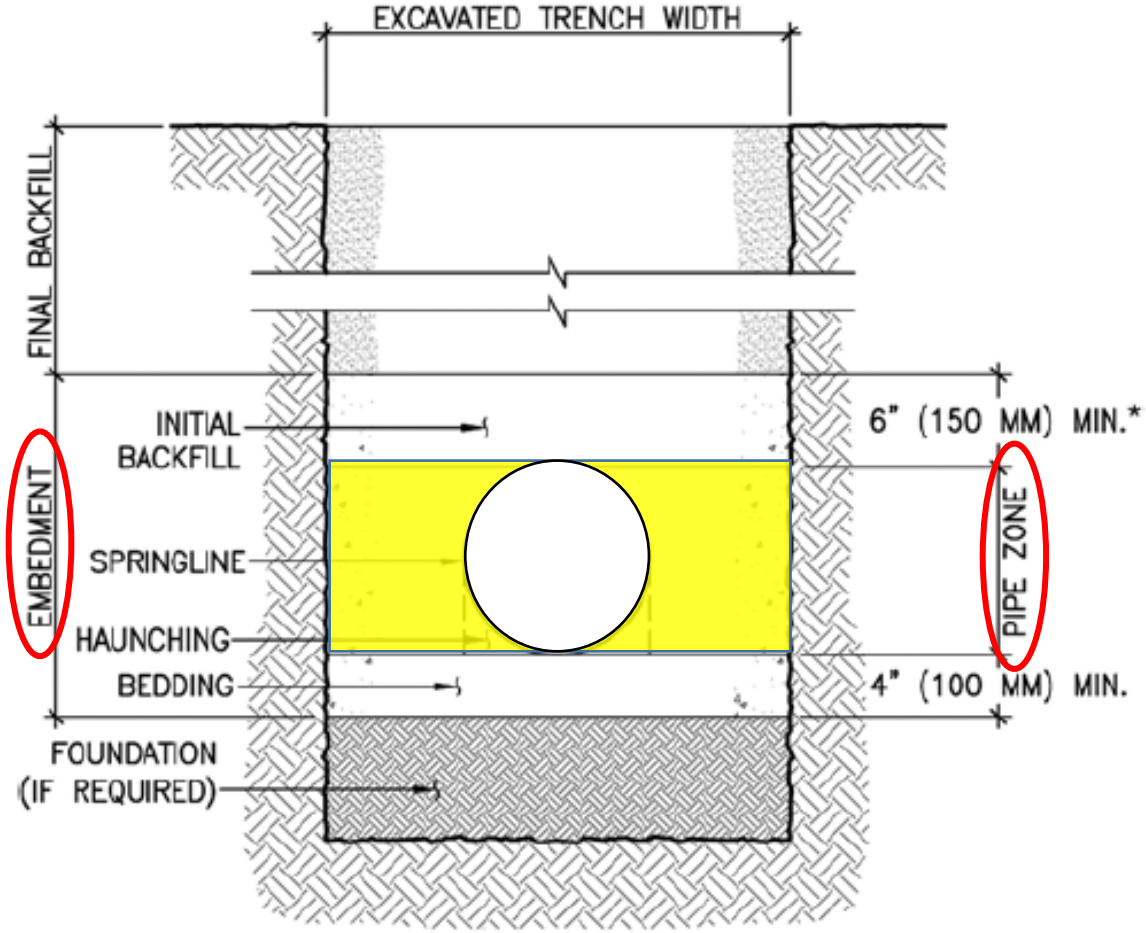
FIG. 3 Standard Trench Installations

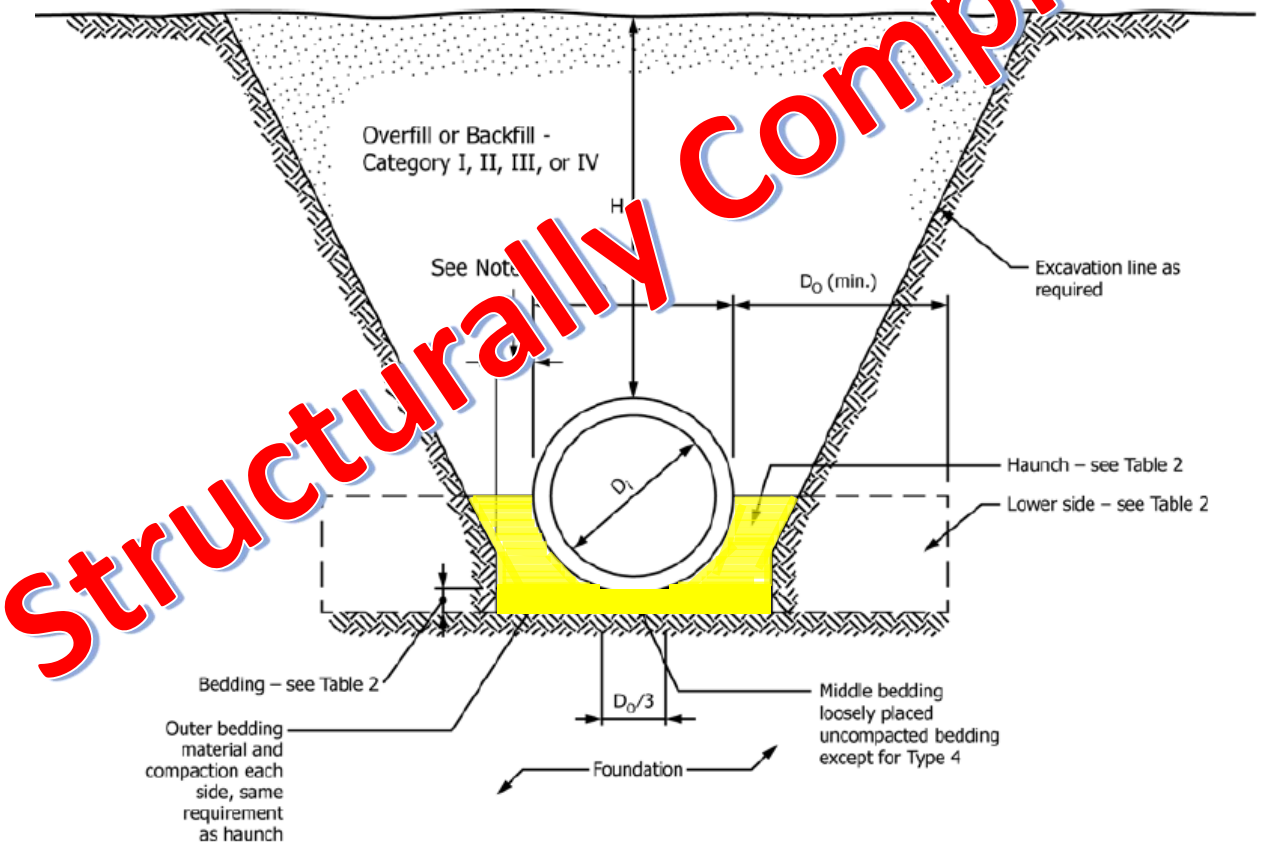
Flexible Pipe



* See 7.6 Minimum Cover

FIG. 1 Trench Cross Section

Concrete Pipe



Structurally Complete!

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FIG. 3 Standard Trench Installations

Flexible Pipe

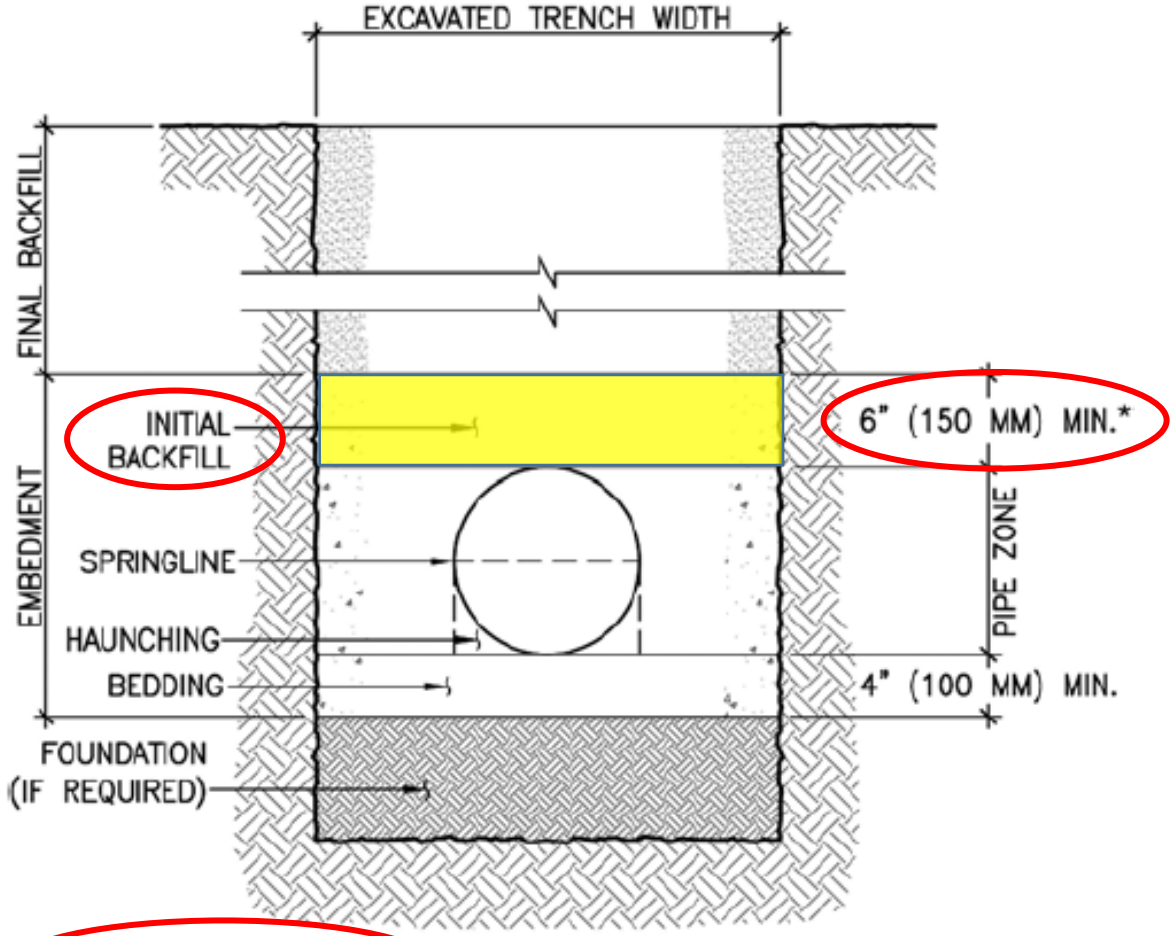


FIG. 1 Trench Cross Section

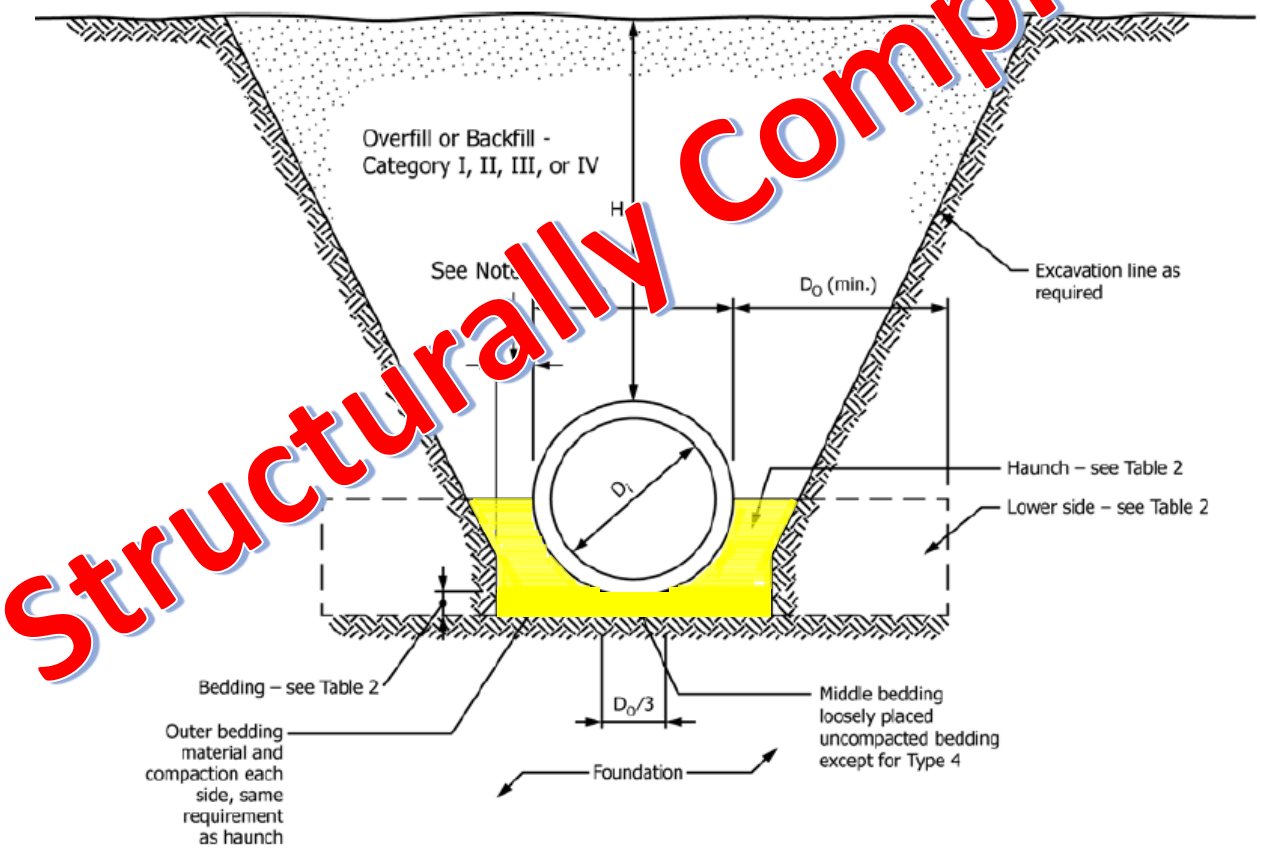
Designation: D2321 – 14ε1

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

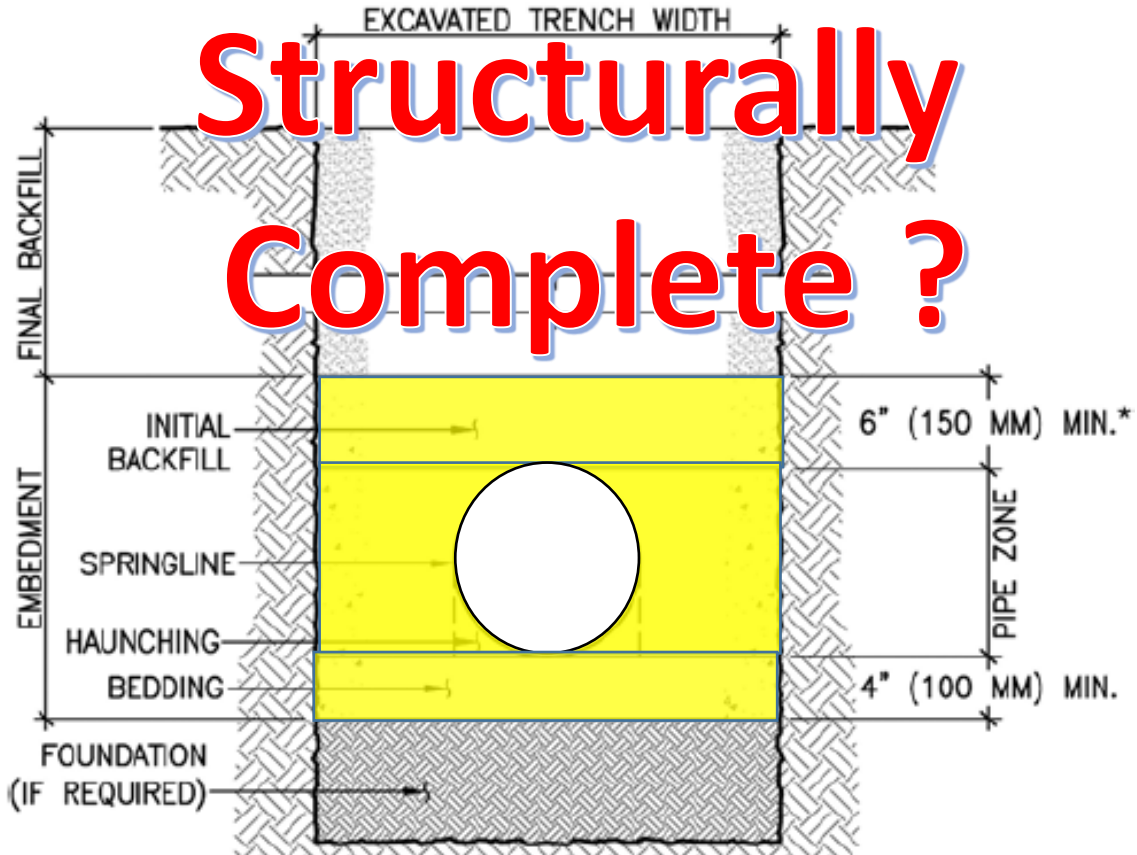


NOTE 1—Clearance between pipe and trench wall shall be adequate to enable specified compaction but not less than $D_o/6$.

FIG. 3 Standard Trench Installations

Structurally Complete!

Flexible Pipe



* See 7.6 Minimum Cover

FIG. 1 Trench Cross Section

Structurally Complete ?

How Would You Know?


BACK TO THE DIRT

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

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

5. Materials

5.1 *Classification* — Soil types used or encountered in burying pipes include those classified in Table 1 and natural, manufactured, and processed aggregates. The soil classifications are grouped into soil classifications in Table 2 based on the typical soil stiffness when compacted. Class I indicates a soil that generally provides the highest soil stiffness at any given percentage of maximum Proctor density, and provides a given soil stiffness with the least compactive effort….

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

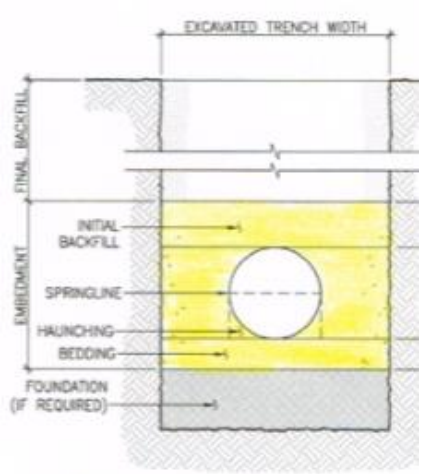
Designation: D2321 – 18

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
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

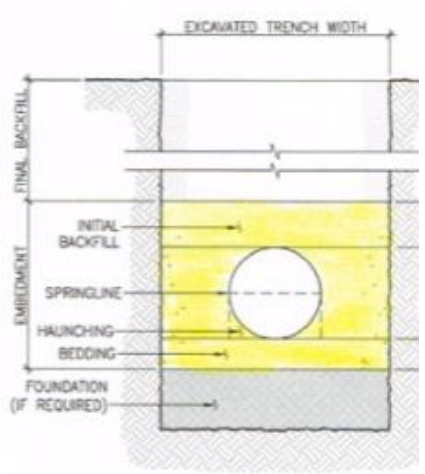


* See 7.6 Minimum Cover

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
General Recommendations and Restrictions	Acceptable and common where no migration is probable or when combined with a geotextile filter media.	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	Do not use where water conditions in trench prevent proper placement and compaction. Not recommended for use	Difficult to achieve high-soil stiffness. Do not use where water conditions in trench prevent proper placement
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



* See 7.6 Minimum Cover

FIG. 1 Trench Cross Section

How well does this play out in the field?

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

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)

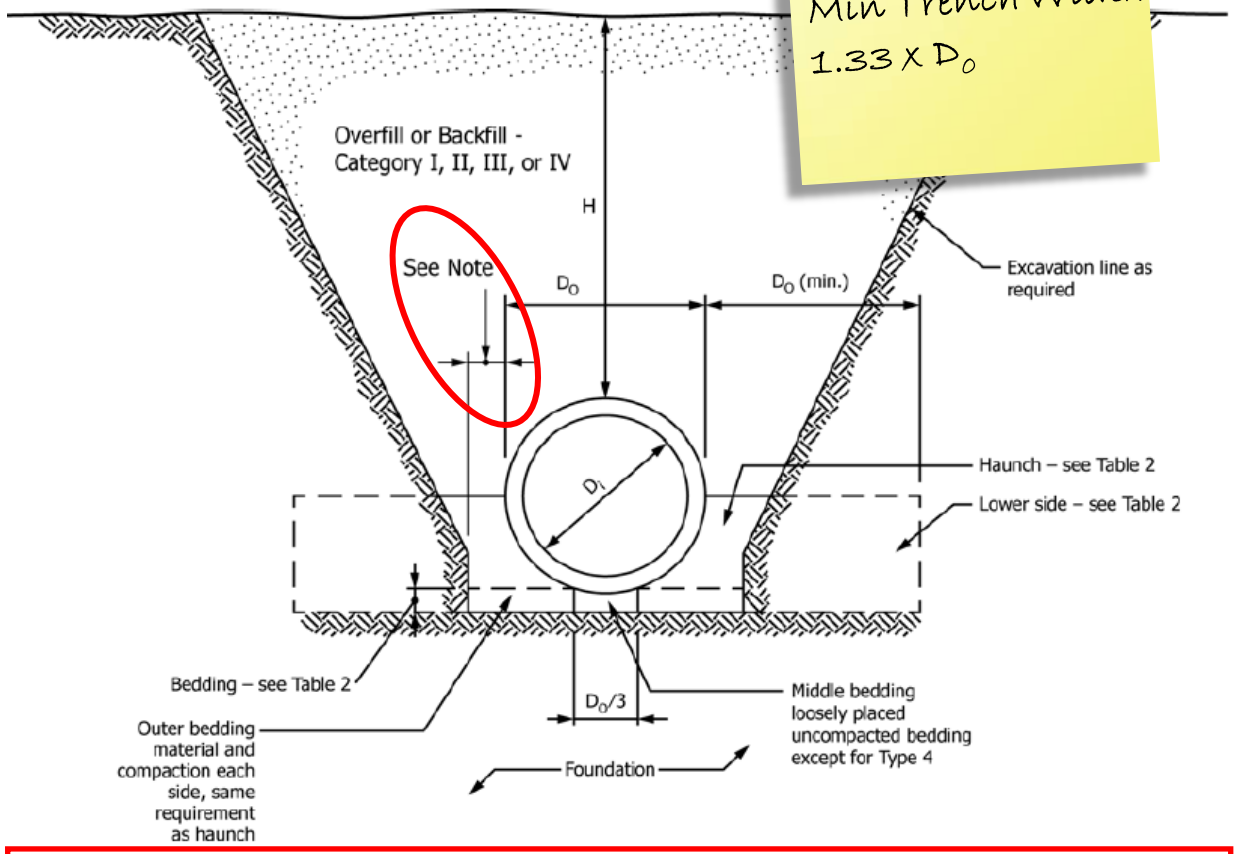
Notes:

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.*

Concrete Pipe

Designation: C1479 – 16

Fig. 3
Min Trench Width
1.33 x D_o

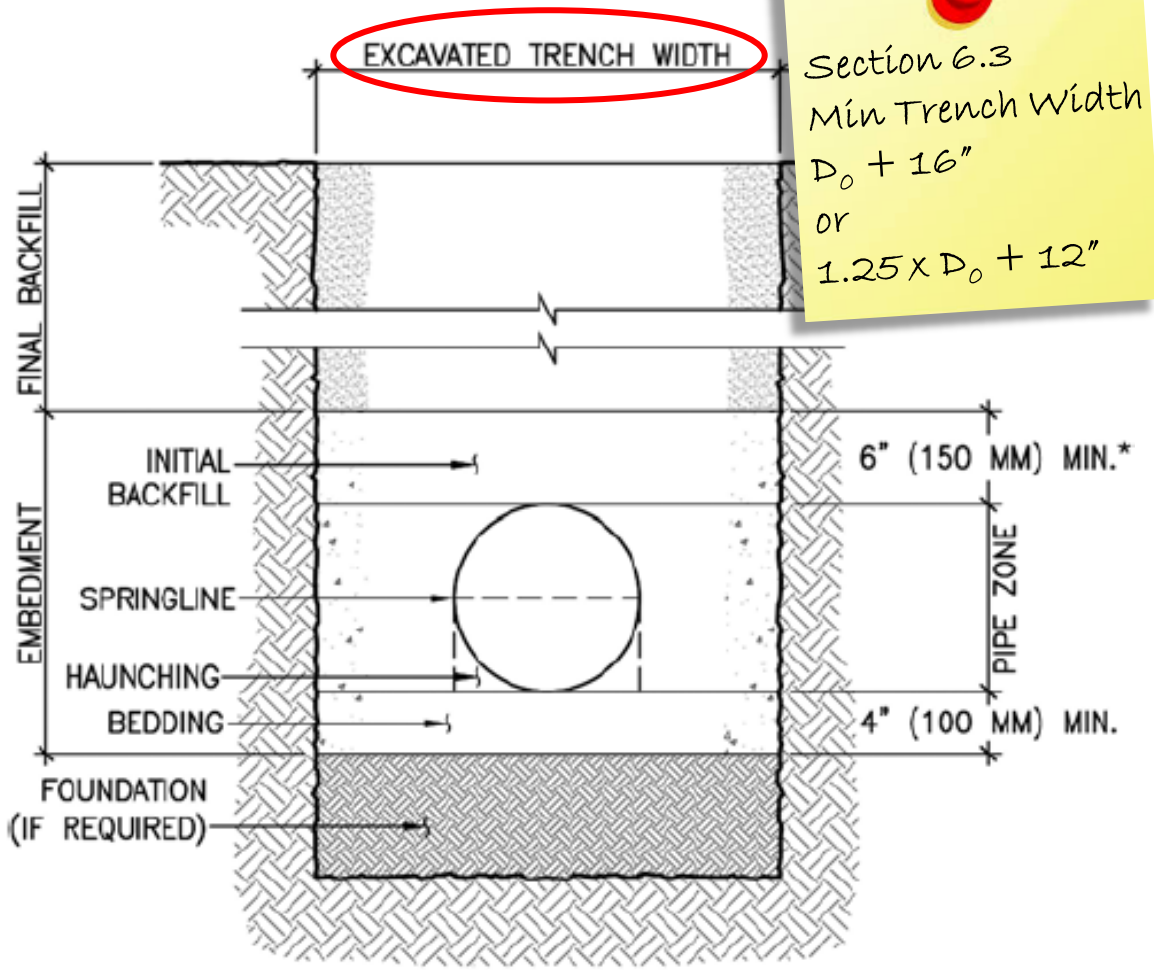


NOTE 1—Clearance between pipe and trench wall shall be adequate to enable specified compaction but not less than $D_o/6$

FIG. 3 Standard Trench Installations

Flexible Pipe

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



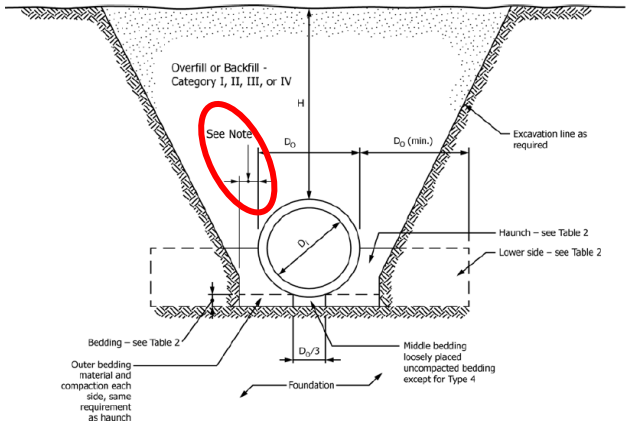
* See 7.6 Minimum Cover

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.*	O.D + O.D./3	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”

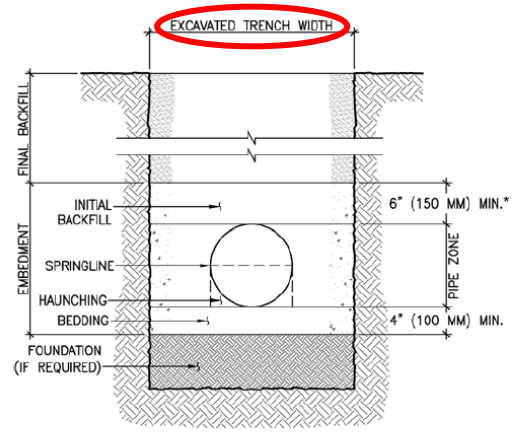
* B-Wall

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

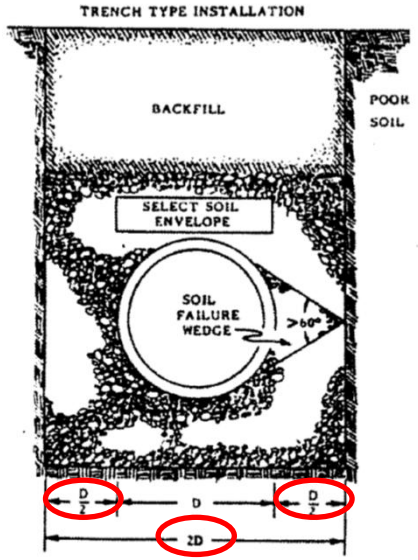
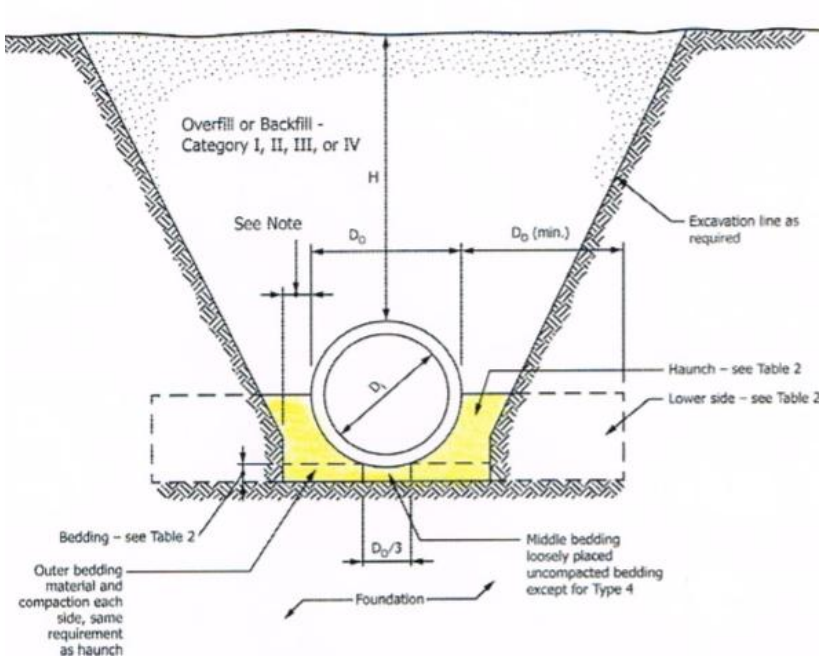


FIG. X1.1 Minimum Embedment Width When Trench and Native Soil Can Sustain a Vertical Cut

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

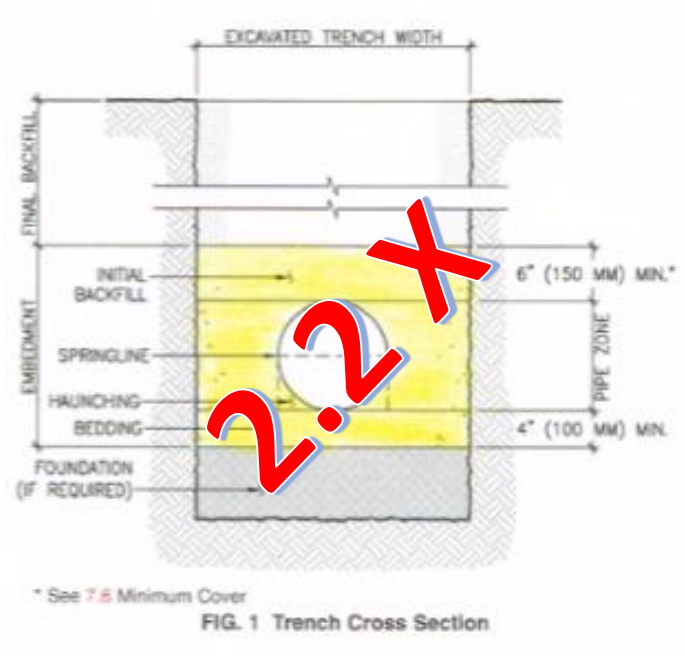


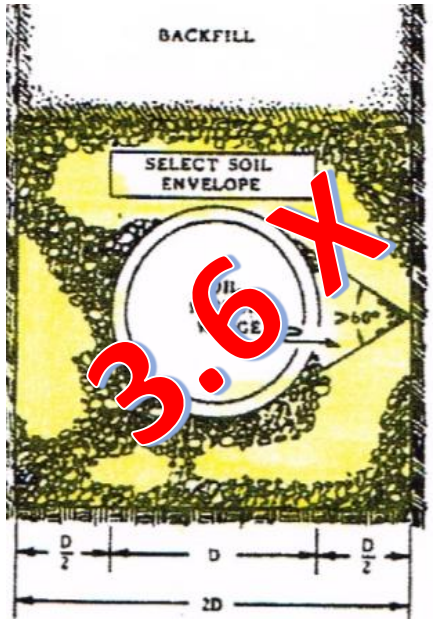
9.0 ft^3/ft Soil

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

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

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.
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Flexible Pipe

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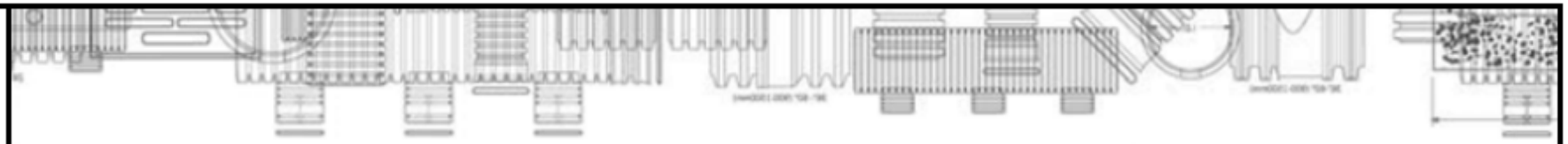
Designation: D2321 – 18

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).

How do we know?

Was Floatation considered?



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.

Table 2
Minimum Recommended Cover to Prevent Flotation of ADS Thermoplastic Pipe

Nominal Diameter in. (mm)	Minimum Cover in. (mm)
4 (100)	3 (77)
6 (150)	4 (102)
8 (200)	5 (127)
10 (250)	7 (178)
12 (300)	9 (228)
15 (375)	11 (280)
18 (450)	13 (330)
24 (600)	17 (432)
30 (750)	22 (559)
36 (900)	25 (635)
42 (1050)	29 (737)
48 (1200)	33 (838)
60 (1500)	40 (1016)

Calculation Notes:

1. The pipe is assumed to be empty. This not only simplifies the calculations but creates a condition that would encourage flotation. Unless the system is constructed to be watertight, this condition would not likely be found in an actual installation.
2. The outside diameter of the corrugated pipe was used to determine soil and water displacement.
3. Saturated soil density used was 130 pcf which is typical for many saturated soil mixtures. Soils of greater densities will reduce the chance of flotation.
4. The water table was assumed to be at the ground surface, as illustrated in Figure 1(c), simulating a fully saturated soil. This assumption creates a "worst case" condition to yield more conservative results.
5. The soil load prism shown in Figure 2(a) was used to determine soil weight.
6. For structural purposes, a minimum cover of 12" (0.3m) shall apply for 4"-48" (100-1200mm) pipe, and 24" (0.6m) for 60" (1500mm) pipe.

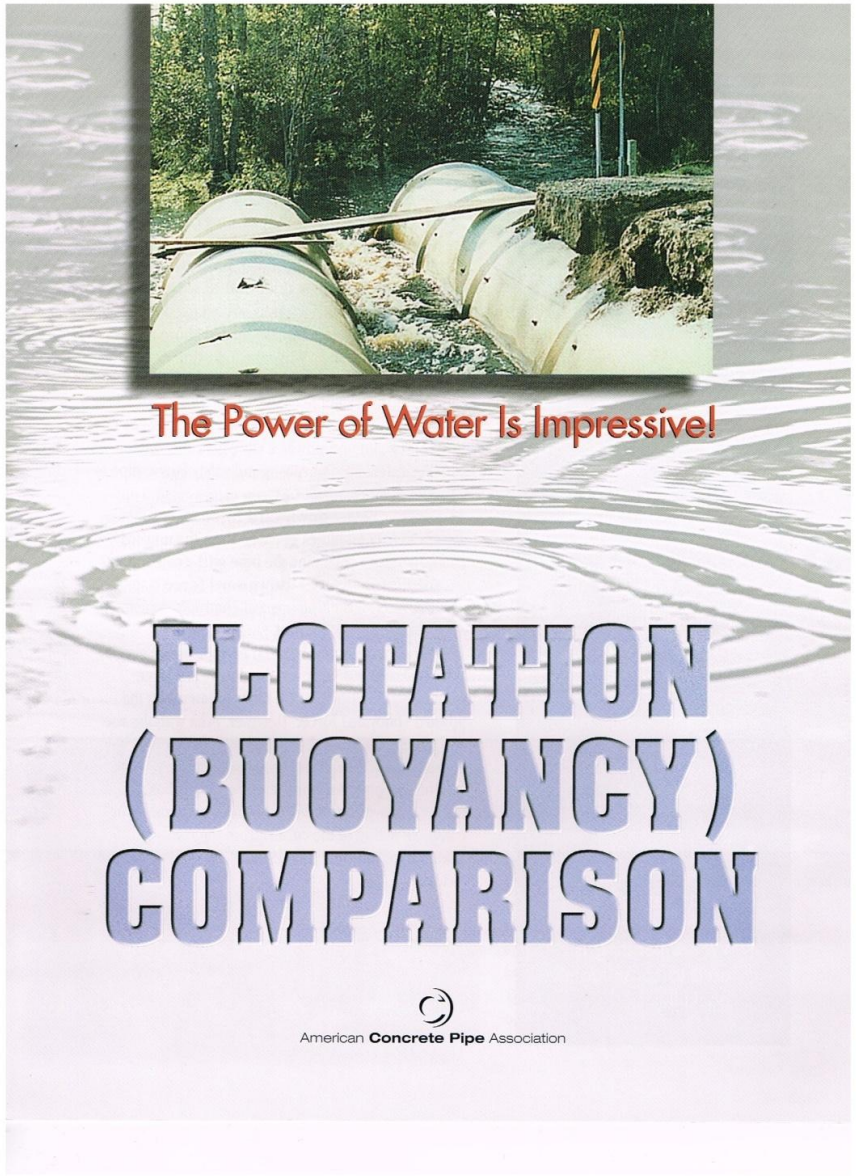
7.6 *Minimum Cover* — ...The minimum depth of cover should be established by the engineer based on evaluation of specific project conditions. In the absence of an engineering evaluation, the following minimum cover requirements should be used...

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”


Soooo…
Were calculations performed?
CAUTION

Concrete Pipe

Floating RCP caused by Earthquake in CA



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.

Flexible Pipe

Designation: D2321 – 18

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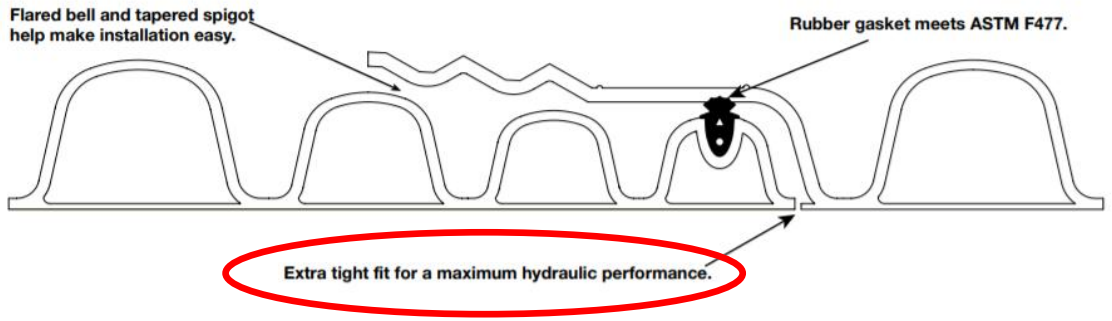
Flexible Pipe

N-12 ST IB SOIL-TIGHT JOINT



ASTM INTERNATIONAL

Designation: D2321 – 18

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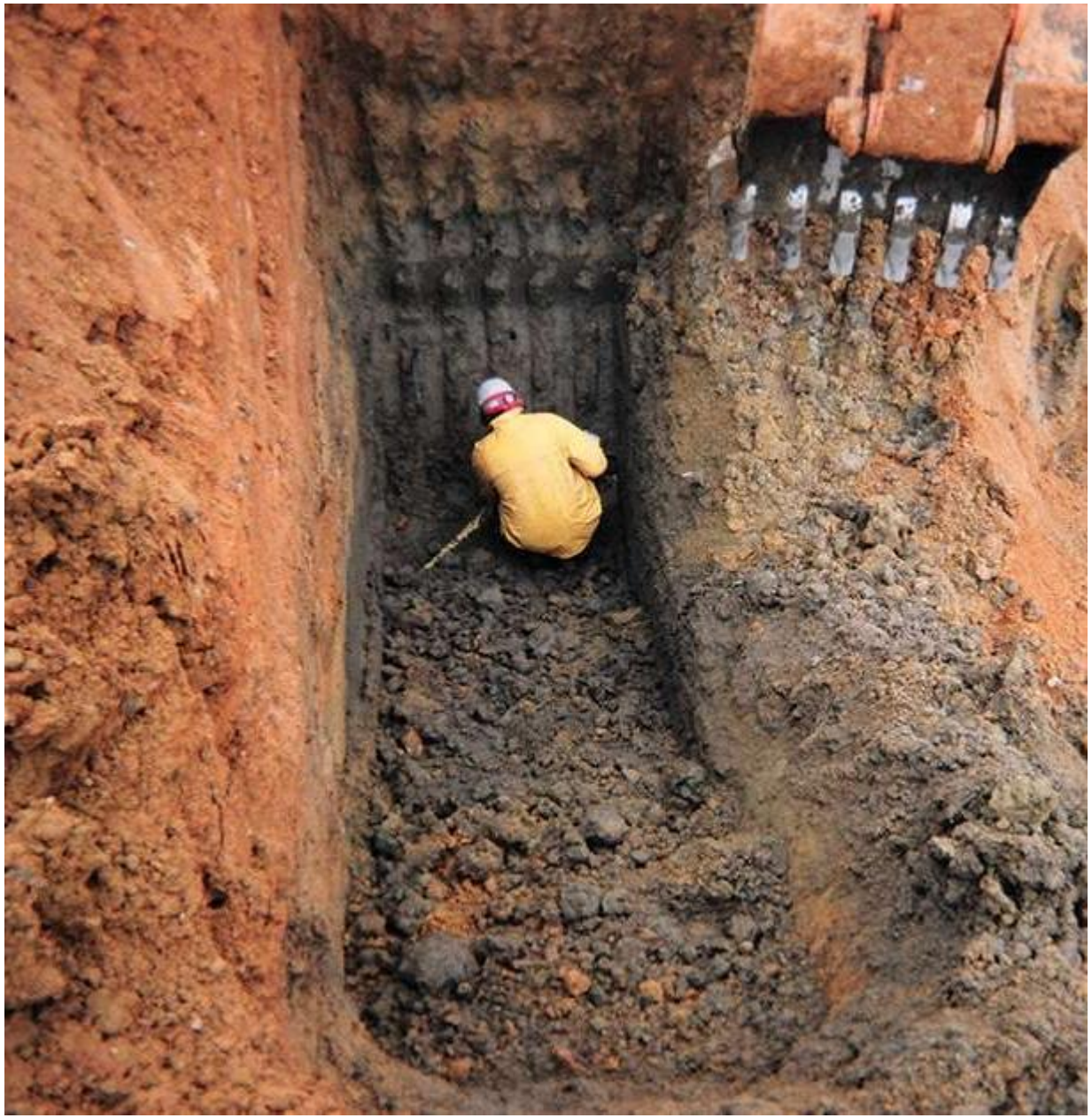

Flexible Pipe

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Concrete Pipe

Designation: C1479 – 16

Flexible Pipe

Designation: D2321 – 18

Concrete Pipe

Flexible Pipe

Designation: C14

Successful install?

- **Y/N?**

When Field Inspection of Pipes happens too late!

Concrete Pipe

Designation: C1479 – 16

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.

Flexible Pipe

Designation: D2321 – 18

Concrete Pipe

Designation: C1479 – 16

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

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.

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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

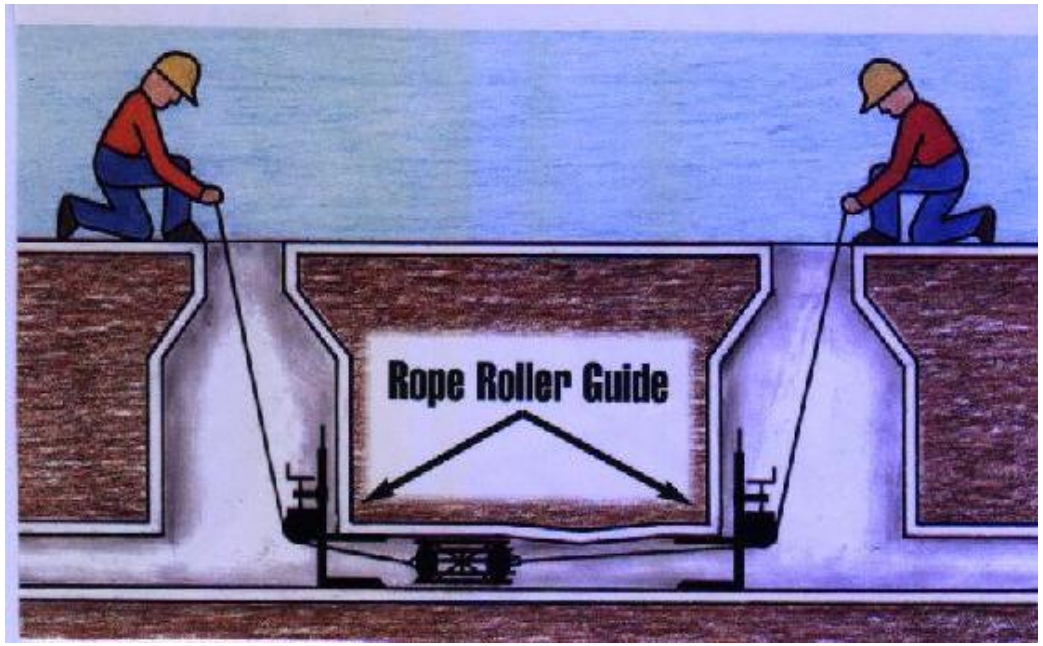
Designation: C1479 – 16

Strength Verified Before Shipment
Deflection Testing – Not Relevant

Flexible Pipe

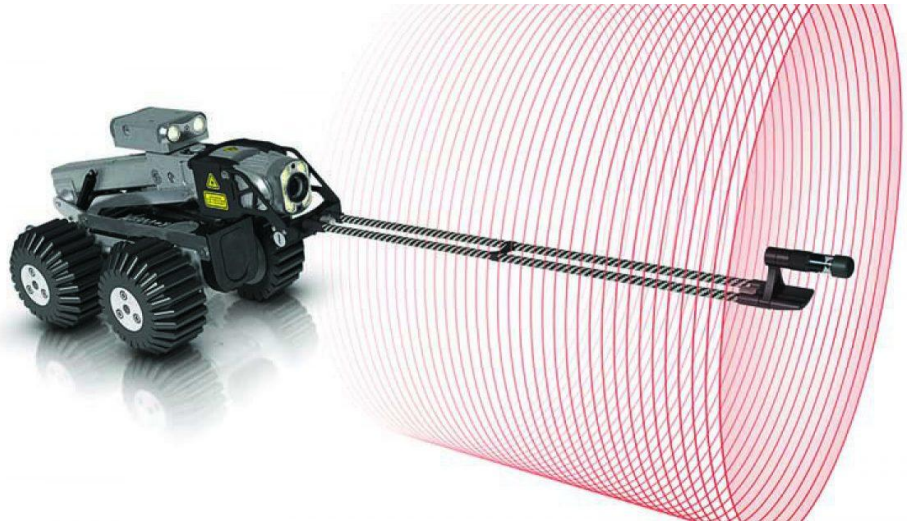
Designation: D2321 – 18

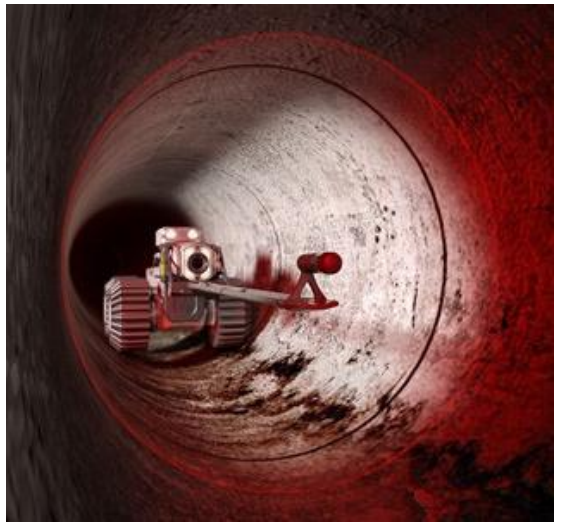
- **Go-No-Go device**
- **5% Deflection**
- **Stuck if deflection exceeded**

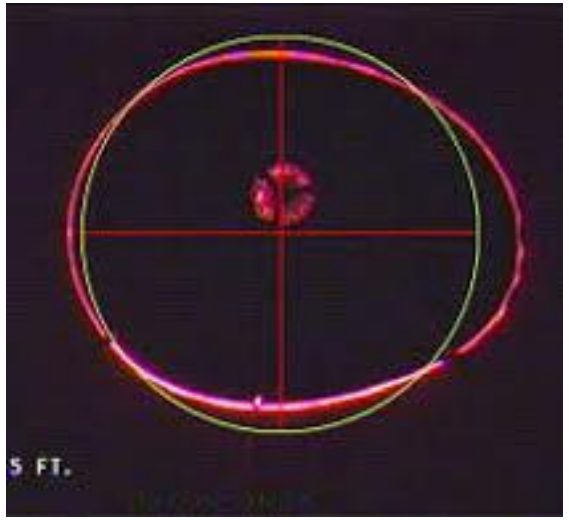


Concrete Pipe

Flexible Pipe







Concrete Pipe

AASHTO Section 27

Concrete Pipe Crack Limits Limits

27.6.4 – Longitudinal Cracks

Cracks </= 0.01” – Minor and only require a note

Cracks > 0.01” shall be measured and evaluated by the contractor for the engineer to review and approve.

Cracks > 0.01” and determined detrimental shall be sealed by a method approved by the engineer.

Cracks > 0.1” and determined by the engineer to be beyond satisfactory structural repair shall be remediated or replaced.

Flexible Pipe

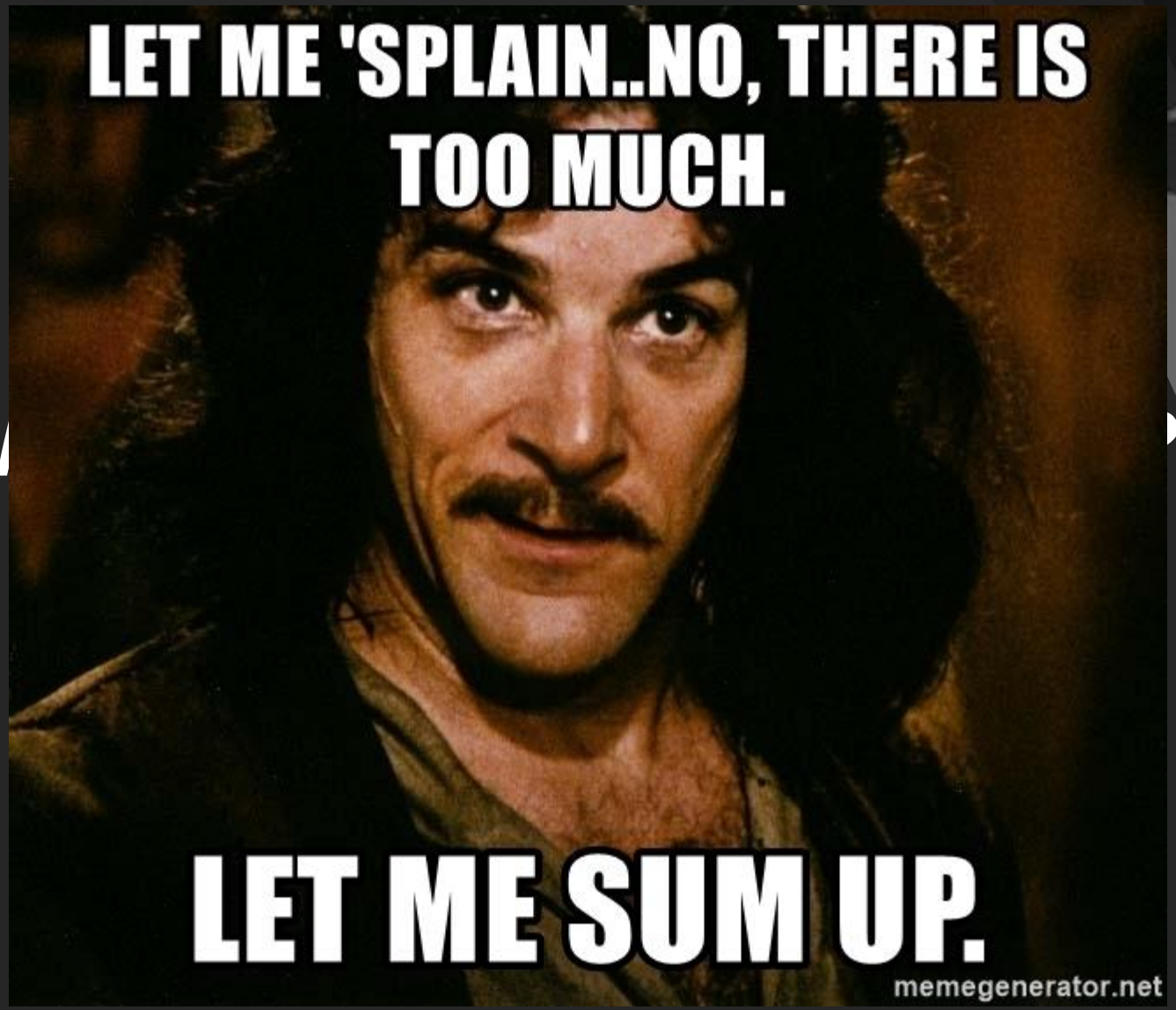
AASHTO Section 30

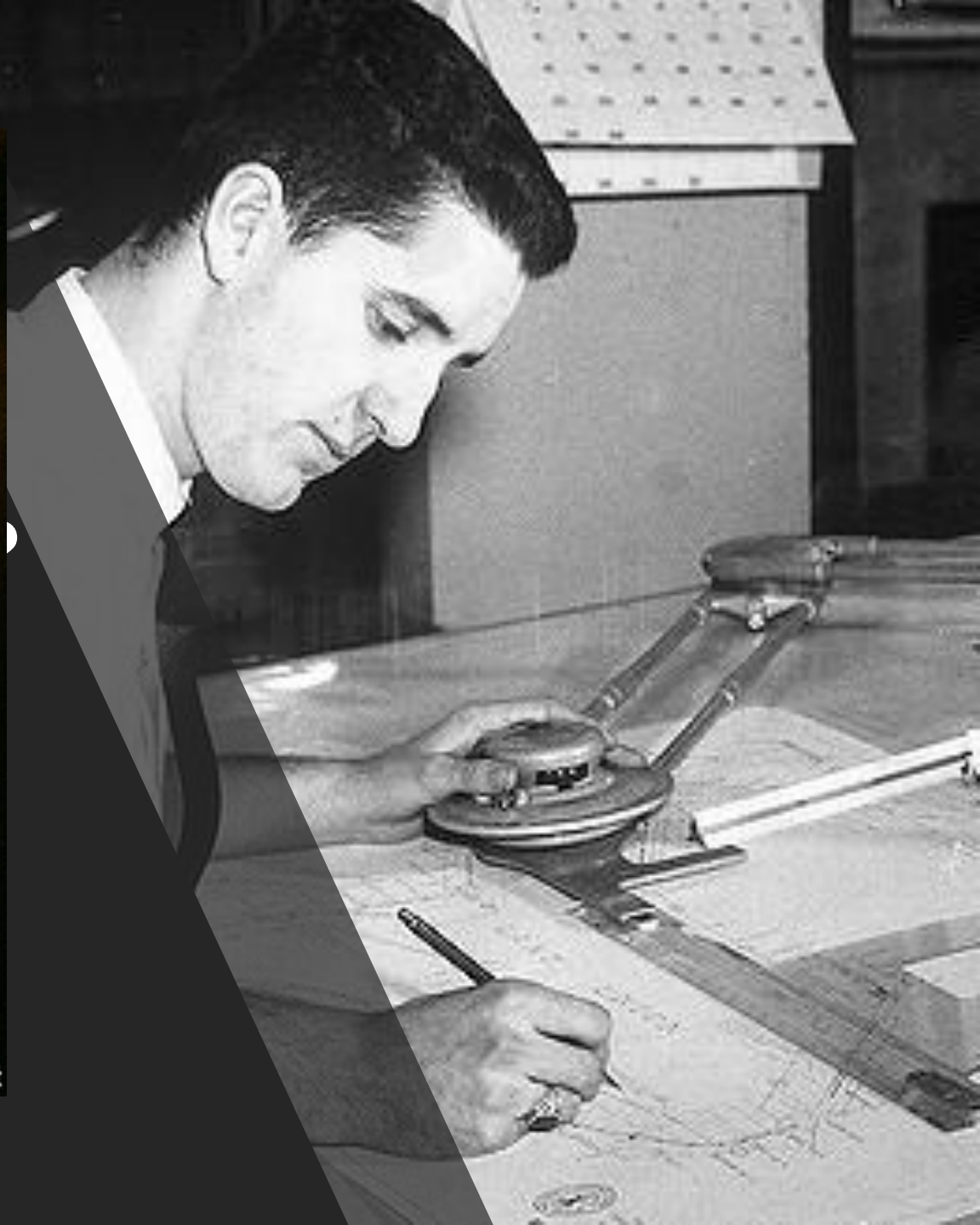
Thermoplastic Deflection Limits

30.7.2 – Installation Deflection

5% Installed Deflection Exceeded – may indicate that the installation was substandard. Appropriate remediation, if any, will depend on the severity of the deflection, the condition of the pipe, and evaluation of the factor of safety using Section 12 “Buried Structures and Tunnel Liners” of the *AASHTO LRFD Bridge Design Specifications*.

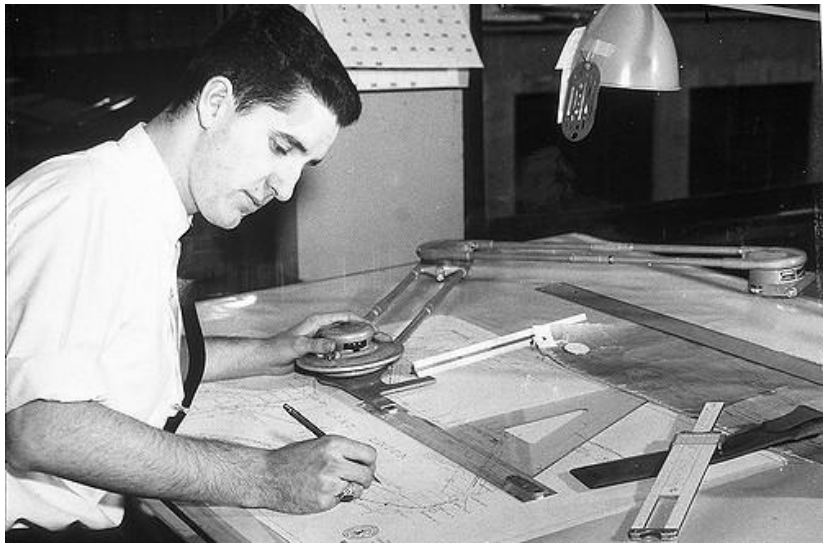
7.5% Installed Deflection Exceeded – will require remediation or replacement of the pipe.


LET ME 'SPLAIN..NO, THERE IS TOO MUCH.
LET ME SUM UP.
memegenerator.net



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 Requirements

Concrete Pipe

An Engineered Product

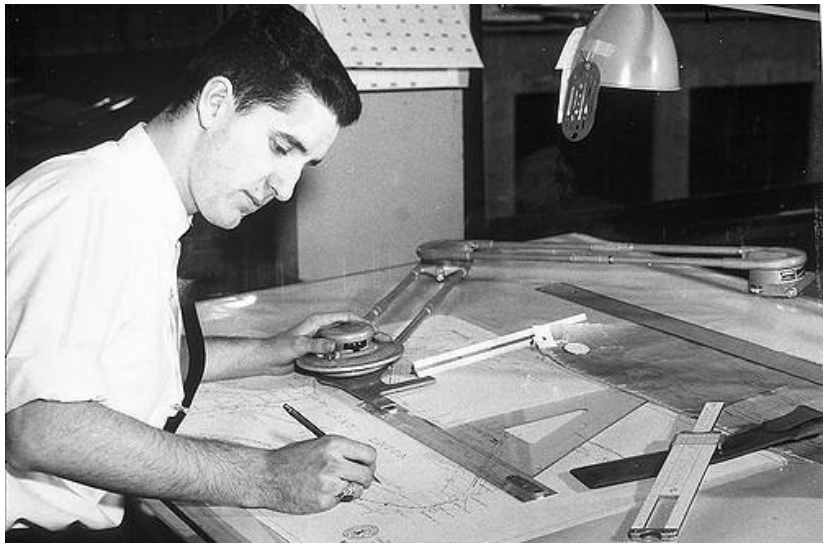
Determine In-Situ Soils

Select Installation Type

Determine Strength Class Req'd

Specify Pipe Class & Installation Type

Specify Post Installation Requirements



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

APPLY

- Consider Risks associated with installing Pipe incorrectly (roadway settlement, poor pipe performance, reduced service life)
- Identify Ways to mitigate these Risks for Flexible Pipe and Rigid Pipe

Thank You!

ALEC PARLIAMENT, P.E.
aparliament@foleyproducts.com
205.440.5775