Designation: D 3839 – 02$^{\epsilon 1}$

An American National Standard

Standard Guide for Underground Installation of "Fiberglass" (Glass-FiberReinforced Thermosetting-Resin) Pipe[1]

This standard is issued under the fixed designation D 3839; 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.

ϵ^1 NOTE—Table 3 was editorially revised in November 2003.

1. Scope

1.1 This practice establishes procedures for the burial of pressure and nonpressure "fiberglass" (glass-fiber-reinforced thermosetting-resin) pipe in many typically encountered soil conditions. Included are recommendations for trenching, placing pipe, joining pipe, placing and compacting backfill, and monitoring deflection levels. Guidance for installation of fiberglass pipe in subaqueous conditions is not included.

1.2 Product standards for fiberglass pipe encompass a wide range of product variables. Diameters range from 1 in. to 12 ft (25 mm to 3600 mm) and pipe stiffness range from 9 to over 72 psi (60 to 500 kPa) with internal pressure ratings up to several thousand pound-force per square inch. This standard does not purport to consider all of the possible combinations of pipe, soil types, and natural ground conditions that may occur. The recommendations in this practice may need to be modified or expanded to meet the needs of some installation conditions. In particular, fiberglass pipe with diameters of a few inches are generally so stiff that they are frequently installed in accordance with different guidelines. Consult with the pipe manufacturer for guidance on which practices are applicable to these particular pipes.

1.3 The scope of this practice excludes product-performance criteria such as a minimum pipe stiffness, maximum service deflection, or long-term strength. Such parameters may be contained in product standards or design specifications, or both, for fiberglass pipe. It is incumbent upon the specified product manufacturer or project engineer to verify and ensure that the pipe specified for an intended application, when installed in accordance with procedures outlined in this practice, will provide a long-term, satisfactory performance in accordance with criteria established for that application.

NOTE 1—There is no similar or equivalent ISO standard.

NOTE 2—A discussion of the importance of deflection and a presentation of a simplified method to approximate field deflections are given in AWWA Manual of Practice M45 Fiberglass Pipe Design.

1.4 *This standard does not purport to address all of the safety concerns, 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 Pavements[2]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[3]

D 698 Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft (600 kN-m/m))[3]

D 883 Terminology Relating to Plastics[4]

D 1556 Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method[3]

D 1557 Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56 000 ft-lbf/ft (2 700 kN-m/m))[3]

D 2167 Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method[3]

D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock[3]

D 2321 Practice for Underground Installation of Flexible Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications[5]

D 2487 Classification of Soils for Engineering Purposes[5]

D 2488 Practice for Description of Soils (Visual-Manual Procedure)[3]

[1] This practice is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.23 on Reinforced Plastic Piping Systems and Chemical Equipment.

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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 08.01.

[5] *Annual Book of ASTM Standards*, Vol 08.04.

D 2922 Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)[3]

D 3017 Test Method for Moisture Content of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)[3]

D 4253 Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table[3]

D 4254 Test Method for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density[3]

D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils[3]

D 4564 Test Method for Density of Soil in Place by the Sleeve Method[3]

D 4643 Method for Determination of Water (Moisture) Content of Soil by the Microwave Oven Method[3]

D 4914 Test Method for Density of Soil and Rock in Place by the Sand Replacement Method in a Test Pit[3]

D 4944 Test Method for Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester Method[6]

D 4959 Test Method for Determination of Water (Moisture) Content of Soil by Direct Heating Method[6]

D 5030 Test Methods for Density and Unit Weight of Soil and Rock in Place by the Water Replacement Method in a Test Pit[6]

D 5080 Test Method for Rapid Determination of Percent Compaction[6]

F 412 Terminology Relating to Plastic Piping Systems[5]

2.2 *Other Standards:*

AASHTO LRFD Bridge Design Specifications, 2nd Edition, American Association of State Highway and Transportation Officials[7]

AAHSTO M145 Classification of Soils and Soil Aggregate Mixtures[7]

AWWA C 950 American Water Works Association Standard Specification for Fiberglass Pressure Pipe[8]

AWWA Manual of Practice M45 Fiberglass Pipe Design Manual[8]

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Unless otherwise indicated, definitions are in accordance with Terminologies D 8, D 653, D 883, and F 412.

3.2 *Definitions of Terms Specific to This Standard:* Descriptions of Terms Specific to This Standard:

3.2.1 *bedding*—backfill material placed in the bottom of the trench or on the foundation to provide a uniform material on which to lay the pipe.

3.2.2 *deflection*—any change in the inside diameter of the pipe resulting from installation or imposed loads, or both; deflection may be either vertical or horizontal and is usually reported as a percentage of the nominal inside pipe diameter.

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

3.2.4 *fiberglass pipe*—a tubular product containing glass-fiber reinforcements embedded in or surrounded by cured thermosetting resin; the composite structure may contain aggregate, granular, or platelet fillers, thixotropic agents, pigments, or dyes; thermoplastic or thermosetting liners or coatings may be included.

3.2.5 *final backfill*—backfill material placed from the top of the initial backfill to the ground surface.

3.2.6 *fines*—soil particles that pass a No. 200 seive.

3.2.7 *foundation*—in situ soil or, in the case of unsuitable ground conditions compacted backfill material, in the bottom of the trench the supports the bedding and the pipe (see Fig. 1).

3.2.8 *geotextile*—any permeable textile material used with foundation, soil, earth, rock, or any other geotechnical engineering related material, as an integral part of a man-made product, structure, or system.

3.2.9 *haunching*—backfill material placed on top of the bedding and under the springline of the pipe; the term haunching only pertains to soil directly beneath the pipe (see Fig. 1).

3.2.10 *initial backfill*—backfill material placed at the sides of the pipe and up to 6 to 12 in. (150 to 300 mm) over the top of the pipe, including the haunching.

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

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

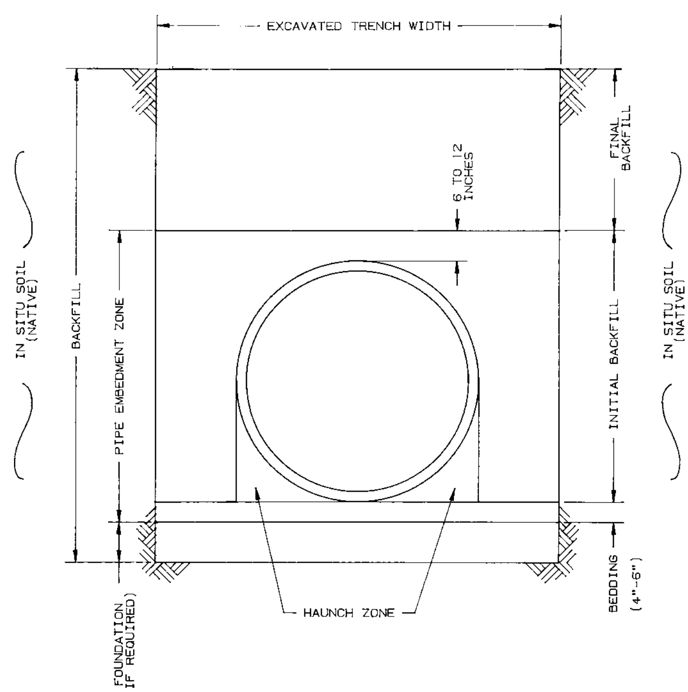

FIG. 1 Trench Cross-Section Terminology

[6] *Annual Book of ASTM Standards*, Vol 04.09.

[7] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001.

[8] Available from American Water Works Association (AWWA), 6666 West Quincy Ave., Denver CO 80235.

3.2.13 *native (in situ) soil*—natural soil in which a trench is excavated for pipe installation or on which a pipe and embankment are placed.

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

3.2.15 *optimum moisture content*—the moisture content of soil at which its maximum density is obtained. (See Test Method D 698.)

3.2.16 *pipe zone embedment*—all backfill around the pipe; this includes the bedding, haunching, and initial backfill.

3.2.17 *processed aggregates*—aggregates which are screened or washed or mixed or blended to produce a specific particle-size distribution.

3.2.18 *relative density*—a measure of the density of a granular soil based on the actual density of the soil "relative" to the soil in its loosest state and the soil in its densest state (see Terminology D 653 for a precise definition) as obtained by laboratory testing in accordance with Test Methods D 4253 and D 4254.

3.2.19 *soil stiffness*—a property of soil, generally represented numerically by a modulus of deformation that indicates the relative amount of deformation that will occur under a given load.

3.2.20 *split installation*—an installation in which the initial backfill consists of two different materials; the first material extends from the top of the bedding to a depth of at least 0.6 times the diameter and the second material extends to the top of the initial backfill.

4. Significance and Use

4.1 This practice is for use by designers and specifiers, manufacturers, installation contractors, regulatory agencies, owners, and inspection organizations involved in the construction of buried fiberglass pipelines. As with any 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 X1.

5. Materials

5.1 *Classification*—Soil types used or encountered in burying pipes include those classified in Table 1 and natural, manufactured, and processed aggregates. The soil classifications are grouped into soil-stiffness categories (SC#) in Table 2 based on the typical soil stiffness when compacted. Category SC1 indicates a soil that generally provides the highest soil stiffness at any given percentage of maximum Proctor density, and a soil that provides a given soil stiffness with the least compactive effort. Each higher-number soil-stiffness category provides successively less soil stiffness at a given percentage of maximum Proctor density and requires greater compactive effort to provide a given level of soil stiffness.

NOTE 3—See Practices D 2487 and D 2488 for laboratory and field visual-manual procedures for identification of soils.

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

5.2 *Installation and Use*—Table 3 provides recommendations on installation and use based on soil-stiffness category and location in the trench. Categories SC1 to SC4 should be used as recommended in Table 3. Soil-stiffness Category 5, including clays and silts with liquid limits greater than 50, organic soils, and frozen soils, shall be excluded from the pipe-zone embedment.

5.2.1 *Soil-Stiffness Category 1 (SC1)*—SC1 materials provide maximum stability and pipe support for a given percent compaction due to the low content of sand and fines. With minimum effort these materials can be installed at relatively high-soil stiffnesses over a wide range of moisture contents. In addition, the high permeability of SC1 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 SC1 materials. (See 5.5.)

5.2.2 *Soil-Stiffness Category 2 (SC2)*—SC2 materials, when compacted, provide a relatively high level of pipe support; however, open-graded groups may allow migration and the sizes should be checked for compatibility with adjacent material; see 6.5.

5.2.3 *Soil-Stiffness Category 3 (SC3)*—SC3 materials provide less support for a given density than SC1 or SC2 materials. Higher levels of compactive effort are required and moisture content must be near optimum to minimize compactive effort and achieve the required density. These materials provide reasonable levels of pipe support once proper density is achieved.

5.2.4 *Soil-Stiffness Category 4 (SC4)*—SC4 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, SC4 materials can provide reasonable levels of pipe support; however, these materials may not be suitable under high fills, surface-applied wheel loads, or under high-energy-level vibratory compactors and tampers. Do not use where water conditions in the trench may prevent proper placement and compaction.

NOTE 5—The term "high energy level vibratory compactors and tampers" refers to compaction equipment that might deflect or distort the pipe more than permitted by the specifications or the manufacturer.

5.2.5 *Soil-Stiffness Category 5 (SC5)*— SC5 materials should be excluded from pipe-zone embedment.

5.3 *Moisture Content of Embedment Materials*—The moisture content of embedment materials must be controlled to permit placement and compaction to required levels. For non-free draining soils (that is, SC3 and SC4 and some borderline SC2 soils), moisture content is normally controlled to ±3 % of optimum (see Test Method D 698). The practicality of obtaining and maintaining the required limits on moisture content is an important criterion for selecting materials, since

TABLE 1 Soil Classification Chart (see Classification D 2487)

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification	
				Group Symbol	Group Name[B]
Coarse-Grained Soils More than 50 % retained on No. 200 sieve	gravels more than 50 % of coarse fraction retained on No. 4 sieve	clean gravels less than 5 % fines[E]	$Cu \geq 4$ and $1 \leq Cc \leq 3$[C]	GW	well-graded gravel[D]
			$Cu < 4$ and/or $1 > Cc > 3$[C]	GP	poorly graded gravel[D]
		gravels with fines more than 12 % fines[E]	Fines classify as ML or MH	GM	silty gravel[D,F,G]
			Fines classify as CL or CH	GC	clayey gravel[D,F,G]
	sands 50 % or more of coarse fraction passes No. 4 sieve	clean sands less than 5 % fines[I]	$Cu \geq 6$ and $1 \leq Cc \leq 3$[C]	SW	well-graded sand[H]
			$Cu < 6$ and/or $1 > Cc > 3$[C]	SP	poorly graded sand[H]
		sands with fines more than 12 % fines[I]	Fines classify as ML or MH	SM	silty sand[F,G,H]
			Fines classify as CL or CH	SC	clayey sand[F,G,H]
Fine-Grained Soils 50 % or more passes the No. 200 sieve	silts and clays liquid limit less than 50	inorganic	PI > 7 and plots on or above “A” line[J]	CL	lean clay[K,L,M]
			PI < 4 or plots below “A” line[J]	ML	silt[K,L,M]
		organic	$\frac{\text{liquid limit} - \text{oven dried}}{\text{liquid limit} - \text{not dried}} < 0.75$	OL	organic clay[K,L,M,N] organic silt[K,L,M,O]
	silts and clays liquid limit 50 or more	inorganic	PI plots on or above “A” line	CH	fat clay[K,L,M]
			PI plots below “A” line	MH	elastic silt[K,L,M]
		organic	$\frac{\text{liquid limit} - \text{oven dried}}{\text{liquid limit} - \text{not dried}} < 0.75$	OH	organic clay[K,L,M,P] organic silt[K,L,M,Q]
Highly organic soils	primarily organic matter, dark in color, and organic odor			PT	peat

[A] Based on the material passing the 3-in. (75-mm) sieve.
[B] If field sample contained cobbles or boulders, or both, add “with cobbles or boulders, or both” to group name.
[C] $Cu = D_{60}/D_{10}$ $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$
[D] If soil contains ≥15 % sand, add “with sand” to group name.
[E] Gravels with 5 to 12 % fines require dual symbols:
GW-GM well-graded gravel with silt
GW-GC well-graded gravel with clay
GP-GM poorly graded gravel with silt
GP-GC poorly graded gravel with clay
[F] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.
[G] If fines are organic, add “with organic fines” to group name.
[H] If soil contains ≥15 % gravel, add “with gravel” to group name.
[I] Sands with 5 to 12 % fines require dual symbols:
SW-SM well-graded sand with silt
SW-SC well-graded sand with clay
SP-SM poorly graded sand with silt
SP-SC poorly graded sand with clay
[J] If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay (see Test Method D 4318).
[K] If soil contains 15 to 29 % plus No. 200, add “with sand” or “with gravel,” whichever is predominant.
[L] If soil contains ≥30 % plus No. 200, predominantly sand, add “sandy” to group name.
[M] If soil contains ≥30 % plus No. 200, predominantly gravel, add “gravelly” to group name.
[N] PI ≥ 4 and plots on or above “A” line.
[O] PI < 4 or plots below “A” line.
[P] PI plots on or above “A” line.
[Q] PI plots below “A” line.

failure to achieve required density, especially in the pipe zone embedment, may result in excessive deflection.

5.4 *Maximum Particle Size*—Maximum particle size for pipe-zone embedment is limited based on pipe diameter as listed in Table 4. For final backfill, the maximum particle size allowed should not exceed 75 % of the lift thickness. When final backfill contains cobbles, boulders, etc., the initial bedding should be extended above the top of the pipe at least 12 in. (300 mm). Backfill containing particles larger than 8 in. (200 mm) shall not be dropped on the backfill or rolled down a sloping trench wall from a height greater than 6 ft (1.8 m) until the depth of fill over the top of the pipe is greater than 24 in. (600 mm).

NOTE 6—The limits of 200 mm (8 in.) particles and a drop height of 6 ft (1.8 m) are somewhat arbitrary, but serve to establish the principle that dropping boulders onto the backfill can damage the pipe even though some backfill has already been placed on the pipe.

5.5 *Migration*—When 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 increasing deflections that may eventually exceed design limits. The gradation and relative size of the embedment and adjacent materials must be compatible in order to minimize migration. In general, where significant ground water is anticipated, avoid placing coarse, open-graded materials, such as SC1, above, below, or adjacent

TABLE 2 Soil-Stiffness Categories

NOTE 1—Soil stiffness categories group types together as a function of the relative level of soil stiffness developed when compacted to a given level. At any given level of compaction, SC1 soils provide the highest stiffness and SC5 soils the lowest.

NOTE 2—The soil-stiffness categories are similar but not identical to the soil classes in Practice D 2321.

Soil Group	Soil Stiffness Category
Crushed rock: 15 % sand, maximum 25 % passing the ⅜ in. sieve and maximum 5 % passing a #200 sieve	SC1
Clean, coarse grained soils: SW, SP, GW, GP or any soil beginning with one of these symbols with 12 % or less passing a #200 sieve	SC2
Coarse grained soils with fines: GM, GC, SM, SC, or any soil beginning with one of these symbols, containing more than 12 % passing a #200 sieve; Sandy or gravelly fine-grained soils: CL, ML, (or CL-ML, CL/ML. ML/CL) with more than 30 % retained on a #200 sieve	SC3
Fine-grained soils: CL, ML, (or CL-ML, CL/ML. ML/CL) with 30 % or less retained on a #200 sieve	SC4
MH, CH, OL, OH, PT	SC5 Not for use as embedment

to finer materials, unless methods are employed to impede migration such as the use of an appropriate soil filter or a geotextile filter fabric along the boundary of the incompatible materials.

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

$$D_{15}/d_{85} < 5 \quad (1)$$

where:

D_{15} = sieve opening size passing 15 % by weight of the coarser material, and

d_{85} = sieve opening size passing 85 % by weight of the finer material.

$$D_{50}/d_{50} < 25 \quad (2)$$

where:

D_{50} = sieve opening size passing 50 % by weight of the coarser material, and

d_{50} = sieve opening size passing 50 % by weight of the finer material. This criterion need not apply if the coarser material is well-graded (see Classification D 2487).

5.5.2 If the finer material is a medium to highly plastic clay without sand particles (CL or CH), then the following criterion may be used instead of 6.5.1:

$$D_{15} < 0.02\ in.\ (0.5\ mm) \quad (3)$$

where:

D_{15} = sieve-opening size passing 15 % by weight of the coarser material.

NOTE 7—Materials selected for use based on filter-gradation criteria such as in 6.5 should be handled and placed in a manner that will minimize segregation.

5.6 *Cementitious Backfill Materials*—Backfill materials supplemented with cement to improve long-term strength and/or stiffness (soil cement, cement stabilized backfill) or to improve flowability (flowable fill, controlled low strength material) have been shown to be effective backfill materials in terms of ease of placement and quality of support to pipe. While not specifically addressed by this standard, use of these materials is beneficial under many circumstances.

6. Trench Excavation

6.1 *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. Place excavated material away from the edge of the trench. Open only enough trench that can be safely maintained by available equipment. Place and compact backfill in trenches as soon as practicable, preferably no later than the end of each working day.

6.2 *Water Control*—It is always good practice to remove water from a trench before laying and backfilling pipe. While circumstances occasionally require pipe installation in standing or running water conditions, such practice is outside the scope of this practice. At all times prevent run-off and surface water from entering the trench.

6.2.1 *Ground Water*—When ground water is present in the work area, dewater to maintain stability of in situ and imported materials. Maintain the water level below pipe bedding. Use, as appropriate, sump pumps, well points, deep wells, geotextiles, perforated underdrains or stone blankets of sufficient thickness to remove and control water in the trench. When excavating while lowering the ground water level, ensure that 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 surface drainage 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 as soon as practical after the pipe is installed to prevent disturbance of pipe and embedment.

6.2.3 *Materials for Water Control*—Use suitably graded materials in the foundation as drainage blankets for transport of running water to sump pits or other drains. Use properly graded materials or perforated underdrains, or both, to enhance transport of running water. Select the gradation of the drainage materials to minimize migration of fines from surrounding materials. (See 5.5.)

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

TABLE 3 Recommendations for Installation and Use of Soils and Aggregates for Foundation and Pipe-Zone Embedment

Soil Stiffness Category[A]	SC1	SC2	SC3	SC4
General Recommendations and Restrictions	Acceptable and common where no migration is probable or when combined with a geotextile filter media. Suitable for use as a drainage blanket and under drain where adjacent material is suitably graded or when used with a geotextile filter fabric (see 6.5).	Where hydraulic gradient exists check gradation to minimize migration. Clean groups are suitable for use as a drainage blanket and underdrain (see Table 2). Uniform fine sands (SP) with more than 50 % passing a #100 sieve (0.006 in., 0.15 mm) behave like silts and should be treated as SC3 soils.	Do not use where water conditions in trench prevent proper placement and compaction. Not recommended for use with pipes with stiffness of 9 psi or less	Difficult to achieve high-soil stiffness. Do not use where water conditions in trench prevent proper placement and compaction. Not recommended for use with pipes with stiffness of 9 psi or less
Foundation	Suitable as foundation and for replacing over-excavated and unstable trench bottom as restricted above.	Suitable as foundation and for replacing over-excavated and unstable trench bottom as restricted above. Install and compact in 12 in. (300 mm) maximum layers	Suitable for replacing over-excavated trench bottom as restricted above. Install and compact in 6 in. (150 mm) maximum layers	Not suitable.
Pipe Zone Embedment	Suitable as restricted above. Work material under pipe to provide uniform haunch support.	Suitable as restricted above. Work material under pipe to provide uniform haunch support.	Suitable as restricted above. Difficult to place and compact in the haunch zone.	Suitable as restricted above. Difficult to place and compact in the haunch zone.
Embedment Compaction:				
Min Recommended Density, SPD[B]	[C]	85 %	90 %	95 %
Relative Compactive Effort Required to Achieve Minimum Density	low	moderate	high	very high
Compaction Methods	vibration or impact	vibration or impact	impact	impact
Required Moisture Control	none	none	maintain near optimum to minimize compactive effort	maintain near optimum to minimize compactive effort

[A] SC5 materials are unsuitable as embedment. They may be used as final backfill as permitted by the engineer.
[B] SPD is standard Proctor density as determined by Test Method D 698.
[C] Minimum density typically achieved by dumped placement.

TABLE 4 Maximum Particle Size for Pipe Embedment

Nominal Diameter (D_i)) Range, in. (mm)	Maximum Particle Size, in., (mm)
D_i= 18 (D_i= 450)	0.50, (13)
18< D_i= 24 (450< D_i= 600)	0.75 (19)
24< D_i= 36 (600< D_i= 900)	1.00 (25)
36< D_i= 48 (900< D_i= 1200)	1.25 (32)
48< D_i(1200< D_i)	1.50 (38)

and compact haunching and other embedment materials. The space between the pipe and trench wall must be wider than the compaction equipment used in this region. For a single pipe in a trench, the minimum trench width should be 1.25 times the outside diameter of the pipe plus 12 in. (300 mm). For multiple pipes in the same trench, interior spaces between pipes must be at least the average of the radii of the two adjacent pipe for depths greater than 12 ft (3.5 m), and ⅔ of the average of the radii of the two adjacent pipe for depths less than 12 ft (3.5 m); the distance from the outside pipe to the trench wall must not be less than if that pipe were installed as a single pipe in a trench. If mechanical compaction equipment is used, the minimum space between pipe and trench wall, or between adjacent pipe shall not be less than the width of the widest piece of equipment plus 6 in. (150 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. Specially designed equipment may facilitate 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 practice, minimum trench widths may be reduced if 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 the embedment is maintained throughout the installation process. 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 *Support Left in Place*—Unless otherwise directed by the engineer, sheeting driven below the top of the pipe should be left in place to preclude loss of support of foundation and embedment materials. When the top of the sheeting is to be cut off, make the cut 1.5 ft (0.5 m) or more above the crown of the pipe. Leave rangers, walers, and bracers in place as required to support cutoff sheeting and the trench wall in the vicinity of the pipe. 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 8—Certain preservative and protective compounds may pose environmental hazards. Determination of acceptable compounds is outside the scope of this practice.

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 embedment zone, unless approved methods