



CONCRETE PIPE 101

www.concrete-pipe.org

June 2007

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Agenda

- **Terminology**
- **Manufacturing Methods**
- **ASTM Specifications**
- **Pipe Joints**
- **Pipe Testing**
- **Fittings**
- **Manholes**
- **Sizing**
- **Flotation**

Manufacturing Methods



- **Wet Cast**
- **Dry Cast**

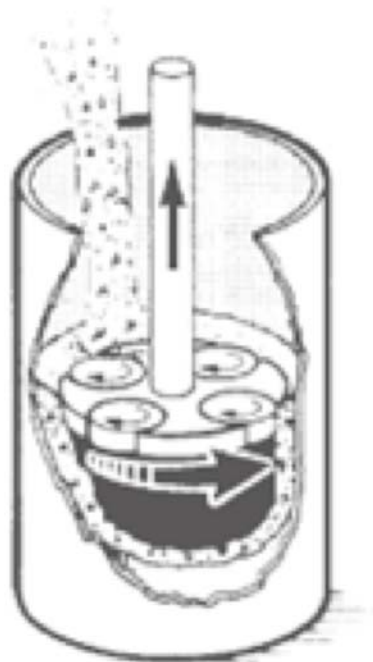


Manufacturing Methods

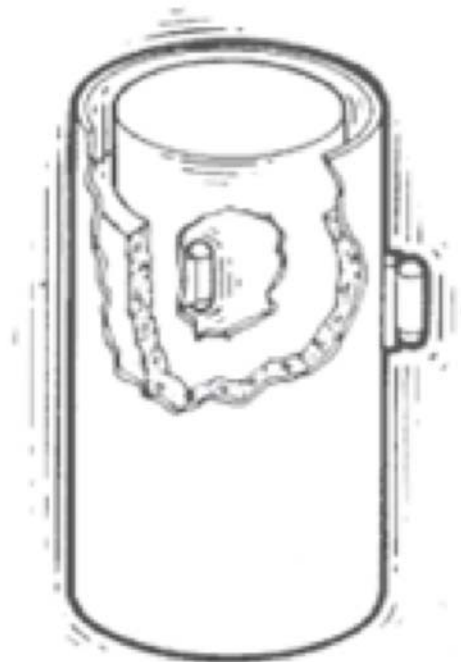


- **Wet Cast-** Uses a concrete mix that is wet relative to the mixes used in other processes. Usually contains a slump less than 4 inches and used for production of large diameter pipe.
- **Dry Cast-** Uses a concrete mix with zero slump. The method has several variations but all use low frequency-high amplitude vibration to distribute and densely compact dry mix in the form.

Two Methods of Dry Cast Manufacturing



Packerhead



Dry Cast

- **Internal Hydraulic**
- **External Pneumatic Electric Hydraulic**

Dry Cast 84"x 16'



Dry Cast Box Culvert



3 Types of ASTM Standards



- **Manufacturing**
- **Testing**
- **Installation**

Manufacturing Specifications



- **C-14 – Non-reinforced Concrete Pipe**
- **C-76 – Reinforced Concrete Pipe**
- **C-361 – Low Pressure RCP**
- **C-443 – Rubber Gasket Joints for RCP**
- **C-478 – Manholes**
- **C-506 – Arch RCP**
- **C-507 – Elliptical RCP**
- **C-1433 – Precast Box Culverts**
Replaced C-789 & C-850

Pipe Design Considers Installation



Note from ASTM C76: This specification is a manufacturing and purchase specification only, and does not include requirements for bedding, backfill, or the relationship between field load condition and the strength classification of pipe. However, experience has shown that the **successful performance** of this product depends upon the proper selection of the class of pipe, type of bedding and backfill, and care that installation conforms to the construction specifications. The owner of the reinforced concrete pipe specified herein is cautioned that he must correlate the field requirements with the class of pipe specified and provide inspection at the construction site.

Test Specifications



- **C-497 – Test Methods for RCP & MH**
 - **3 Edge Bearing**
 - **Core & Cylinder Strength**
 - **Hydrostatic Test**
- **C-924 – Low Pressure Air Testing, up to 24"**
- **C-969 – Infiltration/Exfiltration Test of Installed Concrete Pipe**
- **C-1214 – Vacuum Testing of Installed Pipe**
- **C-1244 – Vacuum Testing of Installed MH**

Installation Specifications



- **C-1479 – Installation of RCP Using Standard Installations**
 - **Companion Design Spec w/ ASCE 15**
- **Section 27 of AASHTO LRFD Bridge Construction Specifications**



Joins

The links that make the system whole

Additional Info in the Concrete Design Manual - [click here](#)

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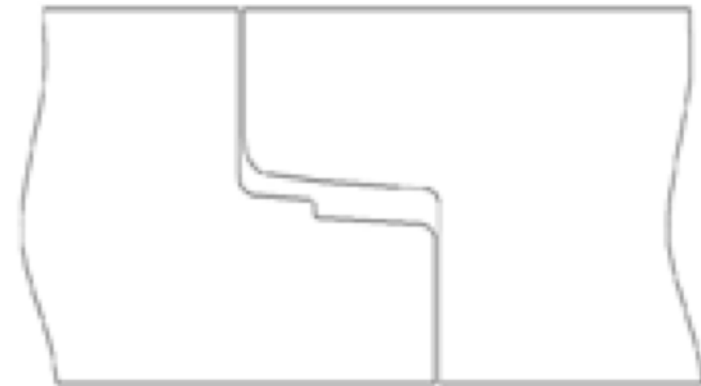
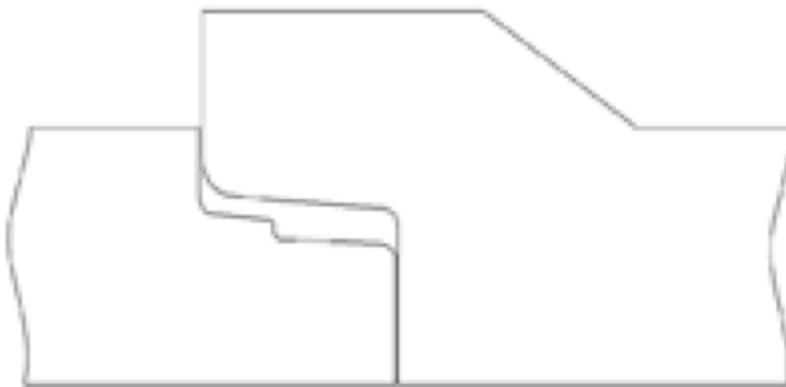
Bell & Spigot or Tongue & Groove

What's the Deal?

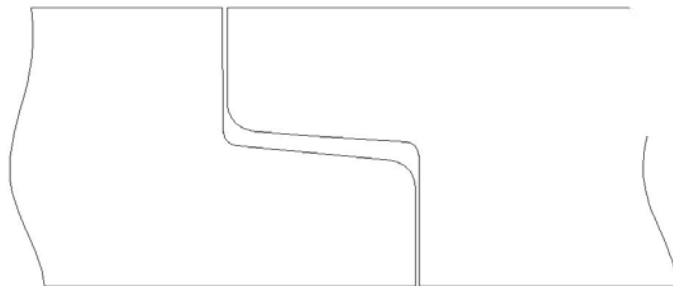
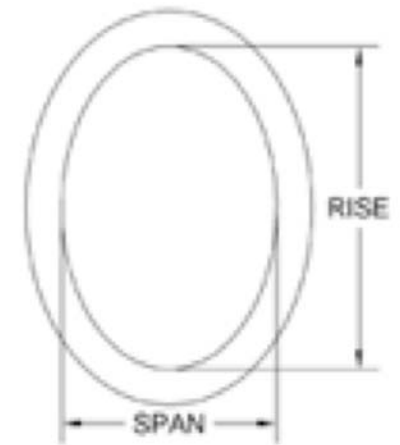
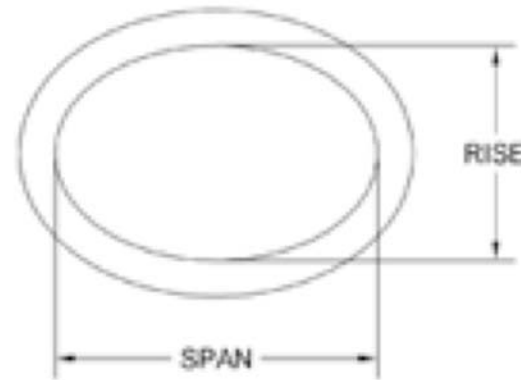
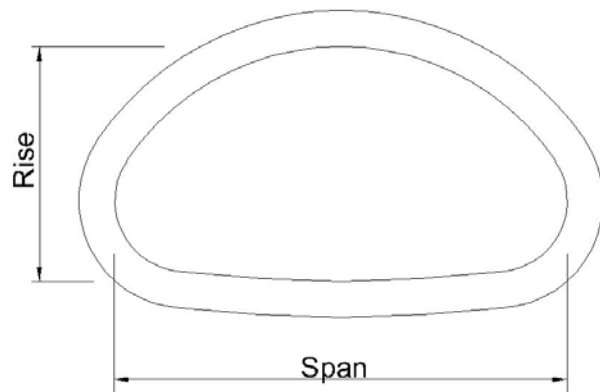


Female end of pipe (bell, groove) – portion of the end of the pipe, regardless of shape, which overlaps a portion of the end of the adjoining pipe

Male end of pipe (spigot, tongue) - portion of the end of the pipe, regardless of shape, which is overlapped by portion of the end of the adjoining pipe



Arch & Elliptical Shapes



Define the Service Requirements



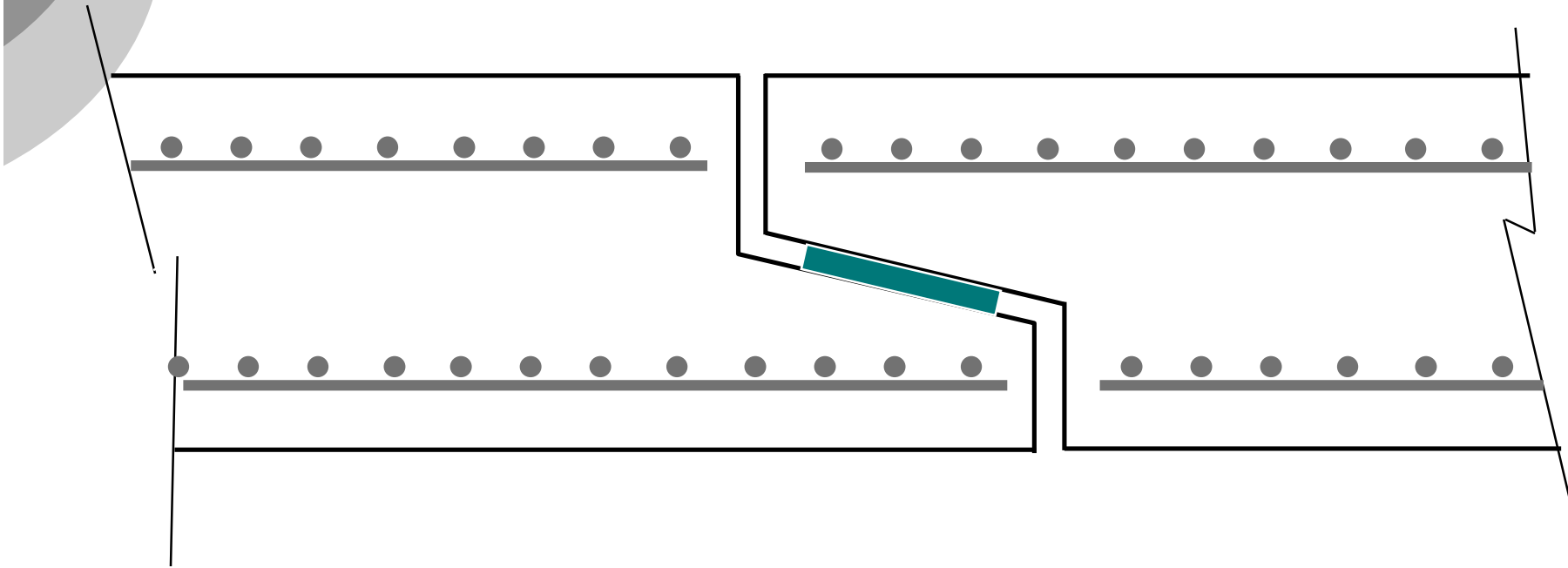
- **Soil Tight**
- **Silt Tight**
- **Watertight gravity**
- **Watertight pressure**

Soil Tight/ Silt Tight



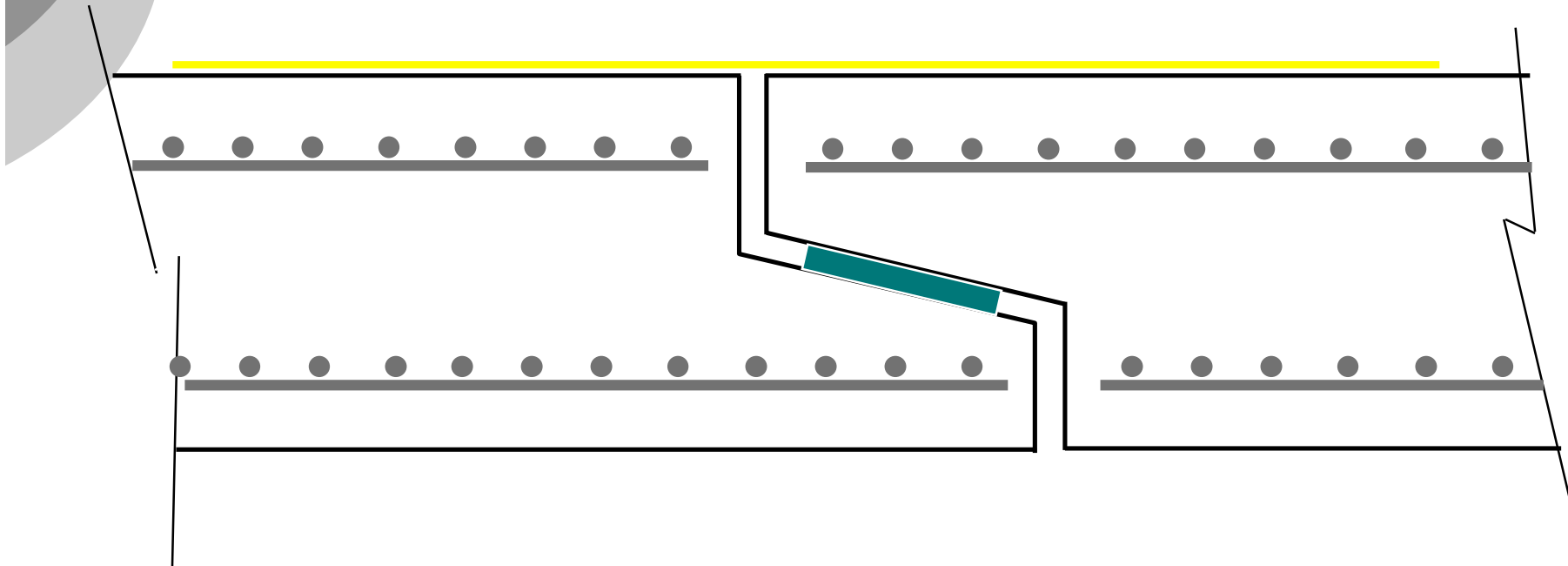
- **Storm drains and culverts only!**
- **Intended to preclude soil / silt transfer through joint**
- **Non-precision joint**
 - **Mastic sealant**
 - **Preformed butyl sealant**
 - **Mortar Joint**
 - **Fabric**
 - **External Wrap**
- **ASTM C990**

Soil Tight Joint





Soil Tight Joint with Fabric



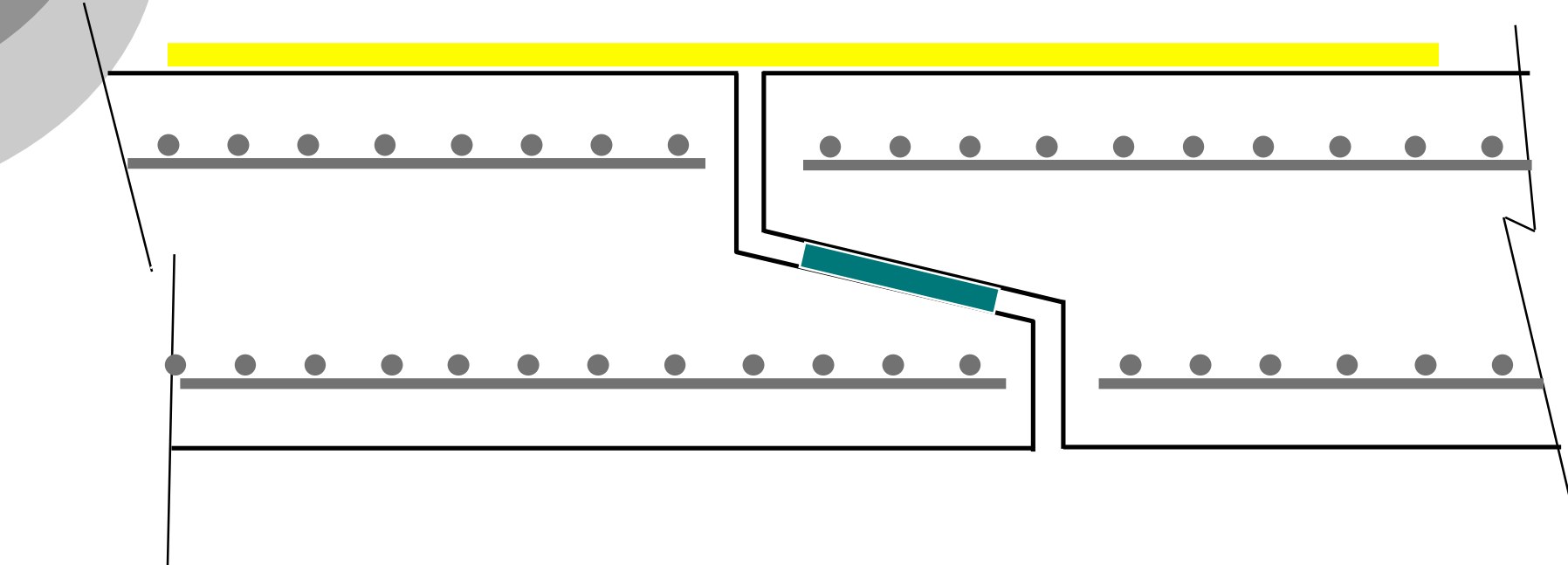
Pushing Box Joint Home



Soil Tight/Silt Tight Joint with External Wrap



ASTM C877



Soil/ Silt Tight Joint



Soil Tight Joint





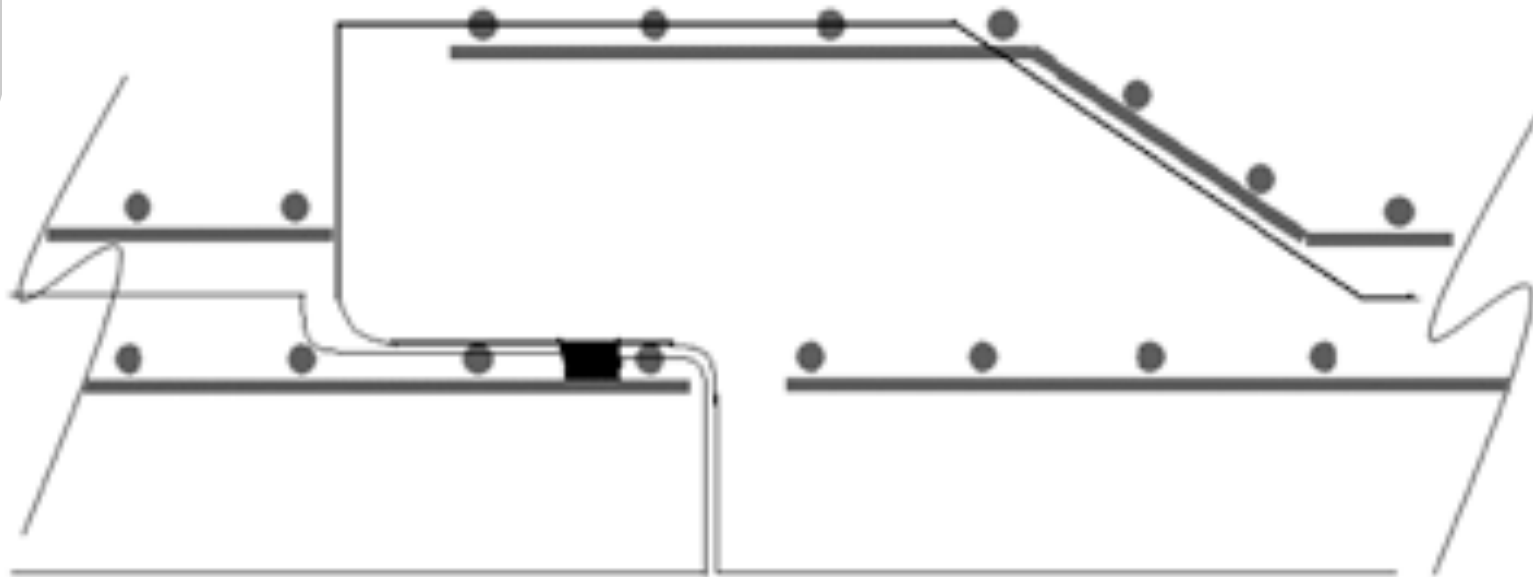
Watertight – Gravity*

- **Precision Joint**
 - **O-Ring gasket**
 - **Profile gasket**
- **ASTM C443**
- **ASTM C1628**

* Tested to zero leakage in the manufacturing plant



Watertight - Gravity Joint

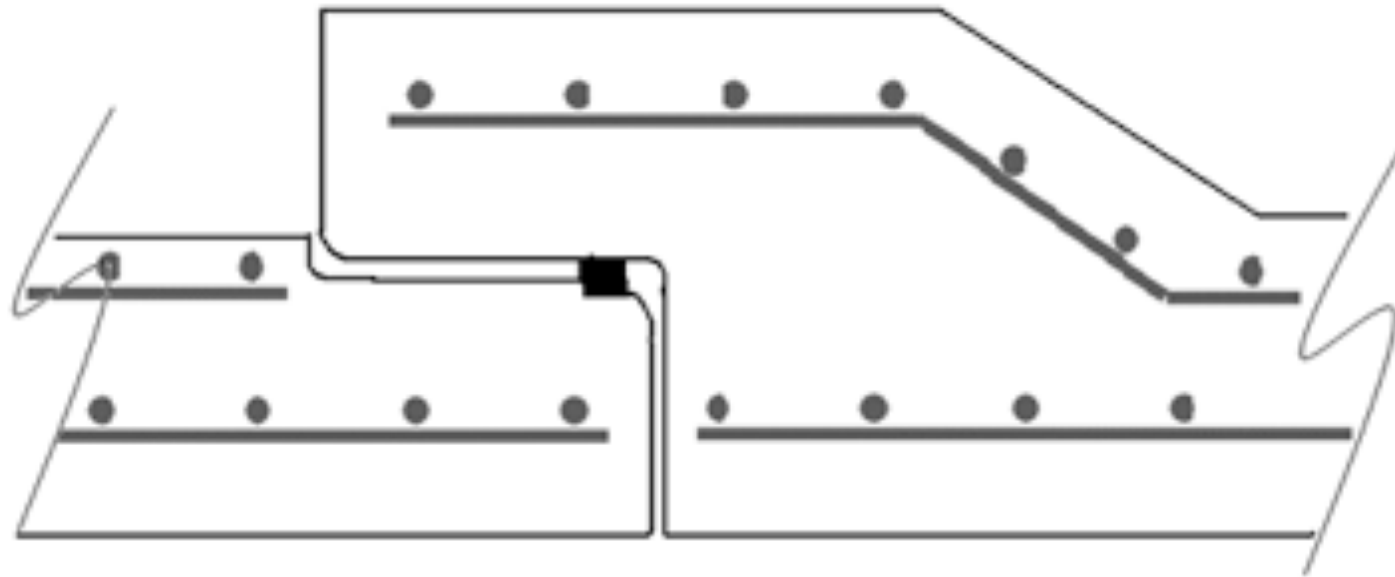


Confined Gasket - O-Ring or Profile

Watertight - Gravity Joint



Watertight - Gravity Joint



Offset Spigot - Profile Gasket

Watertight - Gravity Joint

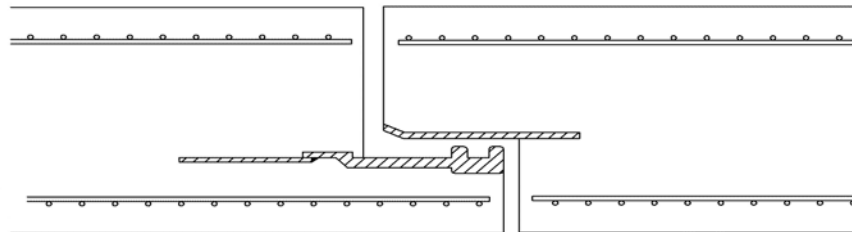




Watertight - Pressure

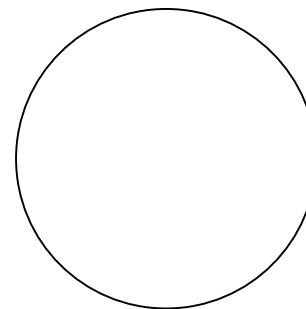
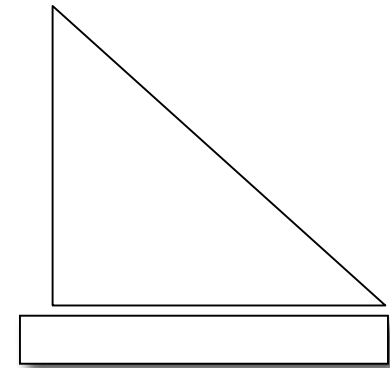
- **Precision Joint**
 - **O-Ring gasket**
- **ASTM C361**

Steel Joint Ring Pipe

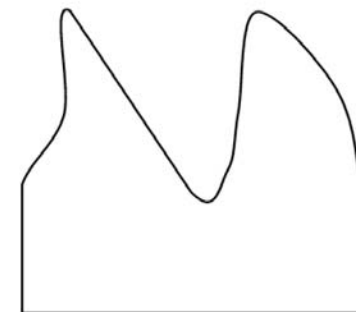


Gasket materials

- **Polyisoprene - standard use**
- **Chloroprene - moderate hydrocarbon resistance**
- **Nitrile / Viton - high hydrocarbon resistance**



o-ring gasket



profile gasket

Joint Testing



Ensures joint integrity after installation

ASTM C497



- **Bevels / Radius, not always available**
- **Bends**
- **Tees**

NOTE: Check supplier for availability

Additional Info in the Concrete Design Manual - [click here](#)

Bevels / Radius Pipe or Boxes



Design Data 21



Curved Alignment

Additional Info. – [Click Here](#)

Figure 3 Radius Pipe

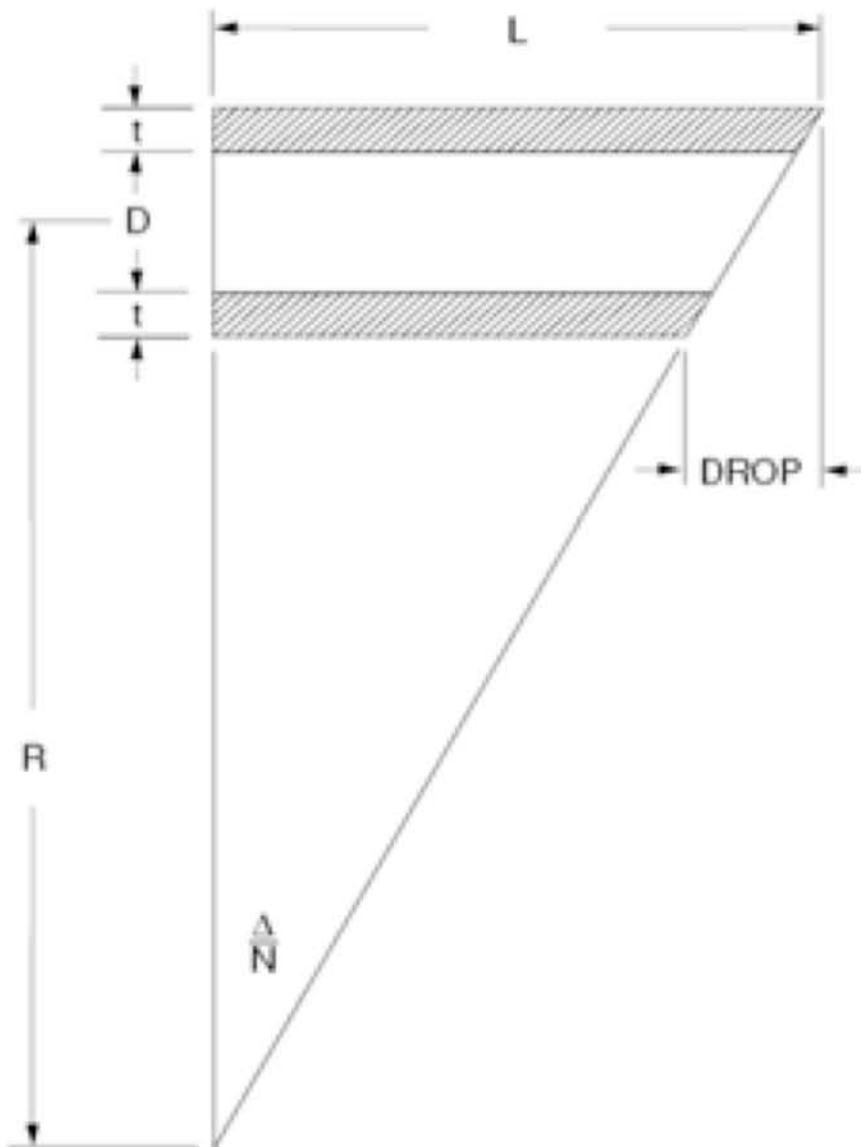
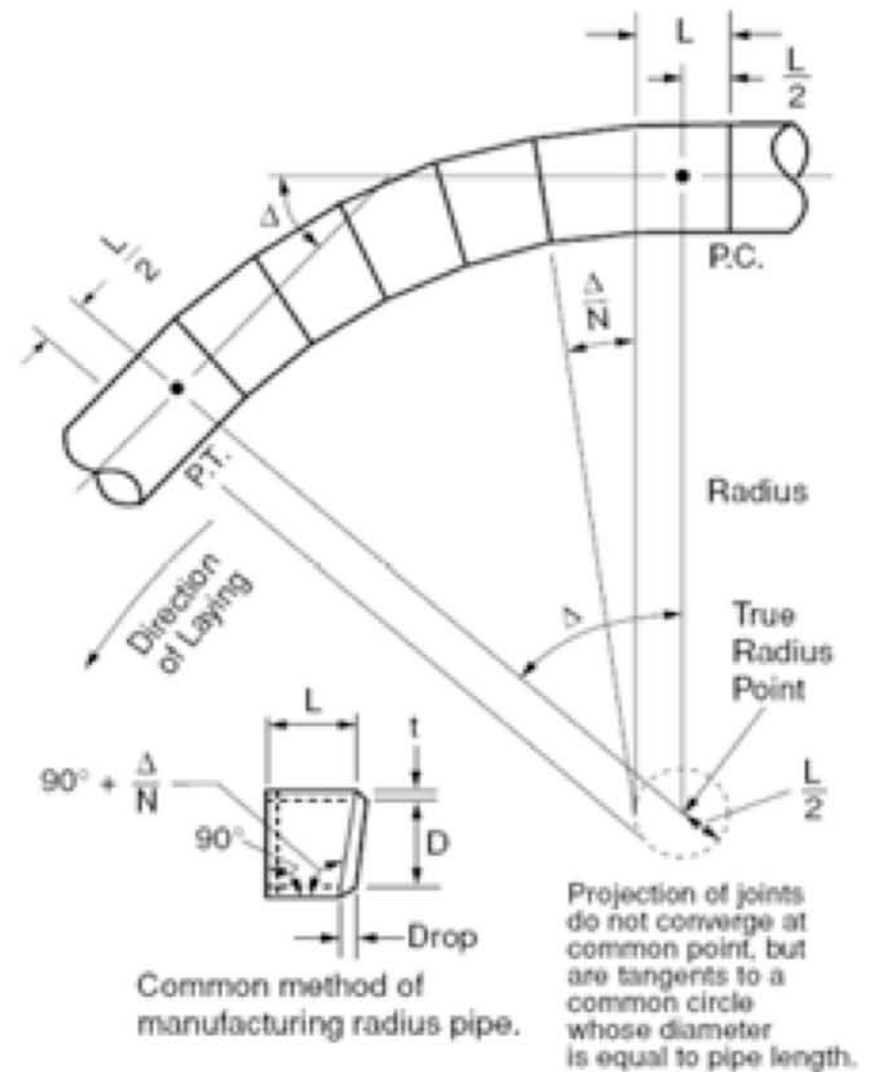


Figure 4 Curved Alignment Using Radius Pipe



Fittings



- **Bends**
- **Tees/Wyes**
- **Reducers/
Increases**
- **Adapters**



Fittings



- **Bends**
- **Tees/Wyes**
- **Reducers/Increases**
- **Adapters**





Manholes

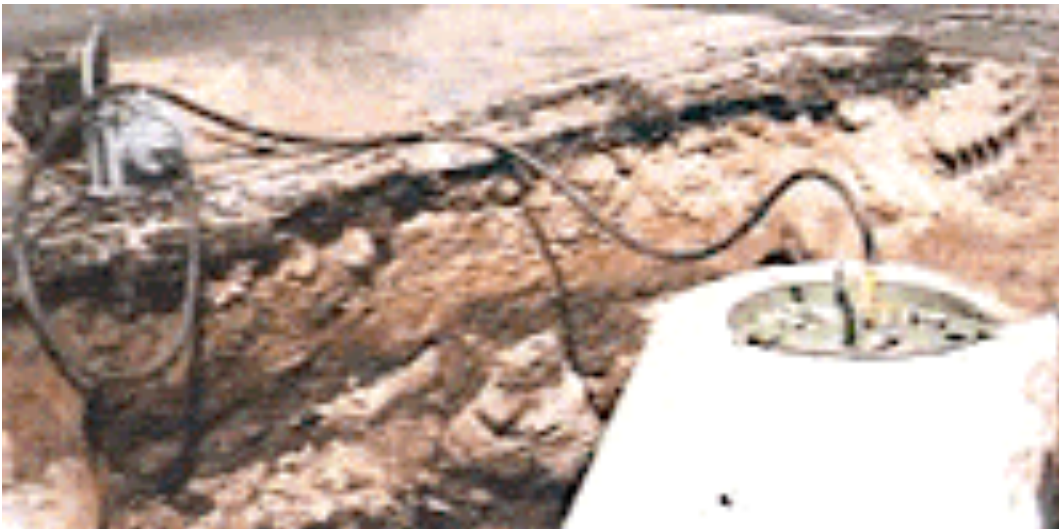


- **Testing**
- **Sizing**
- **Flotation**
- **Connectors & Joint Sealants**
- **Depth – Round or Square**

Additional Design Data – [Click Here](#)

Additional Info in the Concrete Design Manual - [click here](#)

Vacuum Testing Manholes ASTM C-1244





Designation: C 1244 – 02^{e1}

Standard Test Method for Concrete Sewer Manholes by the Negative Air Pressure (Vacuum) Test Prior to Backfill¹

This standard is issued under the fixed designation C 1244; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

^{e1} Note—Permissive language and a value in Table 1 were editorially corrected in August 2004.

1. Scope

1.1 This test method covers procedures for testing precast concrete manhole sections when using the vacuum test method to demonstrate the integrity of the installed materials and the construction procedures. This test method is used for testing concrete manhole sections utilizing mortar, mastic, or gasketed joints.

1.2 This test method is intended to be used as a preliminary test to enable the installer to demonstrate the condition of the concrete manholes prior to backfill.

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

1.4 This test method is the companion to metric Test

C 969 Practice for Infiltration and Exfiltration Acceptance Testing of Installed Precast Concrete Pipe Sewer Lines

3. Terminology

3.1 For definitions of terms relating to manholes, see Terminology C 822.

4. Summary of Practice

4.1 All lift holes and any pipes entering the manhole are to be plugged. A vacuum will be drawn and the vacuum drop over a specified time period is used to determine the acceptability of the manhole.

5. Significance and Use

5.1 This is not a routine test. The values recorded are applicable only to the manhole being tested and at the time of

Manhole Flotation

[Additional Design Data – Click Here](#)



Design Data 41

American Concrete Pipe Association

Manhole Flotation

Introduction

The proper functioning of a sewer system is dependent to a large degree on the performance of its appurtenances, and especially its manholes. As with many buried structures, the proper design of manholes should take into account the effect of the water table and its specific effect on installation and operating conditions.

The Buoyancy Concept

From a fluid dynamics standpoint, the buoyant force acting on a submerged object is equal to the weight of fluid which that object displaces. In the case of a buried structure or manhole, this concept is applicable when a high ground water table or other subaqueous condition exists. As with the design of buried pipe, flotation should be checked when conditions such as the use of flooding to consolidate backfill, flood planes or future man-made drainage changes are anticipated.

Manhole Buoyancy Analysis

Vertical manhole structures of two types (Figure 1) are generally constructed, and each type should be considered when analyzing the flotation potential. The first case to be considered is a structure in which the base does not extend past the walls of the manhole. This structure will be called a smooth-wall manhole installation. Smooth-wall manholes utilize the weight of the structure itself and the downward frictional resistance of the soil surrounding the manhole to resist the upward buoyant force. Some manufacturers and designers use an extended base to provide additional resistance to buoyant forces. These structures are constructed with a

Figure 1 Manhole Installations

Cross Section of Extended Base Manhole Installation

Cross Section of Smoothwall Manhole Installation

Figure 1 consists of two cross-sectional diagrams of manhole installations. The top diagram, titled 'Cross Section of Extended Base Manhole Installation', shows a manhole with a base that extends further outwards than the walls of the manhole. A label 'Extended Base' points to this wider base. The bottom diagram, titled 'Cross Section of Smoothwall Manhole Installation', shows a manhole with a base that is flush with the exterior surface of the walls. A label 'Base Flush with Exterior Surface' points to this base. Both diagrams show the manhole structure within a surrounding soil mass, with a water table indicated by a dashed line.



Manhole Sizing



- **Flexibility**
- **Handling**
- **Weight**

SIZING MANHOLES

MULTIPLE HOLES AT SAME ELEVATION

MH Dia.	M, in/deg
48"	0.4189
60"	0.5236
72"	0.6283
84"	0.7330
96"	0.8378

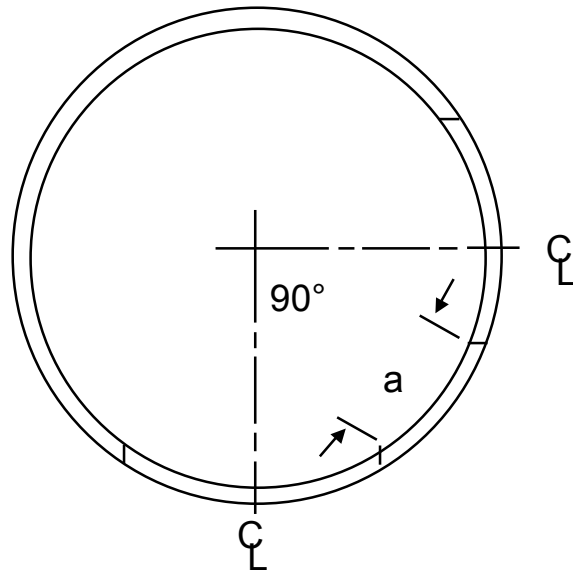
$M = \text{Circumference} / 360^\circ$

$M \times \text{Angle} = Y$

$Y - \text{Pipe \#1 Opening} / 2 - \text{Pipe \#2 Opening} / 2 = a$

A = Distance between the two openings

Minimum "a" is ≥ 6 " for 48" - 72" Dia. MH and ≥ 8 " for ≥ 72 " Dia. MH



Pipe #1

Example:

Pipe #1 = 36" RCP "B" Wall @ 6:00

Pipe #2 = 36" RCP "B" Wall @ 3:00

Angle = 90°

Try 72" Dia. MH

$Y = 0.6283 \times 90^\circ = 56.55$

$A = 56.55" - 53/2 - 53/2 = 3.55" < 6"$; too small

Therefore, try 84" Dia. MH:

$Y = 0.7330 \times 90^\circ = 65.97"$

$A = 65.97" - 51/2 - 51/2 = 14.97" > 8"$; OK

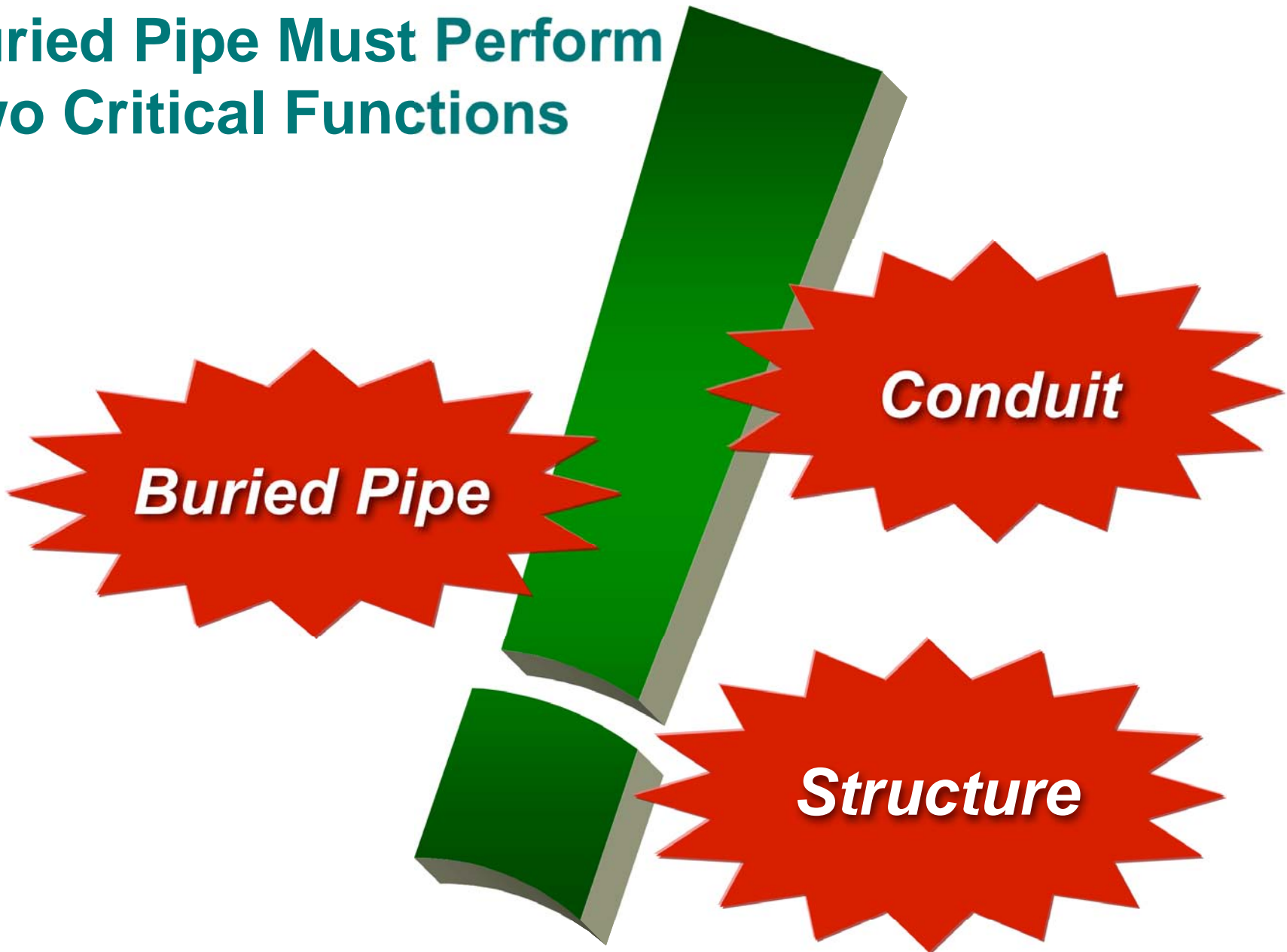
Pipe Dia., in.	Hole chord Dim., in.	Hole Size (Arc) per MH Diameter, in.				
		48"Ø	60"Ø	70"Ø	84"Ø	96"Ø
12	20	20.5	20.4	20	20	20
15	24	25	25	24.5	24	24
18	27	29	28	28	27.5	28
22.4	34	38	36	35	35	35
30	41		45	43	43	45
36	48/50		55.5/59	51/55	51/53.5	50/53
42	55/57		70/75	63/66	60/63	59/61
48	62/64			75/79	70/72.5	67/70
54	71				84	80
60	78					91
66	85					105

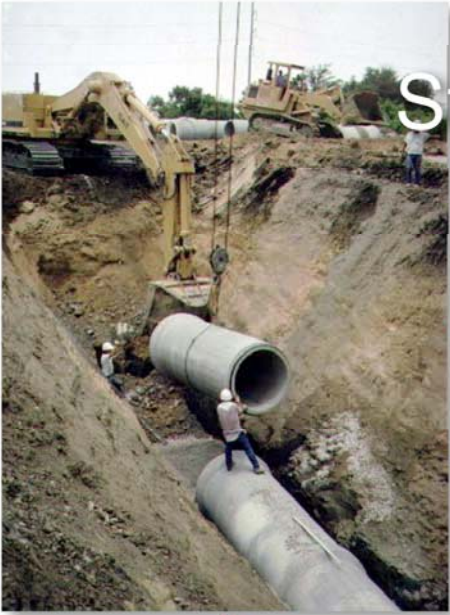
Note: Where two dimensions are shown, i.e. 48/50, the first one is for "B" Wall pipe and the second one is for "C" Wall pipe. Use the Arc length for calculations.



Concrete Pipe Design Basics

Fact :
**Buried Pipe Must Perform
Two Critical Functions**





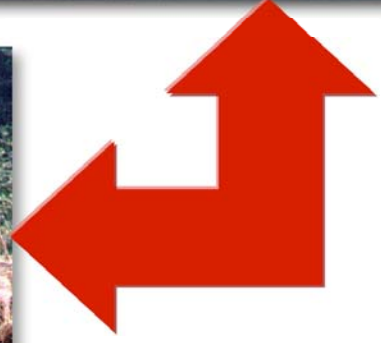
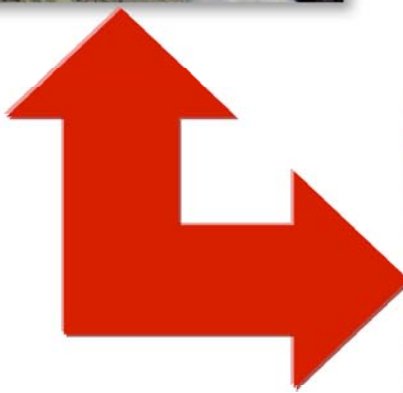
Structure



Conduit



Concrete Pipe





Traffic Load

Final Backfill

Earth Load

Loads

Haunching

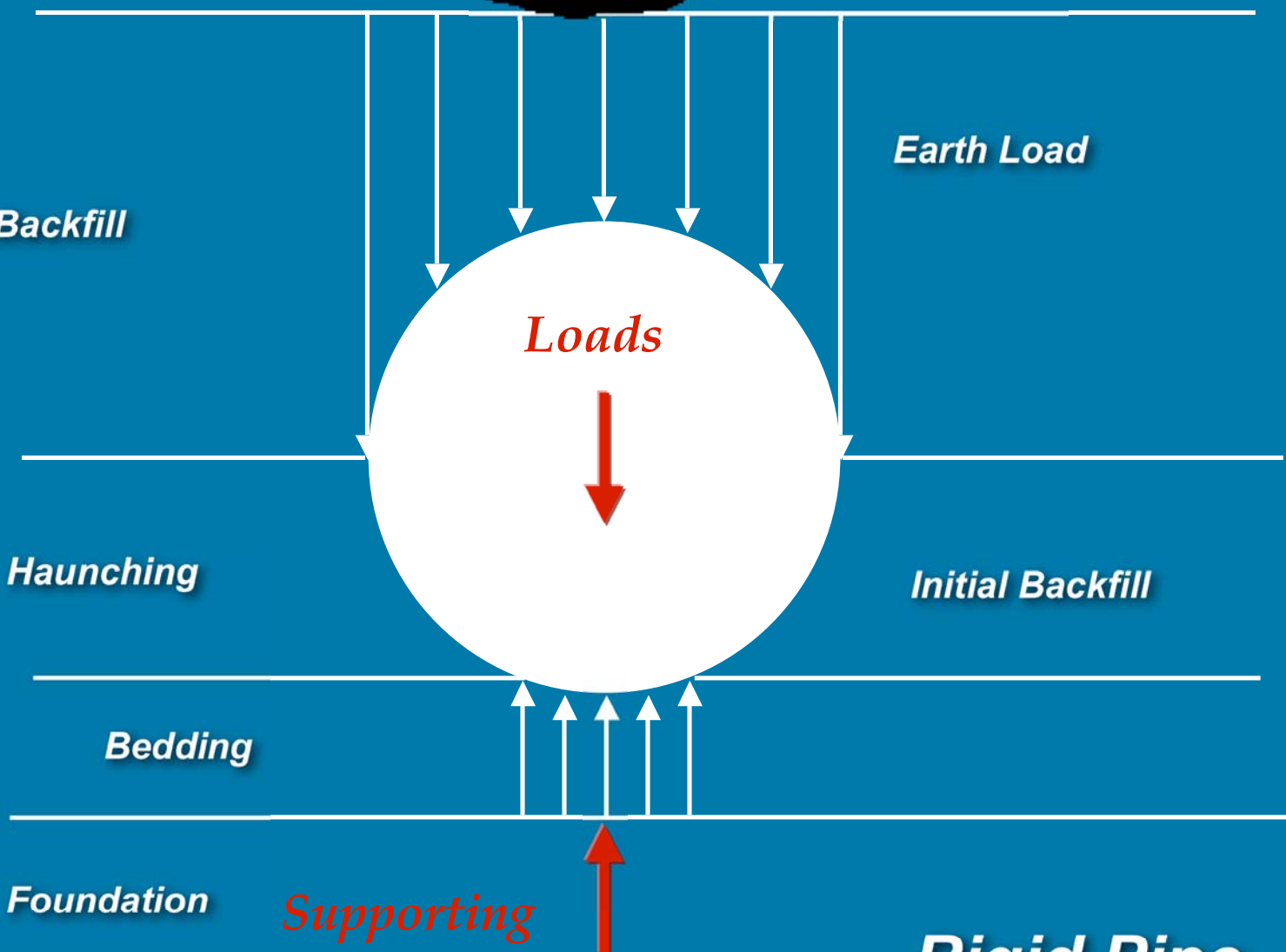
Initial Backfill

Bedding

Foundation

Supporting Strength

Rigid Pipe



Unstable Foundation!



How do we define the strength of concrete pipe?



D-Load ?

3-Edge Bearing

Class

Wall Thickness ?

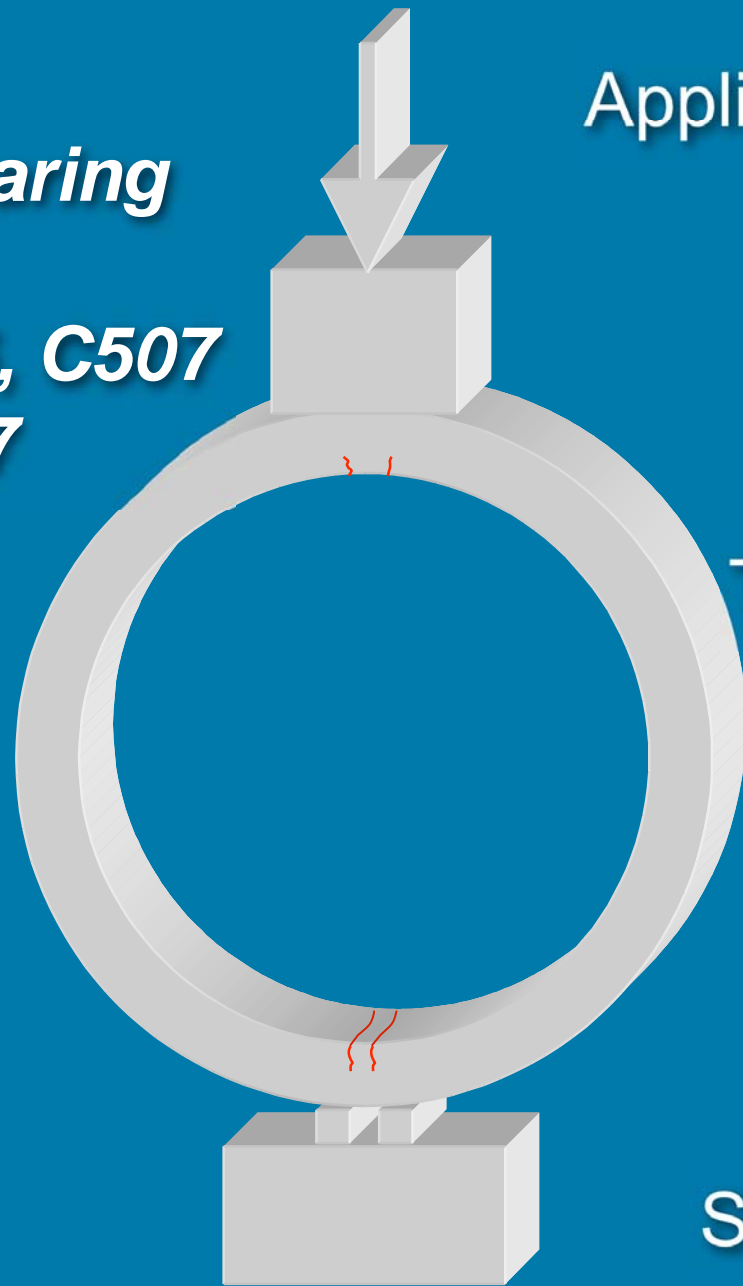
Wall Thickness & Reinforcement



- **A-Wall – Wall thickness in inches = Diameter in feet**
- **24" Pipe = 2" Wall**
- **B-Wall – Wall thickness in inches = Diameter in feet + 1"**
- **24" Pipe = 3" Wall**
- **C-Wall – Wall thickness in inches = Diameter in feet + 1.75"**
- **24" Pipe = 3.75" Wall**

Three-Edge-Bearing

***ASTM C76, C506, C507
ASTM C497***



Applied Load

Test Specimen

Support

D-Load

Supporting strength of a pipe loaded under three-edge bearing test conditions, expressed in pounds per linear foot per foot of inside diameter or horizontal span when tested according to ASTM C497.

$D_{0.01}$ = load (lbs/ft. span/ft. length) to produce 0.01" crack, 12" long

D_{ULT} = load (lbs/ft. span/ft. length) to cause structural failure



60" ASTM C-76 Class IV 8'

$$D_{0.01} = 2000$$

$$D_{ULT} = 3000$$

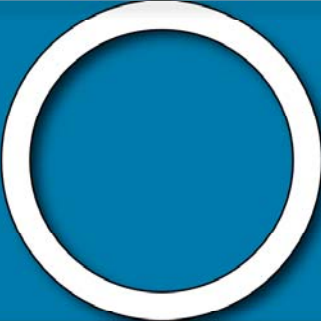
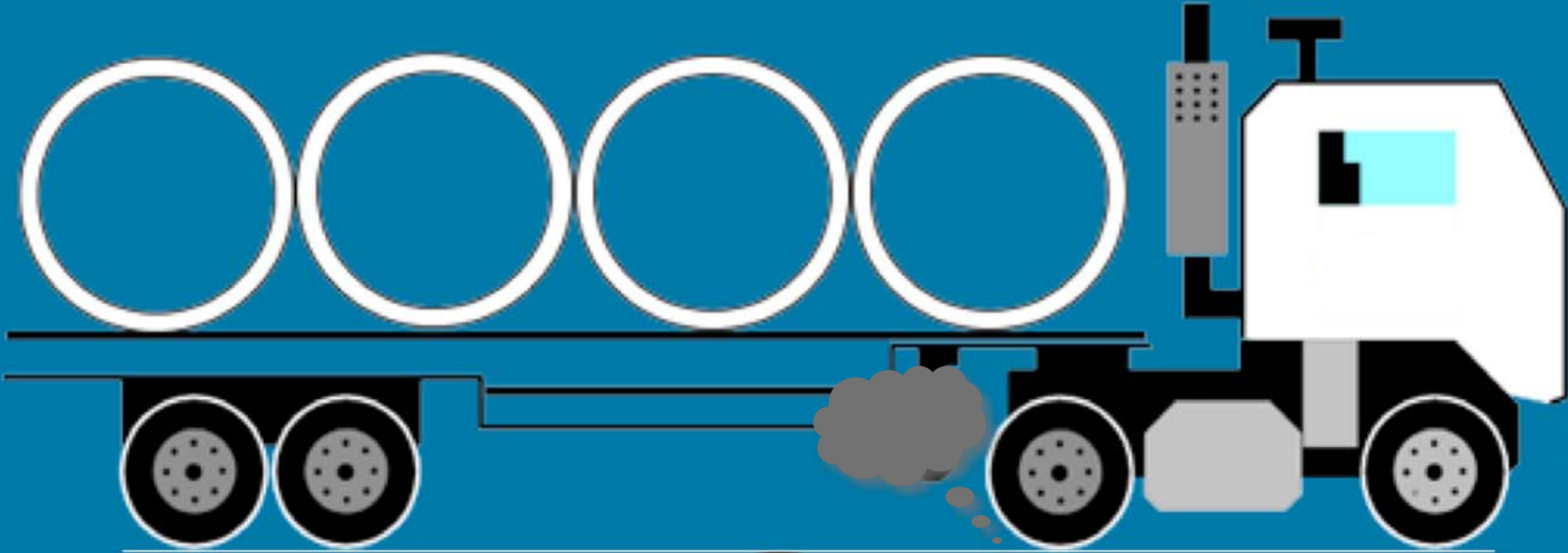
Total Load Required:

$$\begin{aligned} D_{0.01} &= (60/12)(8)(2000) \\ &= 80,000 \text{ lbs.} \end{aligned}$$

$$\begin{aligned} D_{ULT} &= (60/12)(8)(3000) \\ &= 120,000 \text{ lbs.} \end{aligned}$$



80,000 lbs.



60" CI IV RCP

Loads on Pipe

- **Earth**
- **Live**
- **Construction**
- **Other**



Additional Design Data – [Click Here](#)

Selection of Pipe Strength

$$D\text{-load}_{.01} = \left(\frac{W_E}{B_{FE}} + \frac{W_L}{B_{FL}} \right) \times \left(\frac{FS}{D} \right)$$

Where:

$D\text{-Load}_{.01}$ = Required structural capacity, lb./ft.²

W_E = Earth load, lb./ft.

W_L = Live load, lb./ft.

D = Pipe diameter, ft.

B_{FE} = Earth Load Bedding Factor

B_{FL} = Live Load Bedding Factor

FS = Factor of safety

Additional Info in the Concrete Design Manual - [click here](#)

TABLE 3 Design Requirements for Class III Reinforced Concrete Pipe^A

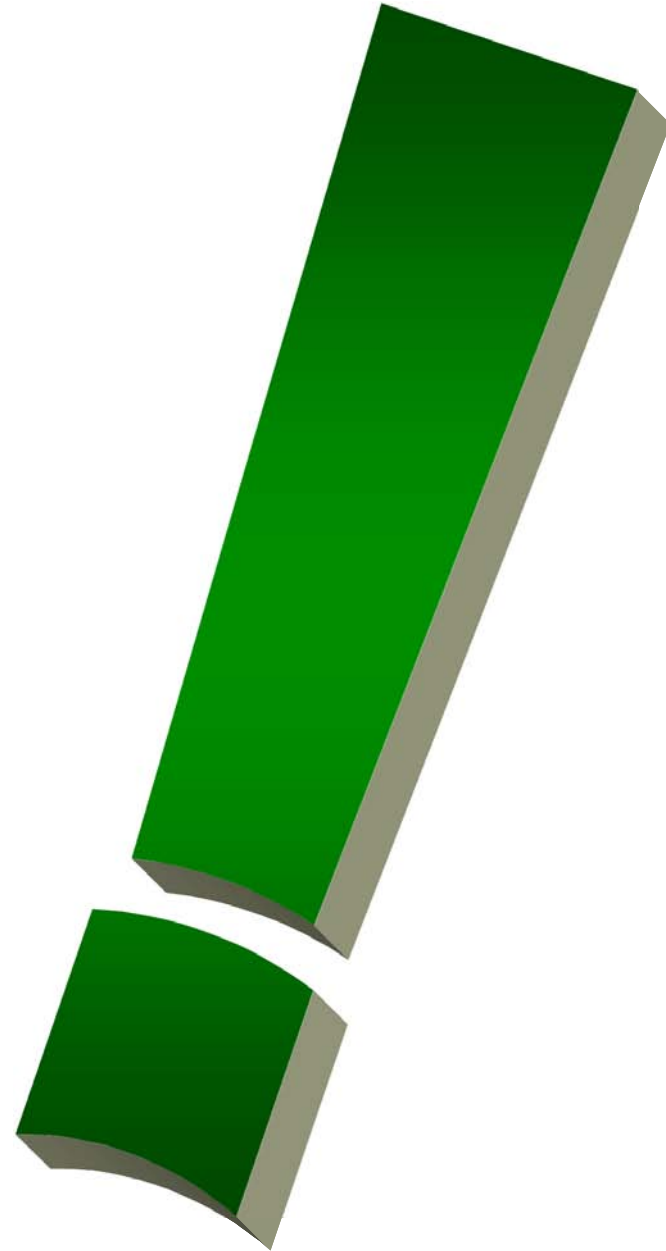
NOTE 1—See Section 5 for basis of acceptance specified by the owner.
 The strength test requirements in pounds-force per linear foot of pipe under the three-edge-bearing method shall be either the D-load (test load expressed in pounds-force per linear foot of diameter) to produce a 0.01-in. crack, or the D-loads to produce the 0.01-in. crack and the ultimate load as specified below, multiplied by the internal diameter of the pipe in feet.
 D-load to produce a 0.01-in. crack
 D-load to produce the ultimate load

Internal Designated Diameter, in.	Reinforcement, in. ² /linear ft of pipe wall														
	Wall A					Wall B					Wall C				
	Concrete Strength, 4000 psi					Concrete Strength, 4000 psi					Concrete Strength, 4000 psi				
	Circular Reinforcement ^B		Elliptical Reinforcement ^C	Wall Thicknesses, in.	Circular Reinforcement ^B		Elliptical Reinforcement ^C	Wall Thicknesses, in.	Circular Reinforcement ^B		Elliptical Reinforcement ^C				
Inner Cage	Outer Cage	Inner Cage			Outer Cage	Inner Cage			Outer Cage						
12	1 3/4	0.07 ^D	—	—	2	0.07 ^D	—	—	2 3/4	0.07 ^D	—	—			
15	1 3/4	0.07 ^D	—	—	2 1/4	0.07 ^D	—	—	3	0.07 ^D	—	—			
18	2	0.07 ^D	—	—	2 1/2	0.07 ^D	—	—	3 1/4	0.07 ^D	—	—			
21	2 1/4	0.14	—	—	2 3/4	0.07 ^D	—	—	3 1/2	0.07 ^D	—	—			
24	2 1/2	0.17	—	—	3	0.07 ^D	—	—	3 3/4	0.07 ^D	—	—			
27	2 3/4	0.18	—	—	3 1/4	0.07 ^D	—	—	4	0.07 ^D	—	—			
30	2 3/4	0.19	—	—	3 1/2	0.07 ^D	—	—	4 1/4	0.07 ^D	—	—			
33	3	0.21	—	—	3 3/4	0.16	—	—	4 1/2	0.07 ^D	—	—			
36	3	0.21	—	—	4	0.18	—	—	4 3/4	0.07 ^D	—	—			
42	3 1/2	0.25	0.13	0.20	4 1/4	0.20	—	—	5	0.07 ^D	—	—			
48	4	0.32	0.15	0.28	4 1/2	0.21	0.10	—	5 1/4	0.07 ^D	—	—			
54	4 1/4	0.38	0.23	0.35	5	0.24	0.13	—	5 3/4	0.07 ^D	—	—			
60	5	0.44	0.26	0.42	5 1/4	0.29	0.14	—	6	0.07 ^D	—	—			
66	5 1/2	0.50	0.30	0.49	5 3/4	0.34	0.17	—	6 1/4	0.21	0.13	0.18			
72	6	0.57	0.34	0.55	6	0.41	0.20	—	6 3/4	0.25	0.15	0.23			
78	6 1/2	0.64	0.38	0.63	6 1/2	0.49	0.29	—	7	0.46	0.25	0.28			
84	7	0.72	0.43	0.71	7	0.57	0.38	—	7 1/4	0.54	0.31	0.34			
90	7 1/2	0.80	0.48	0.80	7 1/2	0.64	0.46	—	7 1/2	0.62	0.36	0.40			
96	8	0.88	0.53	0.88	8	0.72	0.54	—	8	0.70	0.41	0.44			
102	8 1/2	0.96	0.58	0.96	8 1/2	0.79	0.60	—	8 1/2	0.78	0.46	0.48			
108	9	1.03	0.63	1.03	9	0.86	0.66	—	9	0.84	0.51	0.52			
114	9 1/2	1.11	0.68	1.11	9 1/2	0.93	0.71	—	9 1/2	0.91	0.56	0.56			
120	10	1.18	0.73	1.18	10	1.00	0.76	—	10	0.98	0.61	0.61			
126	10 1/2	1.26	0.78	1.26	10 1/2	1.07	0.81	—	10 1/2	1.05	0.66	0.66			
132	11	1.33	0.83	1.33	11	1.14	0.86	—	11	1.12	0.71	0.71			
138	11 1/2	1.41	0.88	1.41	11 1/2	1.21	0.91	—	11 1/2	1.19	0.76	0.76			
144	12	1.48	0.93	1.48	12	1.28	0.96	—	12	1.26	0.81	0.81			

Prescriptive Specification
 "Cook Book Spec"

^A For modified or special designs see 7.2 or with the permission of the owner utilize the provisions of Specification C 656. Steel areas may be interpolated between those shown for variations in diameter, loading, or wall thickness. Pipe over 96 in. in diameter shall have two circular cages or an inner circular plus one elliptical cage.
^B As an alternative to designs requiring both inner and outer circular cages the reinforcement may be positioned and proportioned in either of the following manners:
 An inner circular cage plus an elliptical cage such that the area of the elliptical cage shall not be less than that specified for the outer cage in the table and the total area of the inner circular cage plus the elliptical cage shall not be less than that specified for the outer cage in the table and the total area.
 An inner and outer cage plus quadrant mats in accordance with Fig. 1, or
 An inner and outer cage plus an elliptical cage in accordance with Fig. 2.
^C Elliptical and quadrant steel must be held in place by means of holding rods, chairs, or other positive means throughout the entire casting operation.
^D For these classes and sizes, the minimum practical steel reinforcement is specified. The actual ultimate strength is greater than the minimum strength specified for nonreinforced pipe of equivalent diameters.
^E As an alternative, single cage reinforcement may be used. The reinforcement area in square in. per linear foot shall be 0.30 for wall B and 0.20 for wall C.

**Bedding
Factor
depends on
type and
quality of
installation**



Standard Installations – [Click here](#)

Who Is Responsible for Bedding Factor?

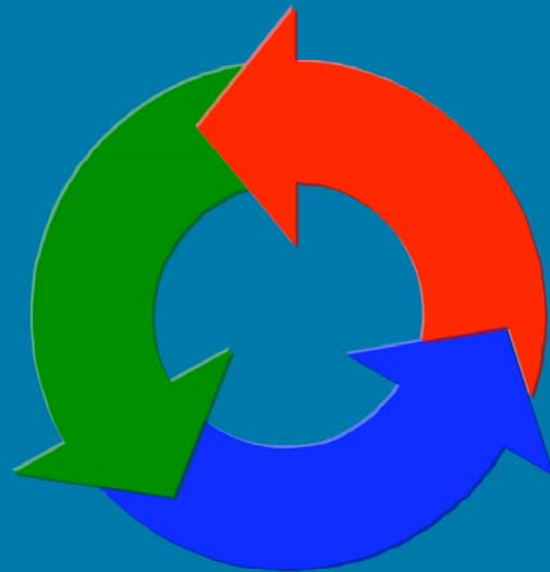
- **Engineer via specification, inspection and testing**
- **Contractor via installation means and methods**
- **Inspector via inspection and testing**

Additional Info in the Concrete Design Manual - [click here](#)

**How do we design
concrete pipe?**

System Design

Structure



Durability

Joint

System Design

Structure



Design Basics

Installation Methodology & Earth Load Determination

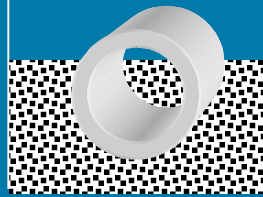
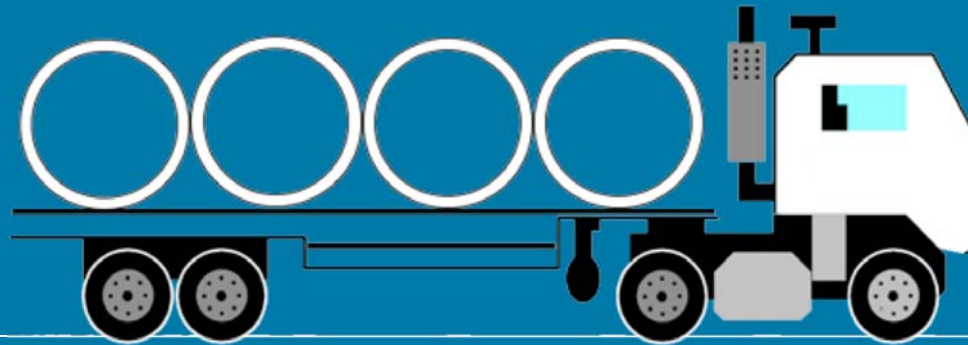
Additional Info in the Concrete Design Manual - [click here](#)

Pipe Installation Methods

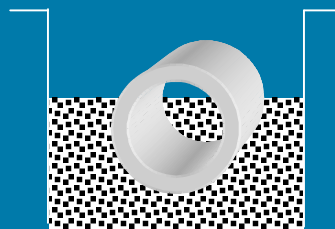
- **Trench**
- **Positive projection embankment**
- **Negative projection embankment**
- **Jacked, bored, or tunneled**

Additional Info in the Concrete Design Manual - [click here](#)

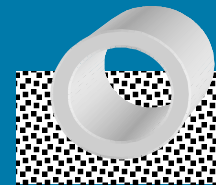
Installation Methods



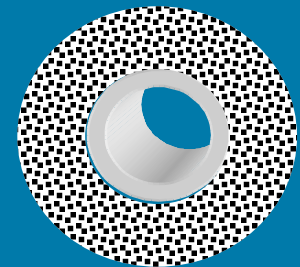
Trench



Negative Projecting



Positive Projecting

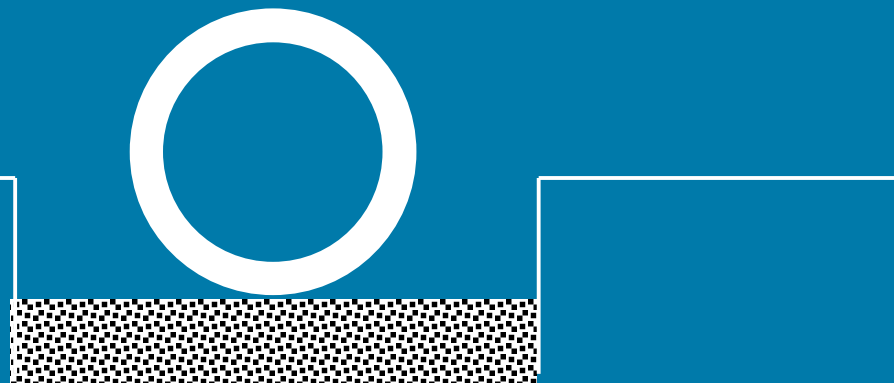


Tunnel

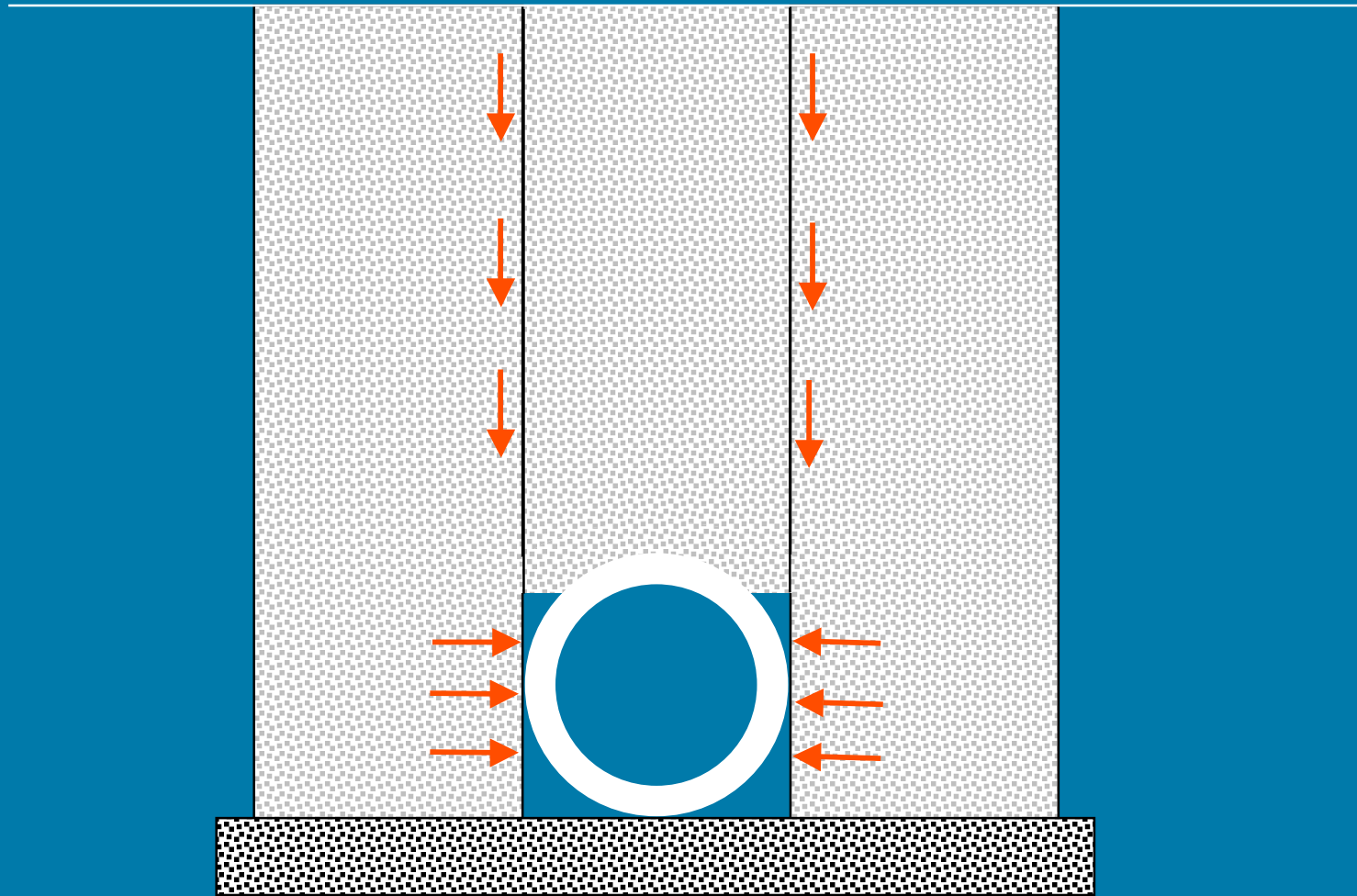
Positive Projecting Embankment

Final Grade

Existing Grade

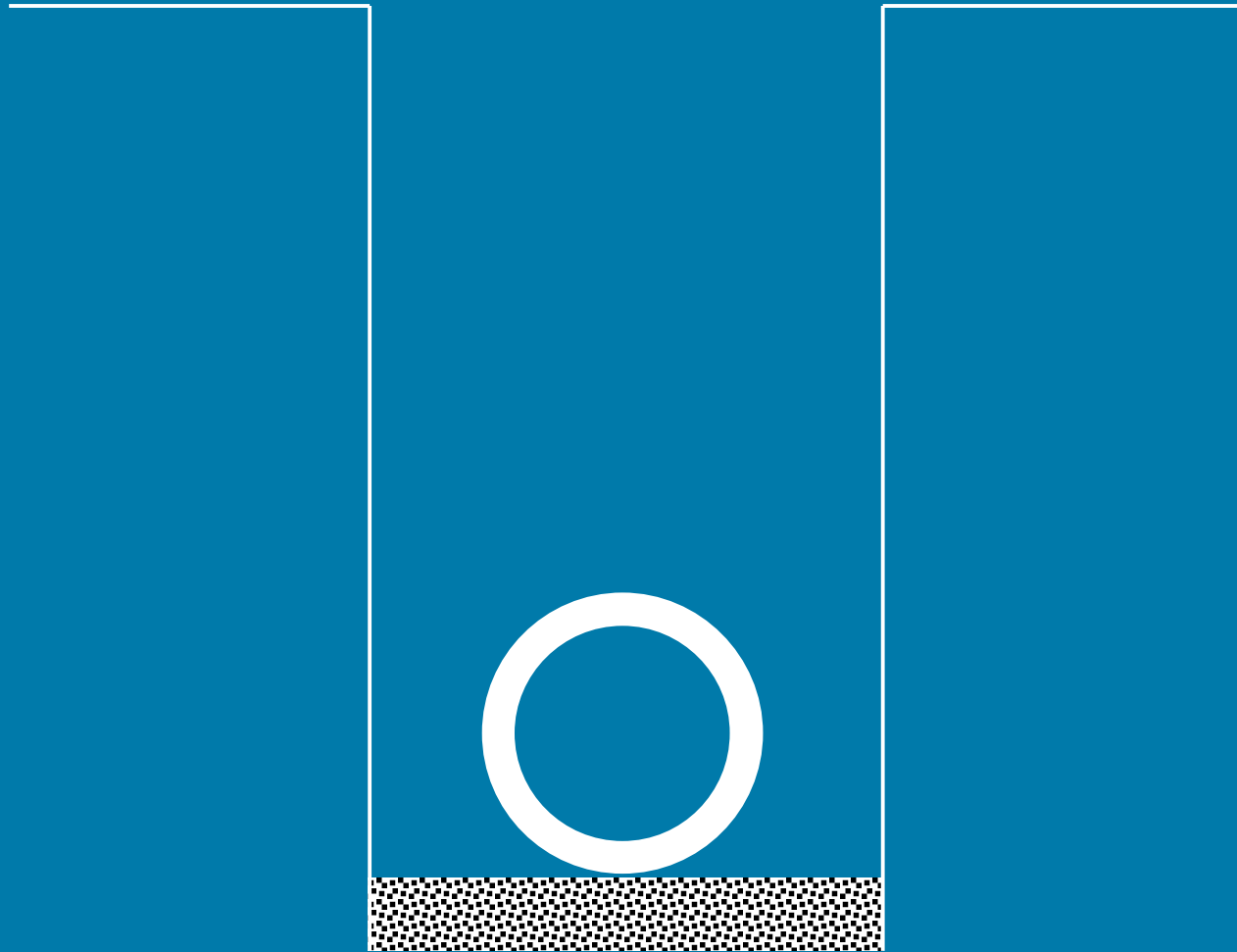


Positive Projecting Embankment

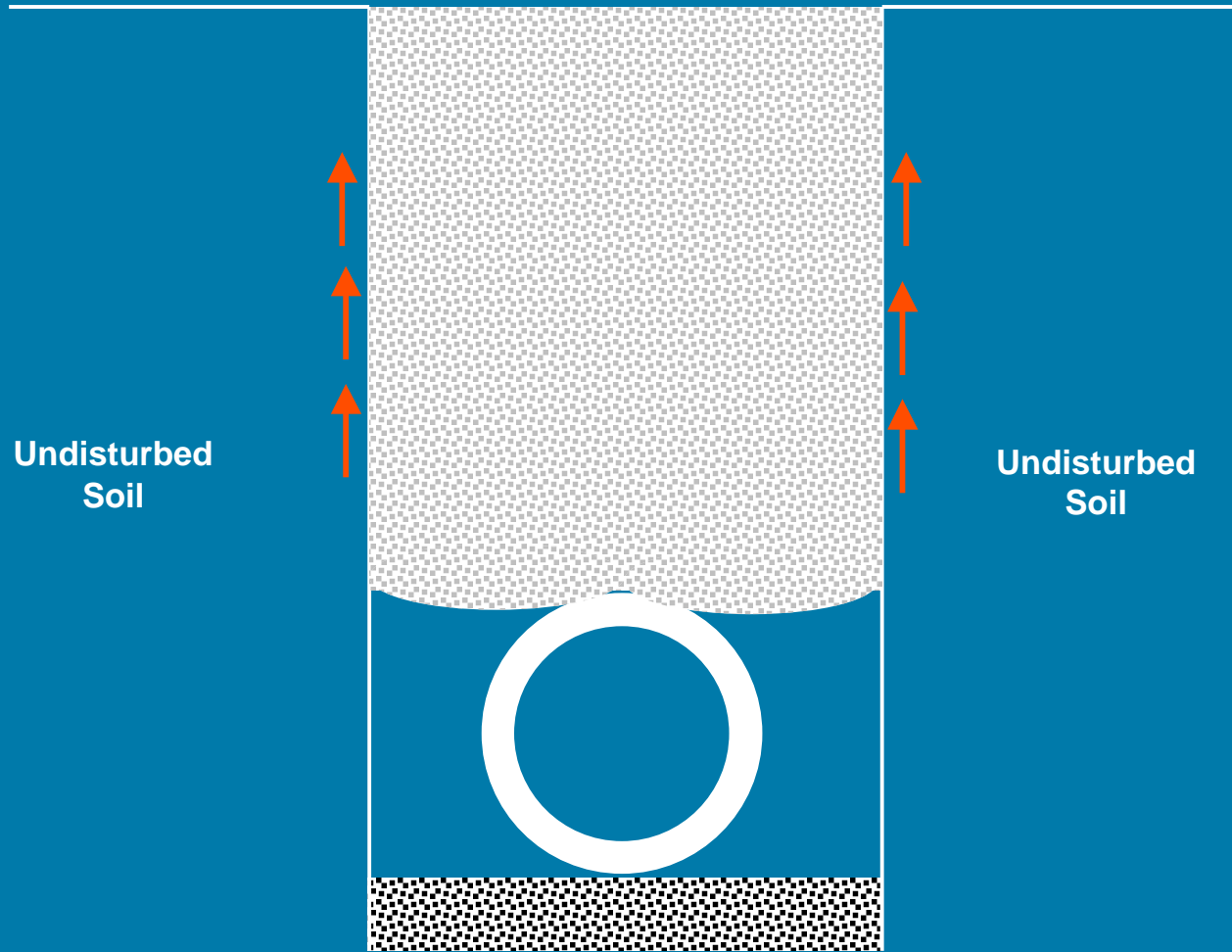


Trench

Existing and Final Grade



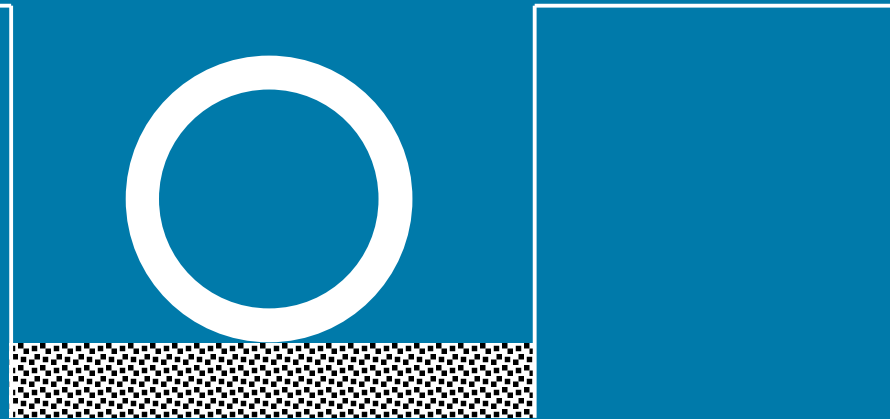
Trench



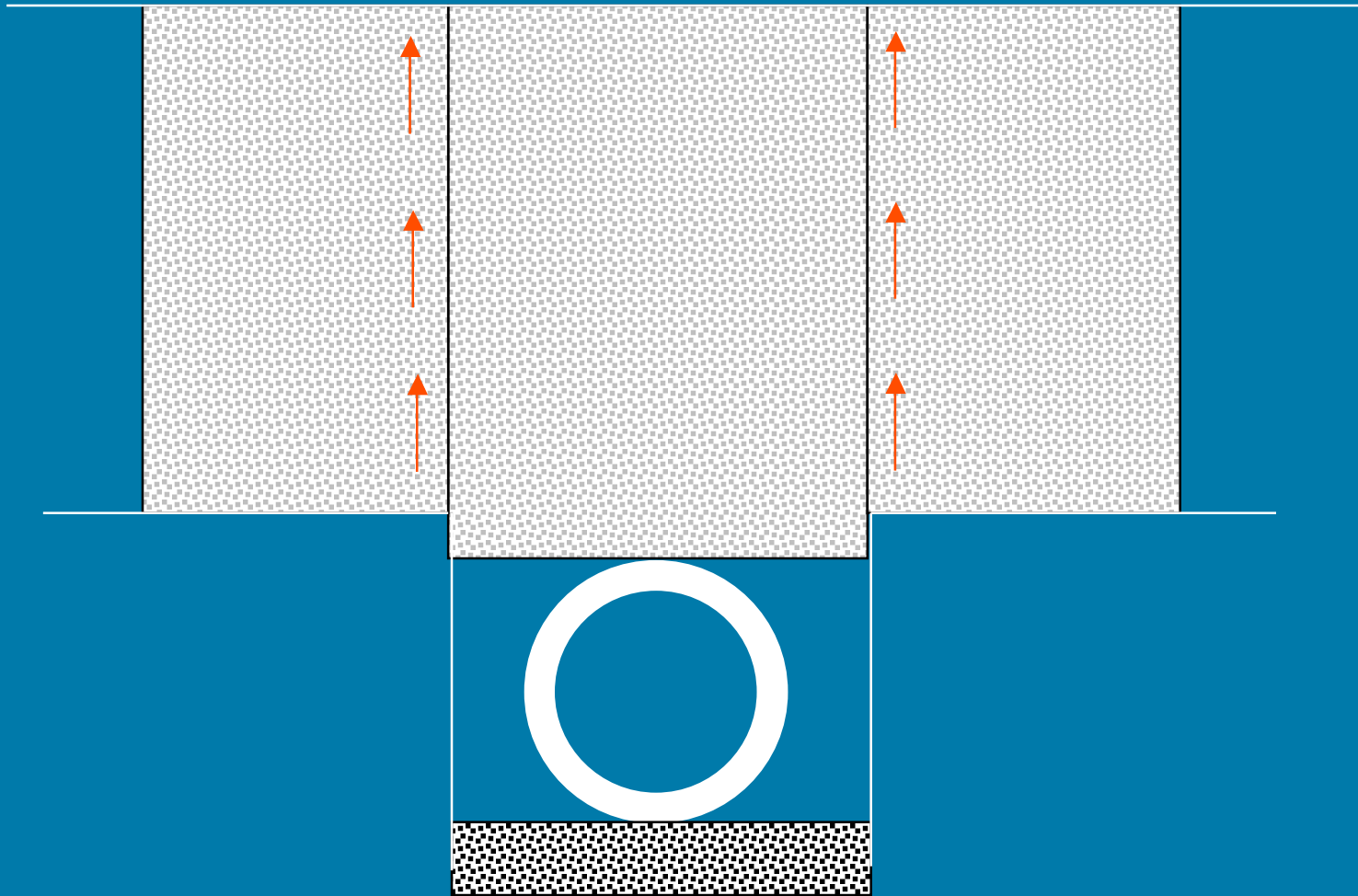
Negative Projecting Embankment

Final Grade

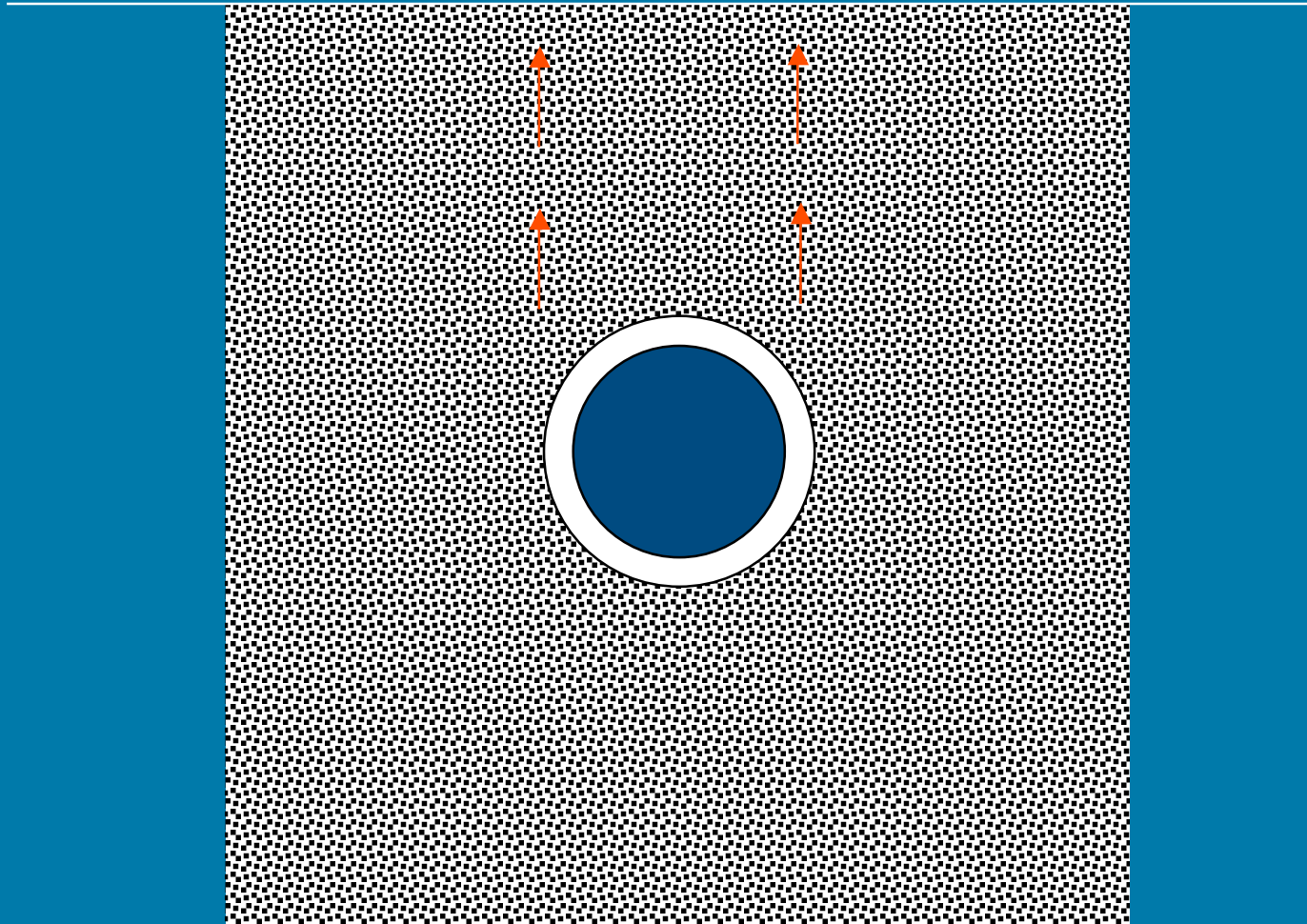
Existing Grade



Negative Projecting Embankment



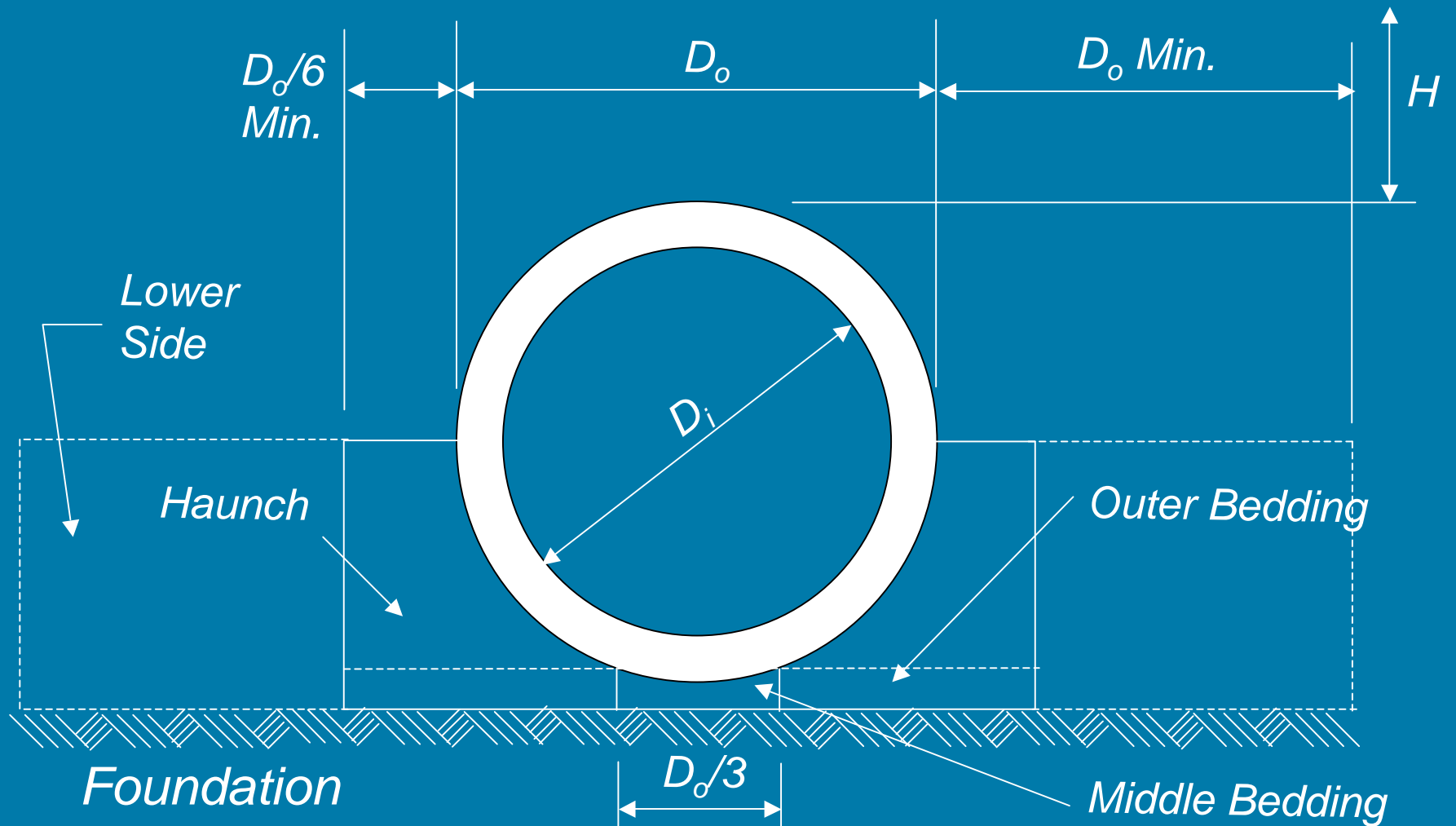
Trenchless



Installation (embedding) Types or Classes

Additional Info in the Concrete Design Manual - [click here](#)

Standard Installations

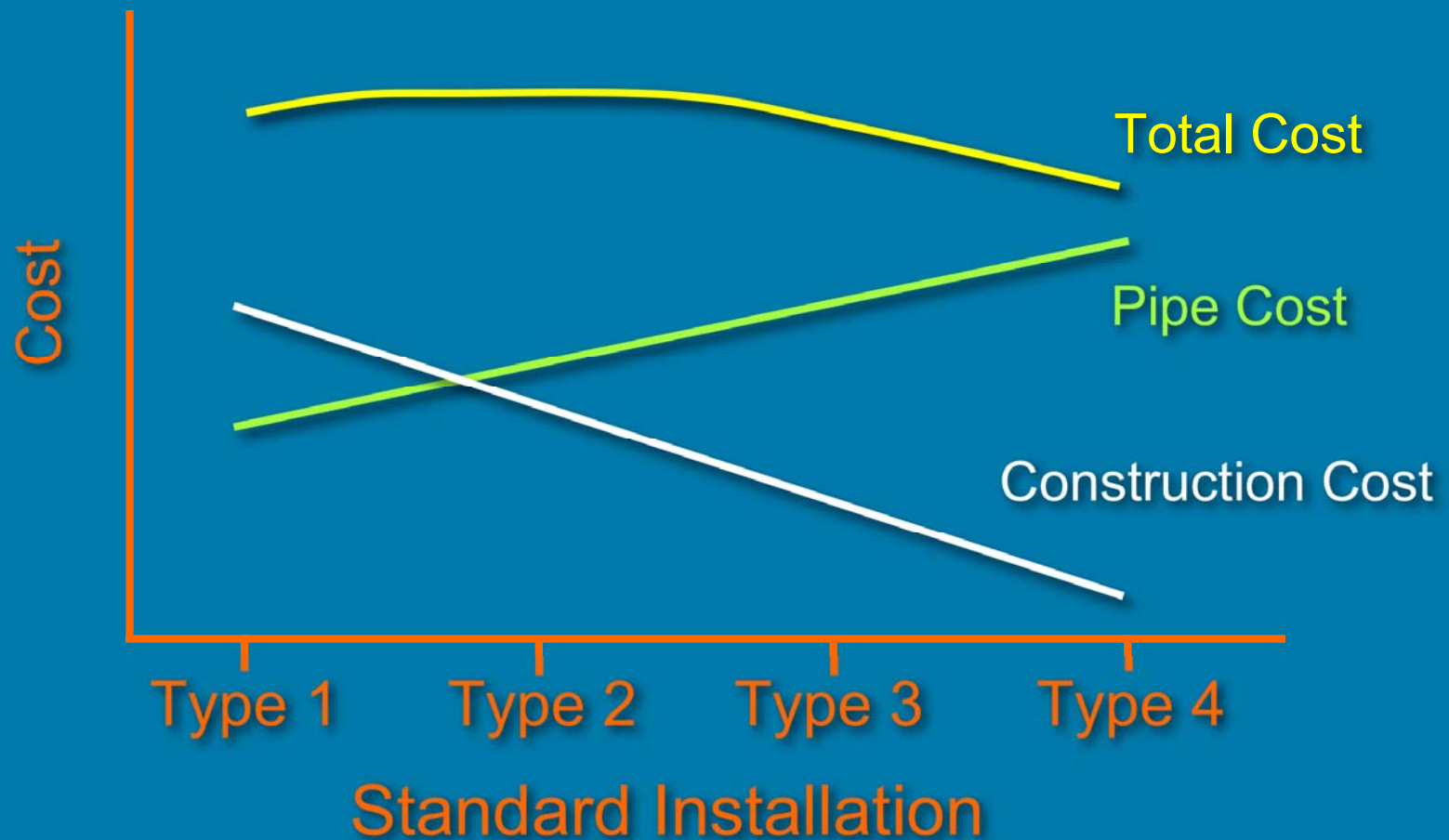


Standard Installations

- ASTM & AASHTO

Installation Type	Bedding Thickness	Haunch & Outer Bedding	Lower Side
Type 1	D _o /24 minimum, not less than 3 in. (75 mm). If rock foundation, use D _o /12 minimum, not less than 6 in. (150 mm).	95% Category I	90% Category I 95% Category II 100% Category III
Type 2	D _o /24 minimum, not less than 3 in. (75 mm). If rock foundation, use D _o /12 minimum, not less than 6 in. (150 mm).	90% Category I 95% Category II	85% Category I 90% Category II 95% Category III
Type 3	D _o /24 minimum, not less than 3 in. (75 mm). If rock foundation, use D _o /12 minimum, not less than 6 in. (150 mm).	85% Category I 90% Category II 95% Category II	85% Category I 90% Category II 95% Category III
Type 4	No bedding required except if rock foundation, use D _o /12 minimum, not less than 6 in. (150 mm).	No compaction required, except if Category III, use 85%	No compaction required, except if Category III, use 85%

Standard Installations



Options for Finding Required Pipe Strength

- **Plug & chug - blue book**
- **Fill height tables**
- **Computer software - PipePac 2000**



The image shows a detailed table titled "Type 1 Burials" which provides fill height data for various pipe diameters and classes. The table is organized into columns for pipe diameter (18, 24, 30, 36, 42, 48, 54, 60, 66, 72, 78, 84, 90, 96, 102, 108, 114, 120, 126, 132, 138, 144, 150, 156, 162, 168, 174, 180, 186, 192, 198, 204, 210, 216, 222, 228, 234, 240, 246, 252, 258, 264, 270, 276, 282, 288, 294, 300, 306, 312, 318, 324, 330, 336, 342, 348, 354, 360, 366, 372, 378, 384, 390, 396, 402, 408, 414, 420, 426, 432, 438, 444, 450, 456, 462, 468, 474, 480, 486, 492, 498, 504, 510, 516, 522, 528, 534, 540, 546, 552, 558, 564, 570, 576, 582, 588, 594, 600, 606, 612, 618, 624, 630, 636, 642, 648, 654, 660, 666, 672, 678, 684, 690, 696, 702, 708, 714, 720, 726, 732, 738, 744, 750, 756, 762, 768, 774, 780, 786, 792, 798, 804, 810, 816, 822, 828, 834, 840, 846, 852, 858, 864, 870, 876, 882, 888, 894, 900, 906, 912, 918, 924, 930, 936, 942, 948, 954, 960, 966, 972, 978, 984, 990, 996, 1002, 1008, 1014, 1020, 1026, 1032, 1038, 1044, 1050, 1056, 1062, 1068, 1074, 1080, 1086, 1092, 1098, 1104, 1110, 1116, 1122, 1128, 1134, 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11808, 11814, 11820, 11826, 11832, 11838, 11844, 11850, 11856, 11862, 11868, 11874, 11880, 11886, 11892, 11898, 11904, 11910, 11916, 11922, 11928, 11934, 11940, 11946, 1

Steps for Determining the Required Pipe Strength



- **1 - Select the method of installation (trench, embankment, etc.)**
- **2 - Determine the earth load (Installation Type: 1-4)**
- **3 - Determine the live load**
- **4 - Determine the bedding factor (installation type: 1 – 4)**
- **5 - Calculate the required D-Load**
- **6 - Specify the class**

$$D\text{-load}_{.01} = \left(\frac{W_E}{B_{FE}} + \frac{W_L}{B_{FL}} \right) \times \left(\frac{FS}{D} \right)$$

Step 1

Determine the Method of Installation

Additional Info in the Concrete Design Manual - [click here](#)

Step 2

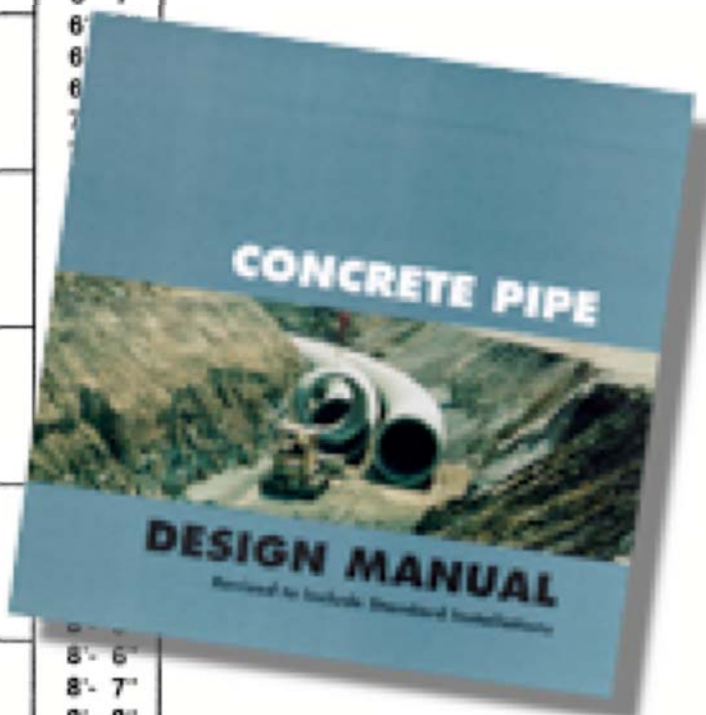
Determine Earth Load

Additional Info in the Concrete Design Manual - [click here](#)

C

ORDINARY CLAY $K_{\mu} = 0.130$

	TRENCH WIDTH AT TOP OF PIPE										▲TRANSITION WIDTH	
	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	8'-6"	9'-0"	10'-0"		
5	2201	2394										5'- 5"
6	2577	2873	3038									5'- 9"
7	2933	3277	3622	3730								6'- 2"
8	3272	3663	4056	4289								6'- 3"
9	3593	4031	4471	4848								6'- 5"
10	3898	4382	4869	5357	5401							6'- 7"
11	4188	4717	5249	5784	5952							6'- 9"
12	4463	5036	5614	6194	6508							6'- 11"
13	4724	5341	5963	6589	7060							6'- 13"
14	4972	5632	6297	6967	7609							6'- 15"
15	5207	5909	6617	7331	8050	8160						6'- 17"
16	5430	6173	6924	7681	8443	8717						6'- 19"
17	5643	6425	7217	8017	8823	9261						6'- 21"
18	5844	6666	7498	8340	9188	9817						6'- 23"
19	6035	6896	7768	8650	9540	10370						6'- 25"
20	6216	7114	8025	8948	9880	10820	10930					6'- 27"
21	6388	7323	8272	9234	10210	11190	11470					6'- 29"
22	6552	7522	8509	9509	10520	11540	12030					6'- 31"
23	6707	7712	8735	9774	10820	11890	12580					6'- 33"
24	6855	7893	8952	10030	11120	12220	13120					6'- 35"
25	6994	8066	9159	10270	11400	12540	13670					6'- 37"
26	7127	8230	9358	10510	11670	12850	14040	14240				6'- 39"
27	7253	8387	9548	10730	11930	13150	14380	14790				6'- 41"
28	7373	8537	9731	10950	12180	13440	14710	15350				6'- 43"
29	7486	8680	9905	11160	12430	13720	15020	15890				6'- 45"
30	7594	8817	10070	11360	12660	13990	15330	16450				6'- 47"
31	7697	8947	10230	11550	12890	14250	15630	16990				6'- 49"
32	7794	9071	10380	11730	13100	14500	15910	17350	17520			6'- 51"
33	7886	9189	10530	11910	13310	14740	16190	17660	18080			6'- 53"
34	7974	9302	10670	12080	13520	14980	16460	17970	18620			6'- 55"
35	8057	9410	10810	12240	13710	15200	16720	18260	19190			6'- 57"
36	8136	9513	10940	12400	13900	15420	16980	18550	19750			6'- 59"
37	8211	9610	11060	12550	14080	15640	17220	18830	20300			6'- 61"
38	8282	9704	11180	12700	14250	15840	17460	19100	20840			6'- 63"
39	8350	9793	11290	12840	14420	16040	17680	19360	21060	21370		6'- 65"
40	8414	9878	11400	12970	14580	16230	17910	19610	21340	21940		6'- 67"



* For backfill weighing 110 pounds per cubic foot, increase loads 10%; for 120 pounds per cubic foot, increase loads 20%.
 ▲ Transition loads (bold type) and widths based on $K_{\mu} = 0.19$, $r_{SDP} = 0.5$ in the embankment equation. Interpolate for intermediate heights of backfill and/or trench widths.



$$W_E = VAF \times PL$$

○ **VAF – Vertical Arching Factor**

- **Type 1** **VAF = 1.35**
- **Type 2** **VAF = 1.40**
- **Type 3** **VAF = 1.40**
- **Type 4** **VAF = 1.45**

- **PL - Prism Load, the weight of the column of earth cover over the pipe outside diameter**

Step 3

Determine the Live Load

Additional Info in the Concrete Design Manual - [click here](#)

Live Load Sources

- **Highway loads**
- **Railroad loads**
- **Aircraft loads**
- **Construction loads**
- **Other**

Step 4

Determine the Bedding Factor



Additional Info in the Concrete Design Manual - [click here](#)



Bedding Factors, Embankment Conditions

Pipe Diameter	Standard Installation			
	Type 1	Type 2	Type 3	Type 4
12 in.	4.4	3.2	2.5	1.7
24 in.	4.2	3.0	2.4	1.7
36 in.	4.0	2.9	2.3	1.7
72 in.	3.8	2.8	2.2	1.7
144 in.	3.6	2.8	2.2	1.7

Notes:

- 1. For pipe diameters other than listed in Illustration 4.21, embankment condition factors, B_{fe} can be obtained by interpolation.*
- 2. Bedding Factors are based on the soils being placed with the minimum compaction specified in Illustration 4.4 for each standard installation.*

Step 5

Calculate the Required D-Load

Additional Info in the Concrete Design Manual - [click here](#)

Selection of Pipe Strength

$$D\text{-load}_{.01} = \left(\frac{W_E}{B_{FE}} + \frac{W_L}{B_{FL}} \right) \times \left(\frac{FS}{D} \right)$$

Where:

$D\text{-Load}_{.01}$ = Required structural capacity, lb./ft.²

W_E = Earth load, lb./ft.

W_L = Live load, lb./ft.

D = Pipe diameter, ft.

B_{FE} = Earth Load Bedding Factor

B_{FL} = Live Load Bedding Factor

FS = Factor of safety

Additional Info in the Concrete Design Manual - [click here](#)

Step 6

Select the Class

Gravity Pipe Classes

ASTM C76

Class

D-Load .01

D-Load ult.

I

800

1200

II

1000

1500

III

1350

2000

IV

2000

3000

V

3000

3750

Fill Height Tables

Installation Type
Type 1

Bedding Thickness
 $D_o/24$ minimum, not less than 3 in. (75 mm). If rock foundation, use $D_o/12$ minimum, not less than 6 in. (150 mm).

Haunch & Outer Bedding
95% Category I

Lower Side
90% Category I
95% Category II
100% Category III

Fill Height Tables are based on:
 1. A soil weight of 120 lbs/ft³
 2. AASHTO HS20 live load
 3. Embankment installation

Type 1 Bedding

	Class I		Class IV
	Class II		Class V
	Class III		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	1125	600	425	375	375	400	400	475	500	550	575	625	675	725	750
15	1050	575	400	375	375	400	425	450	500	525	575	625	650	700	750
18	1000	550	400	375	375	400	425	450	500	525	575	600	650	700	750
21	950	525	375	350	375	400	425	450	475	525	575	600	650	700	750
24	925	525	375	350	375	400	425	450	475	525	575	625	650	700	750
27	875	500	375	350	375	400	425	450	500	525	575	625	675	700	750
30	825	500	375	350	375	400	425	450	500	525	575	625	675	725	775
33	775	475	375	350	375	400	425	450	500	525	575	625	675	725	775
36	750	475	350	350	375	400	425	450	500	550	600	625	675	725	775
42	650	475	350	350	375	400	425	450	500	550	600	650	675	725	775
48	600	450	350	350	375	400	425	450	500	550	600	650	700	750	800
54	575	400	350	350	375	400	425	475	500	550	600	650	700	750	800
60	550	400	350	350	375	400	425	475	500	550	600	650	700	750	800
66	525	375	325	350	375	400	425	475	525	575	625	650	700	750	800
72	525	375	325	350	375	400	425	475	525	575	625	675	725	775	825
78	475	375	325	350	375	425	450	475	525	575	625	675	725	775	825
84	450	375	325	350	375	425	450	475	525	575	625	675	725	775	825
90	400	375	325	350	375	425	450	500	525	600	625	675	725	775	825
96	375	375	325	350	375	425	450	500	550	600	650	700	750	800	850

Fill Height Tables are based on:

1. A soil weight of 120 lbs./ft³
2. AASHTO HS20 live load
3. Embankment installation

Type 1 Bedding

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

Pipe i.d. (inches)	Fill Height (feet)														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
12	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500
15	800	850	900	950	975	1025	1075	1125	1175	1225	1275	1325	1375	1425	1475
18	800	850	900	925	975	1025	1075	1125	1175	1225	1275	1325	1375	1425	1475
21	800	850	900	925	975	1025	1075	1125	1175	1225	1275	1325	1375	1425	1450
24	800	850	900	950	975	1025	1075	1125	1175	1225	1275	1325	1375	1425	1475
27	800	850	900	950	1000	1025	1075	1125	1175	1225	1275	1325	1375	1425	1475
30	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1325	1375	1425	1475
33	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500
36	825	875	925	975	1025	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500
42	825	875	925	975	1025	1075	1125	1175	1225	1275	1325	1375	1425	1475	1525
48	825	875	925	975	1025	1075	1125	1175	1225	1275	1325	1375	1425	1475	1525
54	825	875	925	975	1025	1075	1125	1175	1225	1275	1325	1375	1425	1475	1525
60	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550
66	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550
72	850	925	950	1000	1050	1100	1150	1200	1250	1300	1375	1425	1475	1525	1575
78	875	925	975	1025	1075	1125	1175	1225	1275	1325	1375	1425	1475	1525	1575
84	875	925	975	1025	1075	1125	1175	1225	1275	1325	1375	1425	1475	1525	1575
90	875	925	975	1025	1075	1125	1175	1225	1275	1325	1375	1425	1475	1525	1600
96	875	925	975	1025	1075	1125	1175	1250	1300	1350	1400	1450	1500	1550	1600

Fill Height Tables are based on:

1. A soil weight of 120 lbs/ft³
2. AASHTO HS20 live load
3. Embankment installation

Type 1 Bedding

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

Fill Height (feet)															
Pipe i.d. (inches)	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
12	2275	2325	2375	2425	2475	2525	2575	2625	2675	2725	2775	2825	2875	2925	2975
15	2250	2300	2350	2400	2450	2500	2550	2600	2650	2700	2725	2775	2825	2875	2925
18	2225	2275	2325	2375	2425	2475	2525	2575	2625	2675	2725	2775	2825	2875	2925
21	2225	2275	2325	2375	2425	2475	2525	2575	2625	2675	2725	2775	2825	2875	2925
24	2250	2300	2350	2375	2425	2475	2525	2575	2625	2675	2725	2775	2825	2875	2925
27	2250	2300	2350	2400	2450	2500	2550	2600	2650	2700	2750	2775	2825	2875	2925
30	2275	2325	2375	2425	2450	2500	2550	2600	2650	2700	2750	2800	2850	2900	2950
33	2275	2325	2375	2425	2475	2525	2575	2625	2675	2725	2775	2825	2875	2925	2975
36	2300	2350	2400	2450	2500	2550	2600	2650	2700	2750	2800	2850	2900	2950	3000
42	2300	2350	2400	2450	2500	2550	2600	2650	2700	2750	2800	2850	2900	2950	3000
48	2325	2375	2425	2475	2525	2575	2625	2675	2725	2775	2825	2875	2925	2975	3025
54	2325	2375	2425	2475	2525	2575	2625	2675	2725	2775	2825	2875	2925	2975	3025
60	2350	2400	2450	2500	2550	2600	2650	2700	2750	2800	2850	2900	2950	3000	3050
66	2375	2425	2475	2525	2575	2625	2675	2725	2775	2825	2875	2925	2975	3025	3075
72	2375	2425	2475	2525	2575	2625	2675	2750	2800	2850	2900	2950	3000	3050	3100
78	2400	2450	2500	2550	2600	2650	2700	2750	2800	2850	2900	2950	3000	3050	3100
84	2400	2450	2500	2550	2600	2650	2700	2750	2800	2850	2900	2975	3025	3075	3125
90	2400	2450	2525	2575	2625	2675	2725	2775	2825	2875	2925	2975	3025	3075	3125
96	2425	2475	2525	2575	2625	2675	2725	2775	2825	2875	2925	2975	3050	3100	3150

Installation Type	Bedding Thickness	Haunch & Outer Bedding	Lower Side
Type 4	No bedding required except if rock Foundation, use $D_o/12$ minimum, not less than 6 in. (150mm)	No compaction required, except if Category III, use 85%	No compaction required, except if Category III, use 85%

Fill Height Tables are based on:

1. A soil weight of 120 lbs/ft³
2. AASHTO HS20 live load
3. Embankment installation

Type 4 Bedding

Class I	Class IV
Class II	Class V
Class III	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	1550	950	750	800	875	950	1075	1200	1325	1450	1575	1700	1825	1950	2100
15	1450	900	750	775	850	950	1050	1150	1275	1400	1525	1650	1775	1900	2050
18	1375	850	725	750	825	925	1050	1150	1250	1375	1500	1625	1750	1900	2025
21	1325	850	700	750	825	925	1025	1125	1250	1375	1500	1600	1750	1875	2000
24	1275	825	700	725	800	900	1000	1125	1250	1350	1475	1600	1725	1850	1975
27	1150	800	700	725	800	900	1000	1125	1225	1350	1475	1600	1725	1850	1975
30	1025	800	675	725	800	900	1000	1100	1225	1350	1475	1600	1700	1850	1950
33	925	775	675	725	800	900	1000	1100	1225	1350	1475	1600	1700	1825	1950
36	850	750	675	725	800	900	1000	1100	1225	1350	1450	1575	1700	1825	1950
42	750	750	650	725	800	900	1000	1100	1225	1350	1450	1575	1700	1825	1950
48	700	675	650	725	800	900	1000	1100	1225	1350	1450	1575	1700	1825	1950
54	675	625	650	725	800	900	1000	1100	1225	1350	1450	1575	1700	1825	1950
60	675	600	650	700	800	900	1000	1100	1225	1350	1450	1575	1700	1825	1950
66	650	575	625	700	800	900	1000	1125	1225	1350	1475	1600	1700	1825	1950
72	650	575	600	700	800	900	1000	1125	1225	1350	1475	1600	1700	1825	1950
78	625	575	600	700	800	900	1000	1125	1250	1350	1475	1600	1700	1825	1950
84	575	575	600	700	800	900	1025	1125	1250	1350	1475	1600	1725	1850	1950
90	550	575	600	700	800	900	1025	1125	1250	1375	1475	1600	1725	1850	1950
96	525	575	600	700	800	925	1025	1150	1250	1375	1500	1600	1725	1850	1975

Computer Program

PipePac 2000





Congratulations! You are almost finished.

Please see remaining slides for the exam questions and submittal form to receive your PDH.

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Instructions: Select one answer for each exam question and clearly circle the appropriate letter.

- | | |
|------------|------------|
| 1) a b c d | 5) a b c d |
| 2) a b c d | 6) a b c d |
| 3) a b c d | 7) a b c d |
| 4) a b c d | 8) a b c d |

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Exam



Which two methods are used to manufacture concrete pipe?

- Wet cast and wet-out
- Packerhead and Hydrostatic
- Packerhead and dry cast
- Internal and external hydraulic



Soil Tight Joints are used for what two design types?

- Culverts and Storm Drains
- Manholes and Culverts
- Storm Drains and Manholes
- Sanitary Sewer and Manholes



The supporting strength of a pipe loaded under three-edge bearing test conditions is the same as in the installed condition.

- True
- False



Which installation method results in the highest soil load on the pipe?

- Negative projecting
- Positive projecting
- Trench
- Tunnel

Exam (cont.)



Name the two different types of Watertight joints.

- a) Soil Tight and Water Tight
- b) Tongue & Groove and Bell & Spigot
- c) O-ring and Profile
- d) Pressure and O-ring



What is the test used to determine D-load in a pipe?

- a) There is no test
- b) Three-Edge Bearing Test
- c) Joint Shear Test
- d) Hydrostatic Test



What two critical functions must buried concrete pipe perform?

- a) Barrier and Structure
- b) Framework and System
- c) Structure and Conduit
- d) Channel and Aqueduct



The earth load, live load and bedding factor are all considered in determining what?

- a) D-Load
- b) Hydraulic Capacity
- c) Diameter of Pipe
- d) Type of Joint



Thank you for participating in ACPA's online training.

Please send us an email at info@concrete-pipe.org if you would like to suggest a training topic to be added in the future. In the subject line include “online training topic.”



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