Designation: D3839 – 14

An American National Standard

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.

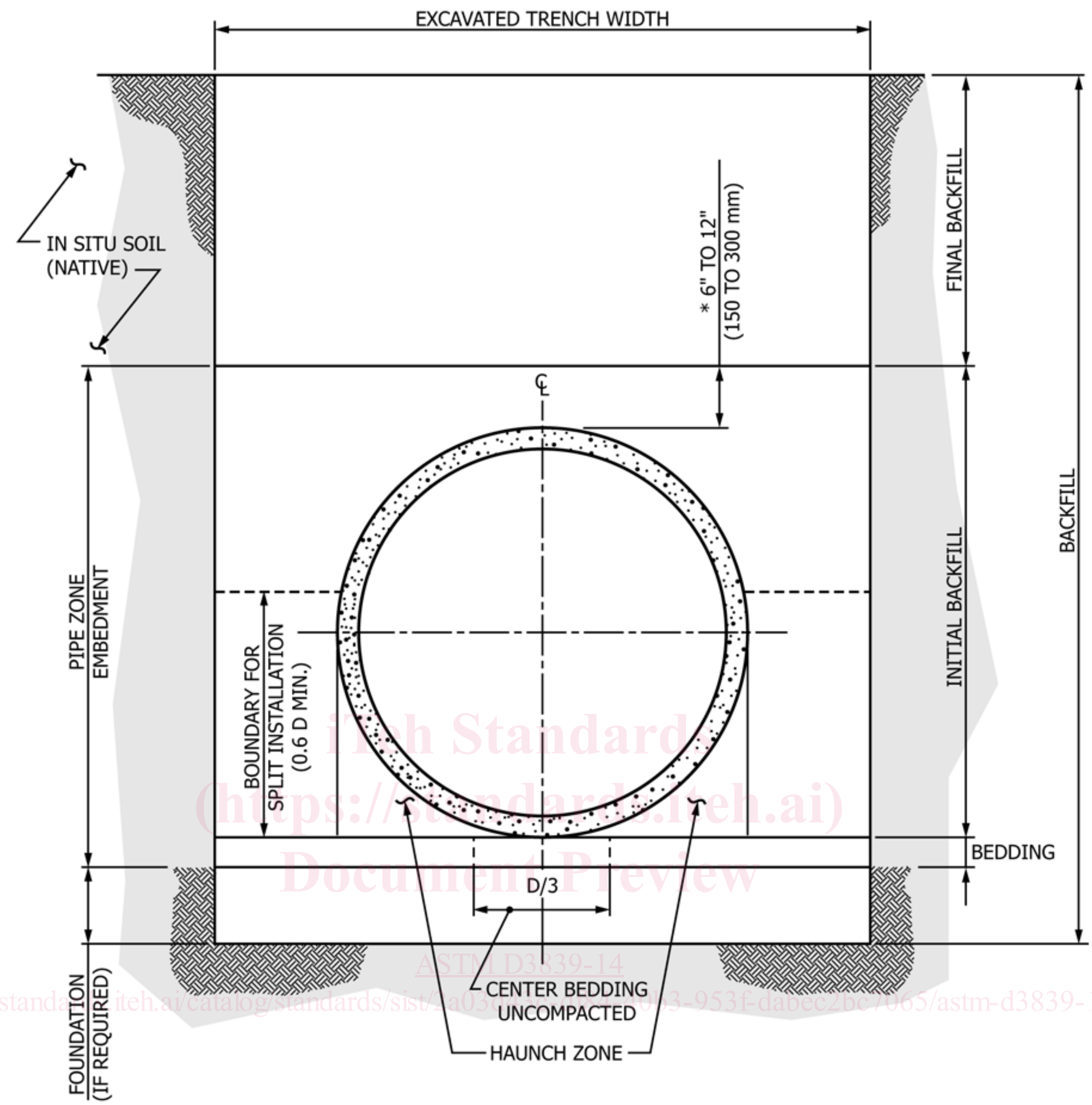
3.2.19 *processed aggregates*—aggregates which are screened or washed or mixed or blended to produce a specific particle-size distribution.

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