

4

INSTALLATION OF PIPE AND TESTING OF PIPE BACKFILL

LEARNING OUTCOMES

- Understand basic pipe and soil concepts and how they relate to preconstruction issues
- Understand fundamental trench concepts and pipe installation procedures
- Understand inspection requirements and backfill testing frequencies and procedures
- Understand the basic principles of pavement drain construction

INTRODUCTION

A well installed pipe should stay in service 50 to 100 years with little or no repair. VDOT states 75 years for higher functional classification roads and 50 years for lower functional classification roads. Proper installation is essential to pavement performance as it increases bearing capacity, increases service life and lowers maintenance costs.



Figure 4.1: Precast Concrete Pipe

BASIC PIPE AND SOIL CONCEPTS

The type of pipe selected for a particular application depends on many factors. The function of the pipe, the soil type present in the trench, the depth of the pipe can all influence the type of pipe selected. See the following table for VDOT recommendations.

PC-1				
TABLE A1 - ALLOWABLE TYPE OF STORM SEWER PIPE FOR ROADWAYS THAT ARE CONSTRUCTED, FUNDED OR WILL ULTIMATELY BE MAINTAINED BY VDOT				
FUNCTIONAL CLASSIFICATION OF ROADS SYSTEM UNDER WHICH PIPE IS TO BE INSTALLED				
HIGHER FUNCTIONAL CLASS - HFC RURAL PRINCIPAL ARTERIAL, URBAN PRINCIPAL ARTERIAL, RURAL MINOR ARTERIAL, URBAN MINOR ARTERIAL, RURAL COLLECTOR ROADS, URBAN COLLECTOR STREETS, SUBDIVISION STREETS WITH AN ADT GREATER THAN 4000		LOWER FUNCTIONAL CLASS - LFC RURAL LOCAL ROADS, URBAN LOCAL STREETS, SUBDIVISION STREETS WITH AN ADT LESS THAN OR EQUAL TO 4000		
ALLOWABLE PIPE CULVERTS NOTES 1 & 2	STATEWIDE	STATEWIDE EXCEPT LOCATIONS SHOWN IN TABLE B	LOCATION SHOWN IN TABLE B	
CONCRETE	✓	✓	✓	
CORRUGATED STEEL ALUMINUM COATED TYPE 2 FULLY CONCRETE LINED NOTE 3		✓		
ALUMINUM COATED TYPE 2 STEEL SPIRAL RIB NOTE 3		✓		
POLYMER COATED (10/10) CORRUGATED STEEL SPIRAL RIB NOTE 3		✓	✓	
POLYMER COATED (10/10) CORRUGATED STEEL DOUBLE WALL (SMOOTH INTERIOR) NOTE 3	✓	✓	✓	
ALUMINUM SPIRAL RIB NOTE 3		✓	✓	
POLYVINYLCHLORIDE (PVC) RIBBED PIPE (SMOOTH INTERIOR)	✓	✓	✓	
POLYETHYLENE (PE) CORRUGATED TYPE S	✓	✓	✓	
POLYPROPYLENE (PP) TYPE D OR S	✓	✓	✓	

TABLE B EXCEPTIONS TO STATEWIDE APPLICATIONS				
COUNTRIES (INCLUDING TOWNS)		CITIES		
ARLINGTON - EAST OF AND INCLUDING RTES. 95 & 395	SURRY - EAST OF AND INCLUDING RTE. 10	SUFFOLK - EAST OF AND INCLUDING RTE. 32		
FAIRFAX - EAST OF AND INCLUDING RTES. 95 & 395	ISLE OF WIGHT - EAST OF AND INCLUDING RTE. 10	CHESAPEAKE	WILLIAMSBURG	
PRINCE WILLIAM - EAST OF AND INCLUDING RTES. 95 & 395		VIRGINIA BEACH	POQUOSON	
WESTMORELAND	JAMES CITY	ESSEX	NORTHAMPTON	
LANCASTER	ACCOMACK	MIDDLESEX	STAFFORD	
MATTHEWS	SPOTSYLVANIA	YORK	KING GEORGE	
GLOUCESTER	NORTHUMBERLAND	RICHMOND	FREDERICKSBURG	

TABLE C					
PIPE TYPE	ALLOWABLE pH RANGE (SEE NOTE 6)		ALLOWABLE RESISTIVITY RANGE (Ohms-cm)		ALLOWABLE VELOCITY (FPS) (SEE NOTE 5)
	MIN.	MAX.	MIN.	MAX.	
ALUMINUM COATED TYPE 2 CORRUGATED STEEL	5.0	9.0	1500	-	5
GALVANIZED STEEL STRUCTURAL PLATE WITH CONCRETE INVERT	6.0	9.0	2000	10000	15
GALVANIZED STEEL STRUCTURAL PLATE	6.0	9.0	2000	10000	5
POLYMER COATED (10/10) CORRUGATED STEEL	4.0	9.0	750	-	15
UNCOATED GALVANIZED CORRUGATED STEEL	6.0	10.0	2000	10000	5
CORRUGATED ALUMINUM ALLOY	4.0	9.0	500	-	5
CORRUGATED ALUMINUM ALLOY STRUCTURAL PLATE	4.0	9.0	500	-	5
ALUMINUM SPIRAL RIB	4.0	9.0	500	-	5
ALUMINUM COATED TYPE 2 SPIRAL RIB	5.0	9.0	1500	-	5
CORRUGATED STEEL ALUMINUM COATED TYPE 2 FULLY CONCRETE LINED	5.0	9.0	1500	-	15
POLYMER COATED CORRUGATED STEEL SPIRAL RIB	4.0	9.0	750	-	15
POLYMER COATED CORRUGATED STEEL DOUBLE WALL	4.0	9.0	750	-	15

NOTES:

- ALLOWABLE TYPES OF PIPES FOR A SPECIFIC AREA ARE TO CONFORM TO THE CRITERIA SHOWN IN TABLES A-1, B, AND C. ANY DEVIATION MUST BE APPROVED BY THE STATE LOCATION AND DESIGN ENGINEER AND THE DISTRICT MATERIALS ENGINEER.
- SEE HEIGHT OF COVER TABLES FOR MINIMUM AND MAXIMUM COVER LIMITATIONS FOR EACH TYPE OF PIPE.
- SEE TABLE C FOR MINIMUM AND MAXIMUM pH, RESISTIVITY, AND VELOCITY LIMITATIONS FOR METAL PIPES.
- USE ONLY UNDER ENTRANCES WHERE THE PIPE SIZE IS LESS THAN OR EQUAL TO 30" DIAMETER (OR EQUIVALENT) AND THE HEIGHT OF COVER IS LESS THAN OR EQUAL TO 15' AND AS AN OUTLET PIPE FOR STANDARD DI-13 SHOULDER SLOT INLETS.
- ALLOWABLE VELOCITY WHERE ABRASIVE BEDLOAD IS PRESENT OR ANTICIPATED, MAXIMUM VELOCITY BASED ON 10 YEAR DESIGN DISCHARGE (Q).
- pH VALUES APPLY TO BOTH THE SOIL AND WATER.

SPECIFICATION REFERENCE	A COPY OF THE ORIGINAL SEALED AND SIGNED STANDARD DRAWING IS ON FILE IN THE CENTRAL OFFICE ALLOWABLE PIPE CRITERIA FOR CULVERT AND STORM SEWERS VIRGINIA DEPARTMENT OF TRANSPORTATION	VDOT ROAD AND BRIDGE STANDARDS REVISION DATE SHEET 18 OF 18 01/13 107.22
232 302		

When planning a pipeline installation, there are 2 key functions that we must design the pipeline to provide. What are those two functions? Clearly the pipe needs to function as a conduit, as the whole idea of a pipe is to move liquid in a controlled manner and direction. And the pipe must provide structure, because if the ground above the pipe collapses then the pipe can no longer perform as a conduit. Having one of these functions without the other is worthless.

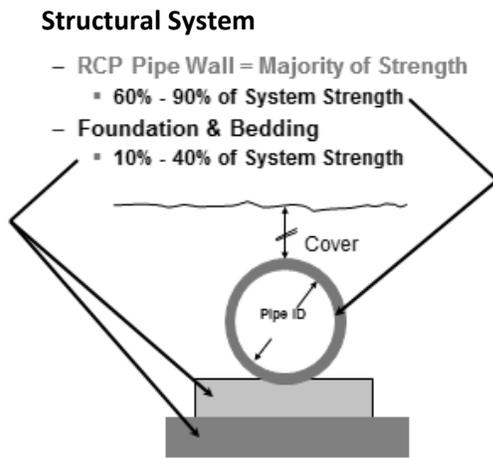


Figure 4.2a: Reinforced Concrete

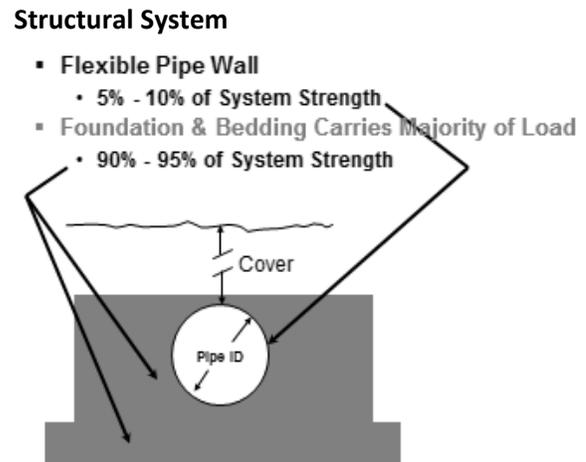


Figure 4.2b: Flexible Pipe

Culverts are generally designed for the loads they must carry after construction is completed. Construction loads often exceed design loads. These heavy loads can cause considerable damage in flexible pipes and can cause D-load cracking in rigid pipes. Additional temporary fill is needed to protect the pipe from construction loads.

Minimum/Maximum Cover

All Culverts

- 24" minimum cover
- Absolute minimum fill height (12")
- Except for entrances (9" minimum)
- All pipe should have three feet of cover on it before construction traffic is allowed across it.

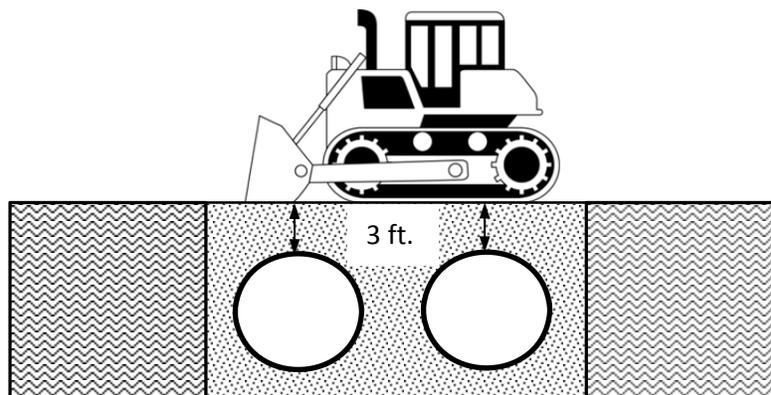


Figure 4.3: Minimum Cover to Allow Construction Traffic over Pipe

The following tables give VDOT specifications for maximum height of cover for some types of pipe.

PC-1						
DIAMETER INCHES	AREA SQ. FT.	MAXIMUM HEIGHT OF COVER IN FEET				DIAMETER INCHES
		NONREINFORCED CONCRETE (STRENGTH) (SEE NOTE 4)	REINFORCED CONCRETE CLASS			
			III	IV	V	
12	0.8	14' (1800)	14'	19'	29'	12
15	1.2	14' (2125)	14'	19'	29'	15
18	1.8	14' (2400)	14'	20'	29'	18
21	2.4	13' (2700)	14'	20'	29'	21
24	3.1	13' (3000)	14'	20'	29'	24
27	4.0		14'	20'	29'	27
30	4.9		14'	20'	29'	30
33	5.9		14'	20'	29'	33
36	7.1		14'	20'	30'	36
42	9.6		14'	21'	30'	42
48	12.6		14'	21'	30'	48
54	15.9		14'	21'	30'	54
60	19.6		14'	21'	30'	60
66	23.8		14'	21'	30'	66
72	28.3		14'	21'	30'	72
78	33.2		14'	21'	30'	78
84	38.5		14'	21'	30'	84
90	44.4		14'	21'	30'	90
96	50.3		14'	21'	30'	96
102	56.7		14'	21'	30'	102
108	63.6		14'	21'	30'	108

NOTES:

- COVER HEIGHTS INDICATED IN TABLES ARE FOR FINISHED CONSTRUCTION.
- TO PROTECT PIPE DURING CONSTRUCTION, MINIMUM HEIGHTS OF COVER PRIOR TO ALLOWING CONSTRUCTION TRAFFIC TO CROSS INSTALLATION ARE TO BE 1/2 DIAMETER OR 3'0", WHICHEVER IS GREATER. THE COVER SHALL EXTEND THE FULL LENGTH OF THE PIPE. THE APPROACH FILL RAMP IS TO EXTEND A MINIMUM OF 10(DIAMETER + 36") ON EACH SIDE OF THE PIPE, OR TO THE INTERSECTION WITH A CUT.
- STANDARD MINIMUM FINISHED HEIGHT OF COVER FOR ALL PIPES, EXCEPT THOSE UNDER ENTRANCES, SHALL BE 2.0' OR 1/2 DIAMETER, WHICHEVER IS GREATER. IN CASES IN WHICH THESE COVER HEIGHTS CANNOT BE ACHIEVED, AN ABSOLUTE MINIMUM FINISHED COVER HEIGHT OF 1.0' WILL BE ALLOWED ONLY IF ALL POSSIBLE MEANS TO OBTAIN THE STANDARD VALUE HAVE BEEN EXHAUSTED. THE MINIMUM FINISHED HEIGHT OF COVER FOR PIPES UNDER ENTRANCES IS 0".
- CRUSHING STRENGTH (POUNDS PER LINEAR FOOT ULTIMATE STRENGTH)
- FOR HEIGHT OF COVER GREATER THAN THAT SHOWN FOR CLASS V, A SPECIAL DESIGN CONCRETE PIPE IS REQUIRED.
- NONREINFORCED PIPE TO BE USED ONLY UNDER ENTRANCES AND LOWER FUNCTIONAL CLASSIFICATION (LFC) ROADWAYS (SEE SHEET 17 OF 18).
- SEE STANDARD PB-1 FOR PIPE BEDDING AND BACKFILL REQUIREMENTS.
- PIPE WITH LESS THAN THE STANDARD MINIMUM COVER IS TO BE MINIMUM CLASS III REINFORCED.

 ROAD AND BRIDGE STANDARDS		CONCRETE PIPE HEIGHT OF COVER TABLE FOR H-20 LIVE LOAD VIRGINIA DEPARTMENT OF TRANSPORTATION	SPECIFICATION REFERENCE
SHEET 1 OF 18	REVISION DATE		302 232
107.05			

PC-1														
CORRUGATED STEEL PIPE 2 2/3" x 1/2" CORRUGATIONS							CORRUGATED STEEL PIPE 3" x 1" AND 5" x 1" CORRUGATIONS							
PIPE DIAMETER INCHES	AREA SQ. FT.	MAXIMUM HEIGHT OF COVER IN FEET					MINIMUM SHEET THICKNESS FOR ENTRANCE PIPES WITH LESS THAN 1 FT COVER INCHES (GAUGE)	PIPE DIAMETER INCHES	AREA SQ. FT.	MAXIMUM HEIGHT OF COVER IN FEET				
		SHEET THICKNESS IN INCHES (GAUGE)								SHEET THICKNESS IN INCHES (GAUGE)				
		0.064 (16)	0.079 (14)	0.109 (12)	0.138 (10)	0.188 (8)				0.064 (16)	0.079 (14)	0.109 (12)	0.138 (10)	0.188 (8)
12	0.79	18	100				0.064 (16)	36	7.1	16	38	47	57	66
15	1.23	18	80	100	100		0.064 (16)	42	9.6	16	30	36	42	48
18	1.77	18	55	71	89	94	0.064 (16)	48	12.6	15	26	30	34	38
21	2.40	18	41	51	62	74	0.079 (14)	54	16.0	15	23	26	28	31
24	3.14	17	33	40	47	55	0.109 (12)	60	19.6	14	21	23	25	27
27	3.98	17	28	33	38	44		66	23.8	14	20	22	23	25
30	4.91	17	25	28	32	36		72	28.3	13	19	20	22	23
33	5.94	17	23	25	28	31		78	33.2	13	19	20	21	21
36	7.1	16	21	23	26	28		84	38.5	12	18	19	20	21
42	9.6	16	20	21	22	24		90	44.2	12	18	19	19	20
48	12.6	15	19	19	20	21		96	50.3		18	18	19	19
54	16.0		18	19	19	20		102	56.7		18	18	18	19
60	19.6			18	19	19		108	63.6			18	18	18
66	23.8				18	18		114	70.9			18	18	18
72	28.3				18	18		120	78.5			17	18	18
78	33.2					18		132	95.0				17	18
84	38.5					17		144	113.0					17

NOTES:

- COVER HEIGHTS INDICATED IN TABLES ARE FOR FINISHED CONSTRUCTION.
- TO PROTECT PIPE DURING CONSTRUCTION, MINIMUM HEIGHT OF COVER TO BE IN ACCORDANCE WITH TABLE A PRIOR TO ALLOWING CONSTRUCTION TRAFFIC TO CROSS INSTALLATION. THE COVER SHALL EXTEND THE FULL LENGTH OF THE PIPE. THE APPROACH FILL RAMP IS TO EXTEND A MINIMUM OF 15 DIAMETERS ON EACH SIDE OF THE PIPE OR THE INTERSECTION WITH A CUT.
- STANDARD MINIMUM FINISHED HEIGHT OF COVER FOR ALL PIPES, EXCEPT UNDER ENTRANCES, SHALL BE 2.0' OR 1/2 DIAMETER, WHICHEVER IS GREATER. IN CASES IN WHICH THESE COVER HEIGHTS CANNOT BE ACHIEVED, AN ABSOLUTE MINIMUM FINISHED COVER HEIGHT OF 1.0' OR 1/4 DIAMETER, WHICHEVER IS GREATER, WILL BE ALLOWED ONLY IF ALL POSSIBLE MEANS TO OBTAIN THE STANDARD VALUE HAVE BEEN EXHAUSTED. THE MINIMUM FINISHED HEIGHT OF COVER FOR PIPES UNDER ENTRANCES IS 9" FOR PIPE DIAMETERS LESS THAN OR EQUAL TO 24" AND 12" OR 1/8 DIAMETER, WHICHEVER IS GREATER. FOR PIPE DIAMETERS GREATER THAN 24", WHERE A POLYMER COATED PIPE WILL BE USED AND THE SURFACE OVER THE TOP OF THE PIPE WILL BE ASPHALT, CLASS 1 BACKFILL MATERIAL IS TO BE PLACED UP TO A MINIMUM OF 6" ABOVE THE TOP OF THE PIPE.
- 16 GAUGE PIPE LIMITED TO THOSE LOCATIONS WHERE PIPE DIAMETER PLUS COVER IS LESS THAN 20'.
- THE MAXIMUM HEIGHT OF COVER SHOWN IN THE COVER TABLES IS BASED ON A SOIL MODULUS OF 700 PSI. ALL OTHER DESIGN CRITERIA ARE IN ACCORDANCE WITH THE AASHTO SPECIFICATIONS AND VDOT MODIFICATIONS FOR SOIL CORRUGATED METAL STRUCTURE INTERACTION SYSTEMS.
- SEE STANDARD PB-1 FOR PIPE BEDDING AND BACKFILL REQUIREMENTS.

TABLE A	
PIPE DIAMETER	MINIMUM COVER HEIGHT DURING CONSTRUCTION (SEE NOTE 2)
12" TO 30"	18"
36" AND ABOVE	1/2 DIAMETER

CONCRETE-LINED CORRUGATED STEEL PIPE

MAXIMUM HEIGHT OF COVER TO BE IN ACCORDANCE WITH THE TABLES BUT SHALL NOT EXCEED 30'.

ROAD AND BRIDGE STANDARDS	CORRUGATED STEEL PIPE HEIGHT OF COVER TABLES FOR H-20 LIVE LOAD VIRGINIA DEPARTMENT OF TRANSPORTATION	SPECIFICATION REFERENCE
SHEET 3 OF 18 107.07	REVISION DATE	302 232

PRE-CONSTRUCTION ISSUES

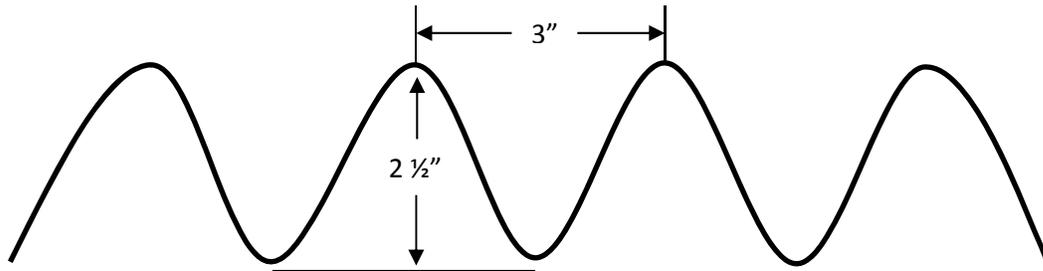
Prior to construction the pipe delivered to the project should be inspected and verified to be the pipe specified for the project. A review of the proper minimum/maximum height of cover for the specific type of pipe should be completed. Inspect how the pipe is being stored on site to ensure no damage is being done to the pipe prior to installation.

Verifying that the correct pipe has been delivered for the applications on your project.

- 1) Metal pipe gauge: Examples – 12, 14, 16
- 2) Metal pipe corrugation dimensions: Examples – 2 2/3" x 1/2"; 3" x 1"
- 3) Concrete pipe strength: Examples – Class III, IV or V
- 4) pH and Resistivity - needs to be known by designer

- 5) Maximum height of cover: Maximum height for each type of pipe must be given
- Compare information from drainage summary with maximum cover chart for pipe to be used
 - Check standards for minimum height of cover

Measuring Metal Pipe Corrugation – example 3" x 2 ½"



Examples of concrete pipe stamp:

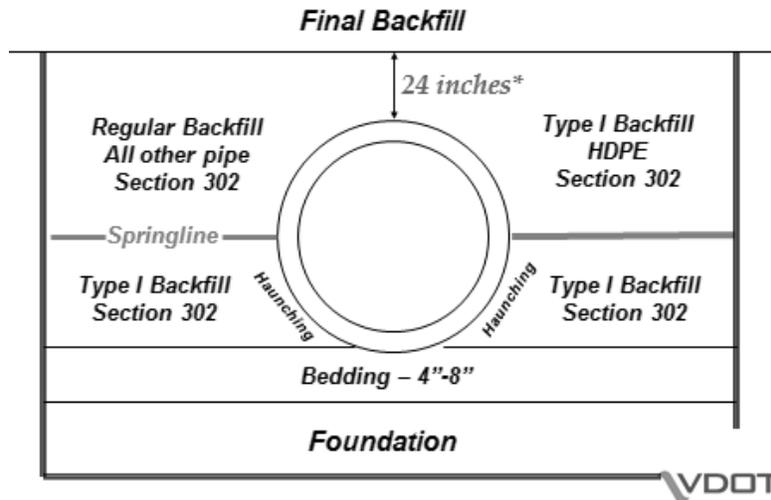
They typically include manufactured date, diameter, pipe type, class, place of manufacturing.



Pipe should be stored in an out of the way location where it will not be damaged. The pipe should be stacked and chocked to avoid movement of the pipe. Pipe should never be stacked on the bells as they could be damaged.

TRENCH FUNDAMENTALS

Trench Terminology

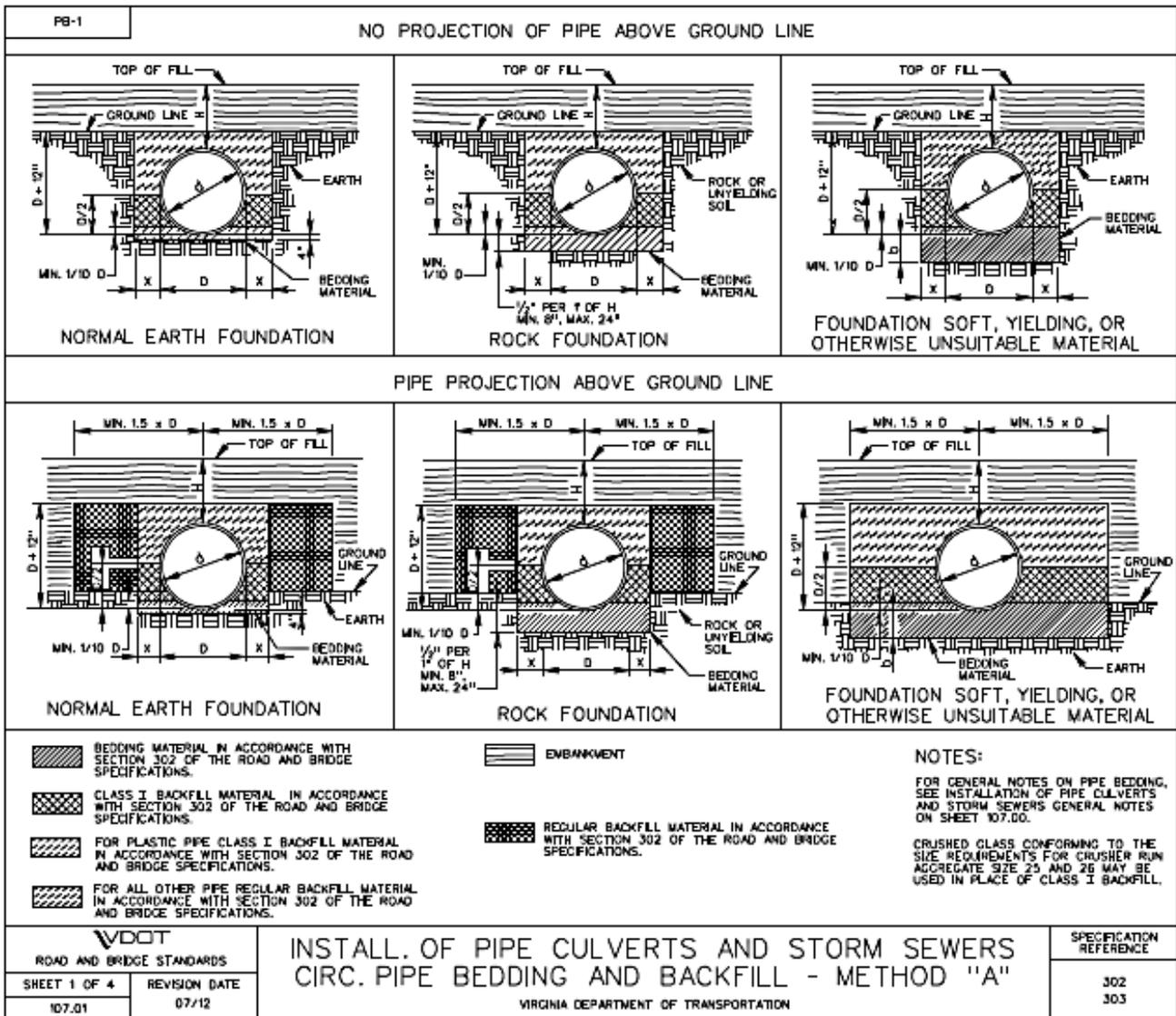


The bedding is typically 4-8" thick. The top few inches should be slightly yielding (loose) and fill the corrugations. Often, shaped beddings are used to insure proper placement and compaction of materials under the pipe haunch.

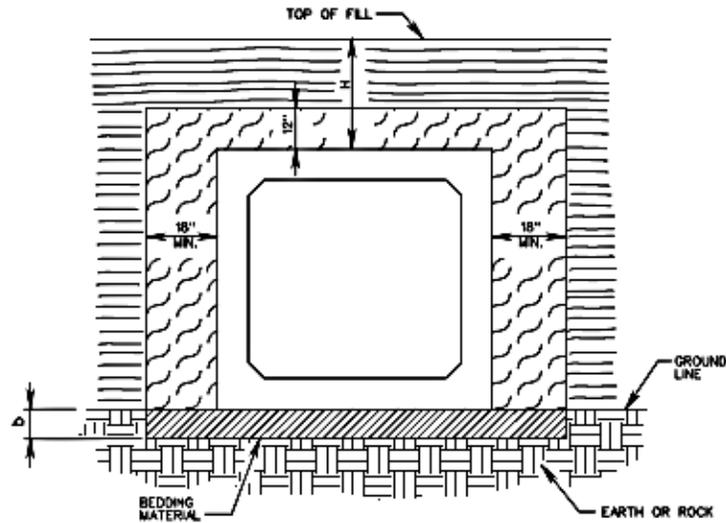
The initial backfill of select Type I backfill protects the pipe during installation from impact damage and extends to the springline of the pipe. In a rigid pipe, this zone has zero effect on the load carrying capacity. In a flexible pipe this zone must protect the pipe from distortions due to loading – extend to 12" above pipe. This zone contains the same select quality backfill material as in the haunch zone for flexible pipe.

Generally excavated embankment material is used as the final backfill. It is placed in 6" loose lifts and compacted to 4". For flexible pipe this begins 12" over top of pipe for smaller pipe and 18" for pipe 54" and larger.

The following drawing provides typical VDOT standards for pipe bedding and backfill.



PB-1



H = HEIGHT OF COVER MEASURED FROM TOP OF CULVERT TO FINISHED GRADE.

FOR NORMAL EARTH FOUNDATION:
FOR PRECAST AND CAST IN PLACE BOX CULVERT b = 6"

FOR ROCK FOUNDATION:
FOR PRECAST BOX CULVERT b = 1/4" PER 12" OF
H - 6" MIN., 24" MAX.
FOR CAST IN PLACE BOX CULVERT b=DEPTH AS SHOWN
ON PLANS OR WHERE NO BEDDING IS SPECIFIED BOTTOM
SLAB TO BE KEYED INTO EXISTING ROCK FOUNDATION.
FOR SOFT, YIELDING OR OTHERWISE UNSUITABLE FOUNDATION:
FOR PRECAST AND CAST IN PLACE BOX CULVERT
b = DEPTH AS SHOWN ON PLANS OR TO FIRM BEARING SOIL.

 BEDDING MATERIAL IN ACCORDANCE WITH SECTION 302 OF THE ROAD AND BRIDGE SPECIFICATIONS.

 REGULAR BACKFILL MATERIAL IN ACCORDANCE WITH SECTION 302 OF THE ROAD AND BRIDGE SPECIFICATIONS.

 EMBANKMENT

SPECIFICATION REFERENCE
302
303

INSTALLATION OF BOX CULVERT BEDDING AND BACKFILL - METHOD "A"

VIRGINIA DEPARTMENT OF TRANSPORTATION

VDOT

ROAD AND BRIDGE STANDARDS

REVISION DATE SHEET 4 OF 4

107.D4

INSTALLATION PROCEDURES

General procedures for pipe installation:

- 1) Locate utilities
- 2) Excavate trench
- 3) Explore foundation
- 4) Place structural bedding material to grade. Do not compact.
- 5) Install pipe to grade
- 6) Compact structural bedding outside the middle third of the pipe
- 7) Place structural bedding in lifts
- 8) Complete structural backfill operation by working from side to side of the pipe, differential not to exceed 24" or 1/3 size of pipe.

Locate Utilities

Prior to excavating the trench area, all utilities should be located by a qualified contractor.

Excavate Trench

Proper trench widths will allow for proper compaction alongside the pipe. Trench widths may be varied, based on the competency of the in-situ soil, backfill materials, compaction levels and loads. Trenching should be completed in existing soils with sidewalls reasonably vertical to the top of the pipe. It is not appropriate to leave a bench of native soil alongside the pipe during construction. The compaction equipment will ride on the native soil and not allow for proper consolidation of backfill. For positive projection embankment installations, the embankment material should be placed and compacted to a minimum of one foot above the pipe and the trench excavated into the embankment. This prevents disruption of the backfill envelope when removing the shoring or trench box.

Explore Foundation

A stable foundation must be provided to ensure proper line and grade is maintained. Unsuitable foundations must be stabilized at the engineer's direction. Unsuitable or unstable foundations may be undercut and replaced with a suitable bedding material, placed in 6" lifts. Other methods of stabilization, such as geo-fabrics may be appropriate based on the engineer's judgment.

The foundation is to be explored below the bottom of the excavation to determine the type and condition of the foundation. The exploration should extend to a depth equal to ½" per foot of fill height or 8", whichever is greater. If it is a routine entrance, or crossover pipe 12" to 30" in diameter, that is to be installed under fills 15 feet or less in height, no exploration is needed. The Contractor shall report findings of foundation exploration to the Engineer for approval prior to placing pipe.

When standing water is in pipe foundation area, No. 57 stone can be used as a backfill in the sub-foundation. No. 57 stone MUST be capped with a minimum of 4" crusher run prior to placement of pipe or box culvert. Compaction testing on No. 57 stone is not required; seat stone in trench.

Place Bedding

Stable and uniform bedding must be provided for the pipe and any protruding features of its joints and/or fittings. The middle of the bedding, should be loosely placed and not exceed 8 inches. The loosely placed center section of the bedding allows the pipe to seat itself and helps minimize point loads. (Road and Bridge Spec. Section 302.03 Procedures)

When lift holes are provided in concrete pipe or precast box culverts, the Contractor shall install a lift hole plug furnished by the manufacturer. After pipe installation and prior to backfilling, plugs shall be installed from the exterior of the pipe or box culvert and snugly seated.

Install Pipe

The grade of the pipe should always be monitored during installation.

When joining pipe:

- Begin at the downstream end (Bell faces upstream)
- Ensure spigot and bell are clean and free of debris
- Properly lubricate spigot and bell with pipe lubricant
- Is Contractor aware of the maximum insertion angle?
- Fully insert pipe. (Make a Mark on Outside of Pipe)
- Moving pipe around after joining may cause pipe joint to work apart.

Rigid pipe – properly fitted, sealed with rubber, preformed plastic, mastic gaskets

Flexible Pipe – properly aligned and joined with approved coupling bands

Joint Performance Terminology

Soil Tight: A joint that is resistant to infiltration of particles larger than those retained on the No. 200 sieve. Soil-tight joints provide protection against infiltration of backfill material containing high percentage of coarse grain soils, and are influenced by the size of the opening (maximum dimension normal to the direction that the soil may infiltrate) and the length of the channel (length of the path along which the soil may infiltrate).

Silt Tight: A joint that is resistant to infiltration of particles that are smaller than particles passing the No. 200 sieve. Silt-tight joints provide protection against infiltration of the backfill material containing a high percentage of fines, and typically utilize some type of filtering or sealing component, such as an elastomeric rubber seal or geotextile.

Leak Resistant: A joint which limits water leakage at a maximum rate of 200 gallons/inch-diameter/mile/day for the pipeline system for the project specified head or pressure.

Types of Joints for Concrete Pipe

Tongue & Groove: A bell & spigot type joint with straight walls (flush bell). The joint consists of a tongue (male end) and groove (female end) with no defining areas for gasket material placement. Rubber gaskets may be used when the joint slope is five degrees or less, however it is usually limited to mastic or butyl sealants.

Bell and Spigot: A pipe with a flared bell has the outside diameter of the bell larger than the outside diameter of the pipe. Another option with the flared bell is the Modified Tongue & Groove, or Baby Bell which is a cross between a straight walled T&G and a Standard Bell – it does not stick out from the barrel as far as a flared bell.

Confined O-Ring: The first “rubber gasket” joint design established by the industry. The spigot end of the pipe contains a confined groove for the gasket to seat, where an o-ring gasket is placed. This type joint-gasket combination provides a leak resistant joint.

Single Offset: This joint first appeared in the early 1990’s. This style of spigot is much easier to manufacture. It is generally easier to install due to less stringent lubrication requirements for the gasket. This type of joint provides a leak resistant joint when a profile gasket is used.

Structural Fill

See Section 302.03 (A)(2)(g) of the *Road and Bridge Specifications* for complete requirements for backfill material.

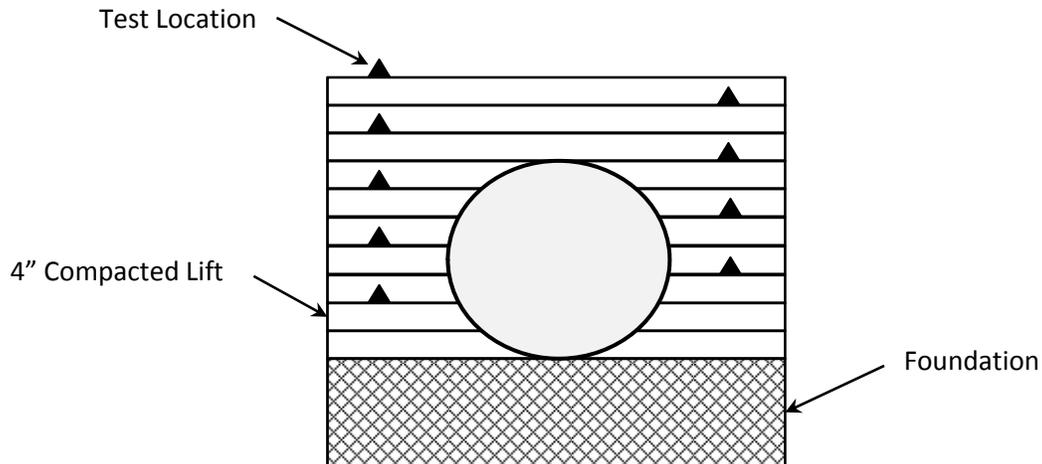
Proper haunching provides support to ensure the pipe’s strength is achieved. Care must be exercised to ensure placement and compaction of the embedment material in the haunches. For larger diameter pipe, >30 inches, embedment materials should be worked under the haunches by hand. Haunching material may be Class 1 and must be placed and compacted in 6-inch loose/4-inch compacted maximum lifts, compacted to 95 percent standard proctor density. Backfill material shall be “knifed” into the area along the bottom edge of the pipe. When backfill is below spring line of pipe, compact next to pipe first and work towards the trench wall. When backfill material is above the spring line of the pipe, start at the trench wall and work towards the pipe. Do not compact directly on pipe as it may damage the pipe.

Each layer of Class I and regular backfill material shall be compacted by rolling, tamping with mechanical rammers, or hand tamping with heavy metal tampers with a face of at least 25 square inches. If vibratory rollers are used in the backfill operations, vibratory motors shall not be activated until at least 3 feet of backfill has been placed and compacted over the pipe. Backfill and compaction shall be advanced simultaneously on both sides of the pipe. The fill above the top of the regular backfill shall be installed and completed as specified for embankment construction. Rock more than 2 inches in its greatest dimension shall not be placed within 12 inches of pipe.

Pipe openings in precast drainage units shall not exceed the outside cross sectional dimensions of the pipes by more than a total of 8 inches regardless of the placement of the pipe, their angles of intersection, or shapes of the pipes.

BACKFILL TESTING FREQUENCIES

Typical Pipe and Box Culvert Backfill:



One test per lift on alternating sides of the pipe for each 300 feet of pipe or portion thereof.

Test pattern is to begin after the first 4" lift above bedding and continue to 1 foot above top of the pipe.

Pipe Testing Frequency Example 1:

- Pipe Diameter = 48 in.
- Length of run = 275 ft.
- $(\text{Pipe Diameter} \div \text{lift thickness}) + (\text{Fill above pipe} \div \text{lift thickness}) - (1 \text{ lift}) =$
 - 1) $(48 \text{ in.} \div 4 \text{ in.}) + (12 \text{ in.} \div 4 \text{ in.}) - 1$ (do not test 1st lift) =
 - 2) $12 + 3 - 1 = \underline{14 \text{ tests}}$ required per 300' (Answer)

Pipe Testing Frequency Example 2:

- Pipe Diameter = 36 in.
- Length of run = 856 ft.
- $(\text{Pipe Diameter} \div \text{lift thickness}) + (\text{Fill above pipe} \div \text{lift thickness}) - (1 \text{ lift}) =$
 - 3) $(36 \text{ in.} \div 4 \text{ in.}) + (12 \text{ in.} \div 4 \text{ in.}) - 1$ (do not test 1st lift) =
 - 4) $9 + 3 - 1 = 11$ tests required per 300'
 - 5) Length of run = 856 ft.; therefore 3 sets of tests required
 - 6) $11 \times 3 = \underline{33 \text{ tests}}$ required for total run (minimum) (Answer)

Backfill around Drop Inlets (minimum)

One test every other lift around the perimeter; beginning after the first 4 inch compacted lift above the bedding and continue to the top of the structure. Stagger tests to ensure consistent compactive effort has been achieved.

Drop Inlet Backfill Frequency Example:

- Depth of Backfill = 9 feet
- Depth of Backfill (ft.) x 12 inches /foot = Depth of backfill in inches
 - 1) 9ft. x 12 in./ft. = 108 in.
 - 2) 108 in. – 4 in. (don't test 1st compacted lift) = 104 in.
 - 3) 104 in. ÷ 8 in. (test every other 4 in. lift) = 13 tests required (minimum) (Answer)

Backfill around Manholes (minimum)

One test every fourth compacted lift around the perimeter; beginning after the first 4 inch compacted lift above the bedding and continue to 5 feet below the top of the structure. In the top 5 feet; perform one test every other lift around the perimeter and continue to the top of the structure.

Manhole Backfill Frequency Example:

- Depth of Backfill = 9 feet
- Depth of Backfill (ft.) – 5 ft. = Depth of Backfill below top 5 feet
 - 1) 9 ft. – 5 ft. = 4 ft.
 - 2) 4 ft. x 3 lifts/ft. = 12 lifts
 - 3) 12 lifts – 1 lift (skip first lift) = 11 lifts
 - 4) 11lifts ÷ 4 (test every fourth compacted lift) = 2.75, round up to 3 tests in bottom 4 ft. of backfill
- Top 5 ft. of backfill x 3 lifts/ft. = 15 lifts
 - 5) 15 lifts ÷ 2 (one test every other lift) = 7.5, round up to 8 tests in the top 5 ft. of backfill
 - 6) Total tests required = (Number of test below 5 ft.) + (Number of test above 5 ft.)
 - 7) 3 + 8 = 11 tests required (minimum)

NOTE: Compaction Tests are required on stone backfill (Class I backfill and bedding material); consult the District Materials Division for Maximum Dry Density and Optimum Moisture Content targets for the specific material being used.

POST-INSTALLATION INSPECTION

The following is an excerpt from Virginia Test Method – 123 Post Installation Inspection of Buried Storm Drain Pipe and Pipe Culverts covering the scope of post installation pipe inspection.

For all roadway projects that are constructed by private contractors for VDOT and for all roadway projects constructed by others that are or will be proposed to be accepted into the VDOT highway system, a visual/video camera post installation inspection is required on all storm sewer pipes and for a selected number of pipe culverts in accordance with the instructions contained in this VTM and Section 302.03 of the VDOT Road and Bridge Specifications. The video camera inspection is to be conducted with a VDOT representative present.

The inspection can be conducted manually if adequate crawl/walking space and ventilation is available to safely conduct the inspection and the individual(s) conducting the inspection have undergone training on working in confined spaces in accordance with VDOT's current Safety Policy and Procedure #8 Confined Space Entry Policy and Procedure - General, or the inspection can be conducted with a video camera. If the inspection is to be conducted with a video camera, the video camera shall have fully articulating lenses that will provide a 360 degree inspection of the pipe/culvert, including each joint and any deficient areas of the pipe/culvert, as well as a means to measure deformations/deflections of the pipe (items such as a laser range finder or other appropriate device for taking such measurements as specified herein and approved by the Engineer).

If the inspection is conducted manually, the person performing the inspection may use a standard video camera or a digital camera to document any observed deficiencies. If the mandrel test is to be performed to mechanically measure deformations/deflections of the pipe/culvert, the mandrel used shall be a nine (or greater odd number) arm mandrel, and shall be sized and inspected by the Engineer prior to testing. The diameter of the mandrel at any point shall not be less than the allowable percent deflection of the certified actual mean diameter of the pipe or culvert being tested. The mandrel shall be fabricated of metal, fitted with pulling rings at each end, stamped or engraved on some segment other than a runner with the nominal pipe/culvert size and mandrel outside diameter. The mandrel shall be pulled through the pipe or culvert by hand with a rope or cable. Where applicable, pulleys may be incorporated into the system to change the direction of pull so that inspection personnel need not physically enter the pipe, culvert or manhole.

A copy of the Storm Sewer/Culvert Inspection Report (inspection report) including any video tape/Digital Video Recording (DVD)/digital photographs shall be provided to the VDOT Inspector within two business days of the completion of the inspection and made part of the project records. Additionally, a copy shall be furnished to local VDOT Asset Management personnel to document the pipe/culvert condition at that point in time. The video tape/DVD/digital photographs should be of such clarity, detail and resolution as to clearly show the conditions of the interior of the pipe/culvert and detect any defects within the pipe or culvert as specified herein. Post installation inspections shall be conducted no sooner than 30 days after completion of installation and placement of final cover (except for pavement structure).

From this we can highlight the following requirements:

- Visual/ Video Inspection is required on:
 - All Storm Sewer Pipes (100%)
 - Selected Number of Pipe Culverts (>10%)

- Must be done with VDOT Rep Present
- Conducted no sooner than 30 days after completion of Installation and placement of final cover (except pavement).

When performing a manual visual inspection:

- There must be adequate crawl/walking space and VDOT Safety Policy and Procedure #8 Confined Space Entry Policy and Procedure must be followed.
- A standard Video/ Digital Camera can be used.
- A mandrel is needed for Flexible Pipe to measure deflection.
- Cracks shall be digitally scanned to allow for accurate measurement.

If the inspection is conducted by video:

- The video camera must have fully articulated lenses (360 degree inspection).
- The camera must have the means to measure deformation/deflection of the pipe.
- All cracks shall be digitally scanned to allow for accurate measurement.

Deficiencies found may include: but are not limited to, the following:

- Crushed, collapsed or deformed pipe or joints
- Alignment defects
- Improper Joints (allow infiltration of soil)
- Misaligned joints (allow debris accumulation)
- Pipe Penetrations (guardrails, utilities, etc.)
- Debris in the pipe
- Coatings free of cracks, scratches and peeling
- Cracks (longitudinal and circumferential)
- Spalls and Slabbing
- For metal and plastic pipe – localized buckling, bulging, cracking at bolt holes, flattening, or racking, etc.

Refer to *VDOT Road and Bridge Specifications, Section 302.03 Procedures (d) Post Installation Inspection* for detail requirements and remediation procedures.

PAVEMENT DRAINS

Pavement subsurface drainage is essential in obtaining a well performing pavement, whether it is flexible, rigid or composite. A drained pavement structure has a higher bearing capacity that can effectively support traffic loadings, and lead to long lasting pavement at the least maintenance cost.

A trench at the edge of the pavement provides a cavity with the least resistance for water to flow and accommodate pavement drainage. The trench's dimensions and location are typically 1 foot wide and 2 to 4 inches below the subgrade and adjacent to the pavement edge. The specific locations are shown on the plans. There is a variety of pavement under/edge drains in the VDOT Road and Bridge Standards Volume 1 (108.01-108.09) with each addressing a specific geometric condition and groundwater condition.

The most common underdrains are known as UD-4 and UD-7. The UD-4 is used with new construction, while the UD-7 is used for retrofitting existing pavements. These underdrains are segmented systems with outlets spaced at 250 to 350 feet.

The components of an underdrain system are:

- 1) Trench
- 2) Non-woven geotextile drainage fabric
- 3) Perforated longitudinal pipe (min. stiffness 35 psi) is the collecting conduit
- 4) Aggregate backfill (#8 or #57)
- 5) Non-perforated smooth wall outlet pipe (min. pipe stiffness 65 psi)
- 6) An end-wall for the protection of the outlet pipe.

The above components are designed to perform three functions to aid in draining water from the pavement; these are:

- Intercept
- Collect
- Discharge

Following is a general guide on the installation of underdrain/edge drain systems:

- 1) Excavate trench making sure the side walls are stable
- 2) Remove any sloughed materials from the trench
- 3) The dug out material is picked up with conveyor belt and loaded in trucks or piled on one side then picked up by a front end loader.
- 4) Provide a minimum 0.5 to 1% longitudinal slope to enhance positive drainage.
- 5) Open only as much trench as can be safely maintained by available equipment.
- 6) Line the trench with the non-woven drainage fabric.
- 7) Install the longitudinal perforated pipe at the bottom of the trench without bedding material.

- 8) At the end of the run (250-350 feet) a 45-degree elbow is used to connect the longitudinal pipe to the non-perforated outlet pipe to force the collected water to discharge. The side is called the drainage side.
- 9) The outlet pipe is connected to the back of the end-wall.
- 10) Backfill the trench using clean #8 or #57 aggregate as soon as practical, but not later than the end of each working day.
- 11) Backfill depth is at least equal to the diameter of the pipe.
- 12) Backfill is usually placed loosely and heaped above the finished level.
- 13) Use vibratory plate with a welded foot to compact the aggregate backfill.
- 14) Fold the drainage fabric to provide 100% overlap at the top of the trench.
- 15) In the case of UD-4, the Open Graded Drainage Layer (OGDL) is placed on top of the completed trench.
- 16) In the case of UD-7, an asphalt concrete cap is used to complete the backfilling and provide the final surface that is even with the shoulder.
- 17) Once the system has been installed, it is critical that inspection is performed to ensure that there are no areas that are crushed, clogged or otherwise non-functioning. Inspection is performed in accordance with VTM-108.

CHAPTER 4 – STUDY QUESTIONS

- 1) What should be located before starting to dig?
- 2) True or False. When moving concrete pipe you should pick it up by one end.
- 3) What are the testing requirements for backfilling around pipe?
- 4) What is the maximum size a rock to be placed within 12 inches of a pipe?
- 5) True or False. You do not have to place pipe bedding material down first when installing a UD-4.
- 6) Where can the typical underdrain drawings be found?
- 7) What is the maximum height of cover for a 48 inch pipe diameter Class IV concrete pipe culvert?
- 8) A 36 inch diameter pipe, 290 feet long, is placed on a project as a drainage culvert. What is the minimum number of density tests that should be run on the backfill material?
- 9) When can No. 57 stone be used?
- 10) What is the maximum backfill lift thickness?
- 11) Pipe openings in precast drainage structures shall not exceed the outside cross sectional dimensions of the pipe by more than how much?
- 12) How long after installation is complete can the video inspection can be done?
- 13) What is the maximum allowed crack size of a rigid pipe?
- 14) What is the maximum deflection allowed for flexible pipe?
- 15) What end of the pipe system do you start installation? Upstream or down- stream?
- 16) What is the level of compaction required for pipe backfill?
- 17) What is the minimum amount of cover over pipe allowed for design loads?
- 18) What is the minimum amount of cover over pipe to prevent damage from construction loads?

