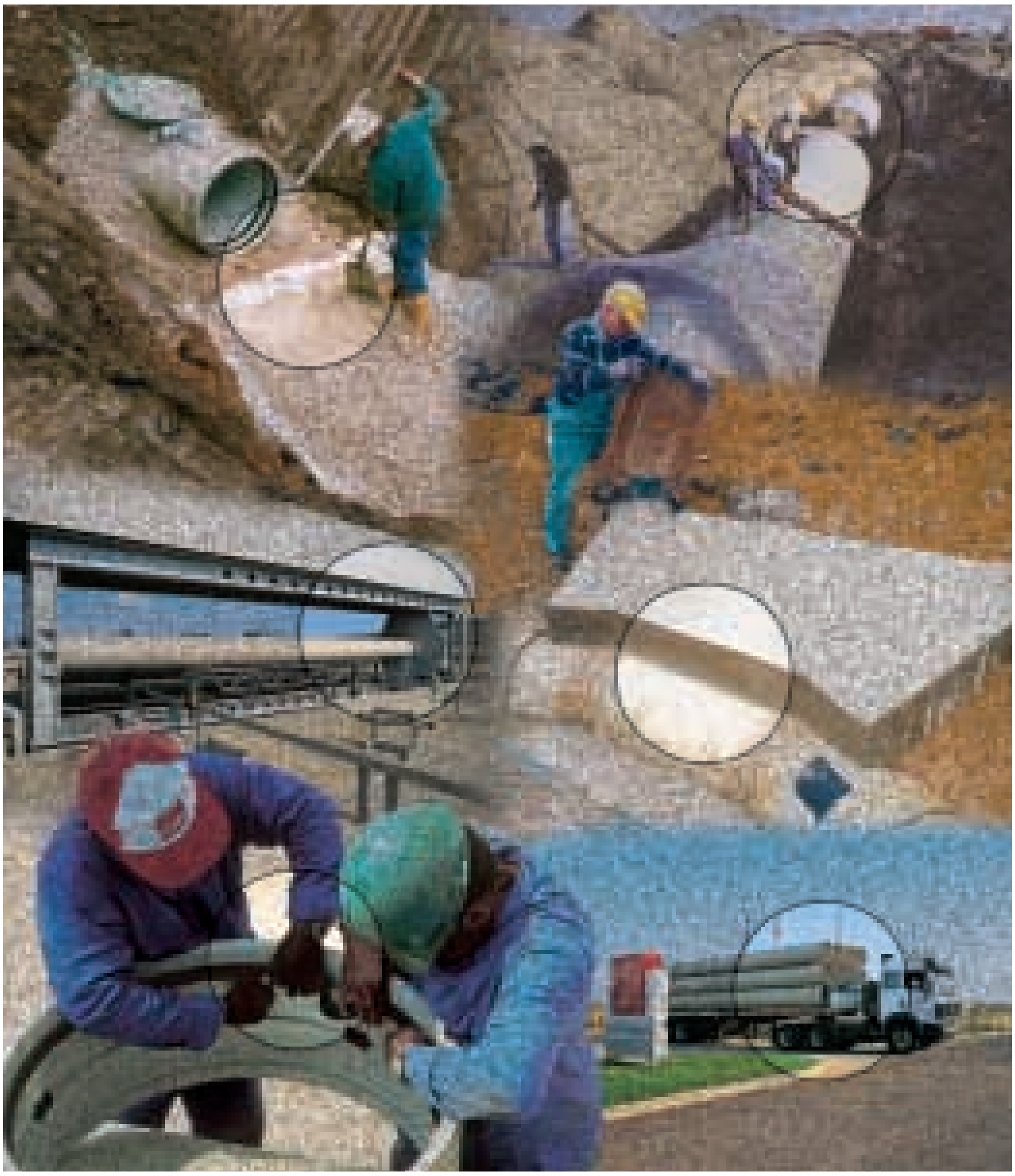
Installation Instructions



Buried Pipe

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Introductory Information

1.1 Foreword

This guide is intended to assist the installer in understanding the requirements and procedures for the successful handling and buried installation of FLOWTITE® pipe. It may also be a helpful source of data for project engineers, although it is *not* a design or system-engineering manual.

We have tried to address the unusual, as well as usual, circumstances that may be encountered in the field; however, it is certain that unique situations requiring special consideration will occur. When this happens, ask the supplier for help.

Also, installations other than direct bury, such as subaqueous or above ground, are not discussed. Consult the supplier for suggested procedures and limitations in these cases.

Most importantly, this guide is not meant to replace common sense, good engineering judgment, safety regulations or local ordinances, nor the specifications and instructions of the owner's engineer, who is the final authority on all jobs. Should conflicts in any of this information create doubts as to how to proceed properly, please consult the supplier and the owner's engineer to obtain assistance.

1.2 Introduction

The excellent corrosion resistance and many other benefits of FLOWTITE pipe will be realized if the pipe is properly installed. FLOWTITE pipe is designed considering the bedding and pipe zone backfill support that will result from these recommended installation procedures. Together, the pipe and embedment material form a high-performance "pipe/soil system."

These instructions are easy to follow and monitor. A good indication of the quality of the installation achieved is immediately verifiable by measuring the vertical diametrical deflection of the buried pipe and by inspecting the pipe shape. Initial deflections of the completely backfilled pipe should not exceed the values in Table 4.1. Bulges, flat areas or other abrupt changes of curvature are not permitted.

Judgement of installation acceptability by measurement of initial deflection is valid only when the specified installation procedures have been followed, enabling long-term effects to be reliably predicted.

The installation procedures outlined in this brochure and the suggestions of the Field Service Representatives, when carefully followed, will help assure a proper, long-lasting installation. Consult the supplier on any questions or when variations in these instructions are being considered.

1.3 Field Service Representative

The supplier can provide a Field Service Representative. The Field Service Representative will advise the installer to help him achieve a satisfactory pipe installation. The "on the job" field service will be available early in the installation and may continue periodically throughout the project. The service will range from continuous (essentially full time) to intermittent depending on the job schedule, complexity and installation results.

1.4 Fire Safety

Glass-reinforced polyester (GRP) pipe, like virtually all pipe made with petrochemicals, can burn and is, therefore, not recommended for use in applications which are exposed to intense heat or flames. During installation, care must be taken to avoid exposure of the pipe to welder's sparks, cutting-torch flames or other heat/flame/electrical sources which could ignite the pipe material.

This precaution is particularly important when working with volatile chemicals in making layup joints, repairing or modifying the pipe in the field.

Shipping, Handling and Storage

2.1 Inspecting Pipe

All pipe should be inspected upon receipt at the job site to insure that no damage has occurred in transit. Depending on length of storage, amount of job site handling and other factors that may influence the pipes' condition, it may be wise to reinspect the pipe just prior to installation. Inspect the shipment upon delivery, as follows:

1. Make an overall inspection of the load. If the load is intact, ordinary inspection while unloading will normally be sufficient to make sure the pipe has arrived without damage.
2. If the load has shifted or indicates rough treatment, carefully inspect each pipe section for damage. Generally, an exterior inspection will be sufficient to detect any damage. When pipe size permits, an interior inspection of the pipe surface at the location of an exterior scrape may be helpful to determine if the pipe is damaged.
3. Check the quantity of each item against the bill of lading.
4. Note on the bill of lading any transit damage or loss and have the carrier representative sign your copy of the receipt. Make prompt claim against the carrier in accordance with their instructions.
5. Do not dispose of any damaged items. The carrier will notify you of proper disposal procedure.
6. If any imperfection or damage is found, immediately segregate the affected pipes and contact the supplier.

Do not use pipe that appears damaged or defective.

If the Field Service Representative is present at the time of your inspection(s), he will be glad to assist you.

2.2 Repairing Pipe

Normally, pipes with minor damage can be repaired quickly and easily at the job site by a qualified individual. **If in doubt about the condition of a pipe, do not use the pipe.**

The Field Service Representative can help you determine whether repair is required and whether it is possible and practical. He can obtain the appropriate repair specification and arrange for the required materials and a trained repair technician, if desired. Repair designs can vary greatly due to pipe thickness, wall composition, application, and the type and extent of the damage. Therefore, **do not attempt to repair a damaged pipe without consulting the supplier first. Improperly repaired pipes may not perform as intended.**

2.3 Unloading and Handling Pipe

Unloading the pipe is the responsibility of the customer. Be sure to maintain control of the pipe during unloading. Guide ropes attached to pipes or packages will enable easy manual control when lifting and handling. Spreader bars may be used when multiple support locations are necessary. Do not drop, impact, or bump the pipe, particularly at pipe ends.

Unitized Loads

Generally, pipes 600 mm and smaller in diameter are packaged as a unit. Unitized loads may be handled using a pair of slings as shown in Figure 2.1. Larger diameters may be delivered in unitized packages also. Consult the supplier if you are in doubt as to the type of packaging you have received. **Do not lift a non-unitized stack of pipes as a single bundle. Non-unitized pipes must be unloaded and handled separately (one at a time).**

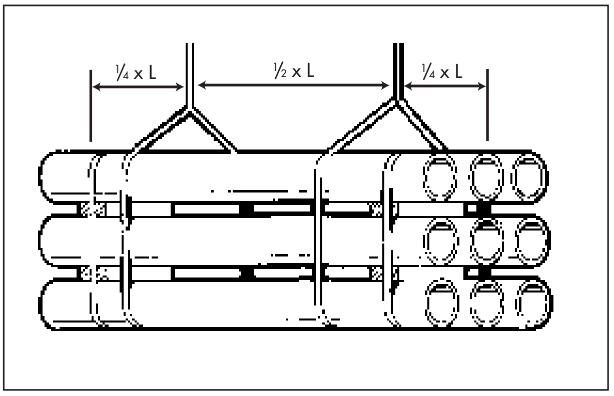


Figure 2.1
Lifting unitized package

Single Pipes

When handling single pipes, use pliable straps, slings or rope to lift. Do not use steel cables or chains to lift or transport the pipe. Pipe sections can be lifted with only one support point (Figure 2.2) although two support points placed as in Figure 2.3 make the pipe easier to control. **Do not lift pipes by passing a rope through the section end to end.**

See Appendix A for approximate weights of standard pipes and couplings.

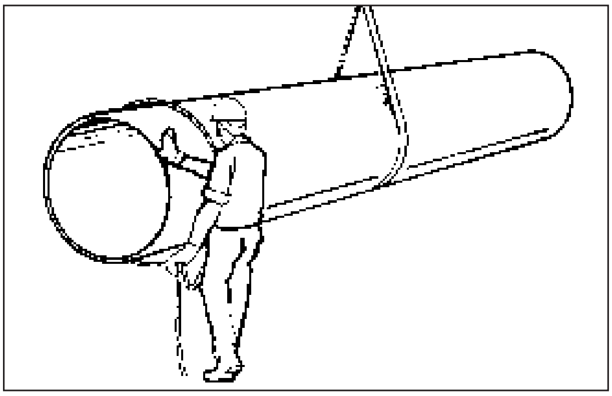


Figure 2.2
Lifting pipe at one support point

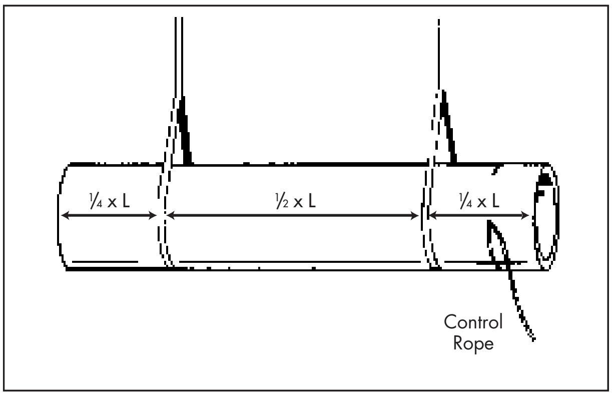


Figure 2.3
Lifting pipe at two support points

If at any time during handling or installation of the pipe, any damage such as a gouge, crack or fracture occurs, the pipe should be repaired before the section is installed. **Contact the supplier for inspection of damage and for recommendation for repair method or disposal. See previous section on Repairing Pipe.**

2.4 Site Pipe Storage

It is generally advantageous to store pipe on flat timber to facilitate placement and removal of lifting slings around the pipe.

When storing pipe directly on the ground, be sure that the area is relatively flat and free of rocks and other potentially damaging debris. All pipes should be chocked to prevent rolling in high winds.

If it is necessary to stack pipes, it is best to stack on flat timber supports (minimum width of 75 mm) at maximum 6 meter spacing (3 meter for small diameter) with chocks. (See Figure 2.4.) If it is available, use the original shipping dunnage.

Insure the stack will be stable for conditions such as high winds, unlevel storage surface or other horizontal loads. If strong winds are anticipated consider using ropes or slings to tie pipes down. Maximum stack height is approximately 3 meters. Stacking of pipes larger than 1400 mm diameter is not recommended.

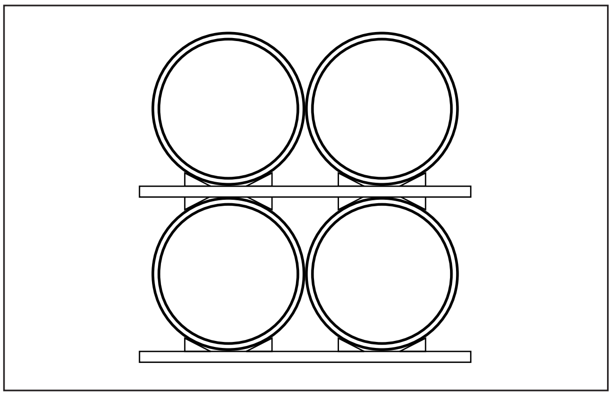


Figure 2.4
Storing pipe

MAXIMUM DIAMETRICAL DEFLECTION MUST NOT EXCEED THE VALUES IN TABLE 2.1. BULGES, FLAT AREAS OR OTHER ABRUPT CHANGES OF CURVATURE ARE NOT PERMITTED. STORING OF PIPES OUTSIDE OF THESE LIMITATIONS MAY RESULT IN DAMAGE TO THE PIPES.

Table 2.1 Maximum Storage Deflection

Stiffness Class SN	Maximum Deflection (% of Diameter)
2500	2.5
5000	2.0
10000	1.5

2.5 Storing Gaskets and Lubricant

Rubber ring gaskets, when shipped separate from the couplings, should be stored in the shade in their original packaging and should not be exposed to sunlight except during the pipe joining. Also, the gaskets must be protected from exposure to greases and oils which are petroleum derivatives, and from solvents and other deleterious substances.

Gasket lubricant should be carefully stored to prevent damage to the container. Partially used buckets should be resealed to prevent contamination of the lubricant.

If temperatures during installation are below 5°C gaskets and lubricant should be sheltered until used.

Shipping, Handling and Storage (continued)

2.6 Transporting Pipe

If it is necessary to transport pipes at the job site, it is best to use the original shipping dunnage when loading the truck. If this material is no longer available, support all pipe sections on flat timbers spaced on a maximum of 4 meter centers (3 meter for small diameter) with a maximum overhang of 2 meters. Chock the pipes to maintain stability and separation. Insure no pipes contact other pipes, so vibrations during transport will not cause abrasion (Figure 2.5).

Maximum stack height is approximately 2 1/2 meters. Strap pipe to the vehicle over the support points using pliable straps or rope – never use steel cables or chains without adequate padding to protect the pipe from abrasion. Also, maximum diametrical deflection must not exceed the values in Table 2.1. Bulges, flat areas or other abrupt changes of curvature are not permitted. Transport of pipes outside of these limitations may result in damage to the pipes.

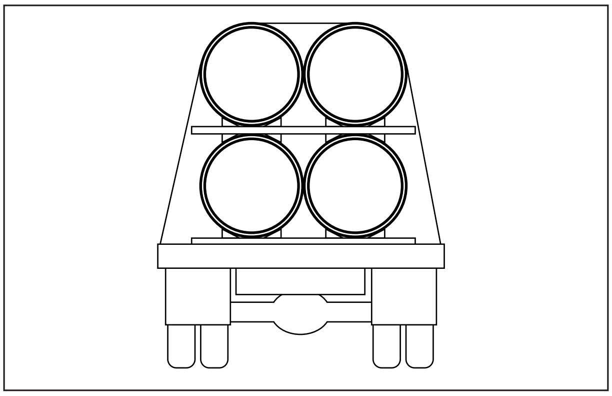


Figure 2.5
Transporting pipe

2.7 Handling Nested Pipes

Pipes to be shipped long distances may be nested (smaller diameter pipes inside of larger sizes) to reduce the transportation cost. These pipes generally have special packaging and may require special procedures for unloading, handling, storing and transporting. Special practices, if required, will be furnished by the pipe supplier prior to shipment. Regardless, the following general procedures should always be followed:

1. Always lift the nested bundle using at least two pliable straps (Figure 2.6). Limitations, if any, for spacing between straps and lifting locations will be specified for each project. Insure that the lifting slings have sufficient capacity for the bundle weight. This may be calculated from the approximate pipe weights given in Appendix A.

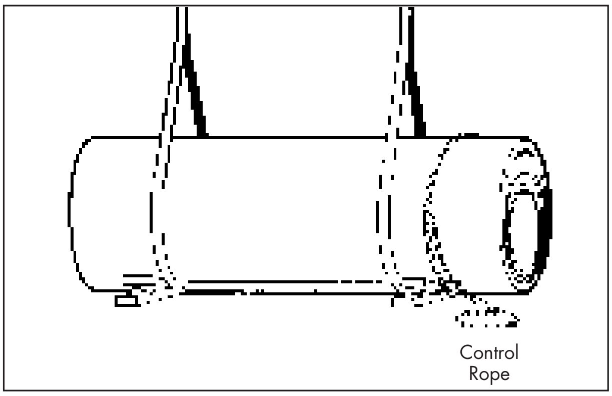


Figure 2.6
Double support point

2. Nested pipes are usually best stored in the transport packaging. Stacking of these packages is not advised unless otherwise specified.
3. Nested pipe bundles can only be safely transported in the original transport packaging. Special requirements, if any, for support, configuration and/or strapping to the vehicle will be specified for each project.
4. Package removal and denesting of the inside pipe(s) is best accomplished at a denesting station. Typically, this consists of three or four fixed cradles to fit the outside diameter of the largest pipe of the bundle. Inside pipes, starting with the smallest size may be removed by lifting slightly with an inserted padded boom to suspend the section and carefully move it out of the bundle without touching the other pipes (Figure 2.7). When weight, length and/or equipment limitations preclude the use of this method, procedures for sliding the inside pipe(s) out of the bundle will be recommended for each project.

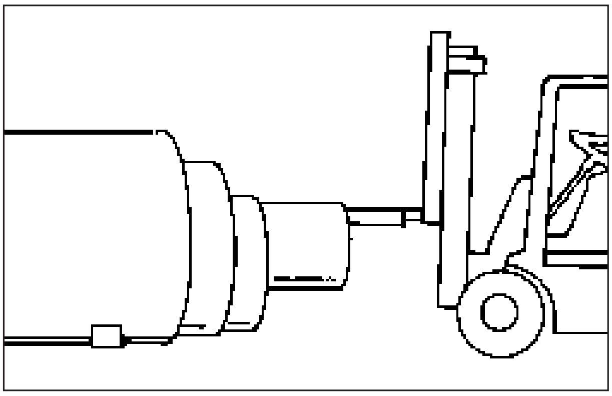


Figure 2.7
Denesting with padded boom on forklift truck

Joining Pipes

FLOWTITE pipe sections are typically joined using FLOWTITE double bell couplings. Pipe and couplings may be supplied separately or the pipe may be supplied with a coupling installed on one end.

The couplings may be supplied with or without an elastomeric center stop register. Factory installed couplings will have the elastomeric stop register.

Other joining systems such as flanges, mechanical couplings and layup joints may also be used for joining FLOWTITE pipe.

3.1 FLOWTITE Double Bell Couplings

Cleaning and Gasket Installation

The following steps (1 to 4) apply to all FLOWTITE double bell coupling joining procedures.

Step 1: Clean Coupling

Thoroughly clean double bell coupling grooves and rubber gasket rings to make sure no dirt or oil is present (Figure 3.1).

Step 2: Install Gaskets

Insert the gasket into the groove leaving loops (typically two to four) of rubber extending out of the groove. Do not use any lubricant in the groove or on the gasket at this stage of assembly. Water may be used to moisten the gasket and groove to ease positioning and insertion of the gasket (Figure 3.2).

With uniform pressure, push each loop of the rubber gasket into the gasket groove.

When installed, pull carefully on the gasket in the radial direction around the circumference to distribute compression of the gasket.

Check also that both sides of the gasket protrude equally above the top of the groove around the whole circumference.

Tapping with a rubber mallet will be helpful to accomplish the above.

Step 3: Lubricate Gaskets

Next, using a clean cloth, apply a thin film of lubricant to the rubber gaskets (Figure 3.3). See Appendix B for normal amount of lubricant consumed per joint.

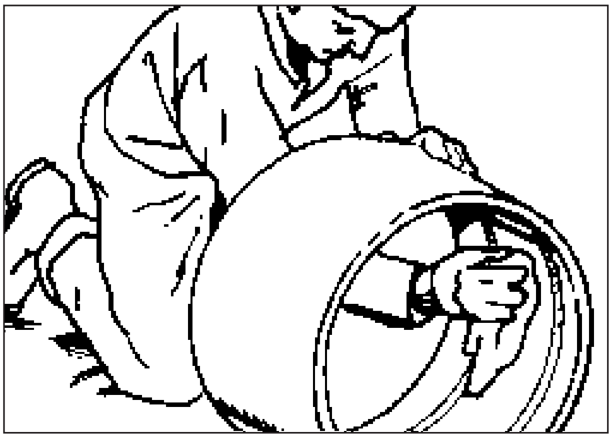


Figure 3.1
Cleaning coupling

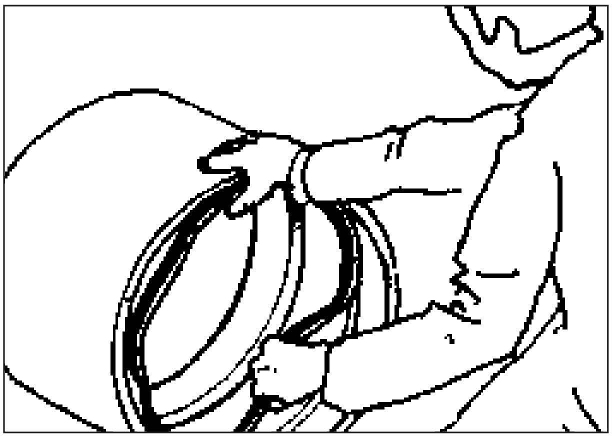


Figure 3.2
Installing gaskets

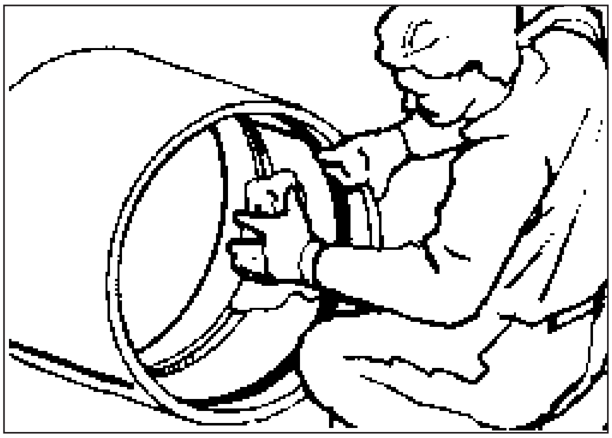


Figure 3.3
Lubricating gaskets

FLOWTITE Joining Pipes (continued)

Step 4: Clean and Lubricate Spigots

Thoroughly clean pipe spigots to remove any dirt, grit, grease, etc. Using a clean cloth, apply a thin film of lubricant to the spigots from the end of the pipe to the black alignment stripe. After lubricating, take care to keep the coupling and spigots clean (Figure 3.4).

Caution: It is very important to use only the correct lubricant. The supplier provides sufficient lubricant with each delivery of couplings. If for some reason you run out, please contact the supplier for additional supply or advice on alternative lubricants. Never use a petroleum based lubricant.

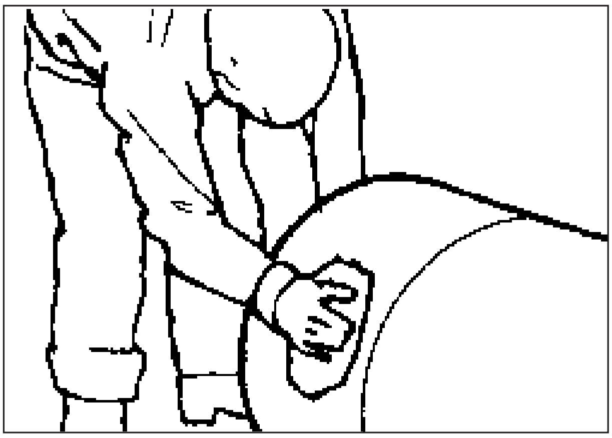


Figure 3.4
Cleaning spigot

Joining Without Center Register

The following steps (5 to 8) apply to joining separate pipe and couplings without the elastomeric center stop register.

Step 5: Fixing of Clamps

Clamp A is fixed anywhere on the first pipe or left in position from the previous joint. Fix Clamp B on the pipe to be connected in the correct position relative to the alignment stripe on the spigot-end so as also to act as a stopper (Figure 3.5).

Note: The mechanical installation clamp is to act both as a stop to position the coupling and as a device on which to attach the pulling (come-along jacks) equipment. Clamp contact with the pipe shall be padded or otherwise protected to prevent damage to the pipe and to have high friction resistance with the pipe surface. If clamps are not available, nylon slings or rope may be used as in Figure 3.6, but care must be taken in the alignment of the coupling. A pipe clamp has the advantage of acting as a stopper, preventing over-insertion. If a clamp is not used, insert the pipe spigots until the homeline (alignment stripe) aligns with the coupling edge.

Step 6: Pipe Placement

The pipe to be connected is placed on the bed with sufficient distance from previously joined pipe to allow lowering the coupling into position.

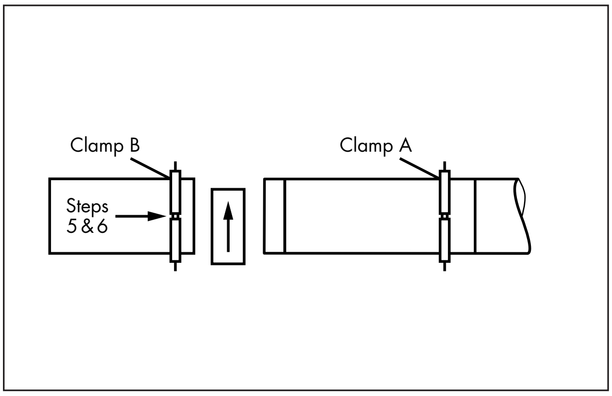


Figure 3.5
Clamp locations

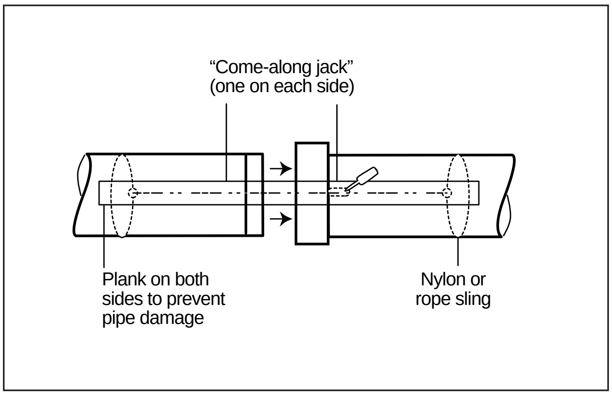


Figure 3.6
Pipe joining without clamps

Step 7: Join Coupling

Come-along jacks are installed to connect the pipe clamps and two 10 cm by 10 cm timbers or similar (larger diameters may require a bulkhead) are placed between the pipe previously connected and the coupling (Figure 3.7). While these are held in position the new pipe is entered into the coupling until it rests against the pipe clamp. Come-along jack might need protective plank under it in order not to touch against the pipe (Figure 3.6).

Note: Approximate joining force 1 kg per mm of diameter.

Note: For smaller diameter (100 mm-250 mm) it may be possible to join pipe and coupling without the use of come-along jacks. The use of levers is common to join small diameters.

FLOWTITE Joining Pipes (continued)

Step 8: Join Pipes

Come-along jacks are loosened and the timbers removed before retightening the jacks for entering the coupling onto the previously connected pipe. Check for correct position of the edge of the coupling to the alignment stripe (Figure 3.8).

Confirm that the gaskets are in proper position after the joint has been assembled. A useful technique is to insert between the coupling and the spigot a very thin strip of smooth metal (commonly called a "feeler gage") and then slide around the circumference of the assembled joint. This will help detect any improperly positioned gasket.

Note: When Step 8 has been completed, Clamp B is left in position while Clamp A is moved on to the next pipe to be joined.

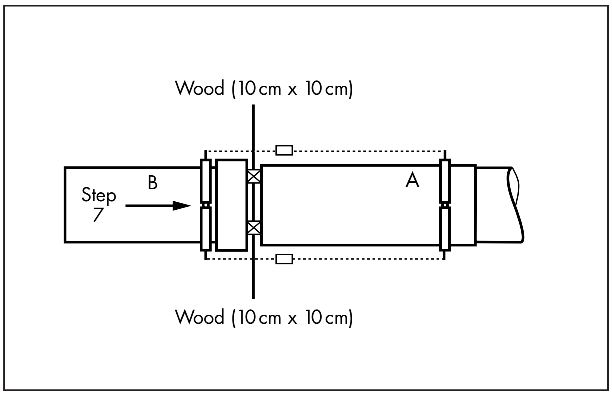


Figure 3.7
Join coupling

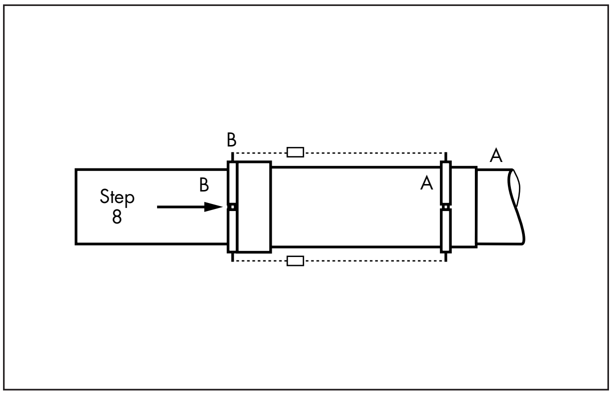


Figure 3.8
Pipe joining

Joining with Center Register

The same basic joining procedures are followed except that:

- The position of Clamp B does not need to be precisely located and,
- Spigots are inserted until both contact the center stop register.

The register maintains pipe ends in proper position without direct reference to alignment stripes.

Note: It is recommended that pipes be backfilled as soon as possible after joint assembly to prevent movement from temperature change. If substantial temperature increase (i.e., 20°C) is expected for unbackfilled pipe, then compensation for possible movement may be achieved by leaving a gap of up to 20 mm between spigot ends.

Joining with Prefixed FLOWTITE Coupling

The factory installed coupling will have the center stop register. Thus the joining step of first installing the coupling on the pipe is eliminated.

Angular Deflection of FLOWTITE Double Bell Couplings

Maximum angular deflection (turn) at each coupling joint must not exceed the amounts given in Tables 3.1 and 3.2. The pipes should be joined in straight alignment and thereafter deflected angularly as required. (See Figure 3.9 for definition of terms.)

Table 3.1 Angular Deflection at Double Coupling Joint

Nom. Pipe Diameter (mm)	Pressure (PN) in bars up to 16	20	25	32
	Nom. Angle of Deflection (deg)			
DN ≤ 500	3.0	2.5	2.0	1.5
500 < DN ≤ 900	2.0	1.5	1.3	1.0
900 < DN ≤ 1800	1.0	0.8	0.5	0.5
1800 > DN	0.5	NA	NA	NA

Table 3.2 Offset and Radius of Curvature

Angle of Deflection (deg)	Nominal Offset (mm) pipe length 3 m	6 m	12 m	Nominal Radius of Curvature (m) Pipe Length 3 m	6 m	12 m
3.0	157	314	628	57	115	229
2.5	136	261	523	69	137	275
2.0	105	209	419	86	172	344
1.5	78	157	313	114	228	456
1.3	65	120	240	132	265	529
1.0	52	105	209	172	344	688
0.8	39	78	156	215	430	860
0.5	26	52	104	344	688	1376

Note: The above is for information purposes. The minimum allowable length is a function of nominal pressure and backfill type and compaction. See pipe supplier for specific information.

Joining Pipes (continued)

Angular deflected coupling joints are stabilized by the stiffness of the soil surrounding the pipe and coupling. Pressure pipes (PN>1) should have angularly rotated joints backfilled to 90% relative compaction.

Coupling joints that are placed with vertical angular rotation should be backfilled to a minimum cover depth of 1.2 meters for pressures of PN16 and greater.

Pipe Misalignment

The maximum misalignment of adjacent pipe ends is 5 mm (See Figure 3.10). It is recommended the misalignment be monitored near thrust blocks, valve chambers and similar structures, and at closure or repair locations.

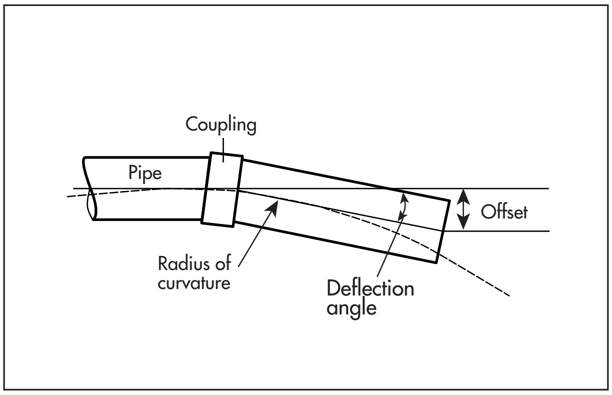


Figure 3.9
Double bell coupling, angular joint deflection

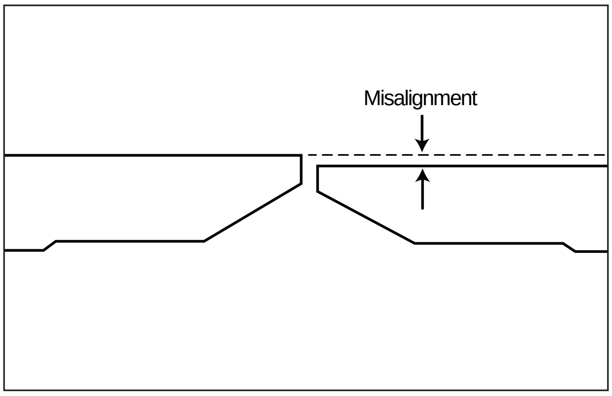


Figure 3.10
Misalignment

3.2 Flanged Joints

GRP flanges should be joined according to the following procedure: (Figure 3.11.)

1. Thoroughly clean the flange face and the 'O' ring groove.
2. Ensure the 'O' ring gasket is clean and undamaged. Do not use defective gaskets.
3. Position 'O' ring in groove and secure in position with small strips of adhesive tape.
4. Align flanges to be jointed.
5. Insert bolts, washers and nuts. All hardware must be clean and lubricated to avoid incorrect tightening. Washers must be used on all GRP flanges.
6. Using a torque wrench, tighten all bolts to 35 N•m (25 lb.-ft.) torque, [20 N•m (15 lb.-ft.) for small diameter] following standard flange bolt tightening sequences.
7. Repeat this procedure, raising the bolt torque to 70 N•m (50 lb.-ft.), [35 N•m (25 lb.-ft.) for small diameter] or until the flanges touch at their inside edges. *Do not exceed this torque.* To do so may cause permanent damage to GRP flanges.
8. Check bolt torques one hour later and adjust if necessary to 70 N•m [35 N•m for small diameter].

Note: When connecting two GRP flanges, only one flange should have a gasket groove in the face.

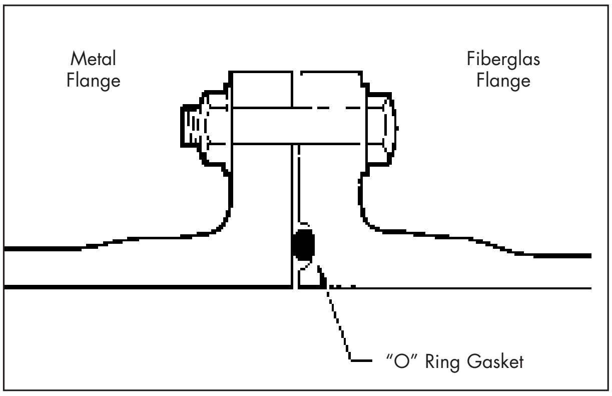


Figure 3.11
Flange joint

Joining Pipes (continued)

3.3 Other Joining Methods

Flexible Steel Couplings
(Straub, Tee Kay, Arpol, etc. – See Figure 3.12)

When connecting FLOWTITE pipe to other pipe materials with different diameters, flexible steel couplings are one of the preferred jointing methods. These couplings consist of a steel mantle with an interior rubber sealing sleeve. They may also be used to join FLOWTITE pipe sections together, for example in a repair or for closure.

Three grades are commonly available:

A Epoxy or PVC-coated steel mantle
B Stainless steel mantle
C Hot dip galvanized steel mantle

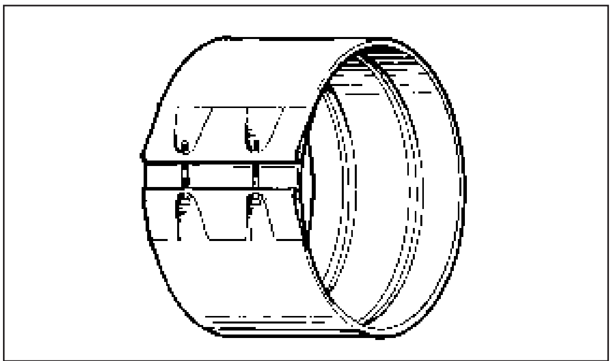


Figure 3.12
Flexible steel coupling

Regardless of the corrosion protection applied to the steel mantle, the balance of the coupling needs to be corrosion protected as well. Typically this involves the application of a shrink fit polyethylene sleeve over the installed coupling.

Control of the bolting torque of flexible steel couplings is most important. Do not over torque as this may over stress the bolts or the pipe. Follow the coupling manufacturer's recommended assembly instructions, but with the pipe supplier's recommended bolt torque limits.

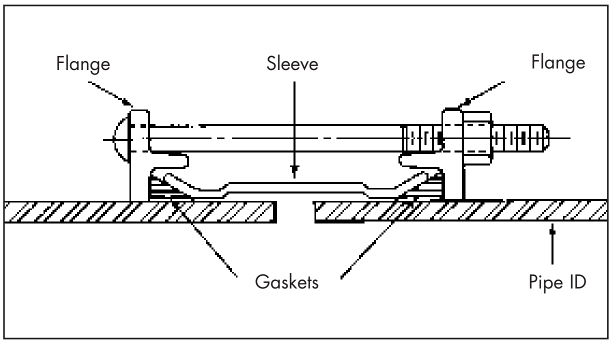


Figure 3.13
Mechanical steel coupling

Mechanical Steel Couplings
(Viking Johnson, Helden, Klamflex, etc. – See Figure 3.13)

Mechanical couplings have been used to join pipes of different materials and diameters, and to adapt to flange outlets. Flowtite Technology has found a wide manufacturing variance in these couplings, including bolt size, number of bolts and gasket design which makes standardized recommendations impossible.

Consequently, we cannot recommend the general use of mechanical couplings with FLOWTITE pipe. If the installer intends to use a specific design (brand and model) of mechanical coupling, he is advised to consult with the local FLOWTITE pipe supplier prior to its purchase. The pipe supplier can then advise under what specific conditions, if any, this design might be suitable for use with FLOWTITE.

3.4 Layup Joints

This joint is made from glass fiber reinforcements and polyester resin. It is typically used in situations where it is required to withstand axial forces from internal pressure **(which requires pipe specifically designed to accept axial pressure thrust forces)** or as a repair method. The length and thickness of the layup depends on diameter and pressure (Figure 3.14).

This type of joint requires clean, controlled conditions and skilled, trained personnel. Special instructions will be provided when this type of joint is required.

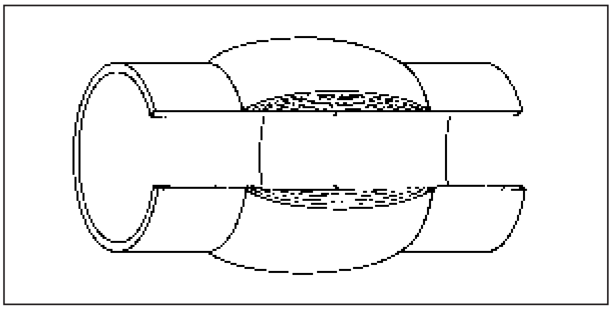


Figure 3.14
Layup joint

Standard Installation

The type of installation appropriate for FLOWTITE pipe varies with pipe stiffness, cover depth, native soil characteristics and available backfill materials.

The native material must adequately confine the pipe zone backfill (see Figure 4.1) to achieve proper pipe support. The following installation procedures are intended to assist the installer in achieving an acceptable pipe installation. However, regardless of soil conditions and installation method, the initial and long-term deflections must not exceed the values given in Table 4.1. Pipes installed outside these limits may not perform as intended.

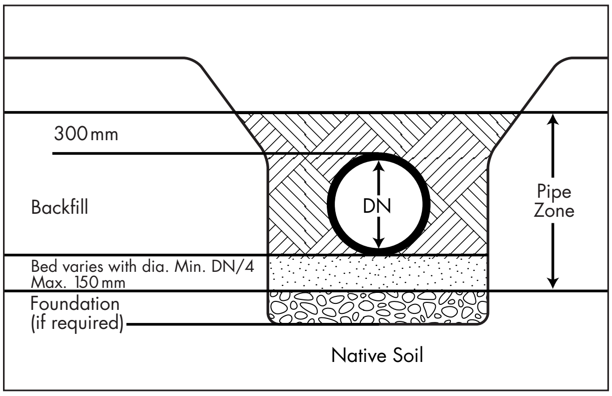


Figure 4.1
Pipe backfill nomenclature

In Table 4.2 are brief descriptions of the native soil groups. Appendix C gives detailed definitions for the native soil groups. Testing of native soil should be done frequently and particularly where changes are suspected. Properties of importance are those obtained at the bed and pipe zone elevation. The blow counts or soil strengths must represent the most severe (weakest) condition expected to exist for any significant period of time. (Normally this occurs when the water table is at its highest elevation.)

Appendices C through F give detailed information on both native and backfill soils.

Appendix C – Classification and Properties of Native Soils
Appendix D – Classification and Properties of Backfill Soils
Appendix E – Field Testing to Assist Classification of Native Soils
Appendix F – Compaction of Backfill
Appendix G – Definitions and Terminology

Table 4.1 Allowable Vertical Deflection

	Deflection % of Diameter
Large Diameter (DN ≥ 300)	
Initial	3.0
Long Term	5.0
Small Diameter (DN ≤ 250)	
Initial	2.5
Long Term	4.0

Table 4.2 Native Soil Group Classification

Soil Group	1	2	3	4	5	6
Cohesive	very stiff	stiff	medium	soft	very soft	very, very soft
Granular	compact	slightly compact	loose	very loose	very loose	very, very loose

4.1 Basic Installation

Long life and good performance characteristics for FLOWTITE pipe can be achieved by proper handling and installation. It is important for the owner, engineer and contractor to understand that glass-reinforced plastic (GRP) pipe is designed to utilize the bedding and pipe zone backfill support from recommended installation procedures. Together, the pipe and embedment material form a "pipe-soil system" that provides support for the installation.

Engineers have found through considerable experience that properly compacted granular materials are ideal for backfilling pipe, including GRP pipes. However, in an effort to reduce the cost of installing pipes, very often the excavated trench soils are used as pipe zone backfill. Recognizing this need, Flowtite Technology engineers have developed burial limitations for FLOWTITE pipe based on the use of six different soil groups ranging from crushed stone to low plasticity fine-grained soils.

Installation procedures simplified

For short lines or those requiring minimal engineering, use the following guidelines:

For any pipe stiffness
Backfill material: gravel, at 70% relative compaction or sand at 90% compaction (Proctor density).

Use of either material will meet the following parameters:

Burial depth	≥ 1 m and ≤ 9 m
Live load	Up to AASHO H20
Pressure	≤ 16 bar
Negative pressure	≤ -.25 bar
Native soil	Group 1, 2 or 3
Trench	Type I, Standard width

For long pipelines, or those with complex installation needs, follow the process outlined in this section.

Standard Installation (continued)

4.2 Standard Trench Width

Dimension "A" (see Figure 4.2) must always be wide enough to allow for adequate space to ensure proper placement of backfill in the haunch region and to operate compaction equipment. Typically dimension "A" is a minimum of $\frac{0.75\,DN}{2}$. The depth limit tables are based on a trench width of 1.75 DN. For larger diameter pipes a smaller value for "A" may be adequate depending on the native soil, backfill material and compaction technique. As an example for native soil groups 1,2 and 3 and backfill materials A and B which require limited compactive effort, a narrower trench could be considered. Consult the pipe supplier for specific guidance and modifications.

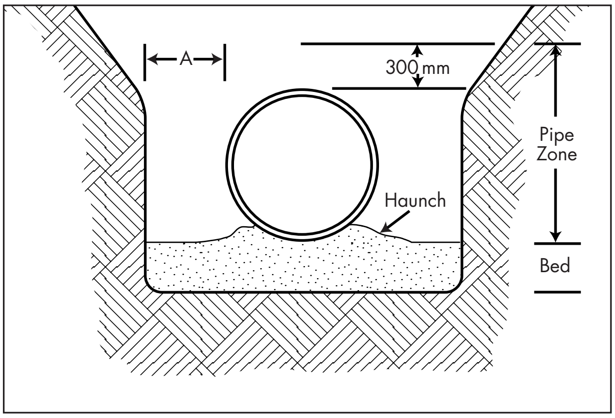


Figure 4.2
Trench

Note: Where rock, hard pan, soft, loose, unstable or highly expansive soils are encountered in the trench bottom, it may be necessary to increase the depth of the bedding layer to achieve uniform longitudinal support.

4.3 Backfill Materials

Table 4.3 groups backfill materials into categories. The group "A" backfill soils are the easiest to use and require the least compactive effort while the group "F" backfill soils will require the greatest compactive effort to achieve a given level of relative compaction.

Regardless of the backfill grouping and whether the backfill soil is imported or is the "native" soil excavated from the pipe trench the following general restrictions apply:

1. The maximum particle size and stone size must respect the limits given in Table 4.4.
2. No soil clumps greater than two times the maximum particle size.
3. No frozen material.
4. No organic materials.
5. No debris (tires, bottles, metals, etc.).

Table 4.3

Backfill Soil Group	Description of Backfill Soils
A	Crushed stone, 12% fines
B	Sand, <12% fines
C	Silty Sand, 12-35% fines, LL<40%
D	Silty, clayey sand, 35-50% fines, LL<40%
E	Sandy, clayey silt, 50-70% fines, LL<40%
F	Low plasticity fine grained soil, LL<40%

Table 4.4 Maximum Particle Size

The maximum particle size in the pipe zone (up to 300 mm over the pipe crown) is per the following:

DN	Max Size (mm)
Up to 450	13
500 to 600	19
700 to 900	25
1000 to 1200	32
1300 & Greater	38

In addition stones larger than 200 mm in diameter should not be dropped on the 300 mm layer covering the pipe crown from a height greater than 2 meters.

4.4 Backfill Soil Modulus (E'b)

The measure of the level of backfill soil support (strength), is expressed as the soil modulus E'b in MPa. For any given backfill soil group the higher the compaction the higher the soil modulus and the higher the support. Tables 4.5 and 4.6 give the E'b values for the backfill soil groups as a function of the relative compaction – % max. Standard Proctor Density (SPD) for non-saturated and saturated soils respectively.

Selection of the backfill soil group and level of relative compaction required for a particular installation will be based on the project conditions including factors such as:

- Nominal pressure (PN).
- Nominal stiffness (SN).
- Nominal diameter (DN).
- Required burial depth.
- Compatibility with in situ native soils.
- Ground water table.

By comparing the project needs with the available backfill materials and level of compaction required the optimum (lowest cost) installation can be achieved.

Backfill groups D, E and F should not be used as bedding or pipe zone backfill materials if there is standing water in the trench. Backfill types A, B or C must be used in areas where standing water exists in the trench. These materials must be used to a level of at least 150 mm over the observed standing water level.

Note: See following section on migration criteria.

Table 4.5 Backfill Modulus of Passive Resistance (Non-Saturated)

Backfill Type	E'b Values (MPa) at Relative Compaction[1] 80%	85%	90%	95%
A	16	18	20	22
B	7	11	16	19
C	6	9	14	17
D	3	6	9	10[2]
E	3	6	9	10[2]
F	3	6	9[2]	10[2]

1. 100% relative compaction defined as maximum Standard Proctor Density at optimum moisture content.
2. Values typically difficult to achieve, included as reference.

Table 4.6 Backfill Modulus of Passive Resistance (Saturated)

Backfill Type	E'b Values (MPa) at Relative Compaction[1] 80%	85%	90%	95%
A	12	13	14	15
B	5	7	10	12
C	2	3	4	4
D	1.7	2.4	2.8	3.1[2]
E	NA[3]	1.7	2.1	2.4[2]
F	NA[3]	1.4	1.7[2]	2.1[2]

1. 100% relative compaction defined as maximum Standard Proctor Density at optimum moisture content.
2. Values typically difficult to achieve, included as reference.
3. Not recommended for use.

4.5 Backfill Migration Criteria

When selecting the backfill material, it is necessary to check its compatibility with the native soil. It is very important that the pipe zone backfill material not wash away or migrate into the native soil. Likewise, potential migration of the native soil into the pipe zone backfill must be prevented. Should this happen, the pipe may lose its side support, deflect excessively and not perform as intended. Typically, migration can only occur if there is movement of water in the pipe zone and the following relationship exists between the two adjacent soils:

D_{85} finer ≤ 0.2D15 coarser

where:

D_{85} finer = sieve opening passing 85% of the finer material

D_{15} coarser = sieve opening passing 15% of the coarser material (Figure 4.3)

Where incompatible materials must be used, they must be separated by filter fabric designed to last the life of the pipeline to prevent wash-away and migration. The filter fabric must completely surround the bedding and pipe zone backfill material and must be folded over the pipe zone area in order to prevent contamination of the selected backfill material.

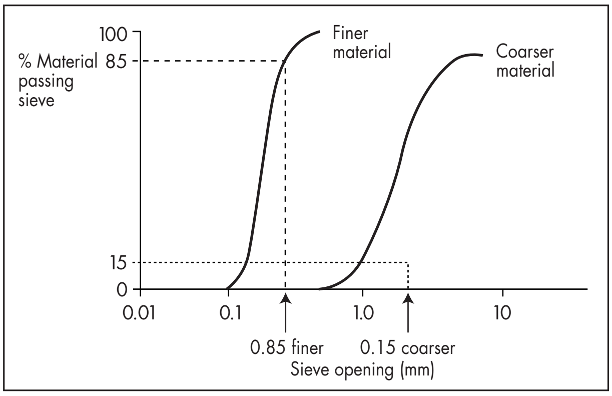


Figure 4.3
Backfill migration criteria

4.6 Burial Limitations – Maximum

Because FLOWTITE pipes are flexible conduits, they must be supported by the surrounding soil to carry the overburden loads. The maximum allowable cover depths are related to the type of pipe zone backfill material and its compaction (density), native soil characteristics, trench construction and pipe stiffness.

Two standard installation types are available (Figure 4.4). The selection depends on the native soil characteristics, the backfill materials, required depth of bury and the pipe operating conditions. The Type 2, "split," installation is generally more utilized for applications of lower pressure, light duty traffic loading and limited negative pressure (vacuum) requirement.

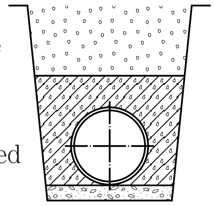
Tables 4.7 give maximum burial depths for:

Table 4.7A – Installation Type 1, no traffic load
Table 4.7B – Installation Type 1, with traffic load
Table 4.7C – Installation Type 2, no traffic load
Table 4.7D – Small Diameter Pipe

Standard Installation (continued)

Figure 4.4
Installations

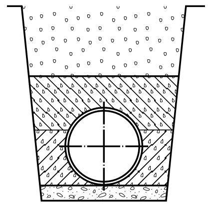
Installation Type 1



- Construct the pipe bed following the guidelines of section 4.9.
- Backfill the pipe zone (to 300 mm) over the pipe crown with the specified backfill material compacted to the required compaction level.

Note: For non-pressure (PN ≤ 1 bar) applications the requirement to compact the 300 mm over the pipe crown may be waived.

Installation Type 2



- Construct the pipe bed following the guidelines of section 4.9.
- Backfill to a level of 60% of pipe diameter with the specified backfill material compacted to the required relative compaction level.
- Backfill from 60% of diameter to 300 mm over the pipe crown with a relative compaction necessary to achieve at least a soil modulus of 1.4 MPa.

Note: Installation Type 2 is not practical for small diameter pipes.

Note: Installation Type 2 is not suitable for heavy traffic loading situations.

Note: Tables 4.7, 4.8 and 4.9 are based on an assumed trench width of 1.75DN. Narrower trenches may affect the depth limits.

Table 4.7A
Standard Trench Installation Type 1 without Traffic Load Maximum Burial Depth (meters)

E'b MPa	Native Soil Group 1	2	3	4	5	6
2500 STIS						
20.7	23.0	18.0	11.0	7.0	2.8	NA
13.8	18.0	15.0	10.0	6.0	2.6	NA
10.3	15.0	13.0	9.0	5.5	2.6	NA
6.9	11.0	10.0	7.5	5.0	2.4	NA
4.8	8.5	7.5	6.0	4.0	2.0	NA
3.4	6.0	5.5	5.0	3.8	1.8	NA
2.1	4.0	3.5	3.5	2.8	1.6	NA
1.4	2.6	2.6	2.6	2.2	1.4	NA
5000 STIS						
20.7	23.0	18.0	12.0	7.0	3.0	1.2
13.8	18.0	15.0	10.0	6.5	3.0	1.2
10.3	15.0	13.0	9.0	6.0	2.8	1.2
6.9	11.0	10.0	8.0	5.0	2.6	1.2
4.8	9.0	7.5	6.5	4.5	2.2	NA
3.4	6.0	6.0	5.0	4.0	2.0	NA
2.1	4.0	4.0	3.5	3.0	1.8	NA
1.4	3.0	3.0	3.0	2.6	1.6	NA
10000 STIS						
20.7	24.0	19.0	12.0	8.0	3.6	1.8
13.8	19.0	16.0	11.0	7.0	3.6	1.8
10.3	15.0	13.0	10.0	6.5	3.4	1.6
6.9	12.0	10.0	8.5	5.5	3.2	1.6
4.8	9.0	8.5	7.0	5.0	2.8	1.6
3.4	7.0	6.5	5.5	4.5	2.6	1.6
2.1	4.5	4.5	4.0	3.5	2.4	1.6
1.4	3.5	3.5	3.4	3.0	2.2	1.6

Table 4.7B
Standard Trench Installation Type 1 with Traffic Load (AASHTO H20) – Maximum Burial Depth (meters)

E'b MPa	Native Soil Group 1	2	3	4	5	6
2500 STIS						
20.7	23.0	18.0	11.0	7.0	NA	NA
13.8	18.0	15.0	10.0	6.0	NA	NA
10.3	15.0	13.0	9.0	5.5	NA	NA
6.9	11.0	10.0	7.5	5.0	NA	NA
4.8	8.5	7.5	6.0	4.0	NA	NA
3.4	6.0	5.5	5.0	3.5	NA	NA
2.1	3.5	3.5	3.0	NA	NA	NA
1.4	NA	NA	NA	NA	NA	NA
5000 STIS						
20.7	23.0	18.0	12.0	7.0	3.0	NA
13.8	18.0	15.0	10.0	6.5	2.4	NA
10.3	15.0	13.0	9.0	6.0	2.4	NA
6.9	11.0	10.0	8.0	5.0	NA	NA
4.8	8.5	7.5	6.5	4.5	NA	NA
3.4	6.0	6.0	5.0	4.0	NA	NA
2.1	4.0	4.0	3.5	3.5	NA	NA
1.4	2.4	2.4	2.2	NA	NA	NA
10000 STIS						
20.7	24.0	19.0	12.0	8.0	3.5	NA
13.8	19.0	16.0	11.0	7.0	3.5	NA
10.3	15.0	13.0	10.0	6.5	3.0	NA
6.9	12.0	10.0	8.5	5.5	3.0	NA
4.8	9.5	8.5	7.0	5.0	2.5	NA
3.4	7.0	6.5	5.5	4.5	NA	NA
2.1	4.5	4.5	4.0	3.5	NA	NA
1.4	3.0	3.0	3.0	2.8	NA	NA

Standard Installation (continued)

Table 4.7C
Standard Trench Installation Type 2 without Traffic Load
Maximum Burial Depth (meters)

E'b MPa	Native Soil Group 1	2	3	4	5	6
2500 STIS						
20.7	16.0	13.0	9.0	5.5	2.6	NA
13.8	12.0	10.0	8.0	5.0	2.4	NA
10.3	10.0	8.5	7.0	4.5	2.2	NA
6.9	7.5	6.5	5.5	4.0	2.0	NA
4.8	5.5	5.5	4.5	3.5	1.8	NA
3.4	4.5	4.5	3.5	3.0	1.6	NA
2.1	3.0	3.0	2.8	2.6	1.4	NA
1.4	2.6	2.6	2.6	2.2	1.4	NA
5000 STIS						
20.7	16.0	13.0	9.5	6.0	3.0	1.2
13.8	12.0	11.0	8.5	5.5	2.6	1.2
10.3	10.0	9.0	7.5	5.0	2.4	1.2
6.9	7.5	7.0	6.0	4.0	2.2	NA
4.8	6.0	5.5	5.0	3.5	2.0	NA
3.4	4.5	4.5	4.0	3.0	1.8	NA
2.1	3.5	3.5	3.5	2.8	1.6	NA
1.4	3.0	3.0	3.0	2.6	1.4	NA
10000 STIS						
20.7	17.0	14.0	10.0	6.5	3.4	1.6
13.8	13.0	11.0	9.0	6.0	3.0	1.6
10.3	11.0	9.5	8.0	5.5	2.8	1.6
6.9	8.0	7.5	6.5	5.0	2.4	1.6
4.8	6.5	6.0	5.5	4.5	2.4	1.6
3.4	5.0	5.0	4.5	4.0	2.2	1.6
2.1	4.0	4.0	4.0	3.5	2.0	1.6
1.4	3.5	3.5	3.5	3.0	1.8	1.6

Table 4.7D
Small Diameter (DN ≤ 250) Pipe Installation Type 1
Maximum Burial Depth (meters)

E'b MPa	Native Soil Group 1	2	3	4	5	6
10000 STIS No Traffic Load						
20.7	18.0	14.0	9.5	6.0	2.8	1.2
13.8	14.0	12.0	8.0	5.0	2.6	1.2
10.3	12.0	10.0	7.5	5.0	2.6	1.2
6.9	9.0	8.0	6.5	4.5	2.4	1.2
4.8	7.0	6.0	5.5	4.0	2.2	1.2
3.4	5.0	5.0	4.5	3.5	2.0	1.2
2.1	3.5	3.5	3.5	2.8	1.8	1.2
1.4	2.6	2.6	2.6	2.4	1.8	1.2
10000 STIS with Traffic Load (AASHTO H20)						
20.7	18.0	14.0	9.5	6.0	2.6	NA
13.8	14.0	12.0	8.0	5.0	2.4	NA
10.3	12.0	10.0	7.5	4.5	2.2	NA
6.9	9.0	8.0	6.0	4.0	2.0	NA
4.8	7.0	6.0	5.0	3.5	1.2	NA
3.4	5.0	5.0	4.0	3.0	NA	NA
2.1	3.5	3.5	3.0	2.4	NA	NA
1.4	2.6	2.4	2.2	2.0	NA	NA

4.7 Negative Pressure

A minimum burial depth of 1.0 meter is recommended for negative pressure (vacuum) situations so as to provide proper soil stabilizing support.

Installation Type 1

The maximum allowable negative pressure (vacuum) in the pipe is a function of both native soil and backfill soil stiffness. Tables 4.8A through 4.8D give the maximum burial depths for allowable negative pressure of 1.0, 0.75, 0.50 and 0.25 bars.

Table 4.8A – SN2500
Table 4.8B – SN5000
Table 4.8C – SN10000
Table 4.8D – Small Diameter Pipe

Installation Type 2

Table 4.9 gives the maximum burial depths for the allowable negative pressures for the three stiffness classes for Type 2 installations.

Standard Installation (continued)

Table 4.8A
Standard Trench Installation Type 1
Maximum Burial Depth (meters)
for Allowable Negative Pressure (bars)

SN2500

E'b MPa	Native Soil Group 1	2	3	4	5	6
(-) 1.0 bar						
20.7	15.0	12.0	5.5	1.5	NA	NA
13.8	12.0	9.0	4.0	1.0	NA	NA
10.3	9.0	7.0	3.0	NA	NA	NA
6.9	5.0	4.0	1.8	NA	NA	NA
4.8	2.4	1.4	NA	NA	NA	NA
3.4	NA	NA	NA	NA	NA	NA
2.1	NA	NA	NA	NA	NA	NA
1.4	NA	NA	NA	NA	NA	NA
(-) 0.75 bar						
20.7	17.0	13.0	8.0	3.5	NA	NA
13.8	14.0	11.0	6.5	2.6	NA	NA
10.3	11.0	9.0	5.5	2.4	NA	NA
6.9	7.5	6.5	4.0	1.6	NA	NA
4.8	4.5	4.0	2.4	1.0	NA	NA
3.4	2.4	2.4	1.4	NA	NA	NA
2.1	NA	NA	NA	NA	NA	NA
1.4	NA	NA	NA	NA	NA	NA
(-) 0.50 bar						
20.7	18.0	15.0	10.0	5.5	1.0	NA
13.8	15.0	13.0	8.5	4.5	1.0	NA
10.3	13.0	11.0	7.5	4.0	1.0	NA
6.9	9.0	8.5	6.0	3.5	NA	NA
4.8	7.0	6.0	4.5	2.8	NA	NA
3.4	4.5	4.0	3.5	2.0	NA	NA
2.1	2.4	2.4	2.0	1.4	NA	NA
1.4	1.0	1.0	1.0	NA	NA	NA
(-) 0.25 bar						
20.7	19.0	16.0	11.0	7.0	2.8	NA
13.8	16.0	14.0	10.0	6.0	2.8	NA
10.3	14.0	13.0	9.0	5.5	2.6	NA
6.9	11.0	10.0	7.5	5.0	2.4	NA
4.8	8.5	7.5	6.0	4.0	2.0	NA
3.4	6.0	5.5	5.0	3.5	1.6	NA
2.1	4.0	3.5	3.5	3.0	1.4	NA
1.4	2.6	2.6	2.4	2.2	1.2	NA

Table 4.8B
Standard Trench Installation Type 1
Maximum Burial Depth (meters)
for Allowable Negative Pressure (bars)

SN5000

E'b MPa	Native Soil Group 1	2	3	4	5	6
(-) 1.0 bar						
20.7	23.0	18.0	12.0	7.0	NA	NA
13.8	18.0	15.0	10.0	6.5	NA	NA
10.3	15.0	13.0	9.0	5.5	NA	NA
6.9	11.0	10.0	8.0	3.5	NA	NA
4.8	9.0	7.5	6.0	2.4	NA	NA
3.4	6.0	4.5	3.0	1.4	NA	NA
2.1	1.4	1.4	NA	NA	NA	NA
1.4	NA	NA	NA	NA	NA	NA
(-) 0.75 bar						
20.7	23.0	18.0	12.0	7.0	2.0	NA
13.8	18.0	15.0	10.0	6.5	1.6	NA
10.3	15.0	13.0	9.0	6.0	1.4	NA
6.9	11.0	10.0	8.0	5.0	1.2	NA
4.8	9.0	7.5	6.5	4.5	NA	NA
3.4	6.0	6.0	5.0	3.5	NA	NA
2.1	4.0	3.5	3.0	2.0	NA	NA
1.4	1.6	1.4	1.4	NA	NA	NA
(-) 0.50 bar						
20.7	23.0	18.0	12.0	7.0	3.2	NA
13.8	18.0	15.0	10.0	6.5	3.0	NA
10.3	15.0	13.0	9.0	6.0	3.0	NA
6.9	11.0	10.0	8.0	5.0	2.6	NA
4.8	9.0	7.5	6.5	4.5	2.4	NA
3.4	6.0	6.0	5.0	4.0	2.0	NA
2.1	4.0	4.0	3.5	3.0	1.4	NA
1.4	3.0	3.0	3.0	2.4	NA	NA
(-) 0.25 bar						
20.7	23.0	18.0	12.0	7.0	3.2	1.8
13.8	18.0	15.0	10.0	6.5	3.0	1.4
10.3	15.0	13.0	9.0	6.0	3.0	1.4
6.9	11.0	10.0	8.0	5.0	2.6	1.4
4.8	9.0	7.5	6.5	4.5	2.4	1.2
3.4	6.0	6.0	5.0	4.0	2.0	1.2
2.1	4.0	4.0	3.5	3.0	2.0	NA
1.4	3.0	3.0	3.0	2.6	1.6	NA

Standard Installation (continued)

Table 4.8C
Standard Trench Installation Type 1
Maximum Burial Depth (meters)
for Allowable Negative Pressure (bars)

SN10000

E'b MPa	Native Soil Group 1	2	3	4	5	6
(–) 1.0 bar						
20.7	24.0	19.0	12.0	8.0	3.5	NA
13.8	19.0	16.0	11.0	7.0	3.5	NA
10.3	15.0	13.0	10.0	6.5	3.0	NA
6.9	12.0	10.0	8.5	5.5	2.8	NA
4.8	9.0	8.5	7.0	5.0	1.6	NA
3.4	7.0	6.5	5.5	4.5	NA	NA
2.1	4.5	4.5	4.0	3.5	NA	NA
1.4	3.5	3.5	3.5	2.5	NA	NA
(–) 0.75 bar						
20.7	24.0	19.0	12.0	8.0	3.5	NA
13.8	19.0	16.0	11.0	7.0	3.5	NA
10.3	15.0	13.0	10.0	6.5	3.0	NA
6.9	12.0	10.0	8.5	5.5	3.0	NA
4.8	9.0	8.5	7.0	5.0	2.8	NA
3.4	7.0	6.5	5.5	4.5	2.6	NA
2.1	4.5	4.5	4.0	3.5	2.4	NA
1.4	3.5	3.5	3.5	3.0	1.4	NA
(–) 0.50 bar						
20.7	24.0	19.0	12.0	8.0	3.5	1.4
13.8	19.0	16.0	11.0	7.0	3.5	1.4
10.3	15.0	13.0	10.0	6.5	3.0	1.4
6.9	12.0	10.0	8.5	5.5	3.0	1.2
4.8	9.0	8.5	7.0	5.0	2.8	1.2
3.4	7.0	6.5	5.5	4.5	2.6	1.2
2.1	4.5	4.5	4.0	3.5	2.4	NA
1.4	3.5	3.5	3.5	3.0	2.0	NA
(–) 0.25 bar						
20.7	24.0	19.0	12.0	8.0	3.5	1.6
13.8	19.0	16.0	11.0	7.0	3.5	1.6
10.3	15.0	13.0	10.0	6.5	3.0	1.6
6.9	12.0	10.0	8.5	5.5	3.0	1.6
4.8	9.0	8.5	7.0	5.0	2.8	1.6
3.4	7.0	6.5	5.5	4.5	2.6	1.6
2.1	4.5	4.5	4.0	3.5	2.4	1.6
1.4	3.5	3.5	3.5	3.0	2.0	1.6

Table 4.8D
Standard Trench Installation Type 1
Maximum Burial Depth (meters)
for Allowable Negative Pressure (bars)

Small Diameter Pipe (SN10000)

E'b MPa	Native Soil Group 1	2	3	4	5	6
(–) 1.0 bar						
20.7	18.0	14.0	9.5	6.0	2.8	NA
13.8	14.0	12.0	8.0	5.0	2.6	NA
10.3	12.0	10.0	7.5	5.0	2.6	NA
6.9	9.0	8.0	6.5	4.5	2.4	NA
4.8	7.0	6.0	5.5	4.0	2.0	NA
3.4	5.0	5.0	4.5	3.5	NA	NA
2.1	3.5	3.5	3.5	2.8	NA	NA
1.4	2.6	2.6	2.6	2.4	NA	NA
(–) 0.75 bar						
20.7	18.0	14.0	9.5	6.0	2.8	NA
13.8	14.0	12.0	8.0	5.0	2.6	NA
10.3	12.0	10.0	7.5	5.0	2.6	NA
6.9	9.0	8.0	6.5	4.5	2.4	NA
4.8	7.0	6.0	5.5	4.0	2.2	NA
3.4	5.0	5.0	4.5	3.5	2.0	NA
2.1	3.5	3.5	3.5	2.8	1.8	NA
1.4	2.6	2.6	2.6	2.4	1.4	NA
(–) 0.50 bar						
20.7	18.0	14.0	9.5	6.0	2.8	1.2
13.8	14.0	12.0	8.0	5.0	2.6	1.2
10.3	12.0	10.0	7.5	5.0	2.6	1.2
6.9	9.0	8.0	6.5	4.5	2.4	1.2
4.8	7.0	6.0	5.5	4.0	2.2	1.2
3.4	5.0	5.0	4.5	3.5	2.0	1.2
2.1	3.5	3.5	3.5	2.8	1.8	NA
1.4	2.6	2.6	2.6	2.4	1.8	NA
(–) 0.25 bar						
20.7	18.0	14.0	9.5	6.0	2.8	1.2
13.8	14.0	12.0	8.0	5.0	2.6	1.2
10.3	12.0	10.0	7.5	5.0	2.6	1.2
6.9	9.0	8.0	6.5	4.5	2.4	1.2
4.8	7.0	6.0	5.5	4.0	2.2	1.2
3.4	5.0	5.0	4.5	3.5	2.0	1.2
2.1	3.5	3.5	3.5	2.8	1.8	1.2
1.4	2.6	2.6	2.6	2.4	1.8	1.2

Standard Installation (continued)

Table 4.9
Standard Trench Installation Type 2
Maximum Burial Depth (meters)
for Allowable Negative Pressure (bars)

Allowable Negative Pressure (bars)	Native Soil Group 1	2	3	4	5	6
SN2500						
(-)1.00	NA	NA	NA	NA	NA	NA
(-)0.75	NA	NA	NA	NA	NA	NA
(-)0.50	1.0	1.0	1.0	NA	NA	NA
(-)0.25	2.6	2.6	2.4	2.2	1.2	NA
SN5000						
(-)1.00	NA	NA	NA	NA	NA	NA
(-)0.75	1.6	1.4	1.4	NA	NA	NA
(-)0.50	3.0	3.0	3.0	2.4	NA	NA
(-)0.25	3.0	3.0	3.0	2.6	1.6	NA
SN10000						
(-)1.00	3.5	3.5	3.5	2.5	NA	NA
(-)0.75	3.5	3.5	3.5	3.0	1.4	NA
(-)0.50	3.5	3.5	3.5	3.0	2.0	NA
(-)0.25	3.5	3.5	3.5	3.0	2.0	1.6

Unburied Pipe Sections

Some sections of a buried pipeline such as in valve pits or chambers may be non-soil supported. As the stabilizing support of the soil is not present the negative pressure capability will be limited. Table 4.10 gives the maximum allowable negative pressure for lengths between restraints of 3, 6 and 12 meters.

Table 4.10
Maximum Allowable Negative Pressure (bars)
for Unburied Sections
Pipe Length Between Restraints 3m/6m/12m

PN	SN2500			SN5000			SN10000		
	3m	6m	12m	3m	6m	12m	3m	6m	12m
6	.50	.25	.25	.75	.50	.50	1.0	1.0	1.0
10	.50	.25	.25	.75	.50	.50	1.0	1.0	1.0
16	.50	.25	.25	1.0	.50	.50	1.0	1.0	1.0
20	.50	.25	.25	1.0	.50	.50	1.0	1.0	1.0
25	NA	NA	NA	1.0	.50	.50	1.0	1.0	1.0
32	NA	NA	NA	NA	NA	NA	1.0	1.0	1.0

NA = Not Available Product

4.8 Burial Limitation – Minimum

Traffic Loading

In situations where pipes are to be buried under a roadway, or continuing traffic loading is anticipated, the backfill material should be compacted to grade level. Consult local road construction codes of practice. Minimum cover restrictions may be reduced with special installations such as concrete encasement, concrete cover slabs, casings, etc.

The burial depth tables are based on an assumed AASHTO H20 load. In general a minimum burial depth of 1.0 meter is recommended for traffic loading, assuming a pipe zone backfill soil modulus (E’b) of 6.9 MPa or higher. Table 4.11 shows the minimum burial depth for other traffic loadings.

For lower backfill soil modulus (E’b) it is recommended that minimum cover for traffic loading be increased to compensate for the lower soil stiffness as shown in Table 4.12.

Table 4.11 Traffic Loads

Load Type	Traffic (Wheel) Load kilo Newtons	lbs. Force	Minimum Burial Depth meters
AASHTO H20 (C)	72	16,000	1.0
BS 153 HA (C)	90	20,000	1.5
ATV LKW 12 (C)	40	9,000	1.0
ATV SLW 30 (C)	50	11,000	1.0
ATV SLW 60 (C)	100	22,000	1.5
Cooper E80	Railroad		3.0

Table 4.12 Minimum Burial Depth for Traffic Loading with Lower Backfill Soil Modulus (E’b)

E’b (MPa)	AASHTO H20	SLW 60
6.9	1.0	1.5
4.8	1.2	1.8
3.4	1.6	2.4
2.1	1.8	2.7
1.4	2.0	3.0

Construction Traffic Loading

In some cases large, heavy earth moving equipment or construction cranes may be present in or near the pipe installation area. These types of equipment can result in very high localized surface loads. The effects of such loading must be evaluated on a case by case basis to establish proper procedures and limits.

Standard Installation (continued)

High Pressure

Higher pressures require consideration of the possible uplift forces at joints both during operation *and* any field hydrotesting.

1. For pressures of 16 bar and greater the minimum burial depth should be 1.2 meters for pipes of DN 300 mm and larger and 0.8 meters for pipes of DN less than 300 mm.
2. During field hydrotesting at pressures below 16 bars the couplings shall be backfilled at least to the crown with pipes backfilled to the minimum cover depth.
3. During field hydrotesting at pressures 16 bar and greater:
   - For pipes in straight alignment backfill to the crown of the coupling or higher before performing the field hydrotest. Pipes must be backfilled to minimum cover.
   - For pipes installed with angular deflection *both the pipe and the coupling* must be covered to the final grade before the field pressure test.

High Water Table

A minimum of 0.75 diameter of earth cover (minimum dry soil bulk density of 1900 kg/m3) is required to prevent an empty submerged pipe from floating.

Alternatively, the installation may proceed by anchoring the pipes. If anchoring is proposed, restraining straps must be a flat material, minimum 25 mm wide, placed at maximum 4.0 meter intervals. Consult the manufacturer for details on anchoring and minimum cover depth with anchors.

Frost Line

The minimum cover depth for the pipe should be such that the pipe is buried BELOW the anticipated frost level. Consult local construction codes of practice for frost penetration levels.

4.9 Pipe Bedding

The bedding shall be placed after the trench bottom is compacted so as to provide proper support. Minimum compaction of the bed shall be 90% relative compaction.

The finished bed shall be plane, shall have a minimum depth equal to DN/4 (maximum 150 mm required) and must provide uniform and continuous support to the pipe. The bed must be over-excavated at each joint location to ensure that the pipe will have a continuous support and does not rest on the couplings. However, this area must be properly bedded and backfilled after the joint assembly is completed. See Figures 4.5 and 4.6 for proper and improper bedding support.

After the bed is prepared and leveled, the center 150 mm of the bed may be loosened (for example with a rake) to a depth not to exceed 50 mm to provide a well-defined soft contact area for the pipe bottom.

4.10 Backfilling Pipe

Immediate backfilling after joining is suggested as it will prevent two hazards – floating of pipe and thermal movements. Floating of pipe can damage the pipe and create unnecessary reinstallation costs. Thermal movement caused by exposure to the elements can cause the loss of seal due to movement of several lengths accumulated at one joint.

If lengths of pipe are placed into the trench and backfilling is delayed, each length should have the center section backfilled to the crown to help minimize misalignment and movement.

Proper selection, placement and compaction of pipe zone backfill is important for controlling the vertical deflection and is critical for pipe performance. Attention must be paid so that the backfill material is not contaminated with debris or other foreign materials that could damage the pipe or cause loss of side support. Backfill placement and compaction under the pipe (the “haunch” area) must achieve the required relative compaction just as does the side fill.

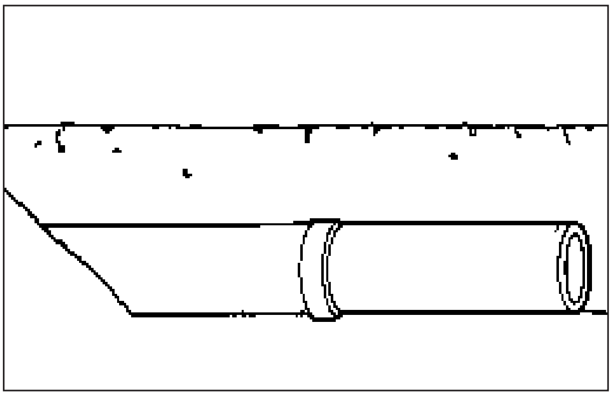


Figure 4.5
Proper bedding support

Standard Installation (continued)

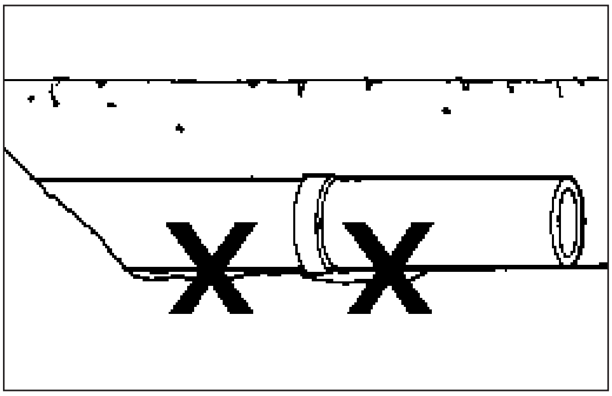


Figure 4.6
Improper bedding support

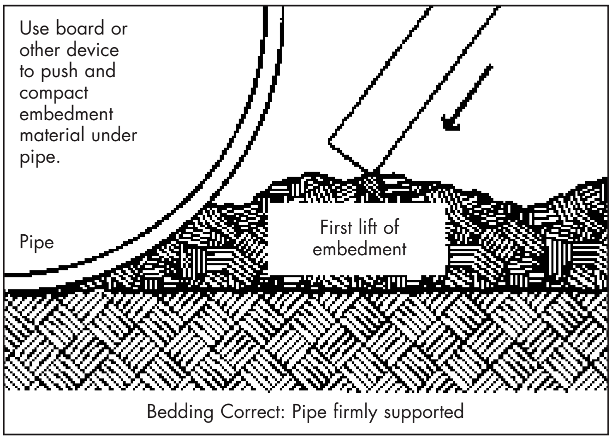


Figure 4.7
Ensuring firm pipe support

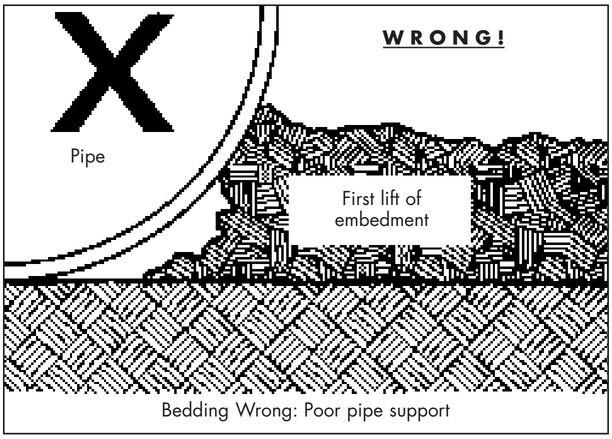


Figure 4.8
Improper haunch

The depth of the layer being compacted must be controlled as well as the energy placed into the compaction method. A blunt tool may be used very effectively to push and compact the backfill under the pipe, without raising the pipe up. (See Figures 4.7 and 4.8.)

Proper backfilling should be done in 75 mm to 300 mm lifts depending on backfill material and compaction method. When gravel or crushed stone is used as backfill material, 300 mm lifts will be adequate since gravel is relatively easy to compact. Finer grained soils need more compactive effort and the lift height should be limited. Note that it is important to achieve proper compaction of each lift to ensure that the pipe will have adequate support.

Backfill Types A and B are relatively easy to use and very reliable as backfill materials for pipe. These soils have low moisture sensitivity. Backfill can be easily compacted using a plate vibrator compactor in 200 or 300 mm lifts. Occasionally, a filter fabric must be used in combination with gravel soils to preclude fines migration and subsequent loss of pipe support.

Backfill Type C soils are acceptable and readily available as backfill materials for pipe installations. Many local soils in which the pipe is installed is Type C and therefore the trenched soil can be directly reused as pipe-zone backfill. Precaution is to be taken with these soils as they can be moisture sensitive. The characteristics of the Type C soil is often dictated by the characteristics of the fines. Moisture control may be required when compacting the soil to achieve the desired density with reasonable compaction energy and easily used compaction equipment. Compaction can be achieved by using plate vibrator compactor or impact compactor in 150 to 200 mm lifts.

Backfill Types D and E are acceptable backfill materials in many conditions; however, their relatively low stiffness precludes their use in deeper installations, and their moisture sensitivity limits their use where standing water interferes with their compaction. To achieve desired relative compaction, moisture control will most likely be required during compaction. When compacting, use lifts of 75 or 150 mm with an impact compactor such as Whacker or pneumatic rammer (pogo stick). Compaction tests should be conducted periodically to assure proper relative compaction is achieved.

Standard Installation (continued)

Backfill Type F can only be used as pipe-zone backfill with the following precautions:

- Moisture content must be controlled during placement and compaction.
- Do not use in installations with unstable foundations or with standing water in the trench.
- Compaction techniques may require considerable energy, and practical limitations of relative compaction and resulting soil stiffness must be considered.
- Moisture control is required to achieve the required relative compaction.
- When compacting, use lifts of 75 to 150 mm with an impact compactor such as Whacker or pneumatic rammer (pogo stick).
- Compaction tests should be conducted periodically to assure proper relative compaction is achieved.

  See Appendix F for further information.

The compaction of finer grain backfill is most easily accomplished when the material is at or near its optimum moisture content. When backfilling reaches pipe springline, all compaction should be done first near the trench sides and proceed towards the pipe.

It is recommended that placing and compacting of the pipe zone backfill is done in such a way as to cause the pipe to ovalize slightly in the vertical direction. Initial vertical ovalization, however, must not exceed 1.5% of pipe diameter as measured when backfill reaches pipe crown. The amount of initial ovalization obtained will be related to the energy required to achieve the relative compaction needed. The high energy levels that may be necessary with backfill Types D, E and F may lead to exceeding the limit. If this occurs consider a higher stiffness pipe or other backfill materials or both.

Table 4.13 shows the minimum cover height over the pipe necessary before certain compaction equipment may be used directly above the pipe. Care must be taken to avoid excessive compactive effort above the pipe crown which may cause bulges or flat areas. However, the material in this area must not be left loose and the desired specific density should be achieved.

Table 4.13 Minimum Cover for Compaction Above Pipe

	Minimum Pipe Cover* (mm)	
Equipment Weight (kg)	**Tamped**	**Vibrated**
Less than 100	250	150
100 to 200	350	200
200 to 500	450	300
500 to 1000	700	450
1000 to 2000	900	600
2000 to 4000	1200	800
4000 to 8000	1500	1000
8000 to 12000	1800	1200
12000 to 18000	2200	1500

*It may be necessary to begin with higher cover so that, as compaction is achieved, the cover will not be less than the minimum.

Alternate Installations

If the burial depth requirement for the selected pipe stiffness, installation type and native soil group exceeds the limits given in Tables 4.7, alternative installation procedures must be considered.

Three alternative installation methods are available:

- Wider Trench
- Permanent Sheeting
- Stabilized Backfill (Cement)

5.1 Wide Trench

Increasing the trench width distances the poor native soil farther from the pipe allowing a deeper installation and higher allowable negative pressures (vacuum). Tables 5.1A, 5.1B and 5.1C give the maximum allowable cover depths for wide trench conditions. Table 5.1D gives the maximum allowable cover depths for negative pressure conditions.

Table 5.1A – Large Diameter Pipe
3 Diameter Trench
No Traffic Load

Table 5.1B – Large Diameter Pipe
3 Diameter Trench
with AASHTO H20 Traffic

Table 5.1C – Small Diameter Pipe
3 Diameter Trench
With and Without Traffic

Table 5.1D – Maximum Allowable Depth
for Allowable Negative Pressures

Table 5.1A
3 Diameter Trench Installation Type 1 without Traffic Load
Maximum Burial Depth (meters)

E'b MPa	Native Soil Group 4	5	6
		2500 STIS	
20.7	16.0	10.0	6.0
13.8	10.0	9.0	4.5
10.3	8.5	7.5	4.0
6.9	6.0	5.0	3.0
4.8	4.0	3.5	2.8
3.4	3.0	3.0	2.6
2.1	2.2	2.0	1.8
1.4	1.6	1.4	1.4
		5000 STIS	
20.7	16.0	10.0	6.5
13.8	10.0	9.0	5.0
10.3	8.5	8.0	4.0
6.9	6.0	5.5	3.5
4.8	4.5	4.0	3.0
3.4	3.5	3.0	2.6
2.1	2.6	2.2	2.0
1.4	2.0	1.8	1.6
		10000 STIS	
20.7	16.0	11.0	7.0
13.8	11.0	10.0	5.5
10.3	9.5	8.5	4.5
6.9	7.0	6.0	4.0
4.8	5.0	4.5	3.5
3.4	4.0	3.5	3.5
2.1	3.0	2.8	2.6
1.4	2.6	2.2	2.2

Table 5.1B
3 Diameter Trench Installation Type 1
with Traffic Load (AASHTO H20)
Maximum Burial Depth (meters)

E'b MPa	Native Soil Group 4	5	6
		2500 STIS	
20.7	16.0	10.0	6.0
13.8	10.0	9.0	4.5
10.3	8.5	7.5	3.5
6.9	6.0	5.0	3.0
4.8	4.0	3.5	2.0
3.4	3.2	2.6	NA
2.1	NA	NA	NA
1.4	NA	NA	NA
		5000 STIS	
20.7	16.0	10.0	6.5
13.8	10.0	9.0	5.0
10.3	8.5	8.0	4.0
6.9	6.0	5.5	3.0
4.8	4.5	4.0	2.6
3.4	3.5	3.0	2.2
2.1	2.2	NA	NA
1.4	NA	NA	NA
		10000 STIS	
20.7	16.0	11.0	7.0
13.8	11.0	10.0	5.5
10.3	9.0	8.5	4.5
6.9	7.0	6.0	4.0
4.8	5.0	4.5	3.5
3.4	4.0	3.5	3.0
2.1	3.0	2.6	NA
1.4	NA	NA	NA

Alternate Installations (continued)

Table 5.1C
Small Diameter (DN ≤ 250) Pipe
Installation Type 1 – 3 Diameter Trench
Maximum Burial Depth (meters)

E'b MPa	Native Soil Group 4	Native Soil Group 5	Native Soil Group 6
	10000 STIS without Traffic Load		
20.7	12.0	8.5	5.0
13.8	8.5	8.0	4.0
10.3	7.0	6.0	3.5
6.9	5.0	4.5	3.0
4.8	4.0	3.5	2.8
3.4	3.2	2.8	2.5
2.1	2.4	2.2	2.0
1.4	2.0	1.8	1.6

E'b MPa	Native Soil Group 4	Native Soil Group 5	Native Soil Group 6
	10000 STIS with Traffic Load (AASHTO H20)		
20.7	12.0	8.5	5.0
13.8	8.5	8.0	4.0
10.3	6.8	6.0	3.5
6.9	5.0	4.5	2.8
4.8	3.6	3.4	2.4
3.4	3.0	2.6	2.2
2.1	2.0	NA	NA
1.4	NA	NA	NA

Table 5.1D
3 Diameter Trench Installation Type 1

Maximum Burial Depth for Allowable Negative Pressure (-bars)

E'b MPa	-1.0 Native Soil Group 4	5	6	-0.75 Native Soil Group 4	5	6	-0.50 Native Soil Group 4	5	6	-0.25 Native Soil Group 4	5	6
SN 2500												
20.7	9.5	4.0	NA	11.5	6.5	NA	13.5	8.5	1.0	15.0	10.0	2.5
13.8	4.5	3.5	NA	7.0	6.0	NA	9.0	8.0	1.0	10.0	9.0	2.5
10.3	2.5	1.5	NA	4.5	4.0	NA	7.0	6.0	1.0	8.5	7.5	2.5
6.9	NA	NA	NA	2.5	1.5	NA	4.0	3.5	1.0	6.0	5.0	2.5
4.8	NA	NA	NA	1.0	NA	NA	2.5	2.0	1.0	4.0	3.5	2.5
3.4	NA	NA	NA	NA	NA	NA	2.0	1.5	1.0	3.0	3.0	2.5
2.1	NA	NA	NA	NA	NA	NA	1.0	NA	NA	2.2	2.0	1.6
1.4	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.6	1.3	1.1
SN 5000												
20.7	16.0	10.0	NA	16.0	10.0	1.5	16.0	10.0	3.0	16.0	10.0	5.0
13.8	10.0	9.0	NA	10.0	9.0	1.5	10.0	9.0	3.0	10.0	9.0	5.0
10.3	8.5	8.0	NA	8.5	8.0	1.5	8.5	8.0	3.0	8.5	8.0	4.0
6.9	6.0	4.0	NA	6.0	5.5	1.5	6.0	5.5	3.0	6.0	5.5	3.5
4.8	2.8	1.5	NA	4.5	3.5	1.5	4.5	4.0	3.0	4.5	4.0	3.0
3.4	1.0	NA	NA	3.0	2.0	1.5	3.5	3.0	2.6	3.5	3.0	2.6
2.1	NA	NA	NA	1.4	NA	NA	2.6	2.0	2.0	2.6	2.2	2.0
1.4	NA	NA	NA	NA	NA	NA	2.0	1.0	NA	2.0	1.8	1.6
SN 10000												
20.7	16.0	11.0	3.5	16.0	11.0	6.0	16.0	11.0	7.0	16.0	11.0	7.0
13.8	11.0	10.0	3.5	11.0	10.0	5.5	11.0	10.0	5.5	11.0	10.0	5.5
10.3	9.5	8.5	3.5	9.5	8.5	4.5	9.5	8.5	4.5	9.5	8.5	4.5
6.9	7.0	6.0	3.5	7.0	6.0	4.0	7.0	6.0	4.0	7.0	6.0	4.0
4.8	5.0	4.5	3.5	5.0	4.5	3.5	5.0	4.5	3.5	5.0	4.5	3.5
3.4	4.0	3.5	3.5	4.0	3.5	3.5	4.0	3.5	3.5	4.0	3.5	3.5
2.1	3.0	1.4	NA	3.0	2.8	2.5	3.0	2.8	2.6	3.0	2.8	2.6
1.4	1.0	NA	NA	2.6	1.5	1.0	2.6	2.2	2.2	2.6	2.2	2.2

FLOWTITE™ Alternate Installations (continued)

5.2 Permanent Sheeting

Use permanent sheeting of sufficient length (at least 30 mm over pipe crown) to appropriately distribute the pipe's lateral loads and of sufficient quality to last the design life of the pipe (See Figure 5.1).

Note that backfilling procedure and maximum cover depths are the same as for standard installations. Permanent sheeting can be assumed to be a "group 1 native soil."

5.3 Stabilized Backfill (Cement)

Typically, 40-50 kg of cement per ton of sand (4-5% cement) will be sufficient. The sand shall have a maximum of 15% passing a 200 sieve. Seven-day strength of the stabilized material should be 690-1380 kPa.

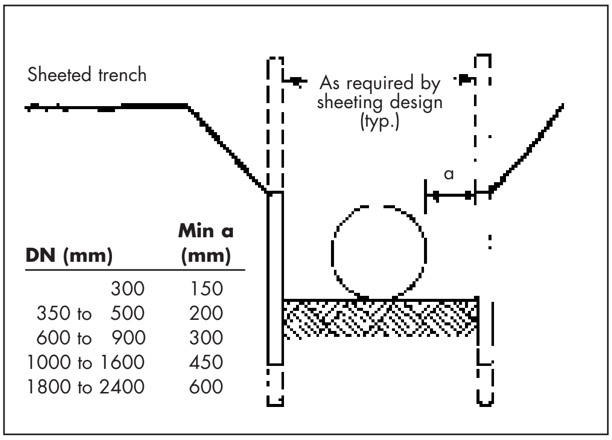
The stabilized backfill should be compacted to 90 SPD in layers of 150 to 200 mm. The stabilized material must be allowed to "set" 24 hours at maximum initial cover before backfilling to grade. Maximum initial cover:

1.0 meter for SN 2500

1.5 meter for SN 5000 and SN 10000

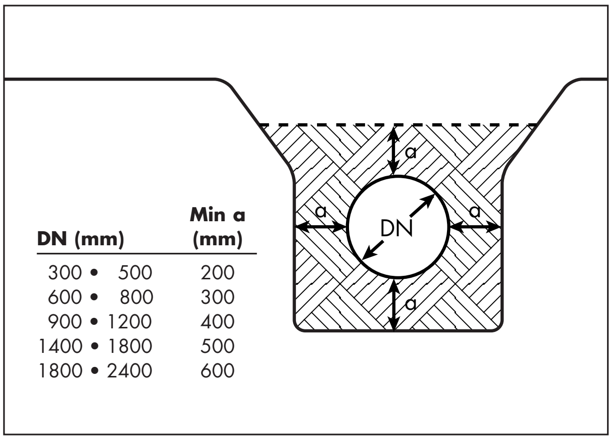
The pipe must be surrounded in stabilized backfill as shown in Figure 5.2. Maximum pipe length is 6 meters.

Over-excavation must be filled with compacted stabilized material, and as trench boxes or temporary sheeting is pulled the stabilized backfill must be compacted against the native soil. Maximum total cover depth is 5 meters.



DN (mm)	Min a (mm)
300	150
350 to 500	200
600 to 900	300
1000 to 1600	450
1800 to 2400	600

Figure 5.1
Permanent sheeted trench



DN (mm)	Min a (mm)
300 • 500	200
600 • 800	300
900 • 1200	400
1400 • 1800	500
1800 • 2400	600

Figure 5.2
Stabilized backfill

Other Installation Procedures and Considerations

6.1 Multiple Pipes in Same Trench

When two or more pipes are installed parallel in the same trench, clear spacing between the pipes shall be as per Figure 6.1. Space between pipe and trench wall shall be as Figure 4.2.

It is advisable when laying pipes of different diameters in the same trench, to lay them with the same invert elevation. When this is not possible, select backfill material must be used to fill all the space from the trench bottom to the invert of the higher pipe. Proper compaction must be achieved.

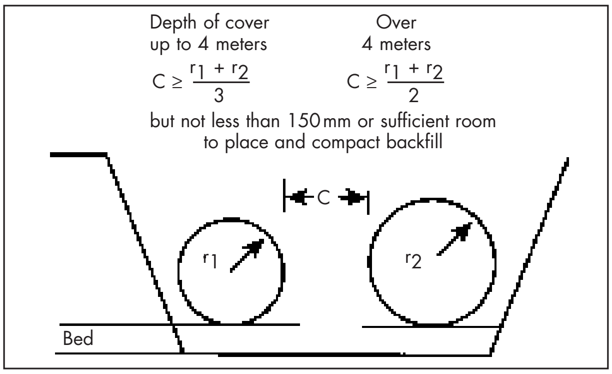


Figure 6.1
Spacing between pipes in the same trench

6.2 Cross-Overs

When two pipes cross, so that one passes over the other, vertical spacing between pipes and installation for the bottom pipe shall be as per Figure 6.2.

In some cases, it is necessary to lay a pipe under an existing line. Extra care should be taken not to damage the existing pipe. It should be protected by fastening it to a steel beam crossing the trench. It is advisable to also wrap the pipe in order to protect it from impact damage. When the new pipe is laid, selected backfill material must be placed back into the trench and hand compacted in order to completely surround both pipes and also achieve the required density.

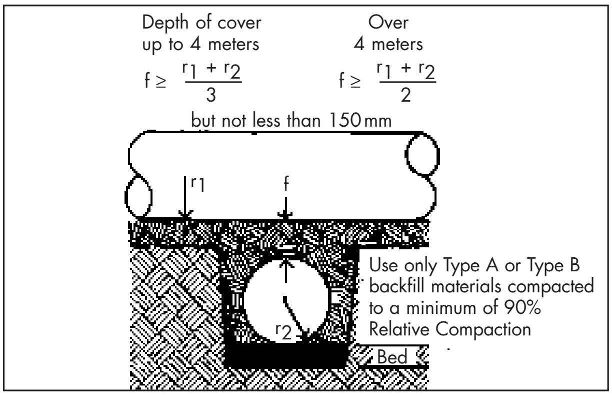


Figure 6.2
Cross-Over

6.3 Unstable Trench Bottom

Where the trench bottom has soft, loose or highly expansive soils, it is regarded as unstable. An unstable trench bottom must be stabilized before laying pipe or a foundation must be constructed to minimize differential settlement of the trench bottom. Gravel or crushed stone is recommended for use in foundation layers.

The depth of the gravel or crushed stone material used for foundation depends upon the severity of the trench bottom soil conditions, but should not be less than 150 mm. The normal bedding must be placed on top of such foundations. The use of filter cloth to completely surround the foundation material will prevent foundation and bedding materials from migrating into one another which could cause loss of pipe bottom support. Additionally, the maximum pipe section length between flexible joints shall be 6 meters.

6.4 Flooded Trench

When the ground water table is above the trench bottom, the water level must be lowered to at least the trench bottom (preferably about 200 mm below) prior to preparation of the bed. Different techniques may be used depending on the nature of the native material.

For sandy or silty soils, a system of well-points to a header pipe and a pump is recommended. The spacing between individual well-points and the depth at which they will be driven depends on the ground water table. It is important to use a filter around the suction point (coarse sand or gravel) to prevent clogging of the well-points by fine grained native material.

When the native material consists of clay or bedrock, well-points will not work. Dewatering is more difficult to achieve in this case if the ground water table is high. The use of sumps and pumps is recommended.

Other Installation Procedures and Considerations
(continued)

If the water cannot be maintained below the top of the bedding, subdrains must be provided. The subdrains shall be made using single size aggregate (20-25 mm) totally embedded in filter cloth. The depth of the sub-drain under the bed shall depend on the amount of water in the trench. If the ground water can still not be maintained below the bed, filter cloth shall be used to surround the bed (and if necessary the pipe zone area as well) to prevent it from being contaminated by the native material. Gravel or crushed stone shall be used for bed and backfill. The following cautions should be noted when dewatering:

- Avoid pumping long distances through the backfill materials or native soils, which could cause loss of support to previously installed pipes due to removal of materials or migration of soils.
- Do not turn off the dewatering system until sufficient cover depth has been reached to prevent pipe flotation.

6.5 Use of Temporary Trench Shoring

If at all possible, the use of temporary trench shoring or sheeting at pipe level should be avoided. This is because it is important that the bedding and pipe zone backfill are compacted hard against the native trench wall. If the shoring or sheeting is pulled out after backfill, the pipe zone material will tend to move into the gap left by the sheeting, reducing support to the pipe, and in many cases, resulting in excessive deflections of the pipes.

In cases where temporary shoring and sheeting are necessary and cannot be avoided, the following requirements should be met:

- Install the shoring to a depth of 300 mm above the top of the pipe, leaving the native trench sides fully exposed at pipe level, or
- Use a type of shoring which can be removed in stages either by pulling up individual sheets or by pulling up the bottom panel of a trench system independent of the upper panels. This lifting of sheets or panels must be done progressively so that pipe bedding and pipe zone material can be compacted hard against the native trench side up to 300 mm above the pipe crown for Installation Type 1, and to 60% of the pipe diameter for Installation Type 2, or
- Use trench boxes. It is fairly easy to pull them in stages using a crane or excavator.

Note: If water and/or native soil are seen to escape between sheets then there are certain to be voids. These must be filled with compacted backfill.

6.6 Trench Construction in Rock

Minimum dimensions for pipe installations in a rock trench shall be per Figure 4.2. Where the rock ends and the pipe passes into a soil trench area (or reverse), flexible joints shall be located as shown in Figure 6.3. Trench construction shall be according to the method applicable for the native soil condition.

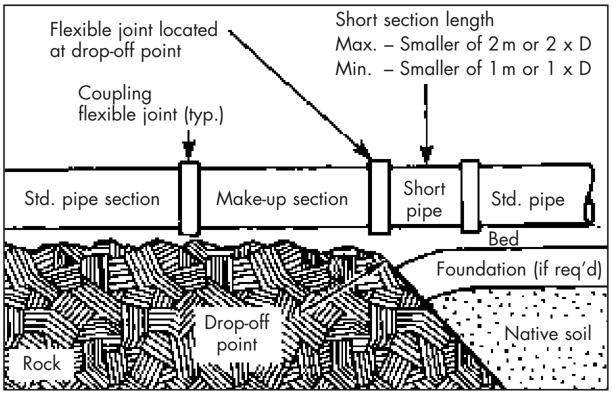


Figure 6.3
Method of trench construction and pipe layout at rock-soil trench transition

6.7 Inadvertent Over-Excavation

Any inadvertent over-excavation of the trench walls or the trench bottom in the foundation, bed or pipe zone areas shall be filled with backfill material compacted to at least 90% relative compaction.

6.8 Installation of Pipes on Slopes

General

- The angle at which slopes can get unstable depends on the quality of the soil. The risk of unstable conditions increases dramatically with slope angle.
- In general, pipes should not be installed on slopes greater than 15 degrees, or in areas where slope instability is suspected, unless supporting conditions have been verified by a proper geotechnical investigation.

Aboveground Installation

- The preferred method of installing pipes on steep slopes is above ground as above ground structures such as pipe supports are more easily defined, the quality of installation is easier to monitor and settlement easier to detect.
- See Pub No. 5-PS22150 (Oct. 1997) for above ground installation information.

Other Installation Procedures and Considerations
(continued)

Buried Installation

Pipes may in special circumstances be installed on slopes greater than 15 degrees provided that:

- Long-term stability of the installation can be ensured with a proper geotechnical design.
- Pipes are backfilled using Installation Type 1 with granular backfill (less than 12% passing 200 sieve) with high shear strength or the shear strength of the backfill is assured by other means. The backfill should be compacted to at least 90% SPD.
- Pipes are installed in straight alignment (plus or minus 0.2 degrees) with a minimum gap between pipe spigots.
- Absolute long-term movement of the backfill in the axial direction of the pipe must be less than 20 mm.
- The installation is properly drained to avoid washout of materials and ensure adequate soil shear strength.
- Stability of individual pipes is monitored throughout the construction phase and the first phases of operation. This can be done by controlling the gap between pipe spigots.
- A special pipe design may be required, consult the pipe supplier.

6.9 Seismic Loading

Analysis of seismic effects is a complex subject and the result is function of the nominal pressure (PN), nominal diameter (DN), nominal stiffness (SN), the pipe length, the burial depth and the backfill soil properties. The analysis is also dependent on the design ground acceleration, and local design codes may vary. Consult the pipe supplier for specific design considerations and analysis.

Thrust Blocks, Concrete Encasement, Rigid Connections

7.1 Thrust Restraints

When the pipeline is pressurized, unbalanced thrust forces occur at bends, reducers, tees, wyes, bulkheads and other changes in line direction. These forces must be restrained in some manner to prevent joint separation. When the surrounding soil cannot provide this restraint, thrust or stress/thrust blocks must be used. Determination of need and design of these restraints is the responsibility of the owner's engineer subject to the following limitations:

Thrust Blocks

Thrust blocks must limit the displacement of the fitting to 0.5% of the diameter or 6 mm, whichever is less. The block must completely surround the fitting for its entire length and circumference (Figure 7.1) and should be placed either against undisturbed earth or backfilled with pipe zone materials as appropriate for the native soil characteristics. See sections on *Rigid Connections* and *Concrete Encasement* for details of pipe installation and system layout.

These blocks are required for the following fittings when the line pressure exceeds 1 bar (100 kPa):

1. All bends, reducers, bulkheads and blind flanges.
2. Tees[1], when the branch pipe is concentric to the header pipe centerline.

1. Concentric manways (blind flange tees) do not require encasement.

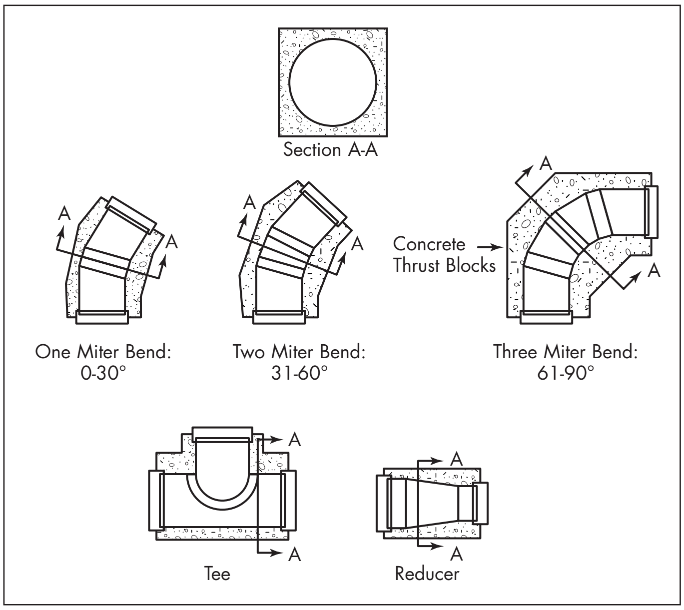


Figure 7.1
Thrust blocks

Note: The thrust block shapes shown are typical for illustration. The exact shape will be dependent on design and project requirement.

Thrust/Stress Blocks

Thrust/stress blocks must limit the displacement of the fitting to 0.5% of the diameter or 6 mm, whichever is less. They must also restrict the radial deformation of the fitting to 0.1% of the radius of the respective pipe sections. The block must completely surround the fitting for its entire length and circumference (Figure 7.1) and should be placed either against undisturbed earth or backfilled with pipe zone material as appropriate for the native soil characteristics.

These blocks are required for the following fittings when the line pressure exceeds 1 bar (100 kPa).

1. Tees, when the branch pipe is eccentric to the header pipe centerline.
2. Custom fittings, such as lateral wyes and bifurcations, as noted by special instructions.

Valves

Valves must be sufficiently anchored to absorb the pressure thrust.

Nozzles

Nozzles are tee branches meeting all of the following criteria:

1. Nozzle diameter ≤ 300 mm.
2. Header diameter ≥ 3 times nozzle diameter.
3. If the nozzle is not concentric and/or not perpendicular to the header pipe axis, the nozzle diameter shall be considered to be the longest chord distance on the header pipe wall at the nozzle/pipe intersection.

Note: It is not necessary to encase nozzle connections in concrete.

Thrust Blocks, Concrete Encasement, Rigid Connections (continued)

7.2 Concrete Encasement

When pipes must be encased in concrete, such as for thrust blocks, stress blocks, or to carry unusual loads, specific additions to the installation procedures must be observed.

Pipe Anchoring

During the pouring of the concrete, the empty pipe will experience large uplift (flotation) forces. The pipe must be restrained against movement that could be caused by these loads. This is normally accomplished by strapping over the pipe to a base slab or other anchor(s). Straps should be a flat material of minimum 25 mm width, strong enough to withstand flotation uplift forces, spaced not to exceed 4 meters, with a minimum of one strap per section length. The straps should be tightened to prevent pipe uplift, but not so tight that additional pipe deflection is caused (Figure 7.2).

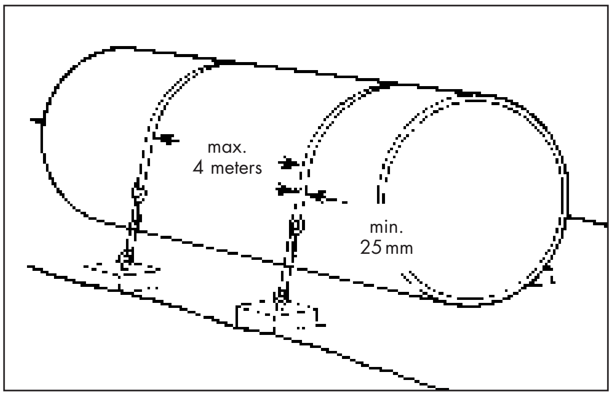


Figure 7.2
Pipe anchoring

Pipe Support

The pipe should be supported in such a way that the concrete can easily flow completely around and fully underneath the pipe. Also, the supports should result in an acceptable pipe shape (less than 3% deflection and no bulges or flat area). Supports are normally placed at strap locations (not exceeding 4 meter spacing) (Figure 7.3).

Concrete Pouring

The concrete surround must be placed in stages allowing sufficient time between layers for the cement to set (no longer exert buoyant forces). Maximum lift height is variable with nominal pipe stiffness:

SN 2500 – larger of 300 mm or 1⁄4 pipe diameter
SN 5000 – larger of 450 mm or 1⁄3 pipe diameter
SN 10000 – larger of 600 mm or 1⁄2 pipe diameter

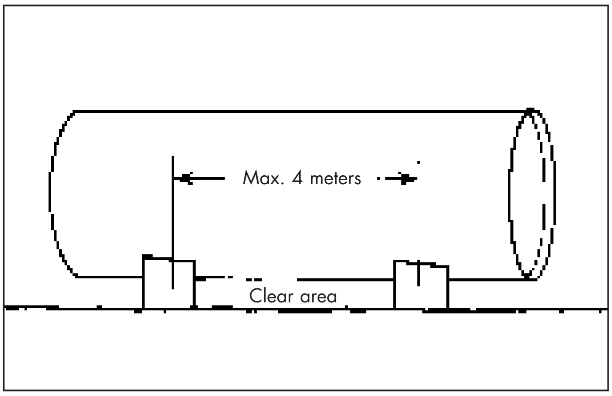


Figure 7.3
Pipe support

7.3 Rigid Connections

When a pipe passes through a wall, is encased in concrete, meets a junction with a manhole, or is flanged to a pump, valve, or other structure, excessive bending stresses may develop in the pipe if differential movement occurs between the pipe and the rigid connection.

For all rigid connections action must be taken by the installer to minimize the development of high discontinuity stresses in the pipe.

Two options are available. The standard (preferred) uses a coupling joint cast into the concrete-pipe interface. The alternate wraps the pipe in rubber to ease the transition.

Standard

Where possible, cast a coupling joint in the concrete at the interface (Figure 7.4) so that the first pipe outside the concrete has complete freedom of movement (within the limits of the joint).

Caution:

1. **When casting a coupling in concrete be sure to maintain its roundness so later joint assembly may be accomplished easily. Alternatively, make up the joint prior to pouring the concrete.**
2. **Since the coupling cast in concrete is rigid, it is very important to minimize the vertical deflection and deformation of the adjacent pipe.**

Alternate

Where the standard method is not possible, wrap (Figure 7.5) a band (or bands) of rubber (Table 7.1 and Figures 7.6 and 7.7) around the pipe prior to placement of any concrete such that the rubber slightly protrudes (25 mm) from the concrete. Lay out the pipeline so the first completely exposed coupling joint is located as shown in Figure 7.5.

Thrust Blocks, Concrete Encasement, Rigid Connections (continued)

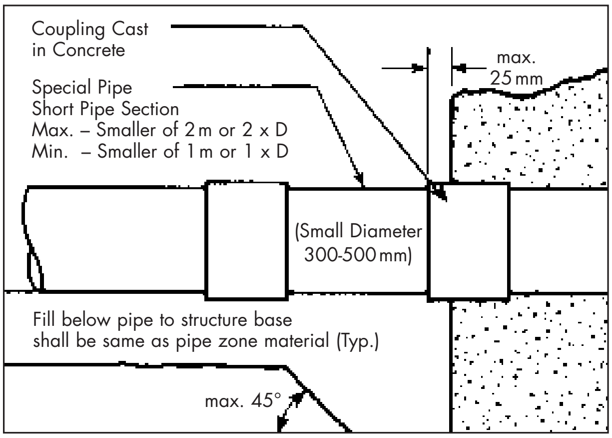


Figure 7.4
Standard

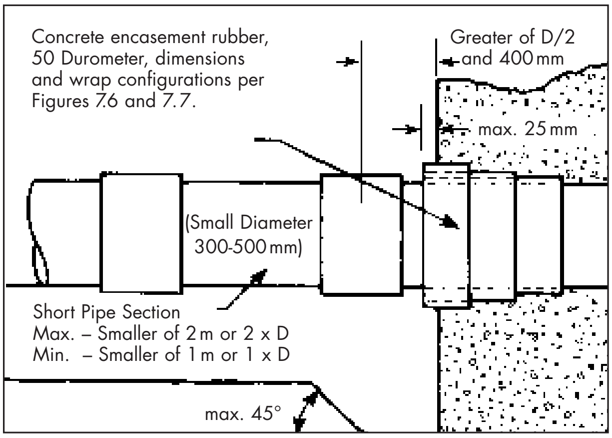


Figure 7.5
Alternate

Construction Guidelines

1. When the design of the concrete structure is considered, it should be noted that any excessive settlement of the structure relative to the pipe can be the cause of a pipe failure.
2. The pipeline layout shall be such that the first pipe section near the rigid connection is a short length (rocker pipe) as follows: (See Figures 7.4 and 7.5.)
   Minimum: smallest of 1 meter or 1 diameter.
   Maximum: smallest of 2 meters or 2 diameters.
   For small diameter pipe (DN ≤ 250 mm) the length of the short piece is 300 mm to 500 mm.
   This rocker pipe section is used to account for some differential settlements that may occur. The rocker pipe should have straight alignment with the concrete structure at the time of installation to provide maximum flexibility for subsequent movements.
   Multiple short lengths or rocker pipes should not be used, as the short spacing between couplings may result in an unstable condition. Misalignment problems should be remedied by rebedding the full pipe sections leading to the rocker pipe.
3. Extra care and caution must be taken to replace and *properly compact* backfill adjacent to the concrete structure. Construction of the concrete structure will frequently require over-excavation for formwork, etc. This extra excavated material must be restored to a density level compatible with surroundings or excess deformation, or joint rotation adjacent to the structure may occur. It is recommended that a backfill soil modulus (E'b) of at least 6.9 MPa be attained in this region to prevent excessive movements. Use of stabilized backfill (cement) adjacent to large concrete structures has also been found to be very effective in preventing excess joint deformation in very large diameters (DN > 1600 mm).

Table 7.1 Quantity and configuration of rubber wraps

Diameter (mm)	STIS 2500 Pressure (kPa) 100	250-300	600	900-1000	1200	1500-1600	STIS 5000/10000 (all pressure classes)
100	A	A	A	A	A	A	
150	A	A	A	A	A	A	
200	A	A	A	A	A	A	
250	A	A	A	A	A	A	
300	A	A	A	A	A	A	A
350	A	A	A	A	A	A	
400	A	A	A	A	A	A	
450	A	A	A	A	A	A	
500	A	A	A	A	A	A	
600	A	A	A	A	A	A	
700	A	A	A	A	A	A	
800	B	B	B	B	B	B	
900	B	B	B	B	B	B	
1000	B	B	B	B	B	B	B
1100	B	B	B	B	B	C	
1200	B	B	B	B	B	C	
1300	B	B	B	B	C	–	
1400	B	B	B	B	C	–	
1500	D	D	D	E	–	–	
1600	D	D	D	E	–	–	
1800	D	D	D	–	–	–	D
2000	D	D	E	–	–	–	
2200	D	D	–	–	–	–	
2400	D	D	–	–	–	–	

Thrust Blocks, Concrete Encasement, Rigid Connections (continued)

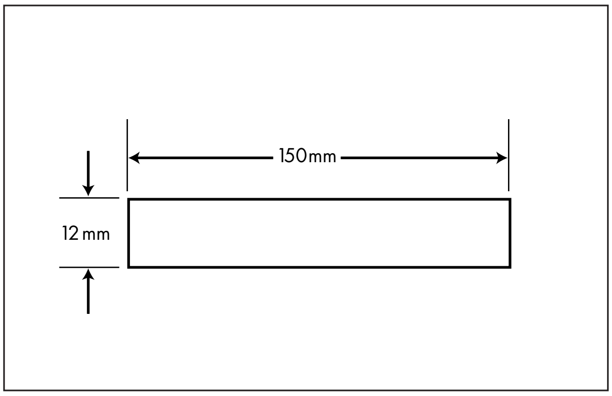


Figure 7.6
Single wrap dimensions (cross-section)

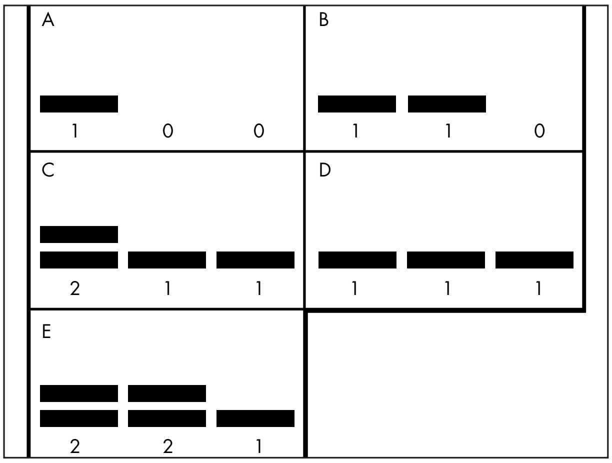


Figure 7.7
Wrap configurations

Rubber Wrap Placement

1. Position as shown in Figures 7.6 and 7.7.
2. Tape all seams and edges to assure no cement can get between the rubber and the pipe or between the rubber wrap pipes edges.

7.4 Casings (Tunnels)

When pipe is installed in a casing the following precautions should be observed.

1. Pipes may be placed into the casing by pulling (drawing) or pushing (jacking).
2. Pipes should be protected from sliding damage by the use of wooden skids attached to the pipe by strapping as shown in Figure 7.8. Skids must provide sufficient height to permit clearance between the coupling joints and the casing wall. (Also, see Figure 7.9.)
3. Installation into the casing is made considerably easier by using lubricant between the skids and the casing wall. Do not use a petroleum based lubricant as it may cause harm to some gaskets.

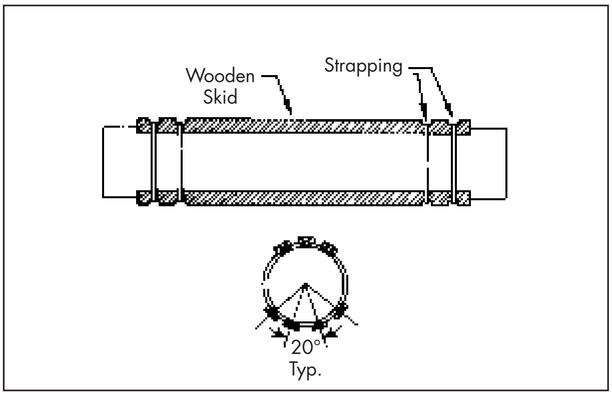


Figure 7.8
Typical skid arrangement

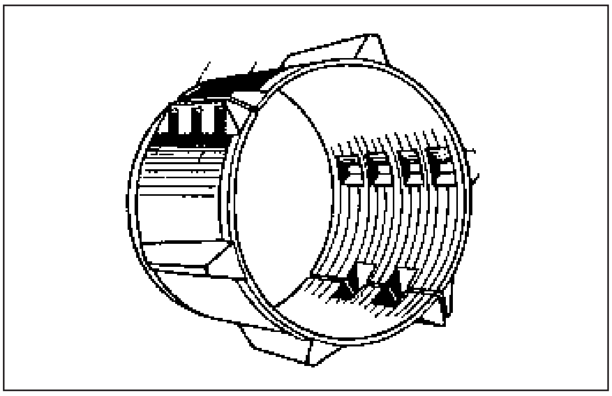


Figure 7.9
Plastic spacer unit

4. The annular space between the casing and pipe may be filled with sand, gravel or cement grout. Care must be taken to not overstress or collapse the pipe during this step, particularly when grouting. Maximum grouting pressure is given in Table 7.2.

Do not wedge or brace the pipe in a manner to cause concentrated or point loads on the pipe. Consult the supplier prior to this step for advice on suitability of the chosen method.

Note: If the pipe will be subjected to negative pressure, the pipe stiffness – installation combination must be sufficient to withstand the load. Consult the supplier for advice.

Table 7.2 Maximum Grouting Pressure

SN	Maximum Grout Pressure (kPa)
2500	27
5000	54
10000	108

Field Adjustments

8.1 Length Adjustment

1. Determine length required and mark a square cut location on the selected pipe.
2. Measure pipe diameter at point of cut with a circumferential PI tape.
3. Compare measurement with spigot tolerance range given in Table 8.1. (Note: manufacturers give the pipe a special marking [Adjustment Pipe] at the factory indicating the entire pipe barrel is within spigot tolerance range). Select one of these pipes (if available) for the field adjustment to avoid spigot machining.
4. Cut the pipe at the appropriate location using a circular saw with a masonry blade. Use proper eye, ear and dust protection. Consult the pipe supplier for recommendations.
5. If pipe diameter is within the spigot tolerance range, clean the surface in the jointing area, sand smooth any rough spots and with a grinder bevel cut pipe end to ease assembly. No further grinding is necessary.
6. If the pipe diameter is not in the spigot tolerance range use a field lathe or grinder and machine the jointing (spigot) surface to the tolerances as indicated in Table 8.1. Bevel pipe end (See Figure 8.1.).

Table 8.1 Spigot Dimensions and Tolerances

Diam. Series	DN (mm)	Minimum (mm)	Maximum (mm)	CL (mm)	BL (mm)
B_2	100	115.5	116.0	107.0	3.1
	150	167.5	168.0	107.0	4.5
	200	220.0	220.5	109.0	4.5
	250	271.6	272.1	109.0	6.4
	300	323.4	324.5	159.0	6.6
	350	375.4	376.4	161.0	8.5
	400	426.3	427.3	162.0	10.4
	500	529.1	530.1	166.0	14.3
B_1	600	616.0	617.0	170.0	17.6
	700	718.0	719.0	172.0	20.0
	800	820.0	821.0	172.0	20.0
	900	922.0	923.0	172.0	20.0
	1000	1024.0	1025.0	172.0	20.0
	1200	1228.0	1229.0	172.0	20.0
	1400	1432.0	1433.0	172.0	20.0
	1600	1636.0	1637.0	172.0	20.0
	1800	1840.0	1841.0	172.0	20.0
	2000	2044.0	2045.0	172.0	20.0
	2400	2452.0	2453.0	172.0	20.0

Note:
1. Series B_2 matches with Ductile Iron spigot O.D.'s.
2. Series B_1 is GRP O.D. series.
3. In some countries the Ductile Iron (B_2) series may not be used.

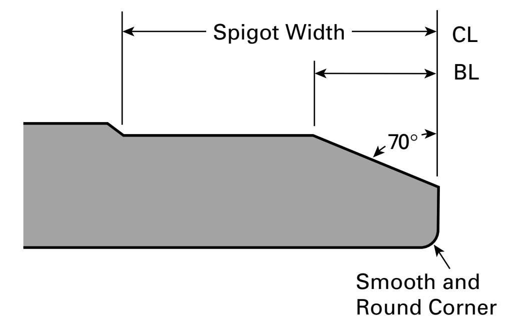


Figure 8.1
Pipe spigot and bevel dimensions definition for coupling joints.
Note: For field closure section, double the spigot width (CL).

8.2 End Coating of Field Cut Sewer Pipe

If sewer pipe is intended to ever be subjected to high pressure water jet cleaning, a special protective end should be applied at the time of manufacture. Customers are advised to so request upon ordering the pipe. It will be necessary for the installing contractor to similarly coat the ends of all field cut pipes. Kits containing the special coating are available from the pipe manufacturer. Please follow the mixing and application instructions furnished with each kit. Alternatively, special short lengths of 1, 2 and 3 meters can be ordered from the pipe manufacturer, thereby avoiding the need to make field cuts. These special lengths need to be ordered at the time the original order is placed.
The above is only necessary for gravity sewer pipes which will be subjected to high pressure (over 80 bar, but less than 120 bar) water jet cleaning. It is not necessary for pipes that are used to convey water or for pumped sewer mains, or where pipes are not cleaned by high pressure water jets.

8.3 Field Closures with FLOWTITE Couplings

1. Carefully measure the space where the closure pipe is to be placed. The closure piece should be no more than 50 mm shorter than the length of the space. The piece should be centered to achieve an equal clearance between the inserted pipe and the adjacent ones.
2. Use a special pipe with long machined ends ordered or prepared specifically for this purpose.
3. Use two double bell couplings without a center register.
4. Pull the couplings onto the machined ends of the closure pipe after lubricating abundantly the ends and the rubber ring. It may be necessary to gently help the second ring over the chamfered end of the pipes.

Field Adjustments (continued)

5. Lubricate well the ends of the two adjacent pipes after they are cleaned thoroughly.
6. Place the closure pipe in its final position and pull the coupling over the adjacent pipes up to the home line (Figure 8.2, Steps 2 and 3).
7. The compaction of the backfill around a field closure pipe is very important. Very often the closure piece area is over-excavated for ease of access. It is essential to provide proper backfill support. It is recommended that a backfill soil modulus (E'b) of at least 6.9 MPa be attained in the closure area to prevent excessive movement and joint rotations.

Note: After the coupling is in final position a "feeler" gauge may be used to assure that gasket lips are properly oriented.

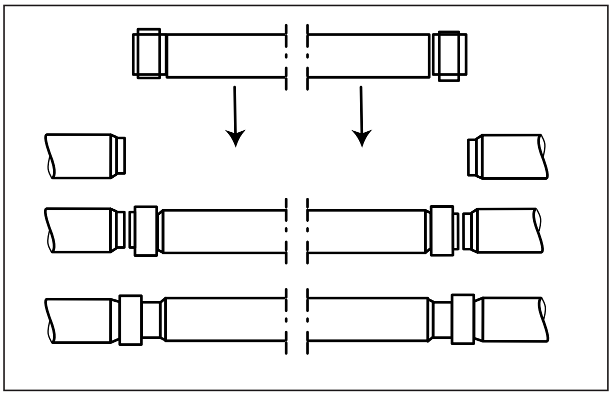


Figure 8.2
Closure section assembly

8.4 Field Closures with Non-FLOWTITE Couplings

Follow the general procedures of 8.3 except that the closure pipe will not typically need to have the special long machined spigot ends. The installation procedures for the particular coupling used must be followed. See Section 3.3.

FLOWTITE Post-Installation

9.1 Checking the Installed Pipe

Requirement: Maximum installed diametrical deflection must not exceed the values in Table 9.1 initially or long term. Bulges, flat areas or other abrupt changes of pipe wall curvature are not permitted. Pipes installed outside of these limitations may not perform as intended.

Checking to insure that the initial requirements have been met is easy to do and should be done for each pipe immediately after completion of installation (typically within 24 hours after reaching maximum cover).

The expected initial pipe deflection is approximately 2% for most installations at the maximum cover given in Tables 4.7 and is proportionally less at shallower depths. Therefore, while initial deflections in Table 9.1 are acceptable for the pipe performance, a value exceeding the expected amount indicates the installation intended has not been achieved and should be improved for future pipes (i.e., increased pipe zone backfill compaction, coarser grained pipe zone backfill materials or wider trench, etc.).

Deflection checks should be done when the first installed pipes are backfilled to grade and continue periodically throughout the entire project. Never let pipe laying get too far ahead before verifying the installation quality. This will permit early detection and correction of inadequate installation methods.

Pipes installed with initial deflections exceeding the values in Table 9.1 must be reinstalled so the initial deflection is less than those values. See Section 9.2, *Correcting Over-Deflected Pipe,* for limitations applicable to this work.

Procedure for checking the initial diametrical deflection for installed pipes:

1. Complete backfilling to grade.
2. Complete removal of temporary sheeting (if used).
3. Turn off the dewatering system (if used).
4. Measure and record the pipe's vertical diameter. **Note: for small diameter pipes, a deflection proving device (commonly called a pig) may be pulled through the pipes to measure the vertical diameter.**
5. Calculate vertical deflection:

$$\%\ \text{Deflection} = \frac{\text{Actual I.D.} - \text{Installed Vertical I.D.}}{\text{Actual I.D.}} \times 100$$

Actual I.D. may be verified or determined by measuring the diameters of a pipe not yet installed laying loose (no pipes stacked above) on a reasonably plane surface. Calculate as follows:

$$\text{Actual I.D.} = \frac{\text{Vertical I.D.} + \text{Horizontal I.D.}}{2}$$

(See Figure 9.1.)

Table 9.1 Allowable Vertical Deflection

	Deflection % of Diameter
Large Diameter (DN ≥ 300)	
Initial	3.0
Long Term	5.0
Small Diameter (DN ≤ 250)	
Initial	2.5
Long Term	4.0

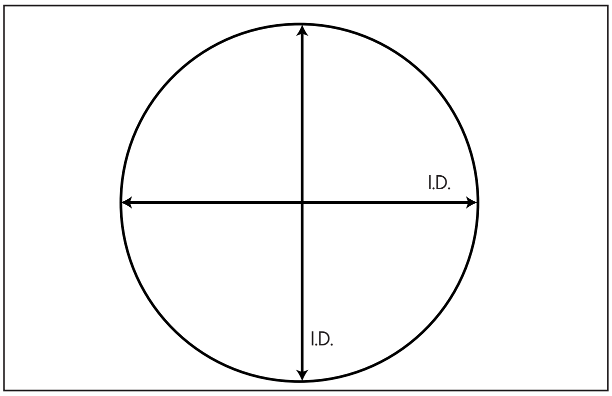


Figure 9.1
Determining actual pipe I.D. on pipe not yet installed

9.2 Correcting Over-Deflected Pipe

Pipes installed with initial diametrical deflections exceeding the values in Table 9.1 must be corrected to insure the long-term performance of the pipe.

Procedure:

For pipe deflected up to 8% of diameter:

1. Excavate to a level equal to approximately 85% of the pipe diameter. Excavation just above and at the sides of the pipe should be done utilizing hand tools to avoid impacting the pipe with heavy equipment (Figure 9.2).
2. Inspect the pipe for damage. Damaged pipe should be repaired or replaced.
3. Recompact haunch backfill, insuring it is not contaminated with unacceptable backfill material soil.
4. Rebackfill the pipe zone in lifts with the appropriate material, compacting each layer to the required relative compaction density.
5. Backfill to grade and check the pipe deflections to verify they have not exceeded the values in Table 9.1.

Post-Installation (continued)

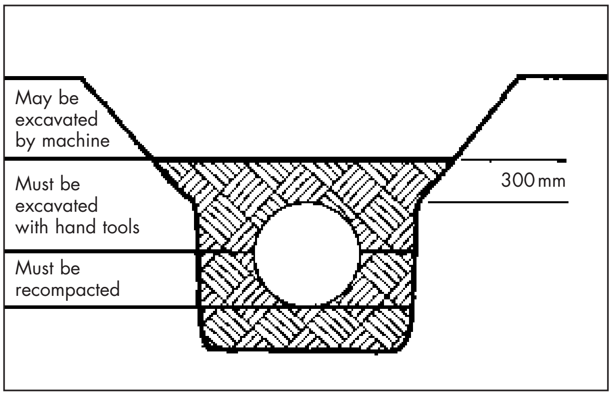


Figure 9.2
Excavating over-deflected pipe

For pipe deflected greater than 8% pipe diameter:

1. Pipes with over 8% deflection should be replaced completely.

Caution: Do not attempt to jack or wedge the installed over-deflected pipe into a round condition. This may cause damage to the pipe.

If excavating multiple pipes, care must be taken to not mound the cover from one pipe over the adjacent. The extra cover and reduction of side support could magnify an over-deflection situation.

9.3 Field Hydrotesting

Some job specifications require the completed pipe installation to be hydrostatically tested prior to acceptance and service. This is good practice as it can permit early detection and correction of some installation flaws, damaged products, etc. If a field hydrotest is specified, it must be done regularly as installation proceeds. Installation should never exceed testing by more than approximately 1 km. In addition to routine care, normal precautions and typical procedures used in this work, the following suggestions should be noted:

1. **Preparation Prior to Test** – Inspect the completed installation to assure that all work has been finished properly. Of critical importance are:
   - Pipe deflection limited to the values in Table 9.1.
   - Joints assembled correctly.
   - System restraints (i.e., thrust blocks and other anchors) in place and properly cured.
   - Flange bolting torqued per instructions.
   - Backfilling completed. SEE SECTION 4.7 ON MINIMUM BURIAL DEPTH AND HIGH PRESSURE AND TESTING LIMITATIONS.
   - Valves and pumps anchored.
   - Backfill and compaction near structures and at closure pieces has been properly carried out. See 7.3 and 8.3.
2. **Filling the Line with Water** – Open valves and vents, so that all air is expelled from the line during filling, and avoid pressure surges.
3. Pressurize the line slowly. Considerable energy is stored in a pipeline under pressure, and this power should be respected.
4. Insure the gauge location will read the highest line pressure or adjust accordingly. Locations lower in the line will have higher pressure due to additional head.
5. Insure the maximum test pressure is not exceeded. (See Table 9.2.) This may be dangerous and result in damage to the pipe system.
6. If after a brief period for stabilization the line does not hold constant pressure, insure that thermal effect (a temperature change), pipe expansion[1] or entrapped air is not the cause. If the pipe is determined to be leaking and the location is not readily apparent, the following methods may aid discovery of the problem source:
   - Check flange and valve areas.
   - Check line tap locations.
   - Use sonic detection equipment.
   - Test the line in smaller segments to isolate the leak.

Table 9.2 Maximum Field Test Pressures

Pressure Class	Maximum Field Test Pressure
100 kPa	150 kPa
250 kPa	375 kPa
600 kPa	900 kPa
1000 kPa	1500 kPa
1600 kPa	2400 kPa

Note: Most projects will specify a maximum pressure loss or volume of water lost. These may vary by project. Consult the supplier for more specific guidance or recommendations.

7. FLOWTITE, being a glass-reinforced polyester pipe, will expand under pressure. Hence additional water will be required to make up for this expansion.

Post-Installation (continued)

9.4 Field Joint Tester

Portable hydraulic field joint test equipment can be special ordered and supplied for diameters 700 mm and above.

This equipment can be used to internally test selected pipe joints. It is required that each pipe adjacent to the joint under test be backfilled sufficiently to prevent pipe movement during testing. Additional details are available from the supplier's Field Service Representative.

Caution: This equipment is designed to allow a test of the joint to verify that the joint has been assembled properly with gaskets in proper position. This equipment is limited to a maximum pressure test level of 6 bars.

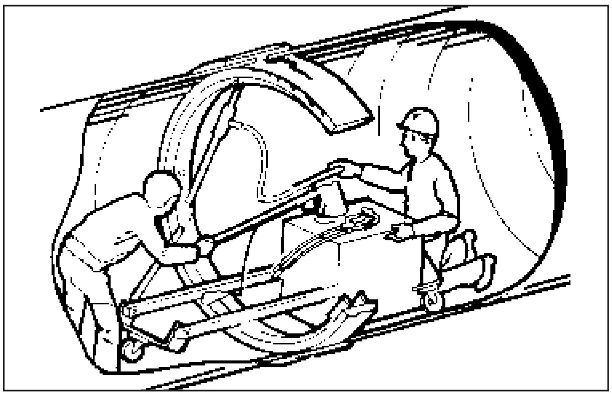


Figure 9.3
Field joint tester

9.5 Field Air Test

An alternate leak test for gravity pipe (PN ≤ 1 bar) systems may be conducted with air pressure instead of water. In addition to routine care, normal precautions and typical procedures used in this work, the following suggestions and criteria should be noted:

1. As with the hydrotest, the line should be tested in small segments, usually the pipe contained between adjacent manholes.
2. Assure the pipeline and all materals, stubs, accesses, drops, etc. are adequately capped or plugged and braced against the internal pressure.
3. Slowly pressurize the system to 24 kPa. The pressure must be regulated to prevent over-pressurization (maximum 35 kPa).
4. Allow the air temperature to stabilize for several minutes while maintaining the pressure at 24 kPa.
5. During this stabilization period, it is advisable to check all plugged and capped outlets with a soap solution to detect leakage. If leakage is found at any connection, release the system pressure, seal the leaky cap(s) or plug(s) and begin the procedure again at Step 3.
6. After the stabilization period, adjust the air pressure to 24 kPa and shut-off or disconnect the air supply.
7. The pipe system passes this test if the pressure drop is 3.5 kPa or less during the time periods given in Table 9.3.
8. Should the section of line under test fail the air test acceptance requirements, the pneumatic plugs can be coupled fairly close together and moved up or down the line, repeating the air test at each location, until the leak is found. This leak location method is very accurate, pinpointing the location of the leak to within one or two meters. Consequently, the area that must be excavated to make repairs is minimized, resulting in lower repair costs and considerable saved time.

Caution: Considerable potential energy is stored in a pipeline under pressure. This is particularly true when air (even at low pressures) is the test medium. Take great care to be sure the pipeline is adequately restrained at changes in line direction and follow manufacturers' safety precautions for devices such as pneumatic plugs.

Table 9.3 Test Time – Field Air Test

Dia. (mm)	Time (min.)	Dia. (mm)	Time (min.)
100	2 1/2	1000	25
150	3 3/4	1100	27 1/2
200	5	1200	30
250	6 1/4	1300	32 1/2
300	7 3/4	1400	35
350	8 3/4	1500	37 1/2
400	10	1600	40
500	12 1/2	1800	45
600	15	2000	50
700	17 1/2	2200	55
800	20	2400	60
900	22 1/2		

Note:

1. **This test will determine the rate at which air under pressure escapes from an isolated section of the pipeline. It is suited to determine the presence or absence of pipe damage and/or improperly assembled joints.**
2. **This test is not intended to indicate water leakage limits. If the pipeline fails this air test, it should not be rejected until a hydrotest is conducted.**

Post-Installation (continued)

9.6 Cleaning of FLOWTITE Sewer Pipe

There are several methods used to clean gravity sewer lines, depending on diameter and the degree and nature of blockage. All of these methods use either mechanical or hydropneumatic force to clean the interior of the pipe. When mechanical means are employed, we recommend the use of plastic scrapers to avoid damage to the pipe's inner surface.

The use of high pressure water, emitted through jet nozzles, is a practice followed in some countries for cleaning sewer pipes. However, water emitted under high pressure through a jet nozzle can cause damage to most materials if not properly controlled. Based on experience gained with water jet cleaning of GRP sewer pipes, the following guidelines must be adhered to in order to avoid damage to the installed pipes:

1. Maximum input pressure at the jetting nozzle must be limited to 120 bars (1750 psig). Due to the smooth interior surface of GRP pipe, adequate cleaning and removal of blockages can normally be achieved below this pressure.
2. Jetting/swabbing sleds with several runners are to be used to elevate the jet nozzle off the pipe's invert (Figure 9.4).
3. The water discharge angle at the outlet nozzle must be between 6° and 15° relative to the pipe axis.
4. The number of jet holes in the nozzle head should be 8 or more, and the bore hole size must be greater than 2.0 mm (0.08 inch).

Please consult with the pipe manufacturer for the names of water jet nozzle and sled manufacturers whose equipment meets the above criteria if uncertain. The use of equipment or pressures that do not meet the above criteria could cause damage to the installed pipe.

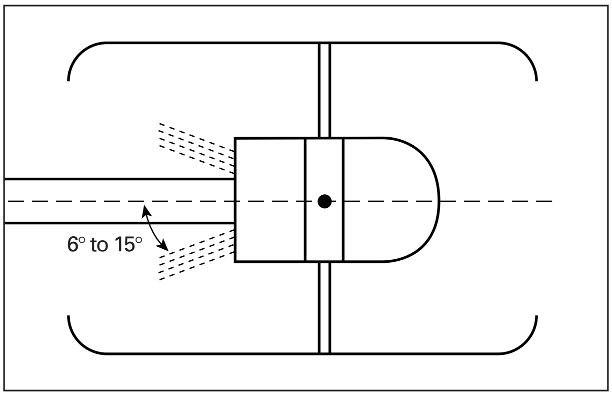


Figure 9.4
Water jetting sled

Appendix

Appendix A

Approximate Weights for Pipes and Couplings

Nominal Diameter (mm)	Pipe Weight (kg/M) SN 2500	SN 5000	SN 10000	Weight Per Coupling (kg)
100	–	–	2.5	2
150	–	–	4.9	3
200	–	–	7.2	4
250	–	–	10.8	6
300	8	10	13	12
350	11	14	18	14
400	15	18	23	16
450	19	23	29	18
500	23	28	36	20
600	31	39	48	32
700	42	53	66	40
800	55	68	85	47
900	69	87	107	55
1000	85	107	132	63
1200	122	152	190	74
1400	166	207	258	91
1600	215	269	336	109
1800	272	340	424	107*
2000	335	418	460	121*
2400	481	498	–	151*

Coupling weights for PN 16, except where noted
* PN 10

Appendix B

Joint Lubricant Requirements

Nominal Pipe Diameter (mm)	Nominal Amount of Lubricant (kg) Required per Joint
100 to 250	.050
300 to 500	.075
600 to 800	.100
900 to 1000	.150
1100 to 1200	.200
1300 to 1400	.250
1500 to 1600	.300
1800	.350
2000	.400
2200	.450
2400	.500

Appendix (continued)

Appendix C

Classification and Properties of Native Soils

For the analysis of pipe behavior, the native soils are classified in six groups and related to stiffness through blow counts as defined by a standard penetration test using a split barrel sampler, ASTM D1586. These native soils, which form the trench walls, range from very stable, dense granular soils and very hard cohesive soils to relatively weak, fine grained soils. These same native soils may be considered for use as backfill.

Representation of the native soil is given in Table C1 which follows the general recommendations provided in AWWA M45. The blow count to be used is the lowest value found over an extended period of time in the pipe zone. Normally, the weakest condition of the soil exists when the soil has been subjected to wet conditions for an extended period.

Table C1: Native Soil Group Classification

Native Soil Group	Blow Counts[1]	E'n value[3,4] (MPa)	Non-Cohesive Soils: Description	Non-Cohesive Soils: Friction Angle (degrees)	Cohesive Soils: Description	Cohesive Soils: Unc. Comp. Str. (kPa)
1	> 15[2]	34.5	compact	33	very stiff	192 – 384
2	8 – 15	20.7	slightly compact	30	stiff	96 – 192
3	4 – 8	10.3	loose	29	medium	48 – 96
4	2 – 4	4.8	very loose	28	soft	24 – 48
5	1 – 2	1.4	very loose	27	very soft	12 – 24
6	0 – 1	0.34	very, very loose	26	very, very soft	0 – 12

1. Blows/foot from standard penetration test, ASTM D1586.
2. For higher blow counts, E'n values increase to 345 MPa for rock.
3. The use of geotextiles in the pipe zone will likely increase the values of E'n above those listed.
4. If permanent sheeting is used in the pipe zone, consider native E'n = E'b, Sc = 1.

Appendix D

Classification and Properties of Backfill Soils

To be used as backfill for pipes, the soil must provide stiffness to the pipe/soil system and maintain the required stiffness with time. The variety of potential soils that can be used as pipe zone backfill is limitless. Pipe zone backfill may be selected from the soil removed from the trench or may require special soils to be imported to the job site, if the trenched soils are not adequate to serve as backfill. The practical selection of a pipe zone backfill soil depends on ease of compaction to achieve the needed stiffness and availability. General guidelines for classifying soils which are suitable to be used as backfill are given in Table D1. The classification of these soils is by soil type, density and potential to become saturated. When combined, these criteria typically determine the modulus (stiffness) of the soil and its ability to provide support to the pipe as a system component. Soil type is primarily a function of a particle size analysis, ASTM C136. Classification based on the percentage of fines (soil particles that pass a #200 sieve, less than 75 microns) because the behavior of the soil and ease of compaction is typically controlled by the fines portion of the soil. The liquid limit requirement is given to limit the backfill soils to those which will retain stiffness with time and can be reliably compacted.

Table D1: Backfill Soil Type Classification

Backfill Soil Type	Description	Unified Soil Classification Designation, ASTM D2487
A	Crushed stone and gravel, < 12% fines	GW, GP, GW – GM, GP – GM
B	Gravel with sand, sand, < 12% fines	GW – GC, GP – GC, SW, SP, SW – SM, SP – SM, SW – SC, SP – SC
C	Silty gravel and sand, 12 – 35% fines, LL < 40%	GM, GC, GM – GC, SM, SC, SM – SC
D	Silty, clayey sand, 35 – 50% fines, LL < 40%	GM, GC, GM – GC, SM, SC, SM – SC
E	Sandy, clayey silt, 50 – 70% fines, LL < 40%	CL, ML, CL – ML
F	Low plasticity fine-grained soils, LL < 40%	CL, ML, CL – ML

Appendix (continued)

To assist with the selection of approximate values of the modulus of passive resistance for pipe zone backfill, Tables D2 and D3 are given. These tables use properties suggested in AWWA M45 as the primary reference for establishing the basic relationship between modulus, soil type and relative compaction. The modulus of passive resistance can be approximated by the one-dimensional constrained soil modulus[1,2,3] as measured by ASTM D2435. Relative densities are based on a maximum dry density defined by ASTM D698, known as the Standard Proctor test. In comparing Tables D2 and D3, note that the effect of moisture increases as the fines portion increases.

Table D2 Backfill Modulus of Passive Resistance (Non-Saturated)

Backfill Type	E'b Values (MPa) at Relative Compaction[1] 80%	85%	90%	95%
A	16	18	20	22
B	7	11	16	19
C	6	9	14	17
D	3	6	9	10[2]
E	3	6	9	10[2]
F	3	6	9[2]	10[2]

1. 100% Relative Compaction defined as maximum Standard Proctor Density at optimum moisture content.
2. Values typically difficult to achieve, included as reference.

Table D3 Backfill Modulus of Passive Resistance (Saturated)

Backfill Type	E'b Values (MPa) at Relative Compaction[1] 80%	85%	90%	95%
A	12	13	14	15
B	5	7	10	12
C	2	3	4	4
D	1.7	2.4	2.8	3.1[2]
E	NA[3]	1.7	2.1	2.4[2]
F	NA[3]	1.4	1.7[2]	2.1[2]

1. 100% Relative Compaction defined as maximum Standard Proctor Density at optimum moisture content.
2. Values typically difficult to achieve, included as reference.
3. Not recommended for use.

References:

1. Greenwood, Mark, "Buried FRP Pipe – Performance Through Proper Installation," Managing Corrosion Problems with Plastics, National Association of Corrosion Engineers, Houston, 1975.
2. Greenwood, Mark E. and Lang, Dennis C., "Vertical Deflection of Buried Flexible Pipes," Buried Plastic Pipe Technology, ASTM STP 1093, George S. Buczala and Michael J. Cassady, EDS., American Society of Testing and Materials, Philadelphia, 1990.
3. McGrath, Timothy J., "Pipe-Soil Interactions During Backfill Placement," Ph.D. Thesis from University of Massachusetts, Amherst, 1998.

Appendix E

Field Testing to Assist Classification of Native Soils

Table E1 Simple Field Test for Determining Soil Group[1]

Native Soil Group	Measurable Characteristic
1	Can be barely penetrated with thumb
2	Can be penetrated with thumb to 4 mm
3	Can be penetrated by thumb to 10 mm
4	Can be penetrated by thumb to 25 mm
5	Can be penetrated by thumb to 50 mm
6	Can be penetrated by fist to 25 mm

1. Based on Peck, Hanson and Thornburn, "Foundation Engineering," 2nd Ed., John Wiley and Sons, Inc., 1974 and ASTM D2488.

Appendix F

Compaction of Backfill[1,2]

This appendix provides helpful tips for compacting the various types of backfill. The maximum and minimum allowable installation depths will be effected by the selection and relative compaction of pipe-zone backfill. The stiffer the soil, the deeper a given pipe can be installed to achieve a limiting deflection or vacuum. This guide offers a general background for soil behavior to provide a better understanding of our installation criteria. Include considerations for seasonal variations when assessing the potential for moisture content of both in situ and backfill soils. The relative compaction value recommended to provide a soil modulus value is to be considered as a minimum value and field densities should be at or higher than the requirement.

As a means of "calibrating" an installation method with a given backfill type, we recommend that specific attention be given to compaction techniques and relative compaction results during the installation of the initial sections of pipe used at a given installation site. By correlating the resulting relative compaction as a function of the soil type, method of placement of soil in the haunch zones and side fill areas, compaction methods for haunch and side fill areas, lift heights used, moisture content and number of passes, a good "feel" for the needed efforts for installation can be determined. When these initial pipes are installed, testing should be conducted frequently to assure relative compaction and pipe deflection criteria are being achieved. With this correlation, a technique for compacting a given soil type can be "calibrated" and the frequency for testing can be reduced. With this correlation, the workers gain a good understanding of the requirements for proper installation when using a specific backfill type for a specific set of requirements. (ASTM D5080 offers a reasonable method for rapidly measuring field density and moisture content of soils.) There are many methods available for measuring field density of the compacted backfill.

A measurement of the increase in the vertical diameter of the pipe is a reasonable measure of compaction effort used during the installation and another good "calibration" measurement. If backfill has been properly placed and compacted in the haunch areas of the pipe, a good method for judging compaction is the vertical diameter measurement when the backfill placement has reached the top of the pipe (or at any stage if consistently monitored). However, be aware that when using high levels of compaction effort, excessive vertical increase in diameter may result. If this condition occurs, contact the pipe supplier for assistance, and do not continue with the installation using the method that creates the excessive increase in vertical diameter.

Pipe zone backfill materials should be placed and compacted in uniform lifts on both sides of the pipe. For backfill placement and compaction in the haunch areas, start compacting under the pipe and work away from the pipe. For side fill, compaction usually progresses best when the backfill is compacted at the trench wall first and compaction progresses toward the pipe. Usually the number of "passes" or repeated applications of the compaction equipment (at a constant rate of movement) will increase the relative compaction. A good way to determine a sufficient compaction method is to measure the relative compaction and other response measurements as a function of the number of passes of a given compaction device. Use the number of passes and other criteria such as moisture content and vertical deflection as a means of controlling the installation procedure. If the compaction equipment is changed, the number of passes to achieve the specified relative compaction may be effected. Heavier and wider plate vibrators typically compact deeper and to a higher degree than lighter and narrower ones. Likewise, the smaller and lighter impact compactors have a less effective depth than the larger, heavier ones.

Compaction over the top of the pipe must assure that there is sufficient material to not impact the pipe. At least 150 mm cover should be sufficient when using a hand operated plate vibrator compactor; however, 300 mm is recommended when using a hand operated impact compactor. A relative compaction of no more than 85% SPD can realistically be achieved when compacting the first 300mm lift over the pipe.

Backfill soils that are granular in character provide relatively high stiffness with minimal compaction effort. Compact granular soils have little tendency to creep or consolidate with time. Granular soils are less sensitive to moisture, both at the time of placement and during long-term use. When finer grained soils are used as backfill, the support for the pipe is typically reduced. Granular soil with more than 12% by weight of fines (soils with partial size less than 75 microns) are significantly affected by the characteristics of the finer materials. If the fines are mostly silts (37 to 7 microns), the typical soils are moisture sensitive, have a tendency to be transported by flowing water and require some additional effort to compact. If the fines are mostly clay (less than 37 microns and cohesive), the soils are more moisture sensitive which reduces stiffness, and the soil will creep with time. Typically, more compaction effort is needed to achieve the required density. By limiting soils to a liquid limit of 40%, the highly moisture sensitive and plastic soils have been eliminated from use.

Backfill Types A and B are relatively easy to use and very reliable as backfill materials for pipe. These soils have low moisture sensitivity. Backfill can be easily compacted using a plate vibrator compactor in 200 to 300 mm lifts. The haunch areas can be compacted using the ends of boards or "pogo stick" impact compactors. Occasionally, a filter fabric must be used in combination with gravel soils to preclude fines migration and subsequent loss of pipe support.

Backfill Type C soils are acceptable and readily available as backfill materials for pipe installations. Many local soils in which the pipe is installed are Type C soils, and therefore, the trenched soil can be directly reused as pipe-zone backfill. Precaution is to be taken with these soils as they can be moisture sensitive. The characteristics of a Type C soil is often dictated by the characteristics of the fines. Moisture control may be required when compacting the soil to achieve the desired density with reasonable compaction energy. Usually, required relative compaction can be achieved by using an impact compactor in 125 to 200 mm lifts, but a plate vibrator compactor may work. "Pogo stick" impact compactors can be used to compact haunch fill; shovel slicing helps to place the haunch backfill. Be sure to "calibrate" the installation.

Backfill Types D and E are acceptable backfill materials in most conditions; however, their relatively low stiffness precludes their use in deeper installations that may become saturated, and cannot be properly compacted where standing water is presented. Extra care should be provided in placing and compacting backfill under the pipe. To achieve desired relative compaction, moisture control will most likely be required during compaction. When compacting, use lifts of 75 to 150 mm with an impact compactor such as Whacker or pneumatic rammer (pogo stick). Haunch fill should be placed with shovel slicing and compacted with a "pogo stick" impact

Appendix (continued)

compactor. Compaction tests should be conducted periodically to assure proper relative compaction is achieved. Be sure to "calibrate" the installation method.

Backfill Type F can be used as pipe-zone backfill with the following precautions:

- Moisture content must be controlled during placement and compaction.
- Do not use in installation with unstable foundations or with standing water in the trench.
- Extra effort is needed to place and compact backfill under the pipe.
- Compaction techniques may require considerable energy and practical limitations of relative compaction and resulting soil stiffness must be considered.
- When compacting, use lifts of 75 to 150 mm with an impact compactor such as Whacker or pneumatic rammer (pogo stick).
- Place haunch backfill in small increments and compact with a "pogo stick" impact compactor.
- Compaction tests should be conducted periodically to assure proper relative compaction is achieved.
- Be careful to cause excessive increase in vertical diameter of the pipe with the use of excess compaction effort.

1. Howard, Amster, "Pipeline Installation," Relativity Publishing, 1996.
2. "Fiberglass Pipe Design," American Works Association, AWWA M45, 1996.

Appendix G

Definitions and Terminology

Term	Description
Nominal diameter, DN	The diameter classification of a pipe, expressed in mm.
Nominal Pressure, PN	The pressure rating of a pipe, expressed in bars or pressure.
Nominal Stiffness, SN	The minimum initial specific stiffness, EI/D^3, of a pipe as measured by a load required to deflecting a pipe ring.
Pipe crown	The top of the pipe.
Pipe invert	The bottom inside surface of a pipe.
Depth of bury	The depth of cover over the top of a pipe.
Deflection	The change in vertical diameter, typically expressed as a percentage of the nominal pipe diameter.
Springline	The mid height of the pipe, the 90 and 270 degree locations of a pipe as measured from the top center of the pipe.
Modulus of passive resistance: E', E'n, E'b	These are soil stiffness terms, originated by Spangler and Watkins, to describe an empirically based property of soil stiffness provided by a soil when the springline of a pipe deflects into the soil.
Constrained soil modulus, Ms	A secant modulus of soil measured by a one dimensional compression test. A reasonable laboratory measurement as a approximation of E'.
Standard Proctor Density, SPD	The maximum dry density obtained at optimum moisture content when tested by ASTM D698, used to define 100% relative compaction.
Percent Relative Compaction	The achieved dry density/maximum dry density expressed in %.
Relative Density	A term used to describe the density of granular soils as a portion of the range between minimum and maximum density using ASTM D4253 and D4254. The density at 0% relative density is typically from 65 to 95% of maximum density. We avoid use of this term to minimize confusion.
Blow Counts	The number of impacts of a 140 pound (64 kg) hammer dropping 30 inches (76 cm) to drive a split barrel sampler 12 inches (30 cm) by ASTM D1586.
Liquid Limit, LL	One of the terms identified by Atterberg limits testing. The liquid limit is the moisture content at which the soil begins to behave as a viscous fluid, ASTM D423. At this level of moisture, the soil is "mud like" and when excited with slight impact will slightly flow.
Saturated	The condition of a soil when the voids are filled with water.
Non-saturated	The condition of a soil when the voids are not filled with water.

1 Start

Identify Nominal Pipe Diameter, DN

Pipe Diameter, mm

Small Diameter	Large Diameter	
100	300	900
150	350	1000
200	400	1200
250	450	1400
	500	1600
	600	1800
	700	2000
	800	2400

2

Identify Pressure Class

Pressure classes of FLOWTITE pipe may be selected from the table below. Not all pressure classes are available in all diameters and stiffnesses.

Pressure Class[1] PN (gravity)	Pressure Rating[2] Bar	Upper Diameter Limit, mm
1	1	2400
6	6	2400
10	10	2400
16	16	2000
20	20	1400
25	25	1400
32	32	800

[1] FLOWTITE pipes can additionally withstand an increase in total pressure due to infrequent waterhammer equal to 140% of the nominal pressure rating. As an example, PN10 can accommodate a temporary surge pressure up to 14 bar. However, the normal continuous operating pressure should not exceed 10 bar for that pressure class of pipe.

[2] Pressure ratings have been established in accordance with the design approach outlined in AWWA M-45, *Fiber Glass Pipe Design Manual.*

3

Native Soil Classification

Native soil type will affect pipe stiffness and backfill soil selection.

E'n is the modulus (stiffness) of the native soil.

Native Soil Classification

Group	1	2	3	4	5	6
Granular	Compact	Slightly Compact	Loose	Very Loose	Very Loose	Very, Very Loose
Cohesive	Very Stiff	Stiff	Medium	Soft	Very Soft	Very, Very Soft
Blow Counts*	>15	8-15	4-8	2-4	1-2	0-1
E'n/Mpa	34	20	10	4	1	0.3

*Blows per 12 inches from standard penetration test, ASTM D1586

NOTE: If native soil is rock, select Soil Group 1

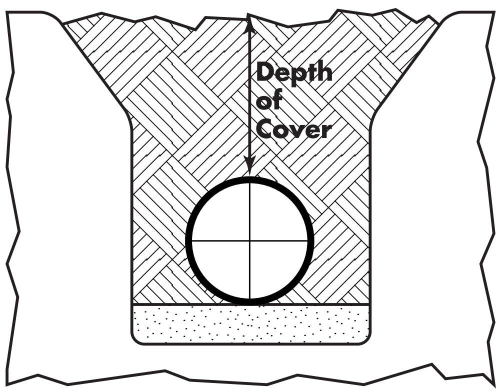
4

Minimum Depth of Cover

Depth of cover must be a minimum of 0.5 meters for operating pressures up to 10 bar.

Operating Pressure and Minimum Depth of Cover

Pipes operating at pressures 16 bar and greater must be buried at least 0.8 meters for small diameters and 1.2 meters for large diameters.



5

Traffic Load Selection and Minimum Burial Depth

Select type of traffic load, if any, to which pipe will be subjected, and the corresponding minimum burial depth, m.

Select Traffic Load Level

Wheel Load (KN)	0	40	50	72	90	100	Railroad
Type	None	ATV LKW 12	ATV SLW 30	AASHO HS20	BS 153 HA	ATV SLW 60	COOPER E80
Min. Burial Depth, m	0.5	1.0	1.0	1.0	1.5	1.5	3.0

6

Negative Pressure

Negative pressure can affect pipe stiffness and backfill selection and limit the maximum burial depth.

Select Vacuum/Negative Pressure Level in Increments of -0.25 bar

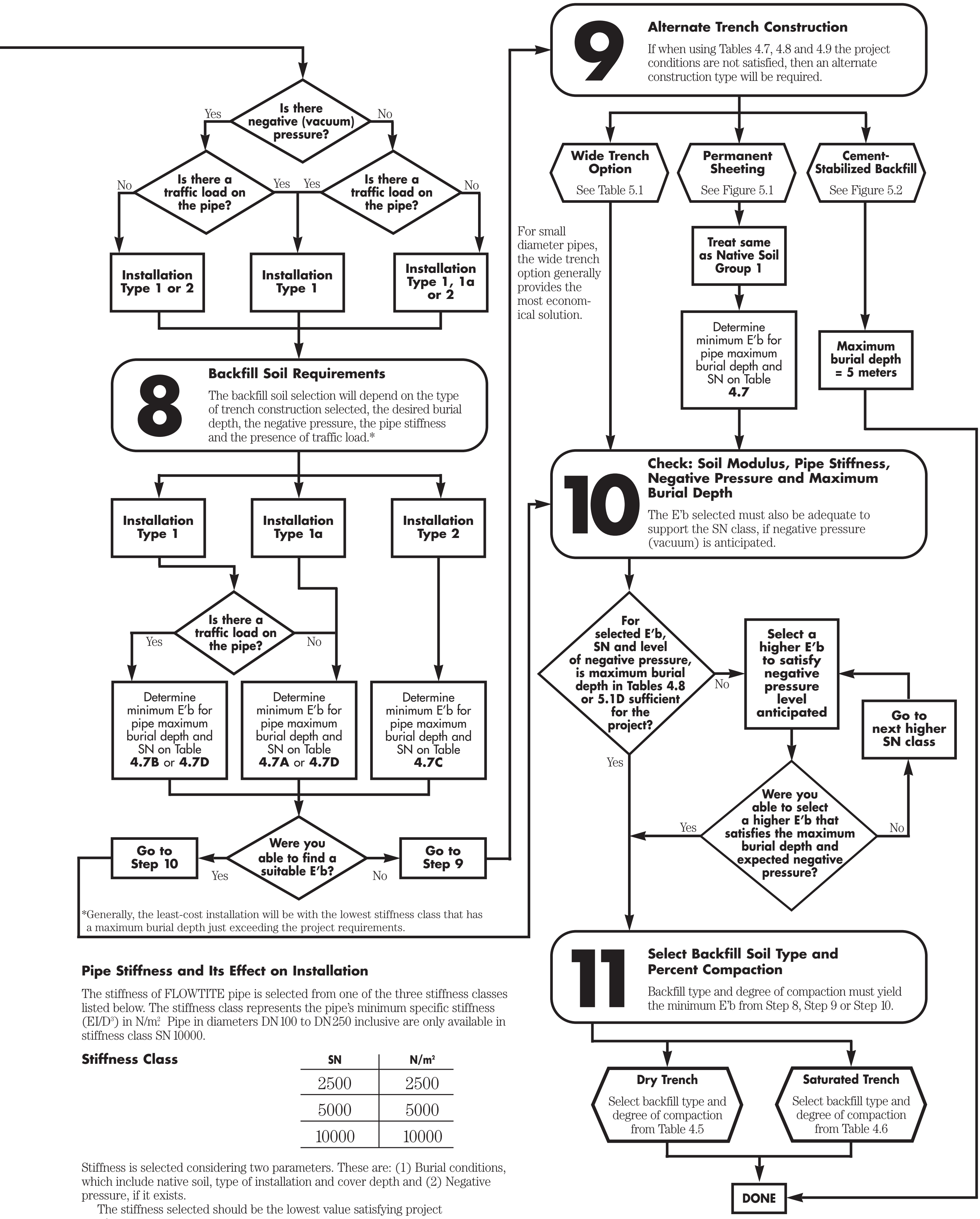
0 (None)	-0.25	-0.50	-0.75	-1.0

Sometimes the backfill requirements for negative pressure can be more demanding than the external soil load. The engineer or contractor is encouraged to design the system to avoid the occurrence of high negative (vacuum) pressure.

7

Trench Construction

The type of trench construction will be affected by negative pressure, traffic load and required burial depth.



Pipe Stiffness and Its Effect on Installation

The stiffness of FLOWTITE pipe is selected from one of the three stiffness classes listed below. The stiffness class represents the pipe's minimum specific stiffness (EI/D^3) in N/m^2. Pipe in diameters DN 100 to DN 250 inclusive are only available in stiffness class SN 10000.

Stiffness Class

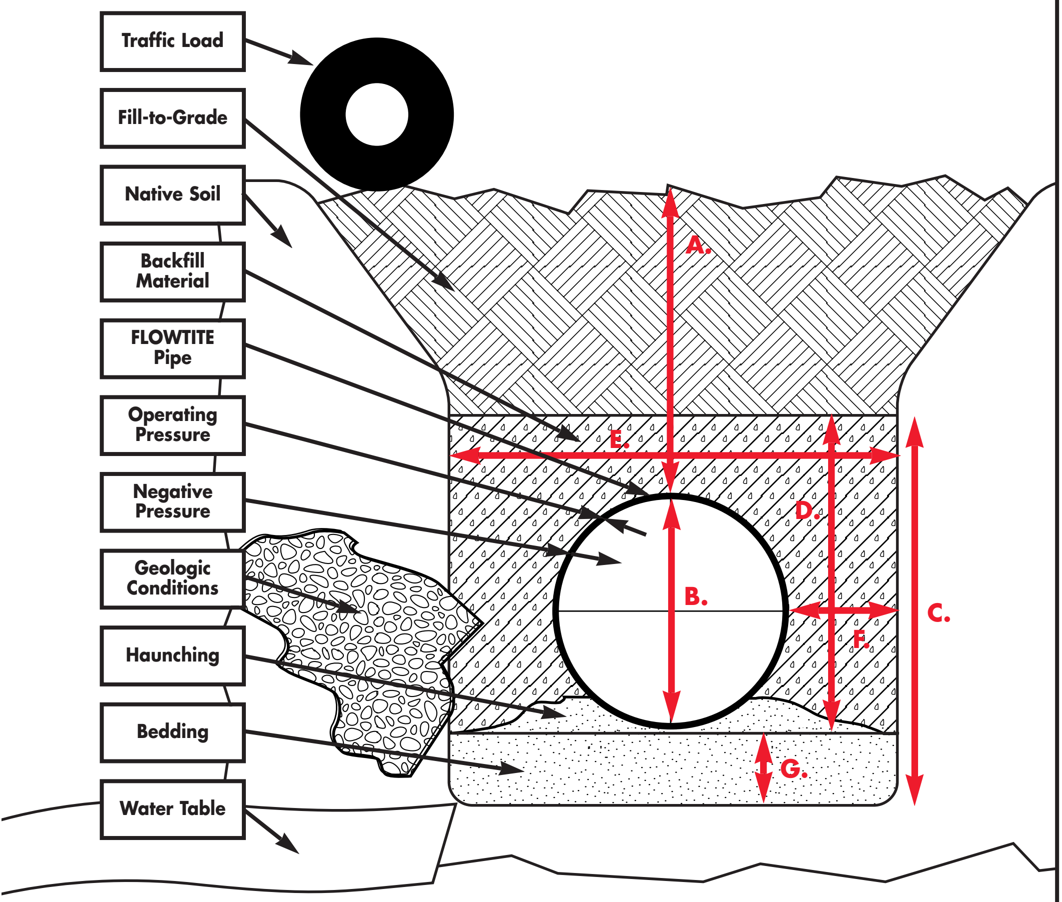
SN	N/m²
2500	2500
5000	5000
10000	10000

Stiffness is selected considering two parameters. These are: (1) Burial conditions, which include native soil, type of installation and cover depth and (2) Negative pressure, if it exists.

The stiffness selected should be the lowest value satisfying project requirements.

Generally, a low-quality backfill soil, even at a high degree of compaction, will be the most economical solution.

Factors Affecting Installation



A. Depth of Cover:
Maximum allowable depth of cover is affected by:
- Backfill soil modulus
- Trench width
- Native soil modulus
- Traffic load
- Pipe stiffness
- Water table elevation
- Negative pressure

B. Pipe Diameter (DN)
DN determines:
- Bedding depth
- Trench width

C. Pipe Zone:
The area from the bottom of the bedding to 300 mm over the crown of the pipe is defined as the pipe zone.

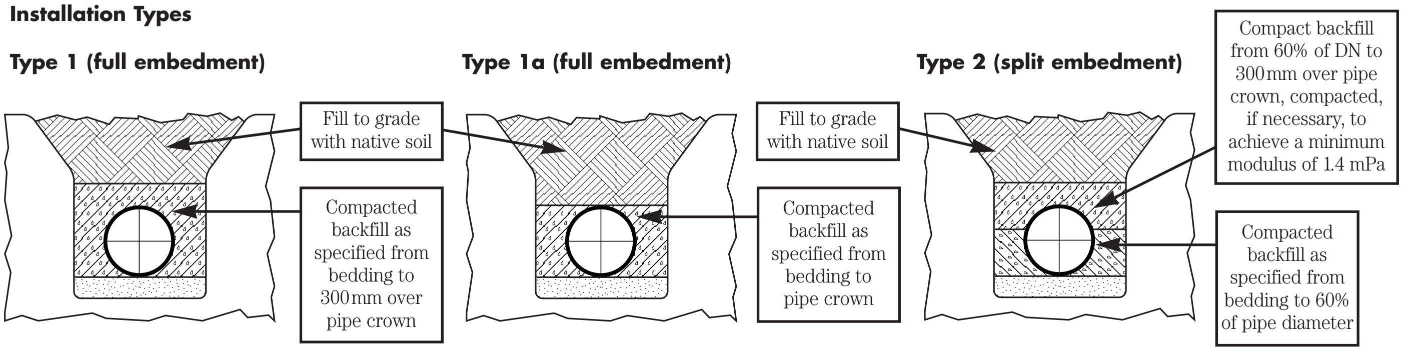
D. Compacted Backfill:
The soil modulus, E'b, of the backfill material depends on type and degree of compaction.

E. Trench Width:
Minimum trench width is a function of pipe diameter.
Standard Width = 1.75 x DN.

F. Side Clearance:
Sufficient side clearance must be allowed to permit specified compaction of haunching and backfill soil.

G. Depth of Bedding:
The compacted bedding for the pipe is calculated as DN/4 with a maximum depth of 150 mm.

Installation Types



Installation Design Process

1	Define diameter
2	Select pressure class
3	Define native soil classification
4	Check minimum depth of cover and operating pressure
5	Check minimum depth of cover for traffic load
6	Define negative pressure (vacuum)
7	Select trench type
8	Check allowable burial depth and select SN and E'b
9	Select alternate trench construction, if necessary
10	Select backfill soil type and degree of compaction

RECORD DATA:	
Effluent:	DN:
PN:	
Group:	
OK?	
OK?	
Negative pressure (Vacuum):	
Type (full or split):	
SN:	E'b:
Alternative:	
Type:	%:

Proven solutions... anywhere in the world.

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