Snap-Tite® Culvert Rehab

Technical Guide & Design Manual

Snap-Tite®, by ISCO, is the best and safest way to rehab your culvert and spillway projects.

The Snap-Tite® joint and installation system allows replacement of failing systems without the need to remove existing pipe by excavation. Snap-Tite® can be typically installed with a backhoe, trackhoe, come-a-longs, and chains.

Snap-Tite®: The proven solution in the field.

We have eliminated the problem of having to excavate aged culverts and spillways. Specially manufactured sections of polyethylene pipe are inserted into the old culvert or spillway, forming one continuous, leak-free liner. Once grouted in place, the new system is virtually maintenance-free.

It's a fast installation with no special training or equipment. It meets the job's requirements.

The Snap-Tite® pipe lining system is unmatched in ease of installation. Since it typically weighs as little as 10% of concrete, ductile iron and clay pipes, it is much easier to handle. Maintenance departments can use their own crews – no special training or specialized equipment is necessary.

Everything for the installer.

Snap-Tite® pipe comes in sizes from 8- to 63-inch OD. Facing a damaged pipe with limited access? Not a problem with Snap-Tite®.

These advantages also make Snap-Tite® the preferred answer for dam spillway renewal. Typical applications are:

- CMP Culvert & Spillway Rehabilitation
- Ductile Iron Culvert & Spillway Rehabilitation
- Concrete Culvert & Spillway Rehabilitation

See what Snap-Tite® can do for you. It may be the last solution you'll ever need for culvert and spillway rehab problems.

Simple installation means light duty equipment, less manpower, minimal disturbance of right-of-way, and indefinite service life. When considering these benefits, it becomes clear that the Snap-Tite® system is the most cost-effective way to rehabilitate deteriorating culvert and spillway systems.

Effective Strengths to depend on.

- Safest solution for installers and motorists
- Save 50% or more compared to pipe replacement
- No disturbance of existing utilities
- No interruption of services
- Little or no surface damage
- Faster project completion
- Improved hydraulic capacity
- Sealed system prevents leakage
- Long service life
- An effective, economical system promotes a cleaner, healthier environment

Snap-Tite® Product Support

With the Snap-Tite® sales force and application engineers you get more than just order takers. They've literally been in the trenches and have extensive project-related experience. They're specially trained to answer the hard questions and give the right recommendations for your unique application needs.

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Chapter 1
Snap-Tite®: Your Culvert Lining Solution

Before rehabilitation

After rehabilitation with Snap-Tite®

The Snap-Tite® HDPE Culvert Lining System was designed and developed as a safe and permanent solution for repairing failing culverts. Many existing culverts are 50 years old and beyond their design life. In the United States, the majority of our highway system was built in the 1950s. The culverts built under these systems were made of either corrugated metal or concrete with a design life of approximately 40-50 years. Repairing these culverts before they enter the critical state of collapse is imperative to the safety of the public.

What happens to a road when the culvert running beneath it is in failure mode?

The picture in Figure 1 shows pothole damage found at the road surface above the culvert along with other road damage. Deteriorating culverts come quickly to mind when roadway damage caused by corroded, rusted and washed-out culverts occurs.

Pavement failure occurs when the soil beneath the road surface is washed away (see Figures 2 through 4). This soil movement and loss of bedding creates a void beneath the road. This makes the roadway unstable. Patching the road is only a short-term answer and does not address the reason for the failure. The reality is the culvert has failed. While it's easy to see this when it's shown to us, culvert damage and aging isn't something we look for everyday.

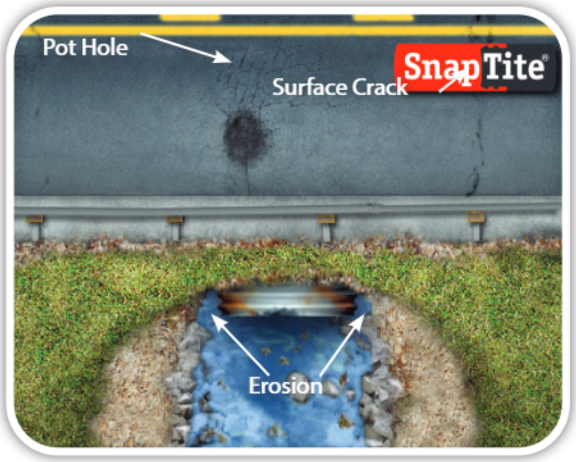


Figure 1

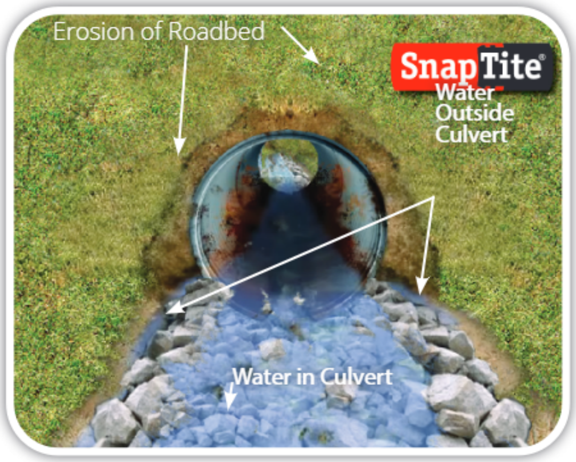


Figure 2

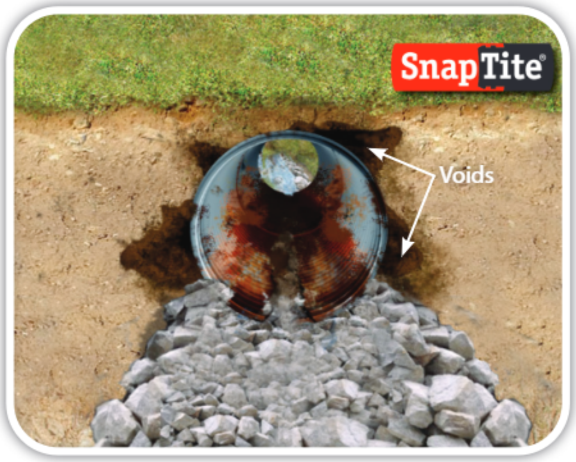


Figure 3

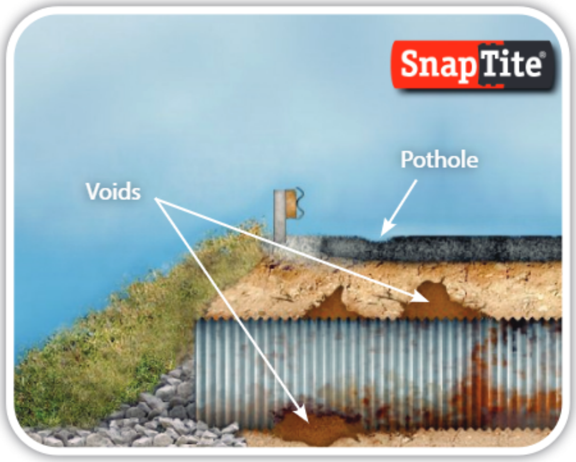


Figure 4

Many automobile accidents and even some fatalities have been attributed to failing culverts. Replacement is an expensive, time-consuming, labor-intensive process which causes traffic headaches and collateral damage to cars, trucks and neighboring property.

The Snap-Tite® HDPE Culvert Lining System is a unique culvert lining solution that not only restores the existing culvert, but also addresses the critical safety and maintenance issues presented by the soil voids.

Snap-Tite® is made from solid-wall high density polyethylene (HDPE) pipe with a male and female end that 'snaps' together during installation, which do not increase the inside or outside diameter of the liner pipe. Therefore, there will be no flow restrictions or coupling hang-ups. A water-tight joint is achieved with the inclusion of the gasket provided (see Figure 8).

Snap-Tite® meets the requirements of AASHTO M326, a standard for relining culverts in the US. Snap-Tite® is viewed by many users as the permanent solution, with numerous advantages over concrete and corrugated metal pipe (CMP) replacement.

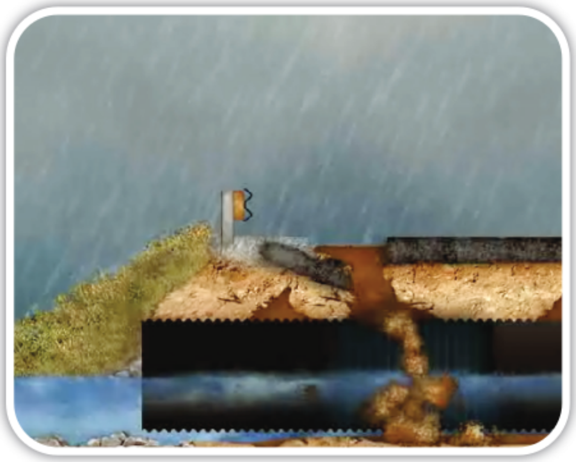


Figure 5

Figure 6

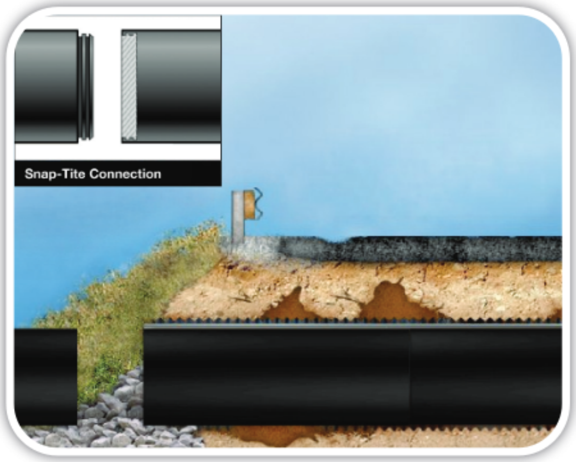


Figure 7

Figure 8

In most cases, Snap-Tite® actually out-performs the concrete and corrugated metal it rehabilitates. Even at smaller diameters than the original pipe, Snap-Tite® allows for better throughput than concrete or corrugated metal due to the smooth wall interior of the pipe. Furthermore, the Snap-Tite® Culvert Lining System is unmatched in ease of installation. Since it typically weighs as little as 10% of conventional materials, it is much easier to handle. Highway departments can use their own crews with no special training or specialized equipment necessary.

Snap-Tite® ranges from 8" to 63" solid-wall HDPE pipe. Because of Snap-Tite®'s ease of installation and variable lengths, 95% of culvert renewal can be done off road. This means increased safety for both your workers and motorists. Traffic disturbance can be a thing of the past; all work is done in the culvert itself, not by digging up roadways.

These advantages also make Snap-Tite® the perfect answer for culvert extensions, road-widening, direct burial applications and sewers with limited access.

There are other culvert lining materials available in the marketplace, but the benefits offered by the Snap-Tite® Culvert Lining System such as superior flow capacity, long life cycle and the minimal traffic disruption concerns provided by a trenchless rehabilitation method make it the best overall solution for culvert lining. In addition, it truly is a permanent solution because its patented water-tight joint provides the soil stabilization required for a roadway and culvert to perform.

Chapter 2
Snap-Tite® High-Density Polyethylene (HDPE) Pipe

Introduction

Snap-Tite® HDPE Pipe, sold and distributed by ISCO Industries, Inc., offers a complete package of sales and support to rehabilitate failing culverts throughout North America. Please call 1-800-CULVERT or visit www.culvert-rehab.com for culvert lining solutions.

Some of the characteristics of Snap-Tite® solid-wall HDPE Pipe are:

Economical	Flexible and Ductile
Corrosion Resistant	Mechanically Joined
Hydraulically Smooth	Strong and Ductile
Long Design Life	Weather Resistant
Weldable	Impact Resistant
Chemically Resistant	Freeze Tolerant
Easily Installed	Durable
Small to Large Diameters	Abrasion Resistant
Non-Toxic	Inert
Lightweight	Listed and Approved
Reliable	Recyclable

Domestically Produced

All components related to the manufacture of Snap-Tite® HDPE pipe, including production of the resin, pipe extrusion, and fabrication of male/female ends occurs domestically. Certification of Snap-Tite products meeting any ARRA or Buy America requirements can be provided additional to this statement, when required.

Important Standards for High Density Polyethylene (HDPE) Pipe

Standards important for Snap-Tite® HDPE pipe relate to the resin the pipe is made from and the standards related to manufacturing sizes and tolerances.

AASHTO Standards:

AASHTO M 326: Specification for Polyethylene (PE) Liner Pipe, 300-to1600-mm Diameter, Based on Controlled Outside Diameter

ASTM Standards:

ASTM D3350 Standard Specification for Polyethylene Plastics Pipe and Fittings Materials. This standard defines the physical properties along with performance levels of the resins used to manufacture pipe and fittings.

ASTM F714 Standard Specification for Polyethylene (PE) Pipe (SDR-PR) Based on Outside Diameter. This standard is used for most large diameter HDPE pipe (6" to 63") Applications.

ASTM F585 Standard Practice for Insertion of Flexible Polyethylene Pipe into Existing Sewers

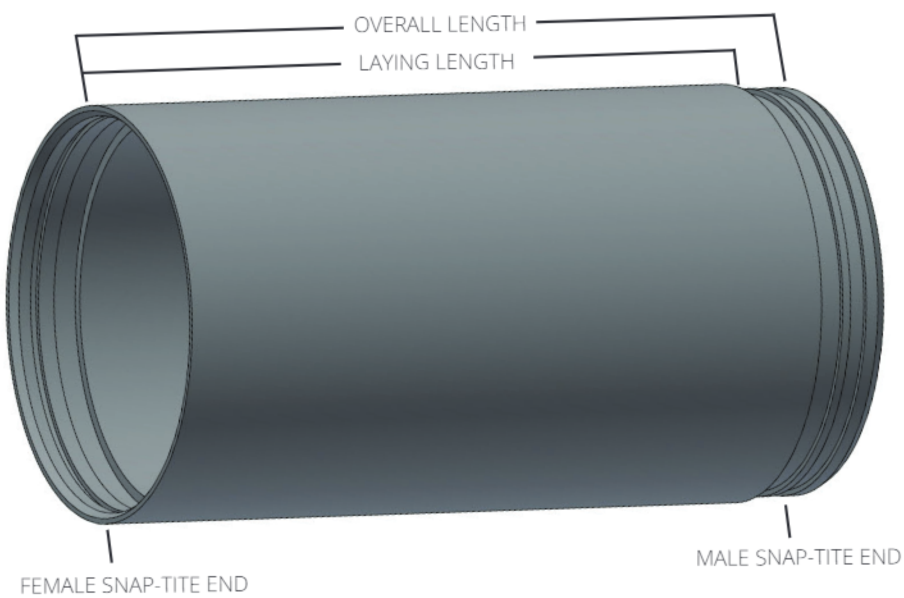
ASTM D3212 Standard Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals Industry Standard for Culvert Relining.

ASTM D2321 Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity Flow Applications.

Table 2-1 | Dimensions and Weight for Snap-Tite

Outside Diameter, OD (Inches)	Minimum Inside Diameter, ID (Inches)	Weight per foot (lbs.)
8.625	7.6	5.69
10.75	10.1	5.91
12.75	12.0	6.67
14	13.1	8.05
16	15.0	10.50
18	16.9	13.30
20	18.8	16.50
22	20.6	19.86
24	22.5	23.62
26	24.3	27.94
28	26.3	32.19
30	28.2	36.93
32	30.0	42.04
36	33.8	63.69
42	39.4	72.37
48	45.0	94.96
54	50.7	119.70
63	59.1	162.98

Dimensions based on standard DR 32.5 pipe for 14"-63", DR 26 for 10"-12", and DR 17 for 8".



Standard lay length:
- 24' except for below
- 21' for 10"/12" (East US)
- 21' for 10"-18" (West US)

Standard "half" lay length:
- 9' for 14" and larger
- 11' for 10"/12"

Custom lengths between 5' - 23':

Non-stock with extended lead times and surcharges

Material Specifications for HDPE Pipe

Polyethylene piping materials are defined or specified using two important standards: the ASTM D3350 cell classification and the ASTM F412 thermoplastic piping material designation code. The ASTM D3350 consists of a series of six digits followed by one letter.

The six digits equate to the specified level of performance required in six separate physical properties, such as density, melt index, flexural modulus, and tensile strength defined within the standard. The final letter specifies the color or UV-resistance requirement. Taken together the D3350 cell classification establishes a minimum range of technical performance for the PE compound used to produce the pipe.

The ASTM F412 thermoplastic piping material designation code is a more generic nomenclature for pressure rated pipe produced from a particular PE compound. This code consists of an abbreviation for the basic material as defined within the ASTM standards. The standardized abbreviation for polyethylene is the term “PE”. This basic polymer designation is then followed by a series of four digits. The first two digits relate directly to specific physical properties for the compound as defined within ASTM D3350. The last two digits are related to the pressure capacity of the compound, indicating the long-term hydrostatic stress rating as recommended by the Hydrostatic Stress Board of the Plastic Pipe Institute in hundreds of psi. The long-term hydrostatic stress rating is the hydrostatic design basis (HDB) multiplied by the appropriate design factor (DF).

So the thermoplastic piping material designation code follows the form below.

PEXYZZ, the format of the thermoplastic material designation code for PE pipe

Where:
PE indicates polyethylene

X is the characteristic density range for the compound used to make the pipe as defined within ASTM D3350

Y is the characteristic slow crack growth resistance range for the compound used to make the pipe as defined within ASTM D3350

ZZ is the long-term hydrostatic stress at 73° F, expressed in hundreds of psi

Historically, the market for PE pipe was dominated by essentially two primary thermoplastic material designation codes. These were PE2406 and PE3408. In 2005, changes were made to ASTM D3350 to allow for the identification and integration of much higher levels of technical performance in PE piping materials within the North American standards system. This resulted in a temporary proliferation of PE thermoplastic piping material designation codes. Today, there still is a fairly broad selection of material designation codes for PE piping systems throughout the marketplace. However, for all practical purposes, the market for PE pipe is characterized by the three common thermoplastics materials designation codes.

PE2708 – This piping product, commonly supplied as yellow colored pipe, is produced from a medium density compound as defined in the current version of D3350 and is widely used in natural gas distribution and some specialty applications.

PE3608 - This piping product is the legacy product resulting from the old PE3408 thermoplastic piping material designation code that was so widely specified and used prior to 2005. Today, products labeled PE3608 are rather uncommon due to higher performing PE4710 resins available at roughly the same price.

PE4710 - This piping product designation represents the culmination of years of technical research on polymer performance in PE piping and offers the designer or end-user exceptional levels of pipe system performance. For example, the PE4710 piping products support a higher long-term hydrostatic stress rating making the pressure rating for a given wall thickness of pipe 25% higher than a comparable PE3608 piping product. By the same token, these piping products exhibit a significantly higher resistance to slow crack growth. Given the exceedingly high physical performance of the PE4710 piping products, it is no surprise that they have replaced the older PE3408/ PE3608 piping products since they meet or exceed all of the technical requirements.

Table 2-2 provides a summary of the different ASTM D3350 cell classifications for each of these materials, based on these three primary thermoplastic piping material designation codes.

Table 2-3 below provides a simplification of Table 2-2 and illustrates the relative ease with which PE piping products may be specified. Using this approach allows the designer or specifier to accurately designate the appropriate PE piping product through the use of a single thermoplastic piping material designation code and a relatively simple text string that establishes the physical property requirements for seven key performance properties.

It should be noted that other PE thermoplastics piping material designation codes do exist and may be encountered in the different markets. However, the three primary PE thermoplastic piping material designations codes of Tables 2-2 and 2-3 represent the principle PE piping products in the pressure pipe market today. Also consider that most HDPE corrugated piping would have an ASTM F412 designation of PE4000 or or PE4200 since it has no Hydrostatic Design Basis, and typically use resins with less flexural modulus and lower stress crack resistance.

Table 2-2
Typical Cell Classification
by Current Thermoplastic Piping Material Designation Code

Physical Property	ASTM Test Method	Units	PE2708		PE3608		PE4710	
			Cell Number	Typical Value	Cell Number	Typical Value	Cell Number	Typical Value
Density	D 1505	GR/CM^3	2	>0.925-0.940	3	>0.940-0.947	4	>0.947-0.955
Melt Index	D 1238	GR/10 MIN	3	<0.4-0.15	4	<0.15	4	<0.15
Flexural Modulus	D 790	PSI	3	40,000 -<80,000	5	110,000 - <180,000	5	110,000 - <180,000
Tensile Strength	D 638	PSI	3	2600 - <3000	4	3000 - <3500	4	3000 – < 3500
Resistance to Slow Crack Growth	F 1473	HOURS	7	500 Minimum	6	100 Minimum	7	500 Minimum
Hydrostatic Design Basis, HDB	D 2387	PSI	3	1250	4	1600	4	1600
UV Stabilizer	D 1603	%	E	Colored with UV Stabilizer	C	2% Min Carbon Black	C	2% Min Carbon Black

Notes:
1. *The density provided is base resin density (without the influence of carbon black). Typical PE4710 HDPE pipe has a density of 0.956 to 0.964 with carbon black.*

Table 2-3
Representative Minimum Cell Classification by Thermoplastic Piping Material Designation Code

Thermoplastic Piping Material Designation Code	Minimum Cell Classification Per ASTM D3350
PE2708	233373E
PE3608	345464C
PE4710	445474C

For the culvert lining market, solid-wall piping systems typically use HDPE resins with a PE4710 designation. Snap-Tite will use only PE4710 resins as noted in the model specification provided in Chapter 13 and online at www.culvert-rehab.com, or by contacting your local Snap-Tite® representative.

Pipe Stiffness Material Properties for HDPE Pipe

ASTM F714 contains the dimensional standards for manufacturing solid wall HDPE pipe in nominal sizes 3" and larger and is mirrored in AASHTO M326. Additionally, Table X2.1 in appendix X2 of ASTM F714 identifies pipe stiffness values for solid wall pipe based on pipe properties that correspond to physical testing values, typically obtained thru methods outlined in ASTM D2412. For solid wall HDPE pipe used for Snap-Tite® products, a range of 16-23 psi is typical. Table 8-1 on page 70 in this Snap-Tite Design Guide uses 16 psi since it is a minimum value for design purposes.

It should be noted that pipe stiffness values need to be considered in the context of a rehabilitated pipe system. ASTM F714 Appendix X2 begins with noting that "control of deflection is achieved primarily through control of the earthwork surrounding buried systems", which in the case of relined culverts is the grout envelope between the host and the liner, and the soil around the host. While pipe stiffness is an indication of the load-deformation characteristics of the pipe, HDPE and other flexible pipe systems are much more dependent for pipe soil interactions for overall strength. Pipe stiffness has very little effect on the deflection of buried pipes and grouted liners, and only represents the resistance to deformation solely by the pipe without any external support.

In simplistic terms:

$$\text{Pipe Deflection} = \frac{\text{Load on Pipe}}{\text{Pipe Stiffness+Soil Stiffness}}$$

And when the pipe stiffness is much lower than soil stiffness and assumed to be insignificant, then the equation is generally viewed as:

$$\text{Pipe Deflection} = \frac{\text{Load on Pipe}}{\text{Soil Stiffness}}$$

For a direct buried flexible pipe, soil stiffness is the most important element in constructing a structurally sound pipeline. For relined pipe systems, pipe stiffness is of greatest importance during the grout placement process, as the pipe stiffness is the ability of the HDPE liner to resist external loads while in an unconstrained condition. Once the grout has fully cured, it becomes an integral component of the rehabilitated pipe system becoming a control fill in the embedment materials used to resist pipe deflection. The cured grout typically exceeds the strength of a compacted sand or gravel fill that is likely to be found beyond the existing host pipe. If the grout develops cracks or breaks, it becomes a granular fill similar to what likely is present for original host pipe embedment. So similar to a buried flexible pipe system, pipe stiffness in this Rehabilitated Pipe System plays only a minor role in resisting external loads, like soil and traffic, which lead to pipe deflection.

Chapter 8 of this Design Guide provides a structural design methodology consistent with AASHTO LRFD Design Section 12 criteria, where the both pipe and grout properties are considered. Chapter 9 provides the results of that approach.

Chapter 3
Hydraulics

3-1 Flow in Culverts

Much of the information in this chapter is a summary of information presented by the Federal Highway Administration's (FHWA) Hydraulic Design Series (HDS) No. 4 and No. 5 publications. HDS 4 is titled Introduction to Highway Hydraulics (FHWA 2008a-Fourth Edition) and deals with culverts as "closed conduits" in chapters 7-9. HDS 5 is titled Hydraulic Design of Highway Culverts (FHWA 2012-Third Edition) and is a comprehensive culvert design publication, developed to standardize procedures and simplify analysis of culvert flow. As stated in both documents, flow conditions depend not on just the culvert (or the inserted liner) but also the interaction with upstream and downstream conditions. The choice of a culvert lining or replacement cannot be made merely along the potential flow capacity of a pipe, but also on hydrology (climatological and watershed characteristics), site data, aquatic ecology concerns, maintenance issues and overall economics.

Ideally, culverts are designed for full-pipe flow in the barrel at the maximum design discharge value. This means that pressurized pipe flow is impending at the design discharge, but at lower flow rates open channel flow exists in the barrel. Under these design conditions, this will allow transport of water with minimal headwater buildup. Headwater is the water surface elevation on the upstream side of a culvert and provides the energy to force water through a culvert. When a channel waterway is constricted like that of culvert through and embankment, conveyance capacity is typically reduced. However, the choice of a culvert (and its relining option) is one that can be economically justified, in the short term and many times long term, against the costs to meet the entire flow criterion. It is not uncommon to accept some increase in upstream water level, or design headwater, as long as it stays below allowable headwater depth or specific distance below the roadway shoulder elevation to prevent overtopping of an embankment and/or roadway.

3-2 The Manning's Equation

Historically, a simplistic approach for comparing flow rates in culverts (host and relined) is determined by using the Manning's equation. With the Manning's equation, the capacity for a pipe as open channel flow(less than full) and gravity full flow conditions can be approximated. Many existing culverts were designed with capacity for 100 year flood conditions and infrequently have water over the top of the inlet, so less than full or gravity full flow conditions would be expected. Culverts flowing with outlet control (see section 3-6) can have the barrel full of water or partly full for either all or part of the barrel length. If the entire cross section of the barrel is filled with water for the total length of the barrel, the culvert is said to be flowing full and is in outlet control.

When Snap-Tite® is inserted into another pipe with a higher roughness coefficient, or Manning's "n" factor, it is not uncommon for the barrel to be capable of handling the same flow, or even increased capacity. For example, when a 36" corrugated metal pipe (CMP) is lined with a 30" Snap-Tite® liner, the calculations show an increase in flow of 35% using Manning's equation. If the existing culvert is not undersized for current hydrological demands, then flow after lining with Snap-Tite® will not be dramatically affected since the capacity of the lined culvert is near that of the old culvert.

To determine the gravity full flow condition in storm drain systems, The Manning's Equation for full flowing circular pipes is:

$$Q = .0006136 \times (d^{8/3} S^{1/2})/n$$

Where:

Q = Discharge/flow, cubic ft per sec

d = pipe inside diameter, in inches

S = culvert barrel slope (feet/foot)= (h1 – h2)/L

- **L** = pipe length, in feet
- **h1** = Entry Culvert elevation in feet
- **h2** = Exit Culvert elevation in feet

n = Manning's factor

3-3 Selection of Manning's Factor

Snap-Tite® is made using solid-wall HDPE pipe. The extrusion of HDPE resin creates a very smooth pipe. The Snap-Tite® joint allows sections of pipe to be joined together mechanically in the field without increasing the OD (outside diameter) or increasing/ decreasing the ID (inside diameter) of the liner at the joint. Snap-Tite® Culvert Liner has been tested in full-flow conditions to determine the Manning's factor. Utah State Water Research Laboratory tests determine that an "n" factor of 0.00914 is valid for Snap-Tite® in full-flow conditions, which is consistent for industry standards for the pipe.

Solid wall thermoplastic pipes appear to remain smooth throughout their lifetime. The surface of some materials may change with time. Based on industry practice, Snap-Tite® and other solid-wall materials are smooth throughout their useful life and the Manning's "n" factor is considered constant.

In low-flow situations, it is possible for sediment to accumulate in a culvert. Sticks, rocks and other debris may collect inside. The condition of a liner is sometimes not the same over its expected life, as cracked, corroded and even deformed liners will affect the smoothness of a pipe and will impact flow. These situations may influence the selection of a different "n" factor. While in many applications the measured "n" factor is normally used, the final selection of the "n" is the owner or engineer's choice based on their experience.

3-4 Velocity

Velocity is the speed at which water flows through a culvert. When the velocity exceeds 3 feet per second (fps), sediment is normally entrained in the flow, and the culvert is considered self cleaning. If the velocity is less than 3 fps, sediment will usually buildup in the culvert. In evaluating sediment potential, factors such as particle size, specific gravity, cohesiveness, flow velocity and roughness of the pipe must also be considered.

Once the flow rate is determined using Manning's equation, then the velocity, V (ft/sec), can be approximated by using the equation below:

$$V = Q/A$$

Where:
Q= flow, cu ft per sec
A = area, ft sq

As the velocity increases, sediment is no longer a problem in most situations. When velocities are over 12 feet per second, they are considered high. Solid wall HDPE pipe has been used in slurry and dredging application at velocities approaching 18 to 20 fps, with excellent wear resistance compared to most other materials. Short-term exposure to high velocity may cause long-term damage. As large rocks and debris strike the Snap-Tite® liner, damage can occur. Damage and wear is more likely at higher velocities.

When the velocity is known to be high, streambed scour and bank erosion may occur at the discharge of the outlet pipe. The high velocity and flow condition can erode a channel. An apron or formed concrete or riprap under the discharge is a commonly used to prevent erosion and scour at the discharge. This document does not intend to address all situations related to high discharge velocities but only makes the designer aware of the potential issues. The National Highway Institute and Federal Highway Administration has published Hydraulic Design of Energy Dissipators for Culverts and Channels(Hydraulic Engineering Circular 14, Third Edition). It provides extensive design information for analyzing and mitigating energy dissipation problems at culvert outlets.

Table 3-1
Comparative Flow Rates for Corrugated Metal Pipe (CMP) lined with Snap-Tite®
Based on Manning's equation n=0.00914 for Snap-Tite®, n=0.024 for CMP, s=0.001 ft/ft

CMP			SnapTite®				% of Flow Relined
Culvert Size ID (in)	Flow (gpm)	Flow (cfs)	Outside Dia. (in)	DR 32.5 Av. ID (in)	Flow (gpm)	Flow (cfs)	
12	274	0.6	10.75	10.05	448	1.0	164%
15	497	1.1	12.75	11.92	706	1.6	142%
18	808	1.8	14	13.09	906	2.0	112%
18	808	1.8	16	14.96	1294	2.9	160%
21	1218	2.7	16	14.96	1294	2.9	106%
21	1218	2.7	18	16.83	1771	3.9	145%
24	1739	3.9	18	16.83	1771	3.9	102%
24	1739	3.9	20	18.70	2346	5.2	135%
24	1739	3.9	22	20.56	3025	6.7	174%
27	2381	5.3	22	20.56	3025	6.7	127%
27	2381	5.3	24	22.43	3815	8.5	160%
30	3153	7.0	24	22.43	3815	8.5	121%
30	3153	7.0	26	24.31	4720	10.5	150%
30	3153	7.0	28	26.17	5755	12.8	182%
36	5128	11.4	28	26.17	5755	12.8	112%
36	5128	11.4	30	28.04	6917	15.4	135%
36	5128	11.4	32	29.91	8216	18.3	160%
42	7735	17.2	32	29.91	8216	18.3	106%
42	7735	17.2	36	33.65	11248	25.1	145%
48	11043	24.6	36	33.65	11248	25.1	102%
48	11043	24.6	42	39.26	16967	37.8	154%
54	15118	33.7	42	39.26	16967	37.8	112%
54	15118	33.7	48	44.87	24224	54.0	160%
60	20023	44.6	48	44.87	24224	54.0	121%
60	20023	44.6	54	50.48	33163	73.9	166%
66	25817	57.5	54	50.48	33163	73.9	128%
66	25817	57.5	63	58.89	50024	111.5	194%
72	32559	72.5	54	50.48	33163	73.9	102%
72	32559	72.5	63	58.89	50024	111.5	154%
84	49114	109.4	63	58.89	50024	111.5	102%

*Many culverts operate under Inlet Control where full flow Manning's equation comparisons are not accurate since they fail to account for inlet and outlet losses, which may not be minor losses, especially when the barrel is short.

Table 3-2
Comparative Flow Rates for Concrete Pipe lined with Snap-Tite®
Based on Manning's equation n=0.00914 for Snap-Tite®, n=0.015 for Concrete, s=0.001 ft/ft

Concrete			SnapTite®				% of Flow Relined
Culvert Size ID (in)	Flow (gpm)	Flow (cfs)	Outside Dia. (in)	DR 32.5 Av. ID (in)	Flow (gpm)	Flow (cfs)	
12	438	1.0	10.75	10.05	448	1.0	102%
15	795	1.8	12.75	11.92	706	1.6	89%
18	1292	2.9	14	13.09	906	2.0	70%
18	1292	2.9	16	14.96	1294	2.9	100%
21	1949	4.3	16	14.96	1294	2.9	66%
21	1949	4.3	18	16.83	1771	3.9	91%
24	2783	6.2	18	16.83	1771	3.9	64%
24	2783	6.2	20	18.70	2346	5.2	84%
24	2783	6.2	22	20.56	3025	6.7	109%
27	3810	8.5	22	20.56	3025	6.7	79%
27	3810	8.5	24	22.43	3815	8.5	100%
30	5045	11.2	24	22.43	3815	8.5	76%
30	5045	11.2	26	24.31	4720	10.5	94%
30	5045	11.2	28	26.17	5755	12.8	114%
36	8204	18.3	28	26.17	5755	12.8	70%
36	8204	18.3	30	28.04	6917	15.4	84%
36	8204	18.3	32	29.91	8216	18.3	100%
42	12376	27.6	32	29.91	8216	18.3	66%
42	12376	27.6	36	33.65	11248	25.1	91%
48	17669	39.4	36	33.65	11248	25.1	64%
48	17669	39.4	42	39.26	16967	37.8	96%
54	24190	53.9	42	39.26	16967	37.8	70%
54	24190	53.9	48	44.87	24224	54.0	100%
60	32037	71.4	48	44.87	24224	54.0	76%
60	32037	71.4	54	50.48	33163	73.9	104%
66	41307	92.0	54	50.48	33163	73.9	80%
66	41307	92.0	63	58.89	50024	111.5	121%
72	52095	116.1	63	58.89	50024	111.5	96%
84	78582	175.1	63	58.89	50024	111.5	64%

*Many culverts operate under Inlet Control where full flow Manning's equation comparisons are not accurate since they fail to account for inlet and outlet losses, which may not be minor losses, especially when the barrel is short.

Table 3-3
Comparative Flow Rates for Concrete Box Culvert lined with Snap-Tite®
Based on Manning's equation n=0.00914 for Snap-Tite®, s=0.001ft/ft

Existing Concrete Box Size	Manning's "n" Factor	Snap-Tite® Liner Size	Box full-flow cfs	Snap-Tite® Flow cfs	% of Flow
3 ft. x 3 ft.	0.012	36"	29	25	86%
	0.015	36"	23	25	108%
4 ft. x 4 ft.	0.012	48"	63	54	86%
	0.015	48"	50	54	107%
5 ft. x 5 ft.	0.012	54"	114	74	65%
	0.015	54"	91	74	81%
6 ft. x 6 ft.	0.012	63"	186	111	60%
	0.015	63"	149	111	75%

**Many culverts operate under Inlet Control where full flow Manning's equation comparisons are not accurate since they fail to account for inlet and outlet losses, which may not be minor losses, especially when the barrel is short.*

High velocity in a liner can cause separation on the liner joints when the liner is not grouted in place. Grouting of the liner into the host culvert eliminates separation concerns.

It should be noted that one of the anomalies associated with circular pipes is that a partially full pipe will have higher discharge flow rates than a full pipe can carry, due to the increased friction along the wetted perimeter (Figure3-1). Flow rates above 80% full will be higher than a pipe than full pipe flow with a peak at 93%. Velocities above 50% will be higher than full pipe velocities with a peak at approximately 80% full mark.

Figure 3-1

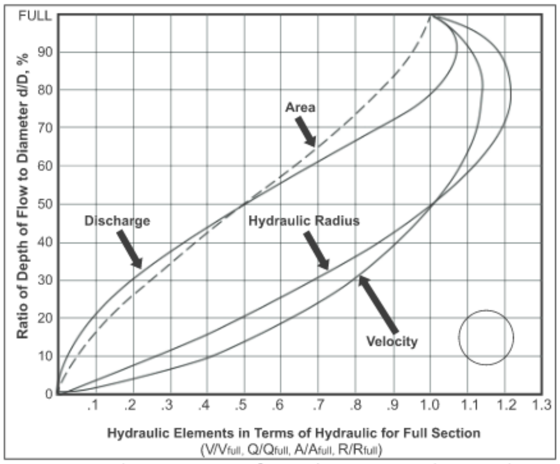


Chart courtesy of Introduction to Highway Culverts.

3-5 Pressure Considerations

Snap-Tite® is made using low-pressure HDPE pipe. The Snap-Tite® joint is designed for use in gravity flow applications and to meet the requirements for AASHTO M 326 . Pressure from headwater or tailwater conditions should not harm the liner or the joint. Snap-Tite® is not designed for long-term pressure applications.

3-6 Types of Flow Control

Once a pipe exceeds the point of full open channel flow, culvert operation is ruled at all times by one of two conditions: inlet control or outlet control. When lining culverts, both inlet and outlet control must be considered. The hydraulic capacity of a culvert depends upon a combination of factors that influence each type of control, identified in Table 3-4. The slope of a culvert, that is barrel slope, is the primary factor influencing whether or not a culvert will be in inlet or outlet control.

Outlet control occurs when flow through the culvert barrel or tailwater can not accept as high a flow as the inlet opening will accept. Full barrel flow with no hydraulic jump is considered to operate under outlet control. Tailwater is the water surface elevation on the downstream side of a culvert as measured from the invert at the culvert exit. High tailwater alone can make a culvert operate under inlet control, but long culverts with rough interiors or slightly sloping culverts are other factors with outlet control.

Table 3-4
Factors Influencing Culvert Design

Factor	Inlet Control	Outlet Control
Headwater	X	X
Area	X	X
Shape	X	X
Inlet Configuration	X	X
Barrel Roughness	-	X
Barrel Length	-	X
Barrel Slope	X	X
Tailwater	-	X

Note: For inlet control, the area and shape factors relate to the inlet area and shape. For outlet control they relate to the barrel area and shape.

Figure 3-2 depicts a couple of instances when outlet control governs flow.

Most culverts relined with Snap-Tite® operate in inlet control since high tailwater water conditions are not as common in well-designed drainage systems. Additionally, the smooth barrel will typically allow more water than the inlet, so the inlet becomes the controlling section of the system.

Inlet control means the discharge capacity of a culvert is controlled at the culvert entrance by depth of headwater, inlet factors like entrance type, barrel/inlet area and inlet shape, and, in rare cases, barrel slope. Inlet shape is typically the same as culvert barrel except when enlarged with tapered inlets and flow enhancement devices at the barrel entrance. In inlet control, the roughness, length of culvert or outlet conditions (including tailwater depth) are not factors in determining culvert capacity.

The entrance type is a major factor for inlet control performance. Commonly found entrance types include square edge with headwall, end mitered to the slope, projecting barrel (also known as projecting edge), and beveled entrance. Relined culvert inlets are likely to also utilize wingwalls (see chapter 6) placed at an angle from the culvert barrel. While providing structural stability for the culvert/bulkhead assembly and the surrounding backfill, wingwalls work well to funnel flow into the culvert opening.

Figure 3-2 | Outlet Control

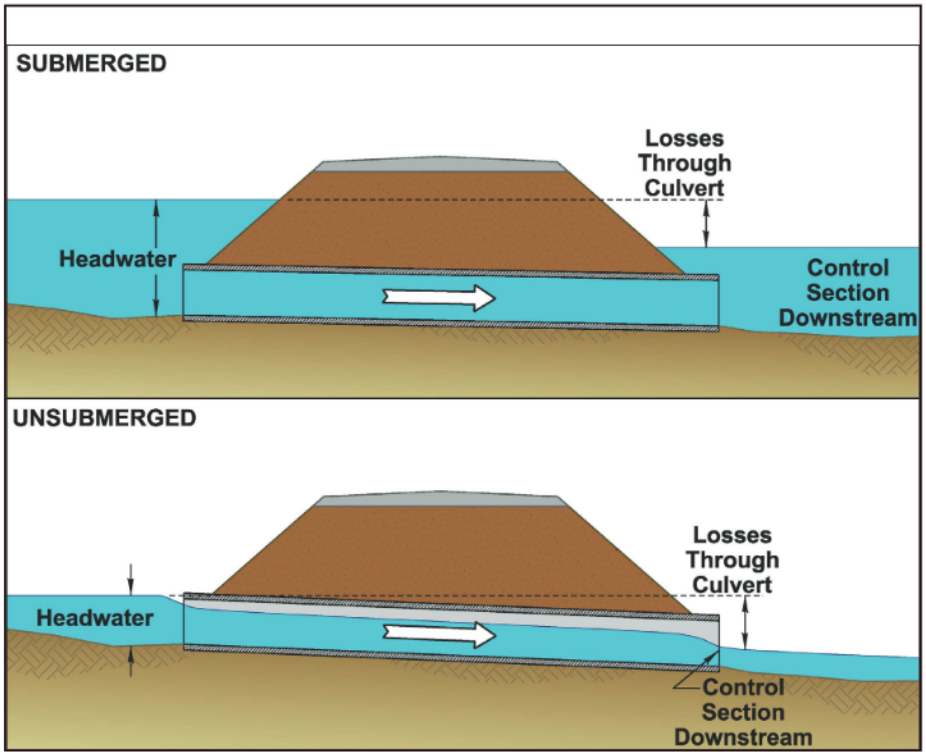


Figure from U. S. Department of Transportation Federal Highway Administration Hydraulic Design of Highway Culverts

Figure 3-3 | Intlet Control

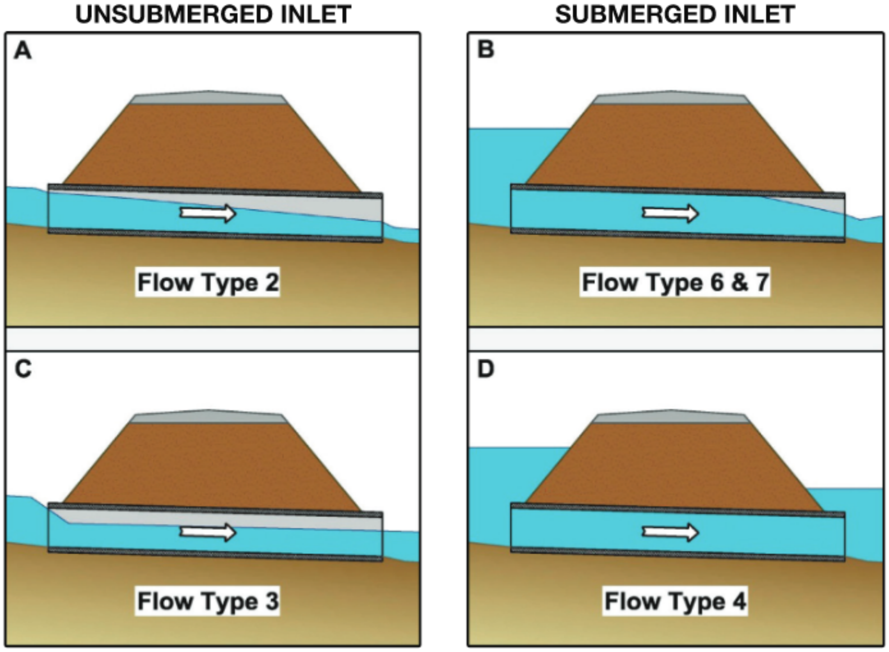


Figure from U. S. Department of Transportation Federal Highway Administration Hydraulic Design of Highway Culverts

Inlet control performance is defined by three regions of flow: unsubmerged, transition and submerged. For low headwater conditions, as shown in Figure 3-3A and Figure 3-3C, the culvert entrance is unsubmerged and the culvert operates as a weir. A weir is a flow control cross-section where the flow rate and the depth of water are related to one another. At much higher flows, as shown in Figure 3-3B and Figure 3-3D, the entrance is submerged and the culvert operates as an orifice. Flow rate through an orifice increases as headwater depth rises above the orifice.

There exists a less distinct flow transition zone between the low headwater (weir control) and the high headwater (orifice control) flow conditions. By plotting the unsubmerged and submerged flow equations and connecting them with a line tangent to both curves, as shown in Figure 3-4, the flow characteristics of the transition can be estimated.

Figure 3-4

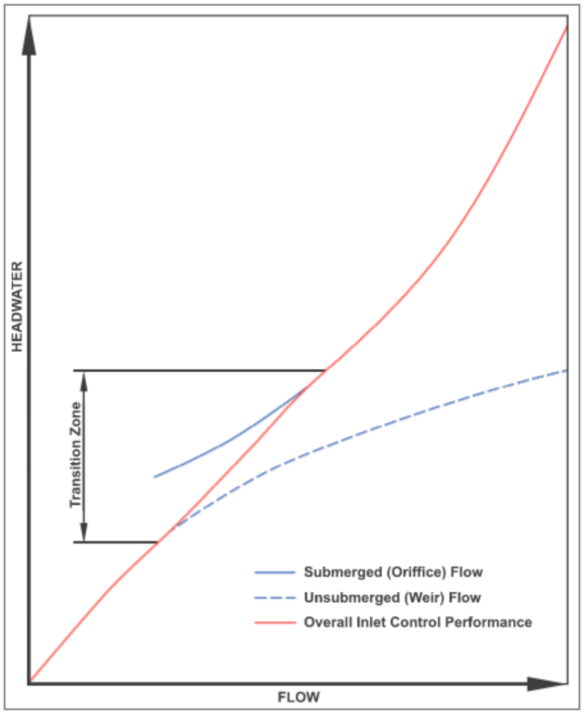


Figure from U. S. Department of Transportation Federal Highway Administration Hydraulic Design of Highway Culverts

Inlet control equations are presented in HDS-5 (2012) that describes unsubmerged and submerged inlet control. Section A.2.1 presents two forms for the unsubmerged case. While both expressions provide acceptable results, Equation A.1 (also known as Form 1) is theoretically more accurate, while Equation A.2 (known as Form 2) is easier to apply. It should be noted that inlet control constants K and M may vary depending which equation is used (HDS 5 Table A.1 has listings for constants for concrete and corrugated metals of differing shapes and ends).

When the culvert entrance is submerged, a different equation must be applied to find the headwater depth under inlet control (Section A.2.2 has Equation A.3). In either case of inlet control, model studies are typically used to develop the inlet control coefficients.

Equation A.1:

$$\frac{HW_i}{D} = \frac{H_c}{D} + K\left[\frac{K_u Q}{AD^{0.5}}\right]^M + K_s S$$

Equation A.2:

$$\frac{HW_i}{D} = K\left[\frac{K_u Q}{AD^{0.5}}\right]^M$$

Equation A.3:

$$\frac{HW_i}{D} = c\left[\frac{K_u Q}{AD^{0.5}}\right]^2 + Y + K_s S$$

Where:

HW_i = headwater depth at the culvert entrance (feet)

H_c = specific head at critical depth (feet)

Q = flow rate through the culvert (cubic feet/ second (ft^3/s))

A = full cross sectional area of the culvert (square feet)

D = culvert inside height or diameter (feet)

S = culvert barrel slope (feet/foot)

K, M, c, Y = inlet control constants

K_u = Unit conversion 1.0 (1.811 SI)

K_s = Slope correction, -0.5 (mitered inlets +0.7)

3-7 Entrance Loss

Entrance loss coefficient (k_e) is commonly used in hydraulic analysis and is a measure of the efficiency of the inlet to smoothly transition flow from the upstream channel into the culvert. The size and shape of the interface between the culvert material and fluid greatly influence the entrance loss coefficient. The coefficient K_e may vary from 0.05 for a smooth, tapered inlet transitions, flush with the culvert barrel, to 0.90 for a projecting sharp edged barrel inlet. So, a square cut abrupt culvert end will result in a higher loss coefficient than a culvert with a beveled or rounded edge. The head loss through a typical inlet structure with inlet control can be calculated by:

$h_f=K_e(V^2/2g)$

Where:

h_f = head loss at culvert entrance (feet);

K_e = entrance loss coefficient;

V = Flow velocity(feet/second);

g = gravitational constant(feet/second^2);

Table 3-5 are some typical values for concrete pipe, a more extensive list can be found Table C.2 of HDS 5.

When relining with Snap-Tite®, the entrance loss coefficient will typically match that of the existing host pipe or headwall (with or without wingwalls) configuration used at the transition. For example, a liner that has been mitered after grouting to conform to

Table 3-5
Entrance Loss Coefficients

Type of Structure and Design End Treatment	k_e
Pipe, Concrete	
Projecting from fill, square cut end	0.5
Square cut with headwall	0.5
Mitered to conform to fill slope	0.7
Beveled edges, 33.7 degree	0.2
Socket end of pipe	0.2

Data from U. S. Department of Transportation Federal Highway Administration Hydraulic Charts for the selection of Highway Culverts fill slope would still be expected to have a .7 value. A liner that projects from fill or the host pipe would have a similar .5 value. A relined culvert that has a headwall with wingwalls to direct flows would be expected to closely match values listed in established tables for the angle of the wingwall. Testing was conducted at Utah State on a configuration representing a plain headwall with HDPE end that is not projecting and a .50 to .55 value was determined, which matches other pipe materials with square edge configurations that have no wingwalls.

3-8 Hydraulics with Hydro-Bell

The Hydro-Bell inlet enhancement uses a patented design to capitalize on the effects of culvert fluid dynamics. Through this design, it is now possible to improve the hydraulic efficiency by increasing the capacity of flow at the inlet of a culvert. It can be used alone as a projection from the culvert headwall, or cast/anchored into a headwall to help channel flow more efficiently at the liner pipe transition.

The Hydro-Bell design consists of rounding the inlet with a leading radius, which transitions to a diametrical recess in the interior of the structure. Figure 3-5 shows the general shape of the Hydro-Bell.

As fluids flow into the pipe, a flow boundary layer can separate from the pipe wall creating turbulent flow and reducing the cross sectional area of the barrel for efficient fluid flow. By creating a smooth transition into the inlet device and accommodating the naturally occurring turbulent flow, the cross sectional area available for flow can be maximized.

Laboratory studies were conducted at Utah State University's Water Research Laboratory. Different versions of the Hydro-Bell shapes were tested to establish the optimal peak flow. Both inlet and outlet control events were simulated and compared to a control plain-end headwall shape. An entrance loss coefficient, k_e, for the Hydro-Bell typically ranged from .2 to .235 across a range of testing condition.

Inlet control constants were also obtained that hydraulically characterizes the Hydro-Bell inlet device. Unsubmerged Form 2 Equation (Eq. A.2 as referenced earlier) was used to develop the constants. The constants are considered valid for Hw/D<~1.2 for Unsubmerged Form 2 and Hw/D>~1.2 for the submerged equation. Table 3-6 lists the inlet control constants for both the Hydro-Bell and the plain-end headwall conditions developed under the laboratory testing.

Figure 3-5

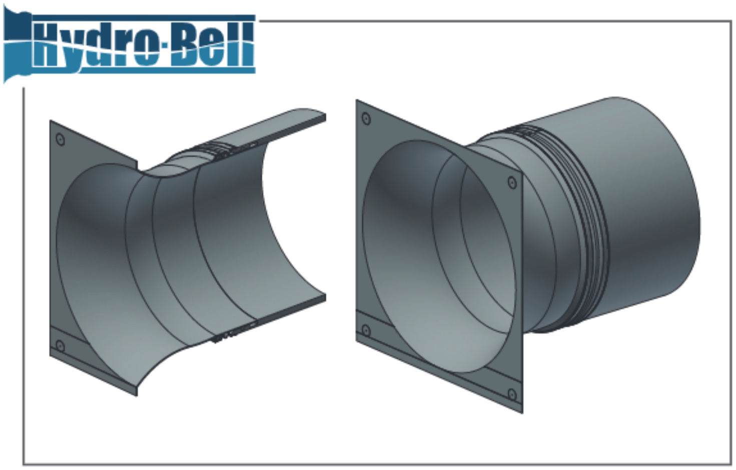
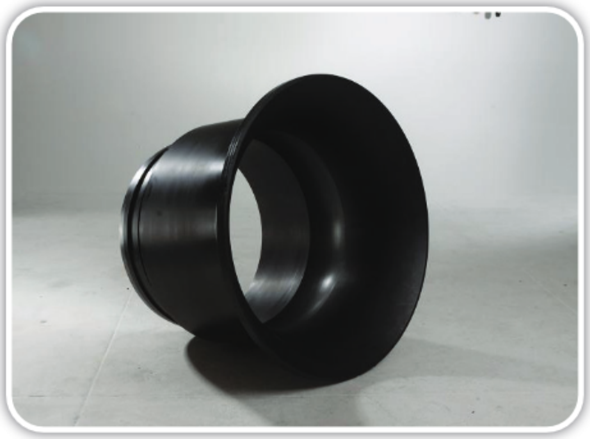


Table 3-6
Inlet Control Constants

Inlet End	K	M	c	Y
Hydro-Bell	0.535	0.509	0.019	0.863
Plain-End HDPE with Flat Headwall	0.591	0.518	0.037	0.780

Due to the geometry of inserting a smaller liner into a failing host pipe, a reduction of inlet area and barrel shape are two essential variables that cannot be controlled. Consequently, the addition of the Hydro-Bell at the inlet of a relined culvert does allow increased flow as compared to a plain-end headwall operating under inlet control conditions. As head pressure increases, the flow rate improvements ranges from 15%-20% in low-head conditions to 35%-40% in high head conditions. Ultimately, a Hydro-Bell improved inlet will result in lower headwater elevations as compared to the same relined pipe with just a headwall/ wingwall combination.



Chapter 4
Oval Pipe

Culverts installed 40-50 years ago are failing at an alarming rate and are in desperate need of rehabilitation.

Finally, there's a no-dig solution to culvert lining and culvert rehab in the form of Snap-Tite®. Utilizing the Snap-Tite® Culvert Lining System for culvert rehabilitation and drainage solutions is an intelligent, cost-effective solution. Snap-Tite® rehabilitates a failing culvert lining system without the need to remove the existing deteriorated pipe.

About one-third of existing culverts are arched, and Snap-Tite® has a solution that maximizes flow: oval pipe. It has the same benefits as round smooth-wall HDPE Snap-Tite®, yet made for a better fit into an existing arched culvert.

Additionally, oval pipe is an innovative approach to relining rectangular box culverts. Whether the existing box culvert is concrete, stone-laid, or even older wooden materials, oval Snap-Tite® is an attractive alternative to dig and replace options.

The Snap-Tite® Culvert Lining System will provide a reliable structural system when grouted, and still offer adequate or improved flows when rehabilitated compared to the existing pipes, arches or box shaped lines. Lightweight, flexible, durable HDPE has an indefinite service life. The Snap-Tite® culvert lining joining system is simple, safe, and fast to join together. Snap-Tite® allows installers to avoid interruption of travel and minimal disturbances to right-of-way areas. As always, we encourage you to contact your local Snap-Tite® representative with any questions regarding hydraulics, structural design, and/or installation methods.

Table 4-1
Flow Comparison of Metal Arch Pipe and Snap-Tite Liner

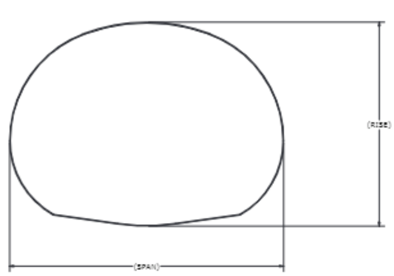
CMP			Equivalent Snap-Tite® Liner (in.)	Outside Liner Diameter (in.)		Inside Liner Diameter (in.)		Flow Q (cfs)	Snap-Tite® Flow Change %
Span (in)	Rise (in)	Q (cfs)		Major	Minor	Major	Minor		
28	20	2.8	20	23	16.5	21.7	15.1	4.7	168%
35	24	6.1	26	30.5	20.5	28.8	18.8	9.2	151%
42	29	9.9	30	36	22.5	34	20.3	12.6	127%
40	31	10.7	30	36	22.5	34	20.3	12.6	118%
49	33	15.1	36	41	30	38.7	27.7	22.9	151%
46	36	15.7	36	41	30	38.7	27.7	22.9	146%
57	38	21.5	42	48.5	34	45.9	31.3	33.7	156%
53	41	22.6	42	48.5	34	45.9	31.3	33.7	149%
64	43	29.5	48	55.6	39	52.3	35.9	48.3	164%
60	46	32.6	48	55.6	39	52.3	35.9	48.3	148%
71	47	39.0	48	55.6	39	52.3	35.9	48.3	124%
66	51	43.4	54	60.2	47	56.6	43.5	70.0	161%
77	52	50.2	54	60.2	47	56.6	43.5	70.0	139%
73	55	55.3	54	60.2	47	56.6	43.5	70.0	127%
83	57	63.1	54	60.2	47	56.6	43.5	70.0	111%
81	59	68.9	54	60.2	47	56.6	43.5	70.0	102%
87	63	85.0	63 oval	67.5	58	63.5	53.9	109.1	128%
95	67	102.5	63 round	63	63	58.89	58.89	111.5	109%
103	71	122.8	63 round	63	63	58.89	58.89	111.5	91%

** Flow is based on slope of 0.1%. HDPE n= 0.00914 / CMP n= 0.024*

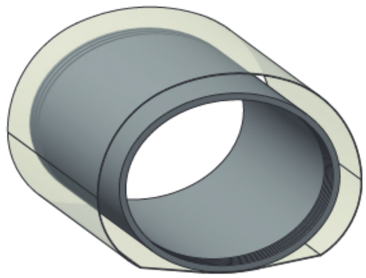
** Oval dimensions shown are the recommended pressed dimensions. Customers can pick any y-dimension between the equivalent round and the pressed dimension if full ovalization is not required. Call a Snap-Tite representative for project flow calculations as needed.*

Metal Pipe Arch: 2 ²/₃ in. × ½ in. Corrugations—AASHTO M36 & M196

Metal Pipe Arch: 3 in. × 1 in. or 5 in. x 1 in. Corrugations—AASHTO M36 & M196



FRONT VIEW OF CORRUGATED METAL PIPE IN CULVERT


OVAL SNAP-TITE INSIDE CORRUGATED METAL PIPE


A culvert, rehabilitated with Snap-Tite® oval pipe.

Table 4-2
Flow Comparison of Concrete Elliptical Pipe and Snap-Tite Liner

Concrete Elliptical Pipe Size (in.)		Concrete Elliptical Pipe Q (cfs)	Equivalent Snap-Tite® Round OD (in.)	Outside Liner Diameter (in.) Major	Outside Liner Diameter (in.) Minor	Inside Liner Diameter (in.) Major	Inside Liner Diameter (in.) Minor	Flow Q (cfs)	Snap-Tite® % of Flow
30	19	6.0	22	26	17	24.6	15.6	5.8	97%
38	24	11.1	28	33.5	21	31.7	19.2	10.6	95%
45	29	18.0	32	37	26	34.9	23.9	16.4	91%
53	34	27.7	40	46	31	43.6	28.4	27.6	100%
60	38	37.8	42	48.5	34	45.9	31.3	33.8	89%
68	43	52.7	48	55.5	39	52.3	35.9	48.3	92%
76	48	70.8	54	62	44.6	58.4	41.1	67.2	95%
83	53	91.0	54	60.2	47	56.6	43.5	70.0	77%
91	58	116.0	63	72.5	52	68.1	47.9	101.2	87%
98	63	143.1	63	67.5	58	63.5	53.9	109.1	76%

**flow is based on slope of 0.1%. HDPE n= 0.00914 / concrete n= 0.015*

** Oval dimensions shown are the recommended pressed dimensions. Customers can pick any y-dimension between the equivalent round and the pressed dimension if full ovalization is not required. Call a Snap-Tite representative for project flow calculations as needed.*

Table 4-3
Flow Comparison of Concrete Arch Pipe and Snap-Tite Liner

Concrete Arch Pipe Nominal Size		Span (in.)	Rise (in.)	Q (cfs)	Equivalent Snap-Tite® Liner (in.)	Outside Liner Diameter (in.) Major	Outside Liner Diameter (in.) Minor	Inside Liner Diameter (in.) Major	Inside Liner Diameter (in.) Minor	Flow Q (cfs)	Snap-Tite® % of Flow
29	18	28.5	18	5.2	22	26	17	24.6	15.6	5.8	111%
37	23	36.25	22.5	9.6	28	33.5	21	31.7	19.2	10.6	111%
44	27	43.75	26.625	15.4	32	37	26	34.9	23.9	16.4	106%
52	32	51.125	31.3125	23.5	36	41	30	38.7	27.7	23.0	98%
59	36	58.5	36	33.9	42	48.5	34	45.9	31.3	33.8	100%
65	40	65	40	45.6	48	55.5	39	52.3	35.9	48.3	106%
73	45	73	45	60.2	54	62	44.6	58.4	41.1	67.2	112%
88	54	88	54	100.4	63	72.5	52	68.1	47.9	101.2	101%
58	91	91	58	116.0	63	72.5	52	68.1	47.9	101.2	87%
102	62	102	62	146.8	63	67.5	58	63.5	53.9	109.1	74%

**flow is based on slope of 0.1%. HDPE n= 0.00914 / concrete n= 0.015*

Chapter 5
Installation Overview

This chapter is a general overview of the lining process. Additional information for installers can be found in the SNAP-TITE® CULVERT LINING FIELD GUIDE FOR INSTALLATION, HANDLING, AND STORAGE, available in print and online for download.

People

Highway departments can use their own crews to install Snap-Tite®- no special training is necessary. Using minimal equipment, a team of four can easily rehabilitate a culvert. Purchase the Snap-Tite® Culvert Lining Systems today, keep it in your yard until you have some down time and install it that day. What would be lost payroll time becomes a money-saving project.

Product

Snap-Tite® Culvert liner is a tough, flexible liner made from solid-wall HDPE pipe. The ends are machined to make a mechanical connection which provides tensile and compression strength.

Equipment

Come-Along Method

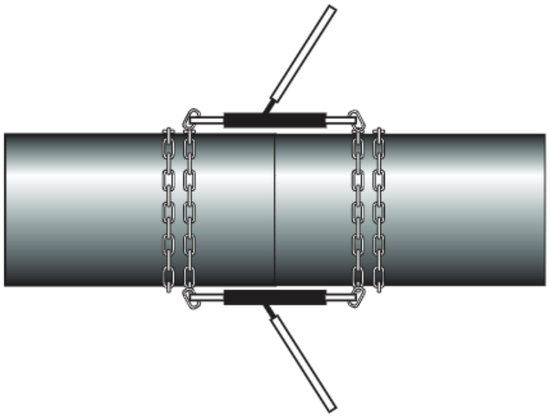
Snap-Tite is so easy to install that most jobs can be completed with a backhoe, shovels, a come-along, and chains. Chain come-alongs are recommended over cable come-alongs for Snap-Tite installations since cable types can stretch and fray. Chains and come-alongs capacities are based on the size of liner to be installed. Standard chain come-alongs are available with load ratings of 1,000 to 5,000 lbs. of force. Verify the amount of force that the come-alongs are capable of applying before using them. For safety reasons, the chains normally are able to handle twice the load applied by each come-along.

Most chains have a working load. The working load is the normal rating for typical lifting applications. The strength at failure is usually four times the working load. When a chain is wrapped around a Snap-Tite liner and tightened with a chain binder, it is under tensile loading.

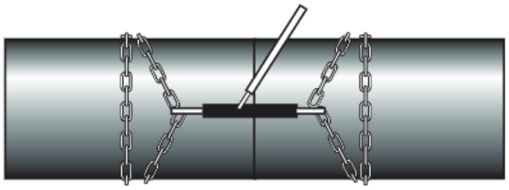
After a come-along is attached to a chain link, the link is subject to cross loading. A cross load occurs because the chain must wrap around the pipe to transfer the forces. As the cross load is increased, the angle of the chain around the liner changes. See diagram below.

Chain manufacturers reduce the working load by 25% for cross loading. A chain with a standard rating of 6,000 lbs. is only rated for 4,500 lbs. in this application. If you have determined that you need 6,000 lbs. working load on the chain for a Snap-Tite Installation, then use an 8,000 lbs. working load rated chain.

Drawing 1: Chain Wrap Position



Position of chain before load – Top View



Chain under load – Side View

Joining forces shown in Table 5-1 change with temperature, type of lubrication, male-female joint alignment, presence of debris, slope and time. Estimated forces are based upon the slow application of force with flat slope and lubricated joint. A slow application of force allows materials to stretch. Fast joining requires more force and energy because material does not immediately increase in size. More force will be required below 73 degrees F. Forces are estimated only! Forces shown in Table 5-1 are based on properly aligned 24-foot lengths. If different lengths are used, more or less force will be required.

Table 5-1

ESTIMATED FORCE TO JOIN SNAP-TITE® LINER					
Liner Size OD (in.)	Weight per foot (lbs.)	Weight of 24 feet (lbs.)	Estimated Joining Force (lbs.)	Estimated Total Force (lbs.)	Typical Min. Load Rating for Each Come-Along
10.75	4.8	118	500	618	1000
12.75	6.7	164	1000	1164	1000
14	8.1	198	1000	1198	1000
16	10.6	260	1000	1260	1000
18	13.4	328	1000	1328	1000
20	16.5	404	1000	1404	1000
22	20.0	490	1000	1490	1000
24	23.8	583	1500	2083	2000
26	27.9	684	1500	2184	2000
28	32.4	794	1500	2294	2000
30	37.2	911	1500	2411	2000
32	42.3	1036	2000	3036	3000
36	53.6	1313	3000	4313	3000
42	72.9	1786	3000	4786	3000
48	95.2	2332	3000	5332	3000
54	102.6	2514	3000	5514	4000
63	164.3	4025	4000	8025	5000

Apply the full load once the male and female joints come together straight on and part of the flat surface on both sides "catches." The best joining procedure is to watch the joining process and make adjustments based on observations. When pipe movement requires more force than expected, look for a reason. If the joints do "catch", rotation of the two liner sections or alignment with a pry bar may solve the problem. Sometimes changing the angle of attack or moving the pipe up and down or side to side will help start the connection.

If the male end is at a slight angle to the female and partially inserted, lower force is required to make the joints mate. Apply force from one come-along until liner bends slightly. Apply force slowly, this allows the female joint to expand.

CAUTION

Be careful when tightening a chain or cable!

Snap-Tite liners are not perfectly round. Take care to get alignment around the circumference of the Snap-Tite joint. Pry bars are sometimes used to help align the joints. Changing the position of come-along on the Snap-Tite liner may be helpful.

Be aware of the applied force. Allow only needed personnel near the come-along and chains. All others must remain at a safe distance from the chain. All personnel must use safety equipment during installation. Use gloves, hard hats, safety glasses and other personal protective equipment (PPE).

Chain wraps on the liner slip less than cable. Chains appear to be safer for this use. The mechanisms used in a come-along often fail when over stressed; be careful when using come-along!

Special safety equipment is required if there is moving water present, electrical lines are close to installation or if there are hazardous material in pipes. Check your job site and be prepared.

Choker Method

The Choker Method is another approach to installing Snap-Tite pipe. With this installation procedure, come-along and chains are not needed. The excavator/backhoe will do most of the work snapping the joints together.

To begin lining, slide the first piece of Snap-Tite pipe into the existing structure with at least two feet extending outside of the existing host pipe to allow room for connecting the joint. Before connecting the next pipe to the first one, install the gasket on the male end to ensure a watertight fit.

Wrap a choker cable (minimum ¾") or chain around the pipe inserted in the culvert. Tighten the cable or chain down on the liner pipe as to keep the cable/chain from moving/sliding and attach the excess cable/chain to the machine used. You can attach the cable/chain in the eyelet. Slowly back the machine up to fully tighten the choker against the liner.

The inserted piece of Snap-Tite is secured to prevent further movement into the host pipe, the operator will lower the mating piece of pipe into the ditch and the crew will vertically and horizontally align the male and female ends.

Line the joints up and slowly pull the pipe towards the 'choked' pipe. The tapered end of the male joint will line up with the beveled end. Once the alignment is equal around the pipe, the operator will slowly apply pressure by pulling the pipe he had held with his bucket and a choker cable/chain. The operator will slowly rock the joint left to right, 'walking' the joint together.

Once the spigot joint is connected, the backhoe can push the remainder of the pipe further into the host pipe. Repeat this process until the liner is installed completely through the host pipe.

STEP 1: PREPARE THE EXISTING CULVERT

■ Inspect the culvert to ensure no obstructions prevent insertion of the liner. Flush and/or clean the existing culvert.

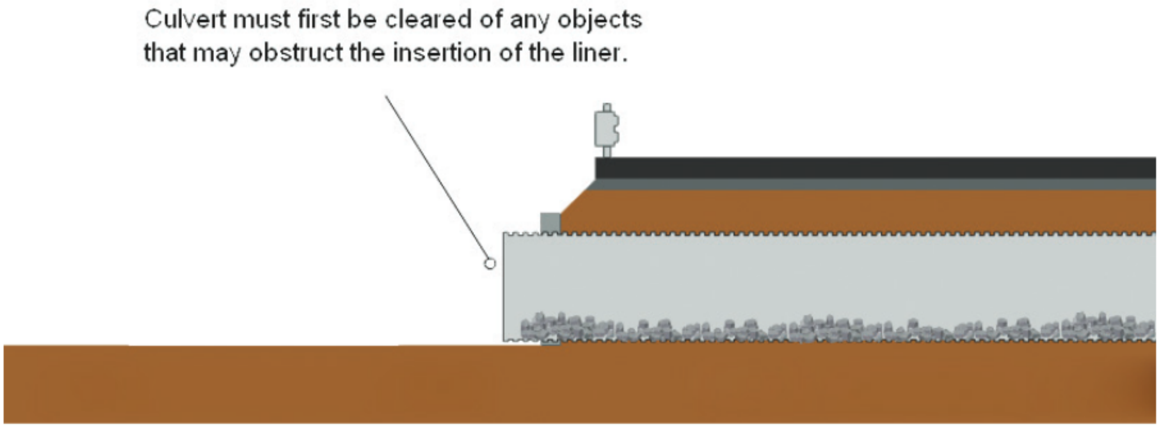
Prior to lining, check each culvert for access. Evaluate the safety of the installation area. Clear an area near the culvert for access. There must be an open area equal to the liner section on at least one end of the culvert.

Inspect vertical and horizontal alignment of host pipe to ensure clearance for the liner pipe. Take measurements at various locations throughout the host culvert to verify the smallest ID, as well as total length. Consider a survey for complex installations.

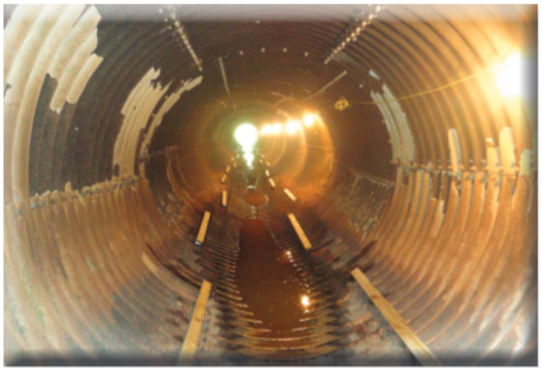
Remove dirt and rocks from the culvert. If a culvert requires cleaning, a water truck or jet cleaner may be needed. After cleaning and preparing the culvert for lining, make sure there is nothing protruding from the culvert that will damage the liner.

Evaluate the invert and channel bed conditions of the culvert. If there are voids around the old culvert, consider filing these voids prior to lining. If a high flow grout is used, these voids will often be filled as the liner is grouted. However, the amount of grout required to complete the job can become high and unknown.

It is possible to install Snap-Tite culvert liners when water is present. Installation during low flow conditions presents low safety risk. Fast flowing water can create a safety hazard. Use good judgement if water is present. Grouting with standard cement grout can be done when water is present. Special precautions may be required when grouting with cellular grout and water is present. Consult your grout supplier if water is present.



STEP 2: ADD BLOCKING TO EXISTING/HOST CULVERT



If needed, attach wooden "blocks" to the top of the host pipe in order to keep the Snap-Tite pipe from rising up.

Controlling the location of the liner inside the culvert is important. Flotation of the liner is of concern when grouting around the liner or there is ground water present. As grout density increases, upward buoyant forces increase. A liner is like a boat - it displaces the grout and if the liner weighs less than the grout, the liner floats. To prevent flotation, use blocks or skids around the pipe to maintain grade of the Snap-Tite Culvert Liners.

Blocking usually is not required for smaller culvert sizes, when the annular space is less than 4". As the culvert size increases and the liner size decreases, the need for blocking to hold grade becomes more important. Use blocking at the top of the host to keep the liner close to the bottom of the culvert. Blocking on the bottom of the existing pipe is not always necessary, but it does help facilitate insertion by helping slide past corrugations, damaged inverts, and separated or misaligned joints.

Figure 3-1 shows typical blocking of Snap-Tite® Culvert Liner. Blocks or skids are typically installed in a staggered pattern. Spaces are left between the blocks or skids allow grout to flow under and around the liner. Beveling skids and blocking may help faciilate easier installation of liner pipe.

Install blocks in the top 120 degrees of the culvert beginning at 4 feet from the inlet and outlet to allow for installation of the bulkhead. For culverts 36" in diameter or larger, blocks are attached to the old culvert. The first blocks are often installed at 11 and 1 o'clock positions, with a space of four to eight feet between the next set of blocks, based on liner size. Blocks are usually four to eight feet in length. The thickness is determined by the difference in the ID of the culvert and the liner.

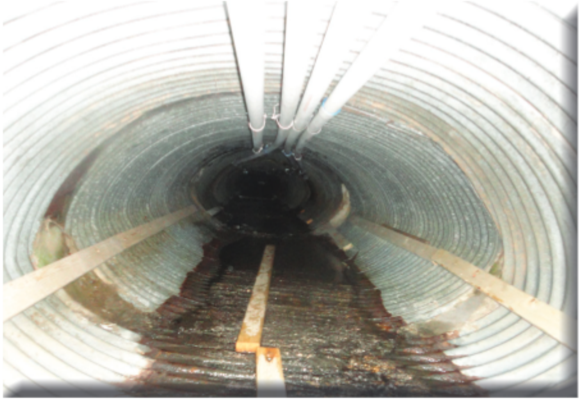
The upper skids must have structural strength adequate to resist the buoyant force created as the liner is grouted in place. Wood and solid plastic will work. Styrofoam does not have adequate compressive strength to work for many liner sizes.

Filling the liner with water is one way to reduce flotation. Since water weight is 62.4 lbs. per cubic foot, if the grout has a higher density, filling the liner with water may not solve the problem. Filling the liner with water is usually not recommended, and can prove to be difficult in many cases.

STEP 3: HANG GROUT TUBES IN EXISTING/HOST CULVERT

If access is large enough, install different lengths of PVC pipe that will deliver the grout flow and also release air.

Before the liner pipe is inserted into the host pipe, use pipe straps and 3" Self Tap Screws to hang grout and vent tubes at approximately 4' spacing. Hang grout tubes between the blocking to protect it from damage during pipe liner installation. Use wire and screws in lieu of clamps if necessary.



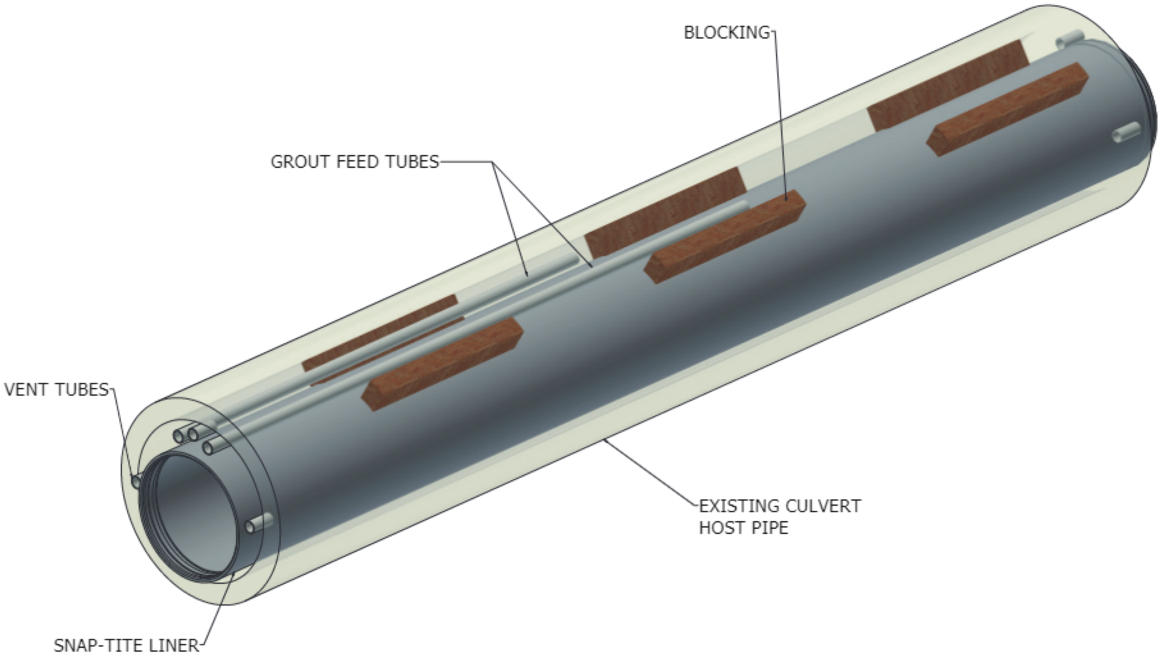


Table 5-2

TYPICAL GUIDE FOR GROUT AND VENT TUBE PLACEMENT SITE CONDITIONS MAY VARY				
CULVERT LENGTH	**AIR VENTS INLET SIDE***	**AIR VENTS OUTLET SIDE****	**GROUT TUBE(S) INLET SIDE (ALL NEAR 12 O'CLOCK)**	**GROUT TUBE(S) OUTLET SIDE (ALL NEAR 12 O'CLOCK)**
50' or less	12, 3, 9 O'Clock	12, 3, 9 O'Clock	1 at 10' long ■	1 at 10' long ▲
50' - 100'	12, 3, 9 O'Clock	12, 3, 9 O'Clock	1 at 20' long ■	1 at 20' long ▲
100' - 150'	12, 3, 9 O'Clock	12, 3, 9 O'Clock	1 at 30' long ■	1 at 30' long ■
150' - 200'	12, 3, 9 O'Clock	12, 3, 9 O'Clock	1 at 30' long ■ 1 at 60' long ■ 1 at 120' long ▲	1 at 30' long ▲ 1 at 60' long ▲
200' - 250'	12, 3, 9 O'Clock	12, 3, 9 O'Clock	1 at 30' long ■ 1 at 60' long ■ 1 at 120' long ■	1 at 30' long ▲ 1 at 60' long ▲ 1 at 120' long ▲
250' - 300'	12, 3, 5, 7, 9 O'Clock	12, 3, 5, 7, 9 O'Clock	1 at 30' long ■ 1 at 60' long ■ 1 at 120' long ■ 1 at 150' long ▲	1 at 30' long ■ 1 at 60' long ▲ 1 at 120' long ▲ 1 at 150' long ▲
300' - 350'	12, 3, 5, 7, 9 O'Clock	12, 3, 5, 7, 9 O'Clock	1 at 30' long ■ 1 at 60' long ■ 1 at 120' long ■ 1 at 150' long ■ 1 at 200' long ▲	1 at 30' long ■ 1 at 60' long ▲ 1 at 120' long ▲ 1 at 150' long ▲
350' - 400'	12, 3, 5, 7, 9 O'Clock	12, 3, 5, 7, 9 O'Clock	1 at 30' long ■ 1 at 60' long ■ 1 at 120' long ■ 1 at 150' long ■ 1 at 200' long ■ 1 at 300' long ▲	1 at 30' long ■ 1 at 60' long ■ 1 at 120' long ▲ 1 at 150' long ▲

***All Air Vents are typically 2" Sch 40 PVC Pipe 3' in length**
****All Grout Tubes are typically 2" Sch 40 PVC Pipe**
For Culverts over 400' in Length, consult a Snap-tite® Sales Rep.

■ **Recommended**

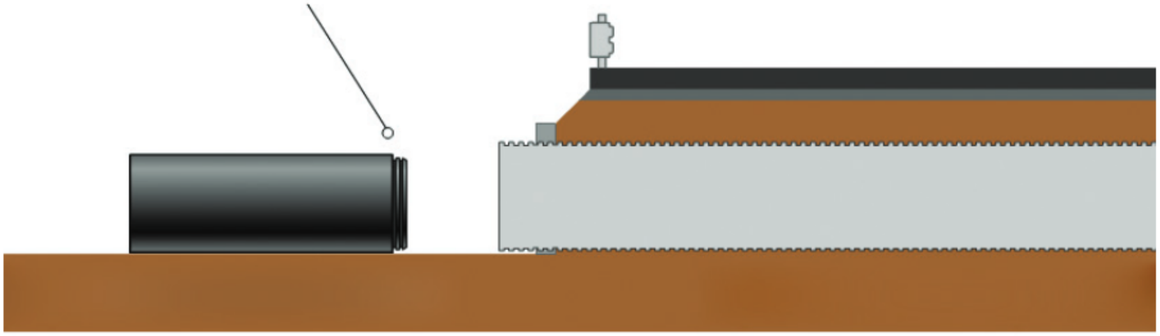
▲ **Suggested as extra tubes for challenging installations**

STEP 4: INSERT ONE END OF SNAP-TITE® CULVERT LINER INTO EXISTING CULVERT

Lower the first piece of Snap-Tite HDPE into position and insert into the host pipe.

To begin lining, slide the first piece of Snap-Tite pipe into the existing structure with at least two feet extending outside of the existing host pipe to allow room for connecting the joint. Point the male end of the Snap-Tite downstream, towards the outlet end. When required to assist installation, it may be necessary to create a "nose cone" by cutting the ends of the pipe.

NOTE: A Hydro-Bell is designed to insert into the female end at the inlet end if these directions are followed and male end are pointed downstream (towards the outlet).

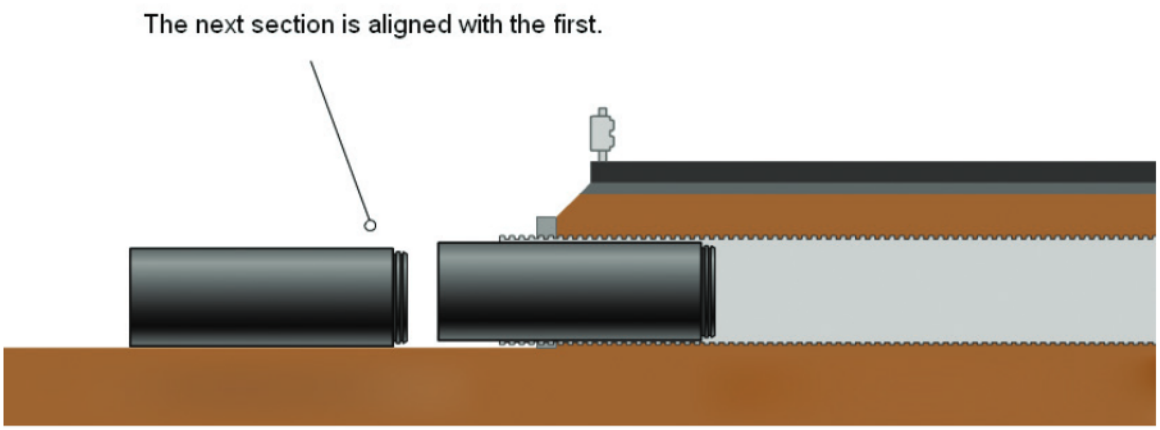


STEP 5: POSITION THE NEXT SECTION OF SNAP-TITE® CULVERT LINER WITH PROPER ALIGNMENT

Lower the second piece of pipe into position and line with the first piece. Place the opposing end of a second section against the exposed end of the first section. The two sections must be in alignment and have the same slope.

Snap-Tite liners are not perfectly round. Due to the flexible nature of HDPE pipe, the male and female ends may not match up as perfectly round shapes. Some ovality may exist. To help with the joining process, this would be a good time to rotate the next section of pipe so that the best fit for alignment is achieved. Using boards, hydraulic rams/jacks, Porta-power, or other methods to reround the pipe may help achieve a better match.

Take care to get alignment around the circumference of the Snap-Tite joint. Pry bars are sometimes used to help align the joints. Changing the position of come-along on the Snap-Tite liner may be helpful.

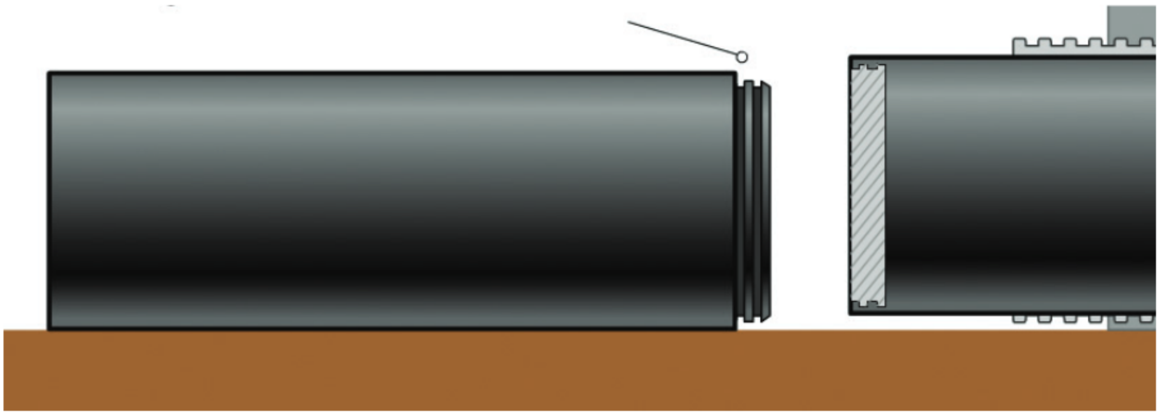


STEP 6: INSTALL GASKET ON MALE END

Place a gasket on the male end of the liner in the first groove (left picture). Apply lubricant evenly to the gasket (right picture).

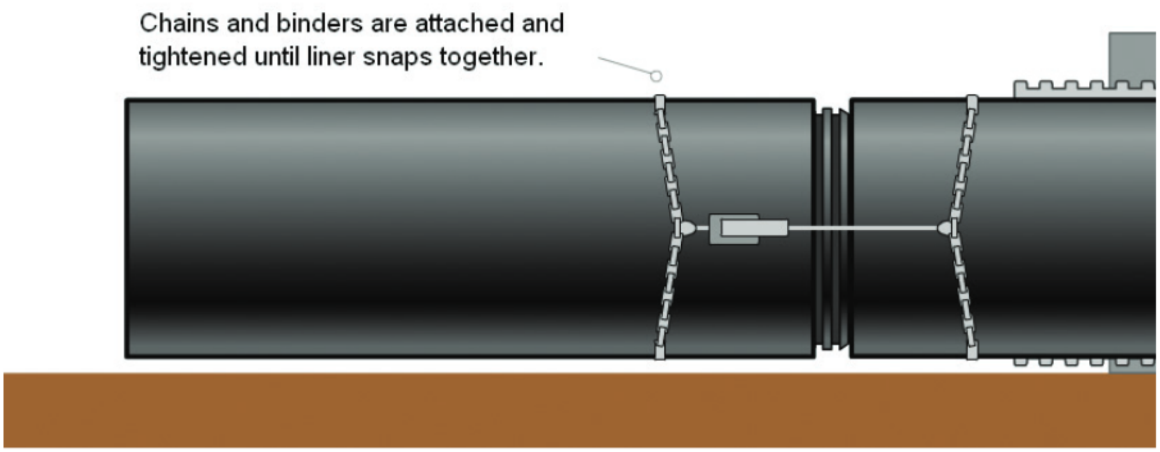
A gasket should be supplied with Snap-Tite pipe. Install the gasket color side up in the first groove from the end on the male end to help make a watertight seal. Check the fit of the gasket around the liner. Apply lubricant to the entire circumference of the gasket. Apply the lubricant evenly to reduce the chance of a torn or rolled gasket.

A gasket is installed on the male end.



STEP 7: ATTACH THE CHAINS AND COME-ALONGS OR CABLE COKER

Use come-a-longs and chains (placed approximately 180 degrees apart on each side) and pressure from the excavator to “snap” the two pieces of pipe together. Double-wrap the chains approximately two feet from the coupling end and tighten with binders. Attach one come-along on each side of joint, 180 degrees apart.



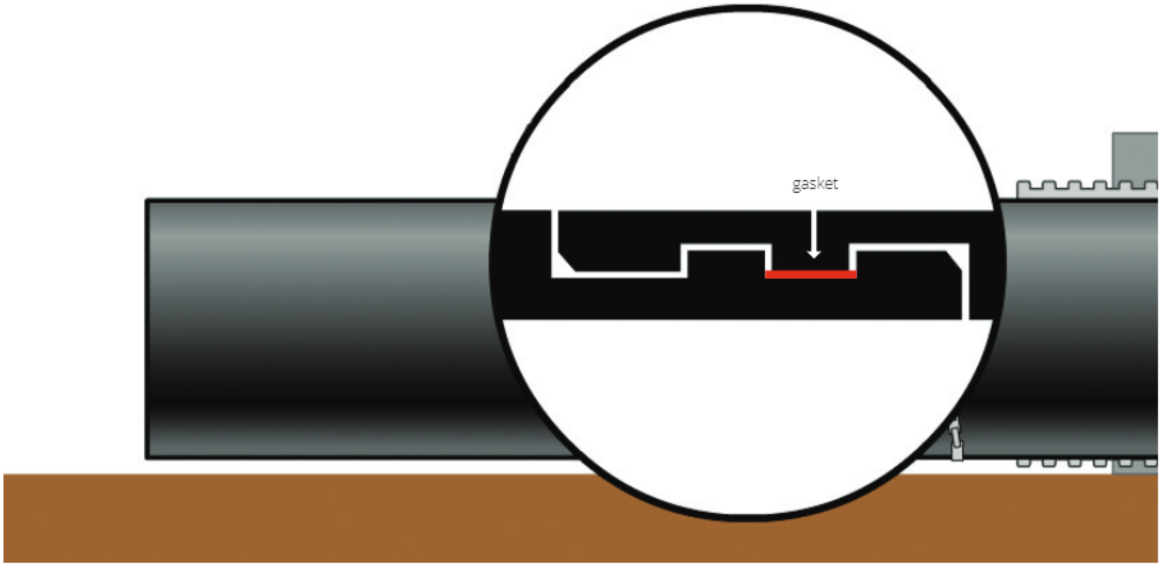
STEP 8: SNAP THE LINER TOGETHER

Align the ends of the male bevel inside the female bevel. Use a pry bar or move the come-along to different positions on liner if pipe is out of round to improve alignment.

Pull the ends together slowly, forcing the female end to expand and allow the male end to move into the female end. Apply force slowly and make observations. Apply force to one side until liner slightly deflects, then apply force on other side. Look for the female side to increase in OD as force is applied. Listen for two distinct popping sounds as they "snap" together

If chain or come-along appears to be overstressed, stop operation! Quickly move away from the chain! When lands and grooves are aligned, the couplings will "snap" and lock together. Allow time for this to occur.

If operation is stopped, check alignment. Often poor alignment or a stone or dirt in the grooves of the male/female ends may cause the need for additional pressure. Rotation of the liner will change alignment. Clean out the joint if needed.



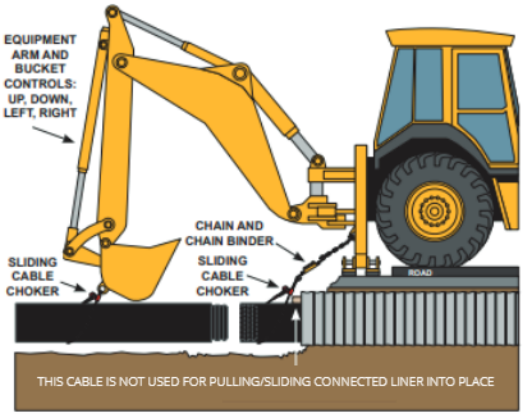
STEP 9: PUSH/PULL JOINED LINERS INTO CULVERT AND REPEAT UNTIL COMPLETELY LINED

Remove chains or chokers and push or pull the joined liners into culvert. In some applications, it may be necessary to both push and pull the liner to achieve insertion in the host.

Repeat steps 5-9. Snap each new piece of pipe onto the proceeding pipe and push into the culvert, leaving enough pipe protruding from the culvert to join with the next length of liner.

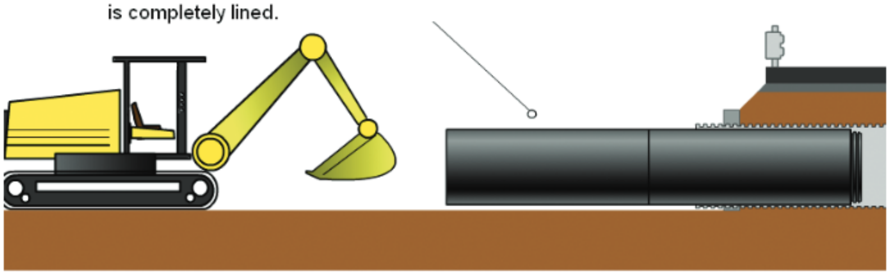
Repeat the process until connected sections of Snap-Tite line the entire length of the culvert. Snap-Tite liner pipe will expand and contact therefore industry standard practice requires that a minimum of six inches of liner pipe to extend beyond the inlet and outlet ends of the host pipe.

PREFERRED



ALTERNATE

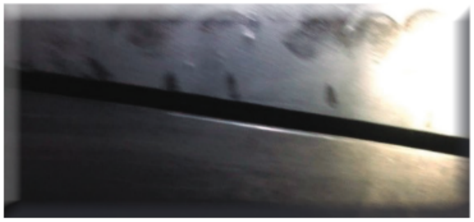
Joined liners are then pushed into the culvert. Process is repeated until the culvert is completely lined.



JOINT INTEGRITY

Carefully following the procedures set out in this Field Guide will reduce the chance of leaks between joints. Dirt, sand, or rock in the joint area may affect the integrity of the joint and create leaks. Placement of a joint where the existing culvert bends or deflects, or where the joint is otherwise stressed may increase the chance of leakage. In these situations, shorter lengths of Snap-Tite Culvert Liner may sometimes be used to avoid the problem.

After the joints are complete, it is normal for a slight separation or gap at the joint due to the flexible nature of the pipe. The size of the gap may vary due to the thermally induced expansion and contraction experience by the pipe material during the course of installation. As liner sizes increase, a gap or separation up to 1" may be observed. The gasketed joint will prevent any grout penetration from outside and the gap should stabilize and not vary once the grout has cured.

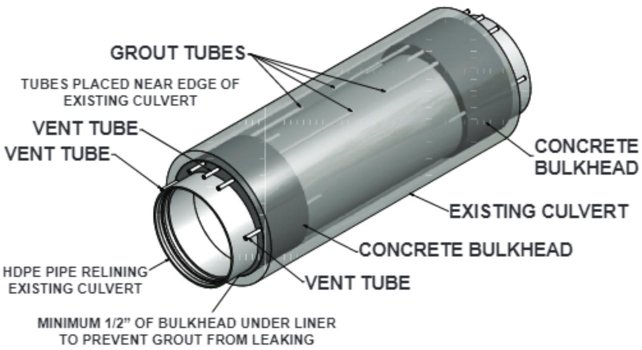


STEP 10: SEAL THE CULVERT ENDS

Once the entire culvert is lined, build bulkheads or end-seals on each end of the culvert.

Before grouting, seal the annular space at both ends of the liner and culvert. Since most grouts flow like water, much of the grout will be lost if the old culvert is not sealed. Bulkheads are the best way to seal the annular space and prevent grout from escaping. Bulkheads must have sufficient strength to sustain hydrostatic pressure during annular grout placement.

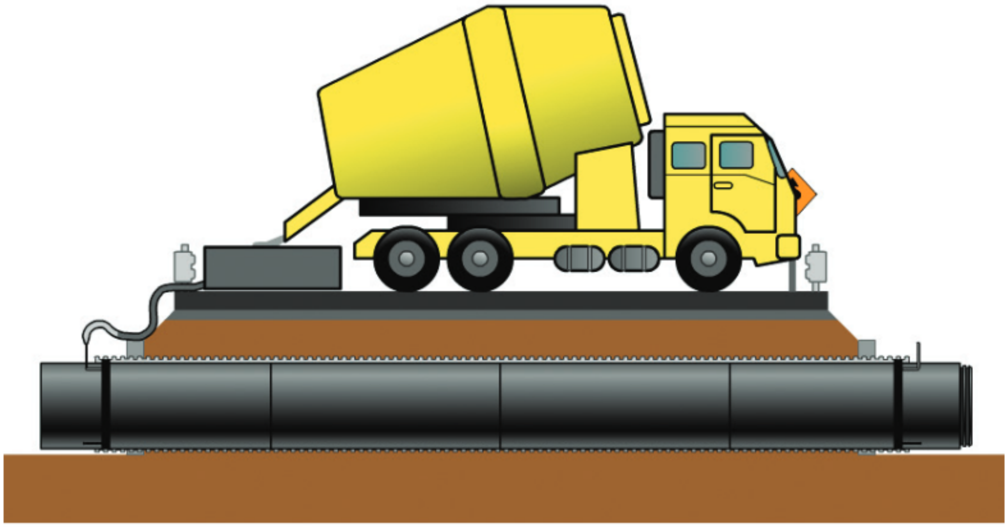
Make an end seal for the annular space at a distance of one to two feet at each end using an appropriate mix. The end seal in the annulus can be made by using various materials. A relatively dry cement grout is used in most situations. Bricks, bags of cement, oakum, and chemical grout have also been used successfully.

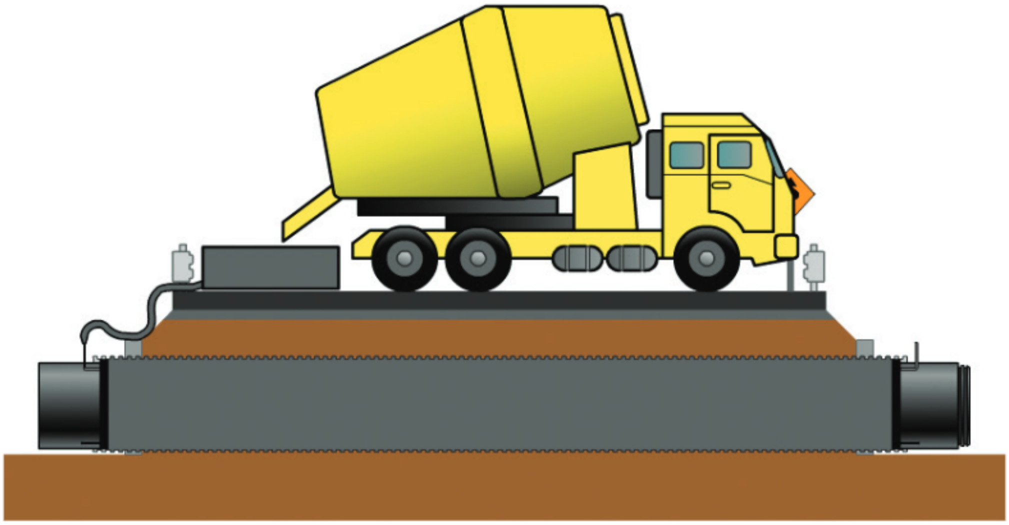


While sealing the annular space, install vents to allow air to escape. Usually vents are installed at both ends of the culvert.

STEP 11: GROUT THE ANNULAR SPACE

It is recommended that the annular space between the existing culvert and the liner be grouted. This will help fill the voids created by previous washouts, provide additional structural support, and prevent point loading. Annular space grouting is discussed in greater detail in chapter 7 of this Design Guide and in the Snap-Tite Installation Guide.





Chapter 6
Annular Closures and End Treatments

End Seals and Bulkheads

When the Snap-Tite® Liner is in place, after it has been pulled or pushed inside the existing host culvert pipe, the annular space between the culvert and the liner must be sealed in order to contain the grout of the annular space and to mitigate leakage from the old pipe.

Bulkheads or end seals can be made in many different ways. The most common way to make end seals is to pack relative dry cement mix around the ends of the liner between the host culvert and the Snap-Tite® liner. The Snap-Tite Culvert Lining Field Guide has a sample mix that has been used on many installations for bulkheads.

Non-shrink mortar cements work well since they do not contract away from the liner and host pipe. Plywood end seals, expandable foams like polyurethane, or roadway millings as seals do not typically seal well or hold up to grouting loads.

A bulkhead must be packed into the annular space between the host culvert and the Snap-Title® Liner to get a good seal and structural soundness. Most bulkhead mixes extend 12 to 24 inches into the annular space. The size of the liner and pressure in the annular space determine the exact depth, but larger and longer culvert linings will place more demand on the bulkhead to seal and resist movement.

Another method is to build a form and pour concrete in the form. If this method is used, it is important that concrete mix extend between the host culvert and the liner for 12 to 18 inches. This length of contact is needed for a good seal to form in this area.

Cast in place headwall

When the Snap-Tite® Liner is installed and the ends annulus is sealed at each end, the flow of water escaping voids has temporarily been stopped; soil and backfill around the existing host will remain in place. However, if the the flow line of the approaching channel or ditch is significantly below the invert of the new liner at the inlet, incoming stormwater may attempt to find or continue a path under the bulkhead. Creating a smooth entrance into the new liner will help prevent continued erosion or washout from underneath the culvert, especially if there is any delay in grouting to fill existing voids.

For sections of liner 80 or more feet in length, it is important to extend the liner through the wall at least six inches on each end to allow for possible contraction of the liner pipe. Unrestrained HDPE pipe can expand and contract by approximately 6” for every 50F change per 100’. A liner exposed to the sun will contract in the shaded environment of a culvert, especially overnight as temperatures cool resulting in a next morning length significantly shorter than one might see with other piping materials.

Headwalls, Wing Walls and Finish End Treatments

While headwalls can be used as end seal to the annular space, a bulkhead can be an intermediate step for grouting purposes. End treatments may be required to create a hydraulically beneficial entrance or exit for the flow thru the culvert liner, or as protection to soil structure around the culvert.

When there is erosion at the ends of the existing culvert, headwalls are cast at the end of the culvert pipe and around the liner. When headwalls are used, the wall must be designed to handle soil loads, hydrostatic pressure, expansion and contraction and other forces from the roadbed. The design should consider sealing of the liner to the headwall plus stopping flow from any french drain effect around the old culvert.

The above picture shows sliplining through a wing wall. An end seal with fill pipes is under construction.

Incorporating existing headwall or wingwall structures are convenient and can offer cost savings. Typically a bulkhead incorporated into the existing structure is all that may be required.

Using a Hydro-Bell (more information provided in chapter 3) with headwall or wingwall creates an efficient Hydraulic entrance. A Hydro-Bell has no hydraulic benefit on the exit but may be considered in areas where wildfires are prominent, since the Hydro-Bell is made with fire retardant resins that can provide additional protection.

The final step in finishing an end seal or headwall is to cut or remove the vent and grout tubes and seal over these areas with a finish mortar coat.

The fiberglass HydroBell has can be installed in 3 different "typical" ways. Reach out to your Snap-Tite representative for installation details of the HydroBell:

1. Framed around with plywood and poured around with new concrete to form a new headwall

2. Mounted to an existing headwall using the square facing of the HydroBell

3. Installed onto the female end of Snap-Tite and then backfilled with riprap; this option is less desirable as it would be ideal to mitigate any scour potential in any installation of the HydroBell.

Chapter 7
Annular Space Grouting

Purpose

When rehabilitating culverts, the primary goals of annular space grouting are:

- To support and secure the liner in place
- Maintain grade and alignment
- Ensure joint integrity of the liner
- Prevent liner movement and flotation from groundwater
- Resist external pressure from groundwater
- Stop movement of road backfill materials

Grouting the annular space is a key process in reaching these goals. Proper grouting of the annular space ensures a long life for the rehabilitated pipe system, and the road above. This can be critical to provide a total-systems approach for culvert rehabilitation.

When the existing culvert has deteriorated to such an extent that bedding material has infiltrated into the culvert, resulting in voids beneath the road base, grout can be used to help fill these voids. Grouting effectively stabilizes the surrounding soils and eliminates the potential for settlement, potholing, or collapse of the roadway.

Groundwater levels higher than the existing culvert will exert pressure on an unsupported liner. Filling the annular space only with sands or other aggregates may loosen or migrate over time. Grouting the annular space with a cementitious grout will provide reliable, continuous support.

With no grout, if the host culverts begin to collapse, there is a danger of point loads, localized deflection, and possible impingement occurring on the Snap-Tite® liner. The grout helps to evenly distribute backfill and vehicle loads. As Chapter 8 discusses in greater detail, the grout becomes the primary structural component of a rehabilitated pipe system, and therefore the liner, which is structurally capable, is not required to be a significant portion of the structural system. The primary role of the liner is to provide a smooth hydraulic surface, often with a pipe that has improved flow characteristics when compared to the original host pipe. While grout can provide support for the existing host pipes in good condition, the existing host provides no structural component to the grouted system and the design life of the rehabilitated pipe system.

Grouting Variables and Considerations

Grout can be placed into the annular space in between a Snap-Tite® Culvert Liner and an existing host culvert in different ways. Evaluate each job based on the site conditions. Some of these factors are:

- Size of liner and size of existing host culvert/volume of annulus
- Length of culvert
- Elevation changes from upstream end to downstream
- Grout Density
- Presence of ground water
- Access to injection point or points
- Limitations on injection points
- Cost

Volume of Annular Space

If there is a large difference between the bottom of the liner and the top of the grout (host ID or void above the pipe), a grout with a higher density will apply more pressure to the liner during installation. A lower density grout or multiple pours are used to limit the lift height.

Grouts containing fine aggregate, such as sand, can begin to settle out of the grout mix and accumulate in the fill tubes or in the annulus when there is a tight fit. This can possibly lead to constricting or clogging the fill tube. Consider using mixes with less aggregate or placing multiple grout insertion pipes at various lengths within the annular space.

Length of Culvert

The length of the pipe is a very important consideration when grouting. If the host pipe is short, i.e., less than sixty linear feet in length, almost any mix discussed can be used as long as grouting pressures are monitored and limited during installation. Availability and economic factors play a larger role in grout selection in these applications.

Elevation can be used to assist with grouting short runs of pipe using the effects of gravity, depending upon the flowability of the grout. As the length of pipe increases, the effort required for grouting the annular space may also increase, unless the viscosity of the grout is reduced.

Slope/Elevation Change

Measure the elevation change and the total distance between the inlet and the outlet and determine the total length the grout must flow. This information will help in the selection of the grout, affect the number of fill or vent tubes, the thickness of the bulkheads, and influence the method of grout placement. As the length of pipe increases, the amount of effort and placement points required for grouting the annular space may also increase. As the length of culvert increases, the amount of pressure generated by grouting the annular space increases.

Conversely, Elevation change can be used to provide natural energy for flowing grout in short runs of pipe, depending upon the flow rate of the grout. When there are large changes in elevation between the ends of a pipe being lined with Snap-Tite®, the grout will exert additional pressure on the liner material and on the bulkhead positioned on the downstream end of the lined host culvert. The grout pressure applied to the liner is usually equal to the static head pressure of the grout measured from the elevation at the bottom of the lift. Grouting in lifts is usually the best method to prevent liner collapse, leakage at the bulkhead and other potential problems.

Condition of Host Pipe

The condition of the pipe to be lined is important in determining the amount of grout that may be required. Grout will fill the space between the liner and the pipe, and assist in maintaining joint integrity. If the existing host pipe has lost integrity, then voids may be present in the soil bedding around the original culvert structure. Establishing the condition of the host pipe will help determine the additional amount of grout (10%, 20%, etc.) that might be required beyond the volume of the annular space between the liner and the host. If corrosion or separated joints have created obstructions along the ID of the pipe, these issues should be addressed to prevent interference during the sliplining and grouting process.

Flotation

During the grouting operation, the polyethylene pipe can float in the grout material and rise to the top of the host pipe, unless it is restrained or held down in some way. Flotation of part or all or the liner may change the grade of the liner, affecting the water flow through culvert. Lower density grouts create lower resulting buoyant forces.

There are methods that can help control this problem. One method is to attach wood, plastic or metallic blocks inside the culvert, along the top of the host pipe or the liner itself, to minimize the flotation. This technique is commonly referred to as bridging or blocking. Runners attached to the bottom of the liner are also used to center the liner.

Sand bags, or other materials, can be used to weigh the liner down and counter the buoyancy forces to prevent the liner from floating. Though more difficult to perform, it is possible to fill the liner partially or fully with water to help offset buoyant forces. Underwater lining applications have been successfully completed with Snap-Tite® and in these installations the liner has almost neutral buoyancy, since the HDPE pipe has a density that is very close to that of fresh water.

Grout Placement Methods

There are a couple of ways that grout can be placed into the annular space of a rehabilitated culvert. It can be pumped in, under low-pressure, or allowed to flow in by gravity. This can be done through injection ports placed through the bulkheads or through a hole or holes cut into the top of a metal culvert pipe, between the bulkheads on each end. The grout may be fed into the annular space though these holes, on one end or in both ends of the culvert.

Grout should be placed into the annular space slowly and patiently. The material must be given time to flow along the pipeline and annular space, exiting out through holes in the host pipe, or separated pipe joints, and replace lost bedding soil around the host pipe. Once the voids are filled, the grout will continue to flow down the pipe length and slowly fill the annular space between the liner and host pipe. Again, patience is critical with the grouting operation.

Flowing Grout and Gravity Fed Pouring

For culvert/liner lengths of less than fifty feet, grout often can be placed by pouring the grout into place with grout holes. When the grade is relatively flat, this is a good approach. Pressure on the liner is usually minimal.

When it is possible to bore multiple openings in the existing host culvert (above the liner), grout can easily be poured in place at regular intervals (often 20-foot spacing). For culverts under roadways, this will usually require stopping traffic at least in one lane and repair of the borehole. Again, the pressure on the liner is minimal, but there may be other factors to consider.

Placing the grout may require some creativity. Typically, a funnel is required to take the grout from a mixer, tank, or truck into a placement hole or pipe. Ideally, a funnel is located at the end of the chute

from the concrete mixing truck so that transfers are eliminated and the amount of pour can be easily controlled.

A standpipe might be used to fill the annular space between the host pipe and the inserted liner. If the old pipe/culvert is well below the roadway, a standpipe or extension hose is a good way to reach the fill pipe(s). However, once the air is fully vented or cannot escape, pressure on the liner can build up and apply a significant force at the bottom of the liner.

Grout Pumping and Injection

Grout pumping may be necessary in some applications. The pump pressure is used to move the grout from the mixing tank, through the injection port, into the annular space. For long culverts, multiple sections of injection pipes in varying lengths can be used to place the grout further into the culvert to efficiently fill the space.

At the point where the grout exits an injection pipe, the pressure should be essentially zero for a vented and unclogged annulus. Grouting with aggregate materials is not recommended due to the higher risk of blockages in grout ports and the annulus. If a back pressure is noted by the pump operator, the pumping should immediately be stopped. Many pump truck pressure gauges don't have the sensitivity to perceive a low-pressure buildup in the system of 2-4 psi. Exerting unnecessary pressure within the annular space, on the outside of the culvert liner, can cause unwanted problems, from grout leaking through the liner joints to deflection or collapse of the liner pipe. Although this occurrence is rare, careful planning, patience, and close observation should be used during the grout injection operation to help mitigate any potential damage to the liner or the bulkheads.

Grouting Pressures and Limits

Liner Strength and Unconstrained Buckle

The grout pressure in the annular space should not exceed the pipe's allowable collapse pressure, determined by the unconstrained wall buckling pressure. The following equation can be used to assist the designer to evaluate an allowable load on the HDPE liner.

Equation 7-1

$$P_{WU} = \frac{f_0}{N_s} \frac{2E}{(1-\mu^2)} \left(\frac{1}{DR-1} \right)^3$$

Where:

P_{WU} = allowable unconstrained pipe wall buckling pressure, psi

f_O = Ovality Correction Factor, Figure 7-1

N_s = safety factor

μ = Poisson's ratio

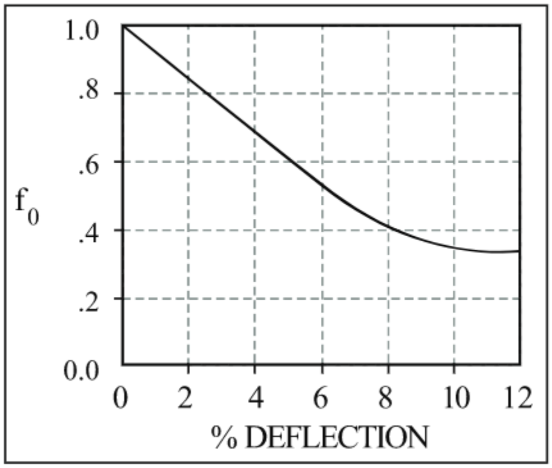
E = apparent modulus of elasticity of pipe material, psi

DR = Dimension Ratio

An approach often utilized by designers is to use a 10-hour pipe modulus based on a temperature of 73° Fahrenheit. This modulus is used since the heat of hydration for the cementations fill usually does not increase until the grout material begins to set up. When the grout materials begin to set up, they also begin to provide support to the liner nearly simultaneously. The Plastics Pipe Institute provides an industry established modulus for a PE3408 material of 62,000 psi based on a 10-hour load at 73° F. Newer 4710 resins used for practically all Snap-Tite pipe has a 10-hour modulus of at least 65,000 psi. Most grouts will provide structural support due to curing within this 10-hour time span.

It is also an industry standard to base calculations on a 0.45 Poisson's ratio and an assumed deflection of 3% existing in the HDPE liner. This would result in an ovality factor of 0.76 using Figure 7-1.

Figure 7-1



Ovality Compensation Factor, f_e

*Ovality compensation factors and buckle equation presented in PPI Handbook of Polyethylene.

If a 2 to 1 safety factor is used with the approach described above, an HDPE liner made with a DR 32.5 pipe wall would have an allowable external pressure of 2 psi. This is consistent with the allowable load suggested by ISCO's Snap-Tite® Division for RPS liners.

Grouting Pressures

The amount of pressure that a grout will exert is primarily determined by two factors, density and depth. Table 7-1 shown on page 57 calculates the pressure of grouts from 30-135 increasing from left to right. It also shows the change in pressures based on depth of grout, or lift height as measured to the bottom of the Snap-Tite Liner. The areas in yellow show values that exceed the grouting pressure limit of 2 psi with a 2:1 safety factor. The areas in orange show values exceeding 4 psi (essentially above the capacity of the pipe with no safety factor).

Grouting in Lifts

The term "lifts" indicates that only a portion of the grout is poured into the annular space at one time. By placing only a portion of the grout around the pipe, the collapse force on the liner pipe is minimized. Grouting in lifts means that only a part of the grout is flowed around the liner and allowed to reach initial set or cure.

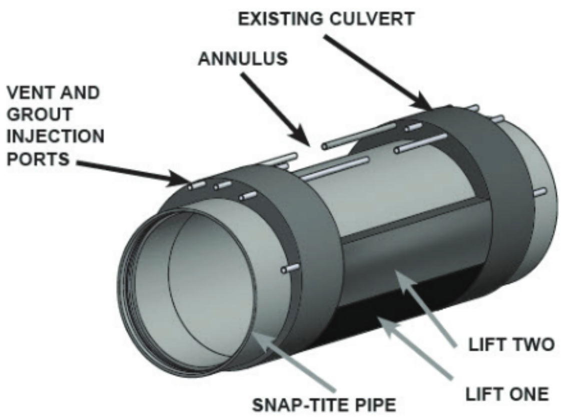
Table 7-1

GROUTING PRESSURE IN PSI BASED ON DENSITY AND DEPTH																						
Lift Height (ft)	GROUT DENSITY (PCF)																					
	TYPICAL CELLULAR GROUT DENSITY RANGE																					
	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135
1	0.21	0.24	0.28	0.31	0.35	0.38	0.42	0.45	0.49	0.52	0.56	0.59	0.62	0.66	0.69	0.73	0.76	0.80	0.83	0.87	0.90	0.94
2	0.42	0.49	0.56	0.62	0.69	0.76	0.83	0.90	0.97	1.04	1.11	1.18	1.25	1.32	1.39	1.46	1.53	1.60	1.67	1.74	1.81	1.87
3	0.62	0.73	0.83	0.94	1.04	1.15	1.25	1.35	1.46	1.56	1.67	1.77	1.87	1.98	2.08	2.19	2.29	2.40	2.50	2.60	2.71	2.81
4	0.83	0.97	1.11	1.25	1.39	1.53	1.67	1.81	1.94	2.08	2.22	2.36	2.50	2.64	2.78	2.92	3.06	3.19	3.33	3.47	3.61	3.75
5	1.04	1.22	1.39	1.56	1.74	1.91	2.08	2.26	2.43	2.60	2.78	2.95	3.12	3.30	3.47	3.65	3.82	3.99	4.17	4.34	4.51	4.69
6	1.25	1.46	1.67	1.87	2.08	2.29	2.50	2.71	2.92	3.12	3.33	3.54	3.75	3.96	4.17	4.37	4.58	4.79	5.00	5.21	5.42	5.62
7	1.46	1.70	1.94	2.19	2.43	2.67	2.92	3.16	3.40	3.65	3.89	4.13	4.37	4.62	4.86	5.10	5.35	5.59	5.83	6.08	6.32	6.56
8	1.67	1.94	2.22	2.50	2.78	3.06	3.33	3.61	3.89	4.17	4.44	4.72	5.00	5.28	5.56	5.83	6.11	6.39	6.67	6.94	7.22	7.50
9	1.87	2.19	2.50	2.81	3.12	3.44	3.75	4.06	4.37	4.69	5.00	5.31	5.62	5.94	6.25	6.56	6.87	7.19	7.50	7.81	8.12	8.44
10	2.08	2.43	2.78	3.12	3.47	3.82	4.17	4.51	4.86	5.21	5.56	5.90	6.25	6.60	6.94	7.29	7.64	7.99	8.33	8.68	9.03	9.37
11	2.29	2.67	3.06	3.44	3.82	4.20	4.58	4.96	5.35	5.73	6.11	6.49	6.87	7.26	7.64	8.02	8.40	8.78	9.17	9.55	9.93	10.31
12	2.50	2.92	3.33	3.75	4.17	4.58	5.00	5.42	5.83	6.25	6.67	7.08	7.50	7.92	8.33	8.75	12.22	9.58	10.00	10.42	10.83	11.25
13	2.71	3.16	3.61	4.06	4.51	4.96	5.42	5.87	6.32	6.77	7.22	7.67	8.12	8.58	9.03	9.48	9.93	10.38	10.83	11.28	11.74	12.19
14	2.92	3.40	3.89	4.37	4.86	5.35	5.83	6.32	6.81	7.29	7.78	8.26	8.75	9.24	9.72	10.21	10.69	11.18	11.67	12.15	12.64	13.12
15	3.12	3.65	4.17	4.69	5.21	5.73	6.25	6.77	7.29	7.81	8.33	8.85	9.37	9.90	10.42	10.94	11.46	11.98	12.50	13.02	13.54	14.06

62.4 PCF= Unit weight of water

- Yellow: Grouting pressure below 2:1 safety factor
- Orange: Grouting pressure exceeds collapse pressure

Figure 7-2



Allow the previous lift to set before beginning the next lift. By allowing each lift to harden before adding the next lift, the liner receives additional support and reduces the likelihood of collapse. The highest forces occur below the pipe's springline, so take your time during the first and second lifts. See Figure 7-2 at left. Lifts may be necessary when there is a large change in elevation between culvert inlet and outlet resulting in higher pressures on the liner or bulkhead. As pipe size and/or slope increases, it becomes more important to evaluate hydrostatic loading and potentially place the grout in lifts. As the height of uncured grout over the liner increases, the weight of the grout can become significant. Grouting in lifts is usually the best way to grout long runs with higher density grout formulations.

When grouting with multiple lifts, measure the amount of grout added per lift. Fill the annular space with the calculated amount of grout. Fill each lift with this calculated amount of grout. More grout will be required if there is a void around the old culvert. If the existing culvert is partially collapsed, less grout maybe required.

Grouting Operation

Preparation

The preparation for the grouting operation begins before installing Snap-Tite® pipe into the existing culvert pipe. The existing culvert should be inspected to determine the following factors:

- Point of entry for grout
- Length and slope of culvert
- Existence of corrosion holes or separated joints in culvert
- Evidence of voids in the road bedding and fill materials
- Available workspace
- Traffic control
- Protection of environment and existing conditions

Point of Entry for Grout

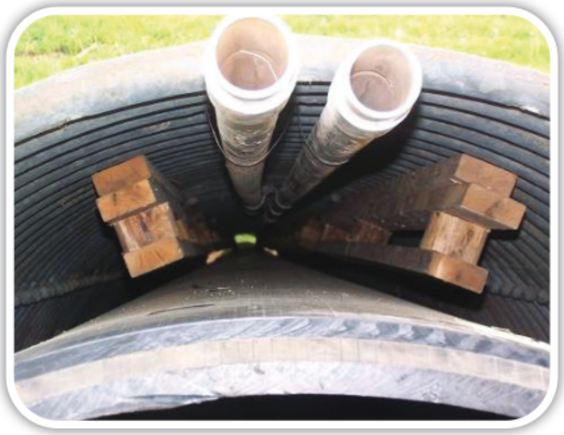
The method of placement may dictate the point of entry. Gravity flow the grout is almost exclusively performed from the highest point of the annulus which is the upstream side. Grout injection is normally done from the upstream end but grout can be forced from the downstream end with pumping forcing the material to fill the annulus from the discharge of the grout tubes. It is recommended to have grout tubes as long as possible to reduce the amount of material that is "pushed" by the filling action.

Grouting from the downstream end may be considered to assist in venting air and water. However, it often can create some challenges with grouting pressures and clogged grout ports. Grouting from the upstream end is preferred unless there are issues with access or space constraints.

Blocking

As discussed before, flotation of the liner can occur when a liner is to be grouted or there is ground water present. To prevent flotation, using blocks or skids around the pipe can center the Snap-Tite® culvert liners, or keep it low against the exiting host invert. Blocks or skids are typically installed in a staggered pattern. Spaces are left between the blocks or skids to allow grout to flow under and around the liner.

Blocks are installed in the top 120 degrees of the culvert. For culverts 48" in diameter or larger, blocks are attached to the old culvert. The first



block is often installed at 11 o'clock, and then a space of four feet is left before the second block is installed at the 12 o'clock position. Then a space is left and the third block is installed at 1 o'clock. These blocks are usually four to eight feet in length. The thickness is determined by the difference in the ID of the culvert and the liner. The upper skids must have structural strength adequate to resist the buoyant force created as the liner is grouted in place. Wood and solid plastic will work. Styrofoam does not have adequate compressive strength to work for many liner sizes.

Blocking can also be used to bridge any gaps created by separated joints in the existing host pipe. This can help to prevent the Snap-Tite® liner from catching on the gaps or separated joints during the sliplining process.

Bulkheads

The purpose of the bulkhead is to retain the grout within the annular space. Refer to Chapter 6 for more information.

When grouting the annular space of a sliplined pipe, the grout is placed within a closed space and exerts pressure on the bulkheads of end walls constructed at each end of the culvert. The best prevention against bulkhead leaks is to construct an end wall strong enough to withstand the internal hydrostatic pressure exerted on it by the grout. A bulkhead with a thickness of 18" to 24" is typically adequate for most culvert relining projects, but 12" thickness may be adequate for short, flat runs.

If a cementitious material, be it a concrete mix or a stiff grout mix, is used for the end walls, then drying/shrinkage of the material is a concern. To protect against grout leaks around the bulkheads, a quick-set, non-shrink grout or repair mortar material should be available during the grouting operation.

A proactive step is to apply this material in a thin layer over the cured bulkhead or end wall prior to starting the grouting operation. This material typically sets in15 minutes and will help plug any cracks in the bulkhead or gaps between the end wall and grout insertion tubes and vent ports. Additionally, a hydraulic cement can be hand placed in leaking cracks between liner or host and the bulkhead.

Vent Ports

Vent ports should be located at strategic positions though the bulkhead or in the top of the host pipe, depending on the site conditions. A minimum of one vent port, in addition to the grout injection ports, is recommended, unless the grout is inserted into the annular space through a hole large enough to serve as both. Vent ports help to prevent pressure buildup in the annular space and also serve as grout verification points. Preparations must be made to adequately close off the opening once grout begins to flow out of the area. A vent port placed at the bottom of the bulkhead will help drain water that may exist in the annular space during the grouting operations.

Grout Verification

Even if venting is done with holes in the top of host, grout verification ports are recommended to monitor the grouting operation. Short pieces of pipe can be placed through the bulkheads to serve initially as vent ports for escaping air in the system and later as grout verification ports, during the installation process. When grout begins to flow from these lines, the pipe is capped or plugged to stop the flow. A verification pipe with a threaded terminating end that extends from the bulkhead can easily be sealed as it will accept a threaded cap to terminate the pipe, but many grouts can simply be plugged with a cloth, shop rags, or even paper towels.

Quality Control & Testing

Practically any grout selected will be stronger compared by to the compressive strength of the bedding material around the host pipe, which is the material that the grout is intended to replace and serve in its absence. As a result, the primary property to identify for QA/QC is the density of the grout which is used to correlate to the compressive strength for the annular fill.

Types of Grout

The American Concrete Institute (ACI) technical committee 552 on Cementitious Grouting defines grout as "a mixture of cementitious material and water, with or without aggregate, proportioned to produce a pourable consistency without segregation of the constituents." For Snap-Tite® culvert lining applications, flowable fills and low density cellular concretes (LDCC) can be used as grouts to fill the annular space in a rehabilitated culvert system. LDCC grouts with lower densities are normally preferred since they offer several advantages when being placed.

It is suggested that grout mixtures, which are utilized to fill the annulus where the wet cast density exceeds 75 pcf, should be independently evaluated for suitability of use by the owner or the installer. Direct consultation with the commercial admixture manufacturer is recommended in these instances. Increased grout densities will increase the likelihood that the annular space grouting will need to be performed in lifts to limit stresses in the liner. The liner pipe may see it highest loads during grouting. Hydrostatic pressures on the liner should always be considered prior to creating or injecting the selected grout, regardless of actual grout density being used.

Flowable Fill Grout

Flowable Fill is also known as controlled low strength material, abbreviated CLSM, and according to ACI is a self-consolidating cementitious material used primarily as backfill as an alternative to compacted fill. It is comprised of a mixture of cement, water, and sometimes includes aggregate (primarily sand) that creates a weak, runny concrete mix used in construction for non-structural purposes. Flowable Fill has the consistency of a milkshake and sometimes includes chemical admixtures designed to affect certain properties of the grout mix.

A portion of the cement component can be replaced with fly ash, which is well suited for flowable fills. The fine particle sizing (nonplastic silt) and spherical particle shape of fly ash enhances mix flowability, while the relatively low dry unit weight helps produce a lighter weight fill than cement only mixes. Flowable Fill mixes using high-calcium fly ash (Class C) may not require any cement. Fly ash can be lower in cost than cement or sand, but may not be readily available or economical for all job locations. Typical mixes involving fly ash are provided at the end of this chapter.

Flowable fills are often used as the backfill around pipes, but are also used to backfill abutments and retaining walls or fill abandoned pipelines, vaults, cavities and settled areas. The extent to which a flowable fill grout can travel within the annular space is limited and a function of the specific mixture. Increasing the sand content not

only increases the chances of clumping but also affects the flowability by increasing the viscosity of the mixture. An annular space within a culvert that is longer than 40 – 50 feet may not be completely encapsulated with a flowable fill that is high in sand content.

Reduced Density Flowable Fill

Certain chemical admixtures are available commercially to reduce the density of a flowable fill grout mix. The grout unit weight may be lowered to a value in the vicinity of 100 – 115 pcf, depending the percentage of the various components in the mix design.

These in plant or on site “bag mixtures” use a chemical reaction to introduce gas bubbles and voids into a flowable fill mix. The chemical reactions are limited in the amount of air that can be introduced as off gases in the formulation of a flowable fill.

Some admixtures are exothermic, which will further raise the curing temperature of the grout. The heat of hydration for the selected grouting agent should always be considered. Increased curing temperatures will result in a decrease on the allowable temporary loads recommended for the liner. Expansive grouts are not recommended.

Low Density Cellular Concrete (LDCC)

LDCC grout is a low-density grout mix comprised of cement and water (or cement, fly ash, and water) with a pre-generated foam added to inject a large volume of macroscopic air bubbles into the grout mix. This admixture greatly reduces the density, or unit weight, of the grout mix, and often will result in 40% to 75% air content in the finished product. A foam generator unit is required to obtain such a high percentage of air and to reduce grout density.

In LDCC, the air bubbles stay in suspension long enough for the cement paste to coat them and begin to hydrate, or “set,” and the air bubbles replace the aggregates commonly found in products such as concrete. Once hardened, the grout mix has a compressive strength that can range from 70 psi to over 1,000 psi. These values are higher than that of the bedding soil that was originally around the host pipe.

Cellular grouts can be designed to have wet densities, while still in the “plastic” stage, ranging from 25 to 50 pcf. In this range,

the grout applies less hydrostatic pressure on the Snap-Tite® liner than with a denser product. An additional benefit is that the grout is able to travel longer distances within the sliplined pipe system while also flowing through the holes or separated joints of the host pipe, filling the voids in the surrounding bedding materials. These voids were originally caused by the soil infiltrating into the host pipe through separated joints or holes in the

Table 7-2

		Condition of Host Pipe		Length of Host Pipe (LF)			Culvert Circumstances	
	Density Range (pcf)	Good	Failed or Failing	< 50	50 – 125	> 125	Light Traffic	Heavy Traffic
Flowable Fill	115-145	x		x			x	x
Reduced Density Flowable Fill	100-115	x	x	x	x		x	x
LDCC	25 – 90	x	x	x	x	x	x	x

pipe. The voids are thus filled with the grout flowing through these same openings.

Culvert Circumstances

The specific culvert circumstances have the greatest impact on the type of grout that should be used to fill the annular space. Table 7-2 is provided to assist in this determination. This is an aid only; it should not be considered a definitive recommendation of what type of grout to use for any particular application.

Grout Properties

Density or Unit Weight

Density is the most crucial property to be specified for the grout since other properties are a function of density. As density decreases, so does viscosity and compressive strength. The density of a grout mix is the weight, in pounds, of a defined volume of the grout, for instance one cubic foot of material. Density is often reported in units such as pounds per cubic foot or pcf. The unit weight is measured by collecting a sample of the grout mix and filling a container of a pre-determined volume. Typically, a one-half or one-quarter cubic foot metal unit weight bucket is used. After completely filling the bucket and striking off the surface, the bucket is weighed. The weight of the empty bucket is subtracted from this value and the resulting number is multiplied by two (using a one-half cubic foot bucket) or four (using a one-half cubic foot bucket) to obtain the density of the grout mix.

Air Content

The air content is the amount of air introduced into the grout mixture; this is reported as a percentage of the total volume. Certain chemical admixtures have the ability to entrain air around sand particles in the mix. These are macroscopic air bubbles and typically add 3-20% of air to the mix. The advantages of having air bubbles in a grout mix are that they provide for better flow of the material and give greater resistance to the damaging effects of a freeze/thaw environment.

Foam generators can introduce up to 70% air to create highly-designed and consistent air incorporation. These air bubbles are attached to the cementitious particles in the grout. The resulting grout mix can appear to have a foam consistency. The larger air content in the material greatly enhances the ability of the grout mix to flow longer distances and through smaller spaces.

Viscosity

While viscosity is viewed as the apparent "thickness" of a liquid, it really is a measure of a fluid's resistance to flow. A low viscosity is desirable for grout mixes in a Snap-Tite® application. The viscosity of a grout mix is measured by use of a flow cone as described by ASTM C939. A slump test is not applicable in determining the flow of a grout mix.

Compressive Strength

The compressive strength of grout is the amount of compressive force that the material can resist after the grout material is allowed to set cure for a specific time period. This is determined by obtaining a grout sample and filling a cylindrical container, typically a mold 3" in diameter and 6" in height, and testing the sample in a compressive strength test apparatus. This test is conducted in pre-determined time increments, such as sample ages of 1, 3, 7 or 28 days after the grout mix is batched. ASTM C1019 describes this testing process. ASTM C495 describes this testing process for LDCC.

While compressive strength is commonly specified for concrete used in many structural applications, this is not a convenient or expedient property to measure for grout used to fill the annular space after sliplining a culvert. Practically any grout used will have compressive strength values greater than the original soil surrounding the host culvert. Since the compressive strength takes 7 to 28 days for verification, the most important property of the grout mix is the density of the material, which can be field verified immediately prior to placement, if required. As grout density increases is increased, so is does the compressive strength of the grout.

Material Sources

Grout Supplier

A concrete ready-mix supplier, or batch plant, local to the project site is a source for the grout and for a material that can be used to construct the culvert bulkheads. These facilities have supplies of cement, sand, and water as well as the equipment to measure and adequately mix the components. A mix design may be submitted to the batch personnel to assure a material with appropriate density is obtained.

In some locations, grouting contractors are available that have all-inclusive units and can provide appropriate grout mixtures, as well as pumping apparatus, to place the grout into the culverts. These contractors are skilled in all types of grout needs and should serve the project well. Similar services can be additionally obtained directly through ISCO and our Snap-Tite® division. Your Snap-Tite® representative can assist you with obtaining grouting services from ISCO.

Admixtures

There are numerous manufacturers of chemical admixtures utilized in grout formulation. Chemical admixtures are the ingredients in concrete other than cement, water, and aggregate that are added to the mix immediately before or during mixing. The admixtures include accelerators, retarders to delay the hydration of the cement in the mix, and air-entraining agents (both ready to use and foaming agents) to increased volumes of air into the grout mix.

There are also many regional and national manufacturers for the foam concentrate additives:

- Aerix Industries,
- Vermillion & Associates,
- Cellular Concrete Technologies
- Elastizell

These companies provide foam generation equipment for use in creating cellular grouts. The admixture manufacturer should be contacted for support on proper use of their specific foaming agents.

Most admixtures are supplied in ready-to-use liquid form and are added to the concrete at the plant or at the jobsite. There are chemical admixture manufacturers that distribute nationwide, such as Aerix Industries, BASF (Master Builders product line), and W.R Grace & Company. Aerflow manufactured by Aerix Industries, is a ready-to-use, self-contained product for use in various flowable fill applications where a limited reduced density grout may be desirable. Direct contact with the chemical admixture manufacturer is recommended when these additive packages are selected for grout formulation.

Grout Pump Equipment

The pumping apparatus best suited for grouting annular space is a peristaltic pump, known also as a roller pump, a squeeze pump, or rotor/stator pump. Other pump types, such as piston pumps, can be used but these may force some of the air out of the grout mixture. With less air in the mix the resulting density will increase.

Grout Mix Designs

The mix design for grout used to fill the annular space created in a Snap-Tite® culvert lining project will vary depending on the type of grout selected for the application, i.e., flowable fill, reduced density flowable fill, or LDCC grout.

Flowable Fill

As stated earlier, flowable fill is comprised of a mixture of cement and water, and may include sand. A portion of the cement may be substituted with fly ash, and chemical admixtures may be used to affect certain properties of the mix.

Different sources of materials will have an impact on the specific gravities of the materials. This is especially true with sand and fly ash. The specific gravity value of the material is used to calculate its absolute volume in the mix. The volume value is used to calculate the total yield of the batch. The quality control manager for the ready-mix supplier can help formulate a flowable fill mix based on their specific materials. Use caution with flowable fills as even though it looks very flowable, as the higher density can lead to unwanted forces being applied to the liner pipe.

Reduced Density Flowable Fill

To reduce the density of a flowable fill an admixture may be considered by the owner or installing contractor for incorporation into the grout formulation mix. Typical admixture products are Aerix Industries Aerflow, MasterCell® 25 manufactured by BASF, and DaraFill® produced by Grace Construction Products.

The addition of the specialty, density-lowering admixture is made at the mix plant or at the jobsite depending on product being used. The admixtures are added directly into the concrete mixer after batching. They are designed to generate air contents from 15% to 35% in the grout mix. Typically, these grouting mixtures exceed a density of 100 pcf.

To produce cellular grout, a concentrated foaming agent is required in combination with various types of foam generating equipment. Foam is created by mixing compressed air with the foaming agent and then added to the mixing drum to a partial volume of grout mix (shown in picture).

LDCC Grout

LDCC grout may be produced with a grout mixture containing cement and water. The cement may be replaced with fly ash to reduce the cost of the grout.

LDCC is made at the jobsite. The foam is manufactured by compelling a mixture of foaming concentrate and water, together with compressed air, through a foam generator. The pre-formed foam is dispensed directly into the concrete mixer. To determine the amount of foaming required, unit weight measurements should be taken until the desired unit weight of the grout mix is obtained per ASTM C796.

The following tables offer mix designs for grouting the annular space between the liner and the old culvert. These mixes are provided as guides only. Aggregates vary greatly. Consult your local ready-mix supplier for their recommendations for grout and flowable fill.

Table 7-3
Cellular Grout Mix - 40 lb/ft³ using Foam Generator

Component		Units	Weight (lbs)	Volume (Yd^3)
Type III Portland Cement	6,950	lbs	6,950	1.3
Water	418	Gallons	3,488	2.0
Foam	179	Cu./Ft.	716	6.6
		Mix Totals	11,154	10.0
		Net Wet Cast Density =	41.3	lb/ft^3

Foam Instructions

Component	
Varimax HS-320	61.71 Oz
Water	82.87 Gallons
Mix together and run through foam generator for 8 minutes and 8 seconds.	

Table 7-4
Cellular Grout Mix - 55 lb/ft³ using Foam Generator

Component		Units	Weight (lbs)	Volume (Yd^3)
Type III Portland Cement	9,700	lbs	9,700	1.8
Water	584	Gallons	4,877	2.9
Foam	143	Cu./Ft.	572	5.3
		Mix Totals	15,149	10.0
		Net Wet Cast Density =	56.1	lb/ft^3

Foam Instructions

Component	
Varimax HS-320	49 Oz
Water	66.2 Gallons
Mix together and run through foam generator for 6 minutes and 30 seconds.	

Table 7-5
Cellular Grout Mix - 75 lb/ft³ using Foam Generator

Component		Units	Weight (lbs)	Volume (Yd^3)
Type III Portland Cement	13,368	lbs	13,368	2.5
Water	805	Gallons	6,720	4.0
Foam	95	Cu./Ft.	380	3.5
		Mix Totals	20,468	10.0
		Net Wet Cast Density =	75.8	lb/ft^3

Foam Instructions

Component	
Varimax HS-320	35.75 Oz
Water	43.98 Gallons
Mix together and run through foam generator for 4 minutes and 51 seconds.	

[1]Mix Ratios provided by Vermillion and Associates.
[2]Construction Specifications are available on www.culvert-rehab.com

The table below for low Density Cellular Concrete (LDCC) uses Aerix Industries Aerlite-iX foam at a 2.0 pcf foam density and 1:60 foam dilution ratio. Other grout mixes (30-90 pcf densities) are available upon request. If you are using a different foam concentrate, please contact Aerix Industries Technical Department.

Table 7-6

MIX DENSITY (LB/FT^3)	CEMENT (LB)	WATER (GAL)	FOAM (LB)		FOAMING INSTRUCTIONS: WATER (GAL)	FOAMING INSTRUCTIONS: AERLITE-IX FOAM CONCENTRATE (OZ)	FOAMING INSTRUCTIONS: FOAMING TIMES (FOR 1 YD^3)
40 pcf	687	36	17.8	←	4.25	8.8	54 secs
55 pcf	958	60	14	←	3.3	6.9	42 secs
70 pcf	1230	76.5	10.5	←	2.5	5.2	32 secs

***Mix produces one cubic yard of Low Density Cellular Concrete (LDCC)**
****Foaming times are based on Aerix Industries T80-20 foam generator producing foam at 20 cfm. When using a different foam generator please contact Aerix Industries Technical Department.**

The Federal Highway Administration provides some sample mix designs in Chapter 5 of the publication Fly Ash Facts for Engineers. While these mix formulations are not specifically designed for culvert applications, the project engineer can determine the suitability. The mix designs are for one cubic yard of flowable fill.

Table 7-7

FHWA MIX	DENSITY (LB/FT^3)	CEMENT (LB)	FLY ASH (LB)	SAND (LB)	WATER (GAL)	AIR CONTENT %
Table 5-1	96.3 pcf	104	2,080	0	50	n/a
Table 5-2	129.6 pcf	100	300	2600	60	n/a
Table 5-3	110.8 pcf	50	350	2300	35	20-24

Table 5-1. High fly ash content mix
Table 5-2. Low fly ash content mix
Table 5-3. Flowable fill mix with high air content.

Additionally, Aerix Industries provides Controlled Low Strength Material (CLSM) flowable fill produced using AERFLOW. AERFLOW is a synthetic anionic liquid concentrate specially formulated to produce a stable, voluminous micro-bubbled foam. Admixtures like AERFLOW are used in direct combination with sand/cement slurries for the production of CLSM concrete, This material, also known as flowable fill, is engineered with densities ranging from 100 to 115 pcf. The mix designs are for one cubic yard of concrete. Other admixture suppliers may have different recommendations including amounts of admixture amounts.

Table 7-8

MIX**	CLSM DENSITY (LB/FT³)	CEMENT (LB)	FLY ASH (LB)	SAND C-33 (LB)	WATER (GAL)	AERFLOW (PER YD³)*
CF1	113.5 pcf	125-150	0	2600	30	3 oz.
CF2	115 pcf	75-100	0	2500	32	3 oz.
CF3	112 pcf	50	250	2500	34	3 oz.
CF4	110 pcf	50	350	2300	35	3 oz.

***AERFLOW is added at the job site and mixed for 5 minutes at mixing speed**
**** Foam Enhancement changes a 1.5" (+/-) slump to 7"-9" slump**

Note that CF4 matches the FHWA Table 5-3 mix and provides the amount of AERFLOW to create 20%-24% air content.

Table 7-9 is a common slurry mix used to create a CLSM flowable fill mix used by some Snap-Tite installers in the midwest and southeast US

Table 7-9

MIX**	CLSM DENSITY (LB/FT³)	CEMENT (LB)	FLY ASH (LB)	SAND C-33 (LB)	WATER (GAL)	ADMIXTURE (PER YD³)*
SLURRY	102 pcf	300	1350	300	105	16.5 oz.

***This mixture will typically entrain 4% air while in the mixing drum.**

Chapter 8
Structural Design

SECTION

FIGURES

TABLES

8-1 Outline of Structural Design Methodology

This chapter describes the design methodology for Snap-Tite® polyethylene pipe in direct burial conditions and for sliplining applications. Critical Snap-Tite® pipe design properties (or section properties) for the pipe are set forth in this chapter. Material properties, backfill criteria, grout properties and load conditions are also factored into the design method presented in this chapter. It is noted that the engineer should verify backfill properties and grout properties for specific project and site conditions. Pipe must be installed as designed to perform as expected.

Direct burial refers to installing Snap-Tite® in embankment conditions. The direct burial design procedure evaluates wall thrust, deflection, buckling, bending strain, and combined strain and establishes limits on each condition. Minimum cover in trafficked installations, and maximum cover heights under a variety of backfill conditions are shown in Tables 8-12, and 8-14, respectively.

Rehabilitated Pipe Systems (RPS) refers to installing Snap-Tite® in an existing culvert and placing cementious grout in the annular space between the two pipes. The RPS design procedure evaluates grout thrust capacity, grout tensile strain, HDPE wall thrust, deflection, buckling, bending strain, and combined strain, and establishes limits on each condition.

Cover heights for Snap-Tite® can be in excess of 50 feet for direct burial applications and 80 feet for RPS systems; however, contact your Snap-Tite® representative for a review of the installation and backfill procedure.

8-2 Design Chapter Introduction

This chapter addresses design considerations for two applications of Snap-Tite®. The most basic application is direct burial installations of Snap-Tite®. A second application of Snap-Tite® addressed in this chapter is a rehabilitated pipe system (RPS).

In the case of direct burial of Snap-Tite® pipe, the design criteria is heavily influenced by proper backfill. Deflection of Snap-Tite® (and other flexible pipe) allows loads to be transferred to and carried by the backfill. The design method presented in this chapter is based on the American Association of Highway Transportation Official (AASHTO) Load and Resistance Factor Design (LRFD) Section 12 design criteria. In the case of the Rehabilitated Pipe Systems (RPS), the design criteria are based on the American Association of Highway Transportation Official (AASHTO) Load and Resistance Factor Design (LRFD) method. Analysis is performed with the CANDE-2007 computer program. Additionally, the CANDE-2007 finite element analysis is supplemented with analytical mechanics of material analysis. The information in subsequent areas of this chapter provides a step-by-step guide for the structural design of Snap-Tite® direct burial and RPS pipe systems. The methodology represents the state-of-the-art design procedure.

8-3 Design Criteria

Design of polyethylene pipe requires an understanding of variables that influence the behavior of the installed pipe. These variables include pipe section properties, material properties, installation conditions, backfill and/or grout properties, and the load situation. All of these elements define the response of the pipe system to loading. As previously mentioned, it is incumbent upon the design engineer to verify the physical properties of the variables that influence the behavior of the installed pipe, which includes backfill and grout properties. This section (8-3) describes the criteria that enter into the design procedure presented in the following sub-categories.

<u>Pipe Section Properties</u>

Pipe properties necessary for soil-structure interaction design include: the moment of inertia of the wall profile (I), distance to the neutral axis (c), and the section area of a longitudinal section (A_S). These properties determine how the pipe will behave when subjected to loading conditions. Pipe stiffness (PS) is a measure of the pipe's flexibility and is measured in the laboratory by gauging the force required to deflect the pipe 5% of its inside diameter. Section

Table 8-1
Section Properties for Snap-Tite® DR 32.5 Pipe

Outside Diameter, OD (Inches)	Inside Diameter, ID (Inches)	Pipe Stiffness, PS* (pii)	Section Area, A_s (in²/in.)	Distance to Centroid, c (Inches)	Moment of Inertia, I (in⁴/in.)
10.75	10.1	16	0.331	0.166	0.0030
12.75	12.0	16	0.392	0.196	0.0050
14	13.1	16	0.431	0.216	0.0067
16	15.0	16	0.492	0.246	0.0099
18	16.9	16	0.554	0.277	0.0142
20	18.8	16	0.615	0.308	0.0194
22	20.6	16	0.677	0.339	0.0259
24	22.5	16	0.738	0.369	0.0339
28	26.3	16	0.862	0.431	0.0534
30	28.2	16	0.923	0.462	0.0655
32	30.0	16	0.985	0.492	0.0795
36	33.8	16	1.108	0.554	0.1133
42	39.4	16	1.292	0.646	0.1799
48	45.0	16	1.477	0.739	0.2685
54	50.7	16	1.662	0.831	0.3823
63	59.1	16	1.938	0.969	0.6070

*Pipe stiffness is based on testing and analytical calculations in ASTM D2412

properties of Snap-Tite® with a dimension ratio (DR) of 32.5 are presented in Table 8-1. For section properties of other DR products contact Snap-Tite®.

HDPE Material Considerations and Properties

High density polyethylene (HDPE) is a visco-elastic material and its behavior is different from elastic materials like steel. Viscoelastic materials, when subjected to constant force, experience stress relaxation over time. Stress relaxation is the decrease in stress under constant force.

When Snap-Tite® is deflected, it will initially experience relatively high stress levels that then quickly decrease. If additional deflection occurs, the stress will again increase and then decrease. More information on this subject is in the Plastic Pipe Institute's Handbook of Polyethylene Pipe in the Engineering Properties Chapter.

Snap-Tite® is made using solid-wall HDPE pipe. The pipe is made to the dimensions and requirements of ASTM F 714. The resin has physical properties as indicated in ASTM D3350 with a minimum cell classification of 345464C. It is noted that Snap-Tite® material exceeds short- and long-term strength requirements established for the corrugated HDPE pipe industry.

The long- and short-term material properties that are critical to pipe design are shown in Table 8-2, along with properties used in the AASHTO LRFD design method described in this chapter. When analyzing H-25 vehicle loading, the short-term material properties are used. When analyzing long-term static loading, the long-term material properties are used.

Table 8-2
Long- and Short-Term HDPE Properties @ 73 degrees Fahrenheit

	Young's Modulus, E		Tensile Strength, F_u	
Grade of HDPE	Short-Term (psi)	Long-Term (psi)	Short-Term (psi)	Long-Term (psi)
Section 12 HDPE	110,000	22,000	3,000	1,440

Based on LRFD section 12 Table 12.12.3.3-1
Please note that 110,000 psi short term modulus covers all HDPE products for highway drainage, but the typical value for resins used to produce Snap-Tite pipe is 135,000-140,000 psi.

Soil Considerations for Direct Burial

For direct burial of Snap-Tite® structural performance depends on the interaction between the embedment, or backfill envelope, and the pipe. This interaction is often referred to as soil-structure interaction. Structural considerations of the backfill include the type of material and compaction level, dimensions of the backfill envelope, and native soil con-ditions. Information presented in this chapter is consistent with the backfill and embedment requirements established in ASTM D2321 "Recommended Practice for Underground Installation of Flexible Thermoplastic Sewer Pipe." Direct burial installations of Snap-Tite® should be installed in accordance with ASTM D2321 and AASHTO Section 30. Additionally, dimensions of the backfill envelope and native soil considerations are discussed in ASTM D2321. The type of material (sand, gravel, clay, etc.) and compaction level (standard Proctor density) determine overall strength of the backfill. Typically, backfill particles that are larger and angular require less compaction effort than particles that are smaller and rounder in order to obtain the required strength.

The strength of the backfill may be described by using modulus of soil reaction (E') or secant constrained soil modulus (M_S). The modulus of soil reaction (E') is an empirical value developed by the Bureau of Reclamation, and is used to calculate deflection. Table 8-3 presents the E' values for several different materials and compaction levels. The secant constrained soil modulus (M_S) is laboratory derived soil property and is used for most design calculations. Values appropriate for design are shown in Table 8-4.

Figure 8-1
Typical Trench and Backfill Dimensions

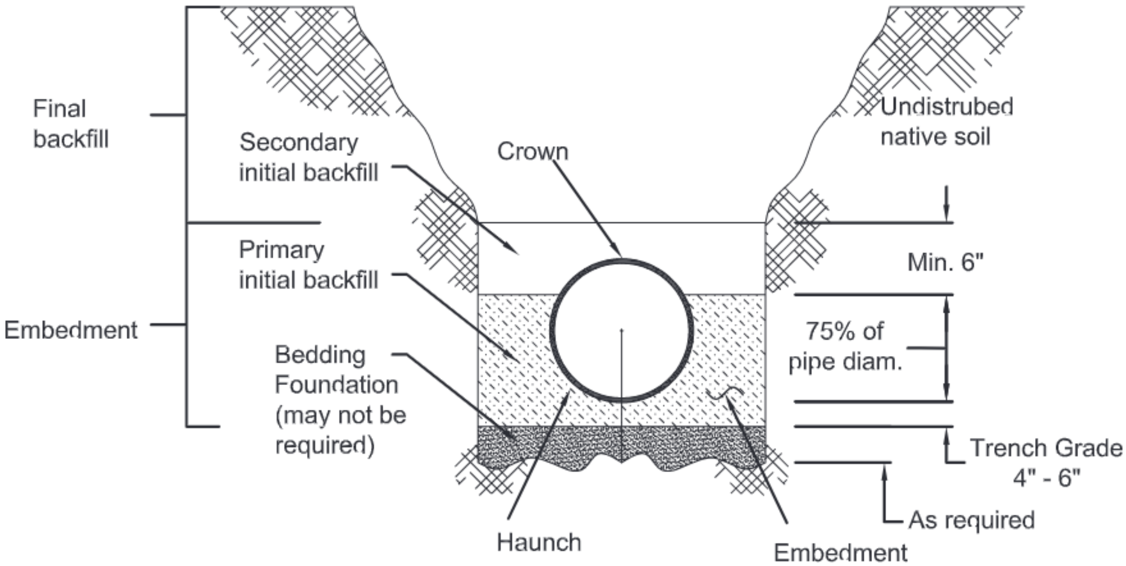


Table 8-3
Modulus of Soil Reduction

EMBEDMENT MATERIAL DESCRIPTIONS					EMBEDMENT PLACEMENT		SOIL MODULUS (E') FOR COMPACTED EMBEDMENT (psi)			
ASTM D2321[1] Class		ASTM D2487 Notation		AASHTO M43 Notation	Min. Std. Proctor Density (%)	Lift Place-ment Depth	Dumped	Slight <85%	Moderate 85%-95%	High > 95%
IA	Open-graded, clean manufactured aggregates	N/A	Angular crushed stone or rock, crushd gravel, crushed slag; large voids with little or no fines	5 56	Dumped	18"	1,000	3,000	3,000	3,000
IB	Dense-graded, clean manufactured, processed aggregates	N/A	Angular crushed stone or other Class IA material and stone/sand mixtures; little or no fines							
II	Clean, coarse-grained soils	GW	Well-graded gravel, gravel/sand mixtures; little or no fines	57 6 67	85%	12"	N/R	1,000	2,000	3,000
		GP	Poorly-graded gravels, gravel/sand mixtures; little or no fines							
		SW	Well-graded sands; gravelly sands; little or no fines							
		SP	Poorly-graded sands, gravelly sands; little or no fines							
III	Coarse-grained soils with fines	GM	Silty gravels, gravel/sand/clay mixtures	Gravel & sand with <10% fines	90%	9"	N/R	N/R	1,000	2,000
		GC	Clayey gravels, gravel/sand/clay mixtures							
		SM	Silty sands, sand/silt mixtures							
		SC	Clayey sands, sand/clay mixtures							
IVA[2]	Inorganic fine-grained soils	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, silts with slight plasticity				N/R	N/R	N/R	N/R
		CL	Inorganic clays of low to medium plasticity; gravelly, sandy, or silty clays; lean clays							
		OH	Organic clays of medium to high plasticity, organic silts							
		PT	Peat and other high organic soils							

Notes:
1) Refer to ASTM D2321 for more complete soil descrpition.
2) Class IVA material may be acceptable for limited applications, contact Snap-Tite® before using
3) Class IVB and Class V are not recommended for use with Snap-Tite®.

Table 8-4
Secant Constrained Soil Modulus, MS

	Constrained Soil Modulus at Various Depths, Compaction							
	Class I		Class II			Class III		
	Crushed Stone		GW, GP, SW, SP			GM, SM, ML(1), GC and SC with <20% passing the 200 sieve		
Cover Height	Compacted	Uncompacted	95%	90%	85%	95%	90%	85%
Feet	psi	psi	psi	psi	psi	psi	psi	psi
1	5500	3500	2000	1280	470	1420	670	360
5	5500	3500	2450	1440	510	1610	720	380
10	5500	3500	2840	1580	550	1730	750	400
15	5500	3500	3090	1660	590	1790	760	410
20	5500	3500	3270	1730	620	1840	770	420
25	5500	3500	3450	1800	650	1880	790	430
30	5500	3500	3610	1860	690	1920	810	450
35	5500	3500	3770	1920	720	1960	830	460
40	5500	3500	3930	1980	780	2010	860	480
45	5500	3500	4090	2040	790	2050	880	490
50	5500	3500	4250	2100	830	2090	900	510
55	5500	3500	4400	2180	860			
60	5500	3500	4550	2260	895			
65	5500	3500	4700	2340	930			
70	5500	3500	4850	2420	965			
75	5500	3500	5000	2500	1000			

Notes:
1) M_s values presented in the table assume that the native material is at least as strong as the backfill material. If the native material is not adequate, it may be necessary to increase the trench width. Refer to ASTM D2321 for additional information on over-excavation.
2) M_s may be interpolated for intermediate cover heights.
3) Constrained modulus for crushed stone conservatively assumes limestone embedment. These constrained modulus are consistent with AASHTO LRFD Section 12; 9th Edition 2020. Other crushed stone such as granite or quartz may have significantly higher constrained modulus properties.

Native soils should be considered for backfill, if they meet the criteria of Table 8-3 and Table 8-4. Other backfill material like flowable fill may be used. However, special construction and installation precautions must be used when using flowable fills. Engineers should contact Snap-Tite® when using flowable fill for direct burial application. Figure 8-1 illustrates a typical trench and backfill dimensions.

Bedding Coefficient (K)

Another soil related design factor is the bedding coefficient (K). The value of the bedding coefficient depends on the support the pipe receives from the trench bottom. The bedding coefficient can vary from 0.083 for full support in the haunch to 0.11 for no haunch support. Haunching backfill is recommended; however, a conservative value used in design

Table 8-5
Shape Factors, D_f

Pipe Stiffness, PS[3] pii	Gravel (1)		Sand (2)	
	Dumped to slight (<85% SPD)	Moderate to High (≥85% SPD)	Dumped to Slight (<85% SPD)	Moderate to High (≥85% SPD)
14	4.9	6.2	5.4	7.2
16	4.7	5.8	5.2	6.8
18	4.5	5.5	5.0	6.5
20	4.4	5.4	4.9	6.4
22	4.3	5.3	4.8	6.3
28	4.1	4.9	4.4	5.9
34	3.9	4.6	4.1	5.6
35	3.8	4.6	4.1	5.6
40	3.7	4.4	3.9	5.4
42	3.7	4.4	3.9	5.3

Notes:
1) Includes crushed stone, GW, GP, GW-GC, GW-GM, GP-GC and GP-GM materials
2) Includes SW, SP, SM, SC, GM, GC or mixtures of these materials
3) Interpolate for intermediate pipe stiffness values.
4) For other backfill materials, use the highest shape factor for the pipe stiffness.
5) Based on LRFD Section 12 Table 12.12.3.5.4b-1

is 0.10. This recommended value accounts for inconsistencies in placement of haunch support.

Shape Factor (D_f)

The shape factor (D_f) is a function of pipe stiffness, type of backfill material, and the compaction level. The shape factor relates deflection and bending behaviors. Table 8-5 lists shape factors for a variety of typical installation conditions. The standard pipe stiffness value for Snap-Tite® pipe is 16.

Grout Considerations for Rehabilitated Pipe Systems

Grout is a variable strength mixture of cementitious material and water, with or without aggregate, and grout formulas may vary substantially. Foaming agents or admixtures are used to control the density of the grout. This chapter addresses typical grout design properties and introduces material properties necessary for the design of Rehabilitated Pipe Systems (RPS). Specifically these properties are the compressive strength, elastic modulus, and strain capacity of the cementious grout.

It is noted that confining pressure for elastic materials has a significant impact on the modulus, strength and strain capacity. In the case of soils, an increase of 25 feet in burial depth results in a 173% increase in modulus. The impact of confining pressure on soils is also seen in grouts. Using unconfined material properties for this design method is a conservative approach. Variation in grout properties is most closely tied to density; however other factors can influence the physical properties. Table 8-6 includes typical grout properties for unconfined grout.

Grout Modulus

Grout testing was conducted on over 20 samples of various grout formulas and densities. As a result of the grout testing a relationship between the grout density and associated strength and modulus were developed. Equation 8-1 illustrates

Table 8-6
Grout Design Properties

Density (lb/ft^3)	Young's Modulus (psi)	Typical Compressive Strength (psi)	Strain Capacity (in/in)
30	43,200	75	0.13%
35	76,900	200	0.28%
40	110,500	375	0.34%
45	144,200	530	0.37%
50	177,900	690	0.39%
55	211,500	850	0.40%
60	245,200	1,010	0.41%
65	278,900	1,100	0.42%
70	312,500	1,300	0.43%
75	346,200	1,490	0.43%
80	379,900	1,650	0.44%
85	413,500	1,810	0.44%

Notes:
1) Design properties based on limited testing. Installations with a design safety factor of less than 2 should perform testing to verify specific grout design properties.
2) Compressive strength based on unconfined compressive strength.
3) Data for modulus and compressive strength is based on independent testing performed by Metro Testing Laboratories.

a linear analytical relationship between grout density and modulus. This linear relationship was developed based on unconfined compression testing for grout densities ranging between 30 lb/ft^3 and 85 lb/ft^3.

Equation 8-1
Modulus as a Function of Density

$$E = 6{,}733\rho - 158{,}747$$

Where:

E ≡ Modulus of Elasticity (psi)

ρ ≡ Grout Density (lb/ft^3)

Grout Strength

Strength testing is based on an unconfined strength of the grout. When the RPS is installed in deep burial conditions, the confining pressure of the overburden can be substantial. Additionally, the host pipe may offer some confinement of the grout. However, for the purpose of this design method the strength of the grout is assumed to be the unconfined grout strength. This offers a substantial level of conservatism in the analytical solution presented in chapter 9. The relationship between density and unconfined grout strength is shown in Equation 8-2:

Equation 8-2
Strength as a Function of Density

$$\sigma = 31.926\rho - 900.98$$

Where:

σ ≡ Unconfined Compressive Stength (psi)

ρ ≡ Grout Density (lb/ft^3)

Grout Strain

Similar to most elastic materials, the grout strength and strain is proportional to the modulus. This relationship is shown in Equation 8-3. Since the modulus and strength are based on unconfined conditions, Equation 8-3 yields the unconfined strain capacity. The grout strain capacity shown in Table 8-6, are based Equation 8-3.

Equation 8-3
Strength as a Function of Density

$$\varepsilon = \frac{\sigma}{E}$$

Where :

$\varepsilon \equiv$ Strain Capacity, in/in

$\sigma \equiv$ Strength, psi

$E \equiv$ Modulus, psi

Loads

Loads are typically either a live load or a dead load. The most common live loads in pipe applications are vehicular loads, usually from construction equipment, trucks, railroads or aircraft. The soil load is the most frequent type of dead load consideration; however, groundwater and foundations are other types of dead loads that should be considered when designing a direct burial pipe system or a Rehabilitated Pipe System (RPS).

Highway Live Loads

Vehicular loads are often based on the AASHTO wheel loading configuration. These wheel loading configurations are shown in Figure 8-2, which represents an H-25 or HS-25 wheel loading (i.e. 25 ton semi-truck). The

Figure 8-2
AASHTO Highway Loads

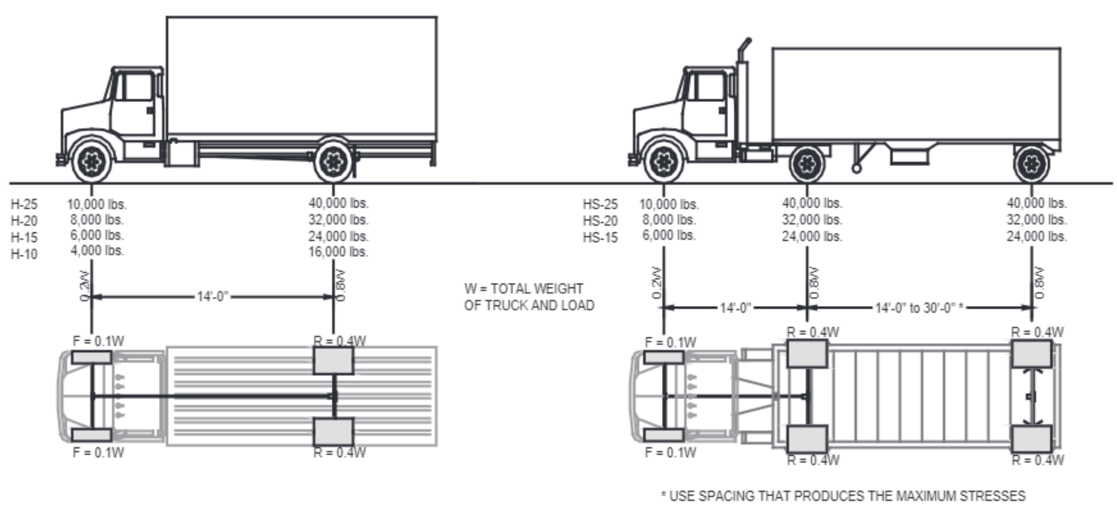


Table 8-7
AASHTO Highway Loads Carried by Wheel Set

Load Type	H-10 Lbs (kN)	H-15 or HS-15 Lbs (kN)	H-20 or HS-20 Lbs (kN)	H-25 or HS-25 Lbs (kN)
W[1]	20,000 (89.0)	30,000 (133.4)	40,000 (178.0)	50,000 (222.4)
F[2]	2,000 (8.9)	3,000 (13.3)	4,000 (17.8)	5,000 (22.2)
R[2]	8,000 (35.6)	12,000 (53.4)	16,000 (71.2)	20,000 (89.0)
Raxle[3]	16,000 (71.1)	24,000 (106.7)	32,000 (142.3)	40,000 (177.9)

1.W is defined as the total vehicle weight

2.F is defined as the front tire load and R is defined as the rear tire configuration load

3.Raxle represents the truck's rear axle load axle loads shown in Figure 8-2 are distributed over a typical design wheel footprint. The tire footprint and wheel loading is defined in LRFD Section 3.6.1.2.2. HL-93 live loads are frequently referenced by design engineers. The HL-93 load is a H-20 or HS-20 live load plus the lane load. The lane load is 0.64 kips/ linear foot of a 10-foot-wide lane. This lane load equates to a 64 lb/ft^2 surface load.

In relatively shallow burial depths the pipe can experience an additional force from the dynamics of the vehicle. To account for this additional force, the tire surface pressure is multiplied by an impact factor. For highway loads, AASHTO establishes a range of impact factors from 1.3 at about one foot of cover to 1.1 at just fewer than three feet. Impact has negligible influence at depths over three feet. Table 8-8 provides information about the resultant H-25 vehicular forces at various cover heights with impact included in the shallow cover situations. For H-20 vehicles decrease the H-25 live load transfer values (shown in Table 8-8) by 20%.

The intensity of the vehicular load decreases as the burial depth increases. Table 8-8 lists the live load distribution width showing this relationship for an AASHTO H-25 or HS-25 load. This width is based on AASHTO information and assumes that the pipe is installed perpendicular to the direction of traffic. Some construction vehicles may need to temporarily traverse shallow culverts during the construction process. Construction vehicles, such as many types of paving equipment are typically not as heavy as the H-25 design load. For situations with relatively light construction vehicles, the one-foot minimum cover criteria discussed can be decreased during the construction phase. Table 8-9 presents the surface applied loads

Table 8-8
Live Load Data for AASHTO H-25 and HS-25

	AASHTO H-25 or HS-25[1]	
Cover, (ft.)	Live Load Transferred (psi)	Live Load Dist. Width, L_w (in.)
1'	15.63	31
2'	6.95	52
3'	5.21	73
4'	3.48	94
5'	2.18	115
6'	1.74	136
7'	1.53	157
8'	0.86	178
10'	negligible	N/A

Notes:
1) Includes impact where necessary
2) N/R indicates that the cover height is not recommended.
3) N/A indicates that the information is not applicable.
4) Information has been modified from Buried Pipe Design, Moser, McGraw-Hill, 1990, p. 34.

and the associated allowable minimum cover for temporary applications. These criteria should only be employed during construction; finished projects should always have minimum cover described in Table 8-9.

Heavy construction traffic is a concern for buried flexible pipe when buried at shallow depths. These high surface pressure loads may reduce the safety factors below recommended levels. It is recommended that two to three feet of cover be used over the pipe in installations involving construction vehicles between 30 ton per axial and 60 ton per axial. Heavier loads will require at least three feet of cover. This additional cover is typically mounded and compacted over the pipe during the construction phase. Following construction,

Table 8-9
Temporary Minimum Cover Requirements for Snap-Tite® DR 32.5 Pipe with Light Construction Traffic

Vehicular Load At Surface, psi	Temporary Minimum Cover, in. for Snap-Tite® 10"-48" Diameters, (in.)	Temporary Minimum Cover, in. for Snap-Tite® 54" and 63" Diameters, (in.)
75	9	12
50	6	9
25	3	6

the mound is removed to the final construction grade.

Railroad Loading

Pipe installed in locations subject to railroad loads should be designed to withstand Cooper E-80 railroad live loads. The E-80 railroad loading system is defined by the American Railway Engineering and Maintenance-of-Way Association (AREMA). Cooper E80 is a locomotive maximum load of 80,000 pound per axial spaced a minimum of 5-feet apart on a specific rail and rail road tie configuration as illustrated in Figures 8-3 below. E-80 loading is a series of point loads (simulating locomotive wheels) followed by uniform distributed load of 8 kips per linear foot of track (the total load on two rails to simulate railcars).

As shown in Figure 8-4, the rail road track cross-section, the axle load is transferred through the rails to the railroad ties, through the surface ballast, then through the compacted subgrade soil and finally to the RPS. E-80 live loads should be considered where the cover height is less than 25-feet. Whereas cover height is measured from the top of the liner pipe to the bottom of the railroad track tie.

Figure 8-3
Cooper E-80 Axle Loading

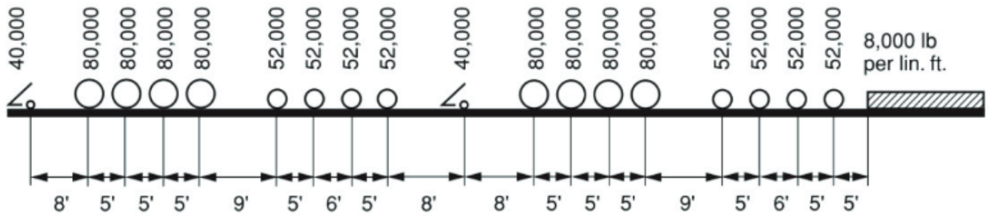


Figure 8-4
Rail Track Cross-Section

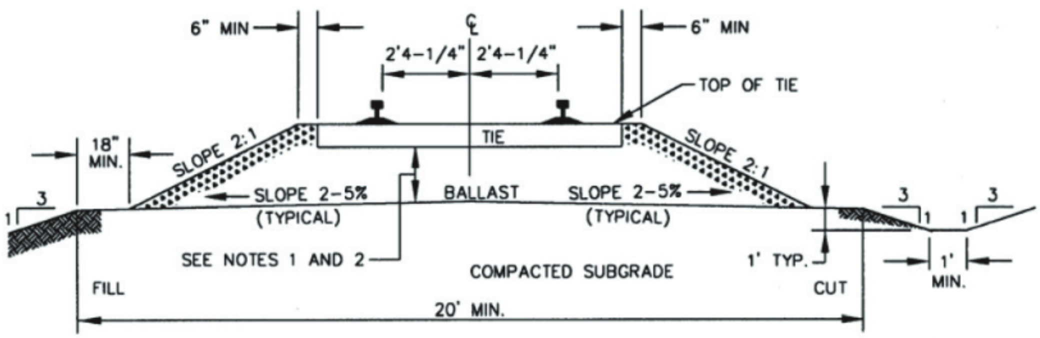
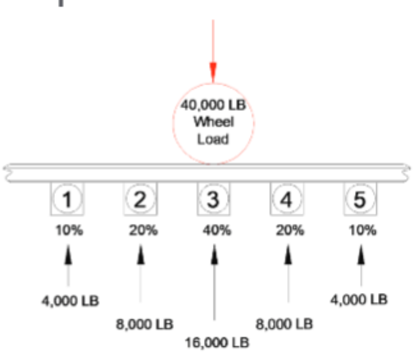


Figure 8-5
Example Wheel Load



Based on the US Army Corps of Engineers publication, Railroad Design and Rehabilitation; TI 850-02 dated March 1, 2000, the E-80 axle load (930 lbs/inch) distributes 40% of its weight to the central tie, 20% to each of the adjacent ties, and 10% to each of the next adjacent ties as shown in Figure 8-5.

In addition to the wheel loading shown above, wheel loads to the left and right of the wheel shown contribute to the loading on the ties. This complex loading scenario requires the use of FEA software as discussed in Section 8-6.

Dead Loads

The soil load is calculated in this design procedure using two different techniques, the prism or soil column load (W_C), and the soil arch load (W_A).

Soil Column Load (W_C)

The soil column load is defined as the weight of the soil directly above the outside diameter of the pipe at the height of the pipe crown. The soil column load is used to determine deflection. For flexible pipe, the actual soil load is less than that predicted by Equation 8-4 because the soil load is reduced by frictional or shear forces associated with the soil adjacent to the soil column.

The soil column load is calculated as follows:

Equation 8-4

$$W_C = \frac{(H)(\gamma_s)(OD)}{144}$$

Where:

W_C = soil column load, lb/linear inch of pipe
H = burial depth, ft.
g_s = soil density, pcf
OD = outside diameter of pipe, in. (Table 8-1)

Soil Arch Load (W_A)

The soil arch load (W_A) analysis more accurately predicts the actual soil load placed on the pipe. The arch load calculation uses the concept of Vertical Arching Factor (VAF), which reduces the load proportional to the stiffness of the pipe. The VAF reduces the soil load in order to account for the support provided by adjacent soil columns.

The soil arch load is determined using the design method specified in AASHTO LRFD Section 12.12.3.4 and is described.

The first step in the soil arch load prediction is to calculate the geostatic load. The geostatic load is determined by calculating the weight of soil directly above the spring line of the pipe. Equation 8-5 is used to calculate the geostatic load above the spring line of the pipe.

Equation 8-5

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

Where:
P_{sp} = geostatic load, psi
H = burial depth, ft.
g_s = unit weight of soil, pcf
OD = outside diameter of pipe, in. (Table 8-1)

The second step in determining the soil arch load is to determine the Vertical Arching Factor (VAF). This factor accounts for the support provided by adjacent soil columns by reducing the geostatic load. Equation 8-6, is used to calculate the Vertical Arching Factor:

Equation 8-6

$$VAF = 0.76 - 0.71\left(\frac{S_h - 1.17}{S_h + 2.92}\right)$$

Where:
VAF = Vertical Arching Factor, unitless
S_h = hoop stiffness factor;
= f_s M_S R / (E A)
f_s = capacity modification factor for soil, 0.9
M_S = secant constrained soil modulus, psi (Table 8-4)
R = effective radius of pipe, in.
= OD/2 - c
OD = outside diameter of pipe, in. (Table 8-1)
c = distance from inside diameter to neutral axis, in. (Table 8-1)
E = modulus of elasticity for polyethylene (Table 8-2)*
A = section area, in^2/in (Table 8-1)

* Note: Consider your load duration in selecting the long or short-term modulus. Dead loads use long term modulus. Impact loads normally are short-term.

The third and final step is to calculate the soil arch load. Equation 8-7 is used to calculate the soil arch load:

Equation 8-7

$$W_A = (P_{sp})(VAF)$$

Where:
W_A = soil arch load, psi
P_{sp} = geostatic load, psi
VAF = Vertical Arching Factor, unitless

Hydrostatic Loads

If groundwater is present and is expected above the spring line, the associated hydrostatic pressure must be accounted for when considering dead loads. Equation 8-8 is used to calculate the hydrostatic load:

Equation 8-8

$$P_W = \frac{\gamma_w (H_g)}{144}$$

Where:

P_W = hydrostatic pressure at springline of pipe, psi

g_w = unit weight of water, 62.4 pcf

H_g = height of groundwater above springline of pipe, ft.

Foundation Loads

Pipe installations beneath or near foundations are subjected to an additional dead load. This additional dead load must be considered before proceeding with the design process. Refer to soil mechanics textbooks to determine the effect of foundation loads.

8-4 Direct Burial Design Procedure

The design of Snap-Tite® in direct burial applications evaluates the critical failure mechanisms of pipe. This design procedure is based on AASHTO LRFD Section 12 design criteria. The design method evaluates the factored capacity and associated factored loading demand placed on the pipe system. The critical failure mechanisms include:

1. Wall Thrust
2. Deflection
3. Buckling
4. Bending Strain
5. Combined Strain

For installations greater than 50 feet contact Snap-Tite® for design guidance. Maximum and minimum cover height tables have been developed based on the following design procedure. See Table 8-14 for maximum allowable burial depths and Table 8-13 for minimum allowable burial depths.

LRFD Section 12 requires that load factors be applied to buried structures such as pipe. As defined by AASHTO, "Load factors are multipliers applied to force effects to account for the variability of loads, lack of accuracy in analysis, and probability of simultaneous occurrences of different loads." These recommended load factors are summarized in Table 8-10.

"Resistance factors are multipliers applied to nominal resistance to account for variability in material, dimensions, workmanship and uncertainty in predicted resistance," as defined by AASHTO LRFD Section 12. Resistance factors related to thermoplastic pipe are specified in LRFD Section 12 Table 12.5.5-1 and are summarized in Table 8-11. Load modifiers account for ductility redundancy and operational importance. Table 8-12, summarizes the LRFD load modifiers as related to thermoplastic pipe design.

Table 8-11
Resistance Factors

Type of Structures	Resistance Factor, Unitless (f)
Thrust	1.00
Soil Stiffness	0.90
Global Buckling	0.70
Flexure	1.00

Table 8-10
Load Factors

Load Combination for Limit State	Earth Pressure Load (g_{EV})	Water Load (g_{WA})	Vehicle Live Load (g_{LL})
Strength Limit I	0.9 – 1.95	1.0	1.75
Strength Limit II	0.9 – 1.95	1.0	1.35
Service Limit I	1.0	1.0	1.0

Table 8-12
Load Modifiers

Load	Modifier (h)	Redundancy
Earth Fill	1.05	None
Live Load	1.0	Redundant
Construction Load	1.0	Redundant

Wall Thrust

The stress (or thrust) in the pipe wall is determined by the total live load and dead load on the pipe. The pipe wall factored thrust resistance, determined by Equation 8-9, must be equal to or greater than the pipe wall factored thrust demand calculated in Equation 8-10. That is to say, the thrust capacity of the pipe wall must be greater than the demand placed on the pipe wall.

Long-term material properties are used in the analysis for dead loads. Short-term material properties are used for live load situations (such as trafficked installations with less than 8 feet of cover) and the analysis includes both live loads and dead loads. The more limiting of the two analyses governs. It is noted that LRFD Section 12 requires that effective wall area be analyzed for profile pipe only. As defined by LRFD Section 12.12.3.5, the factored thrust resistance is as follows:

Equation 8-9

Where:

$$T_{cr} = (F_y)(A)(\phi_p)$$

T_{cr} =critical wall thrust, lb/linear inch of pipe
F_y = tensile strength of polyethylene, psi (Table 8-2)
A = wall area, in²/inch of pipe (Table 8-1)
f_p = capacity modification factor for pipe, 1.0

The pipe wall factored thrust demand calculated as follows:

Equation 8-10

$$T = 1.3(1.5W_A + 1.67P_lC_l + P_w)\left(\frac{OD}{2}\right)$$

Where:
T = calculated wall thrust, lb/in
W_A = soil arch load, psi (Equation 8-7)
P_l = live load transferred to pipe, psi (Table 8-7)
C_l = live load distribution coefficient
= the lesser of $\frac{L_w}{OD}$ or 1.0
L_w = live load distribution width at the crown, in. (Table 8-7)
OD = outside diameter, in. (Table 8-1)
P_w = hydrostatic pressure at springline, psi (Equation 8-8)

Deflection

Deflection is the change in diameter that results when a load is applied to a flexible pipe. In pipe design, the vertical dimension is usually of more concern and is typically limited to 7.5% of the base inside diameter. The base inside diameter is the nominal diameter less manufacturing and out-of-roundness tolerances inherent to the manufacturing process.

Pipe deflection is a function of pipe stiffness (PS), soil column load (W_C) and live (W_L) loads, and backfill conditions (E'). This relationship is described in Equation 8-11.

Equation 8-11

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

Where:
Δ_y = deflection, in.
K = bedding constant, dimensionless, 0.10 (typical)
D_L = deflection lag factor, dimensionless; typically 1.0
W_C = soil column load on pipe, lb/linear inch of pipe (Equation 8-4)
W_L = live load, lb/linear inch of pipe = (OD)(live load transferred to pipe from Table 8-7)
OD = outside diameter of pipe, in. (Table 8-1)
PS = pipe stiffness, pii (Table 8-1)
E' = modulus of soil reaction, psi (Table 8-3)

Buckling

Buckling of a pipe wall is a function of the installed condition (M_S) and the pipe wall properties (A, I, and R). In order to demonstrate resistance to buckling, the capacity of the pipe wall (Equation 8-12) must be greater than the yield stress (Fy = 1,440 psi) in order to demonstrate sufficient structural resistance. Further, if the critical buckling stress is less than the yield stress, then the compressive resistance to thrust (Equation 8-9) must be recalculated using F_{cr} instead of F_y.

Equation 8-12
Critical Buckling Stress

$$f_{cr} = 9.24 \frac{R}{A_{eff}} \sqrt{B' R_W \phi_S M_S \left(\frac{EI}{0.149 R^3} \right)}$$

f_{cr} = critical buckling stress, psi
M_S = secant constrained soil modulus, psi (Table 8-4)
R = effective radius of pipe, in.
= OD/2 - c
OD = outside diameter of pipe, in. (Table 8-1)
c = distance from inside diameter to neutral axis, in. (Table 8-1)
E = modulus of elasticity for polyethylene (Table 8-2)
A = area, in²/in (Table 8-1)
I = moment of inertia, in⁴/in (Table 8-1)
R_w = water buoyancy factor

$$R_W = 1 - 0.33 \frac{H_g}{H}$$

Where:
H =burial depth, ft.
H_g = height of groundwater above springline of pipe, ft.
f_s = resistance factor for soil stiffness (Table 8-10)
B' = nonuniform stress distribution factor
Where:

$$B' = \frac{1}{1 + 4e^{-0.065H}}$$

Bending Strain

LRFD Section 12 design methods requires the bending strain to be evaluated to ensure installed strain levels are within the HDPE material's capability. The bending strain may be computed based on an empirical relationship between strain and deflection as seen in Equation 8-13. It is noted that to account for construction-induced deflections, the AASHTO established permissible construction-induced deflection (Δc) is introduced into the deflection equation. The resultant value (Δ) is the total deflection due to bending. After the resulting value of deflection is determined, bending strain is determined based on Equation 8-14. The AASHTO established bending strain limit is 5%.

Equation 8-13
Pipe Deflection Due to Bending

$$\Delta = \Delta_C D_m - \left(\frac{T_L D_m}{AE\gamma_P} \right)$$

Where:
Δ = deflection of pipe, reduction of vertical diameter due to bending, in.
T_L = factored wall thrust, lb/in
Δ_c = deflection of pipe, construction induced deflection limit 5%
γ_P = load factor, vertical earth pressure, (or f_p = capacity modification factor for pipe from Table 8-10)
A = wall area, in²/inch of pipe (Equation 8-1)
E = long-term modulus of elasticity of polyethylene, psi (Table 8-2)
D_m = mean pipe diameter, in.
= OD - 2c
c = distance from inside diameter to neutral axis, in. (Table 8-1)

Equation 8-14
Pipe Deflection Due to Bending

$$\varepsilon_{bu} = \gamma_B D_f \left(\frac{c}{R} \right) \left(\frac{\Delta}{D_m} \right)$$

Where:
ε_{bu} = factored bending strain, in./in.
D_f = shape factor, dimensionless (Table 8-5)
Δ = deflection, in. (Equation 8-14)
γ_B = load factor, combined strain, 1.5
R = effective radius of pipe, in.
= OD/2-c
Where:
OD = outside diameter of pipe, in. (Table 8-1)
c = distance from inside diameter to neutral axis, in. (Table 8-1)
D_m = mean pipe diameter, in.
= OD - 2c

<u>Combined Strain</u>

LRFD Section 12 design methods requires the combined strain (bending plus compression) to be evaluated to ensure installed strain levels are within the HDPE material's capability. The factored compressive strain from Equation 8-15 must be less than or equal to the combined compressive strain determined by Equation 8-16. Additionally, the factored tension strain determined from Equation 8-17 must be less than or equal to the allowable combined tension strain determined from Equation 8-18.

Equation 8-15
Factored Combined Compressive Strain

$$\varepsilon_{cu} = \varepsilon_{bu} + \left(\frac{T_L}{AE}\right)\left(\frac{\gamma_B}{\gamma_P}\right)$$

Where:
ε_{cu} = factored compressive strain, in./in.
ε_{bu} = factored bending strain, in./in. (Equation 8-14)
T_L = factored wall thrust, lb/in (Equation 8-10)
γ_P = load factor, vertical earth pressure (or f_p = capacity modification factor for pipe from Table 8-10)
γ_B = load factor, combined strain, 1.5
A = pipe wall area, in^2/inch of pipe (Table 8-1)
E = long-term modulus of elasticity of polyethylene, psi (Table 8-2)

Equation 8-16
Limiting Combined Compressive Strain

$$\varepsilon_{cl} = \left(\frac{1.5 * F_y}{E}\right)$$

Where:
ε_{cl} = limiting combined compressive strain, in./in.
F_y = tensile strength of polyethylene, psi (Table 8-2)
E = modulus of elasticity of polyethylene, psi (Table 8-2)

Equation 8-17
Factored Combined Tension Strain

$$\varepsilon_{tu} = \varepsilon_{bu} - \left(\frac{T_L}{AE}\right)\left(\frac{\gamma_B}{\gamma_P}\right)$$

Where:
ε_{tu} = factored tension strain, in./in.
ε_{bu} = factored bending strain, in./in. (Equation 8-14)
T_L = factored wall thrust, lb/in (Equation 8-10)
γ_P = load factor, vertical earth pressure (or f_p = capacity modification factor for pipe from Table 8-9)
γ_B = load factor, combined strain, 1.5
A = pipe wall area, in^2/inch of pipe (Table 8-1)
E = long-term modulus of elasticity of HDPE, psi (Table 8-2)

Equation 8-18
Limiting Combined Tension Strain

$$\varepsilon_{tl} = \gamma_b \varepsilon_t$$

Where:
ε_{tl} = limiting combined tension strain, in/in
γ_B = load factor, combined strain, 1.5
ε_t = allowable tension strain, in/in

8-5 Direct Burial Minimum and Maximum Cover Limitations

The design procedure described in the preceding section is provided for technical completeness and is especially useful for non-standard installations. However, in the case of standard installations, the information in this section is developed to provide a quick reference for maximum and minimum recommended cover heights. Additionally, this section provides a brief explanation of the assumptions used in the development of the burial depths tables.

<u>Minimum Cover in Live Load Applications</u>

Pipe with diameters of 10- to 48-inch installed in trafficked areas (AASHTO H-25 or HS-25 loads) must have at least one foot of cover over the pipe crown, while 54- and 63-inch diameter pipes must have at least 18 inches of cover. The backfill envelope should provide a minimum E' value of 2000 psi. In Table 8-13, this condition is represented by a Class II compacted to 90% standard Proctor density. This minimum cover is measured from the

Table 8-13
Minimum Cover for Direct Burial Snap-Tite® DR 32.5 Pipe with AASHTO H-25 or HS-25 Load

Outside Diameter, OD, in.	Minimum Cover, H, ft.	Outside Diameter, OD, in.	Minimum Cover, H, ft.
10.75"	1'	28"	1'
12.75"	1'	30"	1'
14"	1'	32"	1'
16"	1'	36"	1'
18"	1'	42"	1'
20"	1'	48"	1'
22"	1'	54"	1.5'
24"	1'	63"	1.5'

Note: Minimum covers in this table were calculated assuming Class II backfill material compacted to 90% standard Proctor density and a minimum of 12-inches cover above the crown.

Table 8-14
Temporary Minimum Cover Requirements for Snap-Tite® DR 32.5 Pipe with Light Construction Traffic

Vehicular Load Surface, psi	Minimum Cover, for 10" - 48" diameters, (in)	Minimum Cover, for 54" - 60" diameters, (in)
75	9"	12"
50	6"	9"
25	3"	6"

top of the pipe to the bottom of flexible pavement or to the top of rigid pavement.

Additional information that may affect the cover requirements is found in ASTM D2321.

Maximum Cover

Wall buckling or deflection normally governs the maximum cover a pipe can withstand. The maximum burial depth is predominately influenced by the type of backfill installed around the pipe. Table 8-15 specifies the maximum burial depth for a variety of backfill conditions.

8-6 Rehabilitated Pipe Systems Design Procedure

The design procedure for Snap-Tite® Rehabilitated Pipe Systems (RPS) is complex due to the composite structure nature of the system. This composite structure is typically comprised of a host pipe, Snap-Tite®, and a cementious grout that fills the annular space between the host pipe and Snap-Tite®. In order to accurately predict structural capacity of the RPS, it is necessary to use a combination of traditional engineering analysis and analytical tools such as finite element analysis. The design procedure described evaluates critical failure mechanisms of the Snap-Tite® pipe and the grout filling the annulus between the host pipe and Snap-Tite®.

The existing host pipe or culvert is typically rehabilitated as a result of deterioration or demonstration of structural distress. In order to provide a conservative analysis the structural contribution of the host pipe has not been included in the design procedure.

The RPS design method evaluates the factored resistance and associated factored

Table 8-15
Maximum Cover for Snap-Tite® DR 32.5 Pipe, ft.

	Class 1		Class 2			Class 3		
Diameter	Compacted (ft)	Uncompacted (ft)	95% (ft)	90% (ft)	85% (ft)	95% (ft)	90% (ft)	85% (ft)
10"	65	10	65	37	10	38	13	8
12"	65	10	65	37	10	38	13	8
14"	65	10	65	37	10	38	13	8
16"	65	10	65	37	10	38	13	8
18"	65	10	65	37	10	38	13	8
20"	65	10	65	37	10	38	13	8
22"	65	10	65	37	10	38	13	8
24"	65	10	65	37	10	38	13	8
28"	65	10	65	37	10	38	13	7
30"	65	10	65	37	10	38	13	7
36"	65	10	65	37	10	38	13	7
42"	65	10	65	36	10	37	13	7
48"	65	10	65	36	10	37	13	7
54"	65	10	65	36	10	37	13	7
63"	65	9	65	36	9	37	12	7

Notes:
1) Calculations assume no hydrostatic pressure and a density of 120 pcf for overburden material.
2) Snap-Tite® may be installed deeper than 65 feet; however, the maximum cover calculations have been truncated at 65 feet for this table.
3) Consult with a Snap-Tite® representative for burial depths deeper than 50 feet.
4) Culverts are typically installed in conditions where ground water is not a problem. If ground water is a concern, contact Snap-Tite® for recommended installed burial depths.

loading demand placed on the RPS. Specific design criteria evaluated are summarized in Table 8-16.

Maximum and minimum cover height tables have been developed based on the following design procedure.

Table 8-16
RPS Design Criteria

Snap-Tite® Pipe Design Criteria	Grout Design Criteria
Thrust Yielding	Comprehensive Strength
Global Buckling	Tensile Strain
Combined Strain	
Tensile Strain	
Deflection	

<u>CANDE Finite Element Analysis Model</u>

The design method for the RPS components, the load factors and the resistance factors are based on the specifications in Section 12 of American Association of Highway Transportation Official (AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications. AASHTO sponsored the upgrade of CANDE-2007, a finite element computer program developed for the structural design and analysis of buried culverts; hence the acronym CANDE stands for **C**ulvert **AN**alysis and **DE**sign. Subsequently, the CANDE FEA program was updated in 2017, 2019, and 2022. For simplicity all versions are herein referenced as CANDE. Since CANDE was specifically developed for culvert analysis and has the capability to perform AASHTO LRFD analysis, the program is ideally suited for this complex structure analysis.

In order to accurately model the composite RPS system, it is necessary to develop a level three input file for CANDE. A level three input file is the most complex and adaptable form of CANDE analysis for complex loading and analysis. While it is not anticipated that a CANDE analysis will be used for each installation, the general modeling assumptions are listed below to provide design guidance.

Beam Elements

The CANDE model for the RPS soil-structure system is composed of a ring of beam elements for the host pipe, a ring of beam elements for Snap-Tite® HDPE liner, a ring of continuum quadrilateral elements for the grout, and two rings frictionless interface elements between the grout and the pipe surfaces. The use of frictionless interface elements was chosen since it is most conservative.

Loading

In the case of dead loads, the system should be modeled for conservative loading conditions. Therefore, an embankment condition is recommended. Additionally, it is recommended that the CANDE analysis simulates the layers of soil loading above 1.5 diameters of cover height. Above that height, 2-psi increments of surface pressure for each load step is applied to the system. All load steps are assigned a load factor of 2.05 representing the product of the standard AASHTO earth load factor 1.95 and the redundancy factor 1.05. These LRFD-factored soil loads are recommended to be placed around and over the RPS in construction increments until the factored weight of the overburden soil causes the onset of structural distress in one of the RPS components.

This new construction method is recommended because the soil around the host pipe remains undisturbed and does not produce earth loads in the liner or the grout. Additionally, this "new construction" method of loading is recommended as a level of conservatism. It is noted that for the maximum burial depth analysis (see Table 9-2) structural distress always turned out to be either the compressive strength of the grout or strain capacity of the grout. In all cases the HDPE component was very safe since it never exceeded 25% of its design capacity. Based on these analyses, DR 32.5 Snap-Tite® is the maximum wall thickness required for structural resistance for RPS.

Host Pipe Analysis

As previously mentioned, the host pipe is typically deteriorated and in some locations may not exist (i.e. invert of metal pipe). Therefore for the maximum burial depth analysis, the material modulus and strength of the host pipe is reduced to 1 psi. This modified host pipe strength does not significantly influence structural response of the system and provides for a conservative analysis.

Output Report

CANDE automatically provides the factored-demand/factored-capacity ratios for the HDPE pipes; however, CANDE does not have a built-in design criterion for the grout. Therefore the output report is analyzed to determine the construction step at which grout loading exceeds its capacity.

The CANDE Output Report is examined to find the first load-step at which the factored-demand to factored-capacity ratio exceeds the value of 1.0 among all the design criteria for the grout and the HDPE liner pipe.

Grout Stress and Strain Analysis

As previously mentioned two critical design criteria for grout are analyzed. The first criterion is compressive strength. The second critical design criterion is tensile strain. Since the grout is confined between the host and liner pipes and the shear bond is modeled as frictionless, these two criteria are considered the most crucial for the grout. Maximum burial depth for each of the criterion is determined and the more limiting of the two analyses dictates the maximum burial depth. It is noted that Snap-Tite® is also checked, but as mentioned Snap-Tite® never exceeds 25% of its capacity in the design.

Grout Compressive Strength

The maximum factored thrust stress or compressive stress in the grout component of the RPS is at the spring line of the system orientated in the vertical direction. CANDE's output report calculates the stress and strain in the vertical direction of each node of which one is located at the spring line. Therefore the CANDE output report is examined at each load step to determine the load step at which the factored thrust at the spring line meets or exceeds the maximum unconfined grout strength. As previously mentioned and shown in Table 8-6, the grout strength is a function of density. The load step is equated to a burial depth and that associated burial depth is established as one possible limit state for the RPS.

Grout Tensile Strain

The maximum factored compressive strain in the grout component of the RPS is at the spring line of the system orientated in the vertical direction. CANDE's output report calculates the factored compressive strain in the vertical direction of each node of which one is located at the spring line. Therefore, the CANDE output report is examined at each load step to determine the compressive strain at the springline. As previously mentioned and shown in Table 8-6, the grout tensile strain capacity is a function of density.

Additionally, CANDE's output report determines the deflection at each load step. Therefore, the CANDE output report is examined at each load step to determine deflection of the RPS. With the compressive strain and deflection determined in the CANDE output report, an empirical relationship (See Equation 8-19) can be used to determine the factored tensile strain in the grout.

Equation 8-19 is used to determine the grout tensile strain based on maximum compressive strain and deflection.

Equation 8-19
Grout Tension Strain

$$\varepsilon_{tg} = D_L \varepsilon_{bg} - \varepsilon_{cg}$$

Where:

ε_{tg} = grout tensile strain, in/in

D_L = liner pipe location factor, unitless

ε_{cg} = compressive strain in grout
= compressive strain from CANDE at springline node for grout, in/in

ε_{bg} = bending strain in grout, in/in

$$\varepsilon_{bg} = \gamma_{bg} D_{fg} \left(\frac{c_g}{R_g} \right) \left(\frac{\Delta}{D_{Mg}} \right)$$

Where:

γ_{bg} = load factor, 1.0

D_{fg} = shape factor of grout, 2.0

c_g = distance to centroid of grout, in

R_g = effective radius of grout, in

Δ = deflection of plastic pipe from CANDE output file, in

D_{Mg} = mean diameter of grout, in

It is noted that the grout is poured in place. Therefore a load factor of 1 and shape factor of 2 is conservative for the design. The location factor essentially doubles the grout strain to account for installed, workmanship and uncertainty.

8-7 RPS Design Procedure Railroad Loads

E-80 Analysis and Loading Assumptions

Rail road loading recommended burial depth tables used this manual were developed for Cooper E-80 railroad loads.

The loading configuration, load factors and resistance factors used in the design and evaluation of the structural performance of a RSP are based on the following Rail Design Guide documents:

1. American Railway Engineering and Maintenance-of-way Association (AREMA) Practical Guide to Railway Engineering.

2. U.S. Army Corps of Engineers Technical Instructions for Railroad Design and Rehabilitation; and

3. American Association of Highway Transportation Official (AASHTO) Load Reduction Factor Design (LRFD) Bridge Design Specifications.

The loading analysis is complicated by complex surface loading, existing deteriorated culvert (host pipe) filled with grout and the placement of the relining pipe (SnapTite) inside the host pipe. For these reasons, it was determined a

FEA analysis will be the most accurate method to analyze the RPS system.

The AASHTO sponsored CANDE-2007, a finite element computer program developed for the structural design and analysis of buried culverts; hence the acronym CANDE stands for Culvert ANalysis and DEsign. CANDE can perform complex analysis for composite structures (grout & thermoplastic pipe) and applying unique loading for rail applications.

For the reasons described above, Snap-Tite determined CANDE finite-element solution methodology is the best method to analyze loading on the RPS (Rehabilitated Pipe System) for both shallow loads and deep-burial conditions. The CANDE analysis described herein provides the user with knowledge of the design approach to confidently use the burial depth tables and understand assumptions made in their development.

LRFD Load and Resistance Factors

Dead and live load factors used for the railroad design are shown in Table 8-17.

Table 8-17
LRFD load factors for Railroad Applications

Loading Condition	AASHTO load factor
Dead load of grout with redundancy	1.3
Earth loading layers with redundancy	2.05
Live load (E-80) rail road	1.75
Dynamic impact factor (AREMA)	1.50

Resistance factors for railroad applications are shown in Table 8-11.

Soil Properties

Soil design properties have been grouped into two categories of "Good" and "Fair" soil. This allows the designer to determine the host pipe site and use an embedment soil appropriate for the specific site condition. The Good and Fair soils, used to develop the burial depth tables, are soils described in ASTM D2321 which defines soil classes based on USCS classification plus some additional gradation. These two general soil groups are more specifically described as follows:

+ **Good soils** are described as a Class I or Class II having a constrained modulus greater than 4,825 psi. These materials can be identified in Table 8-4, but are generally described as:

- Class I Compacted Crushed Stone embedment material; and
- Class II material compacted to 95% SPD described as GW, GP, SW and SP Soils in ASTM D2487).

+ **Fair soil** properties are described as Class I uncompacted, Class II or Class III with a constrained modulus greater than 1,485 psi. These materials can be identified in Table 8-4, but are generally described as:

- Class I uncompacted:
- Class II at 95% SPD or Class II at 90% SPD which are described as GW, GP, SW and SP Soils in ASTM D2487:
- Class III at 95% SPD which are described as GW, GP, SW and SP Soils in ASTM D2487

A more comprehensive descriptions of these soils are shown in Table 8-3 of this design manual. Embedment soils falling outside of these definitions are only recommended with special designs.

In most cases, existing host pipe systems have been installed for a considerable length of time therefore, the embedment and adjacent insitu soil is well consolidated with 95% SPD. Design properties used for the two soil groups are shown in Table 8-18 below.

Table 8-18
Embedment properties for Railroad Applications

Soil Stiffness (quality)	Constrained Modulus psi	Poisson's Ration	Soil density pcf
Fair	1,485	0.33	120
Good	4,825	0.33	125

It is noted embedment soil properties used for the CANDE analysis have a Young's Modulus of 3,250 psi for good soil and 1,000 for fair soil. The relationship between Young's modulus and constrained modulus is shown in Equation 8-20 below. Constrained Modulus properties for crushed stone can be found in AASHTO LRFD Section 12 Table 12.12.3.5- 3.

Equation 8-20

$$E = \frac{(M_s\,((1+\nu)(1-2\nu))}{(1-\nu)}$$

Where:

E = Youngs Modulus (psi)

Ms = Constrained Modulus (psi)

ν = Poisson's Ratio (unitless)

The burial depth tables assumed that there are no voids between the host pipe and in-situ soil, or that voids have been filled with grout during the installation process. A site assessment should be made to determine if any voids are between the host pipe and embedment. If voids are found the void should be filled with grout or other structural material. Contact Snap-Tite for guidance with locating voids between the host pipe and insitu soils and filling the voids. An embankment installation is assumed in development of the burial depth tables.

Grout Properties

For the E-80 analysis three grout strengths were evaluated. Grout properties form a grout ring around the SnapTite Liner pipe and are modeled with non-linear properties in the form of a modified Duncan material. Physical properties for the three grouts strengths are summarized in Table 8-19 below. In the case of railroad applications the physical properties of the grout should meet, or exceed, the modulus and strength properties shown in Table 8-19. Grout properties have been grouped into three categories (i.e. high, medium and low strengths). The grout properties used for the CANDE analysis were based on the physical properties, independent of density. The properties used for the CANDE analysis are shown in the table below.

Table 8-19
Grout Properties for Railroad Applicaitons

Grout Description	Modulus (psi)	Typical Compression Strength (psi)	Strain Capacity (in/in)	Typical Grout Density Range
High strength	≥216,500	873	0.40%	>60 psi
Medium strength	≥110,500 to < 216,500	275	0.25%	40-60 psi
Low strength	≥67,000 to < 110,500	84	0.13%	30-40 psi

Actual properties will depend on cement and mix used, curing conditions, and other jobsite conditions.

Chapter 9
RPS Minimum and Maximum Cover Limitations

The design procedure described in Chapter 8 is provided for technical completeness. However, in the case of standard installations, the information in this section is developed to provide a quick reference for maximum and minimum recommended cover heights for most installations. Additionally, this section provides a brief explanation of the assumptions used in the development of the burial depths tables.

Minimum Cover in Highway Live Load Applications

The minimum recommended burial depth for a RPS system is the same as a direct-buried Snap-Tite® pipe, shown in Table 8-13. This minimum cover height is recommended since rutting and other unanticipated field conditions may result in exceeding the RPS system capability.

For construction and short-term traffic loads, the temporary minimum cover for direct burial applications (see Table 8-14) should be used for RPS systems. These minimum cover heights are measured from the top of the pipe to the bottom of flexible pavement or to the top of rigid pavement.

Minimum Cover in Railroad Live Load Applications

Table 9-1 list the minimum burial depths for the most common combinations of host and Snap-Tite pipe. This minimum cover height is from the bottom of the railroad ties to the top of the host pipe. The minimum cover height was determined for the two soil groups shown in Table 8-18 and three grout strengths shown in Table 8-19. Therefore, a total of six installed conditions are available for shallow burial depth conditions as shown in Tables 9-1 and 9-2.

For a specific relining project, the host pipe and snap pipe combinations should be selected. Then the soil type should be selected. Finally, a grout quality should be specified based on the burial depth of the project. In many cases a Low strength grout will be suitable.

Table 9-1
Minimum Allowable Burial Depths for RPS (feet) Subjected to E-80 Loading

Host Pipe Diameter (in)	SnapTite® Diameter (in)	High Strength Grout		Medium Strength Grout		Low Strength Grout	
		Good Soil	Fair Soil	Good Soil	Fair Soil	Good Soil	Fair Soil
12	10.75	*	*	*	*	*	*
15	12.75	*	*	*	*	*	*
18	14	2	2	2	2.25	2	2.5
18	16	2	2	2	2.25	2	2.5
21	18	2	2	2	2.5	2	2.5
24	18	2	2.25	2	2.25	2.25	2.5
24	20	2	2	2	2.25	2	2.5
24	22	2	2	2	2.25	2	2.5
30	24	2	2.25	2	2.5	2	2.5
30	26	2	2	2	2.25	2	2.25
36	32	2	2.25	2	2.25	2	2.5
42	36	2	2.25	2	2.25	2	2.25
48	42	2	2.25	2	2.25	2	2.25
54	48	2	2.25	2	2.25	2	2.25
60	54	2	2.25	2	2.25	2	2.25
72	63	2	2.25	2	2.25	2	2.25

Notes:
1) AREMA does not recommend 10" and 12" liners for railway applications so no minimum depth is provided for those sizes.
2) High, medium and low strength grout are defined in Table 8-19.
3) Fair soil refers to a backfill material with a soil Young's modulus of less than 3,250 to 1,000 psi.
4) All burial depth units are measured in feet from the crown of the pipe to the finished grade elevation.

Maximum Cover

The maximum burial depth is heavily influenced by the type of backfill installed around the pipe. Table 9-2 specifies the maximum burial depth for a variety of backfill conditions. Table 9-2 should be used for a guideline to determine required densities and maximum burial depths. It is noted the maximum backfill cover height is different that the standard RPS system due to greater physical properties requirement for railroad applications. Contact Snap-Tite® for special applications

Table 9-2
Maximum Allowable Burial Depths for RPS (feet)

Host Pipe Diameter (in)	SnapTite® Diameter (in)	High Strength Grout		Medium Strength Grout		Low Strength Grout	
		Good Soil	Fair Soil	Good Soil	Fair Soil	Good Soil	Fair Soil
12	10.75	93	37	90	30	42	28
15	12.75	76	43	67	31	50	21
18	14	144	86	77	40	50	31
18	16	95	55	55	39	42	22
21	18	102	58	60	46	46	23
24	18	89	63	61	48	38	24
24	20	127	72	66	46	47	26
24	22	79	51	52	33	37	18
30	24	147	76	74	43	50	31
30	26	102	59	60	41	46	25
36	32	92	54	55	35	46	21
42	36	114	65	67	48	47	28
48	42	102	58	61	42	44	23
54	48	98	59	61	40	44	24
60	54	100	57	62	38	47	24
72	63	118	64	62	44	51	25

Notes:
1) High, medium and low strength grout are defined in Table 8-19.
2) Fair soil refers to a backfill material with a soil Young's modulus of less than 3,250 to 1,000 psi.
3) All burial depth units are measured in feet from the crown of the pipe to the finished grade elevation.

Chapter 10
Thread-Liner

ThreadLiner

The Thread-Liner Piping System

The Thread-Liner joint and installation system allows rehabilitation of failing systems without the need to remove existing pipe or excavation.

It's quick to install, strong and durable, and save time and money as easily as it fits into the available work space.

Benefits of Using the Thread-Liner Pipe Rehabilitation System

Special threaded sections of polyethylene pipe are inserted into the old pipe, forming one continuous, leak-free liner.

Once anchored and sealed by grouting, the new system is virtually maintenance-free. There is no excavation or costly restoration, no traffic diversions, no interruption to service, and elimination of infiltration and exfiltration problems.

No Special Training or Equipment.

The Thread-Liner pipe lining system is simple to install. Since it typically weighs less than other piping materials, it is much easier to handle. Maintenance departments can use their own crews - no special training or specialized equipment necessary.

Because of Thread-Liner's ease of installation and short lengths, 95% of drainage and sewer pipe renewal can be off road. This means increased safety for both your workers and motorists. Traffic disturbance can be a thing of the past.

Limited Access in Mind

Standard Thread-Liner comes in a diameter range of 4" to 42", and a standard length of 30" (2.5 feet lay length). Additional diameters and custom lengths may be available upon request 18" to 36" lengths may be preferred based on the available opening or footprint for manhole-to-manhole or catch basin installations. These sections can be connected together, all with strong water-tight seals. These advantages also make Thread-Liner ideal for pipe renewal within reduced work areas that are in constrained or confined settings.

Simple installation means light duty equipment, less manpower, and minimal disturbance of right-of-way. When considering these benefits, it becomes clear that the Thread-Liner system is a cost-effective way to rehabilitate deteriorating drainage piping systems. A structural solution with a service life of over 100 years, rehabilitation with Thread-Liner may be the perfection answer to your headache.

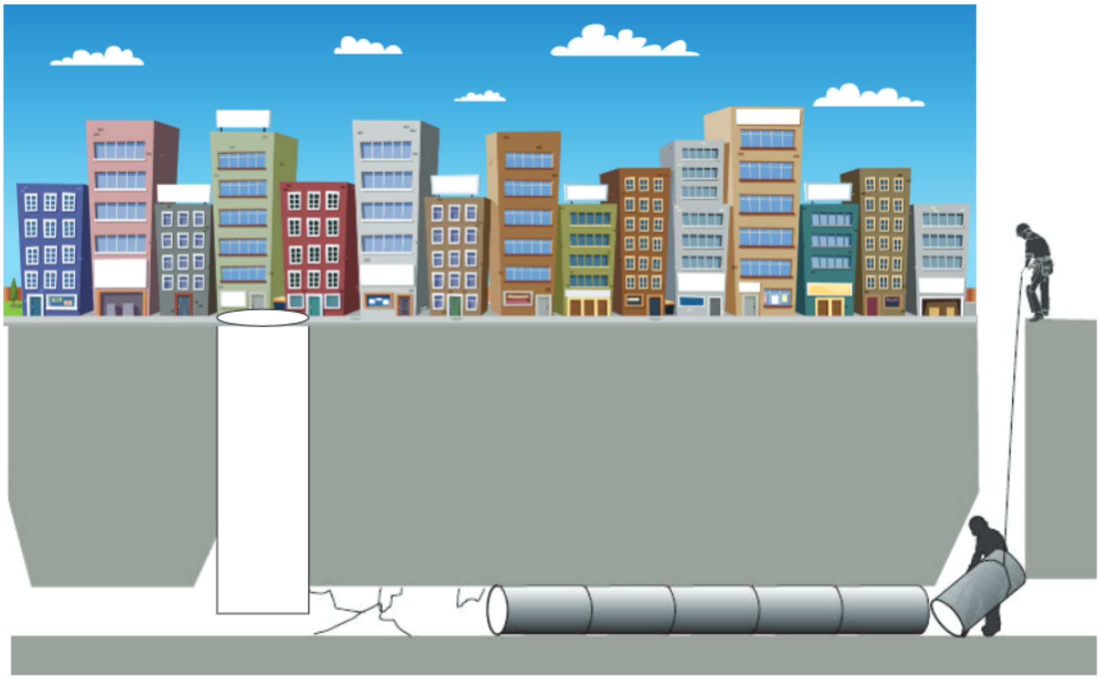
Thread-Liner Applications

Typical applications for Thread-Liner are combined sewer relining, industrial sewer relining, culvert relining and dam rehabilitation.

Compared to pipe replacement, dramatic savings are possible with the following benefits:

- No interruption of services
- Little or no surface damage
- Maintain traffic flow
- Faster project completion
- Maintain or Improve hydraulic capacity
- Structurally strong using pipe that withstands direct burial
- Resistant to seismic demands
- The sealed system prevents entry of ground water, roots, and debris
- A long service life
- High chemical resistance-no corrosion
- Reduced extraneous water allows treatment plants to operate efficiently and owners benefit from lowered volumes for water treatment.

For recommendations and assistance with installation, additional information for Snap-Tite and Thread-Liner can be found in the Snap-Tite Culvert Lining Field Guide for Installation, Handing, and Storage or contact our experts at 1-800-CULVERT.



The Thread-Liner joint and installation system allows replacement of failing systems without the need to remove existing pipe or excavation.

Chapter 11
ISCO Aquatic Life Passage

ISCO A.L.P (Aquatic Life Passage)

Snap-Tite® now offers an interior open profiled HDPE pipe up to 120" in diameter designed to enhance aquatic life passage. ISCO A.L.P.'s internal structure is comparable to that of CMP, but manufactured with a more durable, corrosion-resistant, and abrasion-resistant material. Fish and other aquatic organisms can now migrate more easily through their physical environment but with a pipe constructed of HDPE, offering a much longer service life. The interior profiles act as "roughness elements" that decrease the flow velocity and allow for some silt and stream bed material to collect inside.

ISCO ALP was originally envisioned as a "fish-friendly" solution to failing culverts that is economically feasible, quickly installed and non-disruptive to the motoring public. Relining these culverts with Snap-Tite products has always been a possible and popular solution. However, ISCO ALP is also an ideal solution for a direct buried culvert for enviormnetally sensitve areas where aquatic life demands can be solved with this inventive product approach.

Additionally, Snap-Tite® can install available baffles in both ALP and smooth wall piping to solve depth and velocity problems within a culvert during flow extremes. In low-flow situations, most baffles act as weirs to create small pools of standing water. As the flow increases, the water rises up over the baffles. The baffles help decrease flow velocity while creating resting areas for fish to use during high velocity water flow occurrences.

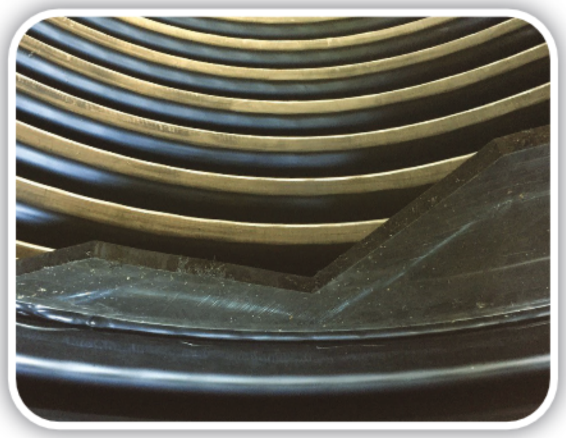


Table 11-1
ISCO A.L.P. Size Range

Nominal Internal Pipe Diameter (in.)	Ring Stiffness Classifications RSC**	Approx. Pipe OD (in.)*	Estimated Weight (lbs./ft length)*
24	160-250	29	20
30	160-250	35	25
36	160-250	41	27
42	160-250	47	30
48	160-250	53	40
54	160-250	59	50
60	160-250	66	60
66	160-250	72	75
72	160-250	78	100
78	160-250	84	125
84	160-250	90	150
90	160-250	96	165
96	160-250	102	180
120	160-250	127	250

* Typical values. Actual values may differ. Additional sizes available.

**RSC is determined by soil properties(direct bury), grout properties(relining), depth of cover, and groundwater elevations. Consult your local Snap-tite Representative

More and more culverts are being accessed as a crossing by fish and other aquatic organisms; however, most culverts are not fully passable. For a fish, on an upstream migration, to successfully negotiate a culvert, it must enter the culvert barrel, traverse the barrel length, exit at the upstream end and proceed to the first resting area. As such, many states are implementing recommendations and guidelines for improving the effectiveness and ecological impact for waterway crossings. Experts tend to agree that the most effective solution for creating unobstructed fish passages is to replace problem culverts with new crossing structures such as bridges or oversized and/or embedded culverts that are able to simulate a natural streambed bottom.

However, many agencies have concluded that due to the number existing culverts and the limited amount of public funds available, it is unlikely and/or impractical that every culvert that impairs fish passage will be removed and replaced with an adequate design. In situations where replacements are not practical or sensible, retrofitting a culvert with baffles may be a reasonable measure to provide some passage improvements. Culvert retrofits are modifications to an existing culvert and/or stream channel in an attempt to reduce barriers and improve fish passage. Baffle retrofits are not considered by many to be long-term solutions, but rather are viewed as a temporary solution until replacement can be logistically and financially viable.

For many years, Snap-Tite® has made its mark as an excellent option for rehabilitating culverts that are failing structurally, where replacement would be costly, untimely, and very disruptive to the surroundings.
Snap-Tite® with factory installed baffles can become a culvert retrofit option that provides the same construction advantages and cost saving benefits, while also providing improvements for aquatic passage.

Most culverts with fish passage problems were designed with a focus on the culvert diameter required to pass a highflow event.

Corner Baffle Design

Baffles are placed off center from the invert or flowline of the culvert and remain on one side of the culvert and do not alternate.

As a result they are undersized because they were designed for stream flow only, without regard to velocity impact on fish passage and other aquatic organisms.

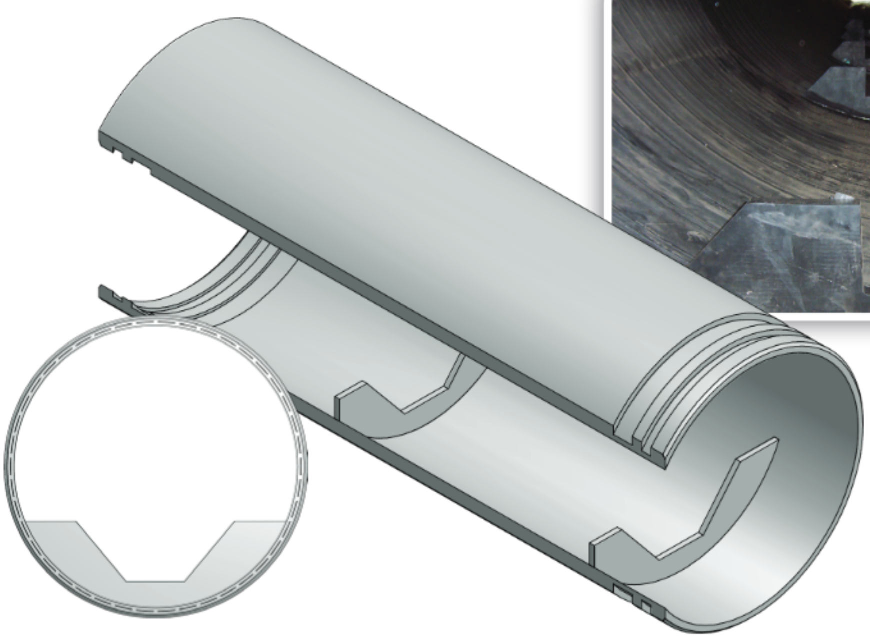
About Baffles

Baffles are used to solve depth and velocity problems within a culvert during flow extremes. In low-flow situations, most baffles act like weirs to create small pools of standing water. As the flow increases, the water rises up on the baffle and the baffles act as roughness elements that decrease the flow velocity, creating resting areas for fish to escape high velocity water streaming through the culvert. Again, it should be noted that baffles are not recommended by leading research organizations for new installations or situations that demand complete replacement of culverts where fish passage is of concern.

When adding baffles to a retrofitted culvert, the culvert now becomes more prone to become blocked or clogged. It is imperative that a regular inspection and maintenance program is developed, otherwise the crossing has exchanged one fish passage problem with another. Inspections and maintenance are typically important during and immediately after high flow events, especially as fish migration occurs in these events. Baffles (and culvert retrofits) are considered part of the hydraulic design option for design methods used in fish passage analysis. Baffles are typically recommended for culverts with a maximum slope of 2.5%-3.5%. (Corner baffles are typically used for slopes less than 2.5% while notched weir baffles are used between 2.5 %and 3.5%.) It is acknowledged that while the goal is to optimize culvert capacity, limit sediment deposition and debris accumulation, limit maximum velocity and maximum turbulence; each criterion will have to be balanced against each of the others for a compromise in the overall design. Culvert retrofits are not expected to be able to satisfy all the requirements of the hydraulic design option. The retrofit design should also be analyzed in conjunction with inlet and outlet control features such as tailwater control measures. The design engineer should consider and evaluate these conditions when specifiying the baffle criterium to Snap-Tite® for fabrication.

The California Department of Transportation (Caltrans) has a published guide, "Fish Passage for Road Crossings", that offers detailed insturuction and information. Chapter 7, Culvert Retrofit Design" is useful for relining considerations. Appendix F, Hydraulics of Baffles, provides information regarding analysis and design of baffled culverts, including baffle configuration, height, and spacing.

Notched Weir Baffle



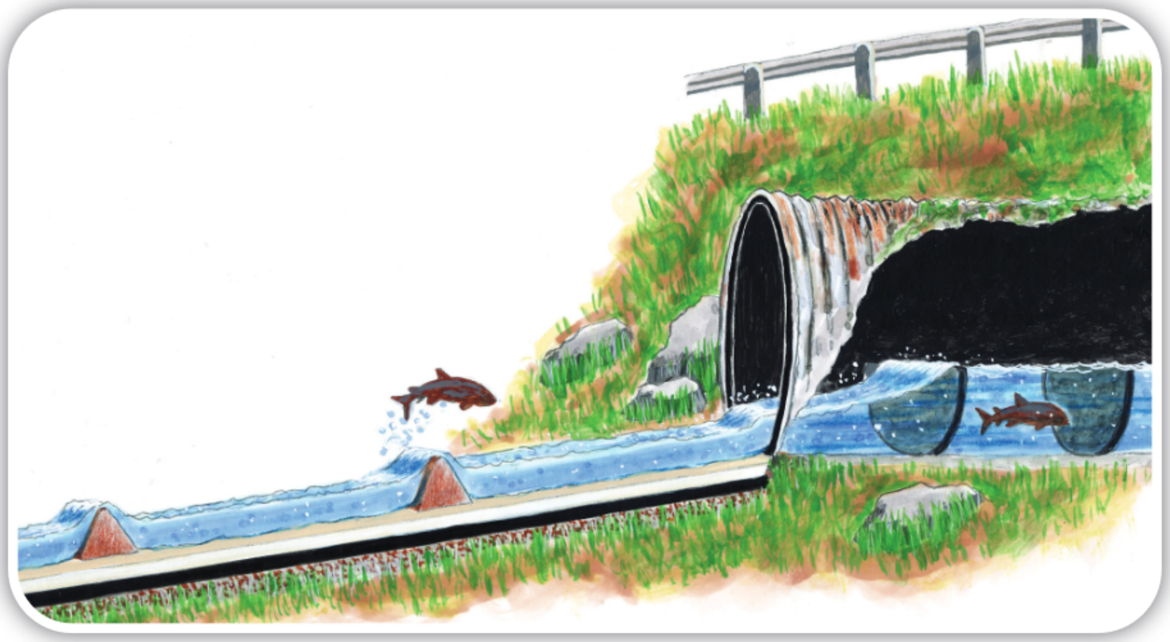
The notched weir baffle design and corner baffle designs are recognized by the Federal Highway Administration along with many state transportation and environmental agencies.

Is Erosion Control a Problem?

Erosion control is a major concern when rehabbing an existing culvert. Snap-Tite® is your no-dig solution to lining failing culverts, and your answer to erosion control challenges. Not only does Snap-Tite® rehab the culvert, it provides erosion control for the areas surrounding the culvert and maintains a constant elevation, thus making it easier for fish to enter the culvert. Snap-Tite® pipe is made from HDPE pipe, which can be made to fit all of your culvert needs.

Pools adjcent to culvert can play important design elements in ISCO A.L.P.

Ponding effect created by baffle/weir design during low-flow.



Chapter 12
Handling and Storage

Lifting Equipment

Unloading and handling equipment must be appropriate for the type of packaging, must be in safe operating condition, and must have sufficient capacity (load rating) to safely lift and move the product as packaged. Equipment operators should be trained and, preferably, certified to operate the equipment.

When using a forklift, or forklift attachments on equipment such as articulated loaders or bucket loaders, lifting capacity must be adequate at the load center on the forks. Forklift equipment is rated for a maximum lifting capacity at a distance from the back of the forks. Reduce the lifting capacity if the weightcenter of the load is farther out on the forks.

Before lifting or transporting the load, spread forks as wide apart as practical. Forks should extend completely under the load, using fork extensions if necessary, and the load should be as far back on the forks as possible. During transport, a load on forks that are too short or too close together, or a load too far out on the forks, may become unstable and pitch forward or to the side, and result in damage to the load or property, or hazards to persons.

Above the load lifting equipment such as cranes, extension boom cranes, and side boom tractors, should use wide fabric choker slings that are secured around the load or to lifting lugs on the component. Spreader bars should be used when lifting pipe or components longer than 20 feet. Before use, inspect slings and lifting equipment. Equipment with wear or damage that impairs function or load capacity should not be used.

Handling and Unloading Snap-Tite® Pipe

HDPE piping product transportation and handling is generally subject to governmental safety regulations such as OSHA in the United States or CCOSH in Canada. Persons transporting and handling HDPE piping products should be familiar with applicable governmental safety regulations. Additional HDPE pipe handling and transportation information is available in the Material Handling Guide from the Plastic Pipe Institute (www.plasticpipe.org). However, the responsibility for safe transport and handling rests primarily with persons that actually perform transport and handling activities.

Loading and unloading areas should be isolated and those not directly involved in the loading or unloading process should vacate the control area during material handling process. The contractor or owner should have written safety procedures to help prevent loss or injury on the work site. At no time shall workers walk on top of pipe loads, nor shall they place themselves beneath suspended loads. Wear appropriate personal protective equipment; hard hats, gloves, safety glasses, and steel-toed boots are recommended. Safety is the responsibility of the installing contractor or owner.

Observe safe handling and operating procedures. Although PE piping components are lightweight compared to similar components made of metal, concrete, clay, or other materials, larger components can be heavy.

Drivers contracted by ISCO Industries, Inc. to pick up and deliver HDPE to job sites are expected to adhere to ISCO standards regarding HDPE pipe handling, loading and unloading pipe. Handling and unloading equipment can be a wide variety of options, such as forklifts, cherry pickers, or front-end loaders with forks. However, the means by which pipe products are unloaded at the job site is the responsibility of the customer.

Give special attention while strapping and unstrapping loads. All personnel must be vigilant for sliding and rolling pipes while near trucks and lifting equipment. Take precautions to ensure that pipe is not dropped or damaged. Pipe, fittings, and special fabrications must not be pushed, rolled, or dumped off the truck.

The following are recommendations and guidelines to motor carriers for handling and unloading HDPE pipe at job sites.

- Park the truck on level ground with parking brake on and wheels chocked.
- Check the load to ensure that it has not shifted.
- Ensure that material handling, such as forklift, cherry picker, or front-end loaders with forks or spreader bar and lifting straps is available and adequate for the lift. Only properly trained personnel should operate unloading equipment. If you are using a forklift, have the forks spread as wide as possible for handling HDPE pipe.
- Be aware that HDPE pipe becomes very slippery to handle when wet, and avoid sharp and sudden movements when pipe is in contact with the forks.
- Do not move the truck if the straps are not secure around the pipe.
- Position the mechanical handling equipment before removing straps from the top unit loads.
- Do not stand on unsupported pipe! This can be extremely dangerous. Make sure the pipe is secure and supported by appropriate material handling equipment before mounting pipe to remove bands
- When cutting bands, cut only the bands securing the top tier to the tiers below. Do not stand on the banded pipe while cutting. Bands under tension can spring back when cut.
- Remove one unit at a time. If a strip board is across the top of a unit, remove it before lifting the pipe.
- When using a forklift to remove the pipe, the forks should enter the load slowly, taking care not to damage the pipe with the fork tips.
- If a forklift is not available, appropriately rated material-handling equipment such as a cherry picker or front-end loader with forks or spreader bar and lifting strap may be used.
- Do not use the forklift or other material handling equipment to push the load off the truck, as this is hazardous to unloading personnel and may damage the pipe and/or trailer.
- Personnel not involved in the unloading of the pipe should remain completely clear of the danger zone.
- Consider appropriate personal protective equipment as necessary such as gloves, hard hats, steel-toed footwear, and eye and hearing protection.
- THINK SAFETY and use caution at all times.

Unloading Sites/Storage

A suitable unloading site will be generally level and large enough for the carrier's truck, handling equipment and its movement, and for temporary load storage. General requirements for long-term storage are for the area to be of sufficient size to accommodate piping components, to allow room for handling equipment to get around them and to have a relatively smooth, flat, level surface free of stones, debris, or other material that could damage pipe or components, or interfere with handling. For some projects, several storage or staging sites along the right-of-way may be appropriate, while a single storage location may be suitable for another job. The site and its layout should provide protection against physical damage to components.

Pipe may be placed on 4-inch wide wooden dunnage or similar as shown in Figure 12-1. Middle support(s)/dunnage board(s) are not always required but may be useful as pipe diameters get smaller or as lengths increase. Using the boards will help maintain clearance for forklift forks or lifting slings. Using boards also helps create clearance for the pipe from water, where flotation of the plastic pipe could be at risk.

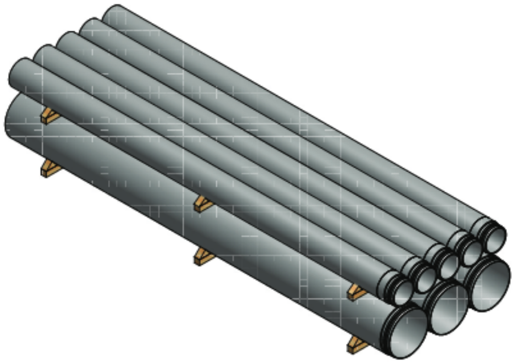
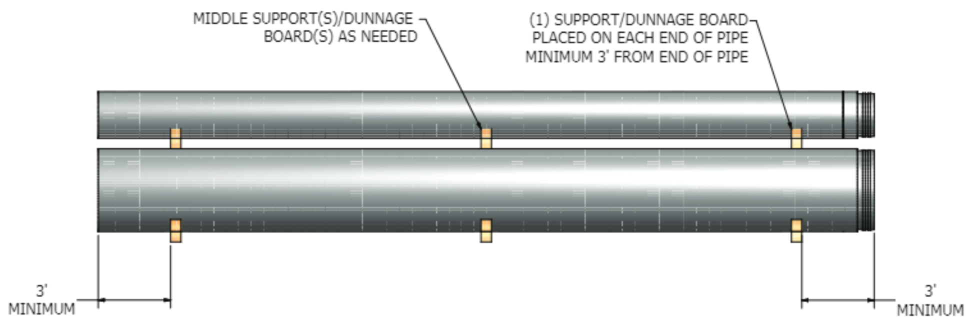


Figure 12-1: Stacking Detail



Avoid storing Snap-Tite pipe in areas where flooding or washout could occur to avoid pipe movement.

Supports for the pipe should be a minimum distance of 3 feet away from each end. Supports that are closer to the ends increase the stress at the Snap-Tite male and female ends and can cause a crack to develop when the loading becomes excessive. Take care to insure no direct impacts or dropping the ends on the ground or against other surfaces as that can create the same stress event.

Environmental: Exposure to UV and Cold Weather

Snap-Tite and other HDPE piping products are protected against deterioration from exposure to ultraviolet (UV) light and weathering effects with antioxidants, and thermal and UV stabilizers. Black HDPE pipe and fittings contain at least 2% carbon black to limit the effects of UV attack. Black HDPE pipe and fittings are suitable for outdoor storage without covering or protection against UV exposure.

Temperatures near or below freezing will affect PE pipe by increasing stiffness and reducing resistance to impact damage. PE remains ductile at temperatures below -40ºF (-40ºC). In cold conditions, allow more time to conduct handling and installation procedures that bend and flex the pipe. Take extra care not to drop pipe or special fabrications, and to keep handling equipment and other things from making forceful impacts to the pipe.

Ice, snow, and rain are not harmful to the material, but unsure footing and traction require greater care and caution to prevent damage or injury. Inclement weather can make pipe surfaces especially slippery. Do not walk on pipe.

Additional Information

Additional information can be found in the Snap-Tite Culvert Lining Field Guide for Installation, Handling, and Storage including safety recommendations. It also includes supplies, equipment, and methods information with material and project checklist for the installer.

Chapter 13
Specifications

Snap-Tite® Sample Specification

This specification covers the purchase of high-density polyethylene (HDPE) pipe liners for rehabilitating existing culvert pipes. The liner shall be capable of being joined into a continuous length by an interlocking method. To eliminate any installation difficulties, the joints shall not create an increase in the outside diameter of the liner pipe. Pipe liners furnished to this specification shall meet or exceed all requirements. Users of this sample specification are encouraged to read all the sections and requirements carefully, as there may be areas that are not applicable for all projects, or additional requirements may be necessary.

SAMPLE SPECIFICATION

Sample Specifications for Snap-Tite® Culvert Liners

1) General — This section shall govern for furnishing, installing, grouting and providing all labor, material and equipment necessary to rehabilitate existing culvert pipe by sliplining with high-density polyethylene (HDPE) pipe. The pipes shall be sizes, types, design and dimensions shown on the plans and shall include all connections, joints and other appurtenances as required to complete the work. The sliplining process will require the installer to completely grout the annular space between the host and inserted liner pipe. The grouting process shall be considered subsidiary to this item.

2) Reference Standards and Specifications

AASHTO M 326 - Standard Specification for Polyethylene (PE) Liner Pipe, 300- to 1600-mm Diameter, Based on Controlled Outside Diameter

ASTM D 2321 - Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications

ASTM D 3212 - Standard Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals

ASTM F 477 - Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

ASTM F 585 - Standard Guide for Insertion of Flexible Polyethylene Pipe Into Existing Sewers

3) Materials — Unless otherwise specified on the plans or herein, culvert pipe renewal shall conform to the following: Snap-Tite® Culvert Liner as provided by ISCO Industries, Inc.

A. Liner Material – High Density Polyethylene (HDPE) Pipe

1. High-density polyethylene pipe and fittings shall meet the material requirements in the AASHTO M326 Section 6.1.1.
2. High-density polyethylene pipe and fittings in 12”-63” nominal diameters shall meet the dimensional requirements in the AASHTO M326 Section 7.3.1 and 7.3.2. Other sizes may be provided when agreed upon by owner and supplier/manufacturer.
3. Individual liner section lengths shall be a minimum of 6-ft but shall not exceed 24 ft. unless pre-approved.

B. Joint Requirements

1. Pipe joints shall comply with AASHTO M326 Section 7.8 for watertight joints.
2. The HDPE pipes used for liners in gravity flow culverts shall be solid wall construction with mechanical end connectors, male and female consisting of dual interlocking machined grooves (2 landing points), meeting requirements of AASHTO M326 Section 7.7.2 and 7.7.3 for compressive and tensile strength.
3. The elastomeric sealing area must have a gasket that encompasses the full circumference of the mating joint with a minimum width of .75”.

C. Hydraulic flow characteristics for the liner pipe shall provide a Manning’s coefficient of n = 0.00914. Pipe Manufacturer shall submit 3rd party test data verifying the Manning’s coefficient has been achieved.

D. HDPE Pipe Liners with male and female mechanical end connectors must be supplied by one manufacturer that has a quality management system registered to ISO 9001:2015 and is certified by a third-party registrar with documented annual audits. Documentation proving ISO certification must be provided with bid proposal.

E. Other pipe liners that do not meet this specification must be submitted for approval prior to bid date.

F. Grouting Material – The installer shall utilize material specifications for solidification of the annular void between host and the inserted liner with low-density flowable fill or cellular grout. The cellular grout with a density between 25 and 75 lbs. per cubic foot is preferred. Reduced density flowable fill grout with a density up to 115 lbs. per cubic foot may be used. Project engineer shall state density of grout to be used on drawings or in specifications.

G. End Treatment – The upstream/inlet end of the new liner pipe shall be fitted with a flow enhancement device to reduce inlet control effects. The opening at the end of the device shall be larger than the ID of the host pipe. Third party test data shall be provided to show improvement of flow by at least 30% at a headwater depth of 1.5 times the liner ID and shall demonstrate an entrance loss coefficient (Ke) of approximately 0.2 for outlet control conditions. The device shall be the Hydro-Bell.

4) Typical/Standard Method of Procedure— The installation contractor should submit a detailed work plan that addresses the following areas:

A. Assessment and Inspection
1. Host Pipe Cleaning (if required)
2. Video Inspection (if required)

B. Sizing and Cleaning (section 5.A)
1. Verification of host pipe length, internal dimensions, and adequate clearance
2. Removal of debris, obstructions, sharp edges, and other hindrances to insertion

C. Methodology, Staging, and Job Prep
1. Water control (coffer dams, bypass pumping) as needed
2. Erosion Control, as required
3. Determination of Push/Pull or combination
4. Coordination of access, storage, and staging areas (section 5.B)
5. Grout Tube lengths and location map
6. Vent Port location map

D. Staging and Site Prep
1. Installation of Blocking and Rails as needed
2. Installation of Grout and Vent Tubes
3. Liner Connection Areas

E. Pipe Installation (Section 5.C)

F. Bulkhead Installation (Section 5.D.1)

G. Grouting of Annular Space (Section 5.D)
1. Grout mix density (including foaming instructions and equipment, when used)
2. Grout lift plan and calculations in cases where multiple lifts are used
3. Pressure monitoring of inlet and/or lowest location

H. Post Installation Acceptance
1. Video Inspection (if required)
2. Testing (if required)
3. Waste removal, cleanup, and restoration

5) Construction

A. Cleaning
1. It is the responsibility of the contractor to clear the line of obstructions, solids, dropped joints, protruding service connections or collapsed pipe that will prevent the insertion of the liner pipe. The owner/engineer all approve all activity prior to the commencement of the work. This work will not be paid for directly, but shall be considered subsidiary to this item.

B. Pipe Stockpiling and Handling –
1. Stockpile pipe and fittings a safe manner at each staging area or pit location. Refer to chapter 12 of Snap-Tite® Design Guide for specific instructions.
2. The stockpiling shall be arranged to cause a minimum of interference to pedestrians and stored outside the safety clear zone of vehicular traffic.
3. When handling liner pipe, the installer shall take all precautions necessary to avoid damaging the pipe. Pipe with cuts greater than 10% of the wall thickness shall be evaluated for acceptance or repair by the owner/engineer.

C. Installation
1. The installer must be pre-approved by the pipe manufacturer and a letter of this pre-approval must be submitted from the manufacturer to the installer at the time of bid.
2. A Manufacturer's Rep must be on site at critical stages of the liner installation and grouting application. In cases where the installer has 2000' of documented prior experience with culvert relining, the manufacturer can elect to waive this requirement.
3. Liner pipe shall be inserted and installed in accordance with manufacturer's recommendations. Slip liner pipe grade shall be maintained parallel to grade of host pipe. Unless conditions warrant otherwise, female ends should face upstream and male ends should face downstream.

D. Grouting
1. The installer shall provide bulkheads to seal the open points of each run of pipe to be grouted.
2. Penetration of the host pipe may be permitted to facilitate grouting of the annular space. Multiple fill pipes may be required.
3. Venting of the annular space shall be performed to allow for escape of air and excess water and to assure uniform grout placement in the annulus. At minimum, an open ended, high point tap or equivalent vent must be provided and monitored at the bulkhead. Additional vents may be employed which can serve as intermediate grout verification points.
4. The annular space shall be fully grouted. Grouting in lifts will require multiple grout ports to maintain access to the annular space for sequential injections. Grouting plans should identify which method (or combination) will be used:
   a. Injecting grout from upstream elevation end of the pipe run and allowing grout to gravity flow toward the other end.
   b. Pumping grout from downstream elevation end of the pipe run and allowing grout to fill the annular space until reaching the vent port on the upstream end of the pipe.
5. The specific grout mix shall be submitted to the owner/engineer by contractor for approval prior to use on this project. The mix shall have a minimum 28 day compressive strength of 150 psi.
6. Recommended pressure on the annular area should not exceed 2 PSI to avoid damage to the standard Snap-Tite liner pipe. The installer shall be solely responsible for any damage or distortion to the liner pipe due to exceeding the recommendations from the liner manufacturer on the grouting limits.

Chapter 14
Frequently Asked Questions

Frequently Asked Questions (FAQ)

1. What is ready-mixed concrete?

Concrete is a mixture of aggregates and paste. The aggregates are coarse aggregates (gravel or rock) and fine aggregates (sand); the paste is water and cement. Cement is a fine, gray-colored powder.

Concrete is usually produced at a Ready-Mix Concrete Batch Plant and delivered to the site in a concrete truck, thus the name "ready-mix" or "ready-mixed" concrete.

2. Are cement and concrete the same?

No; although the terms cement and concrete are often used interchangeably, cement is actually an ingredient of concrete. Cement is a binder, a substance that, when mixed with water, sets and hardens. It can bind other materials together.

So, there is no such thing as a cement sidewalk or a cement mixer; the proper terms are concrete sidewalk and concrete mixer.

3. What is concrete slump?

Slump is a measure of the consistency of concrete, or the ability of the concrete to flow. A slump cone is filled with the plastic (wet) concrete and the cone is lifted up. The amount that the cone of concrete 'slumps' away from its original height is the concrete slump value.

A low slump indicates a stiff mix; a high slump value means the concrete is more fluid. The cone is 12" high so the slump range is zero to twelve inches. A typical slump range for ready-mixed concrete is 3 to 5 inches.

4. When asked what slump to use for grouting the annular space around Snap-Tite® what do you answer?

Slump is a term to describe the consistency of concrete; it is not used to describe the grout. A measurement used for the consistency of grout is the flow value.

The flow value of grout is determined by filling a cylindrical cone with the material and measuring the time it takes for the grout to flow out of the cone. A range of 20-30 seconds is typical. The more liquid the grout, the faster it flows out of the cone and the lower the flow value. This value is not typically taken during culvert rehabilitation projects.

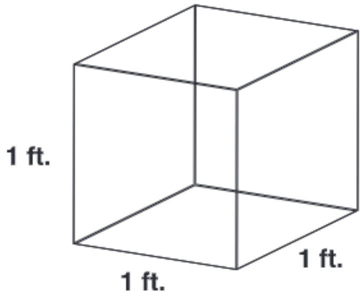
A slump value can be used for the concrete to be placed in the bulkhead. In that case, a low slump of 1" to 2" is appropriate.

5. What is density?

Density is the unit weight of a material; it is measured in pounds per cubic foot. It is the weight of the amount of material it would take to fill a container measuring 1 ft. x 1 ft. x 1 ft.

For reference, here are the densities of common materials

Water	62.4 lbs/cubic foot
Low-density cellular grout	30 to 60 lbs/cubic foot
Normal Concrete	140-150 lbs/cubic foot
Sand	90-100 lbs/cubic foot
Crushed stone	120-130 lbs/cubic foot



6. **How is density related to strength?**

For grout mixes, the higher the density, the higher the compressive strength of the material. A grout mix used to fill annular space does not need a high compressive strength, but needs to be as strong as the soil it is replacing.

Soil is placed around a pipe in new construction or during a "Dig & Replace" operation. The soil is compacted to a certain density; usually 95% of the soil's Standard Proctor value. The compressive strength of the soil is not required.

The same is true for grout mixes that are used to fill annular space in a sliplining operation. The density of the grout (lbs./cu.ft.) is the important value, not the strength (psi).

Grout mixes with higher densities may have sand included, have more cement in the mix, or not have as much foaming agent added to it as a grout mix with a lower density.

7. **What grout strength should be used with Snap-Tite®?**

The grout should be as strong as the soil around the pipe. For reference, the support strength of different types of soils and grout materials are listed here:

Material	Support Strength, (psi)
Sand, (90-100 lbs./cu. ft.)	7 psi
Sand and clay	25 psi
Gravel and clay	14 psi
Crushed stone	21 psi
Cellular grout, 70 lbs./cu. ft.	1300 psi
Cellular grout, 35 lbs./cu. ft.	200 psi

8. **The installer called and wants to use an "8 bag" or "8 sack" mix. Will it work?**

This is a term related to concrete. You will have to question the installer further as to how he plans to use this material. If he is using the concrete for the bulkhead, then an "8 bag" mix is a very strong mix for this task.

If he wants to use the material to grout the annular space, then the installer must be educated about using a grout mix instead of a concrete mix for this chore.

What is an "8 bag" mix? This means that 8 bags of cement will be used per cubic yard of concrete. At 92 lbs per sack, this equates to 736 lbs of cement put into each yard of concrete batched.

Depending on the specifics of the sliplining project (ex: what size Snap-Tite® is going into what size host pipe, how long is the pipe run, etc.), a range of concrete mix designs, from a "3 sack" mix to an "8 sack" mix, can work. The important value to communicate to the concrete batch plant is that the mix must have a low slump value, 1" to 2". You don't want the concrete for the bulkhead to 'flow' too much.

Since there is a minimal volume of concrete needed to form the bulkhead, this is not a major cost component of the job. Having more cement in the mix is better than having too little. It is important that the bulkhead be strong enough to withstand the pressure exerted on it from the grout placed inside.

This information is available on the web at www.Culvert-Rehab.com. You can call (800)-culvert for any questions about cellular grouts.

9. **Why do I need to grout the annular space?**

   When we slipline a culvert with Snap-Tite®, we direct the flow of water through the Snap-Tite® Liner. Grouting supports the Snap-Tite liner within the pipe. It also fills voids in the soil around the host pipe. These voids are formed when the bedding soil of the pipe infiltrates through holes in corroded metal pipe or through joints that have pulled apart with concrete pipe. Thus, grouting the annular space serves both processes which are needed to maintain the roadway long term. See rehab video on website.

   There are certain situations where grouting the annular space is not needed. If there is a small annular space, say a 20" Snap-Tite® pipe is inserted into 24" RCP, then forming concrete end walls on the inlet and outlet side may be all that is required. The concrete is not going to continue to corrode as a corrugated metal pipe may and the water is forced through the polyethylene Snap-Tite® pipe so further soil infiltration is prevented.

10. **How do you determine the liner size?**

    The rule of thumb is to use a liner that is 10% smaller than the ID of the original pipe. When lining concrete pipes, this will result in 80 to 100 percent of flow. When CMP is sliplined, flow is usually increased.

Chapter 15
Glossary of Terms

Glossary of Terms

(Specific for Snap-Tite® Applications)

Admixtures (Ad Mix)
Admixtures are materials other than cement, aggregate and water that are added to concrete either before or during its mixing to alter its properties, such as workability, curing temperature range, set time or color.

Annular Space (Annulus)
The gap between the inside diameter of the host pipe and the outside diameter of Snap-Tite® or other sliplined pipe material. Annular space is typically measured in inches. This space can be typically calculated as the volume of a cylinder.

Apron
Protective material placed on a streambed to resist scour.

Backfill
Material used to refill a ditch or other excavation, or the process of doing so.

Barrels
The number of parallel pipe runs through an embankment or under a road.

Barrel diameter
The internal diameter of a pipe or culvert.

Blocking
The use of blocks of wood or other materials on the top or side of a liner pipe to maintain grade and alignment of Snap-Tite® or other sliplined pipe in the annular space. Blocking is used to maintain grade and alignment during the grouting process.

Blocks
Pieces of wood or other materials used to maintain grade and alignment when attached to the top or side of a liner or host pipe.

Bulkhead
Vertical, or near vertical, wall that supports a bank or an embankment; also seal between host pipe and liner pipe; also may serve to protect against erosion.

Cellular grout
Cement, or cement fly-ash-based grout made with a multitude of macroscopic, non-interconnected air cells, which are distributed throughout the mass to lower the density and increase the ability of the material to flow into the annular space. Various strengths and densities of cellular grout are available.

Cement
In the most general sense of the word, cement
is a binder, a substance which sets and hardens
independently, and can bind other materials together. Hydraulic cements are materials which set and harden after combining with water, as a result of chemical reactions with the mixing water and, after hardening, retain strength and stability. Cement will set (hydrate) even when under water.

Collapse strength
The strength of Snap-Tite® or other reliner pipe to resist a force applied by soil loads, live loads and/or hydraulic loading. The strength is typically measured in feet of head or psi and is commonly referred to during the grouting process of the annular space.

Come-a-long
A lever powered chain puller; it can be used to pull the two sections of Snap-Tite® pipe together. There are both chain and cable come-a-longs available. Chain come-a-longs are safer for this application.

Compressive Strength of grout
The measure of how many pounds per square inch, “psi,” that a grout will hold prior to fracturing. This value is measured by crushing, by compression, test samples or cubes in a machine.

Concrete
A mixture of aggregates and paste. The aggregates are coarse aggregates (gravel or rock) and fine aggregates (sand); the paste is water and cement.

Density of cellular grout
By varying the amount of air content in the cellular grout, the mixture can be made to have a density as low as 20 pounds per cubic foot, and as high as 120 pounds per cubic foot. Each density will exhibit a corresponding compressive strength. Typical densities used with Snap-Tite are 30 – 80 pounds per cubic foot.

Density of grout
Cement grout is usually made using fine sand aggregate with the paste (cement and water). Typical weights are from 90 to 140 lbs. per cubic foot.

Density of water
Water weighs 62.4 lbs. per cubic foot.

Design life
The expected useful life of pipe in a given application when exposed to specific design loads and temperatures. Design life is typically measured in years. Typical HDPE design life is 50-100 years.

Displacement
The result of buoyant forces acting on an object and moving it from its original position or, in the case of pipe, its original grade and alignment. Displacement is typically referred to when describing precautions necessary during the annular space grouting process.

Flotation
The act of being on top of a liquid. The force applied when a liquid is displaced.

Flowable fill
A mixture usually comprised of combinations of cement, water, fine aggregate (sand) and sometimes fly ash. Typically flowable fill is used in place of granular (sand or crushed stone) fill to support pipe in a trench. Snap-Tite® Culvert Liners are often grouted into a rehabilitated culvert with flowable fill.

Fly ash
The powdery residue of matter that remains after burning coal in an electric power plant. It is a fine residue that, when dry literally flies in the air. Fly ash reacts with calcium hydroxide in the presence of water to form compounds possessing cementitious properties. Fly ash is often used to replace some of the cement in concrete mixtures, as can be less expensive and offers positive property attributes to the concrete mix.

Gasket
An elastomer used to make a watertight connection. A gasket constructed of materials meeting the requirements of ASTM F477 is shipped with all Snap-Tite® pipe.

Grout
A mixture of cementitious material and water, with or without aggregate, proportioned to produce a pourable consistency without segregation of its constituents. Grout may also contain fly ash, slag, and liquid admixtures. Grout is different than mortar; grout need not contain aggregate (sand) whereas mortar contains fine aggregate. Grout is used to fill spaces whereas mortar bonds elements together, as in masonry construction.

Grout pump
A machine used to move grout from the mixing container to the culvert location. Specific types of grout pumps are more acceptable for cellular grout, such as Peristaltic Pumps with a progressive squeezing action or Rotor-Stator Pumps.

Headwater
The water surface elevation on the upstream side of a culvert providing the energy to force water through the culvert.

Host Pipe
The existing pipe or culvert that is being repaired or rehabilitated. Typically the host pipe is experiencing structural distress and is relined with a structural element such as Snap-Tite®.

ID
Inside Diameter is the measure of the actual opening of a pipe or liner.

Inlet Control
One of two basic types of flow control in culvert hydraulics where the culvert barrel is capable of conveying more flow than the inlet will accept.

Internal support
Usually wooden boards used inside of a pipe or liner to prevent deformation when load is applied from the outside.

Invert
Lowest point in the channel cross section or at flow control devices such as weirs, culverts, or dams. For a round pipe, the bottom most portion of the pipe inside diameter.

Ladder bracing
Wooden planks or assembled boards to internally support a pipe, liner, or tank. The assembled support looks like a ladder.

Lands and Grooves
Land is a term used to describe a flat, machined surface on a circular part. A groove is a long, narrow cut into a surface. The Snap-Tite® connection is made by machining the OD (male end) on one end of a liner pipe forming lands and grooves; the ID (female end) of the other pipe to be joined with surfaces that will fit and make a strong connection.

Lift
The act of raising the level or surrounding elevation of a structural material in predefined increments. This term is used to describe the process of partial filling of a pipe, trench, or other area with structural material. When the annular space between a Snap-Tite® Culvert Liner and host pipe or existing culvert is partially filled, a lift of grout has been poured or pumped into place.

Lift relief pipes
A relief pipe allows air and water to be removed from the annular space. A lift relief pipe allows filling of the annular space with grout to the level of the relief pipe. When grout flows from the lift relief pipe, the level for that lift has been reached.

Lubricant
A substance used for reducing friction. Soap, vegetable oil, or other non-petroleum-based substances can be used to reduce the force required to make a Snap-Tite® connection. Place the lubricant on the male end of the Snap-Tite® Culvert Liner to reduce the chance that the gasket will be moved out of the groove during installation.

Mastic
A resin used to make adhesive cement. This is sometimes used in addition to the Snap-Tite® gasket to ensure a watertight connection.

Nose cone
A tapered shaped cut into the liner pipe to make it slide into place as the liner is pulled into place.

OD
Outside diameter is the measure of the actual outside diameter of the pipe liner.

Outlet Control
One of two types of flow control in culvert hydraulics where the barrel is not capable of conveying as much flow as the inlet opening will accept.

Retarder
Additives used to delay the time before the curing or setting up of a cement grout or concrete mix. Fly ash, when used, often acts as a retarder.

Ring compression strength
The term used to describe the strength of a pipe, tank or structure to resist collapse from compressive force(s) applied around the circumference of the pipe, tank or structure. Water applies this loading to a submerged pipe. Vacuum on the inside of a pipe can also apply this loading.

Riprap
Layer or facing of rock or broken concrete dumped or placed to protect a structure or embankment from erosion; also the rock or broken concrete suitable for such use.

RPS – Rehabilitated Pipe System
Refers to installing Snap-Tite® in an existing culvert and placing grout in between the liner and host pipe to create a rehabilitated pipe system.

Scour
Erosion of streambed or bank material due to flowing water; often considered as being localized.

Screen
A plate with openings of set sizes to allow only particles of that size or smaller to pass. A 16-mesh screen means that there are 16 holes per square inch. Each hole would be less than .25 inches in diameter.

Skids
Wooden, plastic, or metal blocks mounted on the bottom of Snap-Tite® or other reliner pipe used to facilitate the placement of Snap-Tite® in a host pipe. The use of skids are particularly useful when the host pipe grade and alignment is non-uniform.

Sliplining
The process of pulling or pushing a smaller pipe or liner inside of an existing host pipe or culvert.

Strength of grout
See Compressive Strength of Grout

Tailwater
The depth of water on the downstream side of a culvert measured from the outlet invert, and an important factor in outlet control culvert hydraulics.

Vents
Openings formed to allow the escape or entry of gas or liquid into or out of an enclosed area.

Voids
An empty space within a solid section. When air is trapped in the annular space between the liner and the culvert, grout cannot fill this space. A "void" is formed in the grout. There is a loss of strength in the grout because of the void.

Weight of grout
A term typically used to describe weight of one cubic foot of grout which would equal the density of the grout.

Terms and Conditions

All sales with ISCO Industries, Inc. ("Seller") are subjected to the following terms and conditions.

Acceptance: All sales are subject to the approval and acceptance by an authorized representative of Seller.

Cancellation: Any sale that is in the process of production or shipment is not subject to cancellation, deferment of delivery, or change of specification without the approval of an authorized representative of Seller.

Freight: Unless specifically stated that freight is allowed, all orders shall be F.O.B shipping point. When freight is allowed, the prices are F.O.B. from the shipment point, with freight allowed to specified destination. The point or origin of the shipment, the method of transportation, and the routing of shipments are at the discretion of Seller.

Returned Goods: Buyer shall not return any goods without obtaining authorization from Seller. Goods returned for credit must be in new condition and will be subjected to a minimum twenty-five percent (25%) restocking charge, F.O.B Seller shipping location. Only standard stocking items with a standard part number are eligible for return. Non-standard items, items shipped direct from a manufacturer, or specialty-made goods will not be accepted for return. Any items/structures/goods that require a Seller-furnished Work Order and/or a Computer Automated Drawing will not be accepted for return.

Performance: All promises as to the date of shipment are made in good faith. Seller will attempt to keep such promises by taking every reasonable precaution in the placing of its orders and obligating its manufacturers to ensure that they carry out their agreements. Since all manufacturers accepting orders specifically deny any liability for consequential damages this proposal is made with the distinct understanding that Seller will not be held liable for damages of any kind.

Limited Warranty: Products manufactured by Seller are warranted only to the extent that Seller will furnish replacement parts, free of charge, F.O.B. shipping location; or at Seller's option, will refund the purchase price of any product which, when installed and used was recommended by Seller and in accordance with the best installation and operating practices and techniques, is proven to be defective in material or workmanship within one (1) year from the date of shipment. Seller must receive immediate notice of the defect and the opportunity to inspect the same at the place of installation. Products sold by Seller which are manufactured by others are warranted only to the extent of, and are limited to, the warranty of the manufacturer.

The warranties set forth above are in lieu of all other warranties, express or implied, including the warranties of merchantability and fitness for a particular purpose. Seller shall not be liable to Buyer or any other party for negligence, strict liability, or any other delay, act, or error, for losses of any kind. Seller shall not be liable to Buyer or any other party for direct, indirect, special, or consequential damages.

Without limitation of the foregoing, Seller's liability to any other product whether by warranty or otherwise, shall in no event exceed the original purchase price of the warranted product.

The above stated limitations may be waived or modified only by writing signed by a duly authorized representative of Seller.

Payment Terms: All credit is subject to the approval of Seller's credit department. Unless otherwise noted in the terms of the sale, all sales are on Net 30 terms. A service charge in the amount of one-and-one half percent (1-1/2%) per month or eighteen percent (18%) per year or at the greatest amount permitted by law, will be added to any account thirty (30) days past due. Seller reserves the right to require full or partial payment in advance of shipment when the financial condition of the Buyer does not justify continuance of shipment on the terms of payment specified. Order from buyers with approved credit may be shipped C.O.D. after Buyer's approval.

Taxes: Prices do not include any present or future federal, state, or local taxes unless specifically stated. t is the responsibility of Buyer to assume all taxes. When applicable, taxes may be added to the purchase price and be paid by Buyer unless Buyer furnishes a tax-exemption certificate in a form agreeable to the respective authority.

Waiver, Modification: Waiver of Seller of any breach of these terms and conditions shall not be constructed as a waiver of any other breach. These terms and conditions represent the complete agreement between Buyer and Seller. No terms or conditions in any way adding to or modifying the provisions shall bind Seller; without written consent from a duly authorized representative of Seller.