Designation: F2306/F2306M – 14ε1

Standard Specification for 12 to 60 in. [300 to 1500 mm] Annular Corrugated Profile-Wall Polyethylene (PE) Pipe and Fittings for Gravity-Flow Storm Sewer and Subsurface Drainage Applications[1]

This standard is issued under the fixed designation F2306/F2306M; 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.

ε[1] NOTE—Table 1 was editorially corrected in March 2015.

1. Scope*

1.1 This specification covers requirements and test methods for annular, corrugated profile wall polyethylene pipe and fittings with an interior liner. The nominal inside diameters covered are 12 to 60 in. [300 to 1500 mm].

1.2 The requirements of this specification are intended to provide pipe and fittings suitable for underground use for gravity-flow storm sewer and subsurface drainage systems.

NOTE 1—Pipe and fittings produced in accordance with this specification shall be installed in compliance with Practice D2321.

1.3 This specification covers pipe and fittings with an interior liner using a corrugated exterior profile (Fig. 1).

1.4 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 The following precautionary caveat pertains only to the test method portion, Section 7, of this specification. *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]

D618 Practice for Conditioning Plastics for Testing

D1600 Terminology for Abbreviated Terms Relating to Plastics

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2321 Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications

D2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading

D2444 Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)

D3212 Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals

D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials

F412 Terminology Relating to Plastic Piping Systems

F477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

F2136 Test Method for Notched, Constant Ligament-Stress (NCLS) Test to Determine Slow-Crack-Growth Resistance of HDPE Resins or HDPE Corrugated Pipe

2.2 *AASHTO Standard:*[3]

AASHTO LRFD Bridge Design Specifications

LRFD, Section 12 Bridge Design Specifications Section 12 – Buried Structures and Tunnel Liners

AASHTO M 145 : Classification of Soils and Aggregate Mixtures

2.3 *Department of Agriculture Standard:*

Standard 606 Soil Conservation Service Engineering[4]

2.4 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[5]

[1] This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.62 on Sewer.

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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.

[3] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

[4] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401. http://www.gpo.gov/about/bookstore.htm

[5] DLA Document Services Building 4/D 700 Robbins Avenue Philadelphia, PA 19111-5094 http://quicksearch.dla.mil/

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

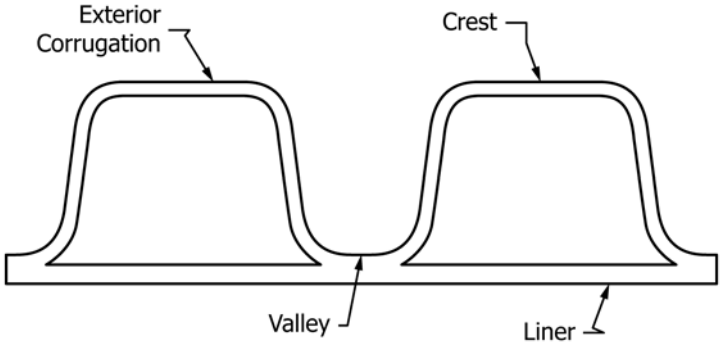

FIG. 1 Typical Annular Corrugated Pipe Profile

2.5 *Military Standard:*
MIL-STD-129 Marking for Shipment and Storage[5]
2.6 *NCHRP (National Cooperative Highway Research Program) Report:*[6]
NCHRP Report 631 Updated Test and Design Methods for Thermoplastic Drainage Pipe

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F412 and abbreviations are in accordance with Terminology D1600, unless otherwise specified. The abbreviation for polyethylene is PE.

3.2 *Definitions of Terms Specific to This Standard:*
3.2.1 *design diameter, n*—the manufacturer's stated inside diameter.

3.2.2 *mold line, n*—a line formed on the product as a result of the mold blocks coming together during manufacturing.

3.2.3 *profile wall, n*—a pipe wall construction that presents an interior liner in the waterway but includes ribs, corrugations, or other shapes, which can be either solid or hollow, that helps brace the pipe against diametrical deformation.

4. Ordering Information

4.1 Orders for product made to this specification shall include the following information to adequately describe the desired product:
4.1.1 This ASTM designation and year of issue,
4.1.2 Perforations:
4.1.2.1 With perforations,
4.1.2.2 Without perforations,
4.1.3 Diameters,
4.1.4 Total footage of each pipe diameter involved,
4.1.5 Pipe laying length,
4.1.6 Fitting type(s):
4.1.6.1 Size and type of fittings, including mainline and branch diameters, and
4.1.6.2 Number of fittings per diameter.

5. Materials and Manufacture

5.1 *Basic Materials:*

5.1.1 *Pipe and Blow-Molded Fittings*—The pipe and fittings shall be made of virgin PE plastic compound meeting the requirements of Specification D3350 cell classification 435400C or 435400E, except that carbon black content shall not exceed 4 %. Compounds that have a higher cell classification in one or more properties shall be permitted provided the density of the base resin shall not exceed 0.955 g/cm^3 and all other product requirements are met. For slow crack-growth resistance, resins shall be evaluated using the notched constant ligament stress (NCLS) test according to the procedure described in 7.8. The average failure time of the five test specimens shall exceed 24 h with no single test specimen's failure time less than 17 h.

5.1.2 *Rotationally Molded Fittings and Couplings*—Compounds used in the manufacture of rotationally molded fittings and couplings shall be virgin PE meeting the requirements of Specification D3350 and cell classification 213320C or 213320E, except that the carbon black content shall not exceed 4 %. Compounds that have a higher cell classification in one or more properties shall be permitted provided the density of the base resin shall not exceed 0.940 g/cm^3 and all other product requirements are met.

5.1.3 *Injection-Molded Fittings and Couplings*—Compounds used in the manufacture of injection molded fittings and couplings shall be made of virgin PE meeting the requirements of Specification D3350 and cell classification 414420C or 414420E, except that the carbon black content shall not exceed 4 %. Compounds that have a higher cell classification in one or more properties shall be permitted provided all other product requirements are met.

5.2 *Rework Material*—Clean rework material generated from the manufacturer's own pipe and fittings production shall be permitted to be used by the same manufacturer, provided that the material meets the requirements of 5.1.1 or 5.1.2 as applicable for the intended part and pipe or fittings produced meet all the requirements of this specification.

6. General Requirements

6.1 *Workmanship*—The pipe and fittings shall be homogeneous throughout and be as uniform as commercially practical in color, opacity, and density. The pipe walls shall be free of cracks, holes, blisters, voids, foreign inclusions, or other defects that are visible to the naked eye and that may affect the

[6] Transportation Research Board, The National Academies 500 Fifth Street, NW Washington, DC 20001. http://www.TRB.org

wall integrity. The ends shall be cut cleanly and squarely. Holes intentionally placed in perforated pipe are acceptable.

6.1.1 Visible defects, cracks, creases, splits, obstruction to flow in perforations, or in pipe are not permissible.

6.2 *Dimensions and Tolerance:*

6.2.1 *Nominal Size*—The nominal size for the pipe and fittings shall be the inside diameter shown in Table 1.

6.2.2 *Inside Diameter*—The average inside diameter for pipe and fittings shall not vary more than ± 1 % from the design diameter when measured in accordance with 7.4.1.

NOTE 2—The outside diameters and the corrugation pitch of products manufactured to this specification are not specified; therefore, compatibility between pipe and fittings from different manufacturers or the same manufacturer shall be verified.

6.2.3 *Length*—The pipe shall be supplied in any length agreeable to both the owner and the manufacturer. Length shall not be less than 99 % of stated quantity when measured in accordance with 7.4.2.

6.2.4 *Minimum Inner-Liner Thickness*—The minimum inner-liner thickness of the pipe shall meet the requirements given in Table 1 when measured in accordance with 7.4.3.

6.2.5 *Perforations*—Perforations shall be cleanly cut, placed in the valley of the corrugation rib, and uniformly spaced along the length and circumference of the pipe. Dimensions of the perforations and the minimum perforation inlet area shall be as listed in Table 2. Other perforation dimensions and configurations shall be permitted, where required to meet the needs of the specifier. All measurements shall be made in accordance with 7.4.4. Pipe connected by bell and spigot joints shall not be perforated in the area of the bells and spigots.

NOTE 3—For perforated pipe applications, the size of the embedment zone and permeability of the embedment material provide the desired level of infiltration or exfiltration. The pipe or embedment zone shall be wrapped with a geotextile designed to prevent migration of fine soils into the pipe or embedment zone. Where a geotextile is not used, the gradation of the embedment material shall be compatible with the perforation size to avoid backfill migration into the pipe.

6.3 *Pipe Stiffness*—Minimum pipe stiffness at 5 % deflection shall meet the requirements given in Table 1 when tested in accordance with 7.5.

NOTE 4—The 5 % deflection criterion, which was selected for testing convenience, is not a limitation with respect to in-use deflection. The engineer is responsible for establishing the acceptable deflection limit.

TABLE 1 Pipe Stiffness and Pipe Dimensions

Pipe Inside Diameter		Minimum Pipe Stiffness at 5 % Deflection		Minimum Inner Liner Thickness	
in.	[mm]	lb/in./in.	[kPa]	in.	[mm]
12	[300]	50	[345]	0.035	[0.9]
15	[375]	42	[290]	0.040	[1.0]
18	[450]	40	[275]	0.051	[1.3]
21	[525]	38	[260]	0.060	[1.5]
24	[600]	34	[235]	0.060	[1.5]
27	[675]	30	[205]	0.060	[1.5]
30	[750]	28	[195]	0.060	[1.5]
36	[900]	22	[150]	0.067	[1.7]
42	[1050]	20	[140]	0.071	[1.8]
48	[1200]	18	[125]	0.071	[1.8]
54	[1350]	16	[110]†	0.079	[2.0]
60	[1500]	14	[95]	0.079	[2.0]

† Editorially corrected in March 2015.

TABLE 2 Perforation Dimensions

Pipe Inside Diameter		Type of Perforation			
		Circular			
		Maximum Diameter		Minimum Inlet Area	
in.	[mm]	in.	[mm]	$in.^2/ft$	$[cm^2/m]$
12	[300]	⅜	[10]	1.5	[30]
15	[375]	⅜	[10]	1.5	[30]
18	[450]	⅜	[10]	1.5	[30]
21	[525]	⅜	[10]	2.0	[40]
24	[600]	⅜	[10]	2.0	[40]
27	[675]	⅜	[10]	2.0	[40]
30	[750]	⅜	[10]	2.0	[40]
36	[900]	⅜	[10]	2.0	[40]
42	[1050]	⅜	[10]	2.0	[40]
48	[1200]	⅜	[10]	2.0	[40]
54	[1350]	⅜	[10]	2.0	[40]
60	[1500]	⅜	[10]	2.0	[40]

6.4 *Pipe Flattening*—There shall be no evidence of splitting, cracking, breaking, separation of seams, separation of the outer and inner wall, or combinations thereof, when tested in accordance with 7.6. Additionally, at or below the deflection limit defined in Eq 1, the specimen shall be considered as failing this test when the load does not increase continuously with increasing deflection.

Buckling Deflection Limit:

$$\Delta b = \frac{6.15\% \cdot 0.5 \cdot D}{D_f \cdot 0.6 \cdot h_p} \quad (1)$$

where:

Δb = minimum buckling deflection limit (%)
D = mean diameter (centroid) of pipe (in [mm])
D_f = shape factor (dimensionless fixed value of 4.27 for parallel plate test)
h_p = corrugation height (in [mm])

NOTE 5—Field deflection limits are typically taken at 5 % (see Annex A1). Eq 1 is based on the results from NCHRP Report 631 and is defined as being derived from the standard parallel plate test equation. The constant value 6.15 % (0.0615) in Eq 1 is the factored combined strain limit for HDPE pipe per AASHTO LRFD Section 12. The constant value 0.6 in this equation is an estimated centroidal distance for typical profiles produced per this specification.

6.5 *Pipe Impact Strength*—There shall be no evidence of splitting, cracking, breaking, separation of seams, separation of the outer and inner wall, or combinations thereof, when tested in accordance with 7.7.

6.6 *Fittings and Joining Systems:*

6.6.1 Only fittings supplied or recommended by the pipe manufacturer should be used. Fittings shall be installed in accordance with the manufacturer's recommendations.

6.6.2 The joining system(s) shall be of a design that preserves alignment during construction and prevents separation at the joints. Bell and spigot, external snap or split couplers are examples of typical designs.

6.6.3 Fittings shall be supplied with joints compatible with the overall system. All joints for gravity-flow Sewer systems shall meet the requirements of 6.6.3.3. All other joints shall meet the requirements of a soil-tight joint unless otherwise specified by the owner/designer.

6.6.3.1 Soil-tight joints are specified as a function of opening size, channel length, and backfill particle size. If the size of the opening exceeds 3 mm, the length of the channel shall be at least four times the size of the opening. A backfill material containing a high percentage of fine-graded soils requires investigation for the specific type of joint to be used to guard against soil infiltration. Information regarding joint soil tightness criteria can be found in AASHTO's Standard Specifications for Highway Bridges, Division II, Section 26, "Metal Culverts."

NOTE 6—The ability of a joint to resist soil infiltration (soil tightness) shall be considered. Soil tightness is a function of opening size, channel length, and backfill particle size. A backfill material containing a high percentage of Class III and Class IVA material as defined in Practice D2321 requires consulting with the manufacturer for the specific type of joint to be used to guard against soil infiltration. Alternatively, the joint shall be permitted to be wrapped with a geotextile designed to prevent migration of these fine soils into the pipe.

6.6.3.2 Silt-tight joints shall be used where the backfill material has a high percentage of fines. Silt tight joints shall meet laboratory test in accordance with Test Method D3212 except that the joint be tested using 2.0 psi (14 kPa) and utilize a bell and spigot joint with a gasket meeting Specification F477.

6.6.3.3 Watertight joints shall meet a 10.8 psi (74 kPa) laboratory test in accordance with Test Method D3212 and utilize a bell and spigot design with a gasket meeting Specification F477.

7. Test Methods

7.1 *Conditioning:*

7.1.1 *Referee Testing*—When conditioning is required for referee tests, condition the specimens in accordance with Procedure A of Practice D618 at 73.4 ± 3.6°F [23 ± 2°C] for not less than 40 h prior to test. Conduct tests under the same conditions of temperature.

7.1.2 *Quality Control Testing*—Condition specimens for a minimum of 4 h prior to test in air or 1 h in water at 73.4 ± 3.6°F [23 ± 2°C] without regard to relative humidity.

7.2 *Test Conditions*—Conduct tests other than those for routine quality control purposes in the standard laboratory atmosphere of 73.4 ± 3.6°F [23 ± 2°C], in the referenced test method or in this specification.

7.3 *Sampling*—The selection of the sample or samples of the pipe and fittings shall be as agreed upon between the owner and the seller. In case of no prior agreement, any sample selected by the testing laboratory shall be deemed permitted.

7.4 *Dimensions:*

7.4.1 *Inside Diameter*—Measure the inside diameter in accordance with Test Method D2122.

7.4.2 *Length*—Measure pipe length in accordance with Test Method D2122. These measurements may be taken at ambient temperature.

7.4.3 *Minimum Inner-Liner Thickness*—Measure the thickness of the inner liner in accordance with Test Method D2122. Each specimen shall be cut perpendicular to the seam line of the pipe directly through a corrugation allowing a plain view of the inner wall 360° around the circumference in order to obtain a minimum of eight measurements in accordance with Test Method D2122.

7.4.4 *Perforations*—Measure dimensions of perforations on a straight specimen without external forces applied. Linear measurements shall be made with an instrument with calibration increments of 0.01 in. [0.25 mm].

7.5 *Pipe Stiffness*—Select three pipe specimens and test for pipe stiffness in accordance with Test Method D2412, except for the following conditions:

7.5.1 The test specimens shall be at least one diameter or 24 in. in length, which ever is less. However, the test specimen shall not be less than three full corrugations in length.

7.5.2 Each specimen shall be cut mid-valley to mid-valley (see Fig. 1) while still meeting or exceeding the minimum length requirement.

7.5.3 Locate the first specimen in the loading machine with the minimum inner wall thickness located at 9:00 and 3:00 when viewing the specimen from the end. The specimen shall lie flat on the plate within 0.125 in. [3 mm] and shall be straightened by hand bending at room temperature. Use the first location as a reference point for rotation and testing of the other two specimens. Rotate subsequent specimens 45° and 90°, respectively, from the original orientation. Test each specimen in only one position.

7.6 *Flattening*—Flatten the three test specimens from 7.5 between parallel plates until the pipe inside diameter is reduced by 40 %. The rate of loading shall be 0.5 in./min [12.5 mm/min].

7.7 *Impact Resistance*—Test pipe specimens in accordance with Test Method D2444 except six specimens shall be tested, or six impacts shall be made on one specimen. In the latter case, successive impacts shall be separated by 120 ± 10° for impacts made on one circle, or at least 12 in. [305 mm] longitudinally for impacts made on one element. Impact points shall be at least 6 in. [150 mm] from the end of the specimen. Impact strength shall not be less than 100 ft×lbf [136 J]. Tup B shall be used and use a flat plate specimen holder. Condition the specimens for 24 h at a temperature of 4 ± 2°C, and conduct all tests within 60 s of removal from this atmosphere. The center of the falling tup shall strike on a corrugation crown for all impacts.

7.7.1 In 12 to 18 in. [300 to 450 mm] diameters, the test specimens shall be equal in length to the nominal diameter. In sizes 21 to 60 in. [750 to 1500 mm] diameters, the test specimens shall be equal in length to one-half of the nominal diameter but not less than 18 in. [457 mm].

7.8 *Slow-Crack Growth Resistance of Resin Compounds*—Test basic resin compounds in accordance with the Test Method F2136, test except for the following modifications:

7.8.1 The applied stress for the NCLS test shall be 600 psi [4138 kPa].

7.8.2 The test specimen is taken from the extruded pipe and is chopped and molded into a specimen.

8. Inspection

8.1 Inspection of the product shall be as agreed upon between the owner and the manufacturer as part of the

purchase contract. Unless otherwise specified in the contract or purchase agreement, the manufacturer is responsible for the performance of all inspection and test requirements specified herein.

8.2 *Notification*—If inspection is specified by the owner, the manufacturer shall notify the owner in advance of the date, time, and place of testing of the pipe or fittings, or both, so that the purchaser may be represented at the test.

8.3 *Access*—The inspector shall have free access to those parts of the manufacturer's plant that are involved in work performed under this specification. The manufacturer shall afford the inspector all reasonable facilities for determining whether the pipe or fittings, or both, meet the requirements of this specification.

9. Rejection and Retesting

9.1 If the results of any test(s) do not meet the requirements of this specification, the test(s) shall be conducted again in accordance with an agreement between the owner and the manufacturer. There shall be no agreement to lower the minimum requirement of the specification by such means as omitting tests that are a part of the specification, substituting or modifying a test method, or by changing the specification limits. In retesting, the product requirements of this specification shall be met, and the test methods designated in this specification shall be followed. If, upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this specification.

10. Certification

10.1 When specified in the purchase order or contract, a manufacturer's or independent laboratory's certification shall be furnished to the owner that the products were manufactured, sampled, tested, and inspected at the time of manufacture in accordance with this specification and have been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished. Where requested, certified actual inside diameter shall be provided.

11. Markings

11.1 *Pipe*—Each length of pipe in compliance with this specification shall be clearly marked with the following information: this designation ASTM F2306; the nominal size; the legend PE, the manufacturer's name, trade name or trademark, plant location, and date of manufacturer. The marking shall be applied at the time of manufacture to the pipe in such a manner that it remains legible after installation and inspection. It shall be placed, at least, at each end of each length of pipe or spaced at intervals of not more than 10 ft [3.0 m].

11.2 *Fittings*—Each fitting in compliance with this specification shall be clearly marked with the following information: this designation ASTM F2306; the nominal size; the legend PE; the manufacturer's name, trade name or trademark; plant location, and date of manufacture.

12. Packaging

12.1 All pipe and couplings and fittings shall, unless otherwise specified, be packaged for standard commercial shipment.

13. Quality Assurance

13.1 When the product is marked with this designation (ASTM F2306), the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

14. Keywords

14.1 fittings; interior liner; PE; pipe; polyethylene; profile wall; sewer; subdrainage

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT/MILITARY PROCUREMENT

These requirements apply only to federal/military procurement, not domestic sales or transfers.

S1. Responsibility for Inspection

S1.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified herein. The manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless the owner disapproves. The owner shall have the right to perform any of the inspections and tests set forth in this specification, where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

NOTE S1—In U.S. federal contracts, the contractor is responsible for inspection.

S2. Packaging and Marking for U.S. Government Procurement

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the manufacturer's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2—The inclusion of U.S. government procurement requirements shall not be construed as an indication that the U.S. government uses or endorses the products described in this document.

ANNEX

A1. STRUCTURAL DESIGN

A1.1 The appropriate design methodology for pipes 12 in. (300 mm) and larger in diameter covered by this specification (F2306/F2306M), is provided in the AASHTO LRFD Bridge Design Specification, (AASHTO LRFD Specification). Live and dead loads for design along with the necessary load resistance factors for design are provided in Section 3 of the ASHTO LRFD Specification. The actual AASHTO design soil load on corrugated HDPE pipes depends, to a degree, on the relative circumferential stiffness of the HDPE pipe versus the stiffness of the backfill compacted around the pipe.

A1.2 *Material Design Properties*—The referenced AASHTO LRFD Specification (provides both initial and long term material properties (Young's modulus, E and ultimate stress limits, F) for design. Long term material properties are used for all loads that are present over a period of time such as soil overburden and ground water loads. Long term properties are also applicable to pipe deflection effects and both global and local buckling evaluations. Initial material properties are applicable to transient, short term loadings, such as rolling wheel loads. These AASHTO material properties are identical to those utilized for Specification F2306/F2306M materials.

A1.3 *Strain Evaluation*—The AASHTO LRFD methodology for plastic pipes provides a strain (versus stress) evaluation. Ring compression strains are essentially stress /E. Where stress is wall thrust divided by wall area, as defined by AASHTO. Long term ultimate compression and tension strains are limited to 4.1% and 5% respectively.

A1.3.1 Design deflection levels, typically taken as the 5% AASHTO pipe deflection limit, may be checked for compliance using Spangler's Iowa formula. Pipe deflection introduces additional ring compression on one side (inner or outer surface) of the pipe wall and the primary tension strain on the other. Bending strains are pipe wall design specific in that they depend on the pipe wall's extreme fiber distance and mean radius such that:

$$\varepsilon_B = K\,(C_{max}/R_{mean})\Delta \qquad (A1.1)$$

Where:

K = defected shape factor (can be taken as 4.27 assuming elliptical deflection)
C_{max} = extreme fiber distance (neutral axis to extreme fiber)
R_{mean} = Mean radius
Δ = pipe deflection (%)
ε_B = deflection bending strain (%)

A1.3.2 Ring compression strains, however, are also pipe wall geometry specific in that they depend upon the actual, effective area (A_{eff}) of the pipe wall which can be significantly less than the theoretical (gross) pipe wall area as measured geometrically or by weight.

TABLE A1.1 Total Strain

Inner wall at pipe crown	Outer wall at pipe crown
$\varepsilon = \varepsilon_s + \varepsilon_w + \varepsilon_{ll} - \varepsilon_b$	$\varepsilon = \varepsilon_s + \varepsilon_w + \varepsilon_{ll} + \varepsilon_b$
Inner wall at pipe springline	Outer wall at pipe springline
$\varepsilon = \varepsilon_s + \varepsilon_w + \varepsilon_{ll} + \varepsilon_b$	$\varepsilon = \varepsilon_s + \varepsilon_w + \varepsilon_{ll} - \varepsilon_b$

A1.3.3 A_{eff} depends on the slenderness (width to thickness) ratio of each pipe wall element as well as the compression strain in the element. Wide, thin elements typically cannot carry compression throughout their entire width. Portions farthest from an end supported of the element become ineffective. Thus only those portions of slender elements immediately adjacent to an end support are effective and can carry compression without buckling locally. Local buckling is not the same as ring (global) buckling in that only small segments of some pipe wall elements become ineffective with increasing strain. This however does reduce wall capacity in both compression and ring buckling. AASHTO LRFD, Section 12 also requires a ring buckling check.D2321.

A1.3.4 With the interrelationship of effective wall area, resulting compression strains, the AASHTO LRFD design method provides the necessary means of analysis in Sections 12. Additionally, the AASHTO LRFD Specification provides the necessary soil modulii to determine the relative soil stiffness in terms of the AASHTO M145 Specification. The AASHTO soil classifications are crossed over in terms of ASTM soils in Table 2, of

A1.3.5 The soil overburden load is also determined by the AASHTO LRFD specification. When the soil backfill is relatively stiff versus the pipes circumferential stiffness, such that the pipe strains (for-shortens due to creep) circumferentially more than the backfill, a vertical arching factor (VAF) is developed, reducing the soil overburden pressure on the pipe. The pipe wall's circumferential stiffness is essentially $A_{eff} \times E_{long\ term}$.

A1.3.6 A VAF of 1.0 indicates the pipe must carry the full soil burden pressure. Similarly, a VAF of 0.85 indicates the pipe carries 85% of the overburden. The remaining portion is carried by the stiffer backfill, in compression. The VAF only applies to soil overburden loads. Ground water, live loads, fixed surface loads, etc. fully bare on the effective pipe wall.

A1.3.7 The Design Engineer then must evaluate the effect of these combined strains on the longitudinal cross section of the pipe, recognizing that deflection bending strains will be compressive on the pipe ID at the springline and compressive on the OD pipe element(s) at the pipe crown and invert.

Relevant strains are:

ε_b = Deflection bending (strain see above)
ε_s = Ring Compression strain due to soil over burden
ε_w = Ring Compression strain do to ground water
ε_{ll} = Ring Compression strain due to intermittent traffic loads

Strain levels for Ring compression loads are:

$$\varepsilon = stress/E = Thrust/(A_{eff})/E \quad \text{(A1.2)}$$

Where:

$E = E_i$ = E initial for intermittent traffic loads
$E = E_{50}$ = E long term for deflection, soil and water table ring compression strain
A_{eff} = Sum of the effective wall area of each pipe wall element (in^2/ft)
T = Thrust = (D/2) (factored ring compression) per AASHTO LRFD, Section 12

APPENDIX

(Nonmandatory Information)

X1. AUTHORITIES

X1.1 Since this product has a wide variety of uses in underdrain and subsurface drainage systems, approval for its use rests with various agencies. The installer shall contact the relevant authority to obtain local installation guidelines. A partial list of authorities, according to product usage is as follows:

X1.1.1 *Subsurface Drainage*—Federal, state, county or local authority.

X1.1.2 The pipe manufacturer(s) shall be able to provide proof of product acceptance by specific agencies, when appropriate.

SUMMARY OF CHANGES

Committee F17 has identified the location of selected changes to this standard since the last issue (F2306/F2306M–13) that may impact the use of this standard.

(1) The NCLS requirement was changed from testing virgin resin to an extruded molded specimen. (7.8.2)