CONCRETE PIPE 101

www.concretepipe.org

June 2007

Agenda

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

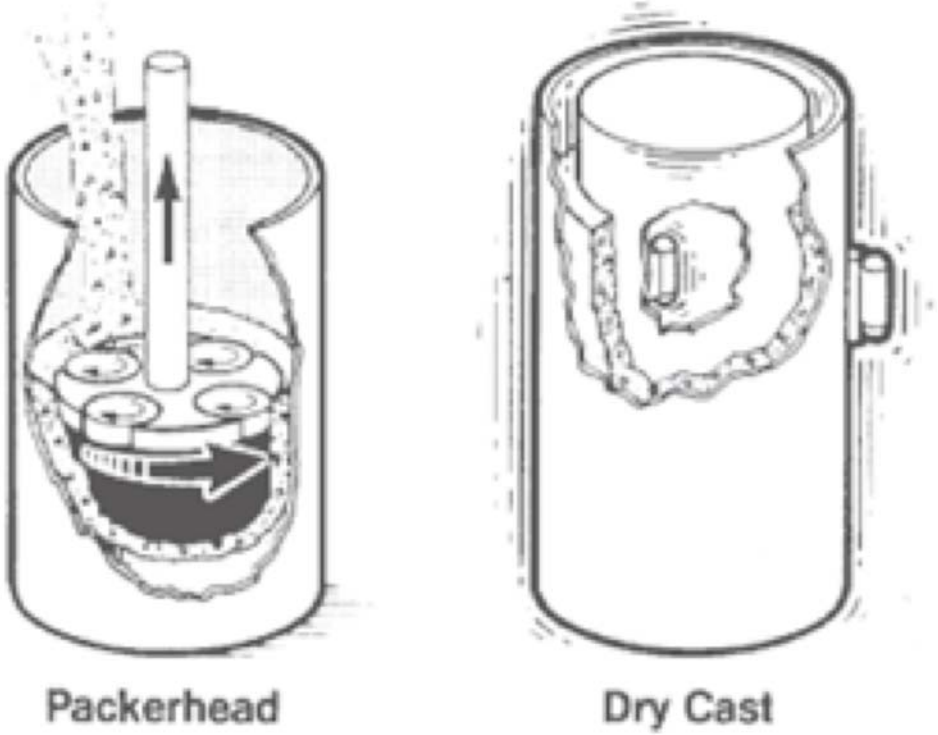
Manufacturing Methods

- **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**

Joints

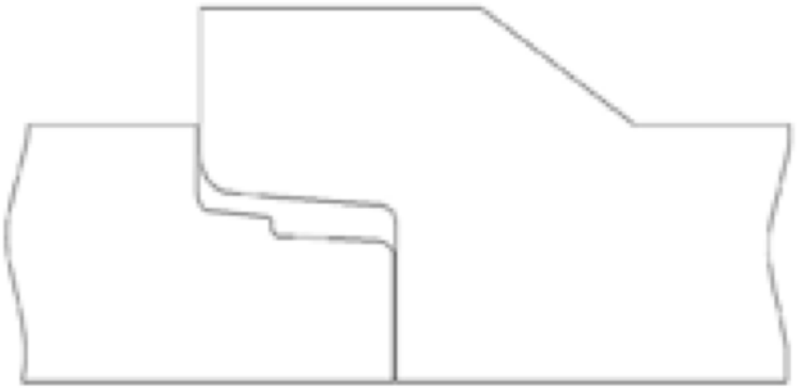
The links that make the system whole

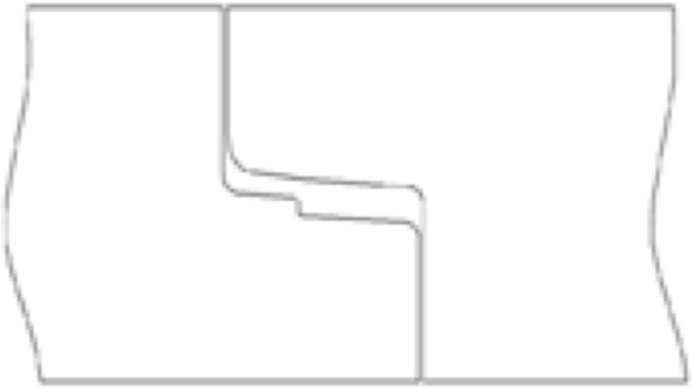
Additional Info in the Concrete Design Manual - click here

Bell & Spigot or Tongue & Groove
What's the Deal?

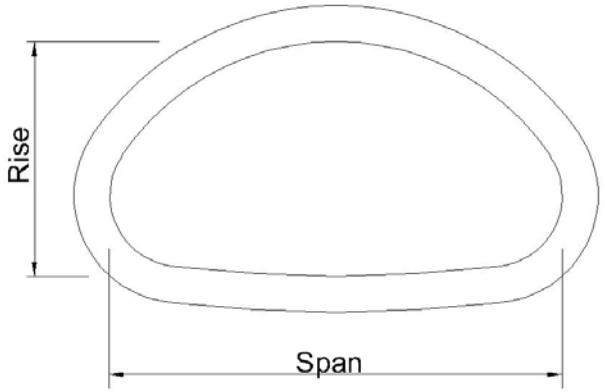
Female end of pipe (bell, groove) – portion of the end of the pipe, regardless of shape, which overlaps a portion of the end of the adjoining pipe

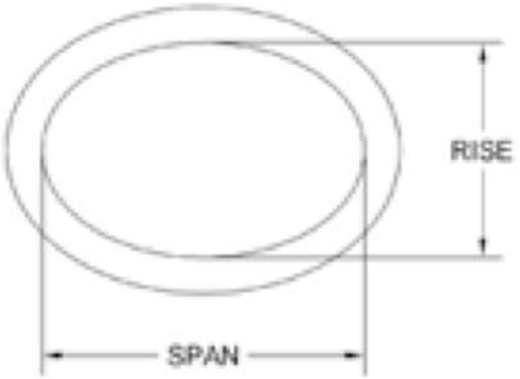
Male end of pipe (spigot, tongue) - portion of the end of the pipe, regardless of shape, which is overlapped by portion of the end of the adjoining pipe

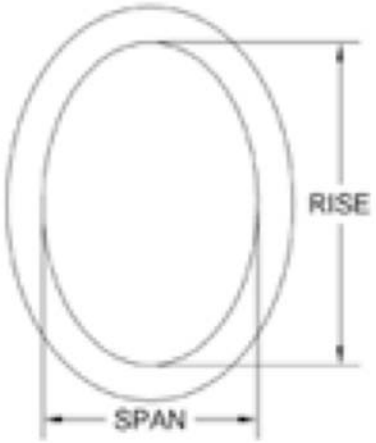


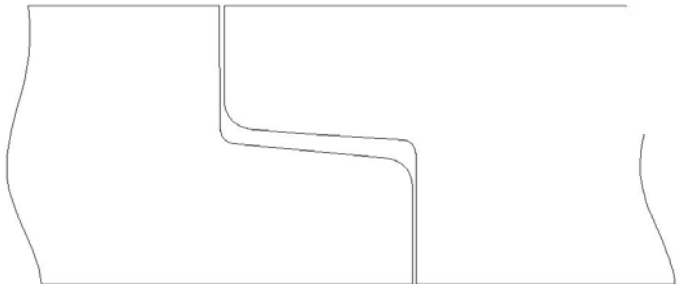


Arch & Elliptical Shapes









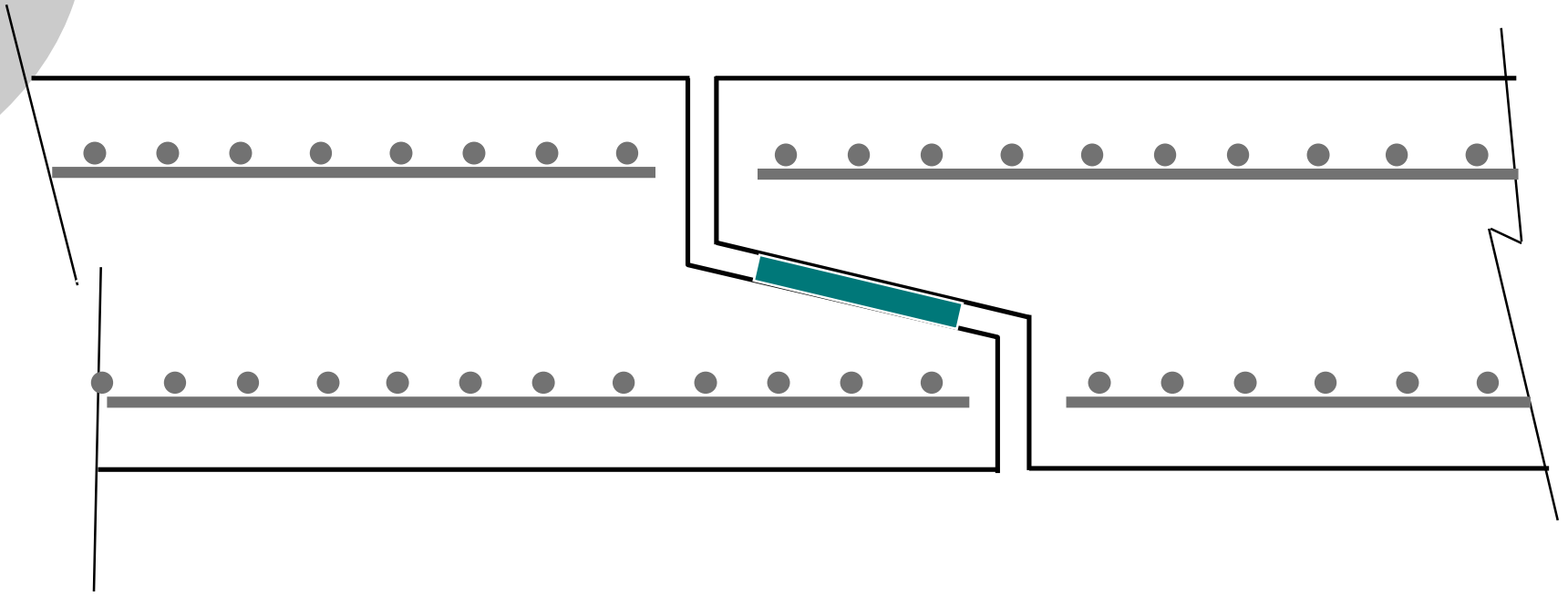
Define the Service Requirements

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

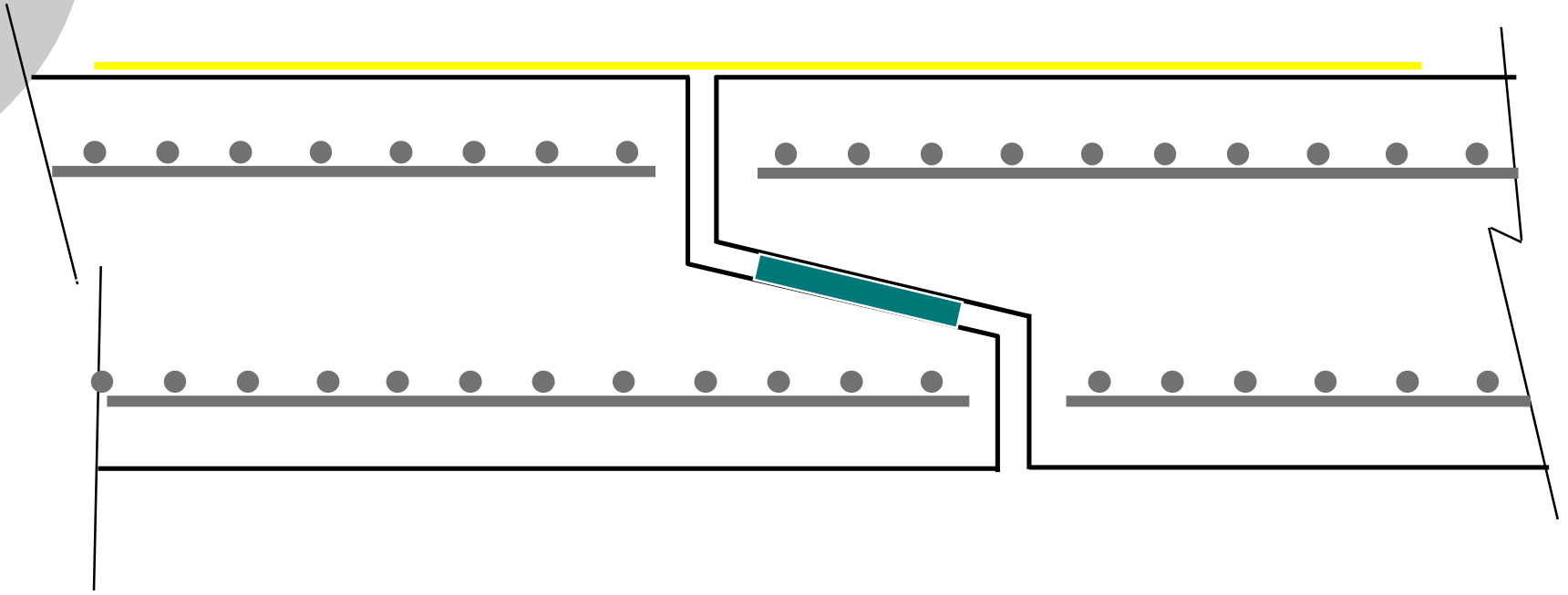
Soil Tight/ Silt Tight

- 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



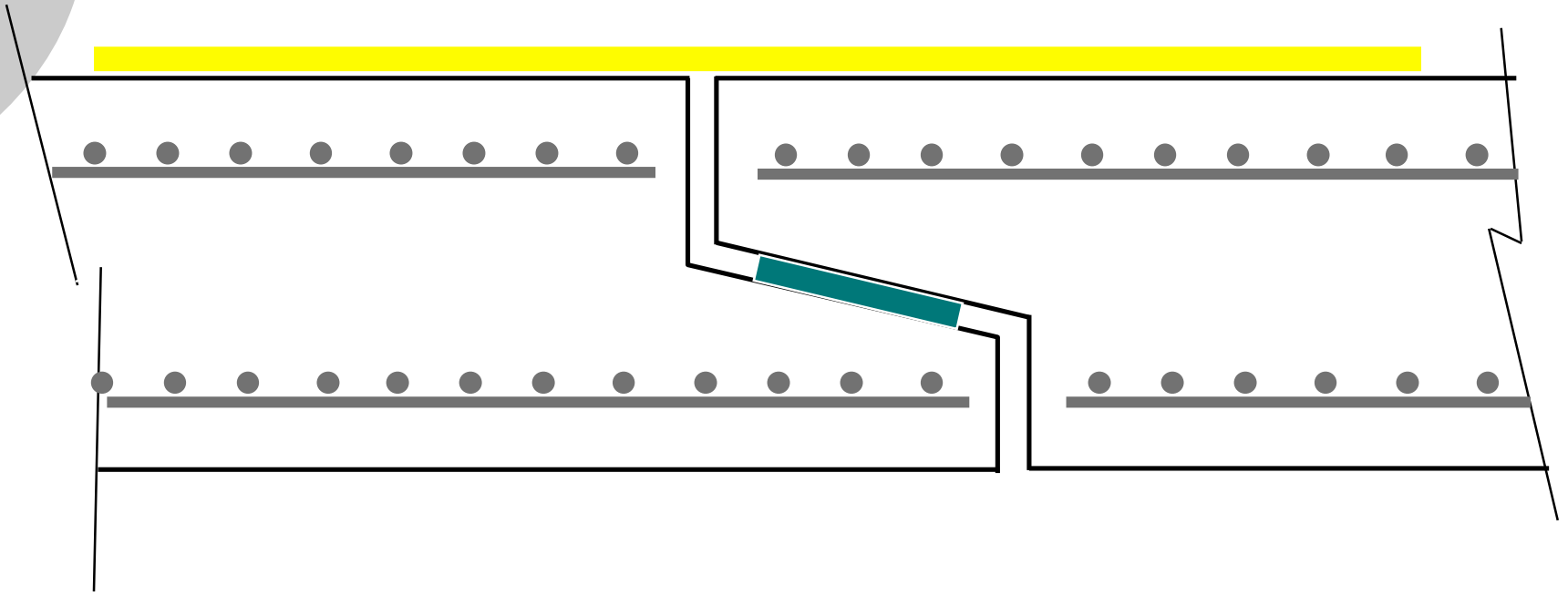
Soil Tight Joint with Fabric



Pushing Box Joint Home

Soil Tight/Silt Tight Joint with External Wrap

ASTM C877



Soil/ Silt Tight Joint

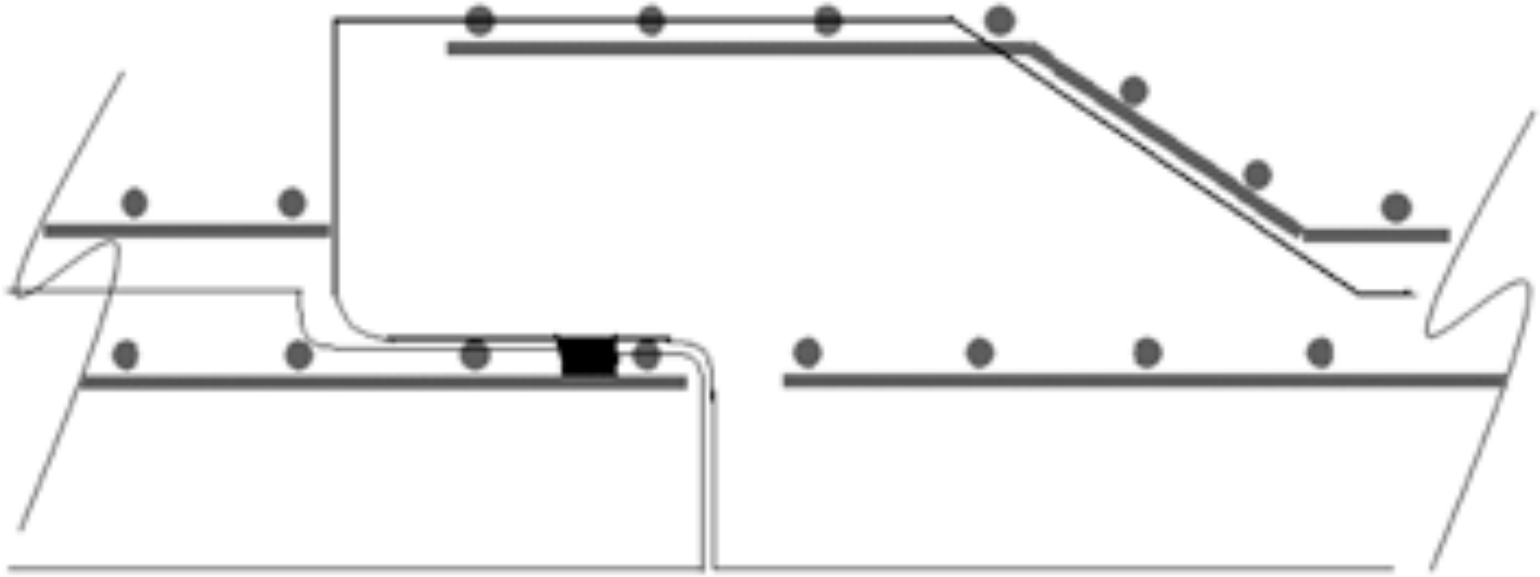
Soil Tight Joint

Watertight – Gravity*

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

* Tested to zero leakage in the manufacturing plant

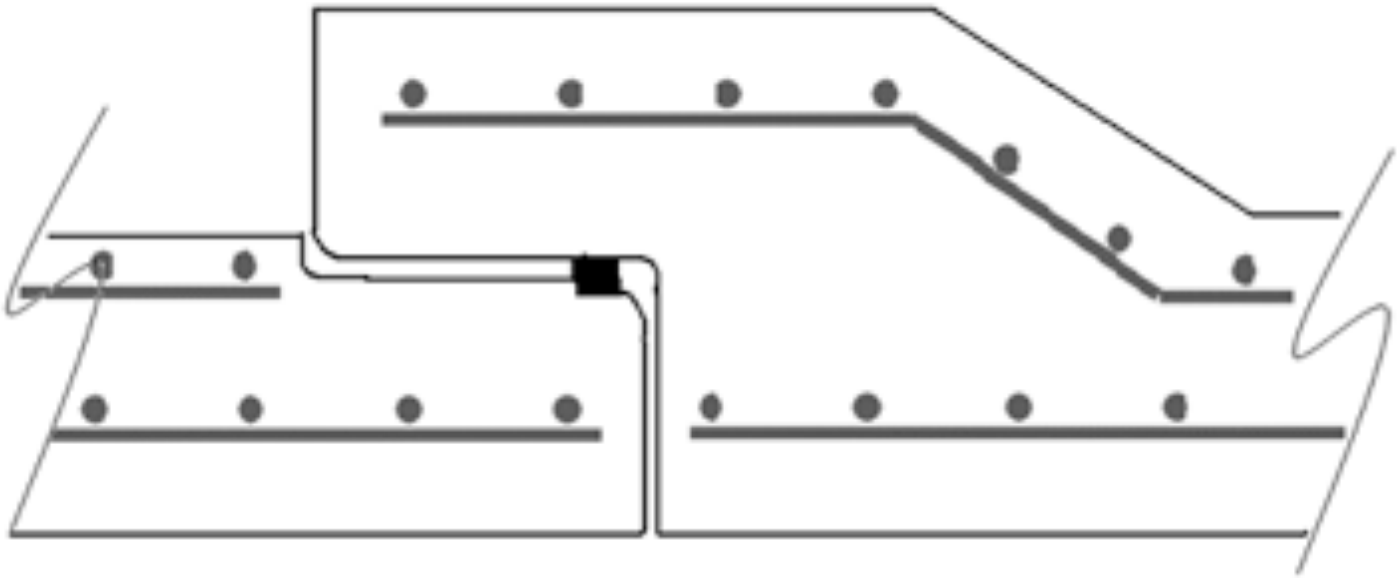
Watertight - Gravity Joint



Confined Gasket - O-Ring or Profile

Watertight - Gravity Joint

Watertight - Gravity Joint



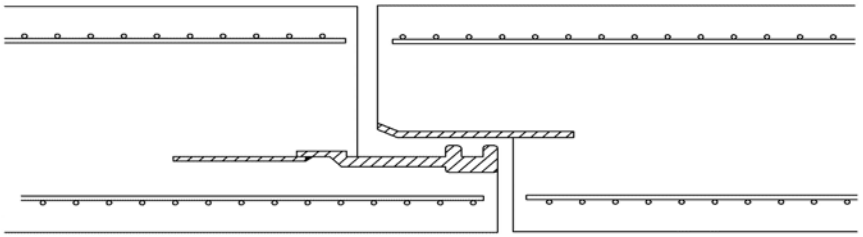
Offset Spigot - Profile Gasket

Watertight - Gravity Joint

Watertight - Pressure

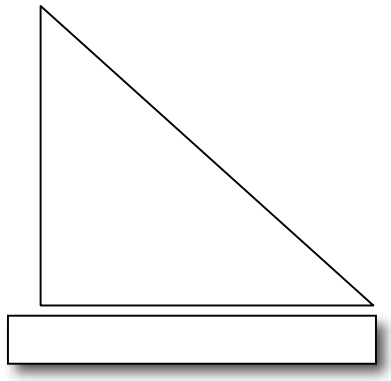
- **Precision Joint**
  - **O-Ring gasket**
- **ASTM C361**

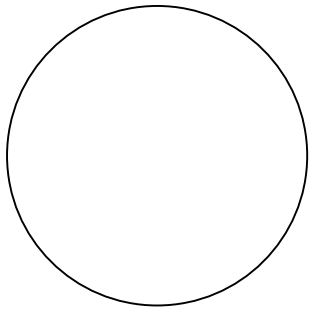
Steel Joint Ring Pipe



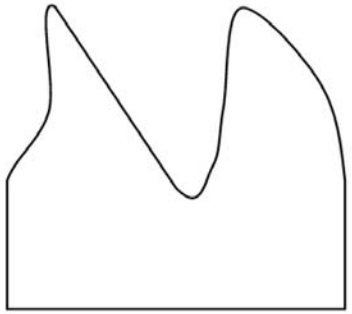
Gasket materials

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





o-ring gasket



profile gasket

Joint Testing

Ensures joint integrity after installation

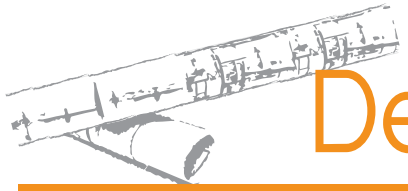
ASTM C497

- **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

American Concrete Pipe Association

Curved Alignment

Additional Info. – Click Here

Figure 3 Radius Pipe

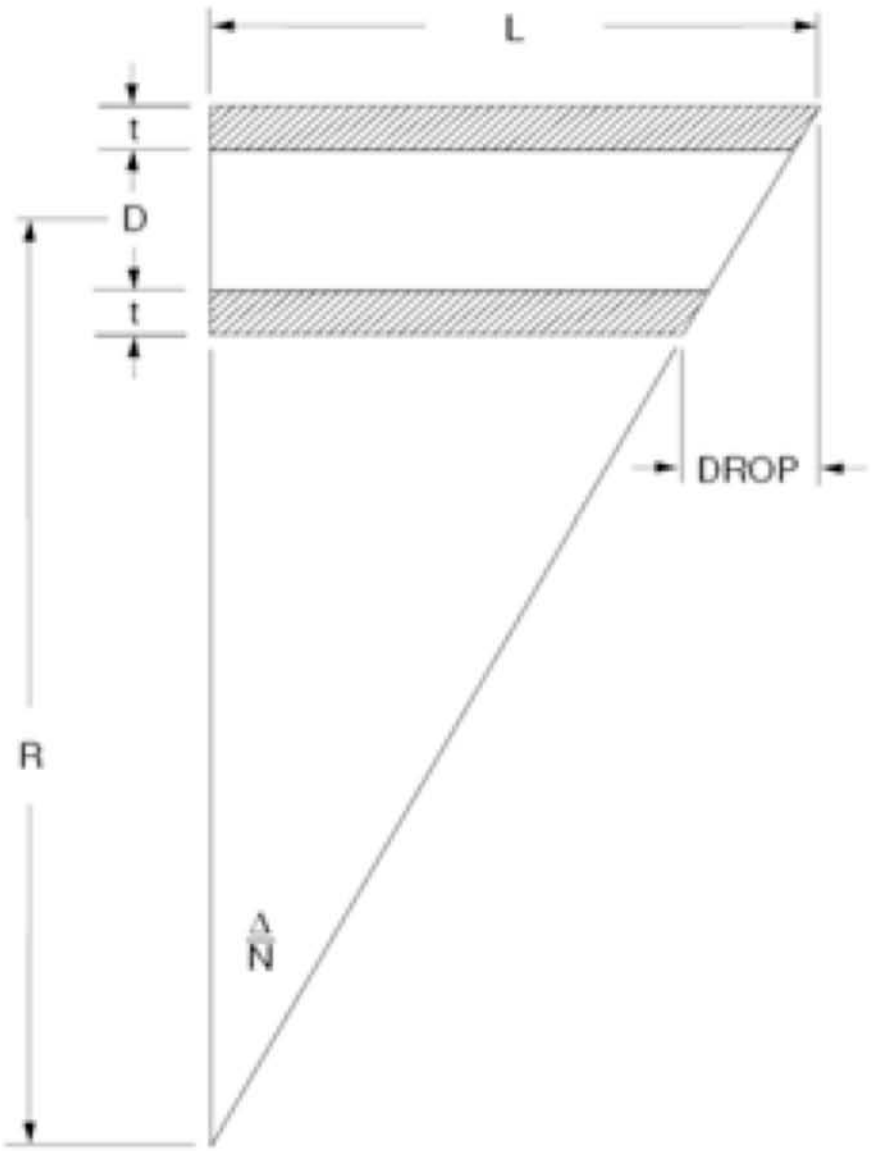
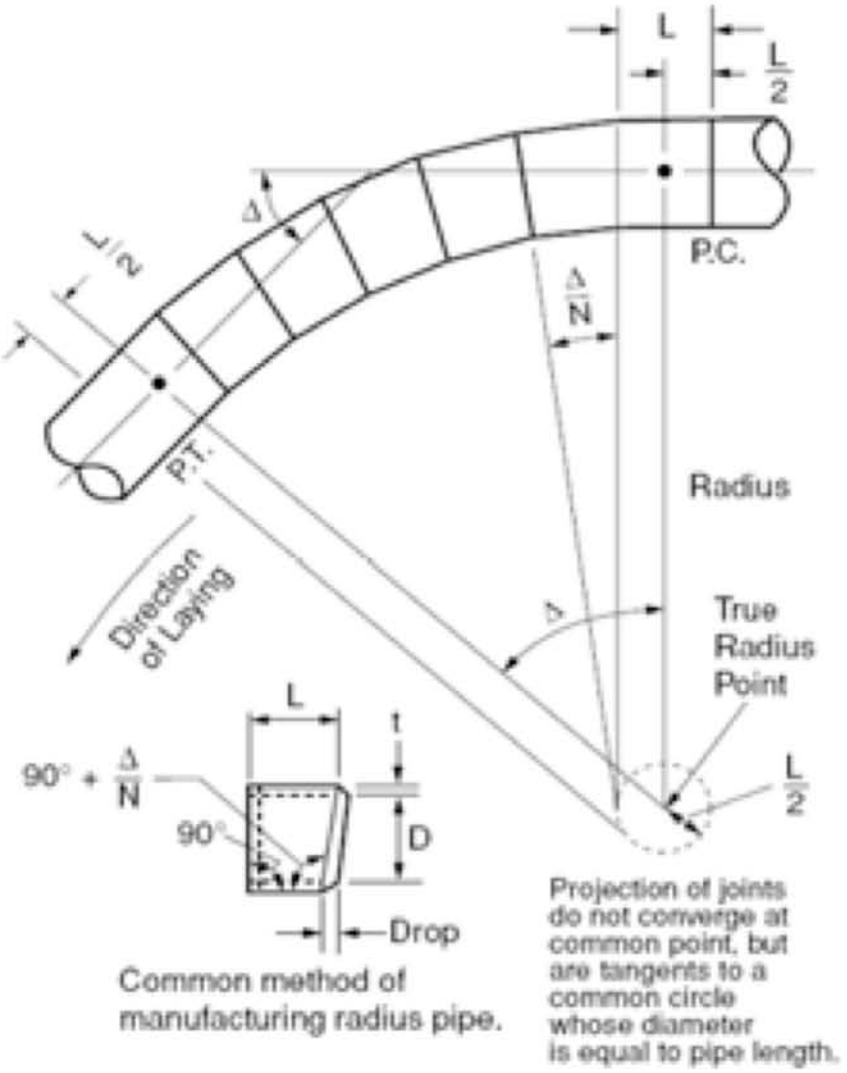


Figure 4 Curved Alignment Using Radius Pipe



Common method of manufacturing radius pipe.

Projection of joints do not converge at common point, but are tangents to a common circle whose diameter is equal to pipe length.

Fittings

- Bends
- Tees/Wyes
- Reducers/
- Increasers
- Adapters

Fittings

- Bends
- Tees/Wyes
- Reducers/Increasers
- Adapters


11/27/2000

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 – 02ε1

Standard Test Method for Concrete Sewer Manholes by the Negative Air Pressure (Vacuum) Test Prior to Backfill[1]

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.

ε1 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

Manhole Sizing

- Flexibility
- Handling
- Weight

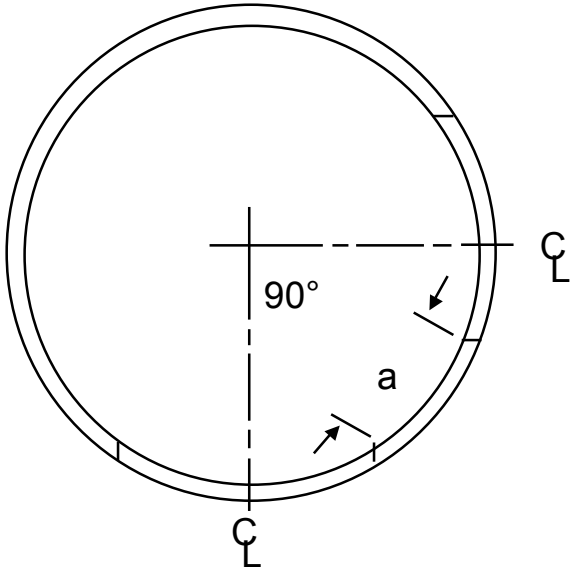
SIZING MANHOLES

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= Circumference/360º

M x Angle = Y
Y - Pipe #1 Opening/2 - Pipe #2 Opening/2 = a
A = Distance between the two openings
Minimum “a” is ≥ 6” for 48” - 72” Dia. MH and
≥ 8” for ≥ *4” Dia. MH



Pipe #1

Example:
Pipe #1 = 36” RCP “B” Wall @ 6:00
Pipe #2 = 36” RCP “B” Wall @ 3:00
Angle = 90º
Try 72” Dia. MH
Y = 0.6283 x 90º = 56.55
A = 56.55” - 53/2 - 53/2 = 3.55” < 6”; too small
Therefore, try 84” Dia. MH:
Y = 0.7330 x 90º = 65.97”
A = 65.97” - 51/2 - 51/2 = 14.97” > 8”; OK

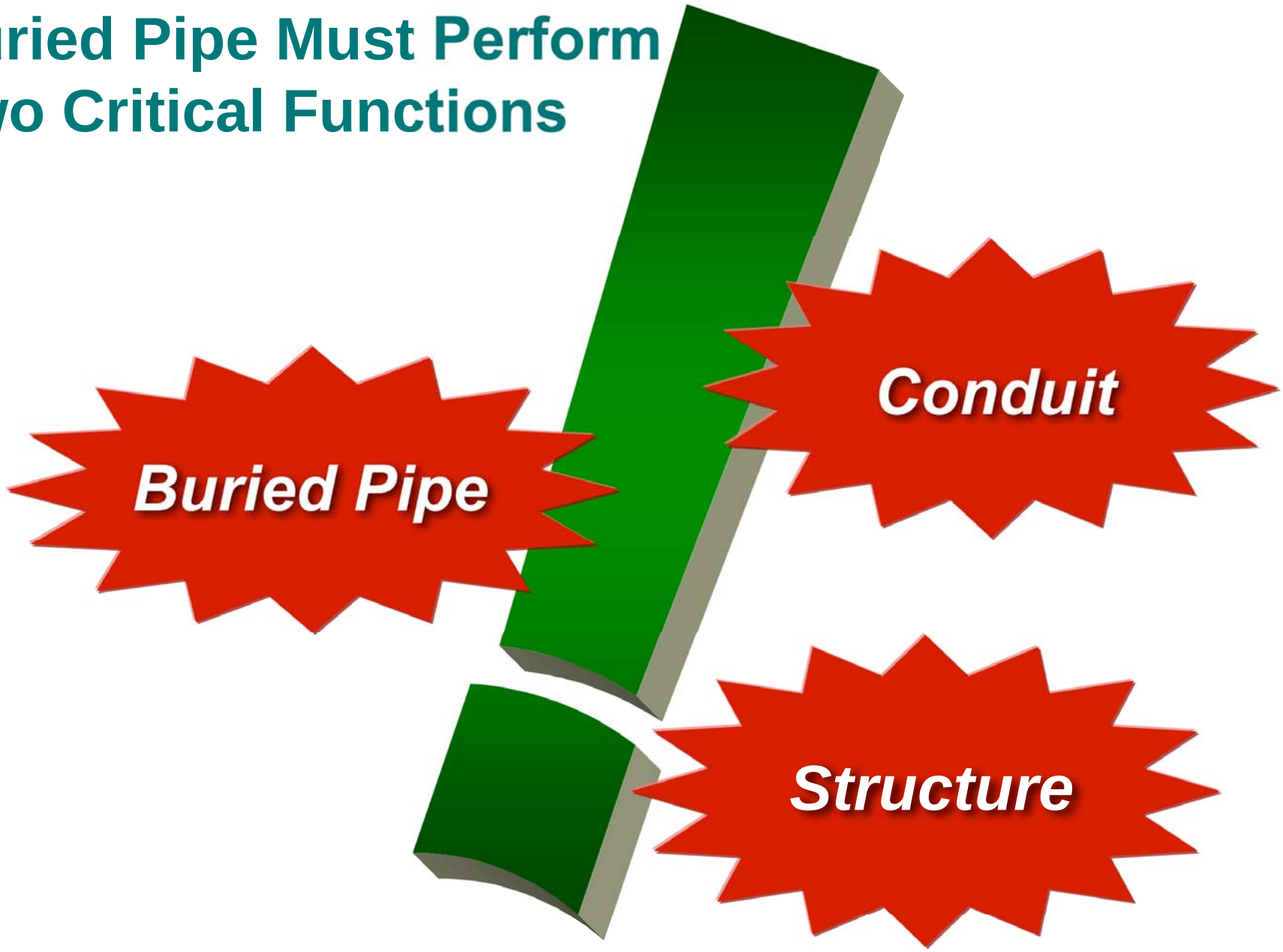
Pipe Dia., in.	Hole chord Dim., in.	Hole Size (Arc) per MH Diameter, in.				
		48”Ø	60”Ø	70”Ø	84”Ø	96”Ø
12	20	20.5	20.4	20	20	20
15	24	25	25	24.5	24	24
18	27	29	28	28	27.5	28
224	34	38	36	35	35	35
30	41		45	43	43	45
36	48/50		55.5/59	5./55	51/53.5	50/53
42	55/57		70/75	63/66	60/63	59/61
48	62/64			75/79	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 :

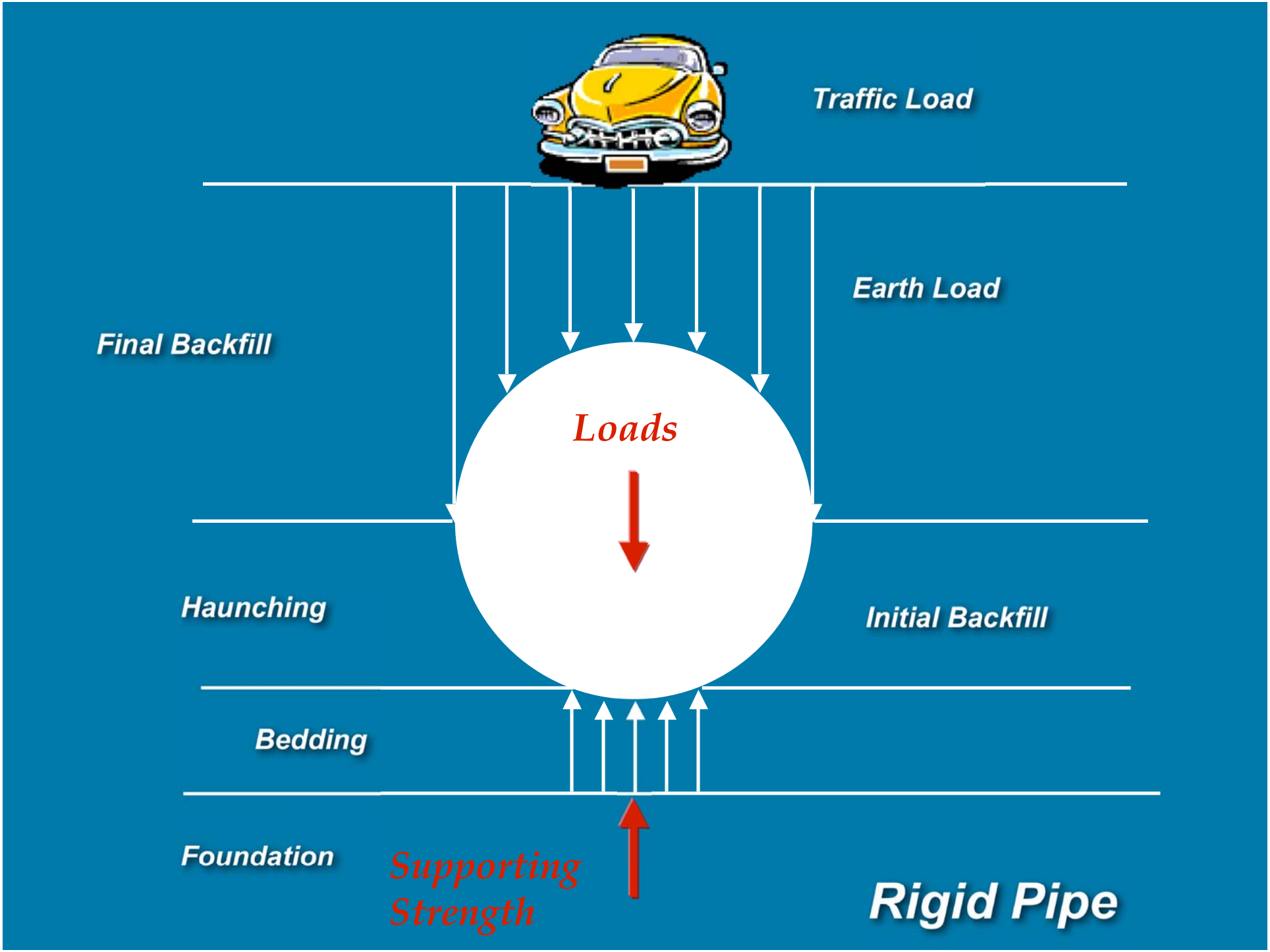
Buried Pipe Must Perform Two Critical Functions



Structure

Conduit

Concrete Pipe


Traffic Load
Earth Load
Final Backfill
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 ?

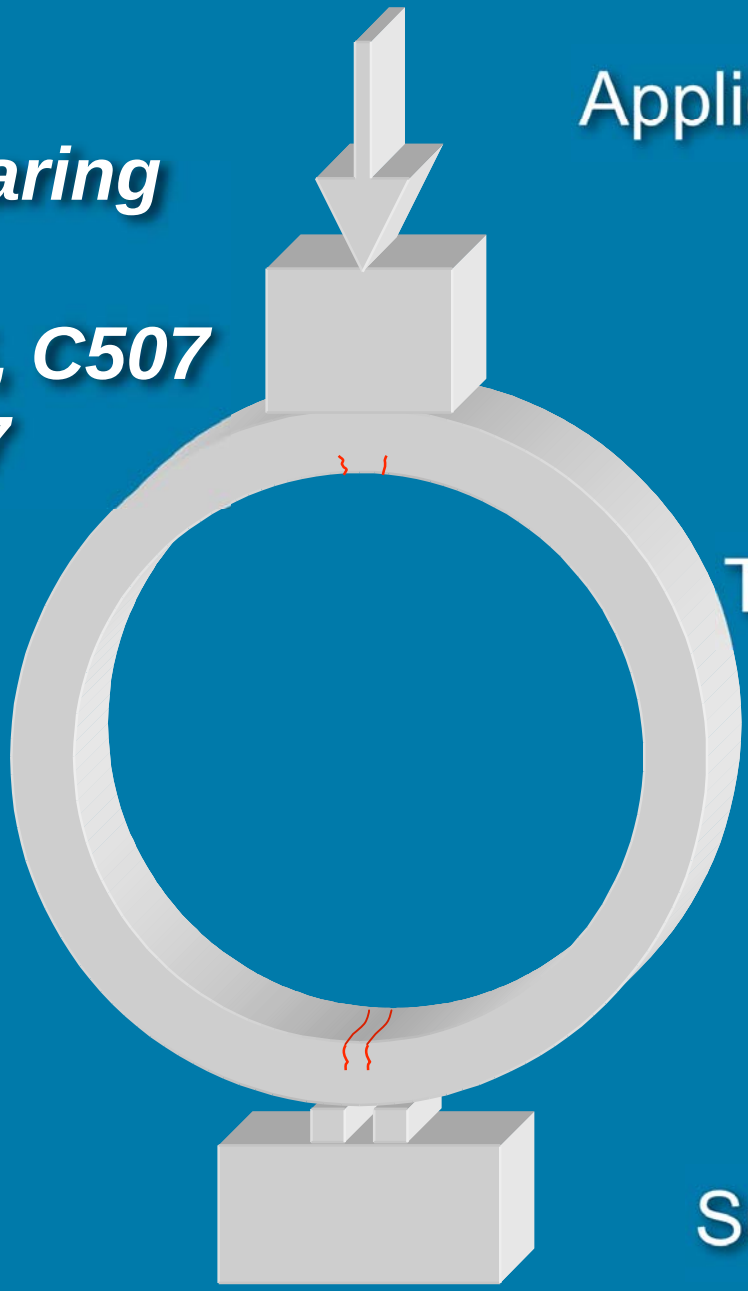
Wall Thickness & Reinforcement

- **A-Wall – Wall thickness in inches = Diameter in feet**
- **B-Wall – Wall thickness in inches =Diameter in feet +1”**
- **C-Wall – Wall thickness in inches =Diameter in feet +1.75”**

- **24” Pipe = 2” Wall**
- **24” Pipe = 3” Wall**
- **24” Pipe = 3.75” Wall**

Three-Edge-Bearing

ASTM C76, C506, C507
ASTM C497



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

Gravity Pipe *Classes*


Designation: C 76 – 00

Standard Specification for
Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe[1]

AASHTO M170 ASTM C76 Class	D-Load .01	D-Load Ult.
I	800	1200
II	1000	1500
III	1350	2000
IV	2000	3000
V	3000	3750

60” ASTM C-76 Class IV 8’

$D_{0.01} = 2000$

$D_{ULT} = 3000$

Total Load Required:

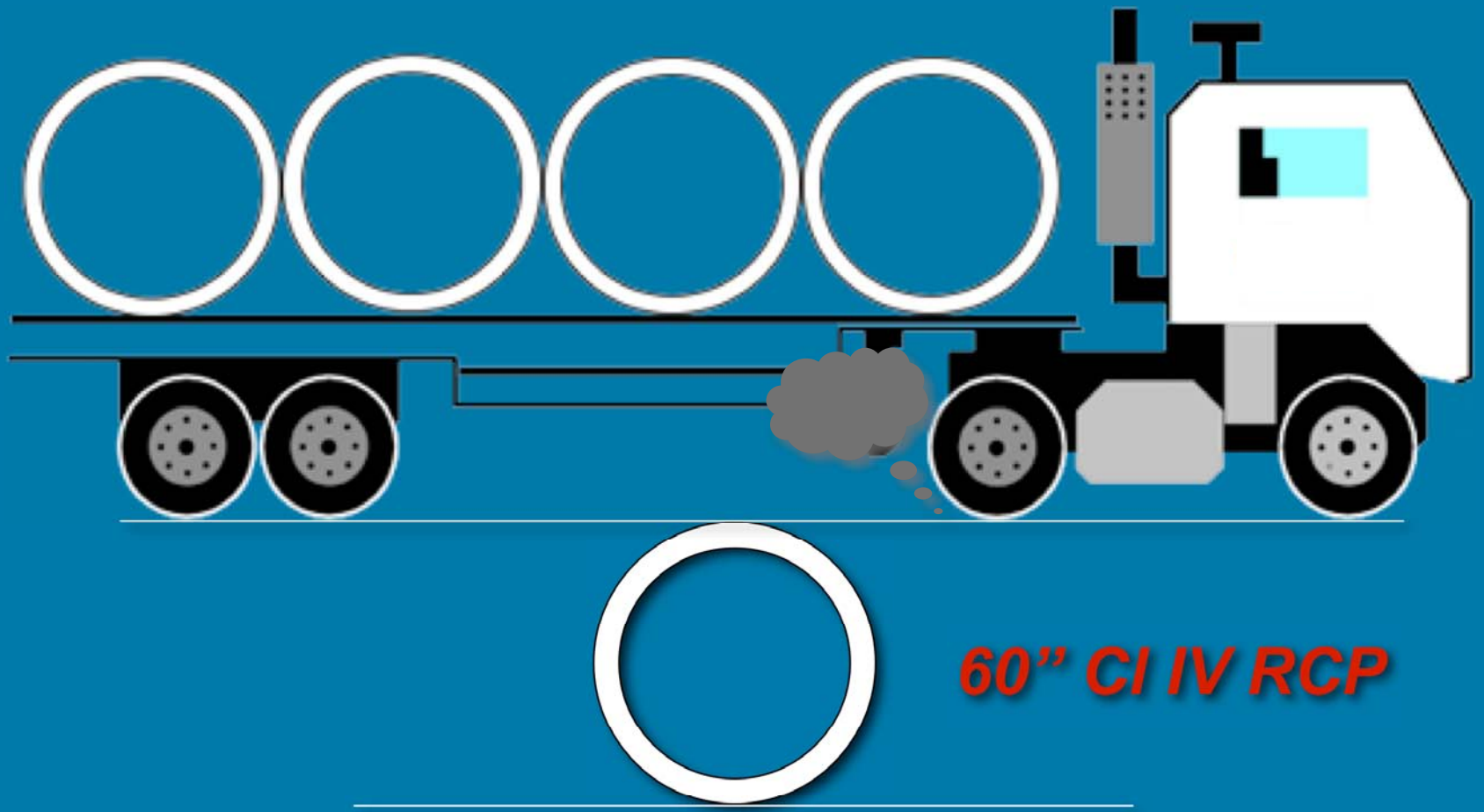
$D_{0.01} = (60/12)(8)(2000)$

$= 80{,}000$ lbs.

$D_{ULT} = (60/12)(8)(3000)$

$= 120{,}000$ lbs.

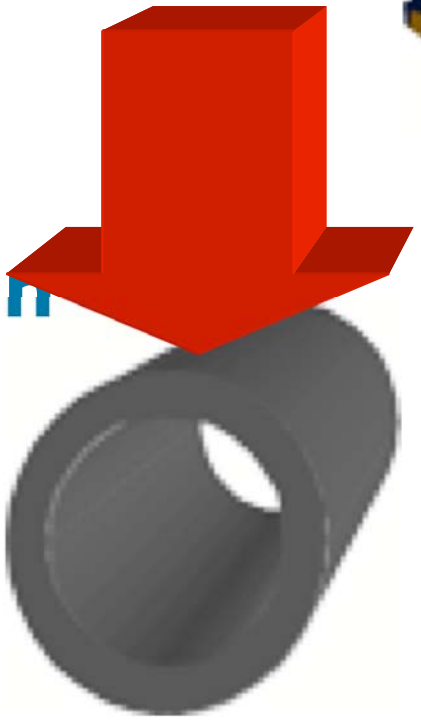
80,000 lbs.



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-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

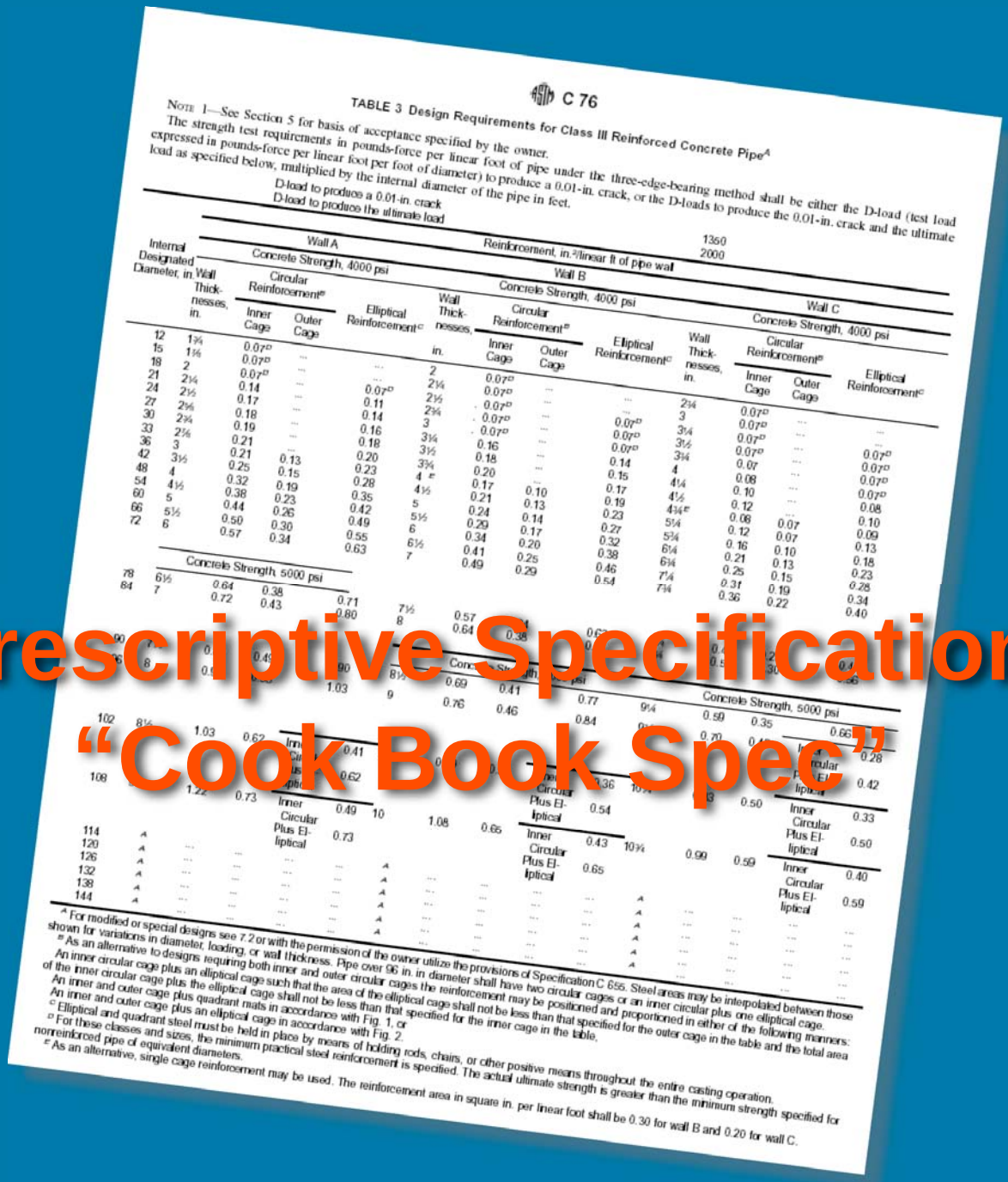
Additional Info in the Concrete Design Manual - click here

Gravity Pipe *Classes*


Designation: C 76 – 00

Standard Specification for
Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe

AASHTO M170 ASTM C76 Class	D-Load .01	D-Load Ult.
I	800	1200
II	1000	1500
III	1350	2000
IV	2000	3000
V	3000	3750



C 76

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 per 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 1350
D-load to produce the ultimate load 2000

Internal Designated Diameter, in.	Wall A Concrete Strength, 4000 psi				Wall B Concrete Strength, 4000 psi				Wall C Concrete Strength, 4000 psi			
	Wall Thicknesses, in.	Reinforcement, in.²/linear ft of pipe wall: Circular Reinforcement[B] Inner Cage	Circular Reinforcement[B] Outer Cage	Elliptical Reinforcement[C]	Wall Thicknesses, in.	Circular Reinforcement[B] Inner Cage	Circular Reinforcement[B] Outer Cage	Elliptical Reinforcement[C]	Wall Thicknesses, in.	Circular Reinforcement[B] Inner Cage	Circular Reinforcement[B] Outer Cage	Elliptical Reinforcement[C]
12	1⅜	0.07[D]	...	...	2	0.07[D]	...	...	2¼	0.07[D]	...	...
15	1⅝	0.07[D]	...	...	2¼	0.07[D]	...	...	3	0.07[D]	...	...
18	2	0.07[D]	...	0.07[D]	2½	0.07[D]	...	...	3¼	0.07[D]	...	...
21	2¼	0.14	...	0.11	2¾	0.07[D]	...	...	3½	0.07[D]	...	0.07[D]
24	2½	0.17	...	0.14	3	0.07[D]	...	...	3¾	0.07[D]	...	0.07[D]
27	2⅝	0.18	...	0.16	3¼	0.07[D]	...	...	4	0.07	...	0.07[D]
30	2¾	0.19	...	0.18	3½	0.16	...	...	4¼	0.08	...	0.08
33	2⅞	0.21	...	0.20	3¾	0.18	...	...	4½	0.10	...	0.10
36	3	0.21	0.13	0.23	4[E]	0.20	...	...	4¾[E]	0.12	...	0.09
42	3½	0.25	0.15	0.28	4½	0.17	0.10	...	5¼	0.08	0.07	0.13
48	4	0.32	0.19	0.35	5	0.21	0.13	...	5¾	0.12	0.07	0.18
54	4½	0.38	0.23	0.42	5½	0.24	0.14	...	6¼	0.16	0.10	0.23
60	5	0.44	0.26	0.49	6	0.29	0.17	...	6¾	0.21	0.13	0.28
66	5½	0.50	0.30	0.55	6½	0.34	0.20	...	7¼	0.25	0.15	0.34
72	6	0.57	0.34	0.63	7	0.41	0.25	...	7¾	0.31	0.19	0.40
		Concrete Strength, 5000 psi									0.22	
78	6½	0.64	0.38	0.71	7½	0.49	0.29	...				
84	7	0.72	0.43	0.80	8	0.57						
						0.64						
					8½	0.69	0.41	0.77	9¼	0.59	0.35	0.66
102	8½	1.03	0.62	1.03	9	0.76	0.46	0.84		0.70	0.42	0.78
108		1.22	0.73	Inner Circular Plus Elliptical 0.49	10	1.08	0.65	Inner Circular Plus Elliptical 0.54	10¾	0.99	0.59	Inner Circular Plus Elliptical 0.50
114	A	...	...	0.73	A	...	...	Inner Circular Plus Elliptical 0.43	A	...	...	Inner Circular Plus Elliptical 0.40
120	A	...	...	...	A	...	...	0.65	A	...	...	0.59
126	A	...	...	...	A	...	...	...	A	...	...	...
132	A	...	...	...	A	...	...	...	A	...	...	...
138	A	...	...	...	A	...	...	...	A	...	...	...
144	A	...	...	...	A	...	...	...	A	...	...	...

[A] For modified or special designs see 7.2 or with the permission of the owner utilize the provisions of Specification C 655. 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 inner cage in the table.
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.

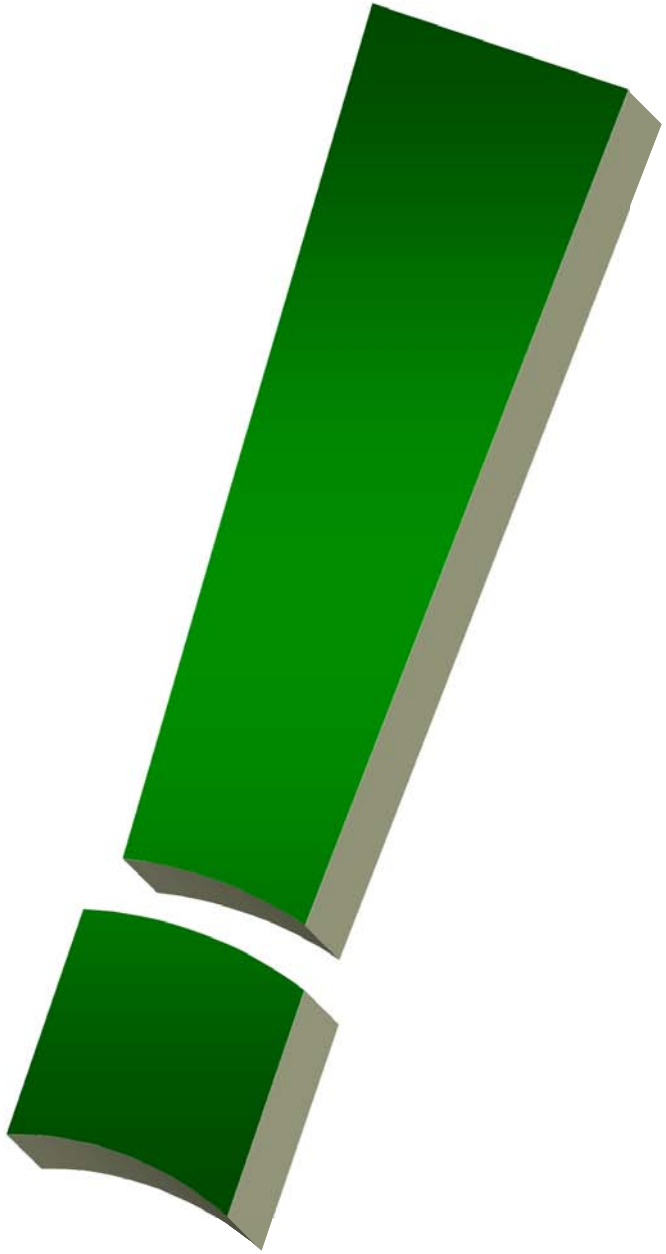
[C] Elliptical and quadrant steel must be held in place by means of holding rods, chairs, or other positive means throughout the entire casting operation.

[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.

Prescriptive Specification
"Cook Book Spec"

Bedding Factor depends on type and quality of installation



Standard Installations – Click here

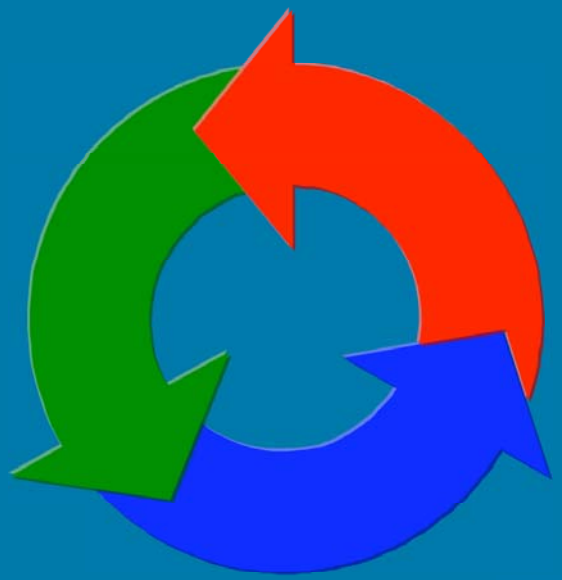
Who Is Responsible for Bedding Factor?

- **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



Durability

Structure

Joint

System Design

Structure

Design Basics

Installation Methodology & Earth Load Determination

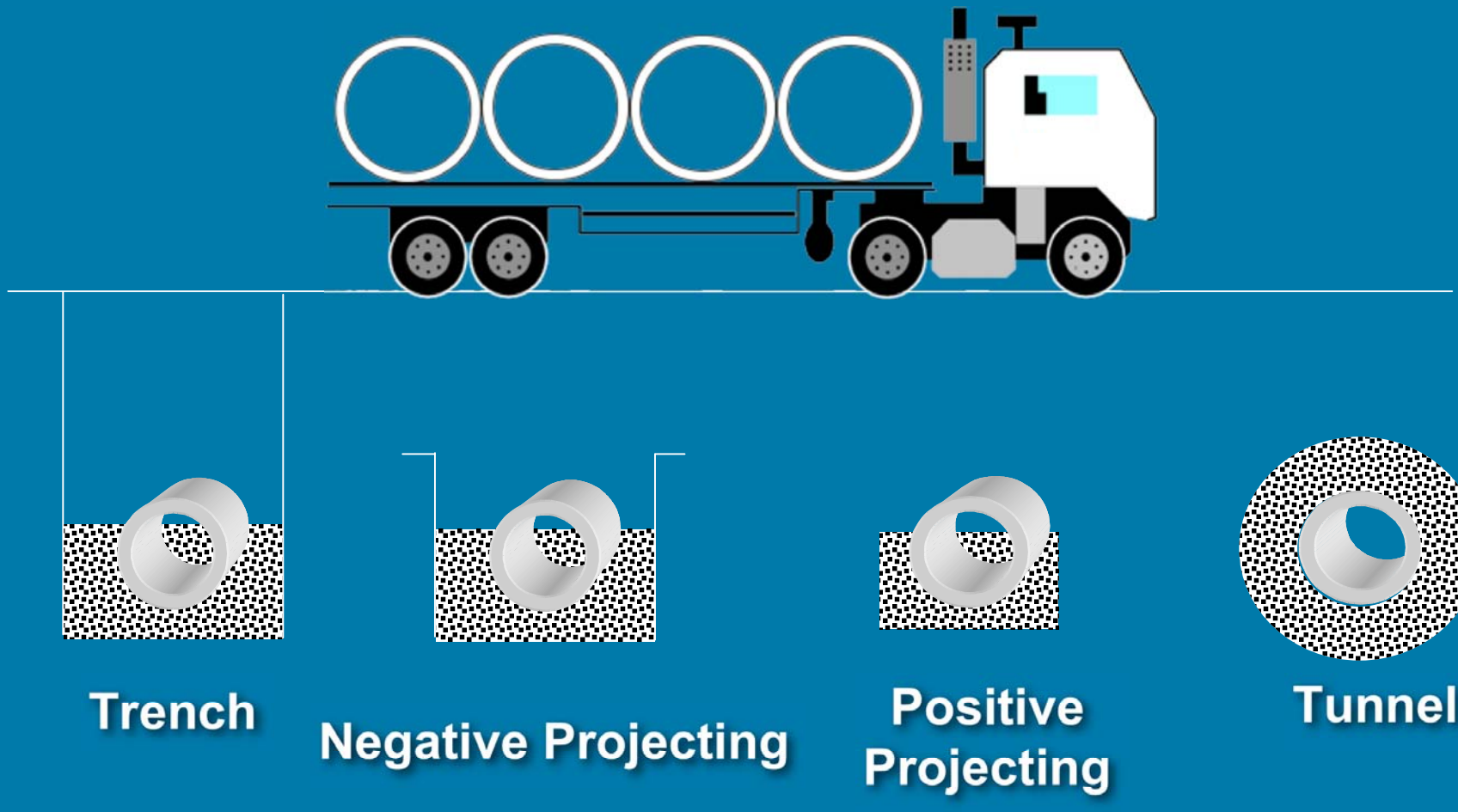
Additional Info in the Concrete Design Manual - click here

Pipe Installation Methods

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

Additional Info in the Concrete Design Manual - click here

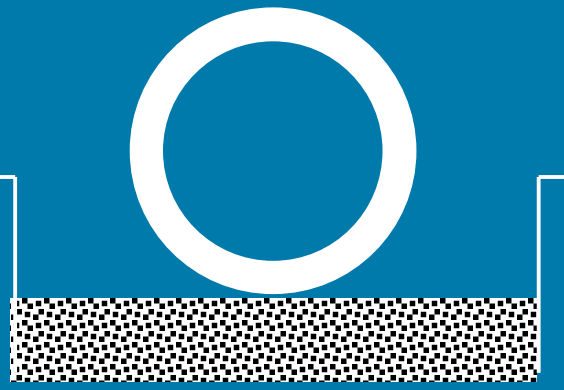
Installation Methods



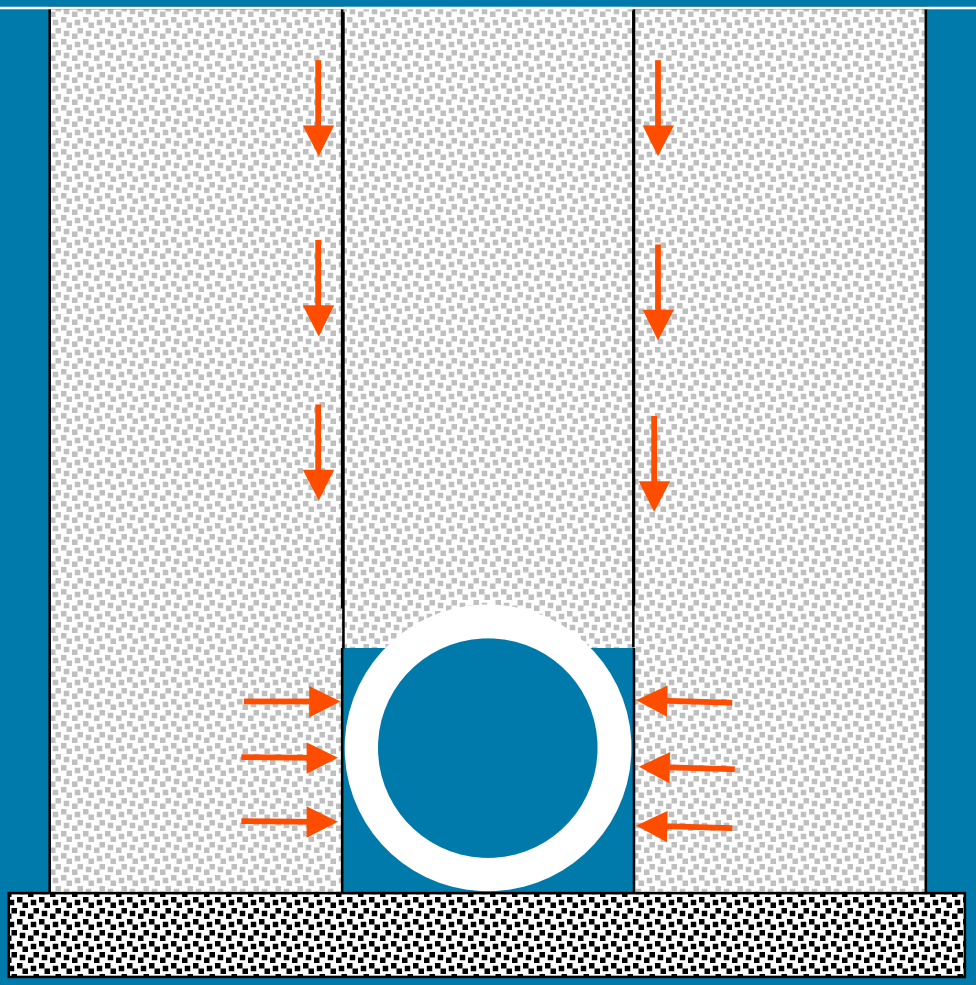
Positive Projecting Embankment

Final Grade

Existing Grade

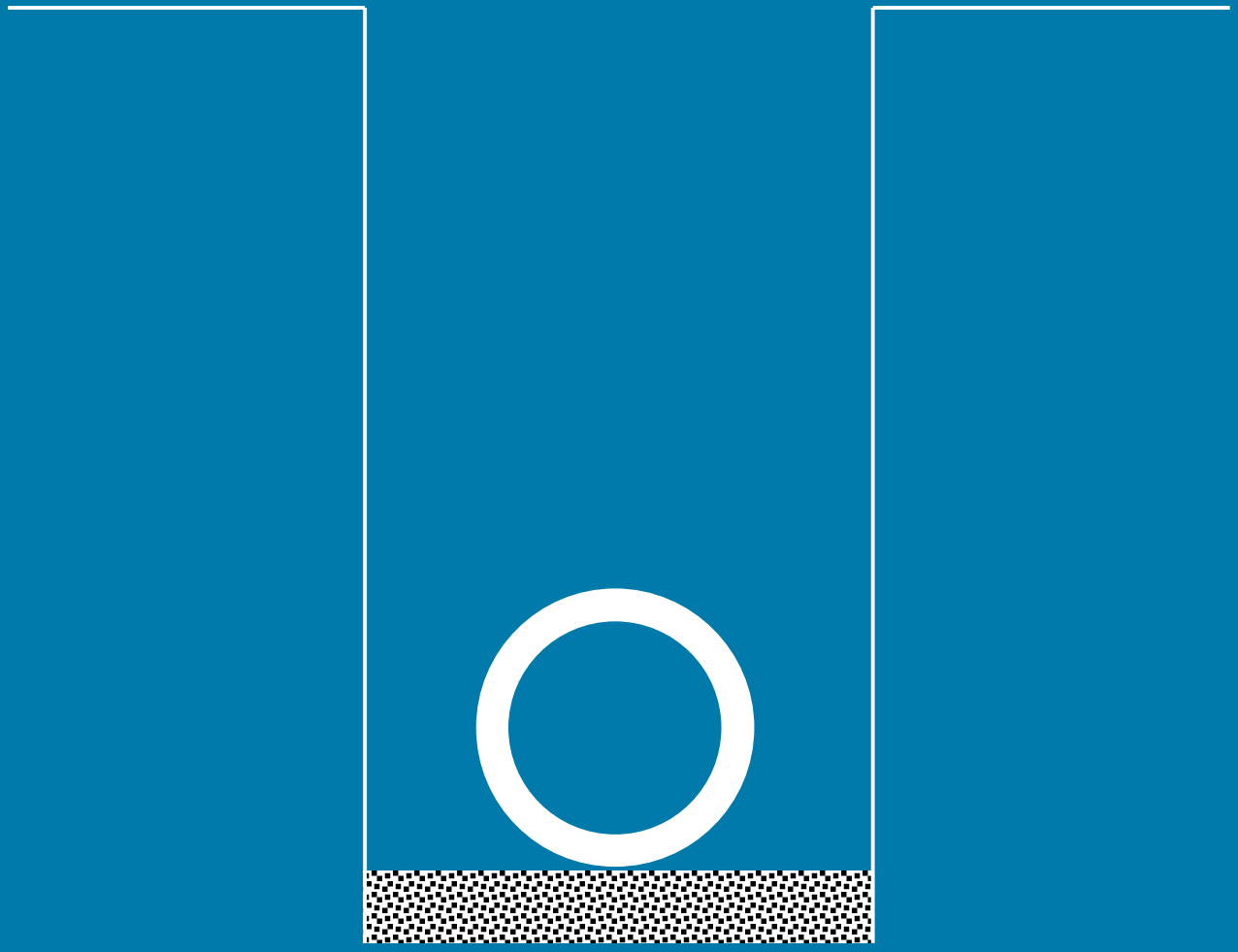


Positive Projecting Embankment

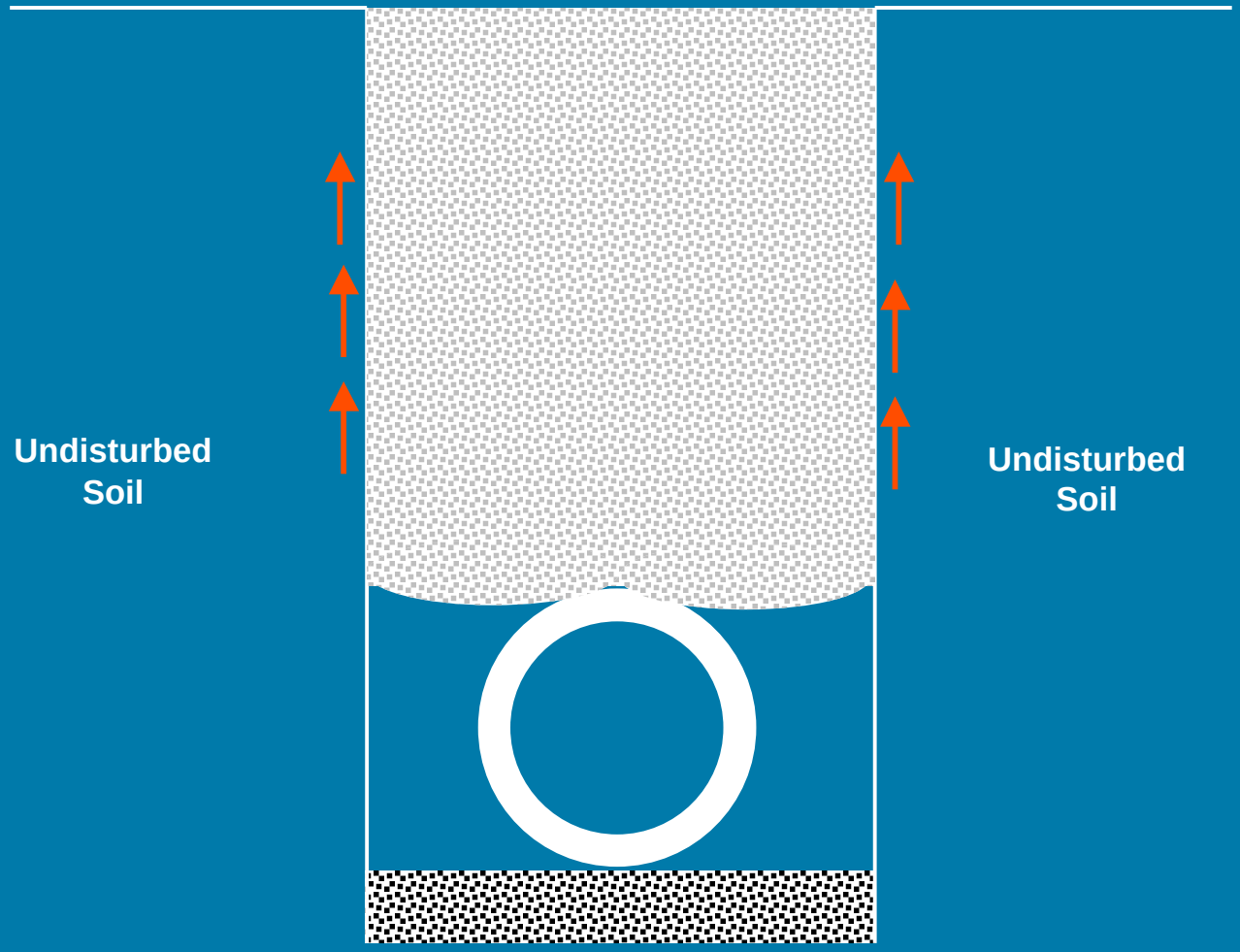


Trench

Existing and Final Grade



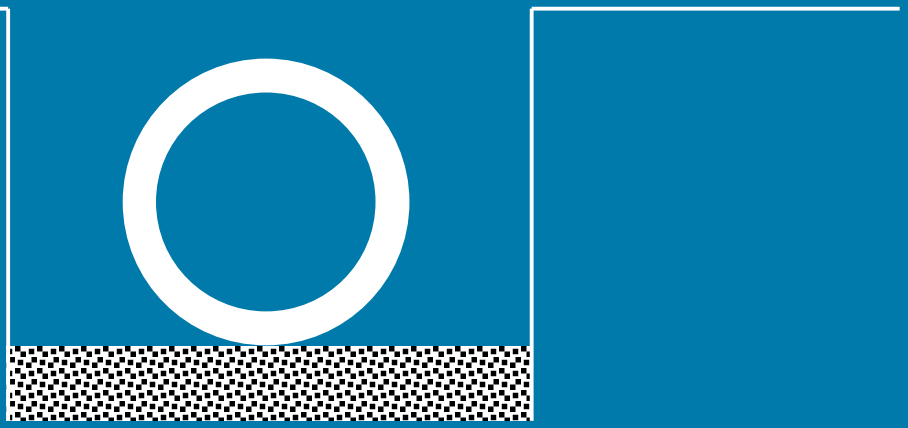
Trench



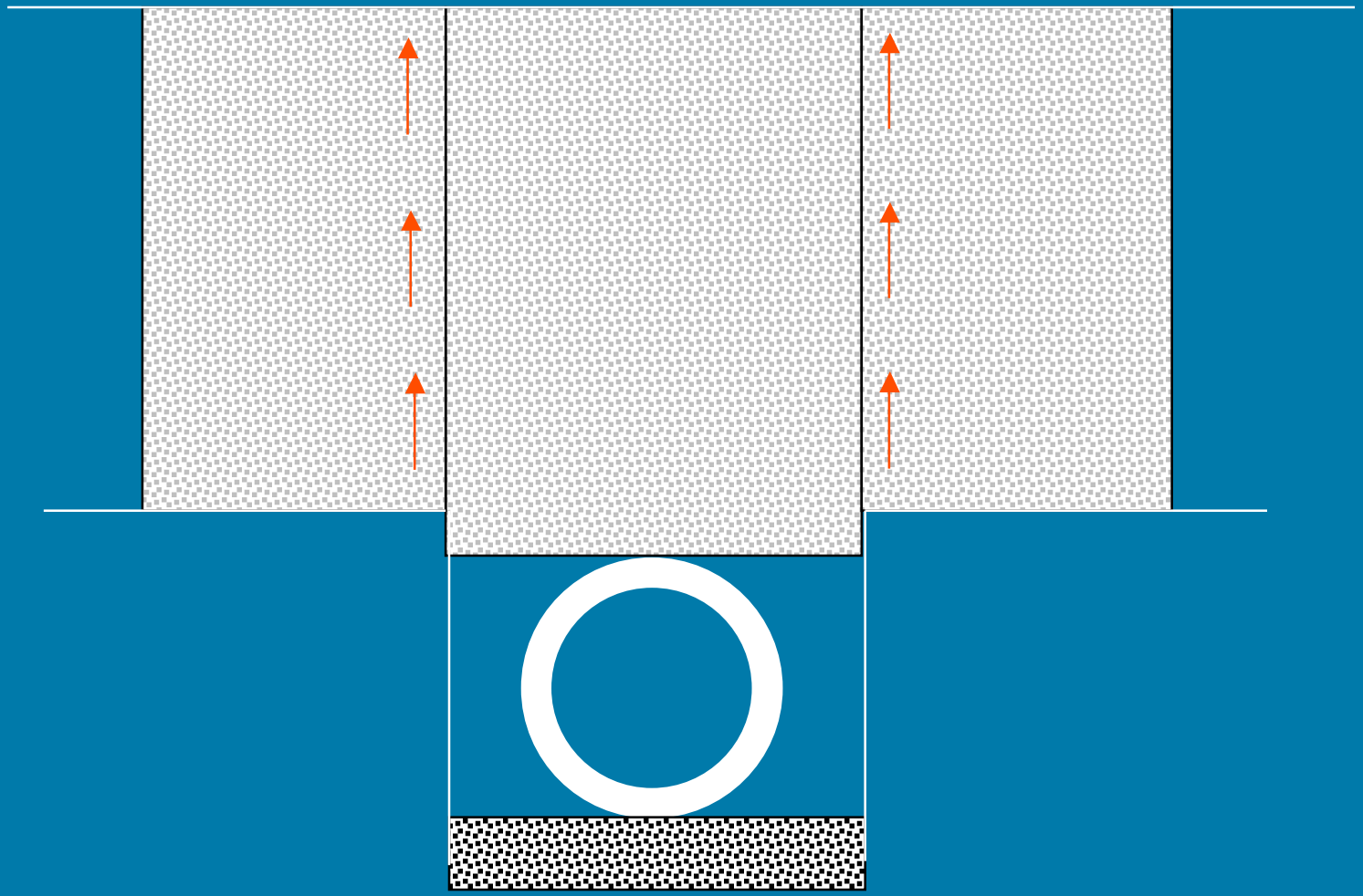
Negative Projecting Embankment

Final Grade

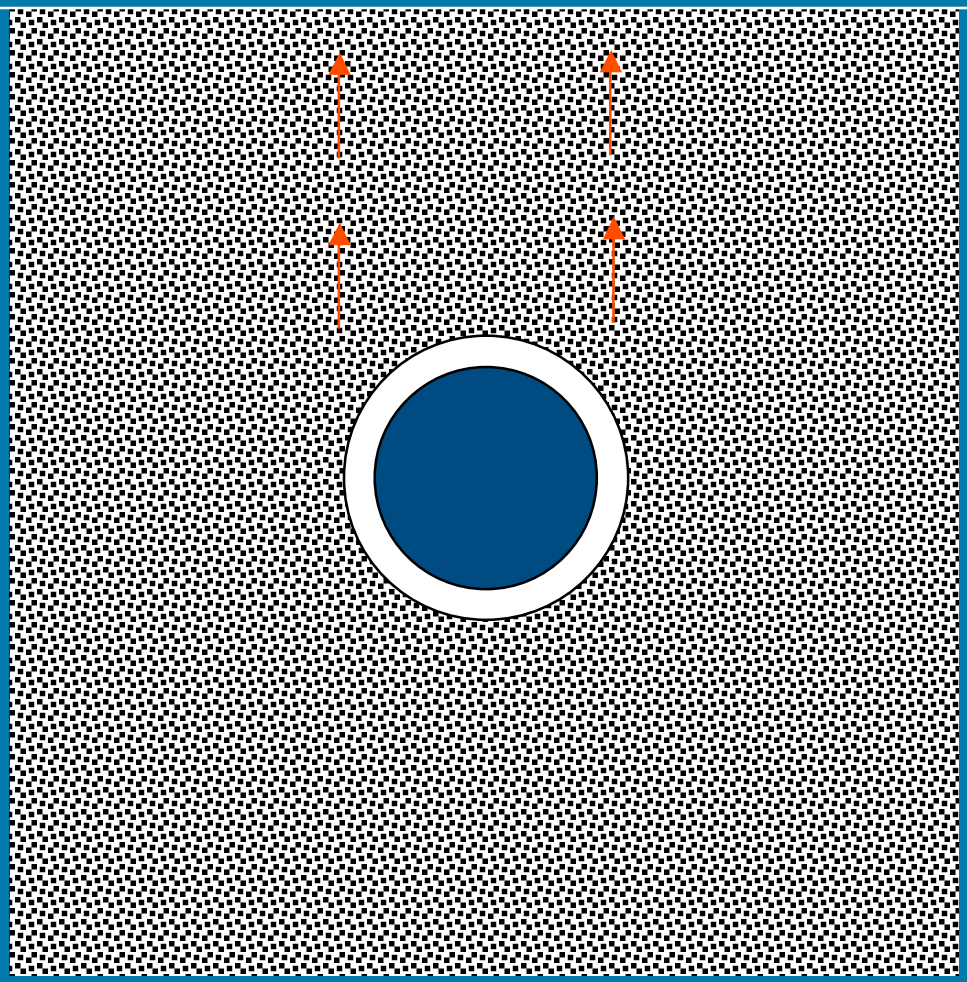
Existing Grade



Negative Projecting Embankment



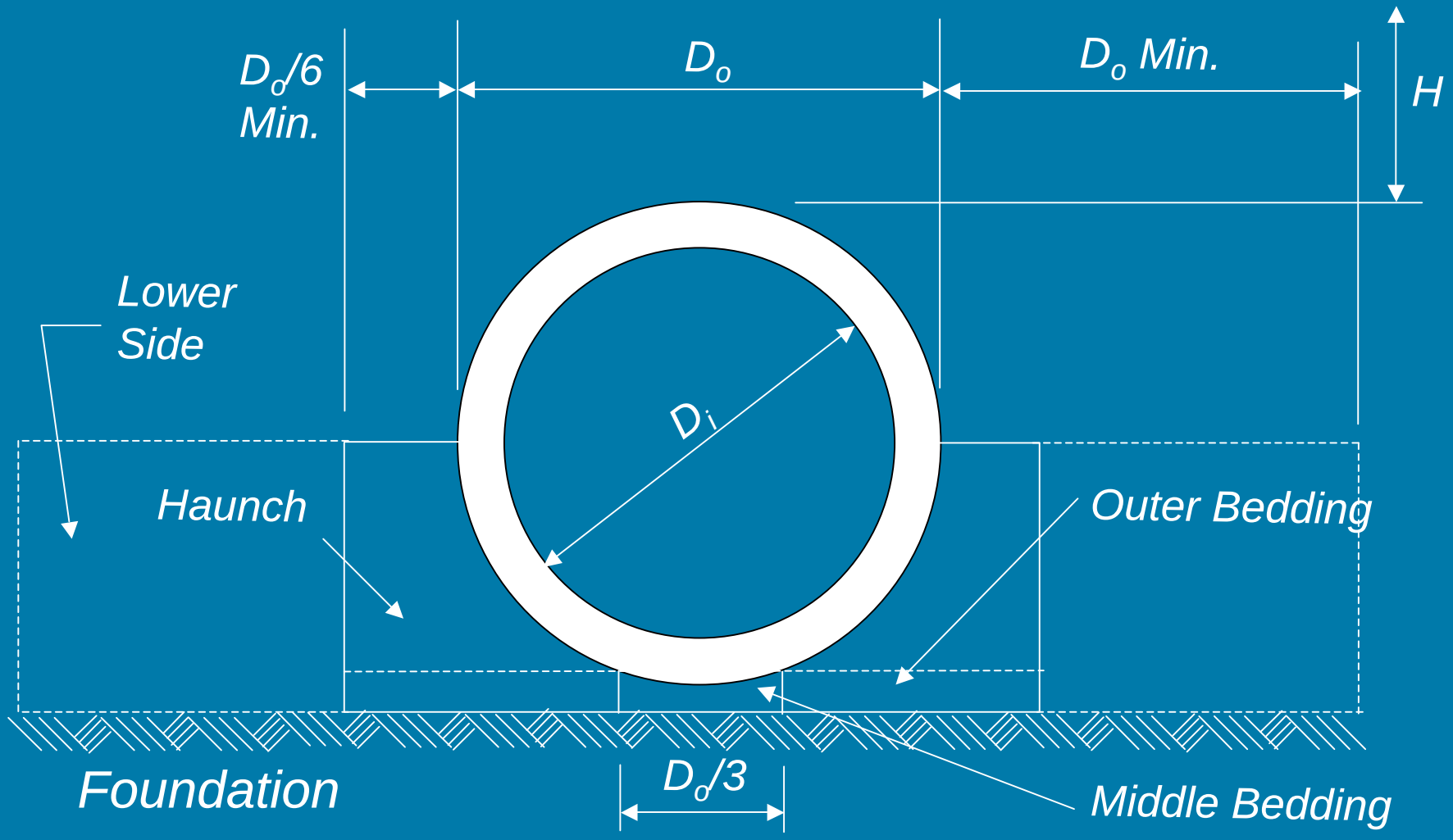
Trenchless



Installation (embedment) Types or Classes

Additional Info in the Concrete Design Manual - click here

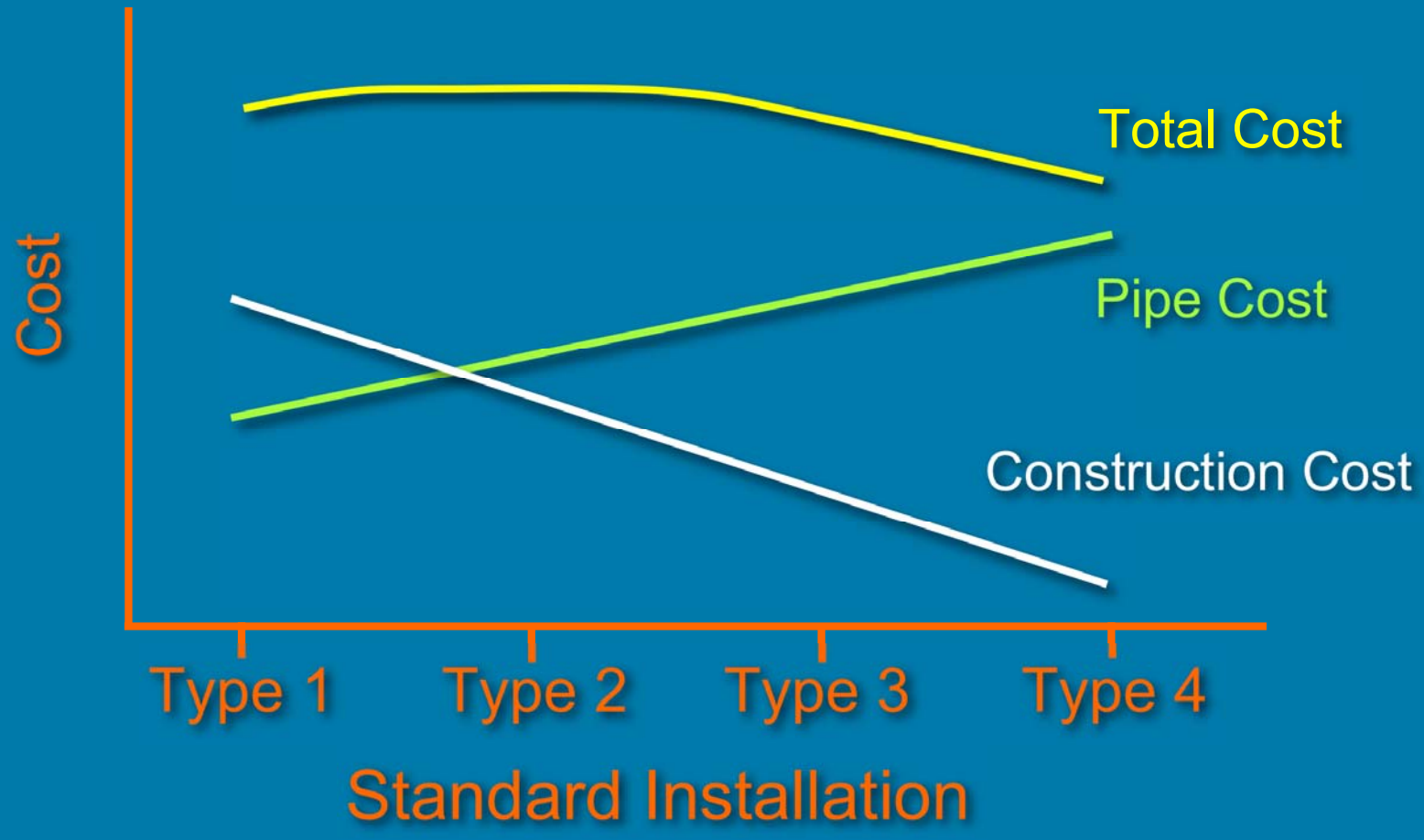
Standard Installations



Standard Installations - ASTM & AASHTO

Installation Type	Bedding Thickness	Haunch & Outer Bedding	Lower Side
Type I	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**

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 Kμ′—0.130

HEIGHT OF BACKFILL H ABOVE TOP OF PIPE, FEET	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	**4846**							6'- 5"
10	3898	4382	4869	5357	**5401**						6'- 7"
11	4188	4717	5249	5784	**5952**						6'
12	4463	5036	5614	6194	**6508**						6
13	4724	5341	5963	6589	**7060**						6
14	4972	5632	6297	6967	**7609**						
15	5207	5909	6617	7331	8050	**8160**					
16	5430	6173	6924	7681	8443	**8717**					
17	5643	6425	7217	8017	8823	**9261**					
18	5844	6666	7498	8340	9188	**9817**					
19	6035	6895	7768	8650	9540	**10370**					
20	6216	7114	8025	8948	9880	10820	**10930**				
21	6388	7323	8272	9234	10210	11190	**11470**				
22	6552	7522	8509	9509	10520	11540	**12030**				
23	6707	7712	8735	9774	10820	11890	**12580**				
24	6855	7893	8952	10030	11120	12220	**13120**				
25	6994	8066	9159	10270	11400	12540	**13670**				
26	7127	8230	9358	10510	11670	12850	14040	**14240**			
27	7253	8387	9548	10730	11930	13150	14380	**14790**			
28	7373	8537	9731	10950	12180	13440	14710	**15350**			
29	7486	8680	9905	11160	12430	13720	15020	**15890**			
30	7594	8817	10070	11360	12660	13990	15330	**16450**			
31	7697	8947	10230	11550	12890	14250	15630	**16990**			8'- 6"
32	7794	9071	10380	11730	13100	14500	15910	17350	**17520**		8'- 7"
33	7886	9189	10530	11910	13310	14740	16190	17660	**18080**		8'- 8"
34	7974	9302	10670	12080	13520	14980	16460	17970	**18620**		8'- 9"
35	8057	9410	10810	12240	13710	15200	16720	18260	**19190**		8'-10"
36	8136	9513	10940	12400	13900	15420	16980	18550	**19750**		8'-11"
37	8211	9610	11060	12550	14080	15640	17220	18830	**20300**		8'-11"
38	8282	9704	11180	12700	14250	15840	17460	19100	**20840**		9'- 0"
39	8350	9793	11290	12840	14420	16040	17680	19360	21060	**21370**	9'- 1"
40	8414	9878	11400	12970	14580	16230	17910	19610	21340	**21940**	9'- 2"

* *For backfill weighing 110 pounds per cubic foot, increase loads 10%; for 120 pounds per cubi*

▲*Transition loads* (**bold type**) *and widths based on Kμ—0.19, r_{sdp}—0.5 in the embankment equ*

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**

Table 42

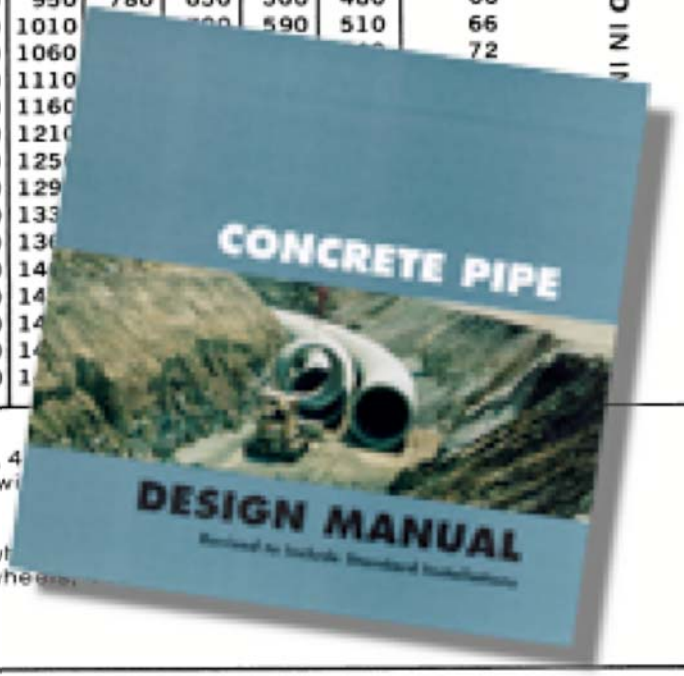
HIGHWAY LOADS ON CIRCULAR PIPE

POUNDS PER LINEAR FOOT

PIPE SIZE D IN INCHES	B_c (ft.)	HEIGHT OF FILL H ABOVE TOP OF PIPE IN FEET													PIPE SIZE D IN INCHES
		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0	9.0	
12	1.33	3780	2080	1470	1080	760	550	450	380	290	230	190	160	130	12
15	1.63	4240	2360	1740	1280	900	660	540	450	350	280	230	190	160	15
18	1.92	4110	2610	1970	1460	1030	750	620	520	400	320	260	220	190	18
21	2.21	3920	2820	2190	1620	1150	840	690	580	450	360	300	250	210	21
24	2.50	4100	3010	2400	1780	1270	930	760	640	500	400	330	280	240	24
27	2.79	3880	2940	2590	1930	1380	1010	830	700	560	440	360	300	260	27
30	3.08	3620	2830	2770	2070	1480	1080	890	750	590	480	390	330	280	30
33	3.38	3390	2930	2950	2200	1580	1160	960	810	630	510	420	360	300	33
36	3.67	3190	2810	2930	2330	1670	1230	1020	860	670	550	450	380	330	36
39	3.96	3010	2670	2850	2440	1760	1290	1070	910	710	580	480	410	350	39
42	4.25	2860	2550	2770	2560	1840	1360	1130	950	750	610	510	430	370	42
48	4.83	2590	2330	2620	2480	1990	1470	1230	1040	820	670	560	470	410	48
54	5.42	2360	2150	2490	2360	2050	1580	1320	1120	890	730	610	520	440	54
60	6.00	2170	1990	2450	2250	1960	1680	1400	1190	950	780	650	560	480	60
66	6.58	2010	1850	2520	2160	1880	1640	1480	1260	1010			590	510	66
72	7.17	1870	1730	2580	2190	1810	1570	1510	1330	1060					72
78	7.75	1750	1630	2630	2240	1770	1520	1460	1390	1110					
84	8.33	1650	1540	2730	2290	1810	1460	1410	1360	1160					
90	8.92	1550	1460	2530	2330	1850	1470	1360	1310	1210					
96	9.50	1470	1380	2410	2290	1880	1500	1330	1270	125					
102	10.08	1390	1320	2300	2190	1910	1530	1350	1240	129					
108	10.67	1320	1260	2200	2090	1830	1560	1380	1230	133					
114	11.25	1260	1200	2110	2010	1760	1540	1410	1260	13					
120	11.83	1210	1150	2020	1930	1700	1480	1420	1280	14					
126	12.42	1160	1100	1940	1860	1640	1430	1380	1300	14					
132	13.00	1110	1060	1870	1800	1580	1380	1330	1290	14					
138	13.58	1070	1020	1800	1730	1530	1340	1290	1250	14					
144	14.17	1020	980	1740	1670	1480	1300	1250	1210	1					

DATA:
1. Unsurfaced roadway.
2. Loads—AASHTO HS 20, two 16,000 lb. dual-tired wheels, 4
loading, four 12,000 lb. dual-tired wheels, 4 ft. on centers wi

NOTES:
1. Interpolate for intermediate pipe sizes and/or fill heights.
2. Critical loads:
   a. For H = 0.5 and 1.0 ft., a single 16,000 lb. dual-tired wh
   b. For H = 1.5 through 4.0 ft., two 16,000 lb. dual-tired whee
   c. For H > 4.0 ft. alternate loading.
3. Truck live loads for H = 10.0 ft. or more are insignificant.



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-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	Bedding Thickness	Haunch & Outer Beddding	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

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 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	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 lb/ft^3
2. AASHTO HS20 live load
3. Embankment installation

Type 1 Bedding

Class I
Class II
Class III
Class IV
Class V
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 lb/ft^3
2. AASHTO HS20 live load
3. Embankment installation

Type 1 Bedding

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

Pipe i.d. (inches)	Fill Height (feet)														
	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 lb/ft^3
2. AASHTO HS20 live load
3. Embankment installation

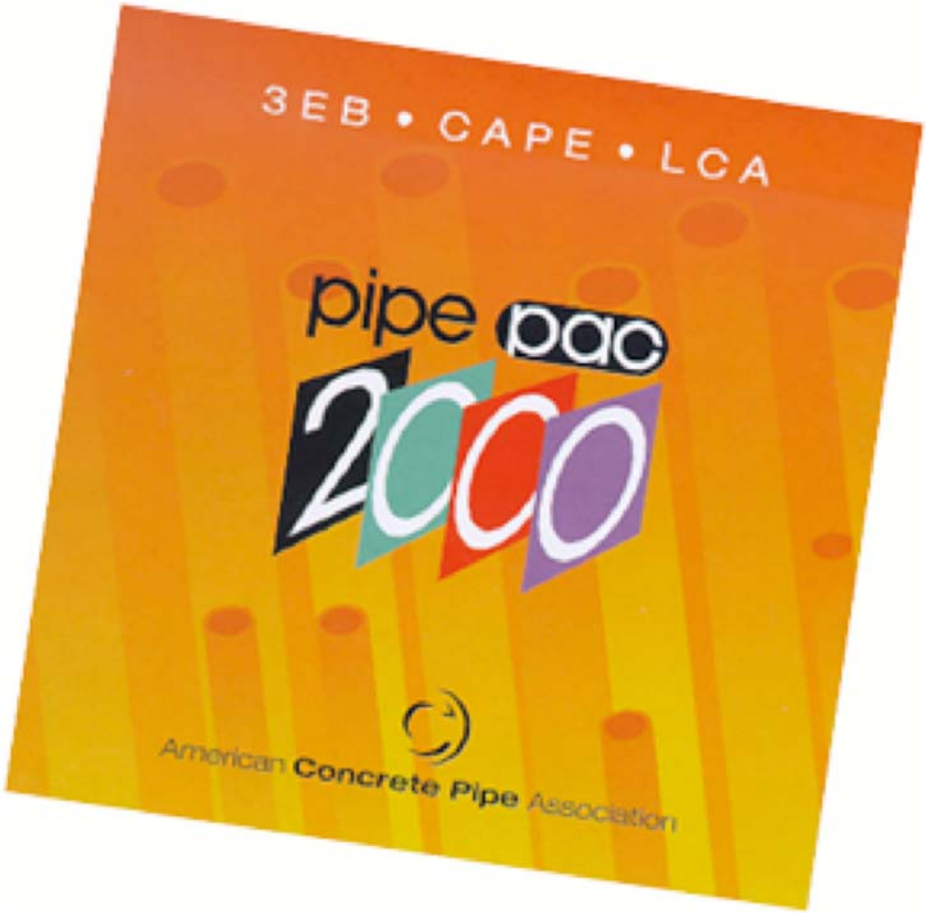
Type 4 Bedding

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	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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  American Concrete Pipe Association

  8445 Freeport Parkway, Suite 350

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  Attn: Professional Membership – Online Exam

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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.**
  - Soil Tight and Water Tight
  - Tongue & Groove and Bell & Spigot
  - O-ring and Profile
  - Pressure and O-ring
- **What is the test used to determine D-load in a pipe?**
  - There is no test
  - Three-Edge Bearing Test
  - Joint Shear Test
  - Hydrostatic Test
- **What two critical functions must buried concrete pipe perform?**
  - Barrier and Structure
  - Framework and System
  - Structure and Conduit
  - Channel and Aqueduct
- **The earth load, live load and bedding factor are all considered in determining what?**
  - D-Load
  - Hydraulic Capacity
  - Diameter of Pipe
  - Type of Joint

Thank you for participating in ACPA's online training.

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