



Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications¹

This standard is issued under the fixed designation D 2321; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This practice provides recommendations for the installation of buried thermoplastic pipe used in sewers and other gravity-flow applications. These recommendations are intended to ensure a stable underground environment for thermoplastic pipe under a wide range of service conditions. However, because of the numerous flexible plastic pipe products available and the inherent variability of natural ground conditions, achieving satisfactory performance of any one product may require modification to provisions contained herein to meet specific project requirements.

1.2 The scope of this practice necessarily excludes product performance criteria such as minimum pipe stiffness, maximum service deflection, or long term strength. Thus, it is incumbent upon the product manufacturer, specifier, or project engineer to verify and assure that the pipe specified for an intended application, when installed according to procedures outlined in this practice, will provide a long term, satisfactory performance according to criteria established for that application. A commentary on factors important in achieving a satisfactory installation is included in Appendix X1.

NOTE 1—Specific paragraphs in the appendix are referenced in the body of this practice for informational purposes.

NOTE 2—The following ASTM standards may be found useful in connection with this practice: Practice D 420, Test Method D 1556, Method D 2216, Specification D 2235, Test Method D 2412, Specification D 2564, Practice D 2657, Practice D 2855, Test Methods D 2922, Test Method D 3017, Practice F 402, Specification F 477, Specification F 545, and Specification F 913.

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

2. Referenced Documents

2.1 ASTM Standards:

- D 8 Terminology Relating to Materials for Roads and Pavements²
- D 653 Terminology Relating to Soil, Rock, and Contained Fluids³
- D 698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft³ (600 kN-m/m³))
- D 2487 Test Method for Classification of Soils for Engineering Purposes^{3,4}
- D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)^{3,4}
- D 3839 Practice for Underground Installation of “Fiberglass” (Glass-Fiber Reinforced Thermosetting Resin) Pipe⁴
- D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils³
- F 412 Terminology Relating to Plastic Piping Systems⁴

3. Terminology

3.1 *General—Definitions used in this practice are in accordance with Terminologies F 412 and D 8 and Terminology D 653 unless otherwise indicated.*

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *foundation, bedding, haunching, initial backfill, final backfill, pipe zone, excavated trench width*—See Fig. 1 for meaning and limits, and trench terminology.

3.2.2 *aggregate*—a granular material of mineral composition such as sand, gravel, shell, slag or crushed stone (see Terminology D 8).

3.2.3 *deflection*—any change in the inside diameter of the pipe resulting from installation and imposed loads. Deflection may be either vertical or horizontal and is usually reported as a percentage of the base (undeflected) inside pipe diameter.

3.2.4 *dense-graded aggregate*—an aggregate that has a particle size distribution such that, when it is compacted, the resulting voids between the aggregate particles, expressed as a percentage of the total space occupied by the material, are relatively small.

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² *Annual Book of ASTM Standards*, Vol 04.03.

³ *Annual Book of ASTM Standards*, Vol 04.08.

⁴ *Annual Book of ASTM Standards*, Vol 08.04.

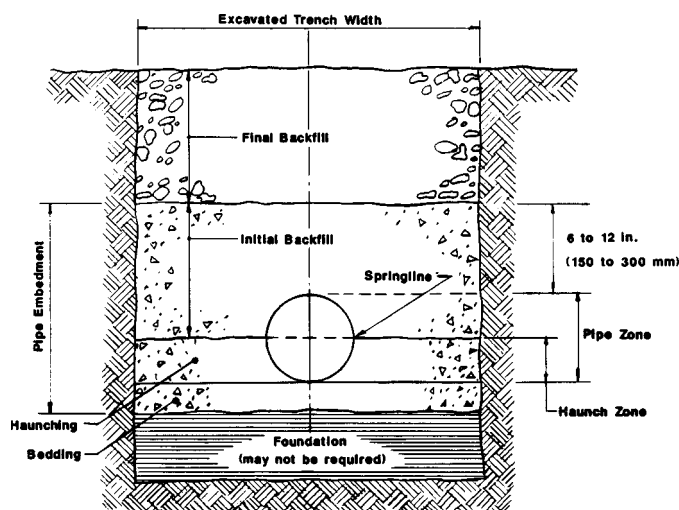


FIG. 1 Trench Cross Section Showing Terminology

NOTE 4—Processed materials produced for highway construction, including coarse aggregate, base, subbase, and surface course materials, when used for foundation, embedment, and backfill, should be classified in accordance with this section and Table 1 according to particle size, shape and gradation.

5.2 *Installation and Use*—Table 2 provides recommendations on installation and use based on class of soil or aggregates and location in the trench.

5.2.1 *Use of Class I to Class IVA Soils and Aggregates*—These materials may be used as recommended in Table 2, unless otherwise specified.

5.2.2 *Use of Class IV-B and Class V Soils and Frozen Materials*—These materials are not recommended for embedment, and should be excluded from the final backfill except where allowed by project specifications.

5.3 *Description of Embedment Material*—Sections 5.3.1 through 5.3.5 describe characteristics of materials recommended for embedment.

5.3.1 *Class IA Materials*—Class IA materials provide maximum stability and pipe support for a given density due to angular interlock of particles. With minimum effort these materials can be installed at relatively high densities over a wide range of moisture contents. In addition, the high permeability of Class IA materials may aid in the control of water, and these materials are often desirable for embedment in rock cuts where water is frequently encountered. However, when ground water flow is anticipated, consideration should be given to the potential for migration of fines from adjacent materials into the open-graded Class IA materials (see X1.8).

5.3.2 *Class IB Materials*—Class IB materials are processed by mixing Class IA and natural or processed sands to produce a particle size distribution that minimizes migration from adjacent materials that contain fines (see X1.8). They are more densely graded than Class IA materials and thus require more compactive effort to achieve the minimum density specified. When properly compacted, Class IB materials offer high stiffness and strength and, depending on the amount of fines, may be relatively free draining.

5.3.3 *Class II Materials*—Class II materials, when compacted, provide a relatively high level of pipe support. In most respects, they have all the desirable characteristics of Class IB materials when densely graded. However, open graded groups may allow migration and the sizes should be checked for compatibility with adjacent material (see X1.8). Typically, Class II materials consist of rounded particles and are less stable than angular materials unless they are confined and compacted.

5.3.4 *Class III Materials*—Class III materials provide less support for a given density than Class I or Class II materials. High levels of compactive effort may be required unless moisture content is controlled. These materials provide reasonable levels of pipe support once proper density is achieved.

5.3.5 *Class IV-A Materials*—Class IV-A materials require a geotechnical evaluation prior to use. Moisture content must be near optimum to minimize compactive effort and achieve the required density. Properly placed and compacted, Class IV-A materials can provide reasonable levels of pipe support; however, these materials may not be suitable under high fills,

3.2.5 *engineer*—the engineer in responsible charge of the work or his duly recognized or authorized representative.

3.2.6 *manufactured aggregates*—aggregates such as slag that are products or byproducts of a manufacturing process, or natural aggregates that are reduced to their final form by a manufacturing process such as crushing.

3.2.7 *open-graded aggregate*—an aggregate that has a particle size distribution such that, when it is compacted, the voids between the aggregate particles, expressed as a percentage of the total space occupied by the material, are relatively large.

3.2.8 *optimum moisture content*—The moisture content of soil at which its maximum density is obtained (see Test Methods D 698).

3.2.9 *processed aggregates*—aggregates that are screened, washed, mixed, or blended to produce a specific particle size distribution.

3.2.10 *standard proctor density*—the maximum dry unit weight of soil compacted at optimum moisture content, as obtained by laboratory test in accordance with Test Methods D 698.

4. Significance and Use

4.1 This practice is for use by designers and specifiers, installation contractors, regulatory agencies, owners, and inspection organizations who are involved in the construction of sewers and other gravity-flow applications that utilize flexible thermoplastic pipe. As with any standard practice, modifications may be required for specific job conditions or for special local or regional conditions. Recommendations for inclusion of this practice in contract documents for a specific project are given in Appendix X2.

5. Materials

5.1 *Classification*—Materials for use as foundation, embedment, and backfill are classified in Table 1. They include natural, manufactured, and processed aggregates and the soil types classified according to Test Method D 2487.

NOTE 3—See Practice D 2488 for a visual-manual procedure for field identification of soils.

TABLE 1 Classes of Embedment and Backfill Materials

Class	Type	Soil Group Symbol D 2487	Description	Percentage Passing Sieve Sizes			Atterberg Limits		Coefficients	
				1½in. (40 mm)	No. 4 (4.75 mm)	No. 200 (0.075 mm)	LL	PI	Uni- formity C _u	Curva- ture C _c
IA	Manufactured Aggregates: open-graded, clean.	None	Angular, crushed stone or rock, crushed gravel, broken coral, crushed slag, cinders or shells; large void content, contain little or no fines.	100 %	≤10 %	<5 %	Non Plastic			
IB	Manufactured, Processed Aggregates; dense- graded, clean.	None	Angular, crushed stone (or other Class 1A materials) and stone/sand mixtures with gradations selected to minimize migration of adja- cent soils; contain little or no fines (see X1.8).	100 %	≤50 %	<5 %	Non Plastic			
II	Coarse-Grained Soils, clean	GW	Well-graded gravels and gravel-sand mixtures; little or no fines.	100 %	<50 % of "Coarse Fraction"	<5 %	Non Plastic		>4	1 to 3
		GP	Poorly-graded gravels and gravel-sand mixtures; little or no fines.						<4	<1 or >3
		SW	Well-graded sands and gravelly sands; little or no fines.		>50 % of "Coarse Fraction"				>6	1 to 3
		SP	Poorly-graded sands and gravelly sands; little or no fines.						<6	<1 or >3
	Coarse-Grained Soils, bor- derline clean to w/fines	e.g. GW-GC, SP-SM.	Sands and gravels which are borderline between clean and with fines.	100 %	Varies	5 % to 12 %	Non Plastic		Same as for GW, GP, SW and SP	
III	Coarse-Grained Soils With Fines	GM	Silty gravels, gravel-sand-silt mixtures.	100 %	<50 % of "Coarse Fraction"	12 % to 50 %		<4 or <"A" Line		
		GC	Clayey gravels, gravel-sand- clay mixtures.					<7 and >"A" Line		
		SM	Silty sands, sand-silt mixtures.		>50 % of "Coarse Fraction"			>4 or <"A" Line		
		SC	Clayey sands, sand-clay mix- tures.					>7 and >"A" Line		
IVA ⁴	Fine-Grained Soils (inor- ganic)	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, silts with slight plasticity.	100 %	100 %	>50 %	<50	<4 or <"A" Line		
		CL	Inorganic clays of low to me- dium plasticity, gravelly clays, sandy clays, silty clays, lean clays.					>7 and >"A" Line		
IVB	Fine-Grained Soils (inor- ganic)	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	100 %	100 %	>50 %	>50	<"A" Line		
		CH	Inorganic clays of high plas- ticity, fat clays.					>"A" Line		
V	Organic Soils	OL	Organic silts and organic silty clays of low plasticity.	100 %	100 %	>50 %	<50	<4 or <"A" Line		
	OH	Organic clays of medium to high plasticity, organic silts.	>50				<"A" Line			
	Highly Organic	PT	Peat and other high organic soils.							

⁴Includes Test Method D 2487 borderline classifications and dual symbols depending on plasticity index and liquid limits.

Note—"Coarse Fraction" as used in this table is defined as material retained on a No. 200 sieve.

surface applied wheel loads, or under heavy vibratory compactors and tampers. Do not use where water conditions in the trench may cause instability and result in uncontrolled water content.

5.4 Moisture Content of Embedment Material—The mois-

ture content of embedment materials must be within suitable limits to permit placement and compaction to required levels with reasonable effort. For non-free draining soils (that is, Class III, Class IVA, and some borderline Class II soils), moisture content is normally required to be held to ±3 % of

TABLE 2 Recommendations for Installation and Use of Soils and Aggregates for Foundation, Embedment and Backfill

	Soil Class (see Table 1) ^A				
	Class IA	Class IB	Class II	Class III	Class IV-A
General Recommendations and Restrictions	Do not use where conditions may cause migration of fines from adjacent soil and loss of pipe support. Suitable for use as a drainage blanket and underdrain in rock cuts where adjacent material is suitably graded (see X1.8).	Process materials as required to obtain gradation which will minimize migration of adjacent materials (see X1.8). Suitable for use as drainage blanket and underdrain.	Where hydraulic gradient exists check gradation to minimize migration. "Clean" groups suitable for use as drainage blanket and underdrain.	Do not use where water conditions in trench may cause instability.	Obtain geotechnical evaluation of proposed material. May not be suitable under high earth fills, surface applied wheel loads, and under heavy vibratory compactors and tampers. Do not use where water conditions in trench may cause instability.
Foundation	Suitable as foundation and for replacing over-excavated and unstable trench bottom as restricted above. Install and compact in 6-in. maximum layers.	Suitable as foundation and for replacing over-excavated and unstable trench bottom. Install and compact in 6-in. maximum layers.	Suitable as a foundation and for replacing over-excavated and unstable trench bottom as restricted above. Install and compact in 6-in. maximum layers.	Suitable as foundation and for replacing over-excavated trench bottom as restricted above. Do not use in thicknesses greater than 12 in. total. Install and compact in 6-in. maximum layers.	Suitable only in undisturbed condition and where trench is dry. Remove all loose material and provide firm, uniform trench bottom before bedding is placed.
Bedding	Suitable as restricted above. Install in 6-in. maximum layers. Level final grade by hand. Minimum depth 4 in. (6 in. in rock cuts).	Install and compact in 6-in. maximum layers. Level final grade by hand. Minimum depth 4 in. (6 in. in rock cuts).	Suitable as restricted above. Install and compact in 6-in. maximum layers. Level final grade by hand. Minimum depth 4 in. (6 in. in rock cuts).	Suitable only in dry trench conditions. Install and compact in 6-in. maximum layers. Level final grade by hand. Minimum depth 4 in. (6 in. in rock cuts).	Suitable only in dry trench conditions and when optimum placement and compaction control is maintained. Install and compact in 6-in. maximum layers. Level final grade by hand. Minimum depth 4 in. (6 in. in rock cuts).
Haunching	Suitable as restricted above. Install in 6-in. maximum layers. Work in around pipe by hand to provide uniform support.	Install and compact in 6-in. maximum layers. Work in around pipe by hand to provide uniform support.	Suitable as restricted above. Install and compact in 6-in. maximum layers. Work in around pipe by hand to provide uniform support.	Suitable as restricted above. Install and compact in 6-in. maximum layers. Work in around pipe by hand to provide uniform support.	Suitable only in dry trench conditions and when optimum placement and compaction control is maintained. Install and compact in 6-in. maximum layers. Work in around pipe by hand to provide uniform support.
Initial Backfill	Suitable as restricted above. Install to a minimum of 6 in. above pipe crown.	Install and compact to a minimum of 6 in. above pipe crown.	Suitable as restricted above. Install and compact to a minimum of 6 in. above pipe crown.	Suitable as restricted above. Install and compact to a minimum of 6 in. above pipe crown.	Suitable as restricted above. Install and compact to a minimum of 6 in. above pipe crown.
Embedment Compaction ^B	Place and work by hand to insure all excavated voids and haunch areas are filled. For high densities use vibratory compactors.	Minimum density 85 % Std. Proctor. ^C Use hand tampers or vibratory compactors.	Minimum density 85 % Std. Proctor. ^C Use hand tampers or vibratory compactors.	Minimum density 90 % Std. Proctor. ^C Use hand tampers or vibratory compactors. Maintain moisture content near optimum to minimize compactive effort.	Minimum density 95 % Std. Proctor. ^C Use hand tampers or impact tampers. Maintain moisture content near optimum to minimize compactive effort.
Final Backfill	Compact as required by the engineer.	Compact as required by the engineer.	Compact as required by the engineer.	Compact as required by the engineer.	Suitable as restricted above. Compact as required by the engineer.

^AClass IV-B (MH-CH) and Class V (OL, OH, PT) Materials are unsuitable as embedment. They may be used as final backfill as permitted by the engineer.

^BWhen using mechanical compactors avoid contact with pipe. When compacting over pipe crown maintain a minimum of 6 in. cover when using small mechanical compactors. When using larger compactors maintain minimum clearances as required by the engineer (See X1.7).

^CThe minimum densities given in the table are intended as the compaction requirements for obtaining satisfactory embedment stiffness in most installation conditions (see 7.5.1).

optimum (see Test Methods D 698). The practicality of obtaining and maintaining the required limits on moisture content is an important criterion for selecting materials, since failure to achieve required density, especially in the pipe zone, may result in excessive deflection. Where a chance for water in the

trench exists, embedment materials should be selected for their ability to be readily densified while saturated (that is, free-draining, cohesionless granular materials).

5.5 *Maximum Particle Size*—Maximum particle size for embedment is limited to material passing a 1½-in. (37.5-mm)

sieve (see Table 1). To enhance placement around small diameter pipe and to prevent damage to the pipe wall, a smaller maximum size may be required (see X1.9). When final backfill contains rocks, cobbles, etc., the engineer may require greater initial backfill cover levels (see Fig. 1).

6. Trench Excavation

6.1 *General*—Procedures for trench excavation that are especially important in flexible thermoplastic pipe installations are given herein.

6.1.1 *Excavation*—Excavate trenches to ensure that sides will be stable under all working conditions. Slope trench walls or provide supports in conformance with all local and national standards for safety. Open only as much trench as can be safely maintained by available equipment. Backfill all trenches as soon as practicable, but not later than the end of each working day.

6.2 *Water Control*—Do not lay or embed pipe in standing or running water. At all times prevent runoff and surface water from entering the trench.

6.2.1 *Ground Water*—When groundwater is present in the work area, dewater to maintain stability of in-situ and imported materials. Maintain water level below pipe bedding and foundation to provide a stable trench bottom. Use, as appropriate, sump pumps, well points, deep wells, geofabrics, perforated underdrains, or stone blankets of sufficient thickness to remove and control water in the trench. When excavating while depressing ground water, ensure the ground water is below the bottom of cut at all times to prevent washout from behind sheeting or sloughing of exposed trench walls. Maintain control of water in the trench before, during, and after pipe installation, and until embedment is installed and sufficient backfill has been placed to prevent flotation of the pipe. To preclude loss of soil support, employ dewatering methods that minimize removal of fines and the creation of voids in in-situ materials.

6.2.2 *Running Water*—Control running water emanating from drainage of surface or ground water to preclude undermining of the trench bottom or walls, the foundation, or other zones of embedment. Provide dams, cutoffs or other barriers periodically along the installation to preclude transport of water along the trench bottom. Backfill all trenches after the pipe is installed to prevent disturbance of pipe and embedment.

6.2.3 *Materials for Water Control*—Use suitably graded materials in foundation or bedding layers or as drainage blankets for transport of running water to sump pits or other drains. Use well graded materials, along with perforated underdrains, to enhance transport of running water, as required. Select the gradation of the drainage materials to minimize migration of fines from surrounding materials (see X1.8).

6.3 *Minimum Trench Width*—Where trench walls are stable or supported, provide a width sufficient, but no greater than necessary, to ensure working room to properly and safely place and compact haunching and other embedment materials. The space between the pipe and trench wall must be wider than the compaction equipment used in the pipe zone. Minimum width shall be not less than the greater of either the pipe outside diameter plus 16 in. (400 mm) or the pipe outside diameter times 1.25, plus 12 in. (300 mm). In addition to safety

considerations, trench width in unsupported, unstable soils will depend on the size and stiffness of the pipe, stiffness of the embedment and in-situ soil, and depth of cover (see X1.10). Specially designed equipment may enable the satisfactory installation and embedment of pipe in trenches narrower than specified above. If it is determined that the use of such equipment provides an installation consistent with the requirements of this standard, minimum trench widths may be reduced, as approved by the engineer.

6.4 *Support of Trench Walls*—When supports such as trench sheeting, trench jacks, trench shields or boxes are used, ensure that support of the pipe and its embedment is maintained throughout installation. Ensure that sheeting is sufficiently tight to prevent washing out of the trench wall from behind the sheeting. Provide tight support of trench walls below viaducts, existing utilities, or other obstructions that restrict driving of sheeting.

6.4.1 *Supports Left in Place*—Unless otherwise directed by the engineer, sheeting driven into or below the pipe zone should be left in place to preclude loss of support of foundation and embedment materials. When top of sheeting is to be cut off, make cut 1.5 ft (0.5 m) or more above the crown of the pipe. Leave rangers, walers, and braces in place as required to support cutoff sheeting and the trench wall in the vicinity of the pipe zone. Timber sheeting to be left in place is considered a permanent structural member and should be treated against biological degradation (for example, attack by insects or other biological forms) as necessary, and against decay if above ground water.

NOTE 5—Certain preservative and protective compounds may react adversely with some types of thermoplastics, and their use should be avoided in proximity of the pipe material.

6.4.2 *Movable Trench Wall Supports*—Do not disturb the installed pipe and its embedment when using movable trench boxes and shields. Movable supports should not be used below the top of the pipe zone unless approved methods are used for maintaining the integrity of embedment material. Before moving supports, place and compact embedment to sufficient depths to ensure protection of the pipe. As supports are moved, finish placing and compacting embedment.

6.4.3 *Removal of Trench Wall Support*—If the engineer permits the use of sheeting or other trench wall supports below the pipe zone, ensure that pipe and foundation and embedment materials are not disturbed by support removal. Fill voids left on removal of supports and compact all material to required densities.

6.5 *Rock or Unyielding Materials in Trench Bottom*—If ledge rock, hard pan, shale, or other unyielding material, cobbles, rubble or debris, boulders, or stones larger than 1.5 in. (40 mm) are encountered in the trench bottom, excavate a minimum depth of 6 in. (150 mm) below the pipe bottom and replace with proper embedment material (see 7.2.1).

7. Installation

7.1 *General*—Recommendations for use of the various types of materials classified in Section 5 and Table 1 for foundation, bedding, haunching and backfills, are given in Table 2.

NOTE 6—Installation of pipe in areas where significant settlement may be anticipated, such as in backfill adjacent to building foundations, and in sanitary landfills, or in other highly unstable soils, require special engineering and are outside the scope of this practice.

7.2 Trench Bottom—Install foundation and bedding as required by the engineer according to conditions in the trench bottom. Provide a firm, stable, and uniform bedding for the pipe barrel and any protruding features of its joint. Provide a minimum of 4 in. (100 mm) of bedding unless otherwise specified.

7.2.1 Rock and Unyielding Materials—When rock or unyielding material is present in the trench bottom, install a cushion of bedding, of 6 in. (150 mm) minimum thickness, below the bottom of the pipe.

7.2.2 Unstable Trench Bottom—Where the trench bottom is unstable or shows a “quick” tendency, excavate to a depth as required by the engineer and replace with a foundation of Class IA, Class IB, or Class II material. Use a suitably graded material where conditions may cause migration of fines and loss of pipe support (see X1.8). Place and compact foundation material in accordance with Table 2. For severe conditions, the engineer may require a special foundation such as piles or sheeting capped with a concrete mat. Control of quick and unstable trench bottom conditions may be accomplished with the use of appropriate geofabrics.

7.2.3 Localized Loadings—Minimize localized loadings and differential settlement wherever the pipe crosses other utilities or subsurface structures, or whenever there are special foundations such as concrete capped piles or sheeting. Provide a cushion of bedding between the pipe and any such point of localized loading.

7.2.4 Over-Excavation—If the trench bottom is over-excavated below intended grade, fill the over-excavation with compatible foundation or bedding material and compact to a density not less than the minimum densities given in Table 2.

7.2.5 Sloughing—If trench sidewalls slough off during any part of excavating or installing the pipe, remove all sloughed and loose material from the trench.

7.3 Location and Alignment—Place pipe and fittings in the trench with the invert conforming to the required elevations, slopes, and alignment. Provide bell holes in pipe bedding, no larger than necessary, in order to ensure uniform pipe support. Fill all voids under the bell by working in bedding material. In special cases where the pipe is to be installed to a curved alignment, maintain angular “joint deflection” (axial alignment) or pipe bending radius, or both, within acceptable design limits.

7.4 Jointing—Comply with manufacturer’s recommendations for assembly of joint components, lubrication, and making of joints. When pipe laying is interrupted, secure piping against movement and seal open ends to prevent the entrance of water, mud, or foreign material.

7.4.1 Elastomeric Seal Joints—Mark, or verify that pipe ends are marked, to indicate insertion stop position, and ensure that pipe is inserted into pipe or fitting bells to this mark. Push spigot into bell using methods recommended by the manufacturer, keeping pipe true to line and grade. Protect the end of the pipe during homing and do not use excessive force that may result in over-assembled joints or dislodged gaskets. If full

entry is not achieved, disassemble and clean the joint and reassemble. Use only lubricant supplied or recommended for use by the pipe manufacturer. Do not exceed manufacturer’s recommendations for angular “joint deflection” (axial alignment).

7.4.2 Solvent Cement Joints—When making solvent cement joints, follow recommendations of both the pipe and solvent cement manufacturer. If full entry is not achieved, disassemble or remove and replace the joint. Allow freshly made joints to set for the recommended time before moving, burying, or otherwise disturbing the pipe.

7.4.3 Heat Fusion Joints—Make heat fusion joints in conformance with the recommendations of the pipe manufacturer. Pipe may be joined at ground surface and then lowered into position, provided it is supported and handled in a manner that precludes damage.

7.5 Placing and Compacting Pipe Embedment—Place embedment materials by methods that will not disturb or damage the pipe. Work in and tamp the haunching material in the area between the bedding and the underside of the pipe before placing and compacting the remainder of the embedment in the pipe zone. Follow recommendations for compaction given in Table 2. Do not permit compaction equipment to contact and damage the pipe. Use compaction equipment and techniques that are compatible with materials used and location in the trench (see X1.7). Before using heavy compaction or construction equipment directly over the pipe, place sufficient backfill to prevent damage, excessive deflections, or other disturbance of the pipe. See 7.6 for minimum cover.

7.5.1 Minimum Density—The minimum embedment density should be established by the engineer based on an evaluation of specific project conditions. Higher or lower densities than those recommended in Table 2 may be appropriate (see X1.6.2). In the absence of an engineering evaluation, the minimum densities given in Table 2 are intended to provide satisfactory embedment stiffness in most installation conditions. They are based on attaining an average modulus of soil reaction (E') of 1000 psi.

7.5.2 Consolidation by Watering—Consolidation of cohesionless material by watering (jetting or puddling) should only be used under controlled conditions when approved by the engineer. At all times conform to the lift thicknesses and minimum densities given in Table 2.

7.6 Minimum Cover—To preclude damage to the pipe and disturbance to pipe embedment, a minimum depth of backfill above the pipe should be maintained before allowing vehicles or heavy construction equipment to traverse the pipe trench. The minimum depth of cover should be established by the engineer based on an evaluation of specific project conditions. In the absence of an engineering evaluation, the following minimum cover requirements should be used. For embedment materials installed to the minimum densities given in Table 2, provide cover (that is, depth of backfill above top of pipe) of at least 24 in. (0.6 m) or one pipe diameter (whichever is larger) for Class IA and IB embedment, and a cover of at least 36 in. (0.9 m) or one pipe diameter (whichever is larger) for Class II, III, and IVA embedment, before allowing vehicles or construction equipment to traffic the trench surface, and at least 48 in.

(1.2 m) of cover before using a hydrohammer for compaction. Do not use hydrohammer-type compactors unless approved by the engineer. Where construction loads may be excessive (for example, cranes, earth moving equipment, etc.), minimum cover shall be increased as determined by the engineer.

7.7 Vertical Risers—Provide support for vertical risers as commonly found at service connections, cleanouts, and drop manholes to preclude vertical or lateral movement. Prevent the direct transfer of thrust due to surface loads and settlement, and ensure adequate support at points of connection to main lines.

7.8 Exposing Pipe for Making Service Line Connections—When excavating for a service line connection, excavate material from above the top of the existing pipe before removing material from the sides of the pipe. Materials and density of service line embedment should conform to the specifications for the existing line, or with this practice, whichever is more stringent.

NOTE 7—Special construction techniques and considerations are required when more than one pipe is installed in the same or adjacent trenches, to ensure that the integrity of the embedment is maintained.

7.9 Pipe Caps and Plugs—Secure caps and plugs to the pipe to prevent movement and resulting leakage under test and service pressures.

7.10 Manhole Connections—Use flexible water stops, resilient connectors, or other flexible systems approved by the engineer to make watertight connections to manholes and other structures.

7.11 Field Monitoring—Compliance with contract documents with respect to pipe installation, including trench depth, grade, water conditions, foundation, embedment and backfill materials, joints, density of materials in place, and safety, should be monitored by the engineer at a frequency appropriate to project requirements. Leakage testing specifications, while not within the scope of this practice, should be made part of the specifications for plastic pipe installations, when applicable.

8. Inspection, Handling, and Storage

8.1 Inspection—Upon receipt, inspect each shipment of pipe and fittings for conformance to product specifications and contract documents, and check for damage. Reject nonconforming or damaged pipe, and remove from the job. If not returned to supplier, dispose of legally.

8.2 Handling and Storage—Handle and store pipe and fittings in accordance with recommendations of the manufacturer.

APPENDIXES

(Nonmandatory Information)

X1. COMMENTARY

X1.1 Those concerned with the service performance of a buried flexible pipe should understand factors that can affect this performance. Accordingly, key considerations in the design and execution of a satisfactory installation of buried flexible thermoplastic pipe that provided a basis for the development of this practice are given in this Appendix.

X1.2 General—Sub-surface conditions should be adequately investigated prior to construction, in accordance with Practice D 420, as a basis for establishing requirements for foundation, embedment and backfill materials and construction methods. The type of pipe selected should be suited for the job conditions.

X1.3 Load/Deflection Performance—The thermoplastic pipes considered in this practice are classified as flexible conduits since in carrying load they deform (deflect) to develop support from the surrounding embedment. This interaction of pipe and soil provides a pipe-soil structure capable of supporting earth fills and surface live loads of considerable magnitude. The design, specification and construction of the buried flexible pipe system should recognize that embedment materials must be selected, placed and compacted so that pipe and soil act in concert to carry the applied loads without excessive strains from deflections or localized pipe wall distortions.

X1.4 Pipe Deflection—Pipe deflection is the diametral change in the pipe-soil system resulting from the process of

installing the pipe (construction deflection), static and live loads applied to the pipe (load-induced deflection), and time dependent soil response (deflection lag). Construction and load induced deflections together constitute initial pipe deflection. Additional time dependent deflections are attributed primarily to changes in embedment and in-situ soils, and trench settlement. The sum of initial and time dependent deflections constitutes total deflection.

X1.4.1 Construction Deflection

Construction deflections are induced during the process of installing and embedding flexible pipe, even before significant earth and surface loads are applied. The magnitude of construction deflections depends on such factors as the method and extent of compaction of the embedment materials, type of embedment, water conditions in the trench, pipe stiffness, uniformity of embedment support, pipe out-of-roundness, and installation workmanship in general. These deflections may exceed the subsequent load-induced deflections. Compaction of the side fill may result in negative vertical deflections (that is, increases in pipe vertical diameter and decreases in horizontal diameter). Approaches given in Practice D 3839 provide allowances for construction deflection.

X1.4.2 Load-Induced Deflection

Load-induced deflections result from backfill loads and other superimposed loads that are applied after the pipe is embedded. Traditionally, typical soil-structure interaction equations such

as the “Iowa Formula”, attributed to Spangler, or other methods have been used to calculate deflections resulting from these loads.

X1.4.3 Initial Deflection

Initial deflection is the deflection in the installed and backfilled pipe. It is the total of construction deflections and load-induced deflections.

X1.4.4 Time Dependent Factors

Time dependent factors include changes in soil stiffness in the pipe embedment zone and native trench soils, as well as loading changes due to trench settlement over time. These changes typically add to initial deflections; the time involved varies from a few days to several years depending on soil types, their placement, and initial compaction. Time dependent factors are traditionally accounted for by adjusting load-induced deflections by a deflection lag factor. The deflection lag factor is the ratio of final load-induced deflection to initial load-induced deflection. Selection of a deflection lag factor is considered in Practice D 3839.

X1.4.5 Final Deflection

Final deflection is the total long term deflection of the pipe. It consists of initial deflection adjusted for time dependent factors.

X1.5 Deflection Criteria—Deflection criteria are often set as limits for the design and acceptance of buried flexible pipe installation. Deflection limits for specific pipe systems may be derived from both structural and practical considerations. Structural considerations include pipe cracking, yielding, strength, strain, and local distortion. Practical considerations include such factors as flow requirements, clearance for inspection and cleaning, and maintenance of joint seals. Initial and final deflection limits should be based on available structural properties with suitable factors of safety applied.

NOTE X1.1—Some ASTM standard specifications for thermoplastic pipe, such as Specifications D 3034, F 679, F 714, and F 949, provide recommended limits for installed deflections.

NOTE X1.2—Deflections may not be indicative of strain levels arising from local distortions caused by non-uniform embedment stiffness or localized loadings. When local distortions may be significant, the engineer needs to establish methods for controlling and monitoring distortion levels.

X1.6 Deflection Control—Embedment materials should be selected, placed, and compacted so as to minimize total deflections and, in any event, to maintain installed deflections within specific limits. Methods of placement, compaction, and moisture control should be selected based on soil types given in Table 1 and on recommendations given in Table 2. The amount of load-induced deflection is primarily a function of the stiffness of the pipe and soil embedment system. Other factors that are important in obtaining deflection control are outlined below.

X1.6.1 Embedment at Pipe Haunches

Lack of adequate compaction of embedment material in the haunch zone can result in excessive deflection, since it is this material that supports the vertical loads applied to the pipe. A key objective during installation of flexible thermoplastic pipe (or any pipe) is to work in and compact embedment material under pipe haunches, to ensure complete contact with the pipe

bottom, and to fill voids below the pipe.

X1.6.2 Embedment Density

Embedment density requirements should be determined by the engineer based on deflection limits established for the pipe, pipe stiffness, and installation quality control, as well as the characteristics of the in-situ soil and compactibility characteristics of the embedment materials used. The minimum densities given in Table 2 are based on attaining an average modulus of soil reaction (E') of 1000 psi, according to Table A 6 of Practice D 3839, which relates soil stiffness to soil type and degree of compaction. For particular installations, the project engineer should verify that the density specified meets performance requirements.

X1.7 Compaction Methods—Achieving desired densities for specific types of materials depends on the methods used to impart compactive energy. Coarse-grained, clean materials such as crushed stone, gravels, and sand are more readily compacted using vibratory equipment, whereas fine materials with high plasticity require kneading and impact force along with controlled water content to achieve acceptable densities (see 5.4). In pipe trenches, small, hand-held or walk-behind compactors are required, not only to preclude damage to the pipe, but to ensure thorough compaction in the confined areas around the pipe and along the trench wall. As examples, vibratory plate tampers work well for coarse grained materials of Class I and Class II, whereas hand tampers or air driven hand-held impact rammers are suitable for the fine-grained, plastic groups of Class III and IVA. Gas or diesel powered jumping jacks or small, walk-behind vibratory rollers impart both vibratory and kneading or impact force, and hence are suitable for most classes of embedment and backfill material.

X1.8 Migration—When coarse and open-graded material is placed adjacent to a finer material, fines may migrate into the coarser material under the action of hydraulic gradient from ground water flow. Significant hydraulic gradients may arise in the pipeline trench during construction when water levels are being controlled by various pumping or well-pointing methods, or after construction when permeable underdrain or embedment materials act as a “french” drain under high ground water levels. Field experience shows that migration can result in significant loss of pipe support and continuing deflections that may exceed design limits. The gradation and relative size of the embedment and adjacent materials must be compatible in order to minimize migration (see X1.8.1 below). In general, where significant ground water flow is anticipated, avoid placing coarse, open-graded materials, such as Class IA, above, below, or adjacent to finer materials, unless methods are employed to impede migration such as the use of an appropriate stone filter or filter fabric along the boundary of the incompatible materials. To guard against loss of pipe support from lateral migration of fines from the trench wall into open-graded embedment materials, it is sufficient to follow the minimum embedment width guidelines in X1.10.

X1.8.1 The following filter gradation criteria may be used to restrict migration of fines into the voids of coarser material under a hydraulic gradient:

X1.8.1.1 $D_{15} / d_{85} < 5$ where D_{15} is the sieve opening size

passing 15 % by weight of the coarser material and d_{85} is the sieve opening size passing 85 % by weight of the finer material.

X1.8.1.2 $D_{50}/d_{50} < 25$ where D_{50} is the sieve opening size passing 50 % by weight of the coarser material and d_{50} is the sieve opening size passing 50 % by weight of the finer material. This criterion need not apply if the coarser material is well-graded (see Test Method D 2487).

X1.8.1.3 If the finer material is a medium to highly plastic clay without sand or silt partings (CL or CH), then the following criterion may be used in lieu of X1.8.1.1: $D_{15} < 0.02$ in. (0.5 mm) where D_{15} is the sieve opening size passing 15 % by weight of the coarser material.

NOTE X1.3—Materials selected for use based on filter gradation criteria, such as in X1.8.1, should be handled and placed in a manner that will minimize segregation.

X1.9 *Maximum Particle Size*—Limiting particle size to $\frac{3}{4}$ in. (20 mm) or less enhances placement of embedment material for nominal pipe sizes 8 in. (200 mm) through 15 in. (380 mm). For smaller pipe, a particle size of about 10 % of the nominal pipe diameter is recommended.

X1.10 *Embedment Width for Adequate Support*—In certain conditions, a minimum width of embedment material is required to ensure that adequate embedment stiffness is developed to support the pipe. These conditions arise where in-situ lateral soil resistance is negligible, such as in very poor native soils (for example, peat, muck, or highly expansive soils) or along highway embankments. Under these conditions, for small diameter pipe (12 in. (300 mm) or less), embedment should be placed and compacted to a point at least 2.5 pipe diameters on either side of the pipe. For pipe larger than 12 in. (300 mm), the engineer should establish the minimum embedment width based on an evaluation of parameters such as pipe stiffness, embedment stiffness, nature of in-situ soil, and magnitude of construction and service loads.

X1.11 *Lumps, Clods and Boulders*—Backfill materials should be free of lumps, clods, boulders, frozen matter, and debris. The presence of such material in the embedment may preclude uniform compaction and result in excessive localized deflections.

X1.12 *Other Design and Construction Criteria*—The design and construction of the pipe system should recognize conditions that may induce excessive shear, longitudinal bending, or compression loading in the pipe. Live loads applied by construction and service traffic may result in large, cumulative pipe deflections if the pipe is installed with a low density embedment and shallow cover. Other sources of loads on buried pipes are: freezing and thawing of the ground in the vicinity of the pipe, rising and falling of the ground water table, hydrostatic pressure due to ground water, and localized differential settlement loads occurring next to structures such as manholes and foundations. Where external loads are deemed to be excessive, the pipe should be installed in casing pipe or other load limiting structures.

X1.13 *Deflection Testing*—To ensure specified deflection limits are not exceeded, the engineer may require deflection testing of the pipe using specified measuring devices. To allow for stabilization of the pipe soil system, deflection tests should be performed at least 30 days after installation. However, as a quality control measure, periodic checks of deflection may be made during installation.

X1.13.1 Optional devices for deflection testing include electronic deflectometers, calibrated television or video cameras, or a properly sized “go, no-go” mandrel. Deflection measurements can be made directly with extension rulers or tape measures in lines that permit safe entry. To ensure accurate measurements, clean the lines before testing.

X2. RECOMMENDATIONS FOR INCORPORATION IN CONTRACT DOCUMENTS

X2.1 This practice may be incorporated, by referral, into contract documents for a specific project to cover requirements for installation of flexible thermoplastic pipe in sewers and other gravity-flow applications. Application to a particular project should be made by means of a list of supplemental requirements. Suggested modifications to specific sections are listed below (the list is keyed to applicable section numbers of this practice):

X2.2 *Sections 5.1, 5.2, and Table 2*—Further restrictions on use of Classes of embedment and backfill materials.

X2.3 *Section 5*—Specific gradations of embedment materials for resistance to migration.

X2.4 *Section 5.5*—Maximum particle size, if different from Table 1.

X2.5 *Section 6.2*—Restrictions on mode of dewatering; design of underdrains.

X2.6 *Section 6.3*—Requirements on minimum trench width.

X2.7 *Section 6.4*—Restrictions or details for support of trench walls.

X2.8 *Section 7.5*—Specific restrictions on methods of compaction.

X2.9 *Section 7.5.1 and Table 2*—Minimum embedment density if different from these recommendations; specific density requirements for backfill (for example, for pavement subgrade).

X2.10 *Section 7.6*—Minimum cover requirements if different from this paragraph.

X2.11 *Section 7.7*—Detailed requirements for support of

vertical risers, standpipes, and stacks to accommodate anticipated relative movements between pipe and such appurtenances. Detailing to accommodate thermal movements, particularly at risers.

X2.12 Section 7.10—Detailed requirements for manhole connections.

X2.13 Section 7.11—Requirements on methods of testing compaction and leakage.

X2.14 Section X1.13—Requirements on deflection and deflection measurements, including method and time of testing.

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