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

This standard is issued under the fixed designation D3839; 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 U.S. Department of Defense.

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 13 ft (25 mm to 4000 mm) and pipe stiffnesses 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 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *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:*[2]

D8 Terminology Relating to Materials for Roads and Pavements

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft^3 (600 kN-m/m^3))

D883 Terminology Relating to Plastics

D1556 Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method

D2167 Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method

D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

D2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)

D4253 Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table

D4254 Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density

[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] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

D4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
D4564 Test Method for Density and Unit Weight of Soil in Place by the Sleeve Method (Withdrawn 2013)[3]
D4643 Test Method for Determination of Water (Moisture) Content of Soil by Microwave Oven Heating
D4914 Test Methods for Density and Unit Weight of Soil and Rock in Place by the Sand Replacement Method in a Test Pit
D4944 Test Method for Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester
D4959 Test Method for Determination of Water (Moisture) Content of Soil By Direct Heating
D5030 Test Method for Density of Soil and Rock in Place by the Water Replacement Method in a Test Pit
D5080 Test Method for Rapid Determination of Percent Compaction
D5821 Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate
D6938 Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
D7382 Test Methods for Determination of Maximum Dry Unit Weight and Water Content Range for Effective Compaction of Granular Soils Using a Vibrating Hammer
F412 Terminology Relating to Plastic Piping Systems
F1668 Guide for Construction Procedures for Buried Plastic Pipe

2.2 *Other Standards:*

AASHTO LRFD Bridge Design Specifications, 2nd Edition, American Association of State Highway and Transportation Officials[4]
AASHTO M145 Classification of Soils and Soil Aggregate Mixtures[4]
AWWA Manual of Practice M45 Fiberglass Pipe Design Manual[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Unless otherwise indicated, definitions are in accordance with Terminologies D8, D653, D883, and F412.

3.2 *Definitions 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 *compactibility*—a measure of the ease with which a soil may be compacted to a high density and high stiffness. Crushed rock has high compactibility because a dense and stiff state may be achieved with little compactive energy.

3.2.3 *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.

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

3.2.5 *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.

3.2.6 *final backfill*—backfill material placed from the top of the initial backfill to the ground surface (see Fig. 1.)

3.2.7 *fines*—soil particles that pass a No. 200 (0.076 mm) sieve.

3.2.8 *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).

3.2.9 *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.

3.2.10 *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).

3.2.11 *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.

3.2.12 *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.

3.2.13 *modulus of soil reaction (E')*—an empirical value used in the Iowa deflection formula that defines the stiffness of the soil embedment around a buried pipe.

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

3.2.15 *open-graded aggregate*—an aggregate with a particle-size distribution such that when compacted, the resulting voids between the aggregate particles are relatively large.

3.2.16 *optimum moisture content*—the moisture content of soil at which its maximum density is obtained. (See Test Method D698.)

3.2.17 *percent compaction*—the ratio, expressed as a percentage, of: (1) dry unit weight of a soil, to (2) maximum unit weight obtained in a laboratory compaction test.

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

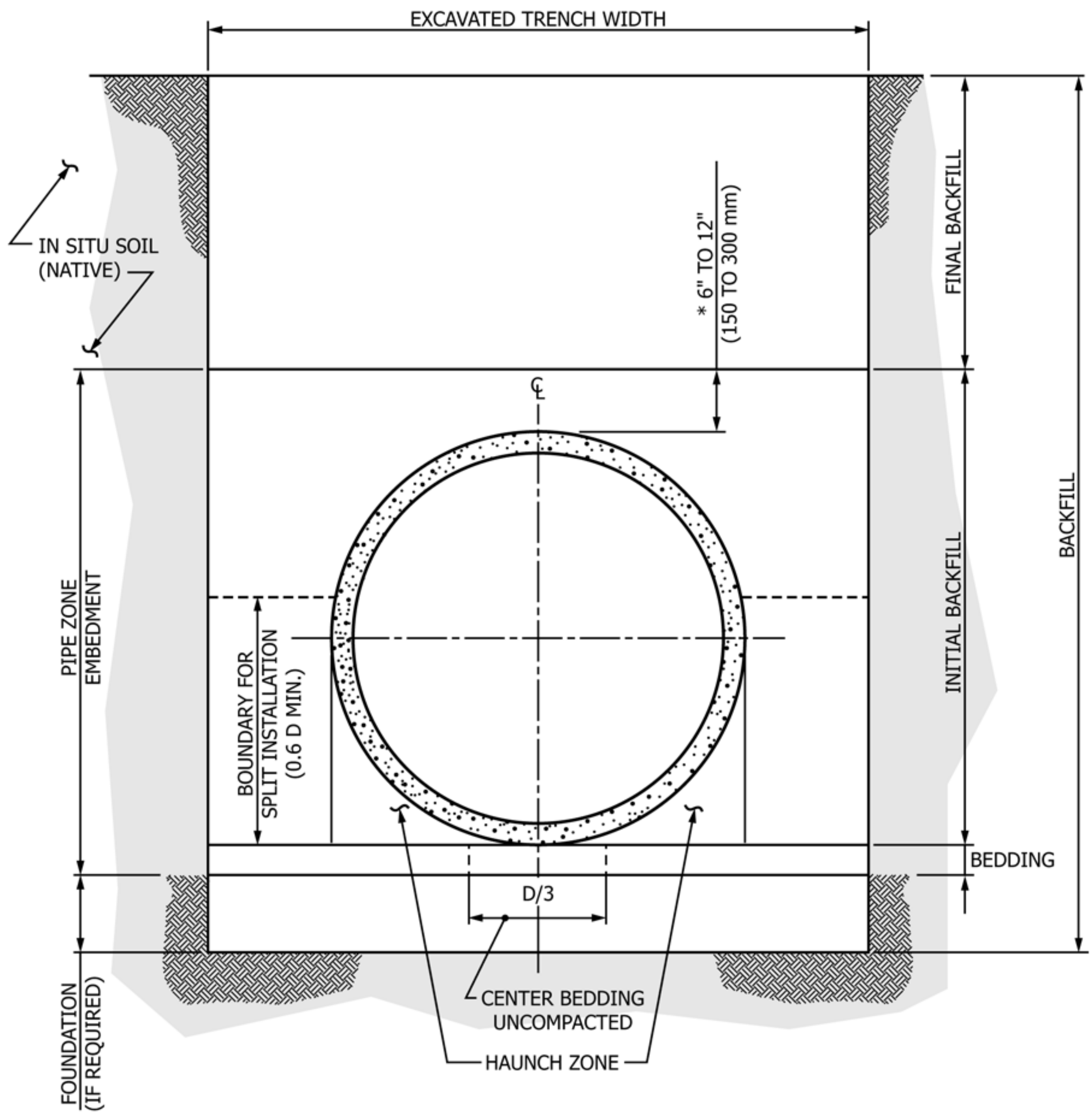
3.2.19 *processed aggregates*—aggregates which are screened or washed or mixed or blended to produce a specific particle-size distribution.

3.2.20 *secant constrained soil modulus (M_s)*—a value for soil stiffness determined as the secant slope of the stress-strain

[3] The last approved version of this historical standard is referenced on www.astm.org.

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

[5] Available from American Water Works Association (AWWA), 6666 W. Quincy Ave., Denver, CO 80235, http://www.awwa.org.



*See 7.7, Minimum Cover.

FIG. 1 Trench Cross-Section Terminology

curve of a one-dimensional compression test; M_s can be used in place of E' in the Iowa deflection formula.

3.2.21 *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.

3.2.22 *split installation*—an installation in which the initial backfill consists of two different materials or one material placed at two different densities; 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.

3.2.23 *standard proctor density (SPD)*—the maximum dry unit weight of soil compacted at optimum moisture content, as obtained by laboratory test in accordance with Test Methods D698.

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 natural soils classified in Practice D2487 and manufactured and processed aggregates. The soil materials are grouped into soil classes in Table 1 based on the typical soil stiffness when compacted. Class I indicates a soil

TABLE 1 Soil Classes[A,B,C,D]

Soil Group[A,E]	Soil Class	American Association of State Highway and Transportation Officials (AASHTO) Soil Groups[B]
Crushed rock[C] : </= 15 % sand, maximum 25 % passing the ⅜ in. sieve and maximum 5 % passing a #200 sieve	Class I	
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[D,F]	Class II	A1, A3
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 any soil beginning with one of these symbols, with ≥30 % retained on a #200 sieve	Class III	A-2–4, A-2–5, A-2–6, or A-4 or A-6 soils with more than 30% retained on a No. 200 sieve
Fine-grained soils: CL, ML, or any soil beginning with one of these symbols, with <30 % retained on a #200 sieve	Class IV	A-2-7, or A-4, or A-6 soils with 30% or less retained on a No. 200 sieve
MH, CH, OL, OH, PT	Class V Not for use as embedment	A5, A7

[A] ASTM D2487 Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)
[B] AASHTO M145, Classification of Soils and Soil Aggregate Mixtures.
[C] Crushed rock is defined as angular and subangular in accordance with ASTM D2488.
[D] Uniform fine sands (SP) with more than 50 % passing a No. 100 sieve (0.0006 in., 0.15 mm) are very sensitive to moisture and should not be used as backfill for fiberglass pipe unless specifically allowed in the contract documents. If use of these materials is allowed, compaction and handling procedures should follow the guidelines for Class III materials.
[E] Limits may be imposed on the soil group to meet project or local requirements if the specified soil remains within the group. For example, some project applications require a Class I material with minimal fines to address specific structural or hydraulic conditions and the specification may read: "Use Class I soil with a maximum of 5% passing the #200 sieve."
[F] Materials such as broken coral, shells, and recycled concrete, with ≤12 % passing a No. 200 sieve, are considered to be Class II materials. These materials should only be used when evaluated and approved by the Engineer.

that generally provides the highest soil stiffness at any given percent compaction, and provides a given soil stiffness with the least compactive effort. Each higher-number soil class provides successively less soil stiffness at a given percent compaction and requires greater compactive effort to provide a given level of soil stiffness.

NOTE 3—See Practices D2487 and D2488 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 Practice D2487 in accordance with particle size and gradation.

5.2 *Installation and Use*—Table 2 provides recommendations on installation and use based on soil-stiffness class and location in the trench. Soil Classes I to IV should be used as recommended in Table 2. Soil Class V, 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 Class I*—Class I 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 Class I 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 I materials. (See 5.6.)

5.2.2 *Soil Class II*—Class II 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 5.6.

5.2.3 *Soil Class III*—Class III materials provide less support for a given percent compaction than Class I or Class II materials. Higher levels of compactive effort are required and moisture content must be near optimum to minimize compactive effort and achieve the required percent compaction. These materials provide reasonable levels of pipe support once proper percent compaction is achieved.

5.2.4 *Soil Class IV*—Class IV materials require a geotechnical evaluation prior to use. Moisture content must be near optimum to minimize compactive effort and achieve the required percent compaction. Properly placed and compacted, Class IV 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 Class V*—Class V 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 soils

TABLE 2 Recommendations for Installation and Use of Soils and Aggregates for Foundation and Pipe-Zone Embedment

Soil Class[A]	Class I[D]	Class II	Class III	Class IV
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 5.6).	Where hydraulic gradient exists check gradation to minimize migration. Clean groups are suitable for use as a drainage blanket and underdrain (see Table 1). 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 Class III 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	Suitable for replacing over-excavated trench bottom for depths up to 12 in. as restricted above. Use only where uniform longitudinal support of the pipe can be maintained, as approved by the engineer. Install and compact in 6-in (150 mm) maximum layers.
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 Percent Compaction, SPD[B]	[C]	85 % (SW and SP soils) For GW and GP soils, see[E] .	90 %	95 %
Relative Compactive Effort Required to Achieve Minimum Percent Compaction	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]Class V 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 D698.
[C]Suitable compaction typically achieved by dumped placement (that is, uncompacted but worked into haunch zone to ensure complete placement).
[D]Class I materials have higher stiffness than Class II materials, but data on specific soil stiffness values are not available at the current time. Until such data are available the soil stiffness of placed, uncompacted Class I materials can be taken equivalent to Class II materials compacted to 95 % of maximum standard Proctor density (SPD95), and the soil stiffness of compacted Class I materials can be taken equivalent to Class II materials compacted to 100 % of maximum standard Proctor density (SPD100). Even if placed uncompacted (that is, dumped), Class I materials should always be worked into the haunch zone to assure complete placement.
[E]Place and compact GW and GP soils with at least two passes of compaction equipment.

with low permeability (that is, Class III and Class IV and some borderline Class II soils), moisture content is normally controlled to ±3 % of optimum (see Test Method D698). The practicality of obtaining and maintaining the required limits on moisture content is an important criterion for selecting materials, since failure to achieve required percent compaction, especially in the pipe zone embedment, may result in excessive deflection.

5.4 *Compatibility of pipe and backfill*—Experience has shown that pipe deflections and strain levels increase when low stiffness pipe is embedded in backfill materials that require large compactive efforts. This occurs because of the local distortions of the pipe shape that result as compactive energy is applied to the backfill. Because of this it is recommended that pipe with stiffness of 9 psi or less should only be embedded in soil types Class I or Class II.

5.5 *Maximum Particle Size*—Maximum particle size for pipe-zone embedment is limited based on pipe diameter as listed in Table 3. 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).

TABLE 3 Maximum Particle Size for Pipe Embedment

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

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.

5.6 *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 groundwater 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 groundwater 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 groundwater is anticipated, avoid placing coarse, open-graded materials, such as Class I, above, below, or adjacent 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.

5.6.1 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 D2487).

5.6.2 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 5.6.1:

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

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.

5.7 *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 *Groundwater*—When groundwater is present in the work area, dewater to maintain stability of in situ and imported materials. Maintain the water level below pipe bedding to provide a stable trench bottom. 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 groundwater level, ensure that the groundwater 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 groundwater 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 5.6.)

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 6 in. (150 mm) wider than the compaction equipment used in this region. For a single pipe in a trench, the 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). 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 or the use of free flowing backfill, such as uniform rounded pea gravel or flowable fill, 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 or backfill material 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 groundwater.

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 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, and ensure the direct compaction of embedment materials against the undisturbed native soil.

6.4.3 *Removal of Trench-Wall Support*— If the engineer permits the removal of sheeting or other trench-wall supports that extend below the top of the pipe, ensure that neither pipe, foundation, nor embedment materials is disturbed by support removal. Fill voids left on removal of supports and compact all material as required. Pulling the trench wall support in stages as backfilling progresses is advised.

6.5 *Trench-Bottom*—Excavate trenches to a minimum depth of 4 in. (100 mm) below the pipe. See 7.2 for guidance on installing foundation and bedding.

6.5.1 When ledge, rock, hardpan or other unyielding material, cobbles, rubble or debris, boulders, or stones larger than 1.5 in. (38 mm) are encountered in the trench bottom, excavate a minimum depth of 6 in. (150 mm) below the pipe bottom, or as directed by the engineer.

6.5.2 If the trench bottom is unstable or shows a "quick" tendency, overexcavate to depths directed by the engineer.

6.6 *Trenching on Slopes*—The angle at which slopes can become 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 (a slope of 1 to 4) or in areas where slope instability is suspected, unless supporting conditions have been verified by a proper geotechnical investigation. Installing pipes above ground may be a preferred method for steep slopes as above ground structures such as pipe supports are more easily defined and, therefore, the quality of installation is easier to monitor and settlement easier to detect. Pipes may be installed on slopes greater than 15 degrees (a slope of 1 to 4) provided that:

6.6.1 Long term stability of the installation can be ensured with proper geotechnical design.

6.6.2 Trenches are backfilled with coarse-grained material (Class I or Class II) with high shear strength or the shear strength of the backfill is assured by other means. Class II backfill should be compacted to at least 90 % of maximum standard Proctor density (Test Method D698).

6.6.3 Pipes should be installed in straight alignment (plus or minus 0.2 degrees) with minimum gap between pipe ends.

6.6.4 Absolute long term movement of the backfill in the axial direction of the pipe must be less than 0.75 in. (20 mm) to avoid joint separation.

6.6.5 The installation is properly drained to avoid washout of materials and ensure adequate soil shear strength.

6.6.6 Stability of individual pipes is monitored throughout the construction phase and the first stages of operation.

6.6.7 The manufacturer is consulted to determine if a special pipe design is required.

7. Installation

7.1 *General*—Recommendations for use of the various types of materials classified in Section 5 and Practice D2487 for the foundation and pipe zone embedment are given in Table 2.

NOTE 9—Additional useful information on procedures for installing pipe can be found in Guide F1668.

NOTE 10—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 *Foundation/Bedding*—Install foundation and bedding as required by the engineer in accordance with conditions in the trench-bottom. Provide a firm, stable, and uniform support for the pipe barrel and any protruding features of its joint. Provide a minimum of 4 in. (100 mm) of bedding below the barrel and 3 in. (75 mm) below any other part of the pipe unless otherwise specified.

7.2.1 *Bedding Material*—Often the bedding material will need to be an imported material to provide the proper gradation and pipe support. The bedding material should be the same material as the initial backfill. Native-soil material can be used as a bedding material if it meets the requirements of the initial backfill. This determination must be made as the pipe installation progresses because native-soil conditions vary widely and may change suddenly along the length of a pipeline. It is increasingly common to leave the bedding uncompacted for a width of ⅓ of the pipe diameter centered directly under the pipe. This reduces concentrated loads on the invert of the pipe.

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

7.2.3 *Unstable Trench-Bottom*—Where the trench-bottom is overexcavated because of unstable or "quick" conditions, install a foundation of Class I, Class II, or larger materials. Complete the foundation with a suitably graded material where conditions may cause migration of fines and loss of pipe support. 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 geotextiles.

7.2.4 *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 12-in. (300-mm) minimum cushion of bedding between the pipe and any such point of localized loading.

7.2.5 *Over-Excavation*—If the trench bottom is over-excavated below intended grade, fill the over-excavation with compatible foundation or bedding material and compact as recommended in Table 2.

7.2.6 *Sloughing*—If trench sidewalls slough off during any excavation or installation of pipe-zone embedment, 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 within acceptable design limits, or both. Pipe should be laid on flat uniform material that is at the appropriate grade. Do not bring pipe to grade by the use of mounds of soil or other material at points along the length of the pipe. 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 *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 joint and reassemble. Use only lubricant supplied or recommended for use by the manufacturer. Do not exceed the manufacturer's recommendations for angular "deflection" (axial alignment).

7.4.2 *Adhesive-Bonded or Wrapped Joints, or Both*—When making adhesive-bonded or wrapped joints, or both, follow recommendations of the pipe manufacturer. Allow freshly made joints to set for the recommended time before moving, burying, or otherwise disturbing the pipe.

NOTE 11—Axial restraint of the joined sections may be required during curing to prevent thermal expansion or contraction which could cause damage to the joint.

7.4.3 *Angularly Deflected Joints*—Large radius bends in pipelines may be accomplished by rotating the alignment of adjacent lengths of pipe (that is, "angularly deflecting" the joint). The amount of angular deflection should not exceed the manufacturer's recommendations.

7.5 *Placing and Compacting Backfill Materials*—Place embedment materials by methods which will not disturb or damage the pipe. Work in and compact the haunching material in the area between the bedding and the underside of the pipe before placing and compacting the remainder of the pipe-zone embedment. Follow recommendations for compaction given in Table 2 and this section. 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 7.7 for requirements for minimum cover.

7.5.1 *Percent Compaction of Embedment*—The Soil Class (from Table 2) and the required percent compaction of the embedment should be established by the engineer based on an evaluation of specific project conditions. The information in Table 2 will provide satisfactory embedment stiffness and is based on achieving an average modulus of soil reaction, E', of 1000 psi or greater (or an appropriate equivalent constrained modulus, M_s).

NOTE 12—The traditional measure of soil stiffness has been the modulus of soil reaction, E', that is commonly used to predict flexible pipe deflection. Recently AASHTO has changed this parameter to the constrained soil modulus, M_s. See Appendix X2 for additional details.

7.5.2 *Densification with Water*—Densification of cohesionless material with water (jetting, puddling, or saturation with vibration) should only be used under controlled conditions when approved by the engineer. Achieving a suitable water content in the soil is crucial and is best determined by trial test areas. Trial test areas may also be useful in determining the size of internal vibrators required and the appropriate spacing of their insertion into the soil. At all times, conform to the lift thicknesses and the compaction requirements given in Table 2.

7.5.3 *Compaction of Soils Containing Few Fines (Soil Classes I and II with Less Than 5 % Fines)*—If compaction is required, use surface plate vibrators, vibratory rollers, or internal vibrators. The compacted lift thickness should not exceed 12 in. (300 mm) when compacted with surface plate vibrators or vibratory rollers and should not exceed the length of the internal vibrator. If percent compaction is to specify the density of these materials, the maximum density should be determined by Test Method D4253 Test Method D7382. In some cases, the density of SW or SP soils may be determined by Test Method D698 (standard proctor) if the test results in a clearly defined compaction curve.

7.5.4 *Compaction of Soils Containing Some Fines (Soil Class II with 5 to 12 % Fines)*—These soils may behave as a soil containing few fines (see 7.5.3) or as a soil containing a significant amount of fines (see 7.5.5). The methods of compaction and density determination should be those methods (7.5.3 or 7.5.5) that result in the higher in-place density.

7.5.5 *Compaction of Soils Containing a Significant Amount of Fines (Soil Classes Class III, Class IV, and Class V)*—These soils should be compacted with impact tampers or with sheepsfoot rollers. Density determination should be in accordance with Test Method D698 (standard Proctor). The maximum density occurs at the optimum moisture content. Less effort is required to reach a given density when the moisture content is within two percentage points of the optimum moisture. A rapid method of determining the percent compaction and moisture variation is described in Test Method D5080. For compaction levels of 90 % standard Proctor and higher, the compacted lift thickness should not exceed 6 in. (150 mm).

7.5.6 *Determination of the In-Place Density of Soils*—The in-place density of any in situ or fill soil may be determined in accordance with Test Method D1556, D2167, D4564, D4914, D5030, or D6938. The applicable test method will depend on the type of soil, moisture content of the soil, and the maximum particle size present in the soil. The moisture content of the soil may be determined in accordance with Test Method D2216, D4643, D4944, or D4959. When using nuclear density-moisture gauges (Test Methods D6938), a standard count should be determined for density measurement in the proximity of the pipe and in the excavation unless otherwise indicated by the gage manufacturer.

7.6 *Backfill Around Angularly Deflected Pipe Joints*—When pipe joints are angularly rotated to accomplish large radii bends in pipelines that will operate at internal pressures of 15 psig (100 kPa) or greater, the backfill surrounding the joint should be compacted to at least 90 % of maximum standard Proctor density (or appropriate alternate standard for soils with few fines) for Class I and Class II materials, and 95 % of maximum standard Proctor density for Class III and Class IV materials. Consult the manufacturer for minimum depths of burial and additional restraint that may be required when the angular deflection is vertical.

7.7 *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 for surface loads, should be established by the engineer based on an evaluation of specific project conditions, including the pipe-zone embedment material and percent compaction, the native-soil characteristics, pipe stiffness, pipe diameter, surface pavement, surface loads, and final backfill compaction. In the absence of an engineering evaluation, the following minimum cover requirements should be used.

7.7.1 For embedment materials installed in accordance with Table 2, provide cover (that is, depth of backfill above top of pipe) of at least 24 in. (0.6 m) for Class I embedment and a cover of at least 36 in. (0.9 m) for Class II, Class III, or Class IV embedment, before allowing vehicles or construction equipment to traffic the trench surface. Provide at least 48 in. (1.2 m) of cover before using a hydrohammer for compaction unless approved by the engineer. Where construction loads may be excessive (for example, cranes, earth-moving equipment, or other vehicles where wheel loads exceed the AASHTO HS-20 loading) minimum cover shall be increased as determined by the engineer. A minimum of one pipe diameter of cover is suggested to prevent flotation of an empty pipe when full soil saturation to the surface exists.

7.8 *Connections and Appurtenant Structures:*

7.8.1 *Connections to Manholes and Rigid Structures*—When differential settlement can be expected, such as at the ends of casing pipe, when the pipe enters a manhole or at anchor block, or where foundation soils change stiffness, provide a flexible system capable of accommodating the anticipated settlement. This may be accomplished by placing a joint as close as practically possible to the face of the structure and a second joint within one to two pipe diameters from the face of the structure. The short length of pipe, called a rocker pipe shall be installed in a straight alignment with the short pipe section coming out of the rigid structure. The rocker pipe should have a minimum pipe stiffness of 36 psi (248 kPa) to transition between lower stiffness pipe and the rigid structure. Multiple rocker pipes should not be used. Alternatively, attach the pipe to the rigid structure with a flexible boot capable of accommodating the anticipated differential movement. Extra care and caution must be taken to replace and properly compact backfill adjacent to any rigid structure. Construction of concrete structures will frequently require over-excavation for formwork, etc. This extra-excavated material must be restored to a compaction level compatible with surroundings to prevent excess deformation and or joint rotation adjacent the structure. In these areas, compact backfill to achieve the same soil compaction as specified for all pipe backfill, but not less than that required to achieve a soil constrained modulus (M_s) of at least 1000 psi (6.9 MPa). Other methods of accommodating the differential settlements may be acceptable if approved in advance.

NOTE 13—The use of cement stabilized or flowable backfills adjacent to large structures has been found to be effective in preventing differential settlement.

7.8.2 *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.

7.9 *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 percent compaction of service-line embedment should conform to the specifications for the existing line, or with this practice, whichever is more stringent.

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

7.11 *Parallel Piping Systems*—Compact the soil between the pipes in the same manner as the soil between the pipe and the trench wall, taking special care to compact the soil in the haunch zone.

8. Monitoring, Inspecting, and Testing

8.1 *Field Monitoring*—Compliance with pipe installation requirements, including trench depth, grade, water conditions, foundation, embedment and backfill materials, joints, compaction of materials in place, and safety should be monitored to assure conformance with accordance with contract documents.

8.2 *Deflection*—Monitor the deflection level in the pipe throughout the installation process for conformance to the requirements of the contract specifications and the manufacturer's recommendations. Conduct deflection measurements early in a project to verify that construction procedures are adequate. The deflection at the time of installation will be less than the long-term deflection due to time-dependent load increase. If necessary, also consider the effects of vertical ovalling during compaction. Deflection testing should be completed prior to undertaking pressure tests.

8.3 *Pressure Testing*—Most pressure pipelines are tested after installation to detect leaks, installation flaws, damaged pipes or other deficiencies (see Appendix X1). As a general rule, such tests should not be conducted using air pressure, unless special precautions, not within the scope of this practice, are used. Additional recommendations for conducting pressure tests include:

8.3.1 Required thrust restraints are properly installed (and sufficiently cured if applicable).

8.3.2 Backfilling should be completed. Some sections of the line may be left uncovered provided suitable lateral and longitudinal restraint is provided.

8.3.3 Pumps and valves are anchored.

8.3.4 Assure test caps and endplugs are properly installed and restrained as necessary.

8.3.5 Vent the pipeline while filling to allow all air to escape.

8.3.6 Pressurize the line slowly to avoid pressure surges.

8.3.7 In determining the test pressure remember that the lowest point on the line will have the highest pressure. If the test pressure gage is not installed at this location, then the pressure should be determined by calculation.

8.3.8 Assure that the test fluid temperature is stable during the test period (to avoid pressure changes due to thermal expansion or contraction that may be misinterpreted as leaks).

9. Inspection, Handling, and Storage

9.1 *Inspection*—Upon receipt, inspect each shipment of pipe and fittings for conformance to product specifications and contract documents, and check for damage. Reject or repair nonconforming or damaged pipe. Remove rejected pipe from the jobsite.

9.2 *Handling and Storage*—Proper handling and storage of the pipe is important to achieve a successful installation. Consult the manufacturer for recommendations and appropriate procedures.

10. Keywords

10.1 backfill; bedding; fiberglass pipe; haunching; soil stiffness; underground installation

APPENDIXES

(Nonmandatory Information)

X1. RECOMMENDATION FOR INCORPORATION IN CONTRACT DOCUMENTS

This practice may be incorporated by referral in contract documents for a specific project, to cover requirements for installation. Applications to a particular project should be made by means of a list of supplemental requirements. Suggested modifications to specific section numbers are listed as follows. (The list is keyed to applicable section numbers of the practice):

X1.1 *Paragraph 5.4*—Maximum particle size if different from this section.

X1.2 *Sections 5 and 7 and* Table 2—Further restrictions on use of classes of embedment and backfill materials.

X1.3 *Paragraph 5.5*—Specific gradations of embedment materials for resistance to migration.

X1.4 *Paragraph 6.1.1*—State specific restrictions on leaving trenches open.

X1.5 *Paragraph 6.2*—Restrictions on mode of dewatering; design of underdrains.

X1.6 *Paragraph 6.3*—Requirements on minimum trench width.

X1.7 *Paragraph 6.4*—Restrictions or details for support of trench walls.

X1.8 *Paragraph 7.5*—Specific restrictions on methods of compaction.

X1.9 *Paragraph 7.5.1 and* Table 2—Minimum embedment percent compaction if different from these recommendations; specific compaction requirements for backfill (for example, for pavement subgrade).

X1.10 *Paragraph 7.6*—Minimum cover requirements if different from this paragraph.

X1.11 *Paragraph 7.7.1*—Detailed requirements for manhole connections.

X1.12 *Paragraph 7.7.2*—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.

X1.13 *Paragraph 8.11*—Requirements on methods of testing compaction and leakage.

X1.14 *Paragraph 8.12*—Requirements on deflection and deflection measurements, including method and time of testing.

X2. SOIL STIFFNESS

X2.1 In 2000, AASHTO adopted new values for soil stiffness for backfill materials used for thermoplastic pipe. The modifications include changing the soil design parameter from the modulus of soil reaction, E', to the constrained soil modulus, M_s. This change is based on the work of McGrath (1998).[6] Design values of the constrained modulus are presented in Table X2.1. The table shows that M_s increases with depth of fill which reflects the increased confining pressure. This is a well-known soil behavior. At moderate depths of fill the values of M_s are close to the E' values proposed by Howard (1977, 1996).[7,8] In design for deflection control, M_s may be substituted directly for E' in the Iowa formula. Use of the constrained modulus in predicting deflection may be completed by making a direct substitution of M_s for E' in the Iowa formula. The Iowa formula is presented in many publications, in particular, AWWA Manual M45, Fiberglass Pipe Design.

[6] McGrath, T. J., "Replacing E' with the Constrained Modulus in Flexible Pipe Design," *Proceedings of the Conference Pipelines in the Constructed Environment*, ASCE, 1998.

[7] Howard, A. K., "Modulus of Soil Reaction Values for Buried Flexible Pipe," *Journal of Geotechnical Engineering* , ASCE, Vol 103, No. GT1, New York, NY, 1977.

[8] Howard, A. K., *Pipeline Installation*, Relativity Publishing, Lakewood, CO, 1996.

TABLE X2.1 Constrained Soil Modulus, M_s Based on Vertical Stress Level, Soil Class and Compaction Condition[A,B,C,D,E,F,G,H]

Vertical Stress Level[E] psi (kPa)	Depth for Soil Density = 120 pcf (18.8 kN/m³) ft(m)	Soil Classes I and II (See[B] for applicability to Class I Soils) SPD100 psi (MPa)	SPD95 psi (MPa)	SPD90 psi (MPa)	SPD85 psi (MPa)
1 (6.9)	1.2 (0.4)	2 350 (16.2)	2 000 (13.8)	1 275 (8.8)	470 (3.2)
5 (34.5)	6 (1.8)	3 450 (23.8)	2 600 (17.9)	1 500 (10.3)	520 (3.6)
10 (69)	12 (3.7)	4 200 (29.0)	3 000 (20.7)	1 625 (11.2)	570 (3.9)
20 (138)	24 (7.3)	5 500 (37.9)	3 450 (23.8)	1 800 (12.4)	650 (4.5)
40 (276)	48 (14.6)	7 500 (51.7)	4 250 (29.3)	2 100 (14.5)	825 (5.7)
60 (414)	72 (22)	9 300 (64.1)	5 000 (34.5)	2 500 (17.2)	1 000 (6.9)
			Soil Stiffness Category Class III		
1 (6.9)	1.2 (0.4)		1 415 (9.8)	670 (4.6)	360 (2.5)
5 (34.5)	6 (1.8)		1 670 (11.5)	740 (5.1)	390 (2.7)
10 (69)	12 (3.7)		1 770 (12.2)	750 (5.2)	400 (2.8)
20 (138)	24 (7.3)		1 880 (13.0)	790 (5.4)	430 (3.0)
40 (276)	48 (14.6)		2 090 (14.4)	900 (6.2)	510 (3.5)
60 (414)	72 (22)		2 300 (15.9)	1 025 (7.1)	600 (4.1)
			Soil Stiffness Category Class IV		
1 (6.9)	1.2 (0.4)		530 (3.7)	255 (1.8)	130 (0.9)
5 (34.5)	6 (1.8)		625 (4.3)	320 (2.2)	175 (1.2)
10 (69)	12 (3.7)		690 (4.8)	355 (2.5)	200 (1.4)
20 (138)	24 (7.3)		740 (5.1)	395 (2.7)	230 (1.6)
40 (276)	48 (14.6)		815 (5.6)	460 (3.2)	285 (2.0)
60 (414)	72 (22)		895 (6.2)	525 (3.6)	345 (2.4)

[A] Class I soils have the highest stiffness and require the least amount of compactive energy to achieve a given density. Class V soils, which are not recommended for use as backfill, have the lowest stiffness and require substantial effort to achieve a given density. Soil classes are explained in Table 1.

[B] Class I soils have higher stiffness than Class II soils, but data on specific soil stiffness values are not available at the current time. Until such data are available, the soil stiffness of placed, uncompacted Class I soils can be taken equivalent to Class II soils compacted to 95% of maximum standard Proctor density (SPD95), and the soil stiffness of compacted Class I soils can be taken equivalent to Class II soils compacted to 100% of maximum standard proctor density (SPD100). Even if placed uncompacted (that is, dumped), Class I materials should always be worked into the haunch zone to assure complete placement.

[C] The soil types Class I to Class V are defined in Table 1. Specific soil groups that fall into these classes, based on ASTM D2487 and AASHTO M145, are also listed in Table 1.

[D] The numerical suffix to the SPD (standard Proctor density) indicates the compaction level of the soil as a percentage of maximum dry density determined in accordance with ASTM D698 (AASHTO T-99).

[E] Vertical stress level is the vertical effective soil stress at the springline elevation of the pipe. It is normally computed as the design soil unit weight times the depth of fill. Buoyant unit weight should be used below the groundwater level.

[F] Engineers may interpolate intermediate values of M_{sb} for vertical stress levels not shown on the table.

[G] For pipe installed below the water table, the modulus should be corrected for reduced vertical stress due to buoyancy and by an additional factor of 1.00 for Class I and Class II soils with SPD of ≥ 95, 0.85 for Class II soils with SPD of 90, 0.70 for Class II soils with SPD of 85, 0.50 for Class III soils, and 0.30 for Class IV soils.

[H] It is recommended to embed pipe with stiffness of 9 psi (62 kPa) or less only in Class I or Class II soils.

X2.2 Example: Determine the constrained soil modulus at a depth of 10 ft for an SW soil with a unit weight of 120 pcf.

X2.2.1 Determine vertical applied stress:
p = 10 ft (120 pcf) = 1200 psf = 8.3 psi.

X2.2.2 Determine constrained soil modulus for SW soil, which is soil type SC2-100 from Table X2.1, note c:

for p = 5 psi, M_s = 3,450 psi;
for p = 10 psi, M_s = 4,200 psi.

X2.2.3 Interpolating for p = 8.3 psi, $M_s = 3450 + (4200 - 3450)\{(8.3 - 5)/(10 - 5)\} = 3945$ psi.

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D3839 – 08) that may impact the use of this standard. (March 1, 2014)

(1) 2.1: Removed D1557, D2922 and D3017 from Reference Documents List.
(2) 2.1: Added D5821, D6938, and D7382 to Reference Documents List.
(3) Figure 1: Added reference to Section 7.7 on Minimum Cover.
(4) 3.1: Added definition for modulus of soil reaction, percent compaction, secant constrained soil modulus, and standard proctor density.
(5) 3.2.16: Removed reference to D1557.
(6) 3.2.19: Removed definition for relative density.
(7) Table 1: Revised "(or CL-ML, CL/ML, ML/CL)" with "or any soil beginning with one of these symbols" under Coarse grained soils with fines classification.
(8) Table 1: Replaced "or less" with "≤" under Fine-grained soils classification.
(9) Table 1: Added Notes C, F and G providing additional guidance on soil classes.
(10) Table 2: Changed recommendation for Class IV Foundation to "Suitable for replacing over-excavated trench bottom as restricted above. Install and compact in 6-in (150 mm) maximum layers."
(11) Table 2: Added Note E for minimum recommended percent compaction of Class II soils for GW and GP soils.
(12) Table 2: Added Note D providing guidance on classification of uncompacted Class I material.
(13) 6.3: Changed the minimum trench width for a single pipe to "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)."
(14) 6.4.3: Added sentence: "Pulling the trench wall support in stages as backfilling progresses is advised."
(15) 7.2.5: Added reference to Table 2.
(16) 7.4: Added sentence: "When pipe laying is interrupted, secure piping against movement and seal open ends to prevent the entrance of water, mud, or foreign material."
(17) 7.4.1: Added "ensure"; replaced "assembly" with "homing".
(18) 7.5.1: Replaced section on "Minimum Density" with new section on "Percent Compaction of Embedment".
(19) 7.5.2: Replaced "vibration" with "puddling"; added reference to Table 2.
(20) 7.5.6: Removed reference to D2922 and D3017 and added reference to D6938.
(21) 7.7.1: Added reference to Table 2.
(22) 7.8.1: Added explanatory clause: "or where foundation soils change stiffness".
(23) Entire standard: Revised wording for "density" and "proctor density" to "percent compaction".
(24) Entire standard: Revised wording for soil "stiffness category" and "SC" to soil "Class".
(25) Entire standard: Miscellaneous editorial changes.